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Sustainable groundwater remediation using bioelectrochemical system

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INTRODUCTION

Nitrate (NO_3^-) is a common pollutant in **groundwater** resources throughout the world, originating from various sources. Excess nitrate in drinking water is linked to serious health issues such as methemoglobinemia and gastric cancer. The **bioelectrochemical systems (BES)** have received considerable attention as new technologies in the remediation of nitrate-contaminated groundwater due to their cost-effectiveness, and minimal secondary pollution, and have shown high potential to convert nitrate to N_2 through autotrophic denitrification carried out by **electroactive bacteria** growing attached to a cathode (**bio-cathode**).

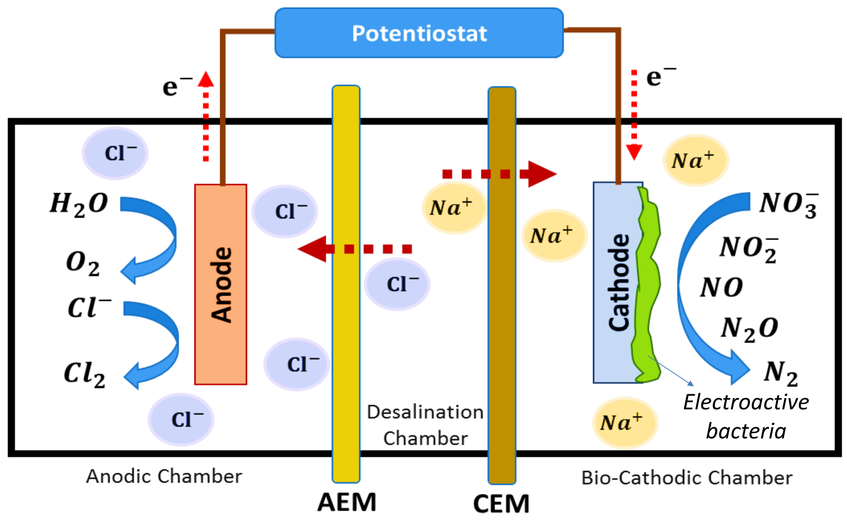

Figure 1. Schematic diagram of BES used in this study

This study aimed to investigate the effect of **hydraulic retention time** (HRT) on the overall performance of a 3-chamber BES for the simultaneous removal of **NO_3^-** and **salinity** from groundwater, as well as **chlorine production and recovery** in the anodic chamber.

MATERIALS AND METHODS

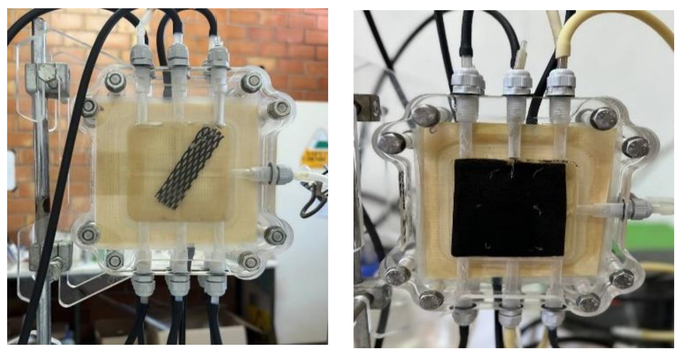

Figure 2. The anodic and bio-cathodic chambers

- A **3-chamber bioelectrochemical cell** made of polycarbonate
- Consisting of the anodic, central, and bio-cathodic chambers
- Central compartment separated by a cation exchange membrane (**CEM**) and an anion exchange membrane (**AEM**) from the bio-cathodic and anodic chambers, respectively
- Anode: a titanium mesh coated with mixed metal oxide (**Ti-MMO**)
- Bio-Cathode: **carbon Felt** connected to a stainless-steel mesh

- Contaminated groundwater from the nitrate vulnerable zone in Arborea (Sardinia, Italy) was **continuously fed to the bio-cathode chamber** under intense recirculation.
- Initial **nitrate concentration** and **salinity** were 28.7 $mgNO_3^-$-N L^{-1} and 3.06 mS cm^{-1}, respectively.
- The **anodic compartment** was filled with tap water and **operated in batch mode** with intense recirculation.

Figure 3. Sampling groundwater from the Arborea zone

RESULTS

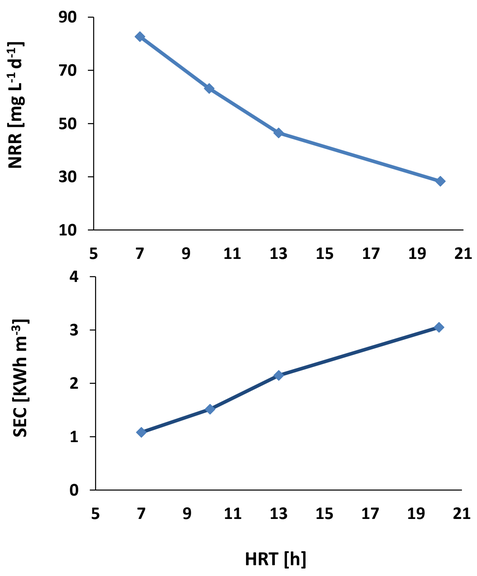

Figure 4. The effect of HRT on NRR and SEC

- First, **four different hydraulic retention times** (HRT= 20, 13, 10 and 7 h) were investigated at an **applied current of 10 mA**.
- The highest nitrate removal rate (NRR, 82.7 $mgNO_3^-$-N L^{-1} d^{-1}) was obtained by applying **7-hour HRT**.
- As the HRT was decreased to 7 h, almost all of nitrate was removed, while the salinity remained above the standard limit for drinking water (i.e., 2.5 mS cm^{-1}).
- In such condition, the **specific energy consumption** (SEC) reached to 1.08 kWh m^{-3} of treated water, comparable to SEC values observed in conventional membrane techniques for nitrate removal.
- Due to the migration of chloride ions to the anodic chamber, **chlorine** was produced as a value-added by-product. As a result, a portion of the operational costs could be offset.

CONCLUSION

The **optimal** result was obtained by applying an HRT of 7 h, which led to an increase in the nitrate removal rate and efficiency in the effluent, along with a decrease in SEC. Further studies are needed to maximize salinity removal and chlorine production.

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