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Initial findings on geochemical interactions of monovalent partial desalinated water infiltration into different dune sands

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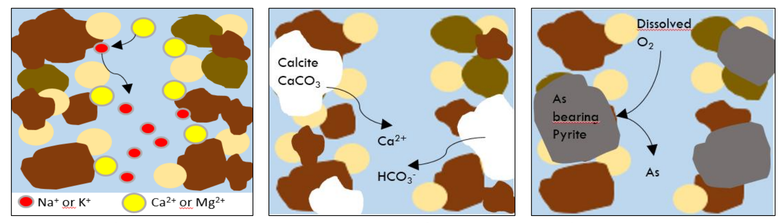
Motivation

Managed aquifer recharge (MAR) with desalinated water is a proven method to secure groundwater resources and quality. But full desalination might not be necessary[1] as it is both energy demanding and costly. Therefore, the development of monovalent selective membrane capacitive deionization in the joint project "innovatION" could be a purposeful method to improve sustain water resources.

The recharge of treated water leads to a chemical disequilibrium between recharge and ambient groundwater that triggers geochemical interactions between water and sediment (Fig.1). It is known that especially the Ca^{2+} concentration of the recharge water is a controlling factor for ongoing chemical processes during MAR.[2,3] In this study we present initial finding on potential geochemical interactions during MAR into different dune sands with a monovalent-partial desalinated water (mPDW) by conducting column experiments.



Cation exchange / Desorption | Mineral dissolution (e.g. Calcite) | Shifting redox conditions (Mobilization of trace elements

Fig. 1: Schematic potential geochemical reactions induced by infiltration of a desalinated water (modified after [3]).

Material & Methods

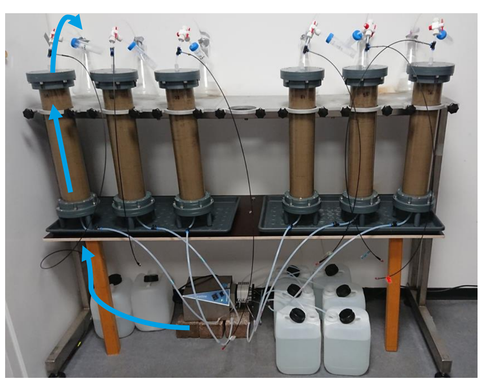


Fig. 2: Experimental set up with flow-through sediment columns.

As a potential MAR site, the East Frisian island Langeoog, Northern Germany, was chosen. For identification of the influence of different sediment characteristics, three sediment types were sampled in June 2021: beach sand, grey dune and brown dune sand.

After determination of the most important soil characteristics, column experiments were conducted, infiltrating artificial produced mPDW (Tab.1) based monovalent partial desalinated water with 5 g/l total dissolved solids . Major ions and parameters such as pH and EC were measured in the outflow continuously during experiments.

The experimental results were compared to a hydrogeochemical model. For this purpose, PHREEQC was used to simulate the influence of different reactions that were expected during the column experiments.

Tab. 1: Parameter of the artificial mixed mPDW infiltration water.

		Inflow mPDW
pH		7.94
EC	[µS/cm]	1380
O_2	[mg/l]	8.3
Cl^-	[mmol/l]	10.6
SO_4^{2-}		1.2
HCO_3^-		0.9
Na^+		9.3
K^+		0.17
Ca^{2+}		0.49
Mg^{2+}		1.9
TDS	[mg/l]	835

Results & Discussion

The experimental results for cation concentrations in the outflow (Fig.3) show that with the start of mPDW infiltration at day 0, the water chemistry changed (periodically) before it adjusts to the inflow concentration. Higher Ca2+ concentrations for beach and grey dune sands indicate calcite dissolution during recharge, whereas it is retained in the decalcified brown dune sands. For all sand types a period of cation exchange is observed between appr. day 10 to 30. Leaching of iron and manganese occurs at the more pedogenic developed brown dune sands.

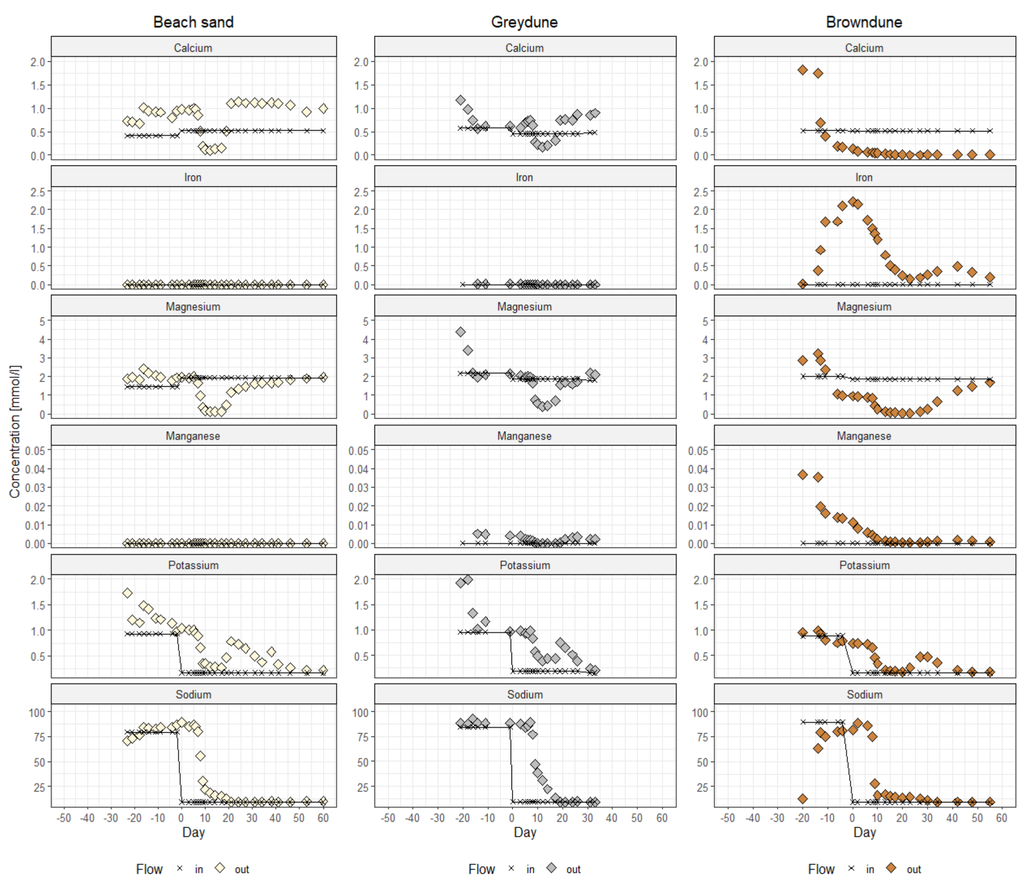


Fig. 3: Experimental results for cation concentrations in the outflow volume of the column experiments.

To outline the effect of every single reaction individually, different model runs of a reactive transport model were conducted. In Fig. 4 the modelling results from the column experiments with grey dune sediment are shown. The model run accounting for cation exchange and calcite dissolution (solid red line) fits the data best and confirms that these reactions occur.

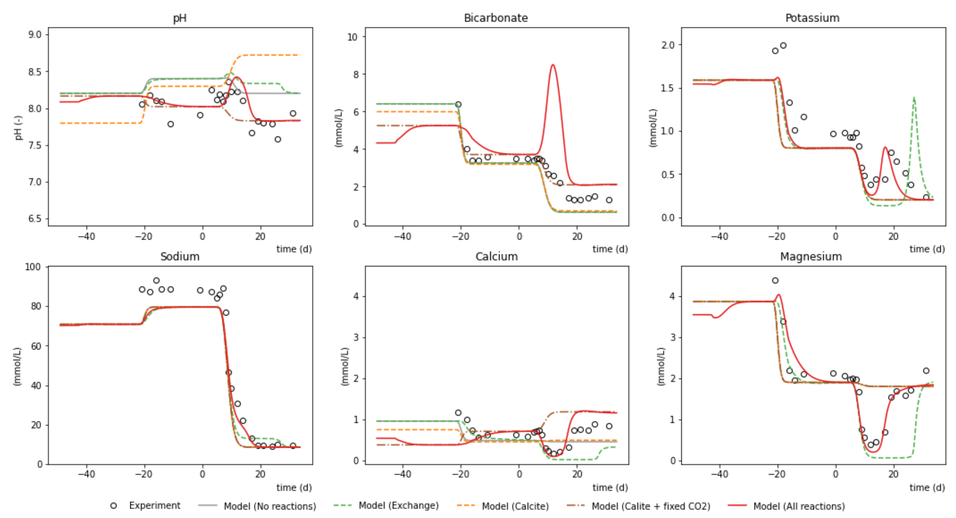


Fig. 4: Reactive Transport Model based on the column experiment with grey dune sands.

Summary & Outlook

- Cation exchange and calcite dissolution/precipitation are the main processes that can be expected during MAR with mPDW water into Langeoog dune sands
- The more pedogenic developed of the sands, the more complex geochemical interactions become
- Grey dune sands appear to be suitable sediments for potential MAR on Langeoog
- Further focus is on trace element mobilization, influence of chemistry and organic content of the recharge water

Literature:

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