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Desalination of Saline Groundwater for Hydraulic Barriers

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Introduction

Fresh groundwater is the most often used water resource for domestic, irrigation and industrial use in (semi-) arid coastal regions. However, due to over-pumping and declining groundwater levels, the intrusion of saltwater decreases the groundwater quality by higher sodium, chloride, nitrate and sulphate concentrations exceeding the thresholds for irrigation and drinking water [1]. Mixed hydraulic barriers can also be used as a managed aquifer recharge method in combination to counteracting saltwater intrusion. However, water in appropriate quality and quantity is often not available to directly feed the positive barrier. Therefore, desalinated saline groundwater can be used within the Abstraction-Desalination-Recharge (ADR) methodology for remediation of saline aquifers (Figure 1) [2]. The sustainable realisation of this ADR methodology bases thereby on cost efficient desalination technologies.

Objective & Method

In this study, we examined the suitability of different desalination technologies for various saline groundwater qualities and various infiltration concentrations. Since a total demineralisation of saline groundwater is not needed for infiltration, we examined pressure-driven and electrochemical membrane processes showing a high removal rate for sodium, chloride and nitrate concentrations within a recovery rate of 20-70%. Ebeling et al. [3] determined the theoretical needed quantity for abstraction and infiltration as well as the duration for remediation using a synthetic 2D variable-density model. With help of experiments and simulations of suitable desalination processes, we calculated the energy costs for different remediation scenarios (Figure 2).

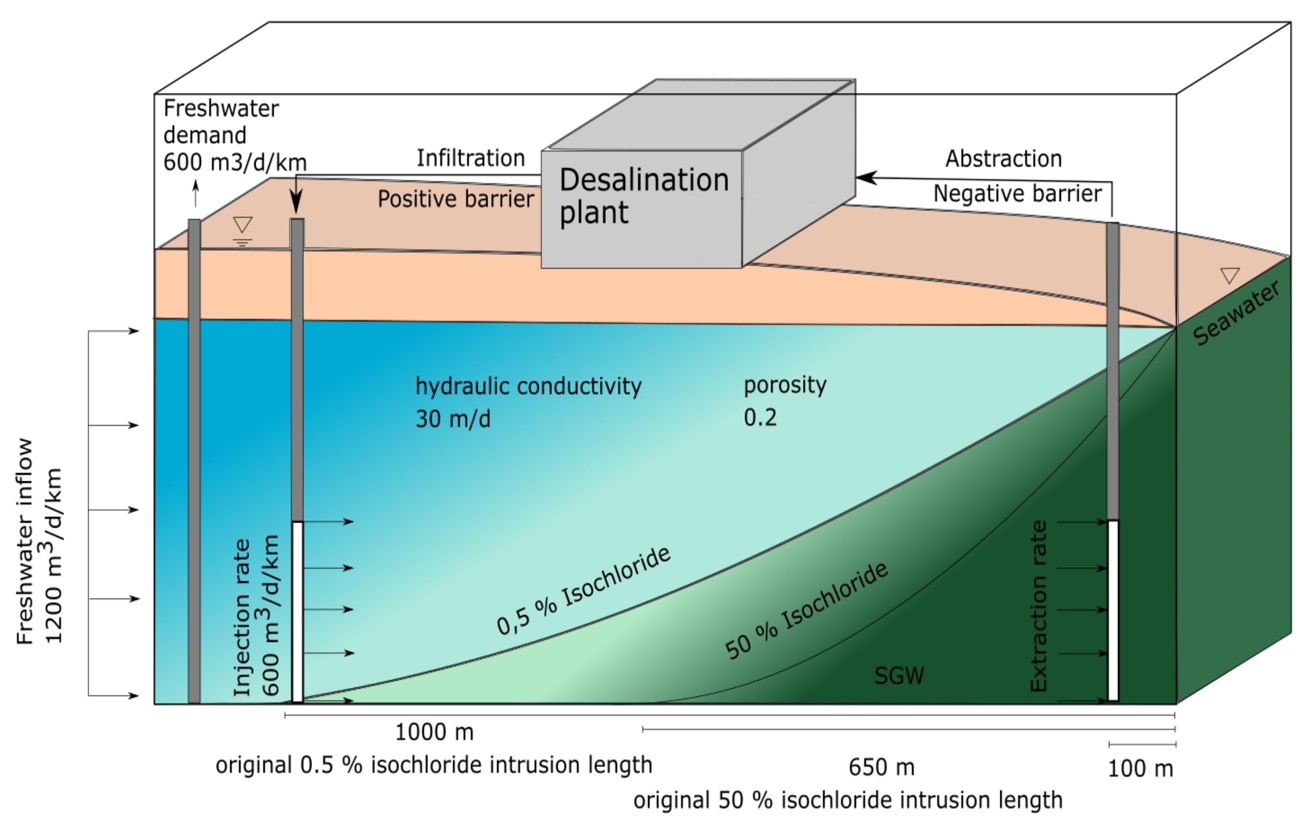

Figure 2. Schematic sketch of a mixed hydraulic barrier system including the boundary conditions to calculate the desalination costs

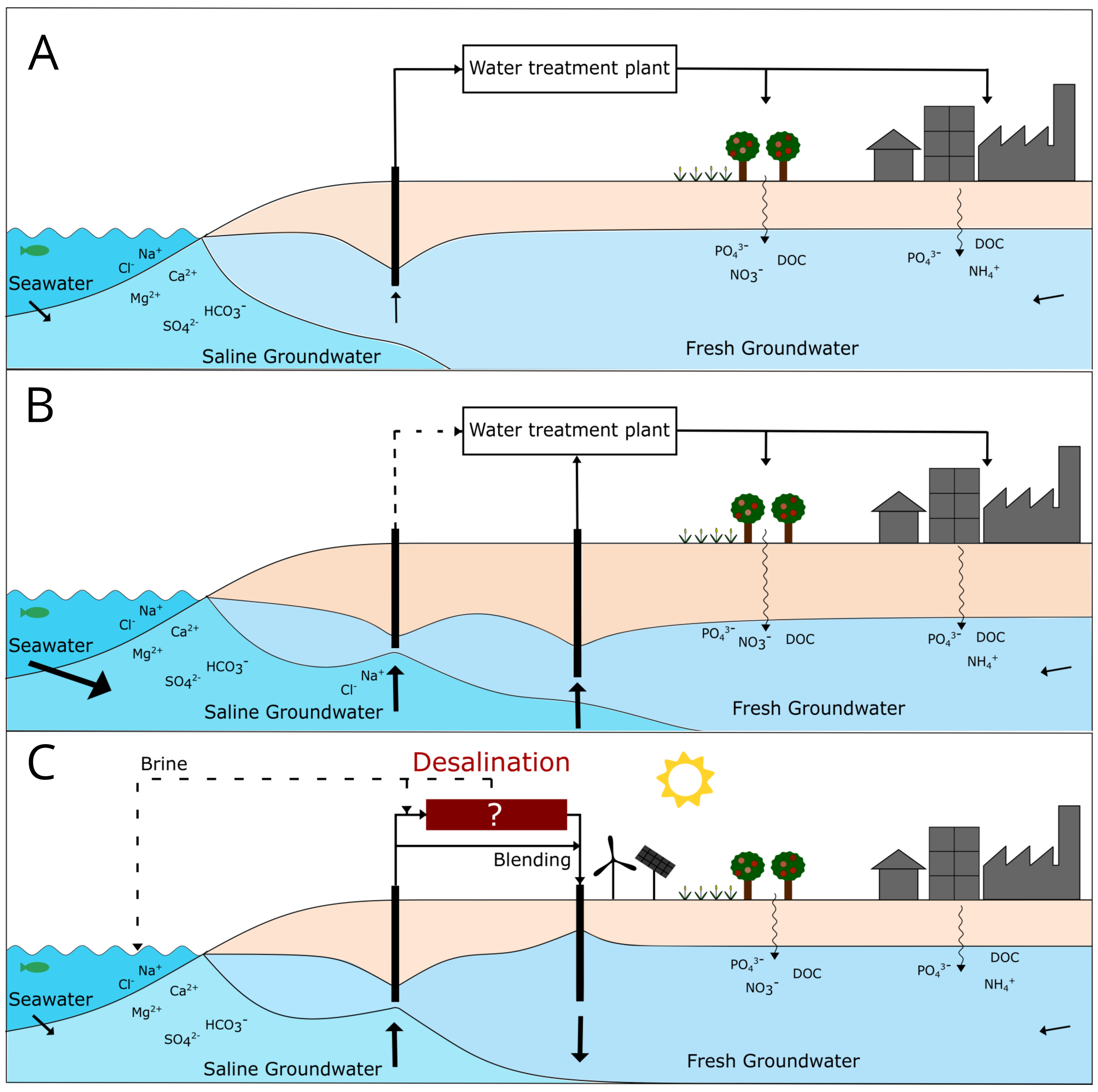

Figure 1. Formation of natural saltwater intrusion (A), intensified saltwater intrusion (B) and remediation of a saline aquifer by mixed hydraulic barriers (C)

Results

Especially for slightly and moderately saline groundwater, membrane capacitive deionisation (MCDI) and nanofiltration have proven to be cost efficient desalination technologies with a specific energy requirement of 0.2-1.7 kWh/m³ infiltrated water (Figure 3). In contrast, highly saline groundwater cannot be sufficiently desalinated by nanofiltration or membrane capacitive deionisation. Therefore, brackish water or seawater reverse osmosis membranes needs to be applied using higher pressure resulting in an energy requirement up to 3 kWh/m³ infiltrated water. The energy costs for desalination can therefore range, depending on the boundary conditions of the aquifer, between 3,000 and 50,000 € per year.

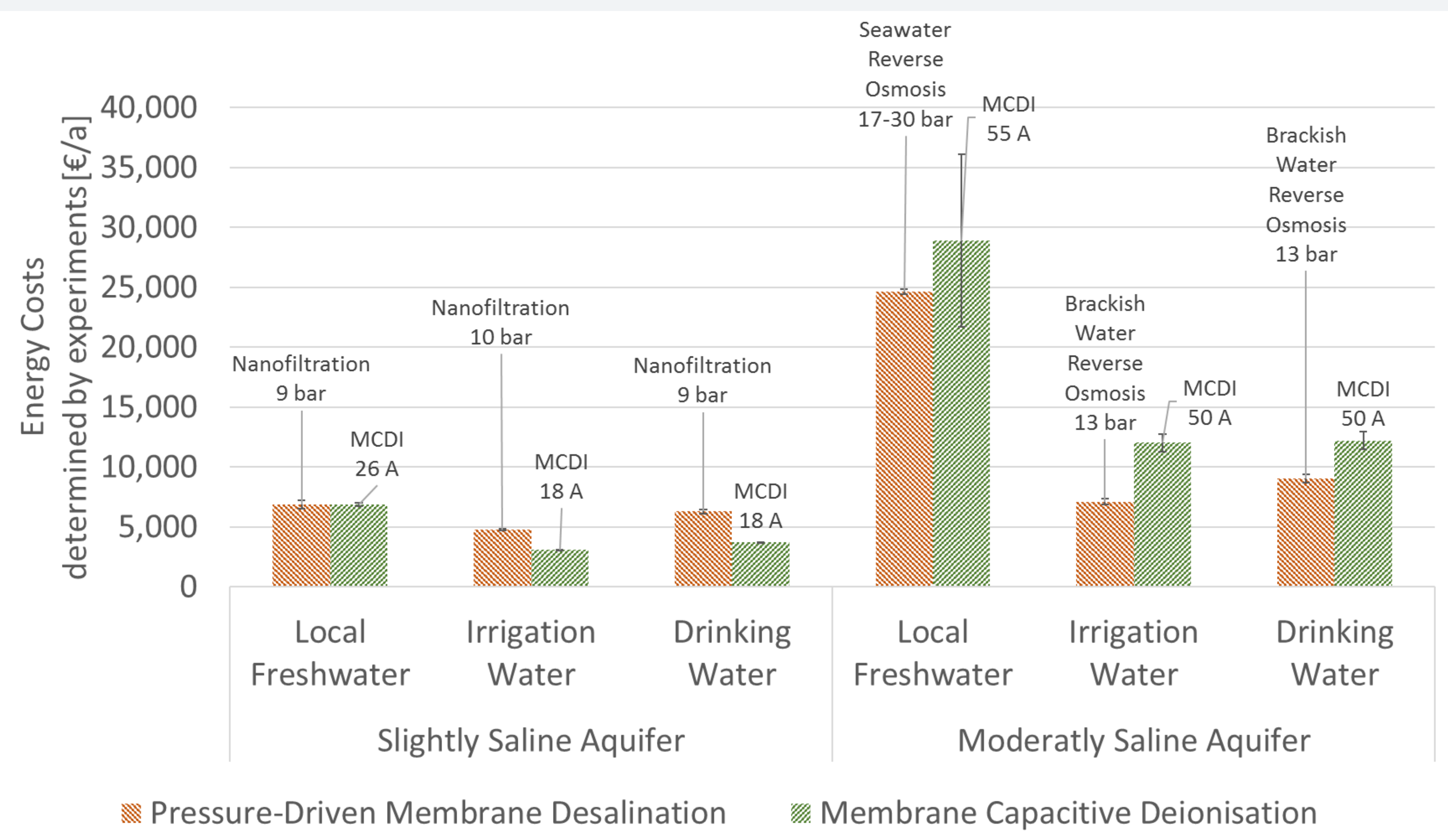

Figure 3. Energy costs according to experimental results by using pressure-driven membrane desalination and membrane capacitive deionization (MCDI)

Literature

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