

Editorial

Flow, Transport, and Reactions in Coastal Aquifers

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1. Motivations and Background

Coastal aquifers are a critically important water resource, which supports coastal populations and economies globally. Flow, transport, and geochemical reactions in coastal aquifers are hot interests of hydrologists and marine geochemists as well as policy makers in charge of environmental management and sustainable development. In this special issue, we cover recent scientific advances in seawater intrusion and submarine groundwater discharge (the flux of geofluids from coastal aquifers to the ocean), as well as field and laboratory methods and techniques that can be used to monitor and better understand the processes occurring in coastal aquifers.

2. Contents of the Special Issue

The purpose of this special issue is to present the most recent studies in these exciting fields. A brief summary of all accepted papers is provided below.

Yan et al. illustrate structured heterogeneity in porous media for a modified setting of the Elder problem. The effects of the permeability and the location (horizontal and vertical) of the low-/high-permeability inclusion on the free convection process are assessed using three assessment indicators: total solute mass (TM), Sherwood number (Sh), and solute center of gravity (COG). The result shows that heterogeneity

in permeability makes the system more unstable. A high-permeability inclusion shows stronger effects on the free convective process than a low-permeability inclusion at the early stage, with significantly unbalanced solute distributions and accelerated transport processes. Free convection is more sensitive to the low-/high-permeability inclusion vertically closer to the source zone.

Guo et al. investigate the effects of a fluctuating sea level and inland recharge on pumping-induced groundwater salinization in coastal multilayered aquifers. Through laboratory experiments and numerical simulations, they conclude that pumping could significantly enhance the amplitude of the groundwater level fluctuation. An increment of the pumping rate causes faster drawdown of the groundwater level in the aquifer. Inland recharge plays a major role in the seawater intrusion for the same pumping rate of groundwater in different seasons. Increasing or decreasing the hydraulic conductivities of the two layers is not able to reproduce the variation of the seawater wedge. Changing the dispersivity has no effect on the arrival time of the steady state saltwater wedge.

Levanon et al. investigate how a variable tidal boundary affects salinity, pressure, and saturation in a coastal aquifer. Tank experiments show that tidal variation affects not only hydraulic heads but also salinity across the freshwater-saltwater interface and saturation within the capillary fringe.

The speed of response varies—hydraulic heads respond quickly to the pressure signal—while both saturation and salinity responses lag tidal fluctuations. Numerical FEFLOW simulations that match the tank experiments allowed further investigation of the lagged response. Lag in the salinity response at the freshwater-saltwater interface increases with depth and lag of capillary fringe saturation response increases drastically toward the top of the capillary fringe.

Song et al. have developed an analytic solution relating to an offshore submarine aquifer. Specifically, they consider tidal groundwater head fluctuations in a submarine leaky confined aquifer overlain by a semipermeable seabed. Both the seabed and the confined aquifer are assumed to extend horizontally infinitely. A one-dimensional mathematical model is established to describe the problem, and the analytical solution is derived. The impacts of the tidal loading efficiency, hydraulic conductivity, and elastic storage of the semipermeable layer and aquifer on the groundwater head fluctuations in the aquifer system are analyzed and discussed. Solution analyses indicated that tidal loading effects tend to enhance the amplitude of the tidal groundwater fluctuation in the confined aquifer system and to reduce the phase shift between the groundwater head and the sea tide fluctuations.

Stoeckl et al. explore postpumping seawater intrusion (PP-SWI), which is the phenomenon of seawater intruding further inland than the location of a well, after pumping has ceased. The paper describes a laboratory-scale investigation of the phenomenon and demonstrates that PP-SWI can be reproduced within physical experiments. They also use numerical modelling to show that PP-SWI is caused by disequilibrium in the flow field following the cessation of pumping. Specifically, the cone of depression persisted after the cessation of pumping (first moving inland and then retreating toward the coastal boundary) which caused a lag in the reestablishment of fresh water flow toward the coast, after pumping had stopped. It was during this period of flow-field disequilibrium that PP-SWI occurred. They predict that systems with larger postextraction disequilibrium will be most susceptible to PP-SWI and recommended future research to improve understanding of the relationship between hydrogeological parameters, extraction rates, well location, and incidence of PP-SWI.

Holt et al. report on the evolution of a freshwater lens below a very young barrier island in the North Sea in Germany that only formed in the past decades. Combining field observations with transient numerical 2-D density-dependent modelling, they assess the impact of both geomorphological changes and storm tides on freshwater lens formation. Results show that the asymmetric freshwater lens is restricted to the elevated dune areas and has nearly reached quasisteady-state conditions. Further growth of the freshwater lens is largely inhibited by annual storm tides that, in the absence of coastal protection measures, regularly flood large parts of the island in winter. The authors conclude that direct implementation of storm floods into numerical models is necessary to explain the groundwater salinity distribution under such highly dynamic conditions.

Post et al. investigate the fate of the hydrological tracers ^3H and ^3He in freshwater lens, transition zone, and saltwater wedge below a barrier island in the North Sea, using numerical variable-density flow and transport models of different complexities. They conclude that bomb-related tritogenic ^3He is a useful tracer to date young (<60 years) groundwater, as it is still mostly present in the freshwater lens, and shows that apparent ages may be biased up to 10 years due to differences in dispersive transport of ^3H and ^3He . They also illustrate the potential of ^3H from seawater as a tracer to study saltwater circulation patterns when it travels into the offshore part of the aquifer. They further explore the effect of mixing between freshwater and saltwater in the transition zone, highlighting remaining knowledge gaps and the need for more research to better understand its controlling factors (i.e., tides, lithological heterogeneity, or transience of recharge and pumping).

The study of Ngueteu et al. focuses on the biodegradation kinetics of benzene and naphthalene in a (semi)-arid saline coastal soil environment subject to saline conditions and continuous water level fluctuations. To quantify sorption and biodegradation, batch experiments considering different environmental conditions were conducted with samples collected at a beach in Qatar. The results show that removal of naphthalene is mainly due to sorption while benzene is mostly removed by biodegradation, whereby biodegradation of the two compounds is attributed to nitrate- and sulfate-reducing bacteria. Although during the experiments, the two petroleum hydrocarbons were considerably removed from the aqueous phase due to sorption and biodegradation processes, the latter is very slow with bulk rate coefficients in the order of 10^{-3} to 10^{-2} day $^{-1}$ as quantified with kinetic models that match the experimental results well.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Acknowledgments

We would like to express our gratitude to all authors who made this special issue possible. We hope this collection of articles will be useful to the coastal community.

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