Geophysical Research Abstracts
Vol. 20, EGU2018-11574-1, 2018
EGU General Assembly 2018

Estimating the potential role of long-term seawater circulation in aquifers in ocean chemistry

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This study focuses on long-term seawater circulation in aquifers and shows its potential to affect ocean chemistry. Circulation mechanisms vary by their spatial and temporal scales, from short-term and small-scale circulation driven by tides and waves, through seasonal exchange driven by sea- or groundwater-level changes, up to long-term, large-scale circulation may be driven by geothermal gradients or density differences and hydrodynamic dispersion. Although short-term circulation has been shown to affect groundwater chemistry and potentially modify the composition of seawater for some elements, the long-term processes have the potential to affect elements that are controlled by long-term geochemical processes. Models and previous studies show that the amount of seawater circulating through the long-term processes may be relatively large, especially in a heterogeneous medium. However, field-based estimation of the long-term circulation is challenging due to the difficulty in isolating the long-term process from the other shorter circulation mechanisms. In this study, we present preliminary results from Indian River Bay, Delaware and the Eastern Mediterranean, showing potential for identifying long-term circulation in the aquifer, based on the geochemistry (Ca, K, Sr) of the groundwater. Our results from seepage meters in Indian River Bay show that some of the groundwater compositions lie on a conservative mixing line, while others are enriched in Ca and Sr and depleted in K. This behavior is typical in the fresh–saline transition zone in coastal aquifers and reflects both silicate and carbonate aquifers. Assuming that the modified composition reflects the long-term process, the long-term circulated seawater discharge is $\sim$10% of the total saline water discharge in Indian River Bay. In addition, $^{234}U/^{238}U$ and $^{87}Sr/^{86}Sr$ isotopic ratios in circulated seawater within the Eastern Mediterranean coastal aquifer show gradual change with distance from the shore and may be used for estimating relative age of the saline groundwater. $^{87}Sr/^{86}Sr$ decreases and $^{234}U/^{238}U$ increases compared to seawater ratios. The $^{234}U/^{238}$ change occurs faster than the $^{87}Sr/^{86}Sr$ change, and therefore these isotopes can be used for identifying the relative timescale of water–rock interaction. Based on existing data of Ca, K and $^{87}Sr/^{86}Sr$ and their oceanic budgets, the long-term seawater circulation may be estimated to be between 4% and 20% of river discharge and thus has a significant role in ocean chemistry, making the flux of Ca to the ocean through long-term seawater circulation as significant as rivers.