Localizing and quantifying groundwater-surface water interactions at different scales: a tracer approach at the River Moselle, Germany

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August 4, 2023

Abstract

Groundwater-surface water interactions (GSI) connect rivers and streams with riparian areas and the adjacent aquifer. Although these interactions represent a substantial control of quantity and quality of both groundwater and surface water, knowledge on GSI along rivers at the regional scale, particularly inland waterways, is still limited. We investigated GSI along the river Moselle, an important federal inland waterway in Germany, by using radon and tritium to identify gaining and losing stream conditions, respectively. Gaining stream conditions were identified by continuously measuring radon along the river as part of boat surveys using a high spatial resolution (every two km) during intermediate (October 2020) and near low flow conditions (August/September 2021). Quarterly tritium inventories from 2017 to 2021 revealed losses of up to 27 % due to losing stream conditions at the upstream locations of damns (particularly near the hydroelectric power plant Lehmen) while gains (up to 51 %) likely triggered by a flood-induced mass transfer of water from the aquifer back into the river. Using radon mass balance modeling, good agreements of simulated versus measured radon data with respect to two groundwater end-member scenarios were obtained during intermediate flow (Spearman's ρ: 0.97 and 0.99; MAE: 10.1 and 3.4 Bq l^{-1}) and near low flow (Spearman's ρ: 0.97 and 0.99; MAE: 11 and 6.5 Bq l^{-1}). Important groundwater inflow was limited to the meander of Detzem, where cumulated groundwater inflow of about 19 $m^3 s^{-1}$ (9.5 % of total discharge) and 4.2 $m^3 s^{-1}$ (3.8 % of total discharge) was simulated during intermediate and near low flow, respectively. However, these groundwater contributions were relatively low compared to alpine streams, for example. Finally, the study will help to better identify and quantify GSI at the regional scale and provide methodological guidance for future studies focusing on inland waterways.

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