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Evaluating surface water and groundwater interaction at a sluice system via tritium and stable water isotope analysis

Jessica Landgraf, Liza-Marie Beckers, Michael Schluesener, Arne Wick, Lars Duester, and Axel Schmidt
Federal Institute of Hydrology, Koblenz, Germany

A comprehensive understanding of surface water and groundwater interaction is crucial to prevent overexploitation and contamination of groundwater. This is especially important for large rivers with installations from hydraulic engineering, such as weirs or sluices, because the interaction may be further intensified by these structures. Stable water isotopes and tritium, being part of the water molecule itself, serve as versatile natural or anthropogenic tracers, here suitable to evaluate water compartment interactions.

Since 2020 we conducted long-term monitoring of tritium and stable water isotopes at a sluice on the Moselle River in Lehmen, Germany. The study site contains several groundwater wells parallel to the river bank with one well slightly further distant to the river for reference of groundwater unaffected by surface water. The study aims to identify and quantify the surface water and groundwater interaction in a highly modified system using stable water isotope and tritium analysis of the according water compartments. The Moselle River water contains elevated tritium concentrations of up to ~400 TU induced by the French nuclear power plant Cattenom. Hence, tritium can be used as an indicator of surface water infiltration. Additionally, hydrological on-site parameters as well as water levels and further chemical parameters like major ions, trace elements and organic micropollutants were monitored to allow for a more holistic assessment of water compartments and identification of further suitable tracers for surface water and groundwater interaction.

We estimated transit times in conjunction with surface water proportions in the various groundwater wells. The transit times varied considerably when estimations were based on surface water grab samples, resulting in 1 to 12 months of travel time and low correlations coefficients (mean: 0.39). This could be attributed to the high variability of tritium concentrations in the surface water caused by random pulse emissions. With monthly composited samples for surface water transit times of 3 to 5 months and higher correlation coefficients (mean: 0.66) were calculated. Estimations using stable water isotopic composition resulted in travel times of 4 to 6 months for both grab and monthly composited surface water samples with slightly higher correlation coefficients for composite samples (grab-mean: 0.79, composite-mean: 0.86). Furthermore, the surface water proportion in the influenced groundwater wells was estimated using both tritium and stable water isotopes. Both tracers indicate a large surface water proportion in the

groundwater wells, highlighting the significance of mixing processes induced by the impounded surface water of the investigated sluice site. Estimated proportions of surface water range from 66 to 74% with deuterium and 73 to 84% with tritium as the utilized tracer. As the tracers overlap at around 73 to 74% it can be assumed that both tracers deliver valid, comparable results. The observed relationship is also supported via major ion composition of the water compartments.

In conjunction with further hydrological parameters the analyses reveal elevated surface water proportions of at least 66% and travel times of 3 to 6 months. Further analysis of additional tracers may support the results gained via stable water isotope and tritium analysis.