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Climate change impacts on Swiss groundwater: insights from historical records

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Knowledge of the impact of climate change on groundwater is limited mainly by a lack of relevant long-term data that would allow the effects of climatic forcing to be assessed empirically. With the aim of assessing the consequences of climate change on groundwater, we collected and statistically analysed historical groundwater data from Switzerland. While most existing studies have focused on the impact of climate change on groundwater quantity, we focus on groundwater quality. As measures of groundwater quality we chose groundwater temperature and oxygen concentration because of their importance for biogeochemical processes and for reasons of data availability.

Our analyses show that in aquifers that are recharged by riverbank infiltration, groundwater temperature has increased by 1°C - 1.5°C over the last 30 years. By contrast, in aquifers that are recharged only by the percolation of precipitation, increases in groundwater temperature are slight or non-existent. A detailed analysis of groundwater temperatures measured in the pumping wells of five aquifers that are recharged by riverbank infiltration revealed that an abrupt temperature increase in the late 1980s, which was also detected in Swiss air temperature and river water temperatures and which is traceable ultimately to a change in the behaviour of the Arctic Oscillation, accounted for a large proportion of the total groundwater warming [1].

Oxygen concentrations were available for four of the five aquifers we investigated. In two of these aquifers the oxygen concentration underwent a strong decrease, in the third a slight decrease, and in the fourth a slight increase. Neither long-term trends in river water oxygen concentration nor altered hydraulic conditions seem to be responsible for the long-term trends in groundwater oxygen concentrations. However, the decreasing oxygen concentrations were accompanied by decreasing DOC concentrations in the groundwater, while DOC concentrations in the river water increased over the same period. We therefore suggest that higher temperatures are resulting in enhanced microbiological activity in the hyporheic zone, resulting in increased oxygen consumption and decreasing groundwater oxygen concentrations.

Based on our analyses of the available long-term Swiss data, we postulate that in aquifers that are recharged by riverbank infiltration, the frequency of occurrence of anoxic conditions will increase in future if temperatures continue to increase, assuming the nutrient load in river water remains constant. Groundwater anoxia may pose a challenge to the water supply infrastructure because of the dissolution of iron and manganese oxides, which, after re-oxidation, precipitate and cause clogging of the pumping wells.

[1] Figura, S. et al. (2011), Geophys. Res. Lett., 38(23), L23401, DOI: 10.1029/2011GL049749.