The Climate Change Imprint: Dynamic Shifts in Spring Yields and Water Quality in the Czech Republic

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Springs are valuable indicators of groundwater quantity and quality. The past few decades have seen a significant rise in air temperatures in Central Europe, impacting the hydrological cycle and altering streamflow patterns. This study examined the annual trends in spring yields from 136 springs across 18 hydrogeological regions (HGR) in the Czech Republic from 1971 to 2020 using Mann-Kendall test. Of these, 56 springs had available mean annual water

quality data, which were analyzed for trends in sulfates, nitrates, dissolved organic carbon (DOC), and ionic strength (calculated using concentrations of major cations and anions: Ca_2^+, Mg_2^+, Na^+, K^+, NH_4^+ , H^+,SO_4^{2-}, NO_3^-, Cl^-, F^-, and HCO_3^-).

A majority of springs (70%) showed no long-term trends in annual yields. Among those with notable trends, declines (28%) were more frequent than increases (2%). Notably, seven HGRs displayed a significant decreasing trend ($p < 0.05$). No region showed an increasing trend. Springs in crystalline bedrock HGRs (4 out of 7) were especially impacted. The decline observed in the North Bohemian Cretaceous Basin region is of particular interest, given its status as a protected water accumulation zone.

In water quality trends, SO_4^{2-} and NO_3^- concentrations exhibited a significant decreasing trend at 46% and 52% of sites, respectively. Conversely, an increasing trend was detected at 21% (SO_4^{2-}) and 16% (NO_3^-) of sites between 1984 and 2020. DOC concentration decreased significantly ($p<0.05$) at 34% of sites from 2002 to 2020. Ionic strength showed a decreasing trend at 16% of sites and an increasing trend at 7% between 2002 and 2020 ($p<0.05$).

Using a linear mixed-effect model, we evaluated the relationships between climatic (precipitation and temperature) and hydrogeological variables (transmissivity) on spring yields. We found a strong positive correlation between precipitation and yields, underscoring that a decrease in precipitation directly contributes to reduced yields ($p < 0.01$). Conversely, an increase in temperature was associated with a decrease in spring yields ($p < 0.01$). The significant negative effect of interaction between temperature and transmissivity revealed that springs, especially in regions with low transmissivity dominated across Czech Republic by crystalline bedrock, are particularly sensitive to climatic variations. These low transmissivity regions already exhibit lower yields compared to high transmissivity areas, such as the Cretaceous basins. Furthermore, our analysis revealed a significant negative correlation between DOC concentrations and temperature ($p<0.001$).