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Understanding the regional occurrence of select groundwater contaminants based on novel and established tracer measurements in age-dated groundwater samples in Alberta, Canada

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Providing enough high-quality drinking water is of key importance for supporting an increasing global population. In many regions, shallow groundwater is a key source of water for domestic and livestock use. However, there is often insufficient knowledge on how evolving water types and redox conditions affect groundwater quality as residence times increase, potentially leading to the mobilization of key contaminants that may render groundwater unfit for drinking water purposes.

Groundwater samples were collected from hundreds of domestic and monitoring wells completed in shallow aquifers (< 150 m) throughout the province of Alberta, Canada. For a considerable number of samples, groundwater ages were determined using various approaches (e.g., tritium, ^{85}Kr, ^{39}Ar, ^{14}C, ^{81}Kr, ^{36}Cl, piezometric heads and other hydrogeological information). For all groundwater samples, concentrations of major ions and trace metals, total dissolved solids (TDS), water types, and redox states were determined. It was observed that increasing groundwater ages were associated with a trend towards Na-HCO_3 waters with low Ca/Na ratios while redox conditions became initially post-oxic transitioning to sulfidic and finally methanic in many aquifers. The commonly reducing conditions explain why the majority of groundwater samples had low to negligible nitrate concentrations, with only 3% of samples with nitrate above the detection limit exceeding 10 mg/L nitrate-N. Manganese and arsenic concentrations exceeding Canadian drinking water quality guidelines were observed in 19 and 15% of the samples measured for these analytes respectively, predominantly from shallow aquifers in sediments above bedrock characterized by post-oxic redox conditions. In contrast, in aquifers with highly reducing conditions methane was usually detected and isotope analyses revealed a predominantly microbial origin. Some groundwater samples in Alberta also contained fluoride concentrations above 1.5 mg/L. Hotspots of elevated fluoride were usually associated with geochemically very evolved Na-dominated and older groundwaters.

This project demonstrated that a) groundwater age-dating combined with b) hydrogeological and c) geochemical models describing the evolution of water types and redox zones in concert with d) isotopic fingerprinting approaches can generate a highly refined understanding of the province-wide occurrence, origin and fate of select groundwater contaminants with health implications for humans, livestock and ecosystems.