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Groundwater age for identification of impacts of land-use intensification and natural hydrochemical evolution on groundwater quality

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Groundwater quality can be affected by land-use activities in the recharge area. Identification of land-use impacts on groundwater quality is, however, not simple because monitoring wells within agricultural or industrial areas can often contain old water that was recharged before land-use impacts started, and water quality prior to historic land-use changes around 1950 is commonly not known.

In order to distinguish between impacts on groundwater quality resulting from natural sources such as water-rock interaction or from human land-use activities, we compared hydrochemical parameters (nutrients, heavy metals, major ions, gases) in water recharged before and after land use activities started. For groundwater dating we used primarily tritium time series data. Extremely high tritium measurement precision is necessary in the Southern Hemispheric low-tritium environment, but once achieved, allows for very accurate groundwater dating in the post nuclear weapons testing world of the SH.

Data from the National Groundwater Monitoring Programme of New Zealand show that:

Hydrochemistry and field parameters that increase with water age, thus indicating natural geological sources, are pH, conductivity, sodium, bicarbonate, silica, and fluoride.

In young groundwater that was recharged after the onset of land-use intensification at around 1950, nitrate, sulphate, CFC-11 and CFC-12, and pesticides were identified as the most representative indicators for the impact of land-use intensification on groundwater quality.

Threshold concentrations of major ions and nutrients for an indication of the impact of land-use intensification were defined by the maximum naturally occurring concentrations of these indicators in groundwater that is older than 60 years because significant land-use intensification started about 1950. The obtained threshold concentrations are 2.1mg/L for NO3-N, 11.5mg/L for SO4, 50mg/L for Ca and Na, 60mg/L for Cl, 15mg/L for Mg, 0.002mg/L for Cr, and 0.22mg/L for Br.

Out of 111 sites, 43% show an impact of land-use intensification. 68 sites have water with mean residence time <60 years and therefore are young enough to potentially reflect impacts of land-use intensification. Out of these, 59% show such impact in major ion chemistry.

Anoxic groundwaters are lower in nitrate by a factor of 4.5, indicating significant nitrate reduction in these anoxic groundwaters due to anaerobic microbial denitrification.

No elevated phosphate, a main element in agricultural fertilisers, was found in young groundwater, implying that non-point source fertilizer phosphate is still retained in the soil. Because phosphate is, together with nitrate, a limiting factor for algal blooms in lakes, this has important implications for lake remediation. Phosphate discharging via groundwater into the lakes is currently still purely of geological origin and therefore naturally occurring in the groundwater. Reducing the critical nutrient loading via groundwater to limit algae growth can therefore be achieved only by limiting nitrate sources in the catchments.