New Approaches for Direct Measurement of Contaminated Groundwater Discharge to Receiving Surface Water

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Background. Measurement of the rate of contaminated groundwater discharge to the receiving surface water is a more direct and often less conservative approach than models that omit attenuation processes and mixing at the groundwater-surface water interface. Not undertaking such measurements can lead to conservative and potentially costly decisions such as inappropriate remedial actions. The groundwater-surface water interface, in particular in marine environments, is a dynamic zone with processes such as tides, wave dynamics, and swash infiltration all contributing to the mixing. These interfaces can also significantly attenuate contaminants given the presence of strong redox gradients.

Approach/Activities.
Ongoing advances in the sampling and analysis of chemicals in water are bringing unprecedented insights to the scientific evaluation of contaminant migration pathways at a gradually decreasing cost. Three families of tracers have been applied to measure the discharge rate at large industrial sites situated along the coast of Australia: (1) Environmental tracers (chloride, stable isotopes of water and radon); (2) compound specific isotope analysis (CSIA); and (3) applied tracers which are added in the environment in a controlled fashion (fluorescent dye).

At one site, high resolution vertical profiles were undertaken within an intertidal groundwater discharge zone using drive point equipment to enable the collection of pore water. The samples were analysed for the stable isotopes of water to identify the mixing proportions along the groundwater-surface water interface. Radon was analysed to assess the residence time of surface water in the underlying hyporheic zone. CSIA of nitrate was used to assess the nature of the attenuation processes for ammonium and nitrate (change in $d^{15}N$ and $d^{18}O$ signature for NO_3^-).

At a second site, single-well fluorescent dye tracer tests were undertaken along a transect of wells with decreasing distance from the inferred connection with the surface water. The tests were undertaken using a recently developed technique referred to as the finite volume point dilution method (FVPDM) to collect in situ and real-time measurements of groundwater and contaminant fluxes under an active industrial wharf.

Results/Lessons Learned.
The vertical pore water profiles demonstrated that the risk from the discharge of contaminated groundwater can be markedly reduced by groundwater-surface water mixing and attenuation. The results from the tracer tests formed a critical piece of information to develop priorities for a source reduction program.

The tools used at these two sites enabled an improved characterisation of transport, mixing and attenuation of the discharge of contaminated groundwater to the receiving environment. These were critical to improving the conceptual models of contaminant transport at the sites, understanding the risk of site impacts and engaging with the regulators. Such an understanding is fundamental to assessing the practicability of adopting various remedial techniques.