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Water quality sample origin in wells under ambient vertical flow conditions

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Sampling from wells remains the key technique for investigation of groundwater contamination. Research into low-flow (pump rate 0.1-0.5L/min) and passive sampling devices and methodologies has largely been driven by needs to minimise sample bias and reduce costs associated with well-volume purge sampling. Such techniques are primarily suited to short-screen (<3m) well sampling, however, their perceived cost/time savings means their use in longer screen wells is attractive. Ambient vertical flows that may perhaps be insignificant in short-screen wells are, however, likely prove increasingly significant as the screen length increases due to the increased probability of vertical flows in greater thicknesses of (layered) geological sequences monitored. The interpretation of sample results assuming idealised horizontal flow conditions may introduce significant bias and prove unsuitable in these conditions. Numerical modelling has been undertaken to investigate the bias introduced under ambient vertical flow conditions.

Sampling scenarios were generated by varying partially penetrating screen length, well diameter, sampling device position, pump rate, aquifer thickness and hydraulic conductivity, and boundary head gradients. In well flow rates were based on literature data for relatively short (2-20m) wells. The degree of sampling bias was quantified by calculating the root mean square error between the simulated scenario under a vertical head gradient and ideal horizontal-flow scenario.

Low-flow and passive sampling device position, pump rate and pump duration were all found to be important in determining the sample origin. The sample may not be drawn from the entire saturated screen interval even under ideal conditions. When considering vertical flow scenarios, measurable deviation from the ideal case and bias towards the zone of highest head begins with ambient in-well flow rates as little as 50% of the pump rate used. The sample may not predominately originate from the zones most important to flow regionally. For a particular in-well vertical flow rate the sampling bias introduced decreases exponentially towards zero with increasing pump rate. To overcome this bias it is necessary to pump at a rate over an order of magnitude greater than the in-well flow rate. This relationship exists for all scenarios considered.

The modelling indicates literature reported flow rates in the relatively short wells considered (3-10m) may introduce significant bias in low-flow and passive sample origin. The assumption of ideal horizontal flows when interpreting sampling results can be very misleading and hence increasing efforts should be made to measure vertical flows during site investigations, even for relatively short screen wells.