Geophysical Research Abstracts
Vol. 16, EGU2014-2023, 2014
EGU General Assembly 2014

Time lag estimates for nitrate travel through the vadose zone in Southland, New Zealand

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A regional-scale study was carried out to calculate the travel time of a nitrate particle from the ground surface into shallow groundwater. The aim of the study was to obtain preliminary answers to two questions. Firstly, if leaching limits are set, how long would it take to see an improvement in shallow groundwater quality? Secondly, have groundwater nitrate concentrations reached equilibrium from recent dairy expansion in the region, or could we expect future increases?

We applied a methodology that provides a balance between the detail and generalisation that is required for a regional-scale study. Steady-state advective transport through the vadose zone was modelled with water retention curves. These curves enable an estimate of the average volumetric water content of the vadose zone. The percentage saturation can then be used to calculate the vadose zone transit time if effective porosity, depth to the water table and annual average soil drainage are known. A time for mixing in the uppermost part of the aquifer has also been calculated.

Two different vadose zone water retention curve models were used for comparison, the Brooks-Corey (1964), and the Van Genuchten (1980) methods. The water retention curves were parameterised by sediment texture via the Rawls and Brakensiek (1985) pedotransfer functions. Hydraulic properties were derived by positioning sediment textural descriptions on the Folk textural triangle, estimates of effective porosity from literature, and hydraulic conductivity values from aquifer tests. Uncertainty of parameter estimates was included by assigning standard deviations and appropriate probability distributions.

Vadose zone saturation was modelled at 6,450 sites across the region with a Monte Carlo simulation involving 10,000 realisations. This generated a probability distribution of saturation for each site. Average volumetric water content of the vadose zone ranged from 8.5 to 40.7 % for the Brooks-Corey model and 12.9 to 36.3% for the Van Genuchten model. The large number of 1-D calculations allows the results to be presented spatially. About 80% of the region is expected to have a transit time of less than five years, and 90% less than two years. Older transit times are associated with mid Pleistocene outwash gravels. These deposits have lower permeability, and are also located at higher elevations above the rivers.

The results indicate that shallow groundwater beneath properties in most of Southland will respond rapidly to a reduction in leaching rates. Large future increases in nitrate concentrations are only expected in discrete areas beneath older more elevated outwash gravel deposits. Preliminary validation of the modelled values has been carried out by comparison with tritium ages at the top of the aquifer and the results are encouraging.