

## **The Nitrate Time Bomb (NTB) Model — A simple but effective method to investigate the impacts of historical nitrate loading on long-term groundwater nitrate concentrations**

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Nitrate water pollution, which remains an international problem, can cause long-term environmental damage and threaten both the economy and human health. Agricultural land is the major source of nitrate water pollution. It can take decades for nitrate leached from the soil to discharge into freshwaters. However, this nitrate time lag in the groundwater system has generally been ignored within the water resource management in many countries including the UK.

We present a nitrate time bomb (NTB) model to modelling nitrate processes in the groundwater system. Whilst NTB contains simplified conceptual models, it can represent the major nitrate and hydrogeological processes in the groundwater system at both national and catchment scales, such as spatio-temporal nitrate loading, low-permeability superficial deposits, dual-porosity unsaturated zones and nitrate dilution in aquifers. The NTB model has been successfully used to simulate annual nitrate concentrations from 1925 to 2150 in the major aquifers in Great Britain and four local aquifer zones in the Eden Catchment, England. Monte Carlo simulations were undertaken to analyse parameter sensitivity and calibrate the model using observed datasets. These results help decision makers to understand how the historical nitrate loading from agricultural land affects the evolution of groundwater quality due to the nitrate time lag in the groundwater system. This NTB approach will be particularly valuable to evaluate the long-term impact and timescale of land management scenarios and programmes of measures introduced to help deliver water quality compliance. This model requires relatively modest parameterisation and is readily transferable to other areas.