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Catchment scale modelling of pesticide fate and transport using a simple parsimonious process-based model

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Pesticides continue to be detected in surface water resources around the world. In the UK to ensure the safety of drinking water supplies, water companies are required to create drinking water safety plans, which take a catchment risk management approach. Models can be used to predict peak pesticide concentrations in raw surface water supplies, these predictions can then be utilised in risk assessments. There is therefore a need to model pesticide fate and transport from agricultural land to surface water resources at the catchment scale.

We present a simple soil water balance model linked with a pesticide fate and transport model to predict hydrological response and pesticide exposures at the catchment outlet which is intended for use in risk assessment of raw drinking water resources.

The model considers two soil water stores (a topsoil store and a subsoil store) for each soil type in the catchment. It employs a daily time-step and simulates changes in soil water content, actual evapotranspiration, overland flow, drainflow, lateral throughflow and potential recharge to a groundwater store which contributes to baseflow.

The model is semi-lumped (not spatially explicit). Calculations are performed for soil type and crop combinations which are weighted by their proportion within the catchment. The model utilises soil properties from the national soil database and can, therefore, be applied to any catchment in England and Wales.

The pesticide fate model assumes first-order degradation kinetics, a linear sorption isotherm and leaching at the rate of the unsaturated hydraulic conductivity. Following application the pesticide is assumed to diffuse into the soil and be evenly distributed in the "non-excluded" pore water (pesticides are assumed to be unable to diffuse into the very small pores). Pesticide concentrations and loads to surface water resources are calculated for rainfall events that generate a hydrological response, assuming that a proportion of the most mobile soil water is displaced.

By calibrating six hydrological parameters model performance in four medium to large catchments (Lugg, Teme, Waveney and Yare) was very good (Nash Sutcliffe Efficiency between 0.6 and 0.79 and percentage bias between ± 5 and 10%), suggesting that the physical basis of the model is reasonable.

For the pesticide fate model given the difficulties in calibrating predicted concentrations made at a daily time-step against infrequently measured data (fortnightly to monthly), a cumulative distribution function model is utilised. The comparisons made between measured and predicted pesticide concentrations were good, suggesting the model is fit-for-purpose as a decision making tool to be used for: predicting likelihood of detection, designing sampling strategies and as an input into risk assessment.

Due to the simplicity of the model it can be used to explore not only current trends in pesticide concentrations, but also how land use change and changes in pesticide regulation could pose new challenges to drinking water resources into the future.