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Prediction of diffuse organic micropollutant loads in streams under changing climatic, socio-economic and technical boundary conditions with an integrated transport model

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Catchments are complex systems where water quantity, quality and the ecological services provided are determined by interacting physical, chemical, biological, economical and social factors. The realization of these interactions led to the prevailing catchment management paradigm: Integrated Water Resources Management (IWRM). IWRM requires considering all these aspects during the design of sustainable resource utilization. Due to the complexity of this task, mathematical modeling plays a key role in IWRM, namely in the evaluation of the impacts of hypothetical scenarios and management measures.

Toxicity is a key determinant of the ecological state and as such a focal point in IWRM, but we still have significant knowledge gaps about the diffuse loads of organic micropollutants (OMP) that leak from both urban and agricultural areas. Most European catchments possess mixed land use, containing rural (natural and agricultural) landscapes and settlements in varying proportions. Thus, a catchment model supporting IWRM must be able to cope with both classes. However, the majority of existing catchment models is dedicated to either rural or urban areas, while the minority capable of simulating both contain overly simplified descriptions for either land use category.

We applied a conceptual model that describes all major land use classes for assessing the impacts of climate change, socio-economic development and management alternatives on diffuse OMP loads. We simulated the loads of 12 compounds (agricultural and urban pesticides and urban biocides) with daily resolution at 11 locations in the stream network of a small catchment (46 km2) in Switzerland. The model considers all important diffuse transport pathways separately, but each with a simple empirical process rate. Consequently, some site-specific observations were required to calibrate rate parameters. We assessed uncertainty during both calibration and prediction phases.

Predictions indicated that future OMP loads were predominantly determined by human activities in each simulated sub-catchment, as reflected by the socio-economic scenarios and management alternatives. Climatic and the corresponding hydrological changes had a much weaker influence. This indicates that – conditionally on the confidence of our predictions – catchment management would possess effective options to prevent the degradation of water quality in the future.

However, prediction uncertainty varied between high and huge levels depending on compound. Most of the identified uncertainty was related to the quality of input data. Application rates and timings could be estimated only roughly for most compounds. Concentration peaks were simulated with high uncertainty. The highest pollutant concentrations were often associated with known but unidentified pollution sources such as accidental spills, or brief high-intensity precipitation events whose amount could only be observed with high uncertainty. So while acute exposure would be as important as the chronic one for IWRM, neither climatic nor catchment models excel at predicting rare and brief events. This deficiency highlights why the assessment of predictive uncertainty should be an integral part of OMP modeling.