Source-Flux-Fate Modelling of Priority Pollutants in Stormwater Systems - DTU Orbit

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The increasing focus on management of stormwater Priority Pollutants (PP) enhances the role of mathematical models as support for the assessment of stormwater quality control strategies. This thesis investigates and presents modelling approaches that are suitable to simulate PP fluxes across stormwater systems, supporting the development of pollution control strategies. This is obtained by analyzing four study areas: (i) catchment characterization, (ii) pollutant release and transport models, (iii) stormwater treatment models, and (iv) combination of the above into an integrated model. Given the significant level of uncertainty affecting stormwater quality models, the identification of sources of uncertainty (based on Global Sensitivity Analysis - GSA) and quantification of model prediction bounds (based on pseudo-Bayesian methods, such as the Generalized Likelihood Uncertainty Estimation - GLUE) are presented as crucial elements in modelling of stormwater PP. Special focus is on assessing the use of combined informal likelihood measures assigning equal weights at different model outputs (flow and quality measurements). Management of the spatially heterogeneous sources of stormwater PP requires a detailed catchment characterization, based on land use and the use of information stored in Geographical Information System (GIS). The analysis carried out in the thesis, which compares different characterization approaches with different level of detail, suggests in fact that this approach allows the identification of the major pollutant sources (and sources of uncertainty) in the catchment and provides the basis for the development of source-control strategies. The thesis shows how conceptual continuous dynamic models, combined with uncertainty analysis, can provide estimation of PP loads that can be used for scenario analysis over long time periods. The combination of GSA with uncertainty analysis techniques enables the identification of interactions between model factors which are commonly ignored by traditional approaches. The analysis performed in the thesis shows how the use of different informal likelihood measures in GLUE can affect the estimation of model prediction bounds and the model applications for stormwater management. The fate of stormwater PP (dissolved and particulate) in treatment units is simulated by extending a dynamic multi compartmental stormwater treatment model with fate processes that are simulated based on the substance inherent properties (degradation rates, solid-water partition coefficient, Henry’s law constant, molecular weight). The developed model (STUMP) thus applies concepts commonly used in chemical risk assessment at the scale of stormwater treatment facilities by providing a dynamic representation of the system. STUMP can simulate different substances (metals, organics) in various treatment units (e.g. ponds, biofilters). The uncertainty analysis performed in the thesis allows the identification of the major sources of uncertainty in different units, depending on the dominating PP fate processes. A reduction in STUMP uncertainty of PP fate estimation can be obtained by a good representation of the physical characteristic of the treatment unit, reducing the need for PP field measurements. The thesis shows how the integration of the investigated models provides results that can be used in the development, assessment, and comparison of different PP control strategies (e.g. source control or improvement of treatment facilities). The combination of the integrated model with uncertainty analysis identifies the information that is necessary to improve the scenario analysis and increase the reliability of the simulation results. The models developed and demonstrated in the thesis are applied in a real catchment to evaluate different scenarios for reduction of PP emissions to the aquatic environment, showing the potential of the proposed approaches as support tools in stormwater quality management. The thesis provides a framework for the trustworthy application of models to estimate PP fluxes from their sources, and through stormwater drainage systems, and to the sink. This fills a knowledge gap regarding stormwater PP and it supplies urban water managers with modelling tools for management of stormwater pollution. Examples in the thesis are focused on heavy metals (Cu, Zn) and selected organic substances (DEHP, Glyphosate, Pyrene, IPBC, Benzene).

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