Modelling approaches for a scenario based assessment of chemically induced impacts on aquatic macroinvertebrate communities (MACROMOD)

Executive summary

The ecological risk assessment of chemicals aims to protect non-target populations and the communities they comprise, while the underlying effect assessment is largely based on individual level toxicity information. Effects caused by the exposure of organisms to chemicals can however to a great extent depend on environmental scenarios as well on the states, behaviour and interactions of organisms with consequences for individual life history, population responses and community dynamics. The quantitative contribution of the environmental scenario, including biotic interactions, to the chemical effect in a multiple stressor situation is however unclear.

In this project, we developed an individual-based population and community model for streams called STREAMcom. This model integrates spatial explicit stream typologies as formulated within the EU Water Framework Directive (EU WFD), temporal information on abiotic factors such as temperature and chemical exposure, as well as functional trait data bases, dynamic energy budget (DEB) models for several species and process based toxicological effect models such as the toxicokinetic-toxicodynamic framework GUTS. This model is designed to simulate the impact of chemical exposure on macroinvertebrate assemblages and fish dynamics, and to explore to what extent community interactions, such as competition and predation, and the choice of the ecological scenario will influence the chemical effect at the community level.

As case studies, we have focused on two different stream types in Germany, lowland streams and upland streams, that are defined within the EU WFD. For each case study site, spatial explicit raster map information on velocity, substrate and water depth, as well as annual temperature profiles serve as model input. A number of ten focal species have been selected from monitoring data to represent the trait composition of typical field communities. For two mayfly species, three amphipods, three snails, one mussel and one isopod species, a dynamic energy budget model has been parametrized.

For this project we have selected the pesticide chlorpyrifos as a model chemical and used typical exposure scenarios (FOCUS scenarios) for the simulations. We have considered both lethal and sublethal effects posed on focal species by chemical exposure. For sublethal effects we focused on feeding inhibition as physiological mode of action due to its role in ecosystem function and individual life history. In order to complement the data derived from the literature, own laboratory feeding experiments and acute toxicity tests were carried out with chlorpyrifos and five macroinvertebrate species in the laboratory.

In environmental risk assessment, it is very important to include enough species to address the variability of species with respect to their sensitivity and vulnerability. However, it is not always possible and very time consuming and expensive to test a sufficient number of species for each test substance in the laboratory in order to be able to parametrize toxicological-toxicodynamic models for the prediction of toxic effects under variable exposure conditions for a set of potentially sensitive species. Therefore, concepts for extrapolating such TKTD parameters across species are urgently needed.

In this project, we developed and verified a concept that allows us to predict TKTD parameters of an untested species through a correlation approach between species parameters. This concept of cross-species parameter correlation approach was directly used in the

STREAMcom model because not for every modelled species toxicity data were available for chlorpyrifos.
The community model STREAMcom allows the prediction of community level effects from individual level toxicity testing, even if the ecological modules need to be further improved and validated. Exemplary simulations show that the model can reflect the interactions of the community model with the toxicological effect models parametrized for chlorpyrifos and the selected FOCUS exposure scenarios. The model, on the one hand, sensitively responds to lethal and sublethal effects, and, on the other hand, shows also indirect effects via e.g. food competition between species, which can considerably add on the chemical effect at higher biological levels. The STREAMcom model allows the quantification of this multiple stressor effect based on scenario analyses. Such scenario-based analyses will increase our understanding how chemicals act on multiple interacting species and provide a basis for bringing more ecological realism into the ecological risk assessment of chemicals.

In comparison to the newly developed STREAMcom model, the existing numerical water quality lake model StoLaM coupled to an individual-based population model for *Daphnia magna* was additionally used in this project to simulate effects of chlorpyrifos on lentic plankton communities. In StoLaM, several phytoplankton and zooplankton groups as well as fish are implemented. Additionally, the one-dimensional vertical structured hydrodynamic model HyLaM as part of the StoLaM allows high resolution of the lake internal physical environment which is required for simulating the nutrient and plankton dynamics in detail. As case studies, we have chosen three lake types based on the classification system of the EU Water Framework Directive (WFD), which differ in relevant lake properties such as morphometry, trophic state, water depth, stratification regime during summer, and food web structure of the pelagic food web. We additionally considered common anthropogenic lakes and ponds (i.e. artificial eutrophic and very shallow lakes and ponds) as further scenarios which are relevant for the ERA of chemicals in Europe. From the presented StoLaM simulations it can be concluded that populations in nutrient-poor deep lakes react more sensitive to direct effects of a toxicant and show longer recovery rates due to a lower resource availability compared to nutrient-rich and shallow lakes. The effect size in highly productive lakes is rather reduced during the reproduction phase of the affected population, but indirect effects may be more pronounced. However, whether this leads to a promotion above the control level or to a long-term decrease under competitive conditions, depends in the nutrient-rich systems on the composition and complexity of the food web.

Within this project a conceptual framework for integrating outputs from community models into Environmental Risk Assessment (ERA) of substances regulated under REACH was developed. This was carried out as a three-step process consisting of: 1. Review of current literature; 2. Development of draft conceptual framework; 3. Consultation process/ dialogue with relevant stakeholders and adjustment/ justification of framework. Based on the stakeholder consultation process, we conclude that the envisioned use of community models for refining hazard assessment and supporting management decisions could be beneficial for ERA of REACH chemicals in cases where data availability is sufficient to reduce uncertainty to an acceptable level. However, we also conclude that since in most cases data is limited for chemicals regulated under REACH, and the models may be put to better use for example for ERA of plant protection products or for evaluation of ecological status under the EU Water Framework Directive.