Influence of test conditions and exposure duration on the result of ecotoxicological tests: Consequences for derivation of environmental quality standards

Chemicals are used extensively and are part of many aspects of human life and society. They are useful and necessary for many purposes, but may also cause adverse effects on natural organisms if they are released to the environment during and after use. Therefore, it is necessary to perform a risk assessment to predict and prevent adverse effects. In Europe, chemical registration and safety is regulated by the European Commission by the implementation of different directives, such as REACH (Registration, Evaluation, Authorization, and restriction of Chemicals, EC 1907/2006), the Biocide Directive (98/8/EC) or the Plant Protection Products Directive (EC 1107/2009). In addition to such risk assessment directives, the Water Framework Directive (2000/60/EC) has been adopted with the objective to protect and improve the quality of European waters and aquatic habitats. This requires, among other things, an assessment of compliance with environmental quality standards (EQS) for xenobiotic chemicals and metals. The basis for the derivation of these EQS is the focus of this thesis. An EQS is the concentration of a chemical, below which no adverse effect of the ecosystem is expected to occur. It will often be calculated from results of ecotoxicological tests performed according to internationally approved guidelines, such as from the Organisation for Economic Co-operation and Development (OECD) or International Standardization Organisation (ISO). Such guidelines were originally developed to enable classification and hazard ranking of chemicals, and therefore their focus is to measure the toxicity of an artificially maintained continuous exposure under test conditions that rarely reflect natural conditions. This may be in contrast to the aim of establishing EQS, i.e. to protect the natural ecosystem from chemical stress. In light of this possible contradiction, the aim of this thesis was to investigate whether EQS derived on the basis of guideline tests will be sufficiently protective of the environment. This was done by exploring the influence of a number of test conditions, such as temperature, light, pH and exposure duration on the toxicity recorded in tests using four sulfonylurea herbicides (SUs) and the aquatic macrophyte Lemna gibba as study objects. The study showed that changing the physical and chemical test conditions influenced the toxicity of sulfonylurea herbicides towards L. gibba. Lowering the temperature from 24 to 15°C caused a two-fold reduction in the toxicity of flupyrsulfuron-methyl, while no statistically significant changes was seen for metolachlor-methyl, rimsulfuron, or thifensulfuron-methyl. Likewise, the introduction of a 12:12-hours light:dark cycle resulted in a two-fold reduction of the toxicity of thifensulfuron-methyl. Again, no clear trend or statistically significant change was observed for the other three test SUs. Finally, the toxicity of the four SUs was tested at three different pH levels (6, 7.5 and 9). Here, it was observed that the difference in toxicity between tests at pH 6 and 9 was in the range of a factor 2-10 for the four SUs, with the tests at pH 6 being most toxic. Hence, the conclusion of this study was that by performing only guideline tests there may be a risk of underestimating the toxicity of a compound. It was recommended to carefully evaluate the physico-chemical properties of the compound prior to testing and to design the test to include the influence of these on the toxicity observed. The effect of a 24-hour pulse of the four SUs was evaluated in another part of the study. It was shown that these short-term high-concentration exposures resulted in EC50 values that were 2-6 times higher than those obtained in guideline tests. Within the WFD, a short-term water quality standard (MAC-EQS) is derived, that should protect against effects from pulse discharges, however when this is compared to the result of the pulse tests from this study, it appears that the WFD approach is under-protective. Hence, a revision of the WFD approach should be considered because protection from pulsed discharges should not be based on the results of tests with a continuous exposure, even if they are short-term tests. Instead, the derivation of a MAC-EQS should be based on pulse tests and possibly also modelling and it should consider the recovery of the organism. The overall conclusion of this thesis is that under the current approach for derivation of EQS, there will be cases where basing the value on results from guideline tests alone will not be sufficiently protective of the environment. However, there are also be cases where the choice of test design would possibly overestimate the toxicity, and consequently the resulting EQS would be too strict. Bringing more environmental realism into the testing by designing tests according to the physico-chemical properties, and taking the use pattern of the compound into consideration, would probably result in a better estimation of the effects and thereby the EQS.