Geography-referenced bioavailability modeling in risk assessment: a case study of copper in Swedish surface waters

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Introduction

Until recently, water quality standards and risk assessment procedures for metals in surface waters were predominantly based on total and/or dissolved metal concentrations (Janssen et al., 2000). However, the importance of bioavailability and toxicity modifying factors like pH, hardness and DOC, is increasingly being recognized. The development of Biotic Ligand Models (BLM) that predict toxicity of metals to fish, invertebrates and algae (e.g. Di Toro et al., 2001; De Schamphelaere et al., 2002; Heijerick et al., 2002a) can be considered as an important step towards a scientifically sound protection of freshwater environments.

Hence, the possible use of these models for regulatory purposes is gaining increased interest in both the scientific and the regulatory community. The correct incorporation of these models in a regulatory framework, however, remains a matter of debate. In this study the potential use of copper bioavailability models is demonstrated using a case study for Swedish surface waters.

The main focus of this paper will be on the *Daphnia magna*-BLM (the most advanced chronic BLM, De Schamphelaere and Janssen, unpublished). As *D. magna* is very sensitive to copper, it may be a good model organism for the initial identification of possible environmental risks.

Additional research aimed at linking bioavailability modeling with Geographical Information Systems (GIS) will be presented. The advantages of such an approach will be demonstrated and visualized with regard to different levels of uncertainty and temporal variability.

Materials and Methods

For the implementation of a BLM-oriented risk assessment procedure for copper in surface waters, a database of monitoring locations is needed that contains data on total or dissolved organic carbon (TOC or DOC), pH, alkalinity, temperature, Ca, Mg, Na, K , Cl, SO_4, and total or dissolved copper concentrations. Databases of Swedish surface water characteristics, which fulfill these requirements, were obtained from http://info1.ma.slu.se. Using these data No Observed Effect Concentrations (NOEC) and Predicted No Effect Concentrations (PNEC) were calculated with the developed chronic toxicity models. Visualization of NOECS and PNECs was carried out using ArcView GIS-software (© ESRI). Monte Carlo simulation techniques were used to account for temporal variation of the water characteristics.

Results and discussion

Figure 1 shows the spatial variability of BLM-predicted NOEC values for *D. magna* in Swedish lakes monitored in the 'Riksinventeringar' database (about 5000 lakes). Similar trends were observed for scenarios in which species sensitivity distributions (SSDs, yielding PNECs rather than single-species NOECs) were taken into account.

For 22 of the 25 counties, average BLM-predicted NOEC values were between 60 and 180 µg Cu/L. NOECs generally increased from north to south, which coincides with a slight increase of TOC levels from north to south (NIVA, 2001). Environmental copper concentrations for those sites were mostly below 3 µg/L and site-by-site probabilistic risk characterization learned that over 99% of the lakes in these counties had NOEC values higher than monitored Cu concentrations, and were thus not at risk. Using SSDs and accounting for different levels of uncertainty and temporal variability indicated that risk ratios generally remained below 1, as demonstrated by Monte Carlo simulations.

On the contrary, three counties showed considerably lower average NOEC-values (<20µg Cu/L). Moreover, average copper concentrations in these counties were close to NOEC values: 6 µg/L in Norbotten, 19 µg/L in Kopparberg and 21 µg/L in Stockholm. Probabilistic risk characterization learned that 13%, 53%, and 75% of the monitored lakes were potentially at risk in Norbotten, Kopparberg and Stockholm, respectively.

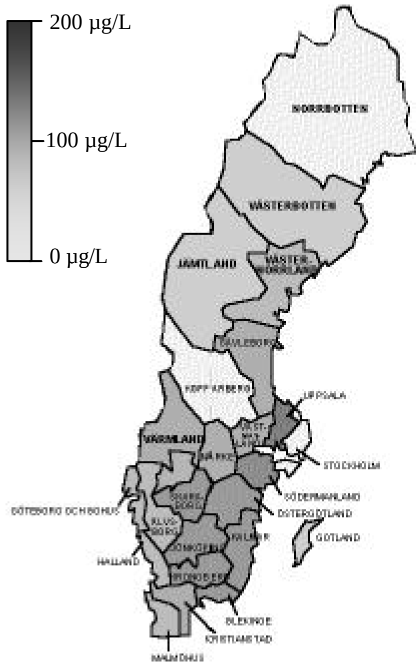

Figure 1 Regional distribution of BLM-predicted NOEC values of copper for *D. magna*. Swedish lakes can broadly be divided into four regions according to PNECs: the south-west (80 to 100 µg/L), the south-east (130 to 180 µg/L), a central part (100 and 130 µg/L), and the north (60 to 100 µg/L)

Conclusion

Geo-referencing PNECs and/or SSDs (in a GIS environment) and incorporating different levels of uncertainty results in a more realistic risk assessment (as spatial information is explicitly accounted for) which is preferable to the current practice of using a single (lumped) PNEC or SSD, representing an entire region or country.

References

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