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Application of species sensitivity distributions as ecological risk assessment tool for water management

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Abstract

Water quality monitoring programs concern measurements of numerous substances in different water compartments such as water, suspended matter and tissues of organisms. The obtained monitoring data are often used for compliance testing of environmental quality objectives. The quality assessment concerns either a binary result (data meet or exceed objective) or a factor by which the measured concentration exceeds the objective (times-to-objective). This factor is often applied in an arbitrarily chosen classification system. Major disadvantage of this method is that the factor of exceedance is meaningless with respect to expected ecosystem health risk (ecotoxicological effects). In the Netherlands, a statistical extrapolation method, which uses the variability in sensitivity (NOEC's) between various test species, is used to derive risk levels for ecosystems. The shape of the distribution curve for species sensitivity is assumed to be a log-logistic one. This statistical extrapolation method can also be applied to assess the potential ecotoxicological effect of environmental concentrations, which can, in that case, be expressed as the potentially affected fraction. A classification system following risk levels chosen in the extrapolation method, provides a more powerful tool for priority setting with respect to ecosystem risk than a times-to-objective or binary approach.

Keywords: Species sensitivity distribution; Ecological risk; Water management

1. Introduction

Since 1989, risk evaluation forms the basis of Dutch environmental policy. The starting point of this risk evaluation is to quantitative risk estimation, which can be a

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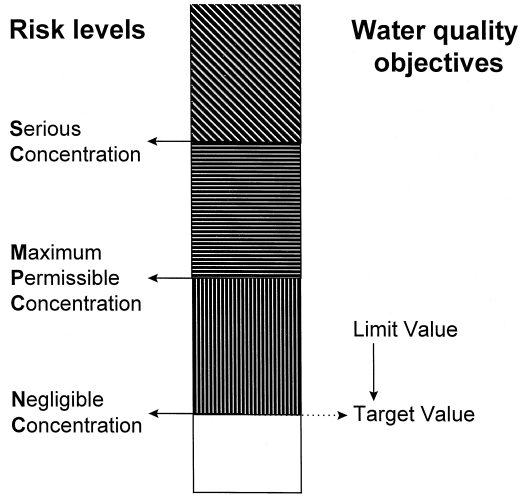

Fig. 1. Relation between risk levels and Dutch water quality objectives.

basis for risk reduction. Risks are quantitatively estimated by deriving risk levels called maximum permissible concentration (MPC) and negligible concentration (NC). When concentrations exceed MPC, the possibility that human or environmental health is affected is unacceptable. A third risk level is defined for soil quality management, called 'serious concentration', indicating possible serious effect of soil functional properties for man, plant or animal. Besides risk levels, other factors like economical feasibility are taken into account in determining environmental quality objectives. The relation between risk levels and water quality objectives are given in Fig. 1. Most target values are equal to NC. Limit values are maximally set on MPC.

In practise, data from water quality monitoring programs concern measurement of several substances in different water compartments such as water, suspended matter, and tissues of organisms. The resulting monitoring data are often used for compliance testing of environmental quality objectives. The quality assessment concerns either a binary result (data meet or exceed objective) or a factor by which the measured concentration exceeds the objective (times-to-objective). This factor is often applied in an arbitrarily chosen classification system (Table 1). Such classification results are used in priority setting for water quality improvement measures or sediment remediation. The aim of

Table 1
Two systems to classify monitoring data as used in Dutch water management

Method A (CUWVO [1]), water concentration	Method B (Eys et al. [2]), water concentration
$\leq$ target value	$\leq$ target value
$\leq$ limit value	$\leq$ limit value
1–2 times limit value	1–2 times limit value
2–5 times limit value	2–10 times limit value
$>$ 5 times limit value	$>$ 10 times limit value

this study is to compare the 'times-to-objective approach' to the risk assessment approach, and to show the usefulness of the risk approach to water management.

2. Theory

To derive the risk levels for ecosystems, a statistical extrapolation method is used, which is based on the variability in sensitivity (NOEC's) between various test species. The variability in sensitivity of test species is assumed to be representative for the variability of all test species in the environment. In this method, developed by Kooijman [3] and van Straalen and Denneman [4] and modified by Aldenberg and Slob [5], the shape of the distribution curve for species is assumed to be a log-logistic one (Fig. 3). With this distribution, the MPC and the SC are defined as the concentrations at which the NOEC is exceeded for 5% and 50%, respectively, of the species. The NC is set at 1% of the MPC.

3. Results and discussion

A comparison of a 'times-to-objective' quality assessment and the ecotoxicological risk assessment of chemical monitoring data for four substances in Dutch freshwater systems is presented in Fig. 2. The ecotoxicological risks are expressed as the potentially affected fraction and the 'times-to-objective' quality assessment as test value/limit value. In Fig. 2, it is shown that an identical times-to-objective factor leads to different

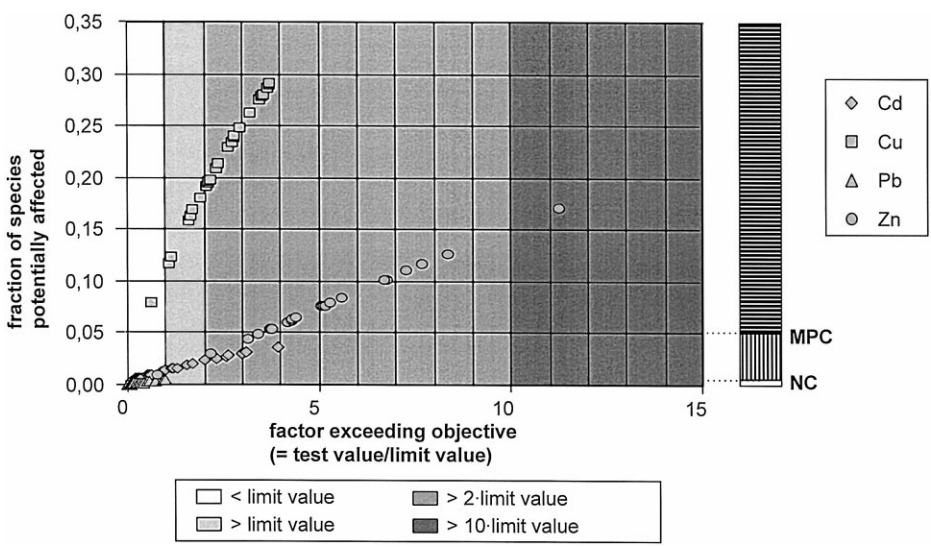

Fig. 2. Relation between a 'times-to-objective' quality classification [2] (presented as factor exceeding quality objective) and ecotoxicological risk assessment (presented as potentially affected fraction).

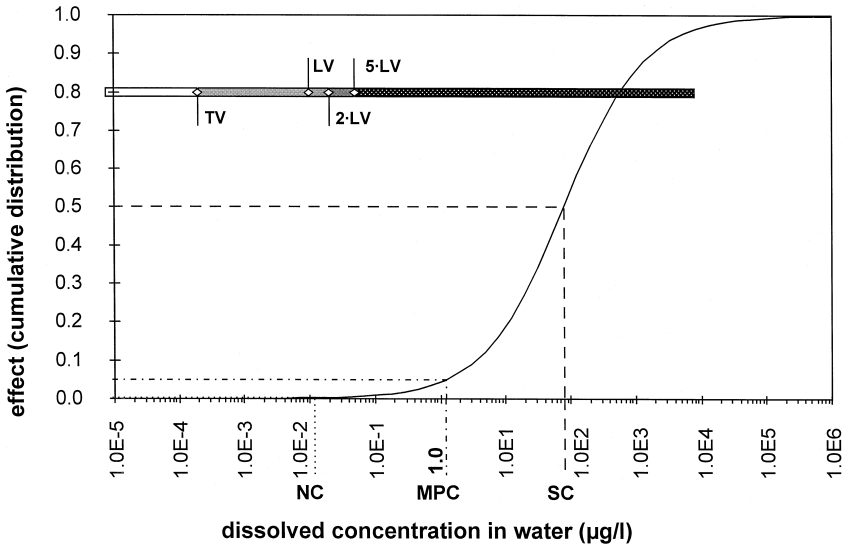

Fig. 3. Sensitivity distribution for water organisms for lindane. The risk levels (NC = negligible concentration, MPC = maximum permissible concentration and SC = serious concentration) are given in the distribution curve. The classification system based on water quality objectives [1] is given as a bar (TV = target value, LV = limit value, 2·LV and 5·LV = 2 and 5 times limit value).

ecotoxicological risks for the four substances. Classification based on risk levels may result in a different priority setting compared to classification based on quality objectives.

An example of discrepancy between a current classification system and ecotoxicological risk assessment is also presented in Fig. 3. Target and limit values for water quality are much lower than NC and MPC for water organisms.

4. Conclusions

The major disadvantage of the present quality classification of substances in Dutch water management is that the factor of exceedance of water quality objectives is meaningless with respect to the expected ecosystem health risk (ecotoxicological effects). Species sensitivity distributions and classification following risk levels based on the species sensitivity provides a more powerful tool for priority setting with respect to ecosystem risk than a times-to-objective or binary approach. Applying this proposed system in evaluating environmental monitoring, data may result in a different judgement on the expected risk of measured concentrations in comparison with the conventional classification based on quality objectives. This may have significant implications for risk management, e.g. for remediation measures to be taken, i.e. a different priority ranking of sediment sanitation sites.

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