COMPARATIVE RISK ANALYSIS OF FOUR ANTIFOULING BIOCIDES USED IN COMMERCIAL SHIPPING

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Abstract

A revised comparative risk analysis of the antifouling biocides tributyltin, Irgarol, Sea-Nine and pyrithionate is presented. As in a previously published study [1], the five risk indicators release, spatiotemporal range, bioaccumulation, biological activity and uncertainty are used for the evaluation. The indicator evaluation is therefore based on literature data, modelling results and expert opinions. Special emphasis is placed on adequate assessment and communication of evaluation uncertainties. The resulting ecotoxicological risk profiles show that the comparison of tributyltin with its alternatives is mostly ambiguous, even if some of the alternatives do seem to be favorable.

Introduction

The concept of a comparative risk analysis presented here is based on the assumption that persistence, bioaccumulation and toxicity are a valid basis for risk evaluation, if they are understood as generalized indicators – and if they are completed by the two additional indicators release and uncertainty. This use of five indicators covers the whole pathway relevant for decisions, starting from information about the entry of the substance into the environment up to reflexive information about the quality of the evaluation (Figure 1).

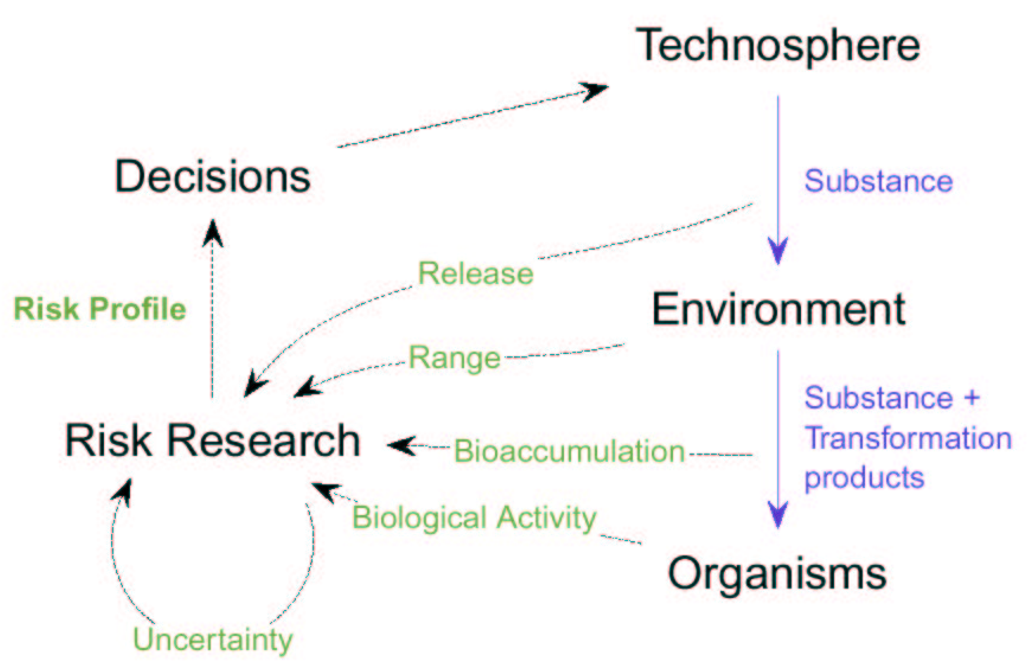

Figure 1: The information cycle of risk management along the pathway of environmental chemicals

Copper and Tributyltin (TBT) are predominant in todays antifouling coatings for commercial ships. 2-*t*-butyl-amino-4-cyclopropylamino-6-methylthio-1,3,5-triazine (Irgarol® 1051, shortly Irgarol), 4,5-dichloro-2-*n*-octyl-4-isothiazoline-3-one (shortly DCOI, active substance in Sea-Nine® 211) and the complexes of 2-Mercaptopyridine-N-oxide (Pyrithionate) were evaluated because of their occurrence in organotin-free coatings for the same type of ships.

When it comes to a choice of alternative biocides in these antifouling coating systems, there seems to be no easy way to avoid the use of copper as a basic biocide. The decision to be taken in the coating design or the purchase of a coating can therefore be viewed as a decision, which additional ("booster") biocide or biocides will be used in the coating. For this reason, the comparison of the complete ecotoxicological risk profiles is only presented for TBT, Irgarol, Sea-Nine and Pyrithionate. Definitions of the indicators, a basic description of their assessment and the resulting risk profiles are shown. Details of the assessment process can be found in [2]. Almost all ecotoxicological data used in the assessment process can be freely accessed in the database UFT_SAR [3].

Release

The release indicator R is quantified by the amount I in tons per year released to the environment during the technospheric life-cycle of the substance.

$$\mathsf{R} \propto \log_{10} I$$

Evaluation of the release rate of the biocides has been carried out in a quite simple manner: In the accessible literature, only detailed data about TBT and copper were encountered. For the evaluation of release rates of the other substances, the percentages used in antifouling coatings served as first basis [4, 5].

Spatiotemporal Range

This indicator S describes the tendency of a substance and its transformation products to cause exposure of organisms by spreading out in space and time - independent of the released amount. A convenient way to quantify this is to divide the steady state mass of the substance and its transformation products in the relevant environment M_{env} by the Input I. This is equivalent to their joint persistence τ_{joint} [6].

$$\mathsf{S} \propto \log_{10} \frac{M_{env}}{I} = \log_{10} \tau_{joint}$$

The persistence of TBT, Irgarol 1051 and Sea-Nine has been analyzed by means of a global Level III fate model, as reported in [7]. However, only primary degradation was taken into account in that study. The evaluation of the spatiotemporal range S also takes the most ecotoxicologically relevant transformation products into account.

Bioaccumulation

The bioaccumulation indicator B aggregates the available information about the tendency of the substance and its transformation products to be taken up by organisms if present in their environment.

A global bioaccumulation indicator can even be quantitatively defined to be proportional to the fraction of a substance plus relevant transformation products in the environment, which is accumulated in any organism.

$$\mathsf{B} \propto \log_{10} \frac{M_{\mathrm{bio}}}{M_{env}}$$

where M_{bio} is the total mass of substance and relevant transformation products taken up by organisms.

This idealized metric has been aimed at with the bioaccumulation evaluation shown in Figure 2 (indicator B). Depending on data availability, octanol-water partitioning constants, bioconcentration factors or other bioaccumulation data were taken into account for the estimations underlying the evaluation of this indicator of ecotoxicological risk.

Biological Activity

This indicator A is most accurately assessed by internal effect concentrations. Single species toxicity tests are less accurate for the context, because they represent both accumulation and toxicity and do not provide information independent of bioaccumulation.

In the present study, only very little data about internal effect concentrations were encountered for TBT, while none were available for the other biocides. Therefore, the biological activity was almost exclusively evaluated according to external effect concentrations like EC_{50} or NOEC values.

Uncertainty

The uncertainty indicator U represents the overall uncertainty of the risk profile. It can be assessed by averaging the uncertainties of the other indicators. Currently, it is not considered uncertain itself.

Results and Discussion

The resulting risk profiles in Figure 2 show the values of the five indicators for each of the four substances as grey bars. The indicator values itself are the higher, the more the bar is located on the outside of the graph. The uncertainty of each indicator for each substance is shown by the length of the grey bars – the longer the bar, the higher the uncertainty.

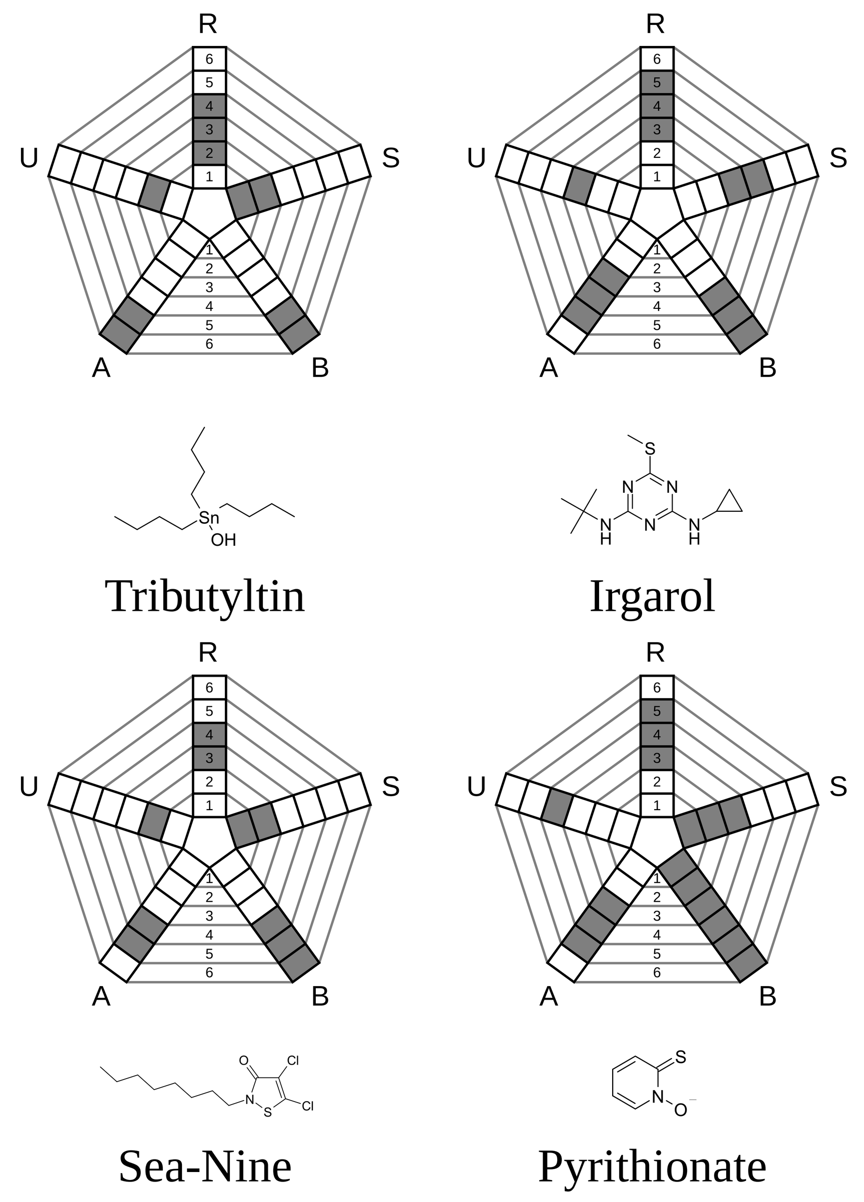

Figure 2: Ecotoxicological risk profiles of the four selected antifouling agents

The comparison of the risk profiles shows, that the advantages of the alternative biocides are partly ambiguous. Actually, the spatiotemporal range of tributyltin is quite favorable compared e.g. to Irgarol. On the other hand, its bioaccumulation and biological activity are outstanding. While Pyrithionate seems to be favorable with respect to its spatiotemporal range and its biological activity, the uncertainty of its evaluation is high. Clearly, more research concerning release, fate and bioaccumulation of the alternative substances is necessary to draw less ambiguous conclusions.

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