



GÖTEBORGS UNIVERSITET

**On the Efficacy and Ecotoxicity of Antifouling
Biocides
Lethal and Sublethal Effects on Target and Non-target
Organisms**

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Akademisk avhandling för filosofie doktorsexamen i Naturvetenskap med inriktning mot Miljövetenskap, som med tillstånd från Naturvetenskapliga fakulteten kommer att offentligt försvaras fredag den 8:e november 2013 kl. 10.00 i Hörsalen, Institutionen för biologi och miljövetenskap, Carl Skottsbergsgata 22B, Göteborg.

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Abstract

From an environmental perspective, there is a need to reduce the amount of biocides from antifouling paints in the marine ecosystem as these biocides can exert a negative effect on the marine life. One way to do this is to optimize the use of biocides in antifouling paints, and thereby avoid unnecessary overdosing. This thesis has been produced within the research program Marine Paint which has the overall aim to produce an antifouling paint with a lower environmental impact than the paints existing on the market today. The aim of the studies presented in this thesis has been to evaluate the efficacy and ecotoxicity of eight antifouling biocides to both target and non-target organisms. The biocides investigated were: medetomidine, triphenylborane pyridine (TPBP), tolylfluanid, copper, irgarol, zinc pyrithione, copper pyrithione and 4,5-dichloro-2-*n*-octyl 3(2H)-isothiazolone (DCOIT). The target organisms investigated were the macroalga *Ulva lactuca* and periphyton (i.e. microbial communities). It is important to keep in mind that all target organisms that antifouling biocides are meant to affect, are also non-target organisms when they grow on natural substrates in the marine ecosystem. Therefore, effects on target organisms are not only of interest for efficacy evaluations, but also for ecotoxicological assessments of the biocides. Both the efficacy and ecotoxicity of the eight biocides has been evaluated for the target organisms in settlement assays in which the organisms were allowed to settle and grow in the presence of the biocides. Full concentration-response curves from 0 to 100 % effect were produced to enable future mixture predictions. Such mixture predictions can be used for paint optimization, but also in environmental applications such as hazard assessments.

Copper pyrithione was the biocide that most efficiently prevented growth of both *Ulva lactuca* and periphyton communities, and for *Ulva lactuca* it was also the biocide with the highest ecotoxicity. Due to different shapes of the concentration-response curves, the toxicity ranking was not consistent at all effect levels (from EC₁₀ to EC₉₈), and irgarol was found to be more toxic to periphyton at lower concentrations than copper pyrithione.

In order to extend the ecotoxicological evaluations of the biocides beyond target organisms, effects on the non-target organism *Acartia tonsa* was investigated. *Acartia tonsa* is one of the most commonly occurring pelagic calanoid copepods in coastal waters world-wide. Effects on mortality and egg production were studied for three of the eight biocides, namely DCOIT, TPBP and medetomidine. It was shown that neither DCOIT nor medetomidine affected the egg production specifically, but inhibition of egg production occurred at the same concentration as mortality. TPBP was on the other hand shown to affect the egg production at concentrations lower than lethal concentrations.

Antifouling biocides present in the marine environment can exert selection pressure on marine life and through the process of natural selection induce tolerance development. An extreme tolerance to the antifouling biocide irgarol in a population of *Ulva lactuca* from the mouth of the Gullmar fjord has been described. This indicates that the use of antifouling paints has made its imprint on the marine ecosystem.

The results from this thesis have deepened the understanding of the biological effects of antifouling biocides. The well-defined concentration-response curves gives information on both efficacy and ecotoxicity, and the information can be used in a number of applications where either biocidal efficacy or ecotoxicity is of interest, such as hazard assessments and in the design of antifouling paints.

Keywords: Antifouling biocides, toxicity, *Ulva lactuca*, periphyton, *Acartia tonsa*, settlement, growth, reproduction