

Short Communication

Photosensitized degradation of Irgarol 1051 in water

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Abstract

Irgarol 1051 (2-methylthio-4-*tert*-butylamino-6-cyclopropylamino-*s*-triazine) is a herbicide analogue that is added to antifouling agents used on ships. Our former study on its degradation in sunlight suggested that unknown photosensitizers in natural waters accelerated the photodegradation to the degradation product, M1. In this study, the photodegradation of Irgarol in water was investigated in the presence of some photosensitizers. Test water containing Irgarol or M1, with or without photosensitizers, was irradiated with light from a UV-A fluorescent lamp for 48 h. The concentrations of Irgarol and M1 in the test water were determined by HPLC after solid-phase extraction. M1 was more stable than Irgarol when irradiated in the presence of photosensitizers such as acetone, benzophenone, tryptophan, and rose bengal. Hydrogen peroxide (HP) accelerated the photodegradation of Irgarol, and the product M1 was degraded in the presence of more than 100 mg l⁻¹ HP after 10 h. Natural humic substances (NHS) also accelerated the photodegradation of Irgarol, but in this case, the product M1 persisted even when Irgarol was completely degraded. Photosensitized degradation of Irgarol by NHS may result in the accumulation of M1 in aquatic environments. © 2004 Elsevier Ltd. All rights reserved.

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1. Introduction

Effective antifouling compounds that prevent the settlement and growth of fouling organisms on submerged structures will always be needed. Some compounds are used as alternatives to organotin biocides, which have been regulated internationally since 1990 due to their severe impact on aquatic ecosystems. Irgarol 1051 (2-methylthio-4-*tert*-butylamino-6-cyclopropylamino-*s*-triazine) is a herbicidal additive used in copper-based antifouling paints. Several studies since 1993 have demonstrated the

presence of Irgarol in European coastal environments. More recently, workers have reported the residue in waters from Bermuda, USA, Singapore, Australia, and Japan. The occurrence and effects of Irgarol and some other biocides have been reviewed by some researchers (Thomas et al., 2002; Voulvoulis et al., 2002; Yamada and Kakuno, 2003; Konstantinou and Albanis, 2004).

Irgarol is known to be stable to biodegradation, hydrolysis, and heat. Liu et al. (1997) demonstrated that Irgarol 1051 was biotransformed by the white rot fungus, *Phanerochaete chrysosporium*, via the mechanism of N-dealkylation to yield a stable metabolite, M1 (2-methylthio-4-*tert*-butylamino-6-amino-*s*-triazine; also called GS26575). Recently, it was clarified that manganese peroxidase, one of the major ligninolytic enzymes produced by *P. chrysosporium*, was involved in the

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