



Photodegradation of the antifouling compounds Irgarol 1051 and Diuron released from a commercial antifouling paint

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Received 19 July 2001; received in revised form 2 January 2002; accepted 10 January 2002

Abstract

The antifouling compound Irgarol 1051 and its degradation product M1 (also known as GS26575), along with another antifouling compound Diuron, have recently been found in Japanese coastal waters. This study was undertaken to find the origin of these chemicals and investigate their aquatic fate. Five glass plates, each coated with 1 g of antifouling paint containing Irgarol and Diuron, were submerged in 250 ml of five different test waters and the plates removed after several months. The aqueous solutions were divided into two groups: one exposed to natural sunlight, and the other kept in the dark as a control. Irgarol and Diuron were detected in all aqueous solutions, suggesting leaching from antifouling paints is the origin of these antifouling biocides found in Japanese coastal waters. Under sunlight conditions, Irgarol underwent a rapid degradation to produce M1, which remained even after Irgarol had disappeared from the system. These compounds were persistent in any aqueous solutions tested under dark conditions, indicating high stability to hydrolysis. Diuron and M1 were more persistent than Irgarol under sunlight irradiation. Since these compounds have high herbicidal activities, their ultimate impact on aquatic ecosystems is closely related to their aquatic fate. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Antifouling compounds; Aquatic fate; Degradation; Diuron; Irgarol 1051; Leaching

1. Introduction

New antifouling compounds are intended as replacements for the widely used antifouling agents organotin biocides (tributyltin and triphenyltin), which were regulated internationally in the late 1980s and early 1990s. Recently, the environmental fate and behaviour of antifouling paint booster biocides was reviewed by Thomas (2001). Among 18 compounds which are currently used as antifouling biocides, Irgarol 1051 (2-methylthio-4-*tert*-butylamino-6-cyclopropylamino-*s*-triazine) is a herbicidal additive for use in copper- and zinc-based antifouling paints (Gough et al., 1994). Irgarol 1051 does not appear to undergo rapid biodegra-

dation, and its residues have been detected in European estuarine, coastal, and lake waters and sediments (Readman et al., 1993; Gough et al., 1994; Toth et al., 1996; Scarlett et al., 1997; Thomas, 1998; Penalver et al., 1999; Sargent et al., 2000; Thomas et al., 2000). There are a few reports of Irgarol residues outside Europe, for example, in Japanese coastal waters (Liu et al., 1999b) and within Australian coastal-water sea grasses (Scarlett et al., 1999). There has been little information in the open literature on Irgarol's environmental persistence and degradation. Liu et al. (1997) demonstrated that Irgarol 1051 could be biotransformed by the white rot fungus *Phanerochaete chrysosporium* via the mechanism of N-dealkylation to yield a stable metabolite named as M1, which is same as GS26575 (2-methylthio-4-*tert*-butylamino-6-amino-*s*-triazine). It was also found that this metabolite, M1, was produced from Irgarol 1051 via two other pathways: mercuric chloride-catalysed hydrolysis (Liu et al., 1999a), and sunlight degradation

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