Preface

Antifouling products play an important role in the shipping industry and are of significant economic importance. It is estimated that, on average, fuel consumption increases 6% for every 100 μm increase in the average hull roughness caused by fouling organisms. For example, at the height of its usage tributyltin (TBT) saved the US Navy an estimated US$150 million annually. Ship fouling is most commonly prevented by the use of antifouling paints. Antifouling paints contain biocides that are released during the lifetime of the coating, creating a concentration of biocide within a surface micro-layer of water adjacent to the paint surface, preventing settlement of juvenile fouling organisms. There are over 4,000 marine fouling species, therefore biocides used in antifouling paints must have a wide spectrum of activity to cover such a diversity of species able to colonise a ships hull.

Due to environmental concerns over the use of TBT as an antifouling biocide and general disquiet over the release of biocides into the environment, new and evolving regulations now demand that antifouling paints must not result in adverse effects on the environment. This has resulted in a significant challenge for the coatings industry, and developments have been underway for many years to emulate the efficiency of antifouling paints based on TBT, while also having significantly reduced environmental impact.

Since the 1970s, widespread use of TBT-based antifouling paints on all vessel types in the commercial and pleasure craft fleets has resulted in elevated ambient concentrations of TBT in water taken from yachting marinas, in busy harbours, and in areas close to ship repair activity. These localised ‘hotspots’ of TBT, including sediments, were implicated as responsible for damage to cultivated oysters in the vicinity of marinas and to populations of the coastal dogwhelk *Nucella lapillus*, which showed imposex (induction of male characteristics in females) and suppression of breeding activity in extreme cases. In response, the use of TBT on vessels less than 25 m length overall was banned in 1989 throughout the European Union, with similar bans introduced in the USA, Canada, Australia and New Zealand.

In 1990, in response to increasing scientific evidence on the toxicity and occurrence of organotin residues from antifouling paints in the aquatic environment, the IMO-MEPC (International Maritime Organization-Marine Environmental Protection Committee) issued a series of recommendations on the use of TBT antifoulings, including a ban on its use on vessels less than 25 m LOA (length overall).

Japan went further, by firstly restricting applications of TBT usage in Japanese shipyards and subsequently, by banning all applications in 1991. In the mid-1990s, imposex and a reduction in the numbers of the common whelk *Buccinum undatum*, were reported in the North Sea, and TBT implicated as the causative agent. In addition, recent analysis of tissues from sea mammals, fish and some birds have also revealed small but detectable concentrations of TBT. This latest data, although not conclusively demonstrating that TBT is impacting on these species, has caused several governments and environmental organisations to call for a total ban on the use of TBT, throughout the world.

Many governments have cited the precautionary approach, as agreed at the United Nations Rio Convention (and as agreed by IMO-MEPC), as justification to call for a global ban on TBT. This approach permits regulatory action to be taken if there is scientific concern that the use of a material is unsafe to the environment, without the need for scientific proof that actual effects are occurring. In response to calls from several governments to ban the use of TBT as an antifouling biocide throughout the world, the 42nd meeting of the IMO-MEPC (November 1998) unanimously passed a 'draft assembly resolution' calling for a global ban on the application of antifouling products containing organotin compounds which act as biocides, by January 1, 2003, and complete prohibition of their presence on ships' hulls by January 1, 2008.

Antifouling biocides are, by their very nature, toxic to aquatic organisms. An environmental risk assessment is therefore often required before an antifouling paint can be approved. Although some 15 organic chemicals and cuprous oxide have been selected as potential biocides in alternative organotion-free antifouling paints and as antifouling agents for fishing nets, only bis-(1-hydroxy-2(H)-pyridine thionate-O, S) zinc (zinc pyrithion; ZnPT), bis-(1-hydroxy-2(H)-pyridine thionate-O, S) copper (copper pyrithion;CuPT), 4, 5-dichloro-2-n-octy1–3-isothiazolone (Seanine-211), pyridinetripehnylboron (PyB), and 2-methylthio-4-t-butylamino-6-cyclopropylamino-s-triazine (Irgarol 1051) are widely used in the newly developed anti-fouling formulations. These organic chemicals are used with cuprous oxide in order to improve anti-fouling efficiency. However, because the behaviour and toxicity of these compounds have yet to be clarified, compared with organotin compounds, little is known about their effects in the aquatic environment.

The contents of this book reflect recent advances in understanding of antifouling biocides in the environment, including behaviour, toxicity, biological impacts, bioaccumulation and regulation. It is hoped that this book will offer the reader a greater insight into the chemistry and fate of these compounds in aquatic systems.

I would like to thank all our authors for their contributions to this volume and our colleagues who put much effort into reading and commenting on individual chapters.

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