

Preface

This book describes the state of the art in antifouling measures using both conventional biocides and some advanced approaches. Related to biocides, the concept of the “Biocide Product Directive” of the European Union is presented as an example of an administrative instrument for curbing excessive use of environmentally undesirable products that may cause ecological damage.

Biofouling is defined as the unwanted accumulation of biological material on man-made surfaces. This definition includes biofilm-forming microorganisms such as bacteria, fungi and algae as well as fouling by macroorganisms like hydroids, barnacles, tubeworms and bivalves on submerged surfaces. The problem is site-, season- and substratum-specific and the control methods effective at a given geographical location may not hold good elsewhere. The definition is clearly operational, as not every biofilm or barnacle is equivalent to biofouling but only after the effect exceeds an arbitrarily given threshold of interference with a technical process. It is impossible to have an immaculately clean surface and the time has come for realization of the fact that we have to “live with biofilms and biofouling”. It is for the plant managers to determine the tolerable threshold of interference, critical to plant operations, and select a biocidal dose and regime to keep biofilms/biofouling at bay.

The problems in technical processes that are posed by biofouling are substantial. An example is the interference with heat exchangers, where both macro- and micro-fouling contribute to losses in heat transfer and to increases in fluid friction resistance. In India, for example, in the next decade 15 large new power plants will be built, all using seawater as a coolant. Designers and operators will have to overcome serious fouling problems. The common concepts of biofouling control are still based on the use of biocides, which only partially and transiently mitigate the problem. With respect to macrofouling control, focussed research on the biocidal dosages required to prevent/inhibit settlement are lacking compared to research on the dosages required for killing established fouling communities. This is important as dosages required to prevent settlement are far lower than dosages required for killing established fouling communities. Oxidizing biocides are a better option than non-oxidizing biocides due to their known mode of action and toxicity, and knowledge of their by-products and degradation pathways. Cost–benefit analysis and meeting the environmental regulations for discharge are vital parameters governing

the selection of biocides in power and desalination plants. Biofouling is a “surface-associated phenomenon” and control measures should concentrate on this aspect. For example, treating the entire bulk water with a biocidal concentration seems to be an economically unviable practice. If technological advancements could be achieved to deliver biocides at the surface on a continuous basis by the use of porous polymeric materials, this would ensure a cleaner surface, reduced biocidal requirements and reduced impact on the environment.

In seawater desalination by membrane filtration, a process meeting the equally important and increasing demand for freshwater, biofouling also represents the “Achilles’ heel” of the technology. Again, the use of biocides is still the state of the art, but their use threatens the material properties of membranes and other equipment, as well as causing environmental problems when disposed of. The scenario for biofouling control measures in the case of the shipping industry is in a transient stage where foul-release coatings alone seem to be an effective alternative. Several alternative replacement techniques for tributyl tin self-polishing coatings are emerging, but currently none have demonstrated their performance at the field level and can be translated into a technology.

The sequence of events leading to biofouling of surfaces comprises the formation of (i) biofilms containing the initial colonizing organisms, causing serious problems, and (ii) layers of the most visibly obvious foulers that succeed them, i.e. macroalgae (*Enteromorpha* sp., *Sargassum* sp., *Gracillaria* sp.) and the hard-shelled foulants (barnacles, hydroids, tubeworms and bivalves). These organisms colonize submerged surfaces that already have a microbial film present. Whether there is a positive or negative effect of the microbial film on the colonization success of the macroorganisms depends on the make-up of the biofilm and the species of invertebrates involved. Various aspects of this topic are covered in several chapters of the book.

The common approach used against fouling biofilms can be compared to a “medical paradigm”: the system is considered to be infected and the cure is seen to be the use of biocides. However, killing the organisms is not the solution, as the problem is usually not caused by their physiological activity but by their mere presence as a physical barrier. Reduction of the extent of fouling layers is clearly more important, but not yet generally the focus of countermeasures.

Antifouling measures are taken all over the world with very unequal levels of success. There is no such thing as a universal solution to the biofouling problem (as with the case of biocidal type, dose and regime) but there are many insights acquired from various fields stricken by biofouling that should be taken into consideration. This book is an attempt to collect some of these approaches and to provide the opportunity to learn from scientific research on biofouling, as well as from interesting approaches in various technical fields.

October 2008

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Marine and Industrial Biofouling

Flemming, H.-C.; Murthy, P.S.; Venkatesan, R.; Cooksey, K.E. (Eds.)

2009, XII, 334 p. 68 illus., 8 illus. in color., Hardcover

ISBN: 978-3-540-69794-7