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Desalination 220 (2008) 326–334
DESALINATION
www.elsevier.com/locate/desal

Measurement of biofouling in seawater: some practical tests

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Received 7 January 2007; accepted 15 January 2007

Abstract

Fouling from the biomass present in seawater is a major drawback in the operation of marine reverse osmosis plants. Much in-plant work has been carried out to reduce or alleviate the problems, and there are some tools that can be used for assessing the probability of water causing biofouling. However, there is not a generalised tool, and more specifically, there is no standard indicator of the biofouling potential in waters loaded with biomass. An indicator such as silt density index (SDI) is often used, although it cannot give precise information about biomass. Other indicators such as the modified fouling index (MFI) have been developed to improve the information acquired from the saline water.

Adenosine triphosphate (ATP) has been suggested as an indicator of biomass contents, therefore indicating biofouling potential. When subjected to the light and luciferine-luciferase is added, ATP produces luminescence, which can be detected and measured in relative luminescence units (RLU). Water samples can be taken with the assistance of a fouling biomonitor and later analysed by photoluminescence.

Although there is some published information about measurements in slightly saline waters that is not the case in seawater. The purpose of the paper is to provide results of measurements of ATP and other indicators of biomass content made on seawater samples in the Atlantic Ocean. The first issue when measuring marine waters is to take care of the saline effect, e.g. the interference in ATP measurements due to the high salinity of seawaters. We have developed some modifications in the analytical procedure to avoid the saline interference, published elsewhere.

With that modified procedure, we have carried out some measurements in different locations and conditions. Both laboratory and field tests were performed. The obvious advantage in the former is a more stable process where sampling is more reliable. The field tests were performed on feed-water before and after passing through sand filters, which gave us the opportunity to analyse the accumulation of biomass in those filters.

Another test is related to a comparison between water extracted from an open sea intake, as compared to seawater drawn from a beach well. In the latter case, the ATP contents are lower, as expected, indicating lower biomass contents and biofouling potential.

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Presented at the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.

doi:10.1016/j.desal.2007.01.037

A first evaluation of the development of ATP along time has also been carried out, in order to determine the biofouling potential rate (BPR), with preliminary results showing little growth, most probably because of the quality of feed water, which is filtered through the beach well.

Keywords: Fouling; Biomass; Reverse osmosis; ATP

1. Introduction

Reverse osmosis membranes are used worldwide for saline water desalination, producing drinking, industrial, and agricultural purpose product water. In the reverse osmosis (RO) systems, one of the frequent drawbacks is fouling of the membranes, due to the contents of the feed water, even when raw water is pre-treated in some form. The most annoying type of fouling is that of biological origin (biofouling), particularly in tropical and subtropical regions. Formation of biofouling is highly influenced by the type of seawater intake used. Generally speaking, the better the raw seawater quality or the pretreatment quality, the fewer problems to deal with during the plant operation. The undesired effects appear as loss in production flow rate, or loss in quality, or a pressure differential higher than admissible. Fouling can become severe, when the systems cannot operate under acceptable conditions, and the membranes must be replaced.

The economical feasibility of reverse osmosis systems depends critically on the capability to maintain an appropriate product flow across the membrane. Flow reduction is mainly due to fouling caused by a combination of the deposition of components rejected by the membranes (inorganic soluble components, organics, colloids, or particulate matter) and the deposition and growth of microorganisms on the membrane surface [1]. The fouling layer poses a barrier to the desalination process [2]. Operating costs rise because the product flow rate decreases and periodical chemical cleanings are required, which demand additional labour, chemicals, and the membranes life span become reduced.

Membrane biofouling can be influenced by the membrane surface properties (hydrophobicity, charge, ruggedness and pore size), chemical properties of the solution (pH, ionic strength, and type of electrolyte), the properties of the microbial suspension (size, number and type of microorganisms), as well as hydrodynamic parameters (permeation and cross flow). The variety of materials which can be used to make a membrane also explains why some are more fouling resistant than others (polymers being less prone to fouling than cellulose acetate) [3], hence being able to delay the microorganisms attack, and the biofilm formation, and therefore expanding the time span between chemical cleanings. The biofilm take the form of a matrix, made up from extra cellular polymeric substances (EPS) produced by the microorganisms [4]. Biofouling proves to be more complicated than other fouling phenomena since microorganisms can grow, multiply, and move. Hence, even a 99.99% removal of microorganisms can lead to an eventual biofilm formation [5].

The high rate of microorganism growth constitutes a major concern for RO plant operators. Biofilm can block the feed water side of membranes, making it necessary to increase the feed pressure in the vessels up to 3–4 bar, as compared to less than 1 bar in clean elements. Biofilm can even reduce the efficiency of biocides used for cleaning [6].

Hence, biofouling consists of live matter — biomass, and the knowledge of the amount of biomass present in seawater and on the biofilm helps to design control and separation strategies. Several parameters have been proposed such as de commonly used silt density index (SDI), or the modified fouling index (MFI) [7,8]. Some