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Organic carbon movement through two SWRO facilities from source water to pretreatment to product with relevance to membrane biofouling

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HIGHLIGHTS

- Measurement of organic carbon through all processes in a SWRO facility aids facility operation.
- A well intake system was found to produce significant seawater pretreatment.
- Bacterial regrowth may periodically occur in the cartridge filter process.
- Greater mass retention of the biopolymer and humic substances occurs in an SWRO plant using a conventional intake.
- SWRO plants with greater retention rates of biopolymers and humic substance foul more rapidly.

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ABSTRACT

The presence of algae, bacteria, various fractions of natural organic matter (NOM), and transparent exopolymer particles (TEP) in the raw water, after each pretreatment process and in the permeate and concentrate streams, were measured at two SWRO plants to assess biofouling potential. It was found that the most significant process controlling the concentration of algae, bacteria, and the biopolymer and humic substances was the intake type with the subsurface intake discharge showing significant reductions. The mixed media filtration process was marginally useful in removing some TOC and NOM, but had little effect on TEP removal. Some bacterial regrowth may be occurring in the cartridge filters, but the evidence is inconsistent. Significant quantities of the biopolymer and humic substance concentrations were found to be retained in the membranes, but the concentrations were significantly greater in the facility using an open-ocean intake. Bacteria and TEP were found in the permeate stream, which may document bacterial regrowth and TEP production downstream of the membrane process. Measurements of the organic carbon passage through SWRO facilities can be successfully used to evaluate pretreatment process effectiveness and to make SWRO plant operational improvements.

1. Introduction

Particulate and dissolved organic matter in feed seawater impacts the operation of seawater reverse osmosis (SWRO) desalination plants by affecting the rate and degree of membrane biofouling [1–4]. Reduction in organic matter can be achieved by design of an intake system that reduces the concentration by natural attenuation (e.g., subsurface intakes) or by the design and proper operation of an appropriate pretreatment system [4–8]. Regardless of how careful the design and operation of an SWRO facility may be, the membranes will foul over time as a biofilm develops [9]. The primary SWRO operational issues are the rate of biofilm development and the impact on facility operation in terms of required membrane cleaning and effects on membrane operational life expectancy. Therefore, it is important to understand the impacts of various processes on organic matter concentrations within a SWRO facility through each stage of treatment to make process design improvements in future facilities.

Many scientists believe that SWRO membrane biofouling is a phased process beginning with the "conditioning" of the membrane surface by the attachment of sticky substances, such as particulate and/or colloidal transparent exopolymers (TEP) [10–17] and other polysaccharides occurring within the biopolymer fraction of natural organic matter (NOM) [18]. The membrane surface after conditioning becomes more

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conductive to the attachment of various types of marine bacteria [19–21]. Recent investigations have suggested that what is called the colloidal fraction of TEP (may not be actual TEP), which consists of various compounds that are stained using Alcian Blue, may have the greatest importance in creating the conditioning layer on SWRO membranes [22]. Therefore, the removal of algae, bacteria, NOM fractions, and TEP from the raw feedwater during the pretreatment processes is very important in determining the rate of biofilm formation on the SWRO membrane surface.

The objectives of this investigation were to evaluate the changes in concentration of potential membrane-fouling types of organic matter from the open seawater through the intake, after each pretreatment process, in the product water and in the concentrate. SWRO facilities using two different intake types, conventional open-ocean and subsurface (wells), were investigated to assess changes. Also, it has been recently suggested that bacterial regrowth can occur in the cartridge filters after pretreatment with subsequent production of TEP at some SWRO facilities [23]. This issue is also assessed at the two facilities. Information was also compiled regarding SWRO facility operations based on the intake types and the pretreatment design used at the studied facilities in comparison to other facilities operated in the Red Sea region of Saudi Arabia.

2. Methods

2.1. Sampling sites, methods, and information on facility operation

Sampling was conducted at two SWRO facilities located along the Red Sea in the vicinity of Jeddah, Saudi Arabia (Fig. 1). The Saudia facility (site A) has a permeate capacity of 13,000 m^3/day and uses a conventional open-ocean intake located at a depth of 9 m below the surface, which produces 29,000 m^3/day of feedwater (Fig. 2a). The North Obhor facility (site B) has a permeate capacity of 14,500 m^3/day and uses an intake system consisting of 14 wells with depths ranging between 50 and 55 m (Fig. 2b). The wells produce 32,000 m^3/day of feedwater for the treatment plant.

Pretreatment at the Saudia plant is a commonly-used, conventional design consisting of dual media filtration followed by cartridge filters. The raw feedwater is pumped directly into the SWRO facility with no storage on the site. At the North Obhor facility, the raw water extracted from wells is pumped into an on-site storage tank before it is directed into the pretreatment system, which also consists of dual media filtration followed by cartridge filters.

Sampling of the raw seawater was conducted from the surface and from the intake (9 m below the surface) at the Saudia site and from the surface seawater and storage tank at the North Obhor site. These samples were used as references to assess changes in water quality during process treatment. Samples were also collected downstream from the dual media and the cartridge filters at both sites as well as from permeate and reject streams.

At both facilities sampling was conducted for a two-month period with 10-day intervals between successive sampling campaigns with a total of 6 overall sampling runs made. Quality control and assurance protocols were followed and the samples were stored at 4 °C after collection. In addition, a solution containing 0.02% (*w*/*v*) sodium azide was added to each sample intended to be used for transparent exopolymer particle (TEP) analysis to inhibit biological activity.

2.2. Measurement of physical parameters

The collected samples were analyzed to measure the basic fundamental water quality parameters. The physical parameters included turbidity, salinity, conductivity, and pH. A portable turbidity meter (HACH 2100Q) was used to measure the sample turbidities while a portable pH meter (WTW pH 3310) was used to measure pH values. The

Fig. 1. Map showing the location of the two SWRO facilities investigated.