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Industrial scale pilot at Maspalomas I desalination plant demonstrates the efficiency of DuPont™ B-Free™ pretreatment – a new breakthrough solution against biofouling

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ABSTRACT

Biofouling is one of the most common and severe issues in the operation of seawater reverse osmosis (RO) systems with open intake. Unchecked, it causes significant operational problems such as frequent interruption, damage to the membranes, intense chemical and energy use, and regular cleaning-in-place (CIP) of the RO membranes. A novel, vessel-based media technology utilized as a membrane pretreatment has shown to efficiently mitigate the effects of biofouling in RO elements. DuPont™ B-Free™ pretreatment works under different mechanisms which are smartly combined to provide a biostatic environment for downstream RO operations. The Maspalomas I desalination plant with a capacity of 14,500 m^3/d in the Gran Canaria Island (Spain), has been suffering from biofouling problems in the RO. To resolve the biofouling challenges, experts from Elmasa, a company with more than 45 years of experience in the water industry, collaborated with DuPont Water Solutions and tested for more than a year and a half the novel pretreatment technology – DuPont™ B-Free™ designed to eliminate the effects of biofouling in the RO system. An extensive trial using seawater open intake as source water showed biofouling prevention and trouble-free operation in an industrial scale pilot plant, while the parallel full-scale plant did continue to suffer from the negative effects of biofouling. DuPont(TM) B-Free(TM)-Free™ creates an instant and sustained biostatic environment for the downstream RO operations and is resilient to upstream upsets.

Keywords: Biofouling; Reverse osmosis; Media; Bacteria; Chemical cleanings

1. Introduction

1.1. Biofouling

From the various fouling types, biofouling is the most difficult to manage in reverse osmosis (RO) systems [1]. Commercial plants are not sterile environments and any microorganism that enters the system, will rapidly multiply. Microorganisms tend to attach and generate biofilms on the membrane, feed spacer and, to a lesser extent, on the membrane surface. The formation of bacterial biofilms is initiated with the attachment of planktonic, free-swimming bacteria on the surface. Biofilm matrix is a sticky polymeric structure used by microorganisms to immobilize themselves and grow on a surface [2]. The main component of the matrix is a strongly hydrated mixture of carbohydrates and proteins, known as extracellular polymeric substances (EPS). EPS stabilize biofilms by holding the microbial cells together and attaching the growing biofilm on the membrane and the feed spacer surface,

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creating structures that gradually clogs the feed-concentrate channel [3]. Thus, the void space of a feed-concentrate channel is reduced and the resistance of water to flow increases. This effect is associated with an exponential pressure drop increase [4]. Biofilms reduce the reverse osmosis module efficiency and increase their energy consumption. Additionally, biofilms are challenging to clean due to the sticky nature of EPS, which provides high mechanical and chemical stability to bacteria [5].

1.2. Method to mitigate biofouling

The sensitivity of polyamide-based membranes to oxidizing agents, such as chlorine, greatly limits the use of chemicals to prevent bacterial growth in the feed water [6]. Additionally, traditional pretreatments such as coagulation, flocculation, ultrafiltration or cartridge filters are not effective in removing the biofouling potential of the feed water [7].

The build-up of biofilm on RO systems is not only challenging to prevent, but also very difficult to remove once established [8]. Caustic solutions can potentially hydrolyze the polysaccharides and proteins from the EPS matrix to disperse the fouling layer. However, cleaning methods for biofouling are not efficient enough [9]. Even harsh cleaning conditions cannot fully remove biofouling from RO modules, resulting in rapid re-growth after each cleaning-in-place (CIP) [10].

Another alternative is the metabolic inactivation of bacteria, that can be applied before water reaches the RO modules, minimizing the risk of bacteria regrowth. The inactivation can be via physical (e.g., ultraviolet light) or chemical (e.g., biocides) [11]. Biocides have been recognized as efficient compounds to prevent biofouling formation. Unlike physical inactivation, biocides are dissolved in the feed water and are effective throughout the system. Many of the commonly used biocides are oxidizing in nature and would damage the polyamide membrane over time (e.g., hypochlorite or chloramines). Only the non-oxidizing biocides might be partially compatible with thin-film composite RO membranes. However, the severe environmental and health hazards that biocides impose must be carefully evaluated when considering implementation.

1.3. New biofouling free technology

DuPont™ B-Free™ aims to avoid the drawbacks of current methods to prevent reverse osmosis biofouling, being a compact, efficient, chemical free and robust technology. This pretreatment technology is vessel-based and eliminates the detrimental effects of biofouling. It creates an instant and sustained biostatic environment [12] for the downstream RO operations without the need to use chemicals during operations and is resilient to process upsets. This protection is created by three different media with each having a specific purpose in the process, as shown in Fig. 1.

The biostatic environment is established by combining three synergic mechanisms:

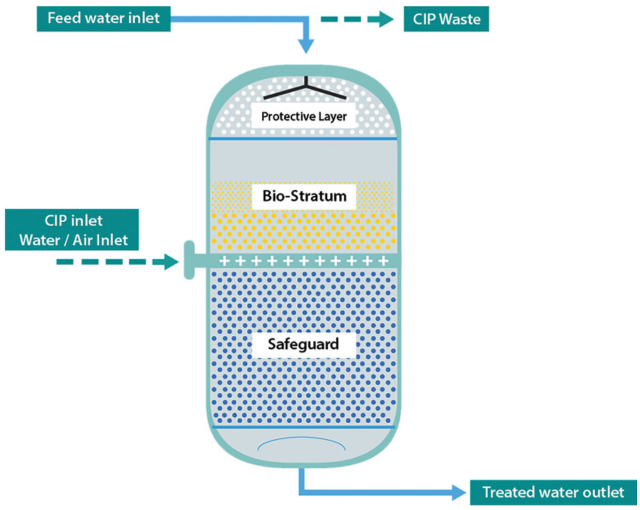

Fig. 1. Vessel layout.

- *Biological*: Bulk nutrients removal by biomass.
- *Filtration*: Barrier against biomass carry-over.
- *Chemical*: Phosphate polishing to create bio-static environment.

During normal operation, the system is maintained by backwash, using water and air only; making it a sustainable chemical free solution against biofouling (Fig. 2). The maintenance interval is influenced by the growth rate of the biomass and the applied filtration linear velocity. The backwash is triggered by the increase of head loss over the media bed caused by accumulation of biomass in the free void fraction of the media or visual observation of the stratum height if a sight-glass is available.

2. Experimental procedure

The study was conducted in Maspalomas I desalination plant located at Bahía Feliz region (San Bartolomé de Tirajana, Gran Canaria, Spain).

The Maspalomas I desalination plant with a capacity of 14,500 m^3/d in the Gran Canaria Island (Spain), has been suffering from biofouling problems in the RO. To resolve the biofouling challenges, experts from Elmasa, a company with more than 45 years of experience in the water industry, collaborated with DuPont Water Solutions and tested for more than a year and a half a novel pretreatment technology – DuPont™ B-Free™ designed to eliminate the effects of biofouling in the RO system.

DuPont™ B-Free™ biofouling prevention performance was evaluated by comparing reverse osmosis element installed in pilot plant to reverse osmosis elements from desalination plant as control (Fig. 3). The pilot plant is operated with same RO type, feed water and operating conditions as the large desalination plant, to allow comparison.

A constant pressure drop over time indicates that biofilm is not developing within the RO module. Desalination plant was operated without DuPont™ B-Free™ technology

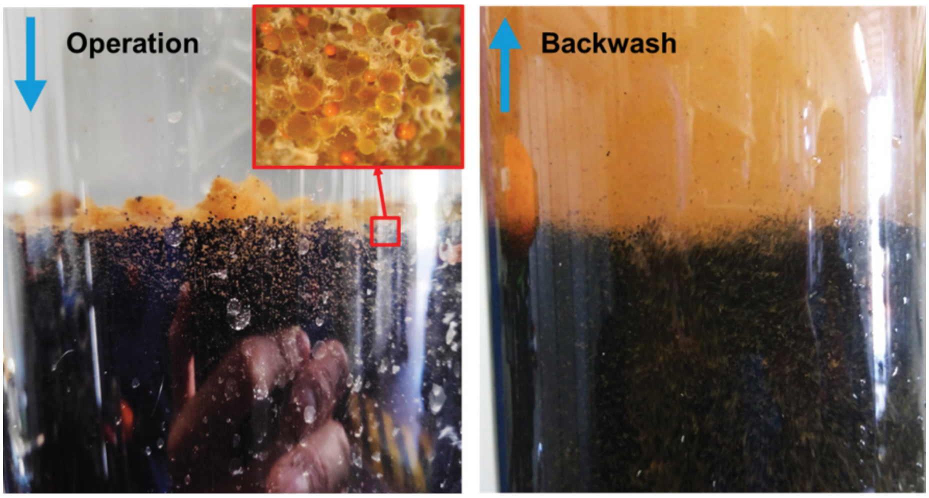

Fig. 2. Media operation.

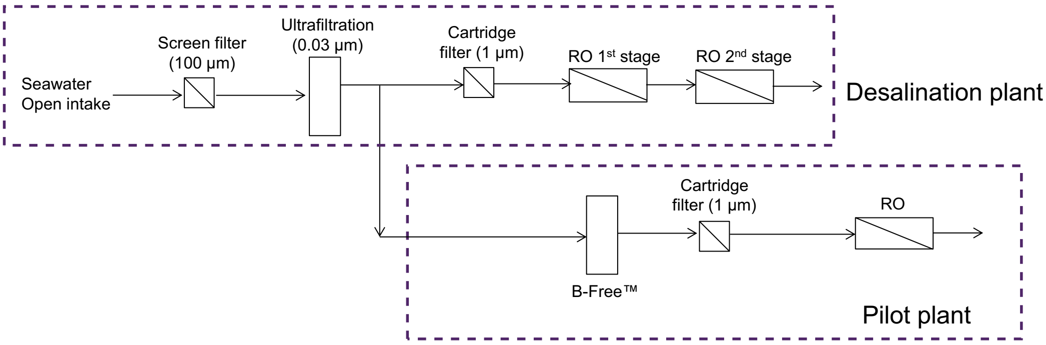

Fig. 3. Pilot plant set-up.

and its pressure drop trend was used to quantify the number of chemical cleanings prevented and assessing the biofouling prevention achieved by the pretreatment. After operation, a detailed visual inspection of RO was completed to confirm operational results in pilot plant.

Feed water to desalination plant has undergone an extensive pretreatment, but despite salinity, low organic load, and low phosphate concentration (Table 1), it still has an intrinsic high biofouling potential, leading to rapid pressure drop build-up.

Table 1
Feed water properties

Source water	Seawater open intake
Plant capacity	17,700 L/h (77.9 gpm)
Conductivity (µS/cm)	56,362
Temperature (°C)	20–23 (68–74 F°)
pH	8.02
Total organic carbon (mg/L)	1.28
PO_4 (µg/L)	40

3. Results

The extensive trial (more than 1.5 years) using seawater open intake as source water highlighted the biofouling prevention levels achieved thanks to DuPont™ B-Free™ for the cartridge filter and reverse osmosis elements.

The main plant did continue to suffer from the negative effects of biofouling. However, the pretreatment installed in the pilot plant creates an instant and sustained biostatic environment for the downstream RO operations and is resilient to upstream upsets.

This can be quantified for the cartridge filter replacement rate, with 12 replacements in the large plant without pretreatment, compared to 3 replacements in the pilot plant (Fig. 4).

Regarding RO operation, 7 chemical cleaning were required during the testing period, compared with the stable operation with no chemical cleaning in the RO operated with DuPont™ B-Free™ (Fig. 5).

The piloted elements were removed and autopsied after the test. As a visual aid, the autopsy of an 8-inch biofouled element from another trial is provided, since the control element from the tests could not be autopsied. Fig. 6 showed very little biofouling presence on the membrane surface despite operating more than 1.5 years.

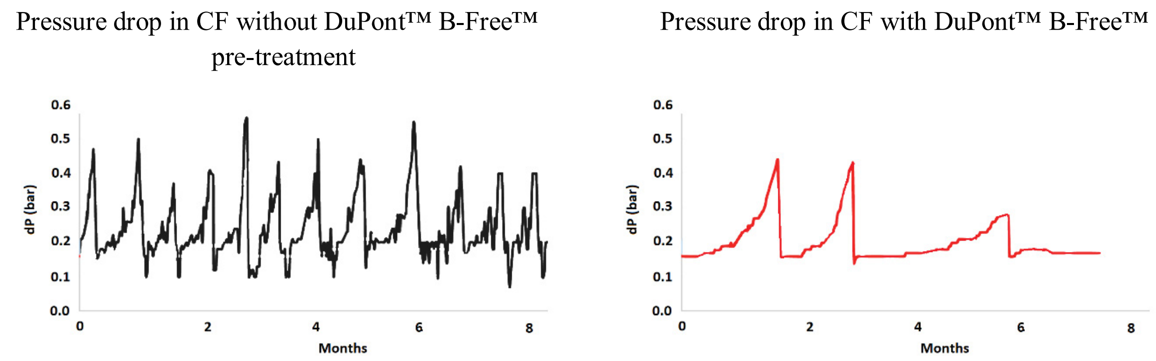

Fig. 4. Cartridge filter pressure drop evolution in seawater test.

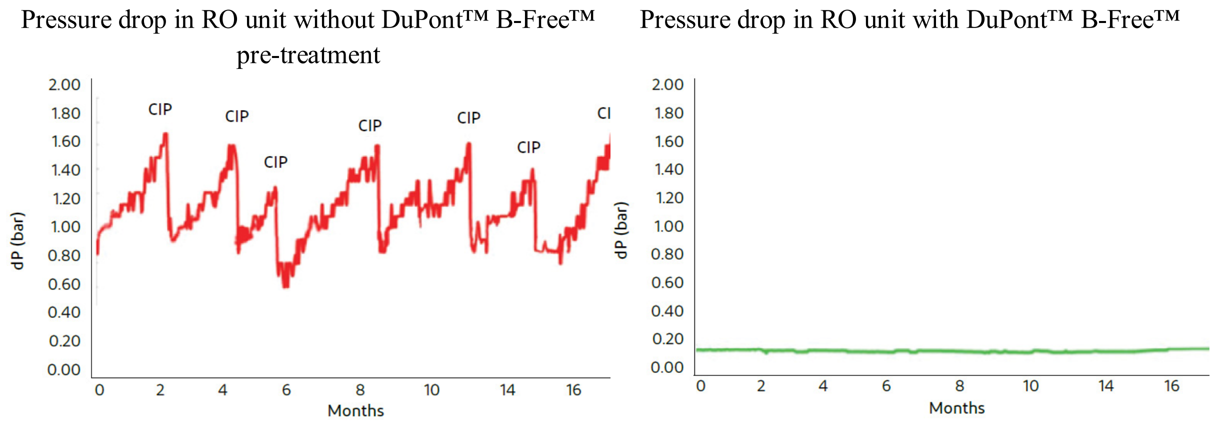

Fig. 5. RO pressure drop evolution in seawater test.

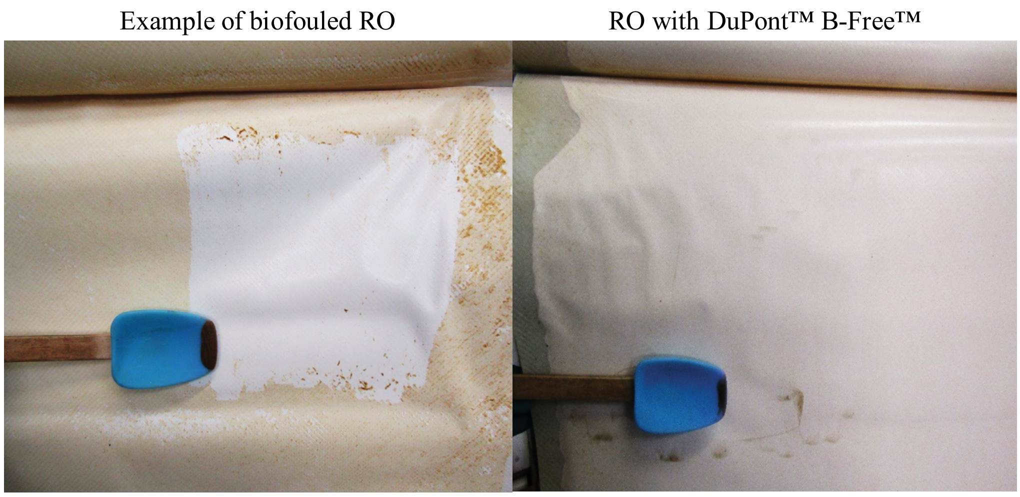

Fig. 6. Municipal wastewater RO elements autopsy.

4. Conclusions

This pretreatment technology for biofouling prevention in RO is a novel vessel-based media technology that provides instant and sustained biofouling protection. It has been validated using seawater at a commercial desalination plant with industrial size elements. For more than 1.5 years of piloting, it provided stable operation minimizing overall system downtime.

DuPont™ B-Free™ is compact, easy to operate, with cleaning performed with only air and water, eliminating the need of chemicals. Additionally, there are no special requirements to upgrade existing systems.

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