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ScienceDirect
Desalination 245 (2009) 723–729
DESALINATION
www.elsevier.com/locate/desal

Ultrafiltration as direct pre-treatment of seawater – a case study

A. Jezowska[a], A. Bottino[b], G. Capannelli[a,*], C. Fabbri[a], G. Migliorini[b]

[a]*Department of Chemistry and Industrial Chemistry, University of Genoa, Via Dodecaneso 31, I-16146 Genoa, Italy*
Tel. +39-0103536197; Fax +39-0103538759; email: capannel@unige.it
[b]*FISIA ITALIMPIANTI, Via De Marini 16, I-16149 Genoa, Italy*

Received 09 July 2008; revised 08 January 2009; accepted 09 February 2009

Abstract

Reverse osmosis (RO) and nanofiltration (NF) processes gain more and more interest in the desalination market. Recently, seawater reverse osmosis (SWRO) has become more widespread, using relatively large plants, whilst NF is being applied before thermal desalination, as an advanced treatment for increased efficiency of thermal processes. A proper and reliable seawater treatment before RO and NF, capable to retain suspended solids that cause fast fouling and plugging of sensitive spiral wound membrane modules, is a key to success of desalination processes. Reliability, high and constant quality of permeate, regardless of changes in seawater characteristics, are major advantages of microfiltration/ultrafiltration (MF/UF) over conventional pre-treatment, allowing a stable and high performance of RO and NF processes. This experimental work evaluates performance of two different UF, hollow-fibre membrane modules, when fed directly with raw seawater taken from the industrial harbour of Genoa. The study reports the performance of nanofiltration process fed with UF permeate versus the performance of NF fed with raw seawater.

Keywords: MF/UF seawater pre-treatment; Harbour seawater; Hollow-fibre membranes; Dead-end operation; Fouling control

1. Introduction

Seawater pre-treatment is one of the major factors determining the success or failure of a desalination plant. This is particularly true for RO, but for distillation process is also highly important [1]. Spiral wound modules used in RO/NF processes require an enhanced pre-treatment of seawater for eliminating suspended solids that may cause membrane fouling or plugging feed channels and spacers. Conventional pre-treatment of seawater, even if well designed,

*Corresponding author.

Presented at the conference Engineering with Membranes 2008; Membrane Processes: Development, Monitoring and Modelling – From the Nano to the Macro Scale – (EWM 2008), May 25–28, 2008, Vale do Lobo, Algarve, Portugal.

0011-9164/09/$– See front matter
doi:10.1016/j.desal.2009.02.043

maintained and operated, does not provide a proper solids removal from seawater in the case of upsets in the process. This fact leads to a decrease in RO/NF efficiency and an increase in frequency of cleanings, resulting in the use of chemicals and sanitizers and shorter membrane lifetime [2]. Recently, MF/UF processes have been considered an alternative to conventional seawater pre-treatment for a reliable supply of constant and high-quality feed to desalination process. UF has been reported to be especially successful in treating difficult water from a surface intake [3].

In particular, UF is capable to retain colloidal contaminants, smaller bacteria and viruses, thus allowing total removal of turbidity and a considerable reduction of Silt Density Index (SDI), assuring a stable operation of RO and NF processes. Although the capital costs of membrane pre-treatment exceeds that of conventional pre-treatment by 20–50%, the improved quality of treated water can reduce the size of the RO plant by allowing a higher RO flux to be used. Further savings are due to reduced replacement rate and cleaning frequency of RO/NF membrane modules. Space savings, because of a high compactness of membrane installations, are an additional advantage of MF/UF pre-treatment over the conventional processes [4]. In this work, the authors focused on the application of hollow-fibre UF modules to seawater pre-treatment before NF process. Performance of two different hollow-fibre ultrafiltration membranes on pilot plant scale is presented, and the positive influence of UF pre-treatment on the performance of NF process is demonstrated.

2. Experimental

2.1. UF membranes and pilot plant

Technical specifications on membrane modules, used for continuous seawater ultrafiltration in Genoa's harbour, are provided in Table 1. The elements are simply named with letters (A and B) because of a secrecy agreement between the authors and the manufacturers. The plant was fed with raw seawater from the industrial harbour of Genoa after pre-screening with 150 μm filters. The plant operated at constant permeate flow rate (Q_p), while transmembrane pressure (TMP) varied. Membrane performance was studied at various permeate flow rates (60, 80 and 100 L/m^2 h). Process parameters (TMP, Q_p, temperature, feed and permeate turbidity) were registered in 10 s intervals. In addition, SDI was measured manually on the permeate line. Feed and permeate samples were analysed for total organic carbon (TOC), total suspended solids (TSS) and bacteria presence once a week, while analysis of seawater were carried out monthly. Periodic backwashing was performed with the UF permeate. Various parameters of the backwash process (BW) like frequency, duration (t_{BW}) and flow rate (Q_{BW}) were studied. Chemical cleanings were performed according to the modules' technical specifications supplied by the manufacturers. Chemically enhanced backwash (CEB) with sodium hypochlorite (20–100 ppm of free chlorine), carried out every 4 h for 2 min contact time, was investigated only with module A. Cleanings using sodium hypochlorite solution (200 ppm of free chlorine), usually followed by sodium hydroxide solution (optionally hydrochloric acid), were carried out when TMP reached 0.8

Table 1
Technical specification of membrane modules used for UF experiments

Parameter	Module A	Module B
Membrane material	PES based	PES based
Fibres ID (mm)	0.9	0.8
Membrane area (m^2)	30	40
Operating mode	In-out; dead-end	In-out; dead-end
Application data (during cleaning)	P = 5 bar T = 40°C pH = 3–10 (1–13)	P = 8 bar T = 80°C pH = 2–12 (1–13)