Desalination and Water Treatment
www.deswater.com
5 (2009) 74–79
1944-3994/1944-3986

Long-term operating experience of Seaguard UF as pretreatment to SWRO in the Mediterranean region

Frans Knops*, Rick te Lintelo

Norit X-Flow, PO Box 739, 7500 AS Enschede, The Netherlands
Tel. +31 53 4287302; Fax +31 53 4287351; knops@xflow.nl

Received 29 August 2008; Accepted 22 February 2009

ABSTRACT

Numerous tests around the world have proven that ultrafiltration (UF) provides optimum pre-treatment for seawater desalination based on reverse osmosis membranes (SWRO). UF will remove all suspended solids and will provide a substantial reduction in microbiological activities. Plugging of RO spacers is completely eliminated and the RO cleaning frequency can be substantially reduced. The main obstacle against use of UF membranes for SWRO pre-treatment has always been the higher operating cost of UF when compared with conventional pre-treatment. A new membrane has been designed with the aim of achieving the lowest whole-of-life cost while enabling membrane desalination of the most difficult to treat seawater. This paper describes 22 months of operational experience of the new Seaguard UF membranes at the Colakoglu steel mill and 10 months of operational experience at Nuh Cimento. Both plants are fed from the Gulf of Izmit near Istanbul in Turkey. The UF pretreatment to SWRO is a pre-requisite to use of this seawater for membrane desalination. This paper describes the following topics: design and technical specification of the UF pre-treatment systems, technical issues during construction and commissioning, process optimization and long-term operational experience, and lessons learned for future plants operating under similar conditions.

Keywords: Desalination pretreatment; Ultrafiltration; Reverse osmosis; Membrane treatment

1. Introduction

The Gulf of Izmit is located in the northwestern part of Turkey. It is located to the southeast of the city of Istanbul (Fig. 1). The Gulf of Izmit is connected to the Sea of Marmara whose salinity averages about 22,000 ppm, which is slightly greater than that of the Black Sea but only about two-thirds that of most oceans. However, the water is much more saline at the sea bottom, averaging around 38,000 ppm — similar to that of the Mediterranean Sea. This high-density saline water, like that of the Black Sea itself, does not migrate to the surface. The salinity of the surface water of the Gulf of Izmit is slightly higher than the salinity of the Sea of Marmara, due to the fact that the Gulf is shallow and has a higher evaporation rate.

The Gulf of Izmit is an area that is heavily populated with fast growing urban developments, e.g. the town of Gebze on the northern shore of the Gulf of Izmit grew from 90,000 inhabitants in 1985 to an estimated 320,000 in 2008. Along the shore several industrial plants are located. These include ship-building yards, factories, storage tanks

*Corresponding author.

Presented at EuroMed 2008, Desalination for Clean Water and Energy Cooperation among Mediterranean Countries of Europe and the MENA Region, 9–13 November 2008, King Hussein Bin Talal Convention Center, Dead Sea, Jordan.

Fig. 1. Gulf of Izmit.

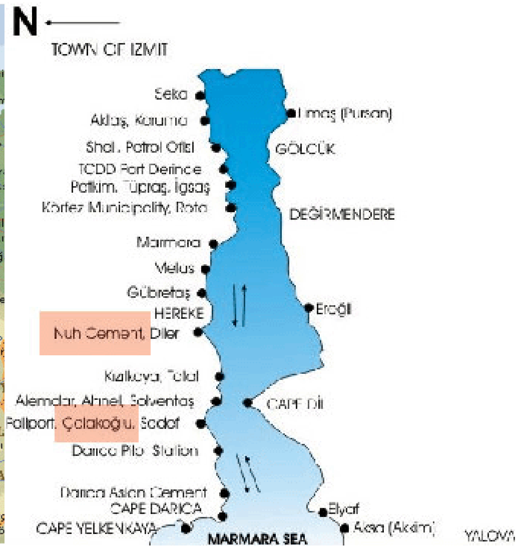

Fig. 2. Industrial complexes near Gulf of Izmit.

for chemical industries, paper mills and oil refineries. Most industrial companies at the Gulf of Izmit have their own berth facilities for import and/or export products. Fig. 2 shows some industrial complexes around the Gulf of Izmit.

2. Desalination

Domestic and industrial water consumption puts a stress on the potable water supply for the region. Furthermore, domestic and industrial waste water discharges have a negative effect on the water quality of the Gulf of Izmit.

Alternative sources of water were historically very limited: seawater desalination by means of reverse osmosis (SWRO) was not an option because conventional pretreatment was not able to cope with the deteriorating water quality, especially the relatively high organic content of the water. Table 1 gives a typical water analysis for the Gulf of Izmit. The high cleaning frequency that would be required for maintaining SWRO performance would increase the operational cost and decrease the SWRO life time to a point that makes it economically unfeasible.

Several industries such as the Colakoglu steel mill and the Nuh cement factory (see Fig. 2) have kept a continuous interest in seawater desalination to provide water to meet their future demands. These companies collaborated with reputable equipment manufacturers, such as Aquamatch and ATS, in order to find new ways for tapping the potential of seawater for their needs.

Aquamatch has been active in the Turkish water treatment market since 1989. Originally Aquamatch acted as an agent for foreign equipment manufacturers; since 1996 Aquamatch has been manufacturing water purification equipment in Turkey. Aquamatch provides turnkey systems with its own in house staff of design, manufacturing and after sales engineers.

ATS (Aritim Teknolojileri Sanayi) was founded in 2000 and provides turnkey water treatment solutions. Since 2007 ATS is part of Veolia Water Solutions & Technologies (VWS).

Table 1
Water quality

Turbidity, NTU	<10
TSS, mg/L	<20
TOC, mg/L	<30
ph	7.9
Oil and grease, mg/L	<2
TDS, mg/L	28,000
Ca, ppm	300
Mg, ppm	880
Na, ppm	8,800
Cl, ppm	14,630
SO_4, ppm	2,570
SiO_2, ppm	5
Temp., °C	10–20

3. Ultrafiltration

In 2005 Norit X-Flow introduced an ultrafiltration (UF) membrane that is specifically designed for pretreatment to SWRO. This membrane uses inside-out hollow-fiber technology. The membrane fibers are fed from the lumen side with the clean water permeating the wall of the fibers.

The hollow-fiber membrane technology is well suited for removing suspended solids and microbiology. UF membranes will not remove any dissolved matter; therefore, the mineral content will remain unchanged.

The Norit X-Flow membrane designed for SWRO pretreatment is called the Seaguard membrane. It has been specifically designed as a pre-treatment UF membrane for large-capacity SWRO desalination plants. The main characteristics for this new membrane are:

- UF for good removal of suspended solids, resulting in low turbidity and SDI.
- Hydrophilic polyethersulfone for high permeability and low fouling tendency.
- Operated in dead-end flow in order to minimize energy consumption.
- Pressurized inside-out filtration, allowing for direct feed from the intake works into the RO high pressure pumps.
- Use of short cleaning cycles, so-called chemically enhanced back-washes. This mode of operation minimizes the flow fluctuations to the RO system.

The Seaguard membrane modules have an outside diameter of 8" and they are installed in glass fiber reinforced epoxy (GRP) pressure vessels. This makes the design of the UF unit very similar to the design of a SWRO unit with spiral-wound RO membranes. Fig. 3 shows a typical UF unit with the Seaguard membranes being loaded.

Since 2005 Norit X-Flow has been successfully implementing the new Seaguard membranes in a number

Fig. 3. Typical UF unit with Seaguard membranes.

Fig. 4. Locations of pilot plants using Norit X-Flow Seaguard membranes.

of pilot plants in different locations. Fig. 4 gives several locations of Norit X-Flow Seaguard pilot plants.

The Seaguard membranes proved to be exceptionally successful under the most demanding applications. They piloted very well during red tide events as well as under extremely difficult situations such as close to shipping routes. Both Aquamatch and ATS contacted Norit X-Flow with a request for using the Seaguard membranes for pretreatment of seawater in the Gulf of Izmit.

This led initially to the design of two seawater desalination plants: one at the Colakoglu steel mill and one at the Nuh cement factory. Due to the successful implementation of the Seaguard membranes, several additional projects will be executed in the near future. One of these will be an expansion to the Nuh cement factory. This paper will describe the Colakoglu and the Nuh projects and the lessons learned for future projects.

4. Colakoglu steel mill

Colakoglu, established in 1968, produces steel billets in an electrical arc furnace and converts the billets into wire rod and rebar. The company has an aggressive expansion program for its production capacity. This increases its demand for fresh water to be used as process water.

The total need for process water is 6,700 m^3/d. Colakoglu contracted Aquamatch to design a SWRO plant of this capacity. Feed water to the SWRO system is taken from the cooling water loop. This cooling water loop has an open surface water intake with coarse straining.

The feed water to the desalination system is further strained by means of a fine mesh Bernoulli-type strainer. The Bernoulli filter works with a patented cleaning system (Fig. 5). The cleaning operation is carried out by a moving disc inside the filter basket. A local vacuum reverses the flow around the moving disc.

The SWRO system operates at a recovery of 40%. Hence the required net capacity of the pretreatment system is 16,750 m^3/d. In order to lower the organic content of the feed water a small dose of inorganic

Fig. 5. Bernoulli-type filter.

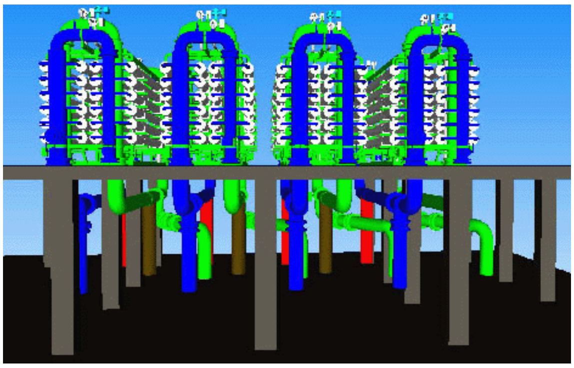

Fig. 6. Layout of plant.

Fig. 7. UF units installed on site.

coagulant in dosed in front of the Seaguard UF system. This coagulant will enhance the removal efficiency of the organics by the UF system and lower the cleaning frequency of the SWRO membranes.

The UF system uses four UF skids, each with 92 Seaguard membrane modules. Each skid can be expanded up to 96 Seaguard modules. The complete plant was engineered in 3D CAD in order to optimize plant lay out (Fig. 6). Fig. 7 shows the four UF units installed on site.

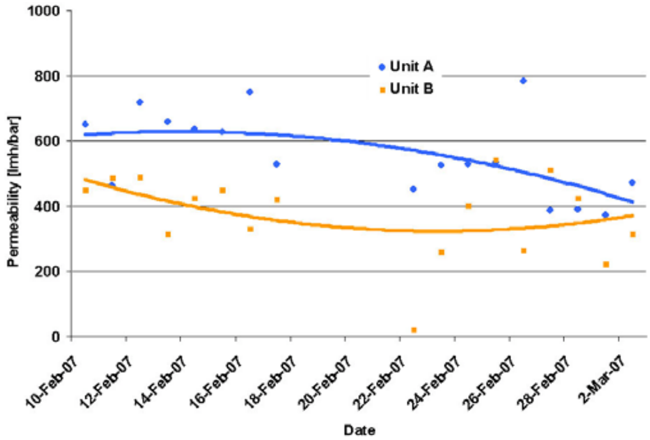

Fig. 8. Initial performance of UF system.

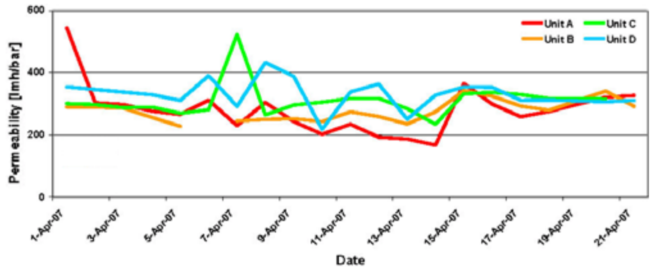

Fig. 9. Performance of UF system during April 2007.

The first two units (A and B) of the UF system were commissioned in early February 2007. The initial performance was very stable with a permeability ranging from 400 to 600 lmh/bar for both units (Fig. 8). The last two units (C and D) were commissioned early March 2007. Between April and May 2007, performance of all four units started slowly decreasing. Although the performance seemed to stabilize at a permeability of 300 lmh/bar (see Fig. 9), Norit X-Flow decided to investigate the causes of this unexpected drop in permeability.

One membrane element was removed from the UF system and returned to the factory for autopsy and for cleaning experiments. The immediate investigation revealed a dark red discoloration of the membrane element (Fig. 10). EDX analysis of the membrane confirmed that the color was caused by iron, with trace amounts of silica and aluminum being present. This indicated that the most probable cause of the drop in performance was fouling with the inorganic coagulant ($FeCl_3$). This coagulant typically contains trace amounts of metals as detected in the EDX analysis of the membranes. Further investigation showed that the mechanical properties of the membrane element where still close to the properties of the new membrane.

Laboratory-scale testing of the performance revealed a sharp drop in permeability when compared to the original value for the new membrane. The permeability could be

Fig. 10. UF membrane that underwent EDX analysis, confirming that red color was caused by iron with trace amounts of silica and aluminum.

restored by cleaning with specialty cleaners that target iron fouling.

An X-Flow service engineer conducted additional tests on site. Several jar tests where conducted to fine tune the coagulant dose, the feed water pH, the amount of mixing energy and the retention time required for optimum coagulation with minimal residual organics and membrane fouling. The normal procedure for cleaning the membranes is a daily maintenance clean with an acidic solution. The acid dosing pump was recalibrated in order to achieve the correct pH for proper cleaning.

A plant Cleaning in Place (CIP) was performed to remove the bulk of the fouling and the plant backwash frequency was temporarily increased to allow for automatic recovery during operation. After plant recovery the plant backwash frequency was stepwise reduced from once per 20 min to once every 34 min.

A procedure was implemented to recover plant performance in case of excessive fouling: if this occurs an additional CIP is executed and plant settings are temporarily adjusted. This procedure proved to be very successful, resulting in stable operation of the plant. The typical frequency of CIPs is once every 6 months.

5. Nuh cement factory

Nuh Cimento Sanayi A S was established in 1966. The company produces clinkers and cement in one of the most modern facilities in Europe. Due to large export demand, capacity is continuously being increased. The latest expansion was a fourth mill that was brought on line in 2007. This increase in capacity increases its demand for fresh water to be used as process water.

The total need for process water was initially 5,500 m^3/d. Nuh contracted ATS to design a SWRO plant of this capacity, with an option for doubling the capacity for future expansion. Feed water to the SWRO system is an open surface water intake with coarse straining. Bernoulli filters are used as fine strainers to protect the UF membranes.

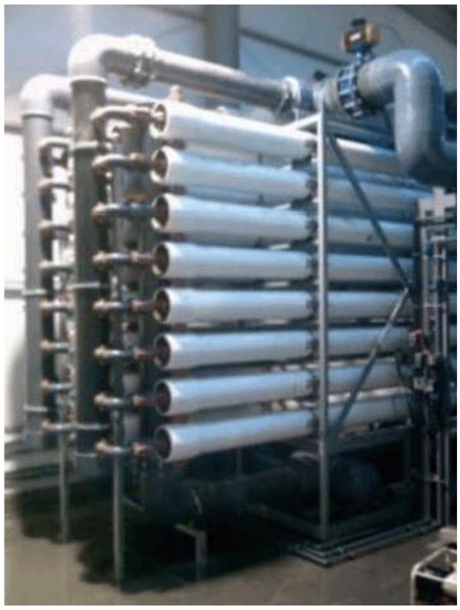

Fig. 11. Set-up of UF units at the Nuh plant.

The anticipated feed water quality at the location of the cement factory is slightly better than the water quality at the steel mill. This allowed for membrane flux that is 10% higher than the membrane flux used for the steel mill. This resulted in a smaller UF system. Required UF capacity is 13,500 m^3/d, which is realized with two UF units each with 128 membrane elements (Fig. 11). The UF skids have an identical design to the UF skids installed at the steel mill, but slightly larger (32 membrane housings instead of 23 membrane housings per skid).

The SWRO system at the Nuh cement factory was commissioned in early 2008, taking all process improvements into consideration. The desalination plant has been operated problem free since then, meeting all goals for capacity and operational costs. In July 2008 the customer decided to double the capacity of the desalination system, which was commissioned at the end of 2008.

6. Conclusions

The Norit X-Flow Seaguard membranes have proven that UF can be used successfully as a pretreatment to spiral-wound SWRO membranes. These membranes enable the use of a seawater quality that previously was deemed to be unsuitable for desalination purposes at an economical cost.

The technical superiority of using UF can be achieved at a cost that is comparable to conventional pretreatment technology. The additional cost of having to replace the UF membranes at the end of their useful life time is more than offset by the cost savings that can be achieved: reduction in use of chemicals (mainly coagulant) and a decrease in RO cleaning frequency (less use of chemicals, shorter down-time and longer RO life time).

Norit X-Flow is implementing UF as a pretreatment to SWRO on a worldwide scale. Seaguard membranes are currently installed in plants in Africa, Asia and Europe. Operational experience shows that up to 5% cost savings can be achieved.