Seawater desalination of the Chilean coast for water supply to the mining industry

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Abstract

Key for successfully operating seawater desalination based on reverse osmosis membranes (SWRO) is the pretreatment. Numerous tests around the world have proven that ultrafiltration (UF) provides optimum pre-treatment for SWRO. UF will remove all suspended solids and provides a substantial reduction in microbiological activity. Plugging of SWRO spacers is completely eliminated and the SWRO cleaning frequency can be substantially reduced.

Key words: **s**eawater desalination, pretreatment, ultrafiltration

Introduction

Water is an important component in the mining industry. With mines often located in remote and dry areas a sustainable supply of water is crucial. The development of seawater desalination, reduced membrane costs and reduced energy consumption have made seawater a viable source of water supply for mining.

Reliability of the desalination plant, quality of the water and the availability of sufficient water supplies are the most important requirements from the mining industry. Therefore best available and proven technologies should be used (Brantes, R. A.*)*.

Key for successfully operating seawater desalination based on reverse osmosis membranes (SWRO) is the pretreatment. Often dissolved air flotation (DAF) and/or dual media filters (DMF) are used giving most of the time adequate protection of the SWRO (Petry, Marc et. al.). The waters at the Chilean coast are rich in nutrients, bacteria, algae, plankton and macro-organisms and face from time to time "red tides": a rapid increase or accumulation of algae. To maintain the SWRO feed water quality within specifications at all times, experienced and skilled operators are needed. Despite the awareness, many desalination plants with "conventional" pretreatment still suffer from SWRO downtime or increased operational costs due to off-spec circumstances.

Numerous tests around the world have proven that ultrafiltration (UF) provides optimum pre-treatment for SWRO. UF will remove all suspended solids and provides a substantial reduction in microbiological activity. Plugging of SWRO spacers is completely eliminated and the SWRO cleaning frequency can be substantially reduced (Huehmer et al.; Pearce, GK., Bartels C., Wilf, M.; Knops, F., Van Hoof, S., Zark, A.).

Northern Chile

Northern Chile consists of the Atacama Desert and the Andes Mountains. The Atacama Desert is a strip of land on the Pacific coast, west of the Andes mountains covering 1,000 km in length and 105,000 km^2 in area. It is, according to many publications (Brantes, R.A.), the driest desert in the world. Along the coast the aridity is, among other factors, the consequence of the Peru (Humboldt) Current, which is characterized by upwelling of cold water from the depths of the ocean.

The region's chief source of revenue is copper mining. Several new mines are being set up and existing mines are increasing capacity.

For mining, the availability and proper management of water is key to its long term sustainability. Desalination and specifically Reverse Osmosis have been identified as a potential source of fresh water. The challenge for desalination is enormous, since the circumstances are among the most difficult globally:

- Being the driest place on earth, absolute security of supply is of utmost importance. Due to the extreme and increasing scarcity, the political decision is to restrict fresh water consumption for industrial purposes.
- The ocean water is experiences upwelling of cold water. Cold water has a higher viscosity than warm water, with associated higher pumping cost.
- The water in the coastal area could suffer, all year round, from high algae and TOC concentrations, with e.g. red tide events.

Ultrafiltration Pretreatment Case I

Gas Atacama operates a combined cycle thermal power plant with an installed capacity of 780 MW. The plant is located in Mejillones. It supplies electricity to the residential market through the Northern Electricity Grid (SING) and to several of the largest mineyards in the northern region, Minera Escondida (BHP Billiton) and Minera Collahuasi (Anglo/Xstrata) among them.

The power plant uses reverse osmosis seawater desalination as the single source of water. Based on an extensive tender evaluation the customer selected a dual membrane desalination system: ultrafiltration pretreatment followed by reverse osmosis desalination.

Main contractor for this project was: Proyectos y Equipos (Chile). The UF and the SWRO system was supplied by: Unitek (Argentina). The desalination plant has been commissioned in June 2011 and has since been in operation. The desalinated water is fed to a final demineralization step.

The feed water is characterized by seasonal variations in turbidity: during autumn and winter the turbidity ranges from 1 to 5 NTU; during spring and summer it ranges from 3 to 35 NTU. Red tide events occur as well, typical frequency is 1 to 3 times per year with a duration of up to a week. Feed water SDI is 18 (SDI5), or even immeasurable.

Figure 1 *UF System*

The ultrafiltration system (Figure) supplies a capacity of 285 to 350 m3/h. The level in the intermediate buffer tank controls the flow set point of the UF system. This level will change, depending on demand of the SWRO system and of the UF backwash pumps. The pretreatment prior to UF consists of only straining, therefore the UF design parameters have been chosen conservatively. For a plant of this size the cost implications of a conservative UF design are relatively small. The cost savings on pretreatment prior to UF outweigh the additional cost of UF membranes.

The UF has performed very stable at these settings. All UF permeate SDI tests show SDI_{15} <2. The reverse osmosis has not been requiring a CIP since start up. RO pressure drop and permeate flow capacity remain stable since the start up.

In close proximity to the dual membrane plant, a second desalination system has been operated since 2000. This system uses conventional pretreatment: dissolved air flotation and single stage media filters. According to the information reported by the end user, the added value of the UF pretreatment is:

- Strong reduction of chemicals consumption. Conventional plant: 25 ppm coagulant + flocculant addition Dual membrane plant: 1 ppm coagulant, no flocculant.
- No sludge treatment/disposal necessary for the dual membrane plant. The UF backwash water blended with RO brine, meets all discharge limits.
- Low CIP frequency. Conventional plant: Autumn – Winter, 1 CIP per month; Spring – Summer, 2 CIP's per month Dual membrane plant: none

- Low cartridge filter replacement. Conventional plant: every CIP Dual membrane plant: negligible

Ultrafiltration Pretreatment Case II

Freeport McMoRan operates the Candelaria copper mine. It has a port facility, Punta Padrones, located in Caldera, about 50 miles northwest of the mine. The current supply of fresh water is by aquifer abstraction. This is a non-sustainable solution: the aquifer is being depleted over time. In order to safeguard supply of water a new desalination plant is under construction. The location is at Caldera Port and the desalination plant is scheduled to enter in operation in 2012.

The project will be executed in two phases: phase one will have a capacity of 30 MLD. This will be expanded to 50.4 MLD in phase two. The original specification of the desalination plant was based on conventional pretreatment: dissolved air flotation, two stage dual media filtration followed by cartridge filtration. Alternative designs based on membrane pretreatment were allowed during the bidding phase.

Based on a thorough tender evaluation, taking into account investment, operational costs, robustness of the process and project capabilities, the project has been awarded to Aqualia. Based on lower Capex and Opex, the decision was made to use ultrafiltration rather than media filtration. Phase one will start operation in 2012, phase two in 2013.

Compared to case I (Gas Atacama), the Candelaria project is characterized by the following design changes:

- Better pretreatment. The Candelaria project uses dissolved air flotation as pretreatment prior to the ultrafiltration system. This allows for a higher membrane flux rate and a longer filtration interval.
- In line operation. The UF is operated at elevated pressure. This creates a backpressure on the UF permeate side that allows for feeding directly into the SWRO high pressure pumps.
- Brine backwash. The UF system is backwashed with SWRO concentrate (brine).

All units are backwashed in a sequence. This is a “train backwash”: the backwash pump is started and all units are backwashed one by one with the backwash pump continuously operating. After backwash of the last unit, the pump is stopped and idles until the next backwash is called for.

The cost implications of the design on this large scale plant are quite considerable:

- A higher flux rate means less membrane surface area. This translates to a reduction in number of membrane elements and in number of ultrafiltration units to be installed.
- A longer backwash interval decreases the downtime of the ultrafiltration system due to backwashing. This translates to a reduction in membrane elements and membrane units as well.
- In line operation eliminates the need for intermediate storage tank, transfer pump and cartridge filters. This reduces cost and footprint.

- Brine backwash decreases the internal water consumption of the UF system. This translates to a reduction in membrane elements and membrane units as well. It should be noted that this plant will be the first worldwide that employs brine backwash on a full scale dual membrane desalination plant.

The train backwash has two effects:

- By minimizing the number of start/stop cycles on the backwash pump the wear and tear is minimized.
- The overall running time of the backwash pump is reduced. This allows for more efficient backwashing: less water loss and a reduced number of backwash pumps being required.

***Figure 2** UF system*

The UF system has a net capacity of 2,778 m3/hr (phase I) and 4,158 m3/hr (phase II). During phase I 11 membrane units will be installed. Figure 2 shows a typical skid. This number will be increased to 16 units for phase II.

Comparison

The two ultrafiltration plants described above use the same Seaguard ultrafiltration membranes as pretreatment to a reverse osmosis system. The goal of the ultrafiltration system is identical in both case studies: proving the best possible pretreatment to a reverse osmosis step at the lowest cost.

The design approach in both case studies is however fundamentally different. The main driver for this difference in design is the size of the desalination system: one small and one large. Based on this different starting point the outcome of the design process looks different. Table 1 below gives a comprehensive overview of the design differences and the selection criteria that drove these differences.

***Table 1** Comparison of design differences between small and large systems*

Systems Size Item	Small Design	Selection Criteria	Large Design	Selection Criteria
Pretreatment	Strainer	Simple and low cost	Dissolved Air Flotation	Better pretreatment to provide savings in UF
Flexibility	Conservative design	Flow modifications by changing process parameters	Modular design	Flow modifications by adding membranes and units
Dual membrane system operation	Decoupled by means of intermediate tank	Easier to control both systems individually	In line operation	Lower investment and operational costs
Backwash water	UF permeate	Easier to control both systems individually	RO concentrate	Higher systems recovery
Backwash strategy	Each unit individually backwashed	Better control of intermediate tank level	Train backwash	Less water loss Lower investment

Conclusions

The conclusion is that a holistic approach needs to be taken for designing large scale desalination plants:

- Pretreatment selection should not only occur based on feed water turbidity as this could lead to inadequate pretreatment and shortfalls in production of the desalination plant. It is therefore proposed to base SWRO pretreatment selection on multiple criteria.
- UF pretreatment has to be an integral part of the desalination plant.
- Investment in UF pretreatment will be offset by savings in investment and operational costs of the total desalination plant.
- Break tanks and intermediate pumping of seawater can be eliminated by installing UF in-line with the SWRO low pressure feed line.
- Use of RO concentrate (brine) will increase the overall systems recovery and can provide investment savings due to smaller intake systems and operational savings due to lower pumping requirements.
- UF pretreatment is becoming the standard for SWRO pretreatment.

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