VATTEN – Journal of Water Management and Research 72: 41–47. Lund 2016

DESALINATION AND BRINE DISCHARGE CASE STUDY FOR PAEW IN OMAN

En fallstudie om avsaltning och utsläpp av retentat för PAEW i Oman

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Abstract

Desalination is an important method for producing drinking water and it has been a freshwater supply alternative for a long time. The water resources in the Gulf Cooperation Council (GCC) countries, are mostly depending on desalination as a major source of (>80 %) drinking water, while the rest comes from groundwater. The largest number of desalination project is located in the Gulf countries (Saudi Arabia, United Arab Emirates, Qatar, Kuwait, Bahrain and Oman) which today counts for more than 45 % of the world production. The Omani production, however, is only about 3 % of the total production in the GCC countries. The International Desalination Association (IDA), Award Program (2014–2015) was designed to facilitate the advancement of global expertise in desalination and water reuse through the exchange of talents, knowledge and skills. This was awarded for the author at Public Authority for Electricity and Water (PAEW), as the host agency in Oman for six weeks. PAEW performs studies and explores and evaluates multiple techniques for providing fresh water and power production to various consumers; residential, industrial and commercial. Oman has several desalination plants, both small (smallest about 100 m^3/d) and large size (largest about 200,000 m^3/d) which are controlled by the PAEW. In the program lecturing, discussions and field visits were conducted to assist the host agency PAEW in Oman.

Key words – Desalination, Brine discharge, Field observation, Water resources, Oman, IDA, PAEW

Sammanfattning

Avsaltning är en viktig teknik för att framställa dricksvatten som har använts under en lång tid. Dricksvattenresurser i Gulfstaterna (Saudi Arabien, Förenade Arab Emiraten, Qatar, Kuwait, Bahrain och Oman) är till stor del beroende av avsaltning (>80 %) för dricksvatten, där den resterande andelen kommer från grundvatten. Gulfstaterna står idag för mer än 45 % av världens avsaltningsprojekt, men står endast för 3 % av dricksvattenförsörjningen i Oman. International Desalination Association (IDA) gav författaren av denna artikel ett resestipendium för att under sex veckor undersöka potentialen för fler avsaltningsprojekt i Oman. Fältstudien gjordes på Public Authority for Electricity and Water (PAEW). PAEW undersöker och utvärderar flera avsaltningsprojekt och undersöker olika tekniker för att producer färskvatten för olika klienter. Oman har flera avsaltningsanläggningar, både mindre (omkring 100 m^3/d) och större (upp till 200,000 m^3/d) vilka alla kontrolleras av PAEW. Under fältstudien hölls föreläsningar, diskussioner och studeibesök, allt för att stödja PAEW i deras arbete.

1 Introduction

Desalination is an important method for producing potable water and is a rapidly growing technology worldwide. Historically, desalination has been a freshwater supply alternative for a long time. With the rapid growth of water desalination technology in recent decades, the development has continued in many arid and semi-arid areas. The capacity of desalination increased rapidly worldwide, from 8000 m^3/d in 1970 to about 32.4 million m^3/d in 2001 from over than 15,000 installed and contracted industrial-scale desalination unites, of this

19.1 million m^3/d seawater desalination plants and 13.3 million m^3/d non-seawater (Wangnick, 2002; Zhou and Tol, 2005).

The contracted desalination plants capacity has also grown to 86 Mm^3/d, which represents the output of over 15,600 desalination facilities worldwide with the online capacity of almost 80 Mm^3/d at the end of 2013 (IDA Year Books 2012–2015). The total capacity has now reached 90.1 Mm^3/d and the online amount of 85.2 Mm^3/d, a rise of about 5 million for both since the 2014–2015 year book (IDA Year Books 2012–2015).

The current situation of water resources in the Gulf countries GCC, is mostly depending on desalination production as a major source of drinking water, where desalinated water accounts for more than 80 % of the total drinking water while the rest comes from groundwater. The largest number of desalination projects is located in the Gulf countries (Saudi Arabia, United Arab Emirates, Qatar, Kuwait, Bahrain and Oman) which today counts for more than 45 % of the world production, of this little more than 3 % total Omani desalination production. Oman is considered as the country among the GCC area with the lowest percentage of desalinated water. Thus, IDA offered an award program for one expert to conduct a study visit in Oman for six weeks in order to evaluate the current situation in all projects and then help them to solve related problems, if any. This program started 10th of October 2015 and ended 22nd of November 2015. The program was schedule as weekly work among divisions of PAEW, as described below. Mr. Sultan Al-Zaidi is the contact person at the host agency in Oman and he provided a very interesting introduction about PAEW, their work and responsibilities in all divisions such as Policy, Strategy and Health, Safety and Environment, the HSE division, planning and assets, projects and operations. As planned with Al-Zaidi for the program, I have spent one week in each division.

We have started with meeting division heads and engineers at different levels every first day of each week following the pre-planned program. Weekly planning for visits was done separately with each division to be able to see most of the plants during and after operation.

The International Desalination Association (IDA), Fellowship Award Program (2014–2015) was designed to facilitate the advancement of global expertise in desalination and water reuse through the exchange of talents, knowledge and skills. As part of this award, I conducted a study visit to Oman for six weeks to participate in an attachment with the host agency, the Public Authority for Electricity and Water. IDA is a non-profit association that serves more than 2,600 core members in 60 countries and reaches an additional 4,000 affiliate members. IDA is also associated with the United Nations as part of a growing international network of non-governmental organizations (NGOs), www.idadesal.org.

The Public Authority for Electricity and Water (PAEW), is the host agency in Oman, located in Ruwi, Muscat, Sultanate of Oman, hosted this program. PAEW performs studies and explores and evaluates multiple techniques for providing fresh water and power production to various consumers; residential, industrial and commercial. Oman has several desalination plants, both small (smallest about 100 m^3/d) and large size (largest about 200,000 m^3/d). PAEW totally controls all plants below 10,000 m^3/d but they also keep their eyes on the rest of the water production from large plants (http://www.paew.gov.om/).

This program was designed as intensive in short time for lecturing, discussing and field visits that was set to help the host agency PAEW in Oman. As the major purposes for this program were directly touches the weak points in each division in order to cover all problems in desalination and brine discharge with the minimum effect. Teaching part is important for any technology such as introduction to desalination and then daily discussion followed by field visit in the next day. The other purpose is to build connection between the officers and the field managers engineers and workers and teach them how to successfully work together.

2 Current Situations in Oman

The Sultanate of Oman has been using desalinated water since 1976 in the Al-Ghubrah power and seawater desalination plant. That was the first commissioned plant located in Muscat, with a few thousand cubic meters a day. The total desalination capacity in 2008 was about 435,000 m^3/day, while today's amount reaches about 700,000 m^3/day. Recently, the Omani government released two new contracts for Sohar and Barka with a total capacity with a little more than 500,000 m^3/day. This will increase Oman's total production to more than one million cubic meters a day (personal communication).

Reported data by Oman Power and Water Procurement (OPWP) in 2008 and after Dr. Al-Barwani, the projected total demand for the desalinated water in the regions is expected to increase from 102 million cubic meter in 2008 to 234 million by 2015 (about 13 % annual increase) as seen in the table below (Al-Barwani, 2008; Al Barwani & Purnama 2010). Table 1 is including most of the desalination production in Oman excluding the small plants

One week was spent in each division started with

Table 1. *Most of desalination plants in Oman excluding small plants (all numbers in thousand m^3/d) (excerpted from: Al-Barwani, 2008; Al Barwani & Purnama 2010).*

Desalination plant by region	2008	2009	2010	2011	2012	2013	2014	2015
Drinking water peak demand	476	602	638	651	664	682	703	723
Al-Ghubrah East (MSF)	182	182	182	182	182	138	138	138
Al-Ghubrah West plant	–	–	–	–	–	136	136	146
Barka I (MSF) plant	91	91	91	91	91	91	91	91
Barka II (RO) plant	–	120	120	120	120	120	120	120
Sohar (MSF) plant	150	150	150	150	150	150	150	150
Sur (RO) plant	12	12	12	12	12	12	12	12
New Sur (RO) plant	–	68	68	68	68	68	68	68
Total desalination capacity	435	623	623	623	623	715	715	715

meeting divisions head and engineers at different levels, listening to them about their duties, work experiences and problems facing and then describing all my experiences through lectures and also individual discussion every day. The second step was the plant visits with a selected plant together for each division separately to be able to see most of the plants in Oman. The visits was very successful because of the pre-arrangement between the planning and asset division and the plant manager. Also the workers at the plants were very kind and well understanding their work especially their explaining to us and their preparedness towards their work and safety. You can see Al-Ghubrah seawater desalination plant as an example including information about the plant and the manufacturer (see Fig. 1).

A few years ago Oman started replacing the MSF desalination technology by RO technology as most of the world desalinated countries does. Both MSF and RO processes dominate the market for both seawater and brackish water desalination, sharing about 86 % of the total installed capacity (Wangnick, 2002). Over last 20 years the RO technology increased significantly from 31 % in 1990 to more than 65 % today, while MSF declined steadily from 56 % in 1990 to less than 21 % today (Bashitialshaaer and Persson 2013). Thus, the RO alone become the main deriving for desalination technology, which mainly because RO has advantages over other technologies.

In each field visit I have highlighted the percentage of input for each type of desalination system (MSF, MED and ED compared to RO system and how is getting highest percentage in the market with rapid improvement to a Nano-technology (membrane and power saving devices), that has lower operation cost. Washing the membrane in the RO desalination plant is possible today to prolong the membrane life as the costliest part

Figure 1. *Left panel: Al Ghubrah seawater reverses osmoses desalination plant, SWRO. Righ panel: source certification and information about the plant.*

Figure 2. *Left panel: old membrnes. Right panel: washing the membranes.*

but until certain time which depend on the quality of the desalinated water (see Fig. 2).

Figure 3 (left panel) shows an example of deep well intakes for desalination plants. This technique is used for some plants in Oman and the rest of the plant uses intakes directly from the sea surface. The well intake depth can vary from one location to another, it typically starts with 30 m. In most cases well intake is safer and cleaner than seawater surface intake. Both intakes should be exposed to pretreatment after micro and Nano-filtration, in new plants ultrafiltration, and then balancing the pH, chlorine and the rest of other chemicals. In Figure 3 (right panel) the treatment point for the injection system for additional dosage of chemicals in order to minimize the pH and to balance chlorine concentration is shown.

The visited plants were almost clean from inside and producing good quality drinking water but looking to the pretreatment point and brine discharge location both are not cleaned enough as seen in the figures. Looking to the brine discharge in the Figure 4 with two different type of discharge e.g. discharge to an infiltration manhole (inland flow) system to distribute the water in all direction and the second is surface discharge which is considered as evaporation pond. Some of the plants are using another method, i.e., sea surface brine discharge. All methods are still under observation because they are not environmentally friendly as seen below. Figure 4

Figure 3. *Left panel: an example of deep wells intake for desalination plant. Right panel: treatment point for the pH and chlorination balance.*

Figure 4. *Left panel: brine discharge point close to the shoreline (inland flow). Righ panel: surface flow pipeline at Al-Zahia RO plant (overland flow similar to evaporation pond).*

(righ panel) shows the major problem in the discharging area; a small pipe flowing in the same location all the time resulting in accumulation of algae and other vegetation that might increase the risk of diseases.

3 Discussion

In general, the whole program was very successful because of the arrangement between the PAEW and the entire plants managers and engineers. Also, the workers at the plants were very cooperative, deep understanding of their work and preparedness towards work and safety. Everything became clear through their explanations and communications.

The Al-kuwiama RO desalination plant is about 400 km from the PAEW building, although far away but good to provide help and taking care of available problems. This plant is functioning with reverse osmosis in two different sections of total production of about 400 m^3/day. Of this, 100 m^3/day is produced from brackish water (TDS about 7000 mg/l) that comes from three wells and 300 m^3/day is produced from seawater (TDS more than 50,000 mg/l), taken directly from the sea surface. The smaller capacity section is functioning well, just taking their input from two wells and the third is out of service. However, the RO plant with capacity of 300 m^3/day has been totally out of service since one year ago. Thus, it is a serious problem for the people in the area living without drinking water.

The last visit was arranged for the joint project Barka desalination and power plant. This plant does not belong to the PAEW, but the produced water goes to the government directly under the control of PAEW. The plant is located at the Gulf of Oman, functioning and operated by ACWA Power, and some operational duties are given to the First National Company for Operations and Maintenances Services (NOMAC) Oman 'Power, Water and Innovation' as a subcontractor. Barka MSF was built in 2003 as the first part of the Barka desalination plant, with a capacity of about 91,000 m^3/day and it produces about 427 MW. Barka has two new expansions, SWRO plants that are called RO1 and RO2, at the same place with total capacity of about 100,000 m^3/day. The intake for all project including MSF, RO 1 and 2 and power plant cooling purpose is taken from the same pipeline directly from the sea (2.2 m in diameter, surface intake) of about 1000 m long having TDS 45,000 mg/l. The brine is also collected from all three parts of the plant and discharged together toward the sea (2.2 m in diameter, surface discharge) about 700 m long.

Oman is always exposed to Red and Autumn Tides which is directly affecting the desalination intakes system especially surface water intake. The two phenomenon are dangerous for Omani projects that located at the coastline. The Red tide is almost occurring every second year but the Autumn tide is occurring every year three months' period. Red Tides is also known as Harmful Algal Blooms (HABs), are blamed for a spate of incidents involving fish kills, clogging of seawater intake systems of refineries and coastal industries, and impacts to coastal tourism according to Muscat-based Middle East Desalination Research Center (MEDRC). According to the site engineers and the PAEW officers the Autumn tide has similar effect but occurs over local area with longer time.

4 Recommendations

I think the result from Al-kuwiama RO desalination plant discharge can bring the diseases and different insects such as mosquito to the area. For this case, I have suggested changing the flow location from time to time or monthly that is depending on the infiltration and evaporation rate. Other possible solution is building an inland pipeline with multi openings to be able to increase the infiltration rate or multi manholes in series with an open surface that increases evaporation rate. We can have more suggestions for this plant and other once to the existing problems and then report it to PAEW right persons.

After visiting small plants, some of the plants intake and outlets was designed smaller than the needed diameter so the blocking percentage was high. In general, we can have more than three different solutions that can minimize the brine discharge impact such as changing the brine discharge flow location, different flow inclination, longer pipeline flow and other possible solutions (Bashitialshaaer et al, 2015).

The result presented in Figure 3 and 4 is showing how the brine discharge is bringing the diseases and different insects to the area and threatening human health. In this case we have to look for a better solution to be able to minimize the effect of brine discharge.

Another problem has been observed is the use of pretreatment antiscalant without control which will be hazardous to the workers because they are using different chemicals e.g. RO antiscalant (high pH) and membrane antiscalant, see Figure 5. Using RO antiscalant helps to control inorganic scales of calcium, magnesium, barium, stronium, fluoride, iron and silica. The pretreatment point or room must be cleaned all the time for the safety of the workers.

5 Conclusions

The purpose of this study was to study problems related to the desalination process and brine discharge system for all desalination plants belongs to the PAEW in Oman and to suggest solutions to most of them, if possible.

Normally desalination has two major parts to consider; intakes and outlets (brine discharge). Desalination brine must be considered when studying environmental impact and assessment in connection with new projects. In reality, most of the recipients, e.g., marginal seas and oceans are naturally considered as the source of intake for desalination plants with a variety of concentration as in Oman. So, using the idea of different discharge and intake locations will decrease the impact of brine discharge and the same time improve the intake quality especially the one from sweater surface.

In my opinion, it was good idea for the PAEW to give the whole service (maintenances and reparations) to private contractor. In this case, the PAEW must be aware of any problems that can occur during services for the desalination plants about the amount of fresh water production quantity and quality control.

Finally, I observed from the site engineers and the PAEW officers that both were significantly thinking towards solutions, ideas were provided from me to use cheaper solution to the existing problem and also to avoid problems in future projects. Such solution can reduce the environmental effects and increases the production amount and quality.

Acknowledgement

It was a great honor that the International Desalination Association selected me for the Fellowship Award, and I would also like to acknowledge both IDA and PAEW

Figure 5. *Left panel: pretreatment room or chamber. Right panel: an example of pretreatment chemical.*

for their great efforts and the opportunities that were given to me through this award program. The program was designed to facilitate the advancement of global expertise in desalination and water reuse through the exchange of knowledge and skills. It is now considered to be one of the industry's most prestigious awards, recognizing individuals who have demonstrated exceptional professional achievements. This program was good opportunity for me and the host agency to exchange our experiences in all directions in the desalination industry, and the host agency also benefitted from my own knowledge.

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