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Salt production by the evaporation of SWRO brine in Eilat: a success story

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Abstract

Mekorot Water Company owns and operates a SWRO plant in Eilat for the production of 10,000 m^3/d of desalinated water. This peculiar plant, commissioned during June 1997, is practically dual purpose, for the production of desalinated water and also for the manufacture of high-quality table salt by the Israel Salt Company. The feed to the desalination plant is a blend of 80% seawater and 20% BWRO brine from adjacent BWRO plants. The brine from the SWRO plant is blended with seawater, and this stream is fed to a series of evaporation ponds, and thereafter to the salt processing factory of the salt company. A brine discharge line and other discharge facilities are not needed. Their cost is spared. Also potential non-homogenous salinity distribution profile of the sea is prevented, leaving the sea fauna and flora at this beautiful resort city untouched. The salt production in this configuration increased by 30% compared to salt production from seawater alone. The salt produced is of the highest quality within the range of the most severe standards. It was not easy to reach these goals, and many difficulties were tackled during the first year of operation. These difficulties and the applied solutions are discussed. Also discussed are aspects of the contract between Mekorot, a governmental corporation, and the salt company, which is a private sector corporation. Issues such as operation of the seawater intake serving both the desalination plant and the evaporation ponds, the sharing of the electric power bills, the investment in the intake and the supply piping, requirements imposed on the quality of brine delivered to the evaporation pond, restrictions imposed on the dosed chemicals in the desalination plant, transfer of data between the companies and mutual responsibility are also presented. The paper stresses that salt production from SWRO brine is a lucrative application for the Gulf countries where similar site-specific conditions prevail: strong solar radiation, very low precipitation, low cost desert land, short and easy transportation to ports, and relatively good accessibility to Asian nations, which are large consumers of salt. Today the brine from desalination sites is polluting the Gulf, imposing ever-increasing environmental problems and difficulties in the operation of desalination plants. The paper analyzes the advantages of salt production vis-a-vis seawater pollution and the investment associated with brine discharge.

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1. Introduction

It is well known that recovery from desalination plants is the major operating parameter in their design and operation. There are many economical models for the optimization of this parameter. An increase in recovery increases brine salinity, osmotic pressure and the pressure profile of the desalination plant with a negative effect on power consumption and investment costs of the construction materials. On the other hand, the feed and brine flow rates decrease, with a positive effect on power consumption and investment cost of feed pipes, the pretreatment section, capacity of the process pumps, the size and the investment in the brine outfall.

In a combined complex for the production of both desalinated water and salt, the optimization schemes change considerably, as an increase in recovery results in a reduction in the size and cost of the evaporation ponds. Appling optimization programs show that the gross optimization range of recovery from a complex of seawater desalination and salt production is 55% to 60%, dependent upon site-specific conditions such as the temperature profile of the seawater during the year and the rate of evaporation in the solar ponds.

The concept of dual-purpose plants for the production of desalinated water and salt has additional economical benefits. The brine outfall facilities, and in particular the pipe entering the sea, are spared. The cost of the brine line entering the sea can be high because its length is generally a few hundred meters in order to prevent short circuits between the brine and feed streams. Also it is well known that works below seawater level are expensive.

The concept of dual production can be very lucrative for the Gulf countries where very favorable conditions for salt production prevail as listed below:

- dry climate similar to the ambient conditions in Eilat;
- low to zero precipitate during the year;
- abundance of low-cost desert land not far from the sea;
- easy connections by inland and sea transportation to the consumers — mainly Asian markets that use salt as a food additive and in industry.

2. Dual-purpose plant in Eilat for the production of desalinated water and salt

In Eilat a dual-purpose plant for seawater desalination and for salt production has been in operation for 9 years. The plant is owned and operated by the Mekorot Water Company, the national water supply corporation, owned by the Government of Israel. The salt production facilities are owned by the Israel Salt Company (Eilat) 1976 Ltd., a private, public sector corporation.

The plant has a production capacity of 10,000 m^3/d of desalinated water. The feed to this plant is a blend of 80% seawater and 20% brine from adjacent BWRO desalination plants. The advantages of the blend feed over seawater feed are obvious: the salinity and osmotic pressure profiles in the desalinator decrease substantially, with a consequent saving in energy of about 15%. Also pre-treatment, investment as well as operating costs are reduced by 20%.

The blending contains negative effects too. The concentration of calcium in the blend feed is higher by 80% in relation to seawater: 0.9 g/L vs. 0.5 g/L. This restraint causes the desalination plant to operate at a recovery of only 50%. Without this restraint, the gross optimization of

Table 1
Ion composition of brine from BWRO and SWRO (80:20) plants, water from the Red Sea, and evaporate SW to SWRO brine concentration (Be)

Component	BWRO brine	SW (Red Sea)	SWRO 80:20 brine	Evaporated SW to same brine concentration (Be)
Ph	5.5	8.2	6.5	6.5
Na (g/l)	2.9	12.5	19.7	20.5
Cl (g/l)	8.4	23	36.5	37.5
Ca (g/l)	2.4	0.5	1.55	0.8
Mg (g/l)	0.8	1.5	2.5	2.4
SO_4 (g/l)	2.7	3.2	5.9	5.1
K (g/l)	0.1	0.5	0.7	0.7
Br (g/l)	0.05	0.07	0.1	0.1
TDS (g/l)	17	41	67	67
Sr (mg/l)		8	33.8	
SiO_2 (mg/l)		5	27	
Fe (ppb)		50	180	
Cu (ppb)		0.1	7	
Pb (ppb)		1	81	
Mn (ppb)		0.2	140	
PO_4 (ppb)		60	135	

the dual-purpose plant would be a much higher recovery. The benefits of operating the desalination plant with a blended feed, and the consequent 50% recovery, override other factors, and indeed the plant has operated according to this regime for the past 9 years.

Table 1 gives the composition of the BWRO brine, the Red Sea at the intake point, and the blended feed.

3. Difficulties during the first year of operation with the SWRO brine

During the first year of operation, difficulties regarding the operation of the salt production, as well as its quality and quantity appeared and were solved. The consequence is that today after 9 years of operation, the annual salt production increased by 30% from 118,000 tons to around 150,000 tons. Also the quality of all the spectrum of the produced salts, from refined table salt, to salt for industrial use, returned to the quality attained during the period when salt was produced from seawater alone. Below some of these problems and their solutions are discussed, excluding certain propieritary information.

3.1. Ion composition of the brine

The chemical composition of the brine from the Mekorot SWRO plant working with a mixture of 80:20 is different than typical seawater (Table 1). The most problematic element is calcium, whose concentration is five times higher than the concentration in seawater (at 4.2 Be): 2.5 g/L instead of 0.5 g/L.

An accelerated precipitation of iron oxide, calcite and mainly gypsum in the initial ponds was observed. This required modifications in the flow regime in the ponds, including increase of the water level of the ponds.

Incidentally advanced evaporated brine shows no significant difference (Fig. 1).

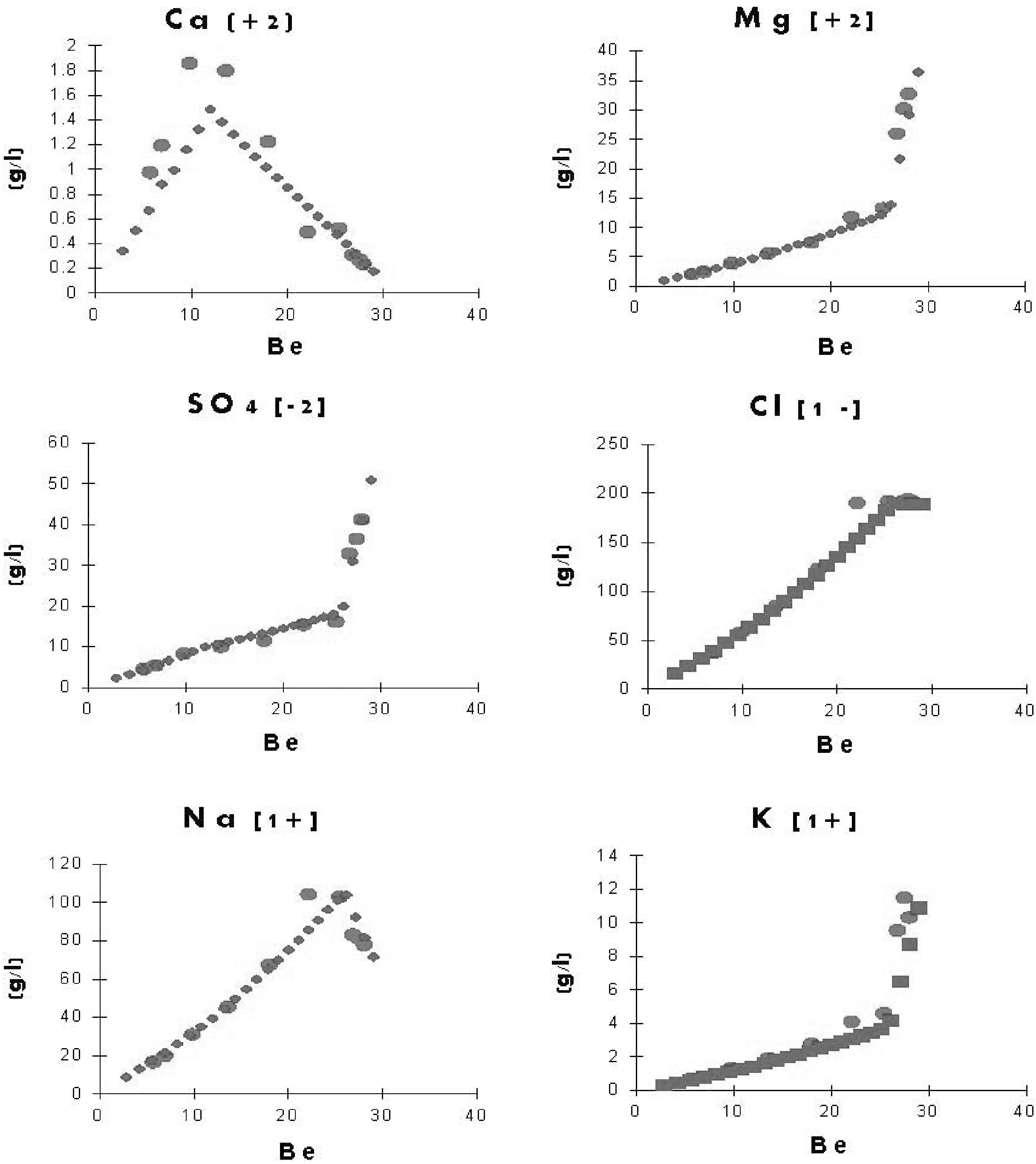

Fig. 1. Ion composition in the brine evaporated from the SWRO plant in Eilat compared to the composition expected from evaporated seawater. ○ brine; ◆ from the literature.

3.2. Algae bloom and biofouling in the ponds

The SWRO was treated with acid to prevent the precipitation of carbonates. Consequently, the brine from the desalination plant was saturated with carbon dioxide, a well known nutrient for biogrowth. Also some of the additives in the desalination plant contained nutrients causing algae bloom and biofouling.

The acidulation of the feed to the desalination plant was abolished; instead other antiscalants were added. After about a year of trial and error, antiscalants which possessed bleaching ability were found. The effect of these antiscalants on the algae was beaching, namely deterioration in photosynthetic metabolism, rather than enhancing it, it was with the original chemicals. All the other dosing chemicals were also screened for any nutrients for biogrowth. Now chemicals are used only if proven that they do not contain any nutrients. The results are very clear: the mat of algae thinned to almost zero, and the foam at the margins of the ponds, a clear sign of water with dissolved organic material, disappeared.

It is well known that dissolved organic material interferes with the crystallization of salt by causing side reactions whose by-products contain sodium, thus reducing the sodium available for salt production. Also dissolved organic material is responsible for the poor shape of the salt crystals. As mentioned, after about a year of trial and error, all these problems were solved, and the production of salt increased by 30%. Its quality returned to the quality before the integration with the desalination plant (Table 2).

3.3. Precipitation of scale in the pipe where the brine is flowing from the "upper ponds"

The brine at a flow rate of about 250 m^3/h enters into a pipe and flows along a distance of about 7 km from the upper ponds where sparingly soluble salts are deposited to the "lower ponds". In this pipe scale started to accumulate. The solution was simple — to blend the same solution with 2% seawater before its entry into the pipe and thus separate the solution from the saturation point. Since the application of this simple solution the pipe is clean from any precipitation.

4. Keystones in the Mekorot/Israel Salt Company contract

The following are the keystones of the agreement between Mekorot and the Israel Salt Company:

- The supply of the sea shall be as required by both companies. This shall be attained by installing the motors of the intake pumps with

Table 2
Impurities in raw salt precipitate in salt ponds before and after the integration of SWRO brine

Element	Salt produced before SWRO integration			Salt produced after integration	
	12/1995	11/1996	6/1997	11/1997	5/2000
SO_4 (%)	1.0	1.02	1.12	1.16	1.06
Ca (%)	0.25	0.24	0.21	0.30	0.23
Mg (%)	0.30	0.28	0.41	0.32	0.32
Fe (ppb)	<1.2	0.8	<1	0.8	1
Mn (ppb)	2.5	0.3	2.5	0.3	<2
Pb (ppb)	<20	0.3	0.1	0.3	0.3
Cu (ppb)	<0.25	0.3	<0.5	0.3	<0.4

variable frequency drivers. An automatic flow control loop, combining the momentary needs of both companies, shall modulate the same frequency drivers.

- The energy bill of the intake pumps shall be shared by both companies according to the relative use of the seawater.
- By Mekorot: The use of the seawater less the quantities utilized for the production of that portion of brine transferred to the salt company.
- By the salt company: The balance — The maintenance of the intake and the supply line shall be divided in equal portions by the parties to the agreement. The same for required investments.
- Mekorot is obliged to supply the brine according to a composition stipulated in the contract, including impurities.
- Mekorot is obliged not to change the nature of the dosing chemicals without consent of the salt company.
- Mekorot is obliged to operate the desalinator according to a minimum plant factor per month.
- Mekorot is obliged to transfer all the relevant plant data to the salt company, on line via wire communication. Some of the data are for the automatic modulation of the intake pumps.

This contract, signed during 1995, is still in effect today to the benefit of both parties.

5. Conclusions

The paper points to a new method for dealing with brine from desalination plants, its economical and profitable utilization, rather than its costly disposal to the sea with potential damages to the ambient. The concept has been in operation for the past 9 years in Eilat, Israel, to the substantial benefit of both Mekorot and the Israel Salt Company.

The Gulf region is a potential global zone for the application of this novel concept according to prevailing site-specific conditions.

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