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THE SCIENCE OF CONCENTRATE MANAGEMENT

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INTRODUCTION

The vast improvements that have been made in membrane systems in recent years have led to increased use of this technology in all parts of the United States and the world. This trend is certain to continue because increasing populations inevitably result in greater demand for potable water. However, inland communities are faced with the major challenge of what to do with the concentrate from the membrane processes. This paper presents the results of laboratory and pilot plant studies regarding procedures for recovering some of the water from silica-saturated membrane concentrates.

CONCENTRATE HANDLING

At the present time, there are essentially two things that can *economically* be done with a membrane concentrate: (1) throw all of it away, or (2) recover some of it and throw the rest away. In order to recover some of the concentrate using membranes, a rather simple systematic procedure can be administered. The steps involved are as follows:

1. Concentrate the concentrate until the system fails (i.e., membrane fouling)
2. Determine what caused the fouling (by mass balances, membrane autopsies, etc.)

3. Identify and implement a treatment scheme
4. Go back to step (1)
5. Continue this process until disposal is cheaper than additional water recovery

SILICA CONSIDERATIONS

In the arid southwestern U.S., silica is often found in groundwater supplies because of the sandy soils of the region. At concentrations above about 100 mg/L, silica can precipitate from solution and foul the membranes. While silica chemistry is quite complex, it is known that hardness is a primary driver of silica precipitation. That is, the *combined* concentrations of hardness and silica (along with other factors like pH, of course) determine when silica will precipitate. Thus, even when the concentration of silica is high (say, above 200-300 mg/L), it will not precipitate if the hardness is low. On the other hand, when the hardness is high, silica will precipitate even at concentrations below 100 mg/L. Therefore, two of the obvious methods for recovering water from silica-saturated brine would be through (1) reduction of the hardness, or (2) reduction of the silica. The project discussed here investigated both methods at the pilot plant level.

PROCEDURE

The first method studied was hardness reduction, and it involved using nanofiltration to remove hardness, followed by reverse osmosis (RO) to remove silica and the other constituents that passed through the nano membrane. The second method employed lime treatment to reduce the silica concentration, followed by reverse osmosis for recovering some of the water.

The concentrate that was used in this study was generated in a 25 gallon per minute (gpm) pilot plant (identified as RO-1) that was operated by CDM, Inc to acquire design data for the 27.5 million gallon per day desalting plant that they were designing for Fort Bliss and El Paso Water Utilities. At the time this study was conducted, the brackish water supplied to RO-1 came from a mixture of wells in the 500-series well field of El Paso Water Utilities. The quality of the brackish water changed somewhat during the course of the investigation because different wells were operated at different times. This, in combination with RO-1 being operated at different recovery rates, resulted in changes in some of the characteristics of the concentrate. Nevertheless, the silica concentration remained fairly constant. The average values for some of the parameters of RO-1 concentrate (e.g., the water supply for this study) are shown in Table 1.

RESULTS

Parameter	Value
Alkalinity	310 mg/L
Chlorides	1310 mg/L
Conductivity	4380 uS/cm
Hardness	710 mg/L
pH	7.3
Silica	122 mg/L
Sulfates	540 mg/L
TDS	3090 mg/L

Table 1. Characteristics of RO-1 Concentrate

Membrane System

The nanofiltration unit was operated at flow rates between 2.0 and 2.5 gpm, with recovery rates that were gradually increased from 50% to 86%. These conditions generated a permeate flow rate of 1.0 to 2.1 gpm, and this served as the influent to the RO unit, which was operated at recovery rates ranging from 40% to 65%. The characteristics of the flows from each unit are shown in Table 2, with the higher values generally associated with the higher recovery rates.

It is believed that the maximum recovery rate in both units was limited by the combination of hardness and silica concentrations in the respective concentrates. As shown in Table 2, most of the hardness that was in the feed to the nano unit (i.e., RO-1 concentrate) stayed on the concentrate side of the nano membrane, as expected. This resulted in increased hardness in the nano concentrate, with the concentration averaging about 2650 mg/L at the highest recovery rate. The silica concentration averaged about 125 mg/L at that time, and the system performed well under these conditions. At higher concentrations of hardness, however, fouling of the nano membrane occurred.

The permeate from the nano unit was the influent to the RO unit and, although most of the hardness was rejected by the nano membrane, about 20% (150-210 mg/L) passed through with the permeate, along with the silica (95 mg/L). When the nano permeate was concentrated in the RO unit, the silica and hardness concentrations increased to 250 mg/L and 460 mg/L, respectively. Fouling began to occur above

Parameter	Concentration, mg/L (except pH and Conductivity)			
	Nano Perm	Nano Conc	RO Perm	RO Conc
Alkalinity	70-250	200-750	10-20	200-750
Chlorides	750-1650	1200-2300	30-50	1800-2800
Conductivity[1]	2900-4600	5700-9100	60-130	5200-9900
Hardness	150-210	1300-3300	5-10	280-590
pH[2]	6.1-7.5	6.3-7.9	4.6-5.9	6.2-7.5
Silica	91-174	108-226	2-21	101-311
Sulfates	0-5	1400-3900	0	0-5
TDS	1570-2860	4000-7850	30-150	3270-6320

1 – Units are uS/cm 2 – Units are pH units

Table 2. Values for Selected Parameters for Flows from Each Membrane Unit

these values. Thus, it appears that hardness plays a very significant role in determining the extent to which silica-saturated brine can be concentrated.

The maximum recovery rate achieved in the nano unit was 86%. This recovery rate, when coupled with the maximum 65% recovery rate in the RO unit, resulted in an overall concentrate recovery rate of about 56% for the membrane processes.

Lime Treatment System

The lime treatment system consisted of a 3-compartment flocculator, a tube settler, sand filters, and the RO unit. A degasification system was added later. Initial lab and pilot plant studies had shown that silica removal via lime treatment could be modeled reasonably well as a first-order reaction. Later studies showed that after the alkalinity was removed, the degree of fit of the model improved significantly. Figure 1 shows the general shape of the silica removal curve. In this study, the first-order portion of the curve (i.e., after the alkalinity was removed) was described by the equation

A lime dosage of 200 mg/L would reduce the silica

$$C = 131e^{-0.0043x} \quad \text{Eq (1)}$$

Where: C = Silica concentration, mg/L
x = Lime dosage, mg/L

concentration in the degassed concentrate to 55 mg/L. A higher dosage would remove more silica, and vice versa, per equation (1). If alkalinity is present (i.e.,

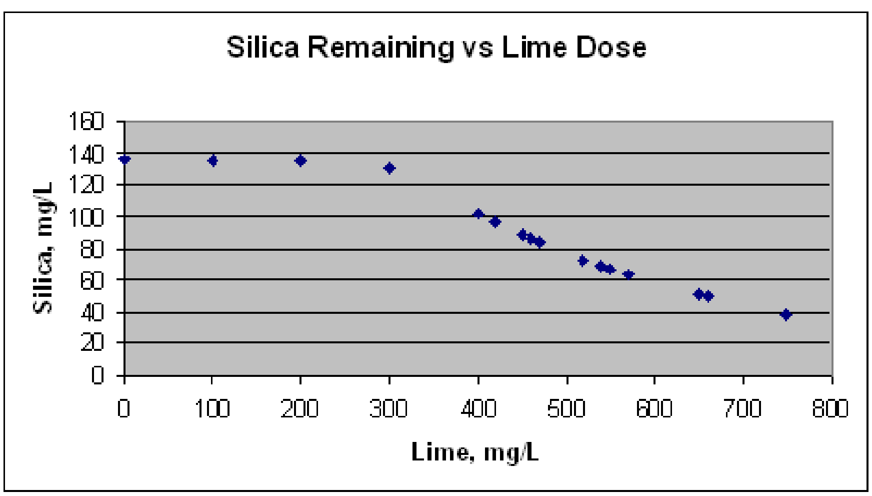

Figure 1. Effect of Lime Treatment on Silica

concentrate not degassed), then the lime dosage has to be increased accordingly as shown in Figure 1.

Reducing the silica concentration in the concentrate would obviously allow for recovery of more water through additional RO treatment. The extent to which the silica should be reduced is dependent on several factors related to cost, including concentrate disposal options, the incremental cost of obtaining new water, sludge disposal costs, and so on. In any case, this study has shown that lime treatment can be used to control silica effectively in brine concentrates so that silica will not be the limiting factor in desalting operations.

CONCLUSIONS

Based on the results of this project, the following conclusions can be made with reasonable certainty:

1. The membrane processes of nanofiltration and reverse osmosis can be used to recover water from silica-saturated brine. The extent of the water recovery appears to be related to the concentrations of hardness and silica in the nano and RO concentrate streams.
2. Lime treatment of silica-saturated brine is effective for reducing the silica concentration in the brine. The dose-response relationship for silica removal appears to be first-order with respect to silica after the alkalinity is removed.
3. By using lime treatment for silica-saturated concentrate, the silica concentration can be reduced to virtually any level that is desired. Factors such as concentrate disposal alternatives, sludge handling options, and overall treatment costs will dictate the extent to which silica should be removed for economically recovering water from the concentrate.

This project has shown that options are available for effectively dealing with silica-saturated brine concentrates.

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