Electronic Supplementary Material (ESI) for Environmental Science: Water Research & Technology.

Supplementary Information

Treatment of Brackish Water Inland Desalination Brine via Antiscalant Removal Using Persulfate Photolysis

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Table of Contents

Fig. S1. The molecular structure of the antiscalant diethylenetriamine pentamethylene phosphonic acid (DTPMP) investigated in this study. ····· 1

Fig. S2. Experimental setup for (A) UV/PS and (B) CDM experiments. ····· 2

Text S1. The details of UV/PS experiments ····· 3

Fig. S3. Calcite saturation index of the Inland Empire Brine at different pH. ····· 4

Text S2. The details of microfiltration experiments ····· 5

Fig. S4. A schematic of dead-end microfiltration membrane setup. ····· 5

Fig. S5. Impact of the addition of orthophosphate to the brine on the removal of total calcium during the CDM process. (A): NaOH softening CDM; (B): Lime softening CDM. ····· 6

Text S3. Calculation on saturation index of calcite ····· 7

Table S1. Input data for saturation index calculations for calcite in the secondary RO concentrate ····· 8

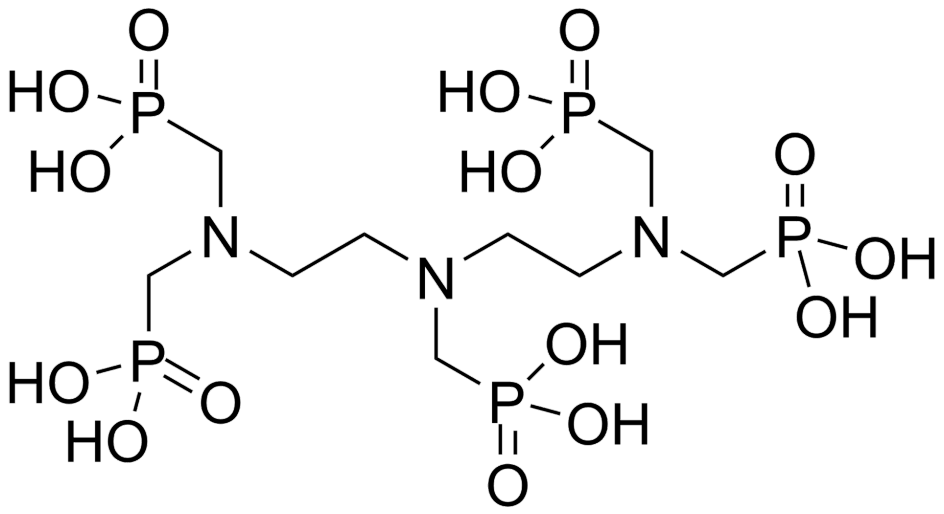
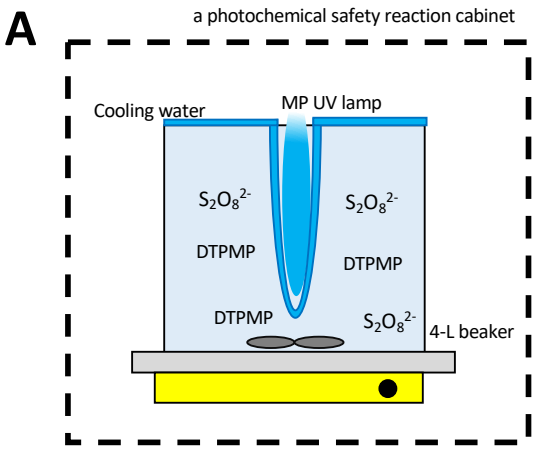


Fig. S1. The molecular structure of the antiscalant diethylenetriamine pentamethylene phosphonic acid (DTPMP) investigated in this study.



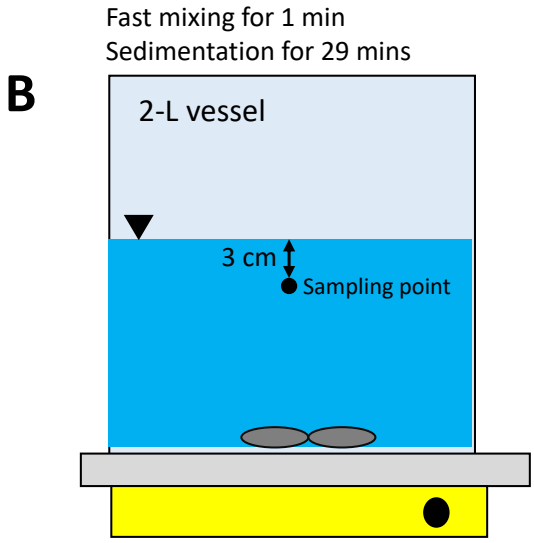


Fig. S2. Experimental setup for (A) UV/PS and (B) CDM experiments.

Text S1. The details of UV/PS experiments

A bench-scale UV reactor consisted of a 4-L beaker, magnetic stirrer, and a 450-W medium pressure UV immersion lamp (Ace Glass, Inc.) with a water-cooling jacket to minimize temperature increase in the reactor. The UV lamp with 42 mW/cm^2 light intensity and spectrum of wavelengths ranging between 200 and 850 nm was placed in the centerline of the 4-L beaker and immersed into feed water to enhance penetration of UV light. Oxidation experiments were carried out in a photochemical safety reaction cabinet. The lamps were warmed up for 10 min prior to the reaction to ensure stable output, and then prepared 3.5-L feed solution was transferred to the 4-L beaker (time zero).

DTPMP degradation and ortho-phosphate kinetic experiment were conducted for 30 minutes with 3.5-L Ca^{2+} absent synthetic brine solutions containing 4 mM persulfate and 0.1 mM DTPMP. To accomplish the UV/PS operating condition investigation, 3.5-L synthetic brine solutions containing 2 -5 mM persulfate and 0.1 mM DTPMP (equivalent of 15.5 mg P/L) were prepared and experiments were conducted for 60 minutes to evaluate the impact of UV irradiation time on the DTPMP degradation. For UV/PS pre-treatment before CDM process, 3.5-L synthetic brine solutions containing 4 mM persulfate and 0.1 mM DTPMP (≅ 15.5 mg P/L) were prepared.

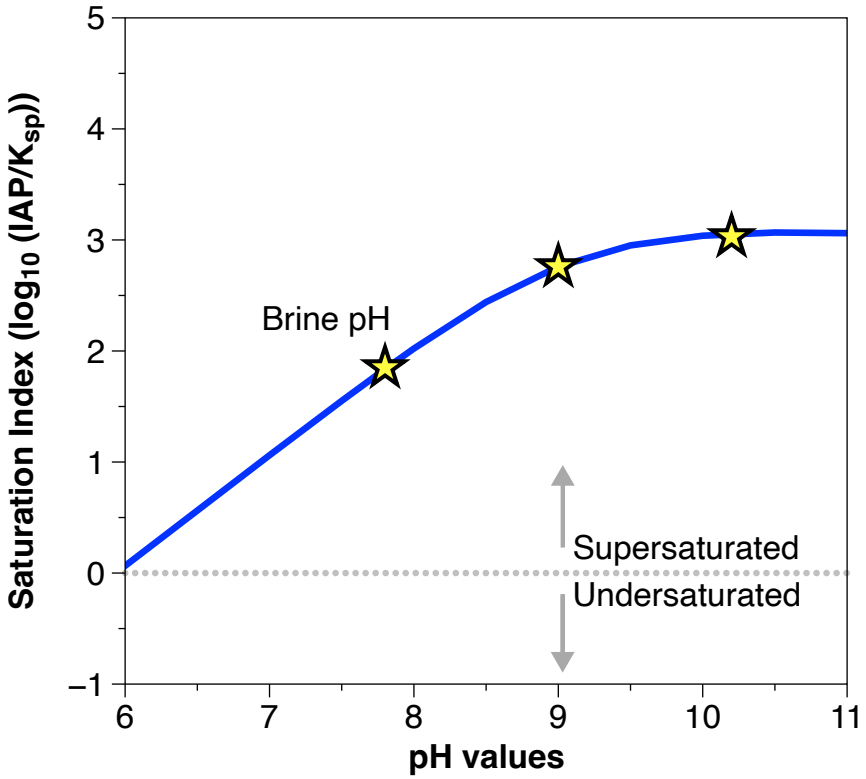


Fig. S3. Calcite saturation index of the Inland Empire Brine at different pH. The saturation index of calcite is defined as: $SI_{CaCO_3} = \log\left(\frac{IAP}{K_{sp,CaCO_3(s)}}\right)$, where $\boldsymbol{IAP}$ is the ion activity product, while, $\boldsymbol{K_{sp,CaCO_3(S)}}$ is the solubility products calcium carbonate (K_{sp}, $CaCO_3 = 10^{-8.48}$).[1]

Text S2. The details of microfiltration experiments

An Amicon stirred cell (200 mL capacity; Millipore Sigma, Burlington, MA) with 28.7 cm^2 of active membrane area was used for the solid/liquid separation after the UV/PS-CDM process. Flat sheet polyvinylidene fluoride (PVDF) membrane with a nominal pore size of 0.1 μm (Durapore®, Millipore Sigma, Burlington, MA) was used in this research. Nitrogen was applied to pressurize the MF cell at 0.5 bar for the membranes.

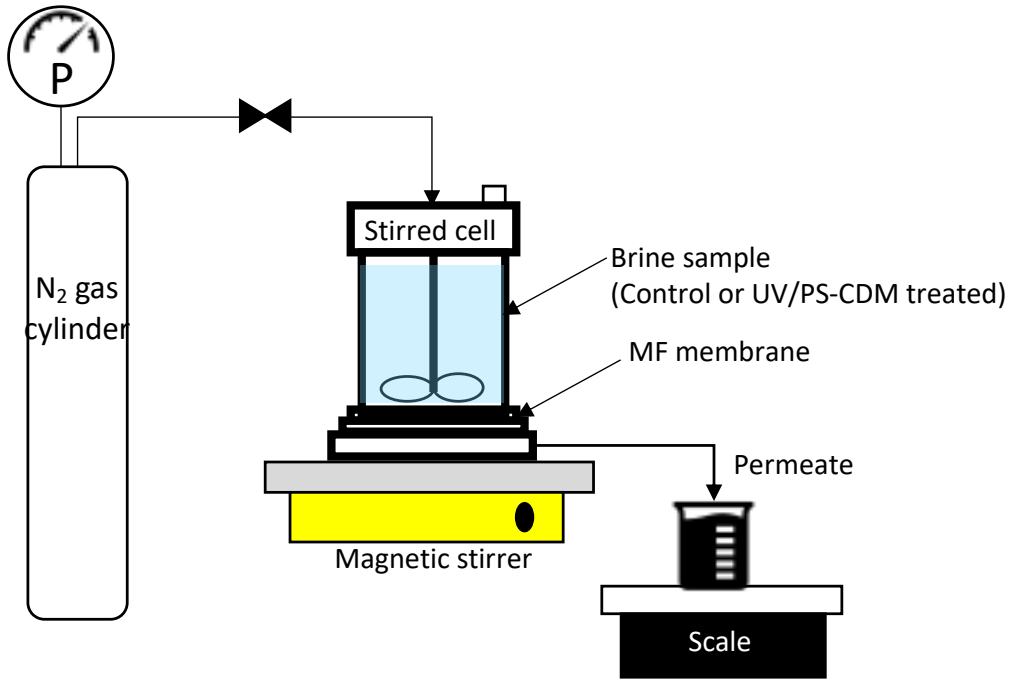


Fig. S4. A schematic of dead-end microfiltration membrane setup.

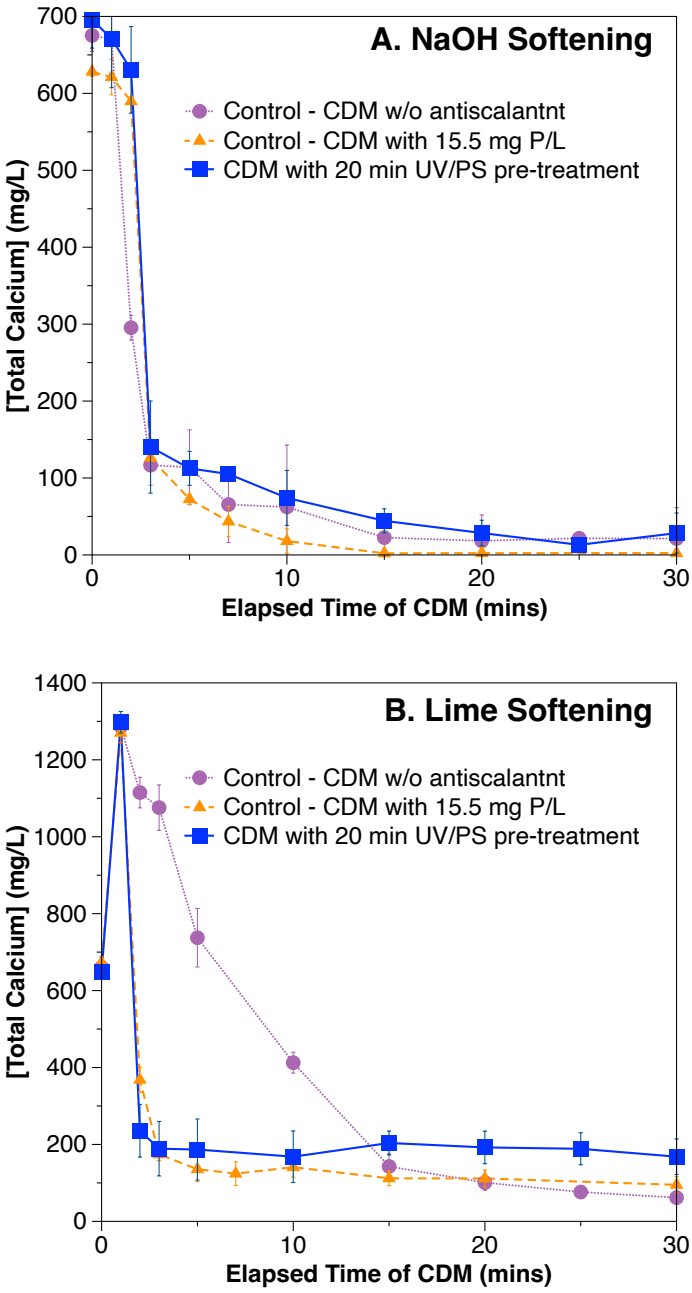


Fig. S5. Impact of the addition of orthophosphate to the brine on the removal of total calcium during the CDM process. (A): NaOH softening CDM; (B): Lime softening CDM.

Text S3. Calculation on saturation index of calcite

SI as a function of the secondary RO water recovery was calculated based on the water quality after the microfiltration process (Table S1). Control stands for no UV/PS-CDM treatment (direct use of brine). Initial water quality data (0% water recovery) for calcite saturation index calculations in the secondary RO concentrate are shown in Table S1. As the secondary RO water recovery increases, the saturation index in the secondary RO concentrates increases. The concentration of the secondary RO concentrate ($C_{concentrate}$) at different water recoveries was calculated based on Equation (S1).

$$C_{concentrate} = \frac{C_{in}(1 - r(1 - R))}{1 - r} \quad \text{(S1)}$$

Where, C_{in} is the initial concentration, r is the fractional recovery, and R is the fractional removal efficiency. We assumed 100% salts rejection at the secondary RO, meaning R is 1. Saturation index calculations in Figure 7 were performed through Visual Minteq (Version 3.1) for a pH of 7.8 at different water recovery.

Table S1. Input data for saturation index calculations for calcite in the secondary RO concentrate; the input data are water quality measured after the microfiltration process (CDM with 20 minutes UV/PS pre-treatment in Fig. 6).

Chemical constituent	Untreated brine	UV/PS-CDM-MF treated brine (NaOH softening)	UV/PS-CDM-MF treated brine (Lime softening)
Calcium	16.5	0.8	3.3
Sodium	54.7	76.5	71.0
Chloride	60.9	60.9	60.9
Bicarbonate	21.3	4.0	3.3
Perchlorate	5.5	5.5	5.5
pH	7.8	7.8	7.8

* All concentration data are in unit of mM.

Reference

1 M. M. Benjamin, *Water chemistry*, Waveland Press, Inc, 2nd ed., 2014.