Project 3.19: Reverse Osmosis with Virtual Curtain to Achieve Minimum Liquid Discharge

NAWI National Alliance for Water Innovation

Project Team

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Project Summary

Concept:
This pilot couples RO technology with CSIRO's patented Virtual Curtain (VC) process to maximize water recovery and minimize brine volume by allowing RO to operate at its osmotic pressure limit.

Drivers & Expected Outcomes:
- Reduce cost of minimal- & zero-liquid discharge (MLD) for RO-based brackish desalination.
- Current approaches that require thermal technologies (brine concentrators/ crystallizers) for RO concentrate (ROC) treatment have high capital and operating costs.
- Improving RO recovery can reduce ROC volume and MLD costs
- Our research will evaluate the VC process, which will promote in-situ formation of a novel compound, hydrotalcite (HTC) to remove key constituents from concentrate that limit RO recovery (e.g., calcium, magnesium, silica, barium, strontium) through multiple mechanisms.

Bench & Pilot Testing:
- Bench testing conducted at New Mexico State University (NMSU).
- Pilot testing conducted at Reclamation's Water Quality Improvement Center (WQIC) in Yuma and evaluate in-line precipitation by VC of various source waters/concentrates, then clarified by a submerged ceramic membrane filter prior to final concentration by SWRO.

Bench Testing Results To Date

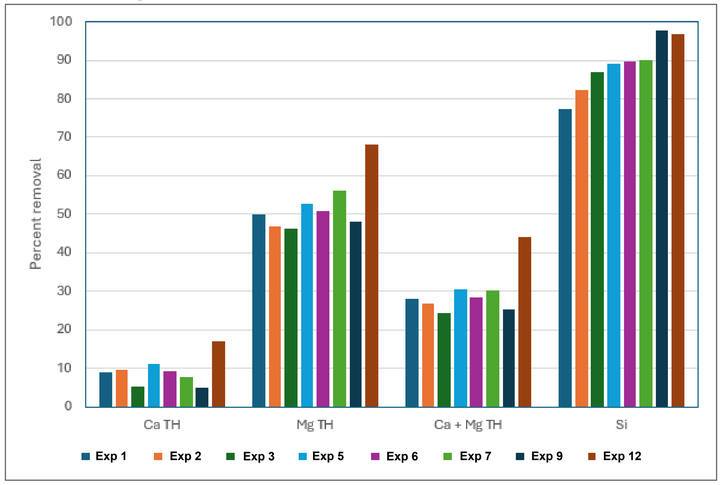
RO Concentrate Quality from Yuma Desalting Plant

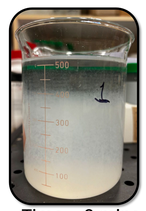
TDS	Ca	Mg	Total Hardness	Alkalinity	SiO2	pH
5700 mg/L	314 mg/L	164 mg/L	1,469 mg/L as $CaCO_3$	40 mg/L as $CaCO_3$	31.3 mg/L	6.5

Bench Testing Conditions

Bench Test	$Mg(OH)_2$ (mg/L)	$NaAlO_2$ (mg/L)	$LaCl_3$ (mg/L)	pH	Reaction Time (min)
Experiment 1	100	270	-	9.5	2
Experiment 2	200	270	-	9.5	2
Experiment 3	600	270	-	9.5	2
Experiment 5	100	300	-	9.5	2
Experiment 6	100	330	-	9.5	2
Experiment 7	100	360	-	9.5	2
Experiment 9	100	300	-	9.5	1
Experiment 12	100	370	400	9.5	5

Bench Testing Results




Time = 0 mins


Time = 5 mins

Hydrotalcite in-situ formation


Cerafiltec filtration


SDI measurement

KEY FINDINGS AND CONCLUSIONS

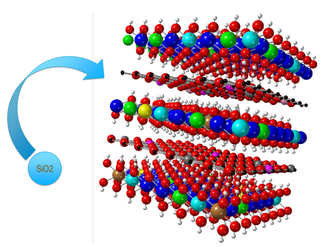
Scalant Reduction in RO Concentrate

Key Findings:
- In-situ formation of hydrotalcite is an effective means of removing key scaling ions in RO concentrate
- HTC formation and scalant incorporation occurs much more rapidly than conventional scalant reduction processes (e.g., high pH softening).
- Optimum scalant removal occurs at low magnesium:aluminum ratios and at pH 9.5, compared to pH 11 or greater for effective removal by conventional softening.
- Addition of lanthanum chloride ($LaCl_3$) enhances calcium and magnesium removal by 'breaking' the Ca/Mg complex with threshold inhibitor present in RO concentrate.
- HTC solids are readily filterable by membrane filtration (Cerafiltec), resulting in a clean filtrate with SDI of <2, suitable for additional RO treatment to further reduce concentrate volume.

Conclusions:
- In-situ formation of hydrotalcite is effective in reducing key scalants present in concentrate generated from RO treatment of saline agricultural drainage water.
- Incorporation of Ca, Mg and SiO_2 within the HTC stucture occurs quickly and at moderately alkaline pH, a significant advancement over conventional methods for removal of these scalants.
- Further testing is planned with other brackish water sources, both at bench and pilot scale, to demonstrate the HTC efficacy on a range of concentrate qualities.

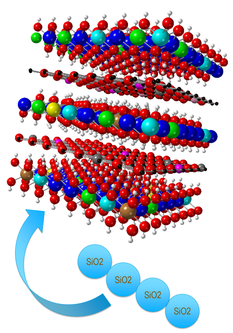
Virtual Curtain and Hydrotalcite Formation

Monomeric SiO_2 incorporation into HTC interlayers



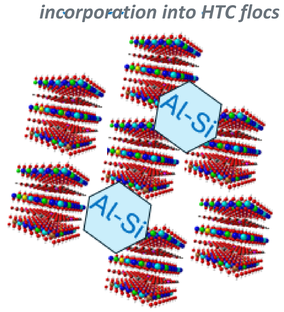
Hydrotalcite (HTC) layered structure of polymetallic metal (M2+/M3+) hydroxide layers (blue-green atoms representing Mg and Ca, with red-white hydroxide ligands) separated by carbonate (black atoms) anionic sheets and interstitial water (red-white atoms).

Polymeric SiO_2 edge complexation on HTC



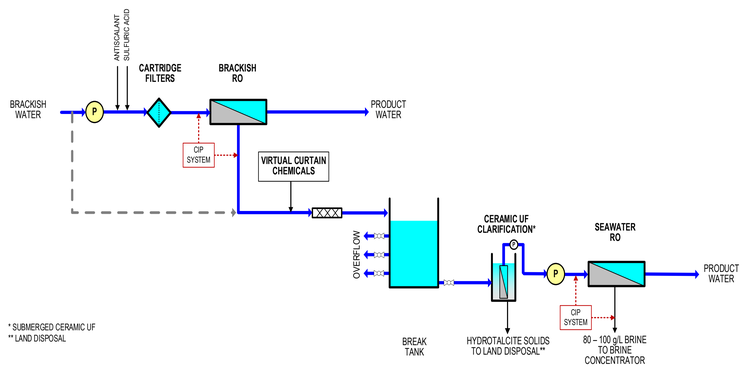
HTCs act as both cation and anion repositories during formation, ion-exchangers and sorbents post-formation, and as flocculants that may incorporate colloidal and particulate materials.

Aluminosilicate (clay) incorporation into HTC flocs



HTC is versatile in binding and incorporating silica in its different forms: monomeric, polymeric, or as part of aluminosilicate clays. The incorporation mechanisms (interlayer, edge complexation, and floc formation) highlight the multifunctionality of HTC to remove diverse contaminants.

Pilot System Overview



Pilot facilities at the Reclamation WQIC will be arranged to allow for testing several sources of water available at the Reclamation Yuma Desalting Plan. For example:
- *Agricultural Drainage Water (ADW) derived from Colorado River Water, including untreated ADW and ADW-based ROC following partial lime softening & media filtration.*
- *Brackish Groundwater (BGW), including untreated BGW and BGW-based ROC following cartridge filtration.*

RELATED REFERENCES

Douglas, G.B. Contaminant removal from acidic mine pit water via *in situ* hydrotalcite formation. Applied Geochemistry. 51:15-22, 2014.
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Douglas, G.B., Shackleton, M. and P. Woods, Hydrotalcite formation facilitates effective contaminant and radionuclide removal from acid uranium mine barren lixivant. Applied Geochemistry. 42:27-37, 2014
URL: https://www.sciencedirect.com/science/article/pii/S088329714000031
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