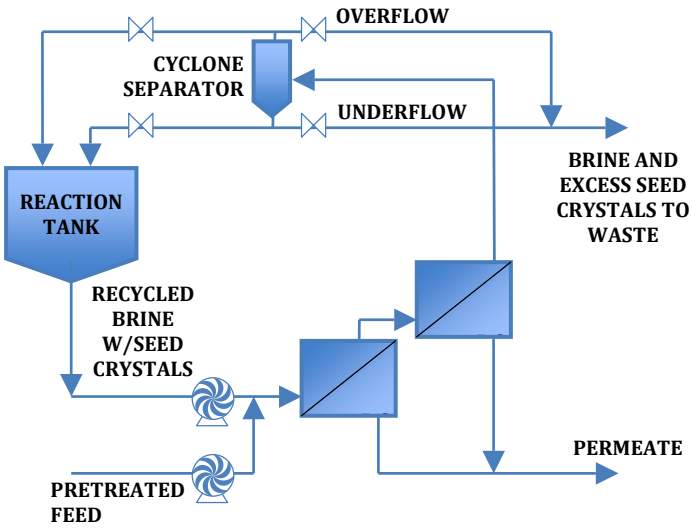
Dual RO with SPARRO: Slurry Precipitation and Recycling RO

Water recovery in reverse osmosis (RO) processes may be enhanced by adding crystals (e.g., gypsum) to the feed water to force the controlled precipitation of sparingly soluble salts. The seeded crystals provide a preferential growth site for calcium, sulfate, and silicates. The seeded crystals are introduced as slurry prior to tubular RO membrane elements. Scaling compounds are precipitated on seed crystals and are retained in the reject stream of the membrane and later removed by a gravity separation process (e.g., cyclone separator). The desired seed concentration is maintained in a reactor tank by controlling the rate of wasting the upflow and/or underflow streams from the separator. Tubular membrane systems are required to reduce clogging within feed channels. The combined water recovery of the process is estimated to be greater than 94%.



Summary of technical assessment of slurry precipitation and recycling RO (SPARRO).

Criteria	Description/Rationale
Status of technology	Pilot-scale testing conducted on impaired water from a mining operation. No previous use for CBM produced water treatment.
Feed water quality bins	Most applicable for TDS ranging from 500 mg/L and 12,000 mg/L. Moderate-to-high removal of monovalent and divalent ions, metals, and organics is expected.
Product water quality	The quality of the permeate depends on feed water salinity and operating conditions. Pilot-scale studies reported 94% rejection of TDS.
Recovery	Product water recovery is estimated to exceed 94%.
Energy use	Energy requirements are estimated at 18.2 kWh/kgal (0.77 kWh/bbl)
Chemical use	The system requires a continuous feed of seeding material. Chemical cleaning frequency depends on feed water quality. Membrane cleaning is triggered when certain operating conditions are exceeded, and may require the use of NaOH, Na_4EDTA, or HCl.

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Criteria	Description/Rationale
Expected lifetime of critical components	No data is currently available.
Infrastructure considerations	This treatment process requires a larger footprint than conventional RO systems. Chemical storage and reaction vessel facilities are required, as well as a second array of RO elements. System mobility is reduced compared to conventional RO systems.
O&M considerations	Monitoring and control required for flow rates, chemical dosing, and RO element pressure. System may require substantial oversight to ensure proper operation of integrated system. Level of flexibility: may have moderate sensitivity to organic and inorganic constituents in the feed water. Level of robustness: TFC membranes have high pH tolerance, but cannot be exposed to feed temperatures in excess of 113˚F (45˚C). Level of reliability: RO systems operate semi-continuously with automated, short duration chemical cleaning or osmotic backwashing cycles (for RO). Types of energy required: electrical.
Capital and O&M costs	Capital costs are estimated to be $4.7/gpd ($199/bpd). Operation and management costs are currently unknown.
Pretreatment of feed water	Process requires coagulation and prefiltration to remove suspended solids prior to contact with the slurry reaction chamber to ensure optimal operation. Other pretreatment options including antiscalent and acid addition may be required. Product water may require pH adjustment and remineralization. This may be achieved by lime bed contacting or by blending small amounts of filtered and sterilized feed water with permeate. The feed stream to the second RO stage requires chemical precipitation and filtration prior to contact with the RO membranes.
Post-treatment of product water	No special concentrate treatment is required. Relatively high recovery rates exceeding 90% generate small volume of concentrated brine.
Concentrate management or waste disposal	Good to excellent - the limiting criteria is sludge disposal and chemical reagent availability
Note: 1 barrel = 42 US gallon	