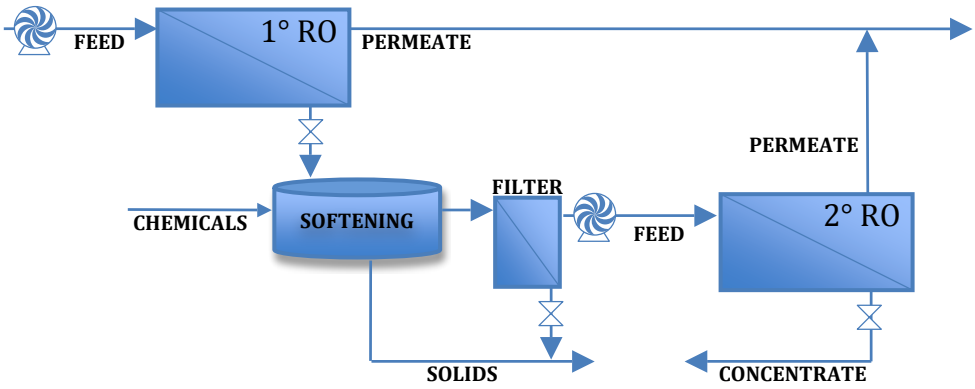
Dual Reverse Osmosis with Chemical Precipitation

Dual reverse osmosis (RO) with chemical precipitation employs both physical (purification through a semi-permeable membrane) and chemical precipitation methods to enhance water recovery beyond that of a single stage RO process. This method is used when high recovery is desired when desalinating hard water. Concentrated brine generated from the first stage RO is treated (softened) with lime ($Ca(OH)_2$) or caustic soda (NaOH), and/or soda ash (Na_2CO_3) to precipitate calcium as $CaCO_3$, magnesium as $Mg(OH)_2$, and to a lesser extent co-precipitate colloidal and dissolved silica. Specific chemicals can be used to precipitate targeted sparingly soluble salts. Precipitation of these constituents reduces the likelihood of membrane scaling in the second stage RO. RO membranes are capable of achieving high removal of monovalent ions (e.g., sodium, potassium, chloride, etc.), divalent and multivalent ions (e.g., calcium, magnesium, sulfate, iron, arsenic, etc.), and many organic constituents from the feed stream. The dual RO with chemical precipitation technology is primarily used for brackish water desalination, where a removal of multivalent ions and increased water recovery are desired. An illustration of the process is shown below.



Summary of technical assessment of dual RO with chemical precipitation

Criteria	Description/Rationale
Status of Technology	Pilot tested at municipal desalination plants. Not previously employed for CBM produced water treatment.
Feed water quality bins	Total dissolved solids application range from 1,000 mg/L to 35,000 mg/L. High removal of monovalent and divalent ions, metals, and organics is achievable. System is likely to achieve additional silica removal through co-precipitation.
Product water quality	Permeate water quality depends on feed water salinity and operating conditions. Pilot studies reported 94% rejection of total dissolved solids.
Recovery	Product water recovery is estimated to exceed 90%.
Energy use	No data is currently available.
Chemical use	Chemical demand of lime ($Ca(OH)_2$) or caustic soda (NaOH) depends on water chemistry and the quantity of calcium and magnesium targeted for removal. Chemical cleaning rates depend on feed water quality. Membrane cleaning will be triggered when certain operating conditions are exceeded, and may require the use of NaOH, Na_4EDTA, or HCl.

Summary of technical assessment of dual RO with chemical precipitation

Criteria	Description/Rationale
Expected lifetime of critical components	No data is currently available.
Infrastructure considerations	This treatment process will require a larger footprint than conventional RO systems. Chemical storage and sludge dewatering facilities will be required, in addition to a second array of RO elements. System mobility is reduced compared to conventional RO systems. Filtration system and chemical storage components are the primary factors in limiting mobility.
O&M considerations	Monitoring and control required for flow rates, chemical dosing, and RO pressures. System may require substantial oversight to ensure proper operation of the primary RO stage brine management systems. Level of flexibility: may have moderate sensitivity to organic and inorganic constituents in the feed water. Level of robustness: thin film composite 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 rinse or osmotic backwashing cycles. Types of energy required: electrical.
Capital and O&M costs	Costing figures are unknown.
Pretreatment of feed water	All high-pressure membrane technologies require extensive pretreatment to mitigate harmful water quality constituents that will otherwise foul or scale the membrane. The feed stream to the second RO stage requires chemical precipitation and filtration prior to treatment by the secondary RO stage.
Post-treatment of product water	Product water may require pH stabilization and remineralization. This may be achieved by lime bed contacting or by blending small amounts of filtered and sterilized feed water with permeate.
Concentrate management or waste disposal	No special concentrate treatment is required. Relatively high recovery rates exceeding 90% generate very minor amounts of concentrated brine.
Applicability for produced water treatment	Good to excellent - the limiting criteria is chemical cost, availability, and disposal considerations.
Note: 1 barrel = 42 US gallon	