

TECHNICAL CHALLENGES TO CONCENTRATE DISPOSAL FROM INLAND DESALINATION

Dr. Kerry J. Howe, P.E.
Department of Civil Engineering
The University of New Mexico

ABSTRACT

With the limited availability of fresh water resources in New Mexico, the growing population is putting a significant amount of stress on the water resources in the Rio Grande Corridor. One way to alleviate the stress on the Rio Grande is to identify alternate sources of water, and brackish groundwater have been identified as one possible source of “new” water. Although the brackish groundwater resources are believed to be significantly larger than the fresh groundwater resources in NM, brackish groundwater currently goes unused. The primary reason that this resource is unused is that brackish water is too salty for human consumption or agricultural purposes, and must be treated to remove the salt before it is useable.

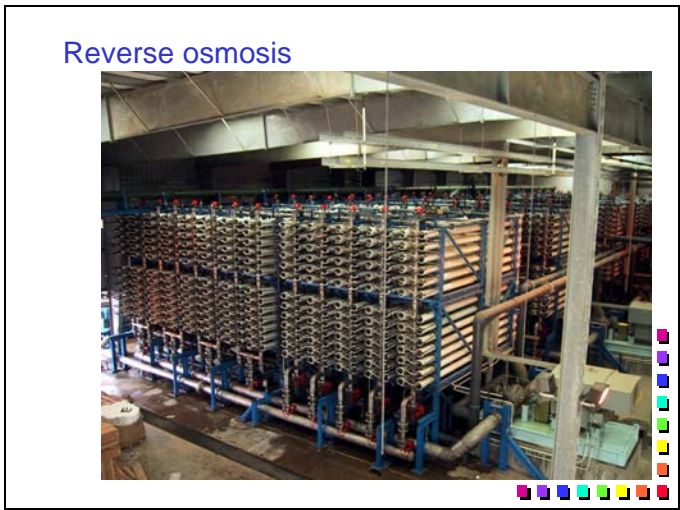
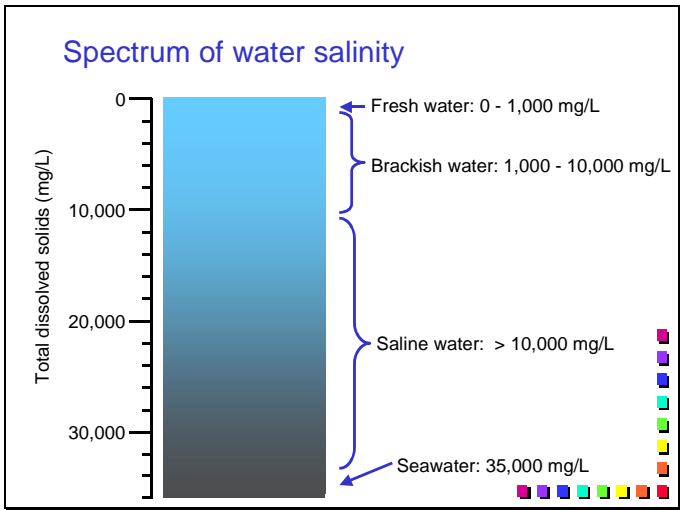
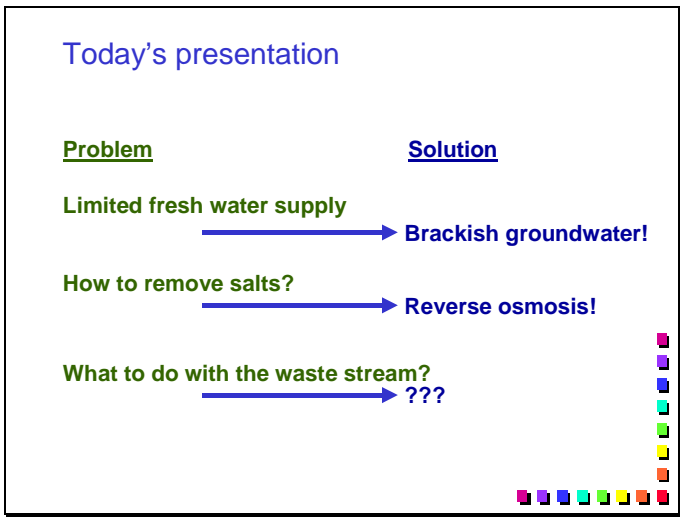
Desalination using reverse osmosis is one way of converting the brackish water to fresh water. Reverse osmosis (RO) has been available on a commercial basis for nearly 40 years. Unfortunately, desalination is expensive and has several technological, operational, and regulatory problems, so its use is limited to locations where brackish or saline water is the only viable water resource. Despite the limitations, reverse osmosis is in use at thousands of locations worldwide, including coastal areas of the US, such as California, Florida, and South Carolina, which have large populations, insufficient fresh water, and abundant brackish or saline water resources.

New Mexico shares many characteristics with these coastal areas, with its own growing population, insufficient fresh water, and abundant brackish water, but is currently not using its brackish water resources because of the technological constraints of the desalination process. One of these constraints is the production of concentrate, a waste stream of concentrated salts. The concentrate stream from reverse osmosis facilities ranges from 15 percent of the feed water flowrate for low-pressure brackish water RO systems to 50 percent of the feed water flowrate for seawater RO systems. The costs associated with this large waste stream are enormous, encompassing everything from capital costs for larger pumping and process equipment, to waste energy costs, to the actual costs of disposal of the waste stream. The high salinity of the concentrate stream makes it toxic to many plants and animals. Many concentrate streams are anaerobic, which makes it toxic even to saltwater fish.

Reverse osmosis concentrate is disposed of by several methods, including surface water discharge, sewer discharge, deep well injection, evaporation ponds, infiltration basins, and irrigation. Of these, the most common disposal methods in the United States are direct surface water discharge (about half of all plants) and sewer discharge (about a third of all plants, and sewer plants nearly always discharge their effluent to surface waters). These disposal methods are viable in coastal areas, where the concentrate can be diluted into saline surface water. In inland areas, concentrate disposal is especially challenging because any discharge to surface water would contaminate the fresh water resources. Thus, concentrate disposal is a major obstacle preventing the implementation of desalination in inland areas such as New Mexico.

One attractive solution to the concentrate disposal issue is to turn this disposal problem into a natural resource. Ideally, it would be beneficial to recover products (sellable chemicals or salts) or find beneficial uses for the waste stream. Options include the recovery of specific chemicals that can be used as feedstock for various industries, use of the brine in an industrial process, or production of electricity from a solar brine pond.

This presentation will summarize the current state of knowledge regarding concentration disposal issues and the state-of-the-art with respect to concentrate reuse strategies. The magnitude of the concentrate problem and its impact on the potential use of brackish groundwater resources in New Mexico will be explained. Potential opportunities for dealing with the concentrate problem, such as beneficial use, will be described. These uses will include the recoverable products, such as salts, and industrial processes that use brine solutions. Finally, research needs that should be addressed to realize the full potential of both the brackish groundwater resources and the concentrate stream as natural resources will be identified.



Water resources are characterized by a continuing cycle of problems and solutions. Brackish groundwater might be perceived as a solution to the problem of a limited fresh water supply, but it generates a new problem; namely, how to remove the salts. Reverse osmosis might be perceived to be a solution to the salt removal problem, but it also generates a new problem; namely, what to do with the salts once they have been removed. This last problem is the focus of this presentation.

Water salinity varies with the source of the water. Fresh water is generally considered to be that which has less than 1000 mg/L of total dissolved solids (TDS), whereas seawater typically has 35,000 mg/L of TDS. Brackish and saline water falls between these values. The feasibility of using a particular water source for a potable supply depends on the salinity; the lower the TDS, the more feasible the supply.

The photograph shows the 100,000 m³/d Point Lisas desalination plant in Trinidad, an example of a large seawater reverse osmosis facility.

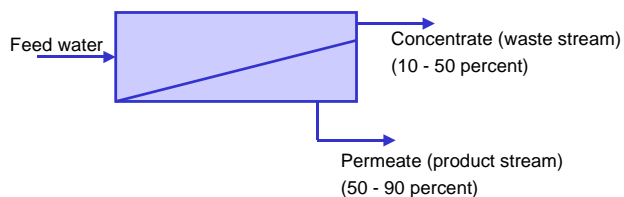
Facts about desalination

- Over 15,000 desalting plants are in operation
- Total capacity is 8.6 billion gal/day
 - Enough water for 43 million people
- 44 percent of plants use reverse osmosis
 - RO has been in use on a municipal scale for 40 years (first plant in Coalinga, CA, in 1965)
 - RO plants are operating many places in the United States, especially Florida and California, but also Arizona, Oklahoma, Iowa, North Dakota, etc,
- RO is currently used on everything from brackish water to seawater



People new to the process of desalination, particularly people in inland areas such as New Mexico, sometimes believe that desalination is a new a technology without any operating history, and therefore will be difficult to implement. In fact, desalination using reverse osmosis has been around for nearly 40 years, and there are more than 15,000 operating desalination plants around the world, producing enough water to provide a municipal water supply for 43 million people. Thus, the utility of reverse osmosis for treating brackish or saline waters to produce potable water is well established.

Reverse osmosis



Issues related to the concentrate stream

- Waste of water resource
- Disposal
 - Highly saline, toxic to terrestrial and aquatic life



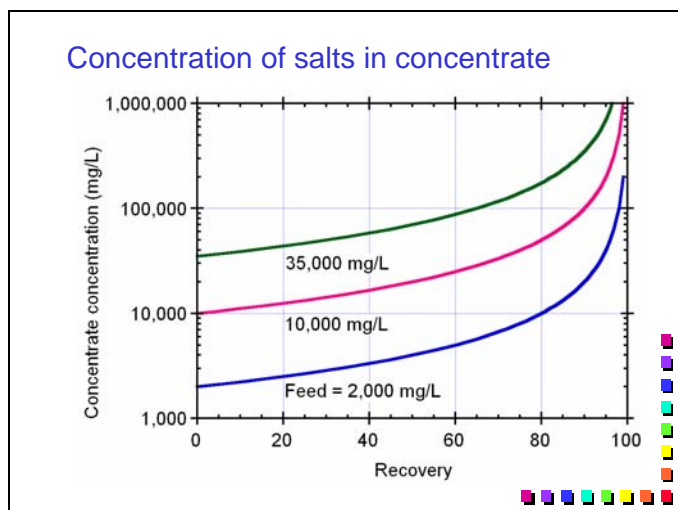
Despite the widespread use of reverse osmosis, implementation in inland areas presents some unique challenges. Slide 6 demonstrates that reverse osmosis takes a feed water stream and splits it into two streams—a product stream of permeate (potable water) and a waste stream of concentrate (brine). The concentrate stream is problematic because it is a high volume stream and might have toxic properties.

Factors limiting recovery

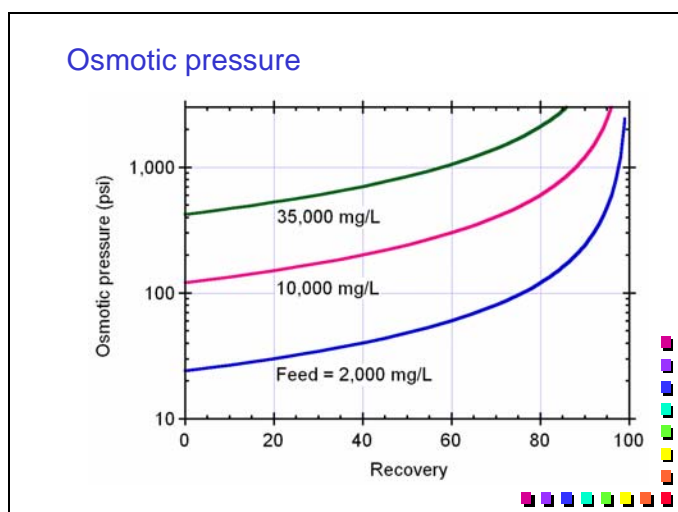
- Solubility
 - Brackish water contains many ions
 - Cations: calcium, barium, strontium...
 - Anions: carbonate, fluoride, sulfate...
 - Ions become more concentrated as recovery increases
 - When solubility limit is reached, salts precipitate
- Osmotic pressure
 - Applied pressure for water production must overcome osmotic pressure
 - Osmotic pressure increases as recovery increases



The concentrate is a high volume stream because of some inherent limitations to the recovery (ratio of permeate to feed water) in reverse osmosis. These limitations include solubility and osmotic pressure.



This slide demonstrates how the salts in the concentrate stream become more concentrated as either the feed concentration increases or the recovery increases. Higher concentration leads to solubility and recovery limitations.



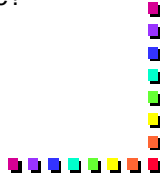
This slide demonstrates how the osmotic pressure of the concentrate stream increases as either the feed concentration increases or the recovery increases. Higher osmotic pressure leads to recovery limitations.

- ### Current concentrate disposal practices
- Discharge to surface water (50 %)
 - Need a saline surface water nearby
 - Discharge to sanitary sewer (25 %)
 - Wastewater plants discharge to surface water
 - Need a saline surface water nearby
 - Deep well injection (10 %)
 - Need a highly-permeable, unusable saline aquifer nearby
 - Land application/irrigation (10 %)
 - Evaporation ponds (5 %)

The concentrate stream from existing reverse osmosis facilities is disposed of by several means, including discharge to surface waters, discharge to sanitary sewers, deep well injection, land application, and evaporation ponds. The options are considerably more limited in inland areas, as surface water and sanitary sewer discharges would not be allowed, and deep well injection may not be feasible depending on geologic features.

Salt production by desalination

- Quantity
 - A 2 MGD facility using a 2,000 mg/L TDS water source will generate 33,000 lbs of dry salt per day
 - A 60 MGD facility using a 10,000 mg/L TDS water source will generate 5,000,000 lbs of dry salt per day
- Is this a waste problem or a resource?



An alternative to disposal of the concentrate stream is to recover it for beneficial uses. The concentrate stream contains a large quantity of a variety of salts, which may actually be a resource instead of a waste problem.

Beneficial uses for concentrate

- Marketable mineral salts
 - NaCl, KCl, Na₂SO₄, K₂SO₄, MgSO₄, Mg(OH)₂, KNO₃, Na₂NO₃...
- Industrial uses of brine
 - Electrolytic production of Cl₂ and NaOH
- Brine shrimp production
- Electricity production in solar ponds
- Irrigation of halophytes
- Aquaculture/habitat/brackish wetlands



A variety of beneficial uses for concentrate are listed on slide 12. Although concentrate streams are not currently recovered for beneficial uses, this list shows the wide variety of opportunities that are available.

Facts about salt (NaCl)

- 45,000,000 tons of salt are produced per year in the United States
- 70 % is used by the chemical industry
 - 21,000,000 tons used for the production of chlorine
 - 4,000,000 tons used for the production of soda ash
- 88 % is used as brine
- Only 4 % used for household purposes



Massive quantities of salt (NaCl) are used in the US every year, essentially providing a large market for the salts in the concentrate stream. In addition, most of the salt is used as brine, so it would not be necessary to recover the salts in concentrate to a dry product for them to be useful. It is possible that the concentrate could be useful in its present form, if a suitable industry could be located next to the water production facility.

Uses for inorganic feedstocks

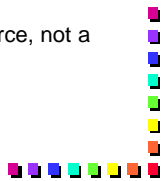
- NaCl – textile dyeing, aquaculture, soil stabilization, ice and snow removal
- Cl₂ – polymers, plastics, synthetic fibers
- NaOH – glass, rayon, synthetic fibers, plastics, polyester, soaps, detergents
- NaSO₄ – pulp and paper, dyes, ceramic glazes
- Na₂CO₃ – glass, pulp and paper, rayon
- Etc, etc...



Slide 14 identifies additional inorganic chemical feedstocks that may be developed from concentrate.

Technical challenges

- Osmotic pressure – must employ combination of membrane and evaporative processes
- Energy – evaporative processes are energy intensive
- Solubility limitations and scaling
- Selective separation of salts
- Modifications to the RO process
 - Paradigm shift – concentrate is a resource, not a waste stream



A variety of technical challenges must be overcome to recover the concentrate stream for beneficial uses. These challenges include osmotic pressure, energy costs, solubility limitations, scaling, identification of processes to recover the salts, and modifications to the RO process.

Research needs

- Identify market value of salts present in brackish groundwater
- Develop technologies to increase water recovery and economically concentrate salts
- Develop technologies to selectively separate salts
- Identify synergistic industries
 - Brine needed as feed stock
 - Waste heat production
 - Co-location of industrial and water facilities?



Research needs include an identification of the market value of the salts present in groundwater, development of technologies to increase water recovery and economically concentrate the salts, development of technologies to selectively separate the salts, and identify synergistic industries.