Boron Removal and Reverse Osmosis

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OUTLINE

- Boron concentrations and guidelines
- Why is boron hard to remove?
- What is the boron removal of a typical RO membrane?
  - Types of membranes
    - Seawater membrane
    - Brackish water membrane
- What is being done in other projects?
- Can we cost effectively reduce boron concentrations?

Boron Concentrations

- Seawater = 4.5 mg/L
- San Diego Wastewater = 0.5 mg/L
- Colorado River Water = 0.1 mg/L
- WHO 1998 guidelines= 0.5 mg/L
- Cal DHS Action Level = 1 mg/L
- USEPA “Maximum Lifetime Exposure” = 0.6 mg/L

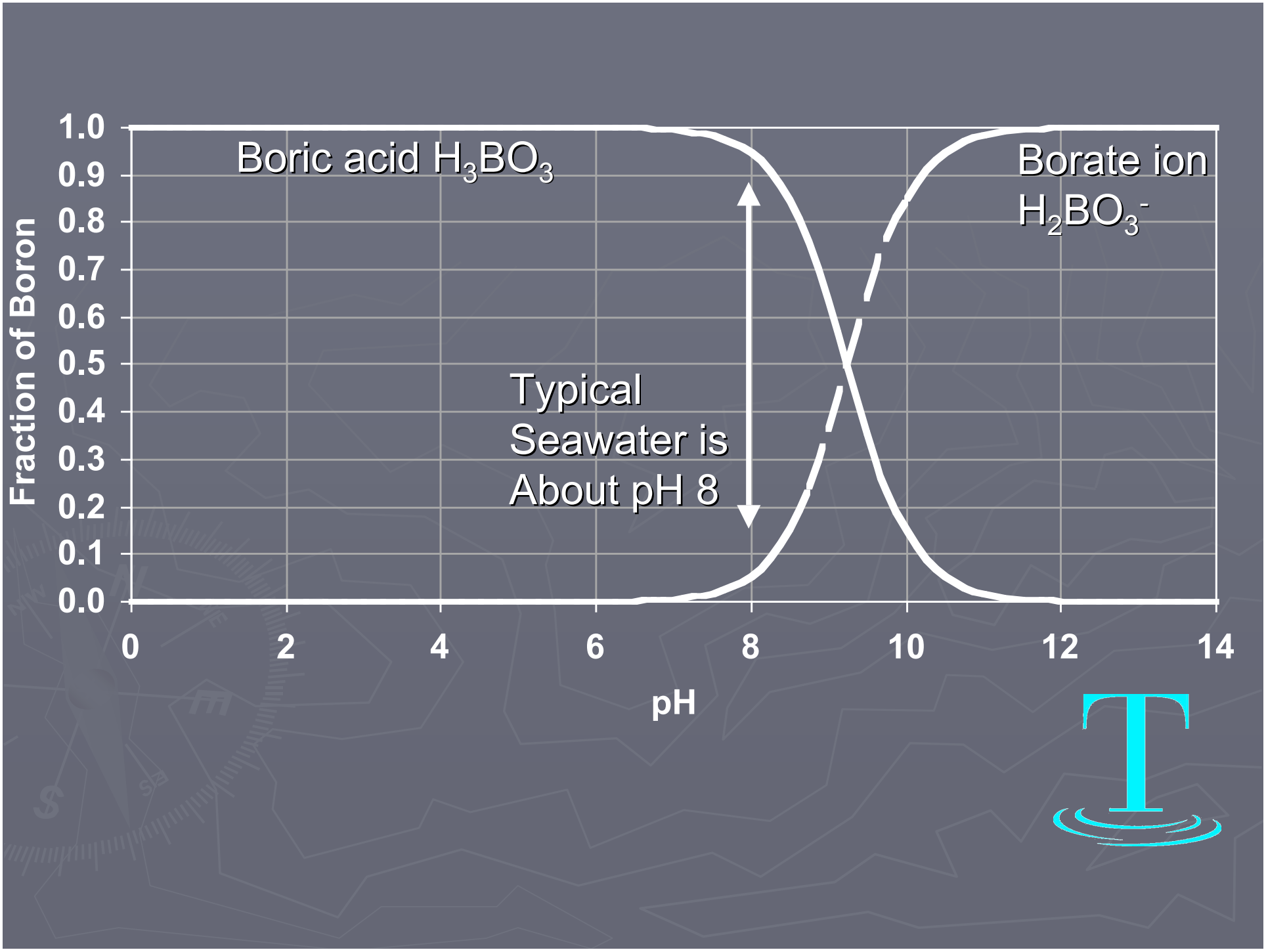
Why is Boron Hard to Remove?

- Unlike most of the elements in seawater, boron is not ionized (i.e. it has no charge)
- Boron takes two forms in drinking water (or seawater):

  Boric Acid: H_3BO_3

  Borate Ion: $H_3BO_2^-$
- RO is ***much*** better at removing charged ions. Hence the removal of borate ion is much better than the removal of boric acid.
- The dominant form (borate or boric acid) depends on the pH:

  $H_3BO_3 = H^+ + H_3BO_2^-$


Boric acid H_3BO_3
Borate ion $H_2BO_3^-$
Typical Seawater is About pH 8
Fraction of Boron
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
pH

Boron Removal by Seawater Reverse Osmosis

- Dow FILMTEC at pH 8:
  - SW30-380 = 88% (85-90%) 0.78 mg/L
  - SW30HR-380 = 90% (88-92%) 0.66 mg/L
- Toray at pH 8:
  - TM820-370 = 92% (91-93%) 0.53 mg/L
  - TM820A-370 = 95% (94-96%) 0.33 mg/L
- Hydranautics at pH 8:
  - SWC3 = 89% (NA) 0.72 mg/L
  - SWC4 = 92% (NA) 0.53 mg/L

Boron Removal by Brackish Reverse Osmosis

[assuming 0.5 mg/L 1st pass]

- Dow FILMTEC at pH 8:
  - BW30-400 = 65% (55-75%) 0.31 mg/L
  - BW30LE-440 = 55% (45-65%) 0.36 mg/L
- Hydranautics at pH 8:
  - CPA3 = 40% (NA) 0.41 mg/L
  - ESPA1 = 38% (37%-40%) 0.42 mg/L

Operating Seawater RO Plants

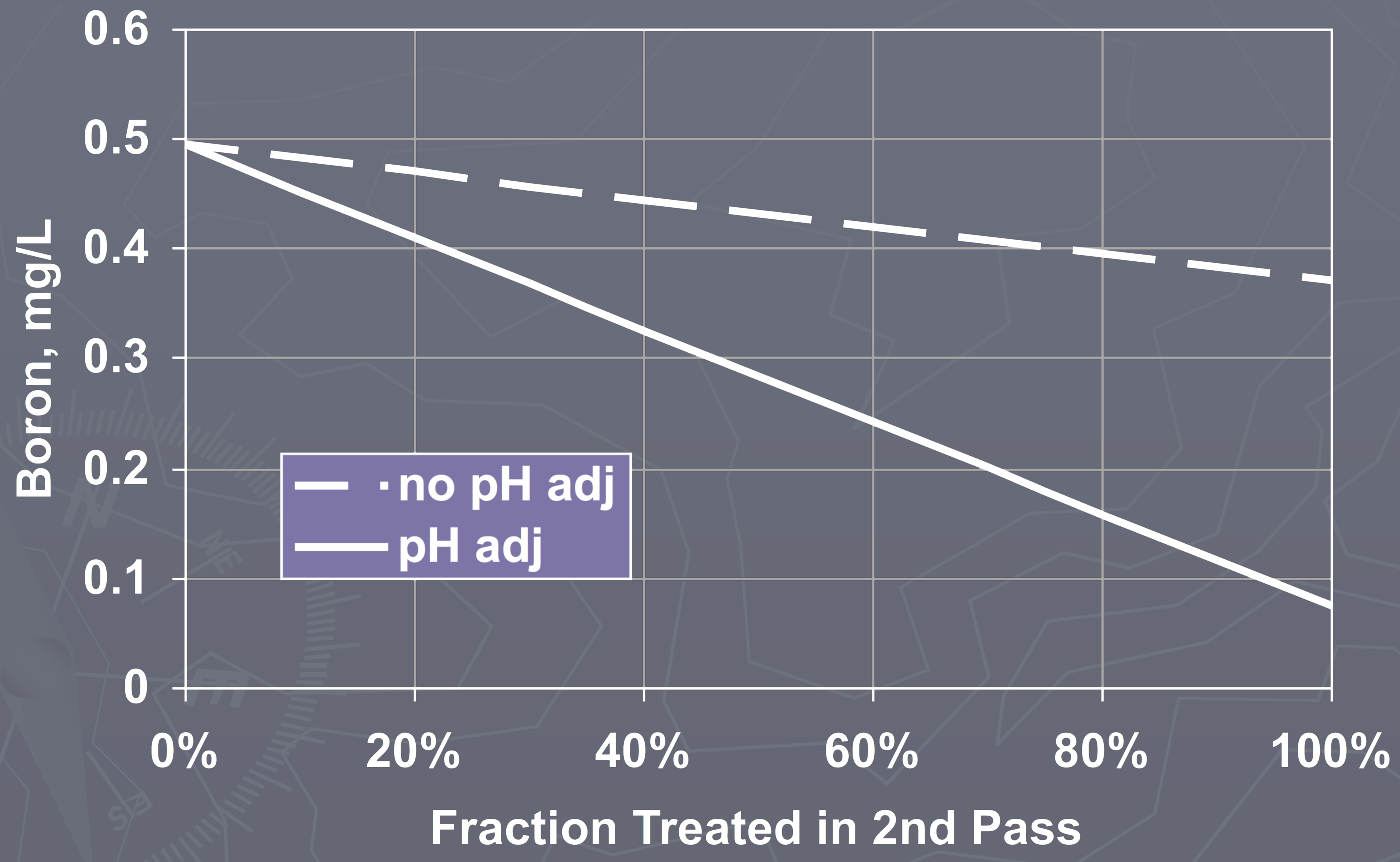
- Trinidad - 2 pass system
- Tampa - 2 pass system
- Larnaca, Cyprus (14 MGD)
  - Partial 2 pass system (25% flow from 1st pass)
  - SWC3 - claim ≤ 1 mg/L Boron after 2 years of operation

Can We Economically Meet a Low Boron Concentration

YES! By doing one or more of the following:

- Choose good SWRO Membranes
- Partial 2nd Pass
- Possible pH adjustment in the 2nd Pass

Effect of 2nd Pass with and without pH adjustment



Meeting a Low Boron Concentration

- The additional water cost for 2nd pass is estimated to be:
  - $20 - 30/acre-ft