Municipal Water Treatment: Recent Advances and Drivers for Change

Vernon L. Snoeyink, Professor Emeritus
Ana Martinez, PhD Student
University of Illinois
NWRI Clarke Prize Symposium
November 2013

What is a major advance?

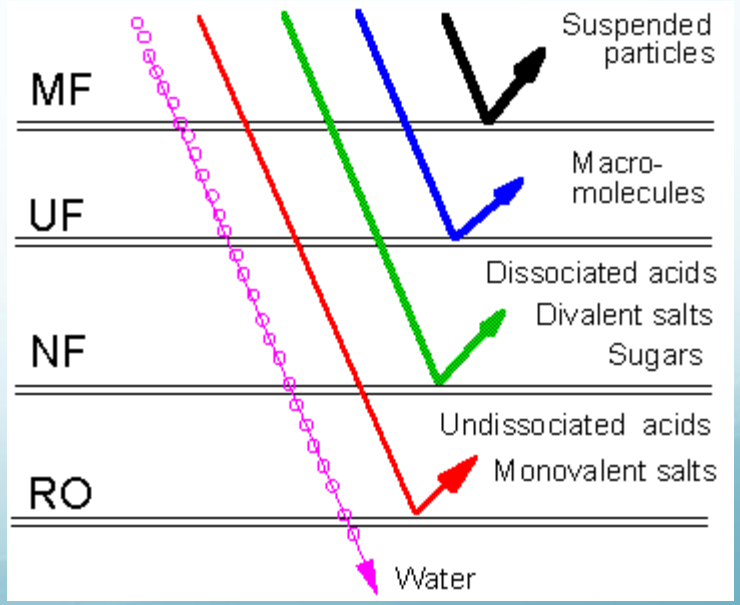
- Number of entities using it
- Beneficial results
- Incremental advances are necessary to make seminal research a major advance

Membranes and Membrane Processes are a Major Advance

Synthetic asymmetric membrane by Sourirajan and Loeb at UCLA in 1960 (S. Sourirajan et al. 1970)[1]

Subsequent advances:

- Membranes and module configurations
- Processes: MF, UF, NF, RO.
- Pre- and post-treatment
- Energy efficiency

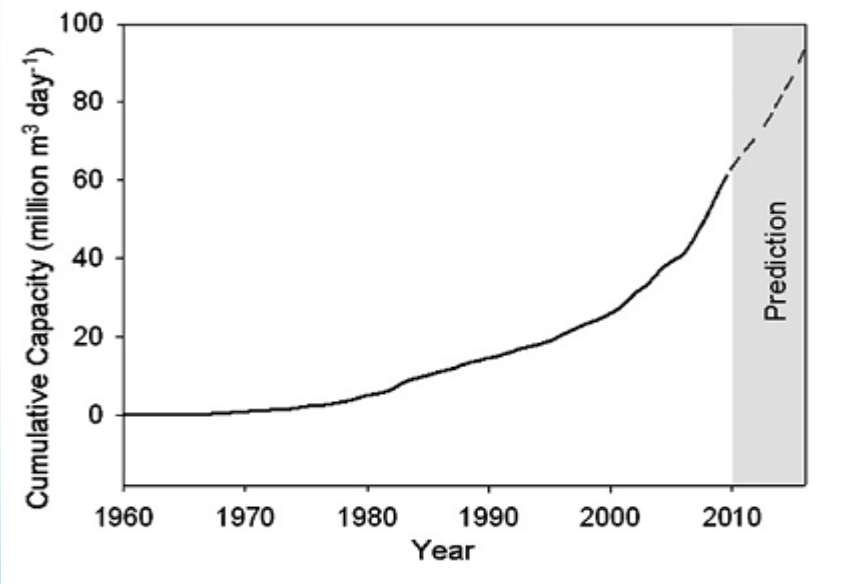


Membrane Processes

(K.P. Lee et al. 2011) [2]

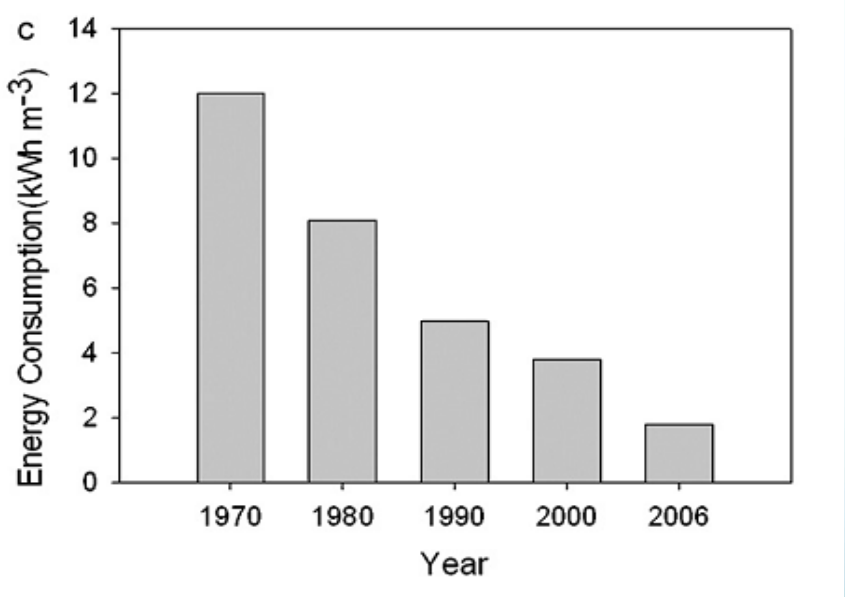
- RO Capacity vs. time

2010: 60 M m^3/d



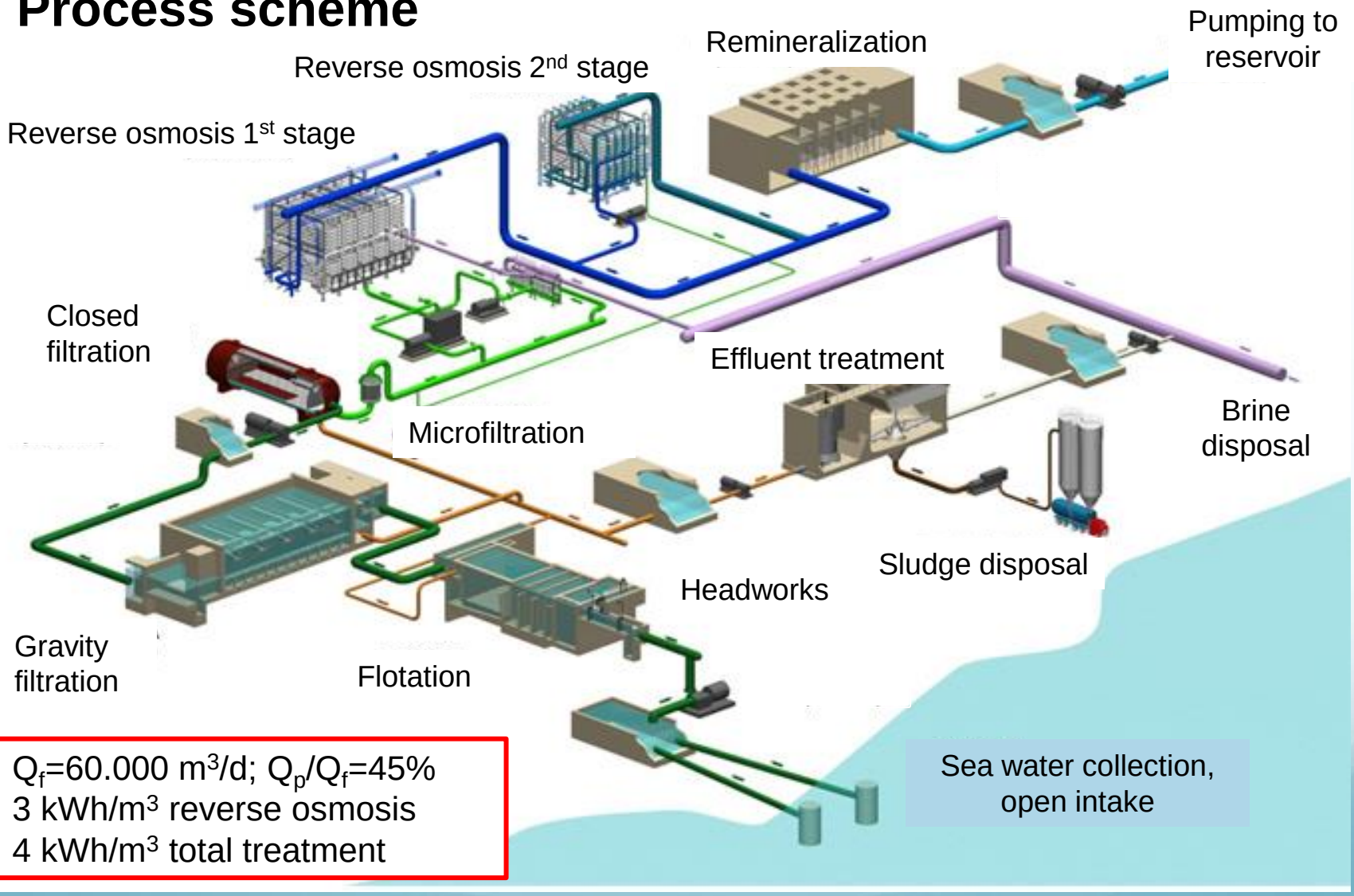
- RO energy required per unit volume vs. time

2 kWhr/m^3 (f(recovery, composition…))



Desalination Plant Barcelona,Spain 2009

Process scheme

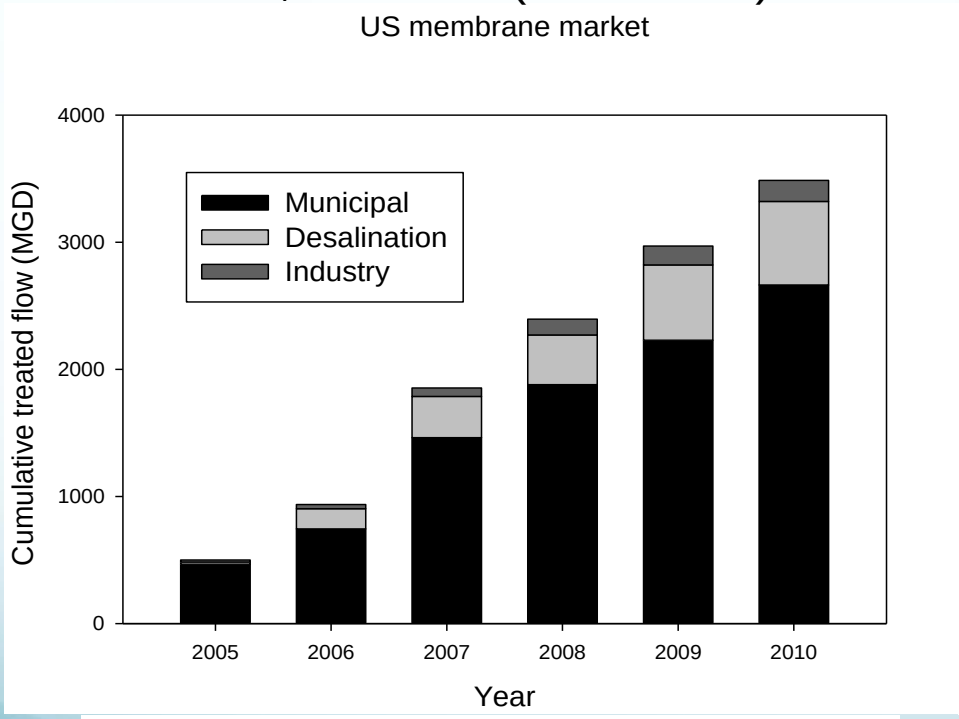


Q_f=60.000 m^3/d; Q_p/Q_f=45%
3 kWh/m^3 reverse osmosis
4 kWh/m^3 total treatment

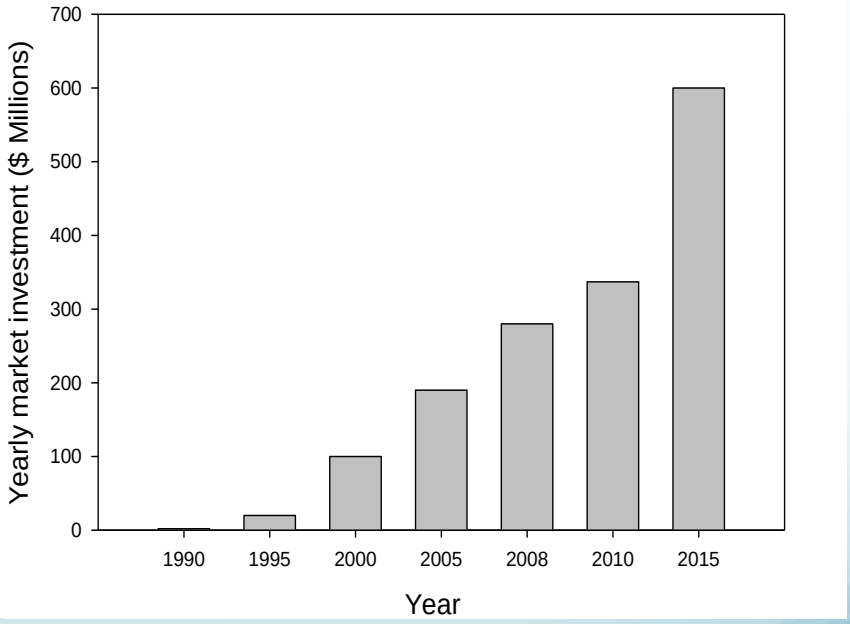
Membrane Processes

- Membrane filtration capacity vs. time[3]
- Membrane bioreactor market investment vs. time.[4]

2010: 3,700 MGD (cumulative)



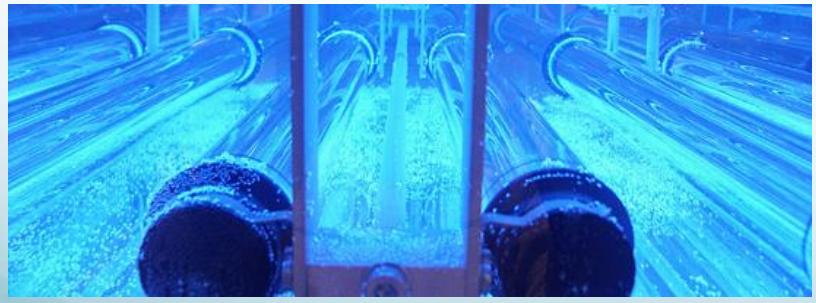
2015: $600 M yearly investment

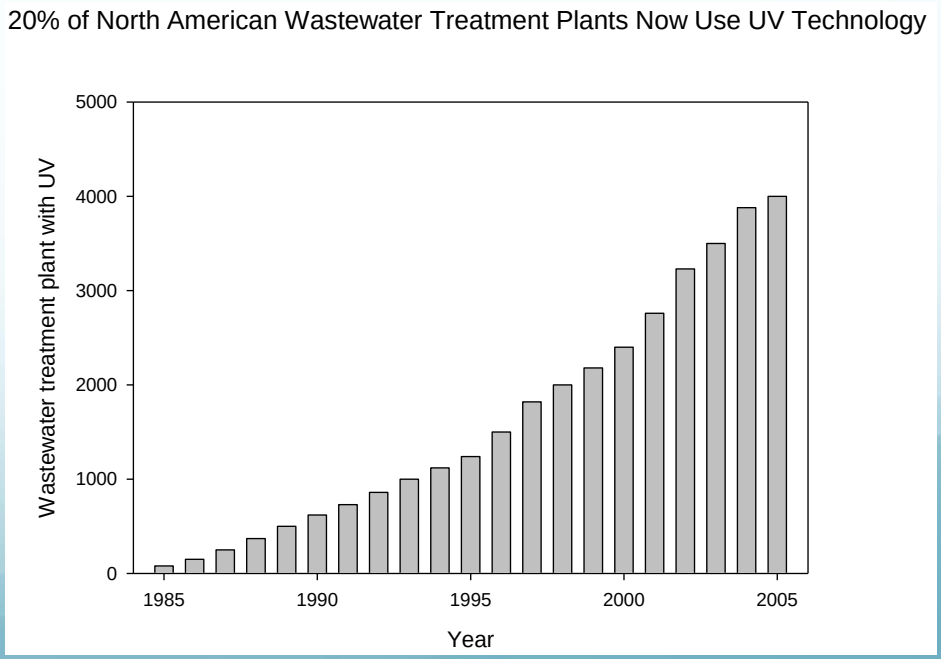


*Includes plants larger than 10,000 m^3/day or 2.6 MGD

Major Advance: UV Disinfection

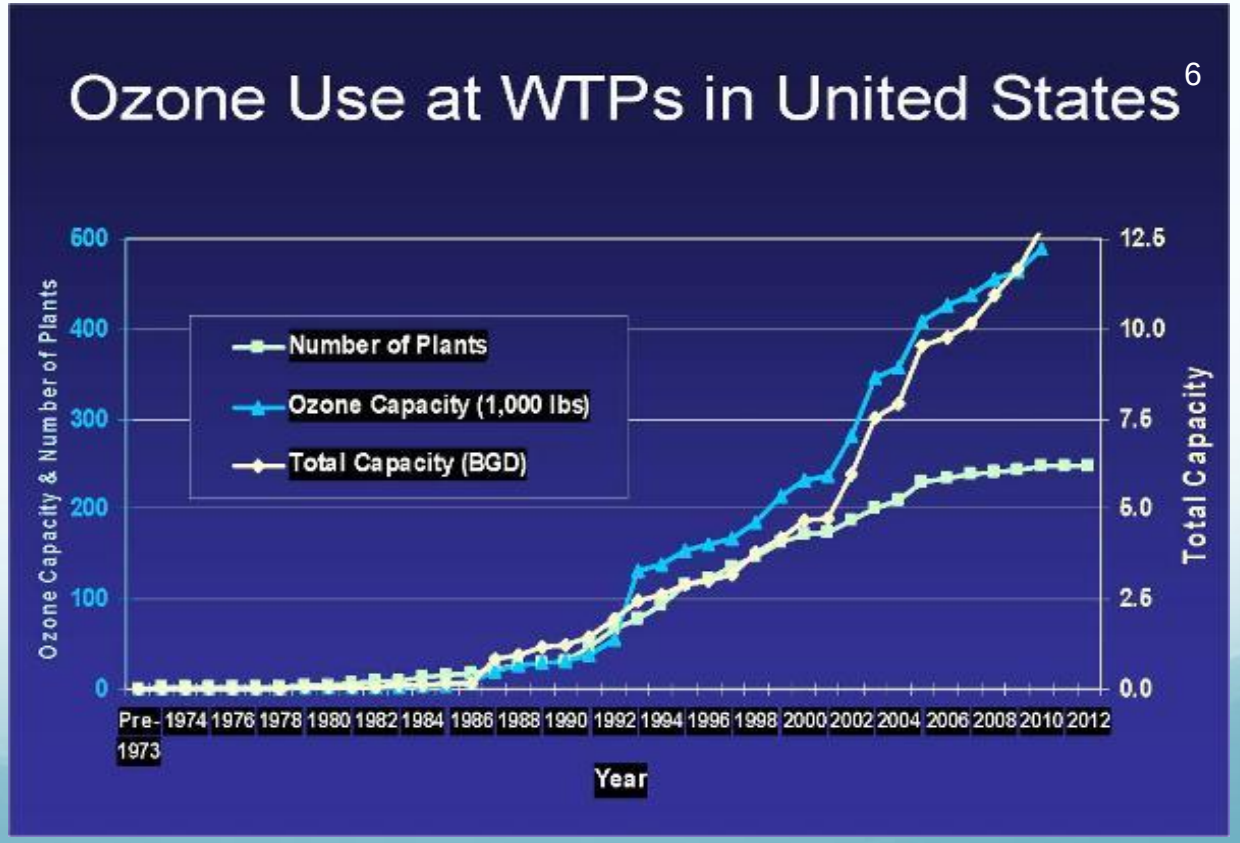
- Drivers: protozoan-cyst water-borne disease outbreaks and toxicity in secondary effluents
- UV capacity vs. time.[5]
- 20% (4000) of N. American wastewater plants use UV in 2008[5]





Major Advance: Ozonation

- Used for T&O and DBP control, disinfection, SOC oxidation, coagulant aid, color removal
- Ozone WTP use: 4000 worldwide; 250 USA



Drivers for Change

Regulations

Water availability

Energy

Distribution systems

Drivers: Regulations

- Disinfection byproducts (DBPs) and nitrite
  - THMs (80 ppb) and HAAs (60 ppb)
  - NO_2-N = 1 ppm
  - Measurable disinfectant at the tap
- NH_2Cl for secondary disinfection (Wahman, D. et al 2011)[7]
  - About 1/3 of our utilities now use NH_2Cl
  - Nitrification: $NH_2Cl \rightarrow NH_3 \rightarrow NO_2^-$ & NO_3^-
  - About 1/3 of utilities using NH_2Cl have nitrification problems: DO loss, chlorine loss, NO_2^- increase, increase in metal ion release
- NH_2Cl works well for many utilities but is it a major advance?

Drivers: Water Shortage

- Poorer quality supplies require better treatment
- Direct potable reuse
- Increasing amounts of treated wastewater and urban runoff are in our water supplies(NRC report[8]; Gerrity et al. 2013[9])

Water Shortage vs. Treatment

RO attractive as barrier, but inland concentrate disposal is a serious problem

- Zero liquid discharge (ZLD) is very expensive and complex
- Near-ZLD?
  - Treatment of RO influent and RO concentrate to achieve 95 to 98 % recovery
  - Exciting area for research

Zero Liquid Discharge

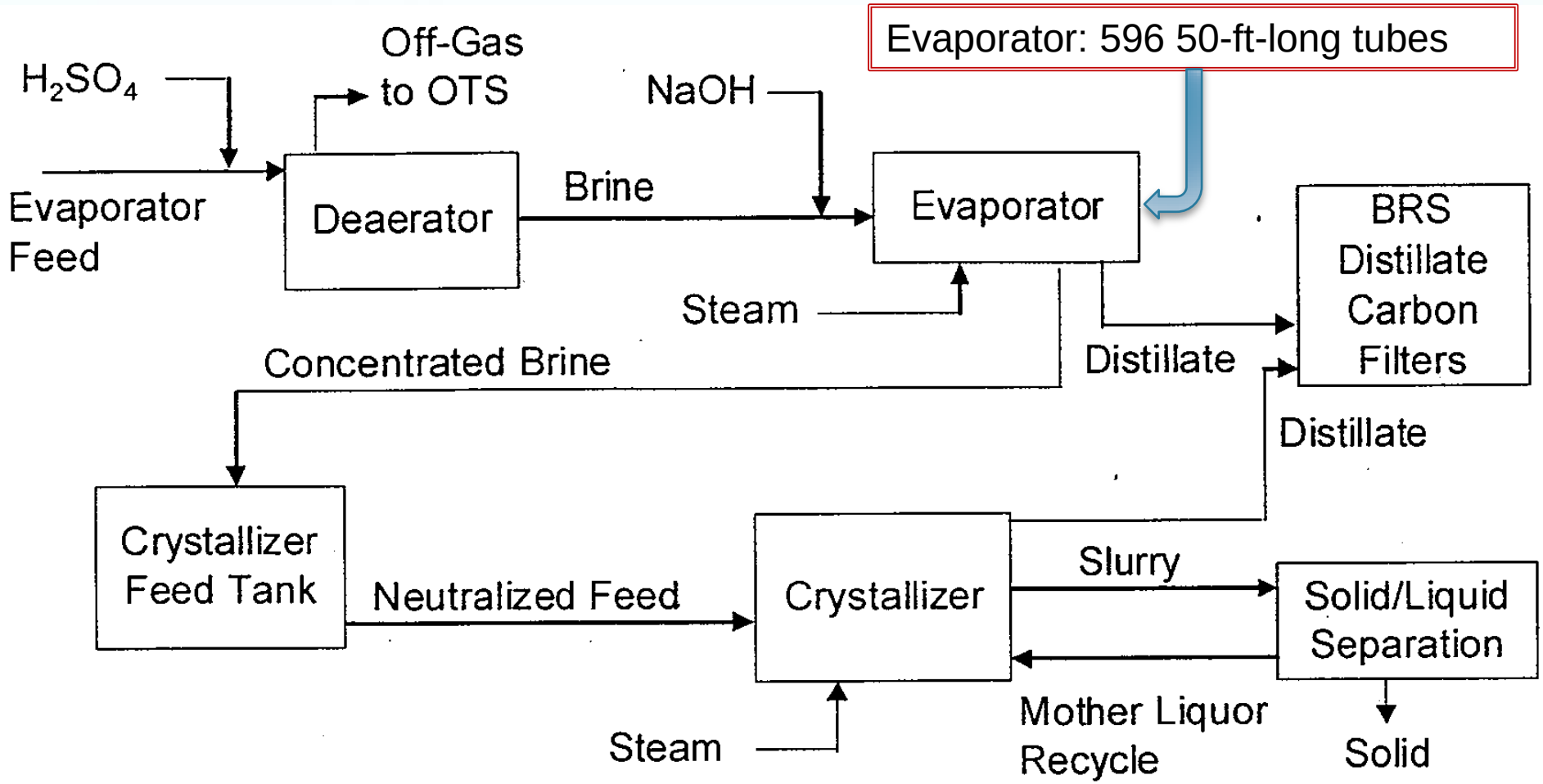
ZLD in water reclamation[10]:

Bioreactor → Evaporation → Crystallization → Dry Cake

Product water collected for reuse. Cake to landfill

0.14 MGD system now being constructed in Pueblo CO at a chemical demilitarization site

Brine Reduction System at Pueblo, CO



Near-ZLD:RO in Water Reclamation

Bioreactor effluent, primary RO and concentrate treatment:

- Lime softening, pellet softening, seeded precipitation
- Cation exchange
- Electrodialysis, Electrodialysis metathesis
- Ozone/BAC
- Capacitive deionization
- Secondary RO

Waste composition and desired water quality important

BUT, all sequences still involve large volumes of concentrate

Drivers: Concentrate Disposal

Water reclamation: do we need RO?

Use O_3/BAC (C. Lee et al. 2012)[11] and O_3/H_2O_2/BAC (Gerrity et al. 2011)[12] to treat filtered secondary effluent:

- Excellent trace organics removal
- Is the effluent of satisfactory quality?

Drivers: Energy

- RO for desalination: is it the best way to go?
- Siemens Patent, uses IX, ED and EDI (electrodeionization)
  - Proposed to reduce the energy to desalinate water by a factor of two[13]

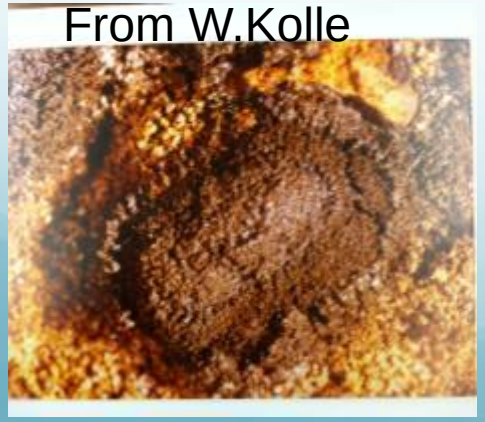
Drivers: Energy

- Recovery of energy from municipal wastewater
- Anaerobic instead of aerobic treatment of wastewater
  - McCarty: last year's presentation on anaerobic MBR/immersed membranes/fluidized GAC
  - Very important area for additional research

Drivers: Distribution Systems

Need to better understand

- The factors that cause water quality to deteriorate
- How to treat water for distribution
- The role of microbes in
  - Mn, Fe and Pb metal ion release from scales
  - Corrosion reactions



Final Thoughts

- Major advances have significantly changed the way that we treat water today
- Many drivers that will force us to do things differently in the future
- Exciting time to be in the field because of the research and development that is needed to meet the new challenges

References

1) *Reverse Osmosis*, by S. Sourirajan, Academic Press, 1970
2) K.P. Lee et al. *J. of Membrane Science 370* (2011) 1–22.
3) http://www.americanwaterintel.com/archive/2/11/analysis/firms-mull-membrane-market-shifts-wake-muni-bust.html
4) http://www.bccresearch.com/market-research/membrane-and-separation-technology/membrane-bioreactors-markets-mst047c.html
5) http://www.businessinsider.com/10-fascinating-trends-in-water-companies-poised-to-gain2011-5?op=1
6) http://www.spartanwatertreatment.com/timeline.html
7) D. Wahman et al., Investigations into Drinking Water Distribution System Nitrification: EPA Microelectrode Research. Presented at Chem., Biol. and Environ. Engr Seminar Series, Oregon State University, 2011
8) NRC *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*, National Research Council, National Academies Press 2012. (Available through http://www.nap.edu)
9) D. Gerrity, et al. *Aqua, 62*, Sept 2013
10) Review of Biotreatment, Water Recovery, and Brine Reduction Systems for the Pueblo Chemical Agent Destruction Pilot Plant, National Research Council, National Academies Press, 2013. (Available through http://www.nap.edu)
11) C. Lee et al., *Wat. Res*. *46*(4), 1005 (2012)
12) D. Gerrity et al. *Wat. Res. 45*, 2155 (2011)
13) Patent # WO2009123751 A2, Oct. 2009