Modern Techniques for Power Plant Makeup Water and Wastewater Treatment

Brad Buecker

Kiewit Power Engineers

Outline

- Makeup water treatment evolution
- Choices for makeup water polishing
- Increasing importance of wastewater treatment

Makeup Water Treatment Guidelines

- Per EPRI, below are established guidelines for makeup water system effluent.
  - Sodium, < 3 ppb
  - Silica, < 10 ppb
  - Chloride, < 3 ppb
  - Sulfate, < 3 ppb
  - TOC, < 300 ppb

The Old Days

- When I began my utility career in 1981, a common makeup treatment arrangement was,
  - Clarification/sand filtration $\rightarrow$ Cation exchange $\rightarrow$ Anion exchange $\rightarrow$ Mixed-bed ion exchange polishing
- This technology would do the job, but with much acid and caustic usage due to frequent regenerations.

A Transformation

- In the last three decades, water treatment schemes have greatly evolved. A very common scenario today is;
  - Primary filtration (often micro- or ultrafiltration) $\rightarrow$ Reverse osmosis (single-pass or two-pass) $\rightarrow$ Polishing either with exchangeable mixed-bed "bottles," or by electrodeionization (EDI)

Factors That Have Influenced This Transformation

- Modern filtration systems without clarifiers can often provide the necessary pre-treatment ahead of RO.
- RO can remove 99+ percent of the dissolved ions in the water.
- Polishing devices such as exchangeable mixed-bed bottles or EDI operate very well with RO-treated influent.

Micro- and Ultrafiltration

- Micro- and ultrafiltration, (MF and UF by acronym) mechanically remove fine particulates.
- MF filtering range: 0.05 to 5 microns.
- UF filtering range: 0.005 to 0.1 microns.
- While several designs are available, most if not all utilize hollow fiber membranes to filter particulates.

MF Types

- Several reputable companies manufacture MF systems.
- In one design, the hollow fibers hang within the water to be purified, and a vacuum pulls water through the membranes.
- In the other major design, pressurized water is pumped through vessels containing the fibers, where the water is forced through the membranes.

Microfilter pressure vessel skid. Photo by Brad Buecker.

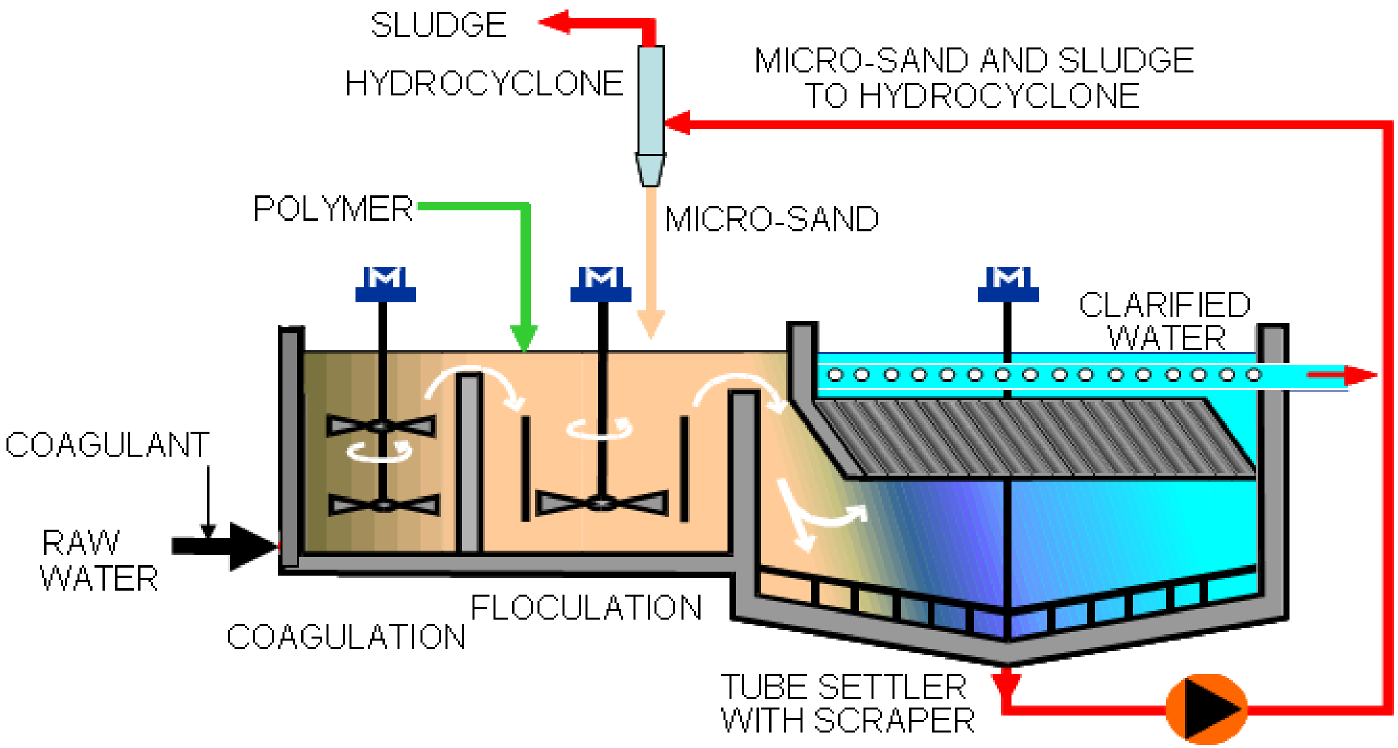
Hollow Fibers

Hollow fibers in a cutaway view. Photo courtesy of the Pall Corporation.

A Note About Clarifiers

- Clarifiers still have a place in many applications, particularly if the raw water exhibits the following characteristics.
  - High hardness (calcium and magnesium)
    - Lime and soda ash softening
  - Intermittent or continuous high suspended solids content
    - Excursions that could overwhelm MF or UF units.
  - More plants are being required to use gray water for makeup.

A Modern Clarifier Design



Schematic of an Actiflo® clarifier.
Illustration courtesy of Veolia.

Primary Dissolved Solids Removal Reverse Osmosis

- Clarifiers/filters, microfilters, and ultrafilters remove suspended solids, but dissolved solids remain.

- Prior to commercial development of RO units, ion exchange resins were exclusively utilized to remove the dissolved ions necessary to produce high purity water.

- RO is, of course, a membrane process. It is quite reliable if the RO influent has been properly pre-treated, particularly to remove suspended solids.

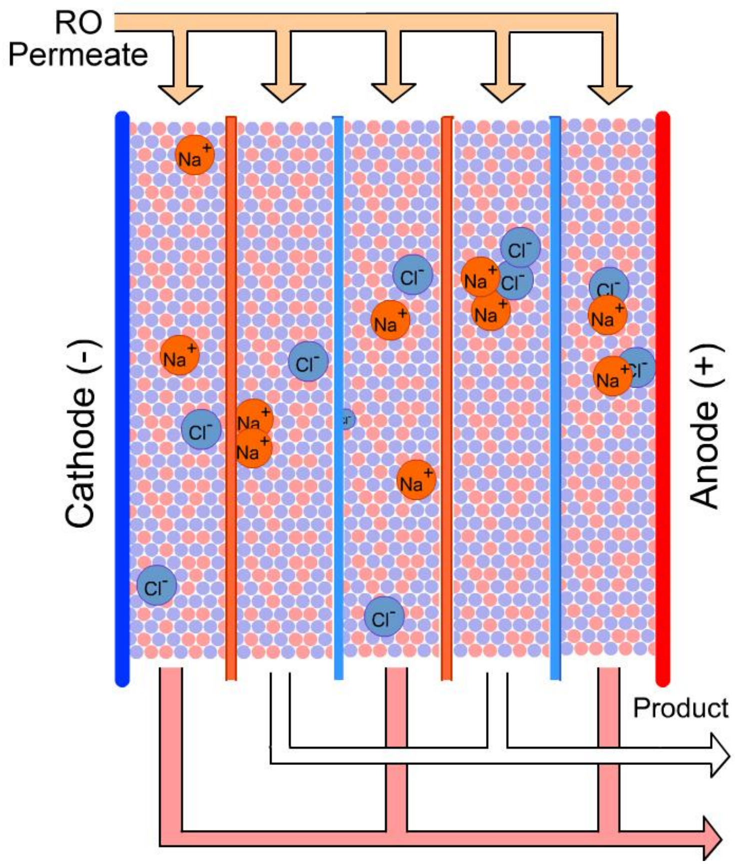
Two-Pass RO

- A quite common application nowadays is two-pass RO, where the permeate of the first pass is treated in a second RO pass.
- The water from the second pass is pure enough to be polished by mixed-bed ion exchange or EDI.
  - The second pass reject is recycled to the first pass inlet.

Polishing Choices

- Two methods currently predominate for polishing.
  - Exchangeable mixed-bed units, commonly termed "bottles" that a vendor replaces on an as-needed basis.
    - No capital cost other than piping from the RO to the MB bottle station
  - Electrodeionization
    - EDI is a permanent system that utilizes ion exchange, membranes, and electrolysis to purify water.

The EDI Process

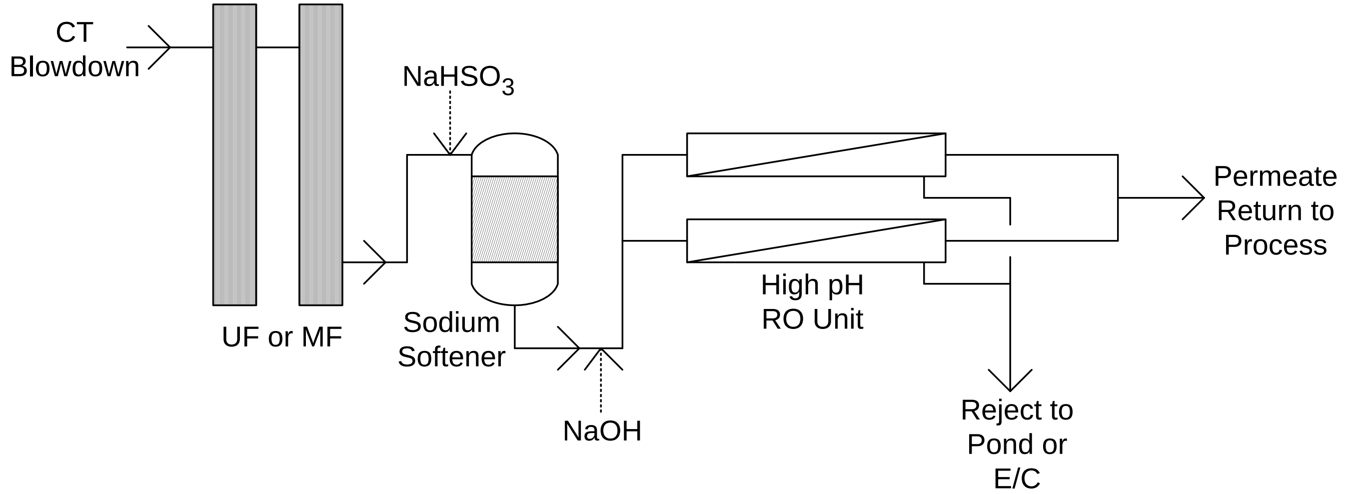


EDI process. Illustration courtesy of Siemens Water Technologies

A Look at Wastewater Treatment

- Many plants are facing restrictions on wastewater discharge quantity (and often quality).
  - Flow rate may be particularly substantial if the plant has a cooling tower.
- Many of the techniques outlined in previous slides are being applied to wastewater treatment. Emerging technologies include HERO® (High Efficiency Reverse Osmosis), licensed by Aquatech and GE, and OPUS®, licensed by Veolia.

Core Design of RO-Based WWT Systems



Core Design of RO-Based WWT Systems

- UF or MF for particulate removal
- Sodium bisulfite ($NaHSO_3$) feed to remove oxidizing biocides
- Sodium softening to remove calcium and magnesium hardness
- Caustic injection to keep silica in a soluble form
- RO to recover ~ 90 percent of the water

Concerns

- The process is not foolproof. Recent issues I have encountered include;
  - Some standard cooling water chemicals may foul the UF membranes.
    - The membrane manufacturer and type can greatly influence fouling.
    - Coagulants may not be effective at converting the chemicals into filterable flocs.
  - Low quality backwash water can cause scaling of UF membranes.
  - Clarification of the influent stream may be required.

Concerns

- Even with 90 percent water recovery, a liquid stream still remains. Possible disposal solutions include;
  - Evaporation ponds
  - Deep-well injection
  - Thermal evaporation/crystallization
  - Truck the liquid off-site to a waste disposal company.