scwd^2 Desalination Program
Informational Meeting

Summary of Pilot Plant Results and Preliminary Recommendations

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September 24, 2009

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Pilot Plant Overview

- Pilot plant was located at UCSC Long Marine Laboratory.
- Testing occurred from March 2008 through April 2009.
- Evaluated alternative treatment systems to meet regulatory drinking water standards.
- Determined optimal design and operating parameters – reduce cost and energy requirements.

Pilot Plant Building

Treated Water Quality Goals

- Meet all Federal & State drinking water regulations.
- Water should taste the same or better as City's and District's current supplies.

Three Principal Treatment Steps

- **Pretreatment** – remove particles that are larger than 0.01 micron (1/100,000 inch) that would otherwise foul the reverse osmosis (RO) membranes.
- **RO membranes** – remove 99%+ of the salinity and 90%+ of the dissolved organics; *approximately 0.5 gallon of desalinated water and 0.5 gallon of concentrate (brine) is produced for every one gallon treated.*
- **Post treatment** – adjust chemical properties of water to meet taste and disinfection goals.

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Pretreatment Evaluation

Slow Sand Filters

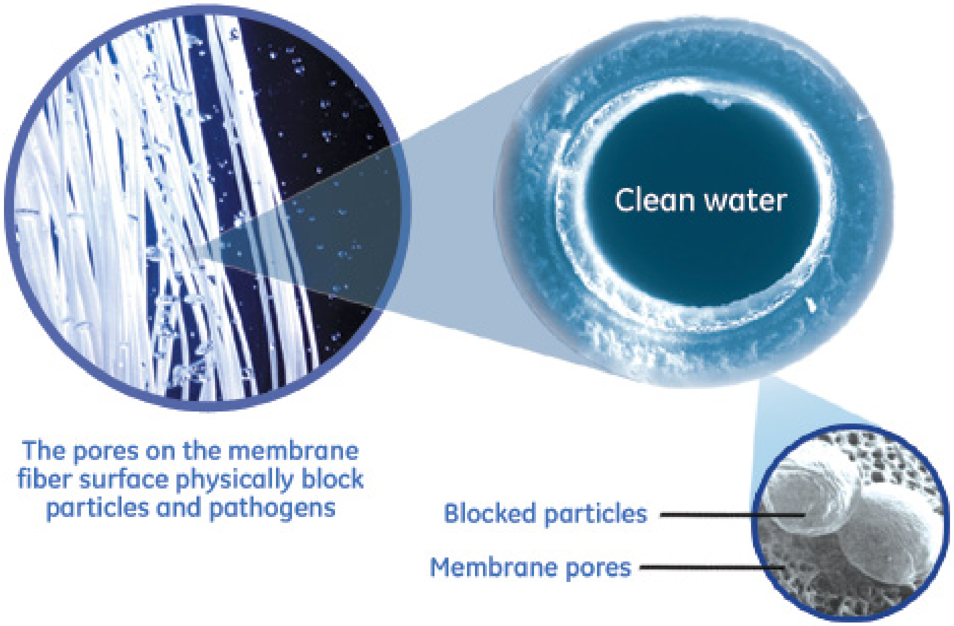
- Simple.
- Effective.
- Low energy.
- No chemicals.
- Large land requirement.

Pressure Granular Media Filters

- More energy.
- Require chemicals.
- More difficult to operate
- Similar to filters at the City's surface water treatment plant.
- Require less land.

How Ultrafiltration Works

- Thousands of hollow fibers (about the diameter of human hair) are bundled together.
- Pressurized water flows from the outside to the interior of each fiber (or from the inside to the outside.
- All particles larger than 0.01 micron (1/100,000 inch) are removed.



Submerged Ultrafiltration (UF) Unit

- Most energy intensive.
- Sometimes require chemicals.
- Easy to operate.
- More equipment to maintain.
- Require least amount of land.

Pressure Ultrafiltration (UF) Unit

- Similar characteristics to submerged UF.

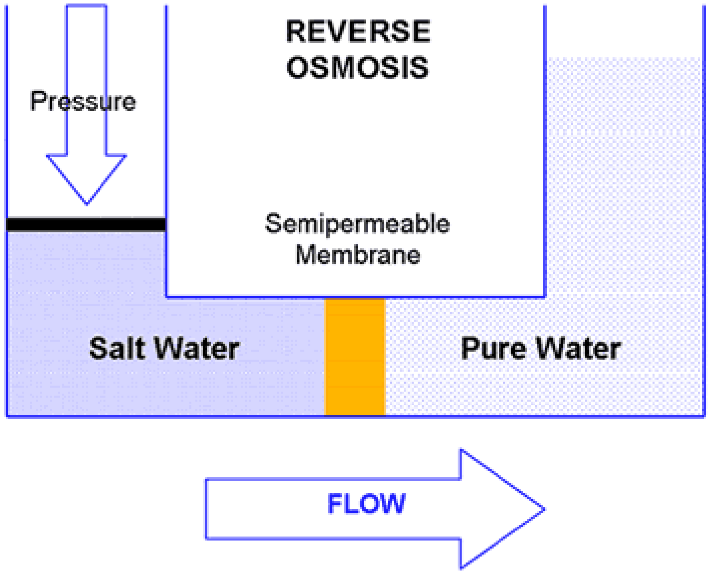
Pretreatment Testing Results

- Each of the four pretreatment systems:
  - met the water quality goals.
  - prevented fouling of the RO membranes.

Reverse Osmosis (RO) Membrane Evaluation

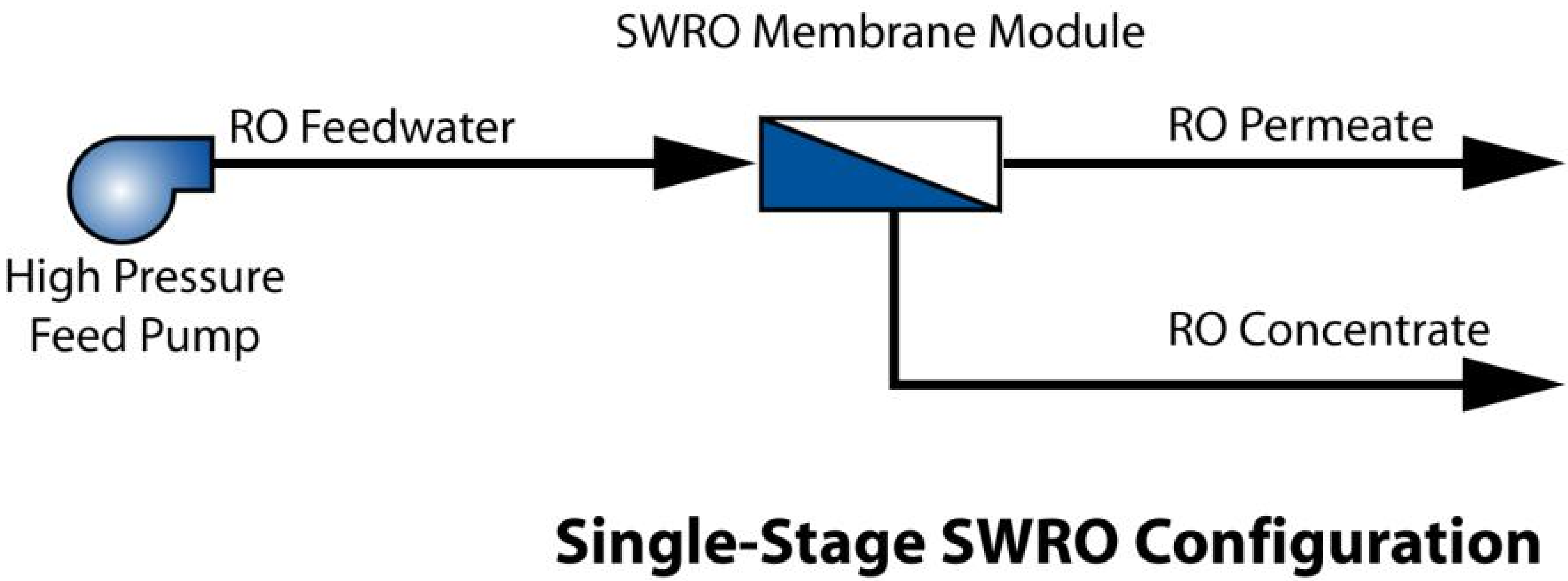
How Reverse Osmosis Works

- Apply salt water under pressure to a semi-permeable membrane.
- These membranes have pores of approximately 0.0005 microns in size (0.00000002 inches).
- Water permeates through a membrane that excludes suspended solids, dissolved salts and larger organic molecules.



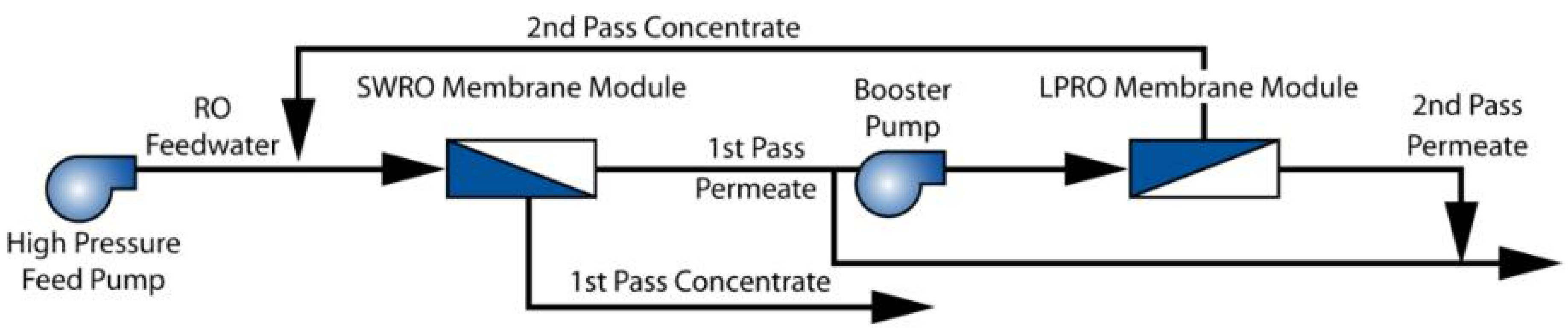
Reverse Osmosis Unit
(pilot plant had 4 RO systems)

Single Stage Seawater (SW) RO Membrane Configuration



- Lowest cost to construct
- Fewest membranes

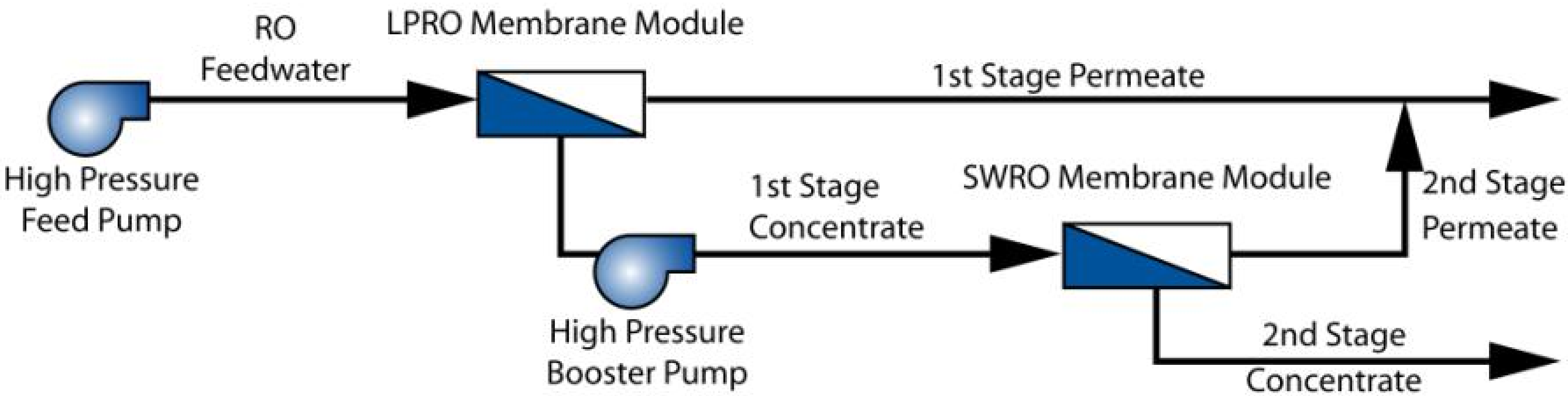
Single Stage SWRO with Partial 2nd Pass Configuration



Single-Stage SWRO Configuration with a Partial Second Pass LPRO

- More membranes
- More energy
- Better water quality

Two-stage Low Pressure RO & SWRO Membrane Configuration



Two-Stage LPRO/SWRO Configuration

- More membranes
- Potential for using less energy

RO Evaluation - Conclusions

- **Two-pass configuration** provides marginally lower salinity during warm water conditions after several years of operation.
- **Two stage configuration** does not meet water quality goals and does not use less energy.
- **Single stage configuration -** achieves water quality goals with the lowest energy use.

Post-treatment test results

- Post treatment tests were successful in determining which chemicals to add to the desalinated water to meet water quality goals, produce a taste consistent with existing water, and is compatible with the existing pipe delivery system.

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Preliminary Recommendations

Treatment Process

1. Add chemicals to aid treatment process.
2. Filter with either granular media filters or UF.
3. Desalinate with single stage SWRO membranes.
4. Add chemicals for flavor consistency and disinfection.
5. Discharge SWRO concentrate to the WWTF outfall (a separate study is evaluating the feasibility of this concept).
6. Recycle filter backwash water through the treatment plant.
7. Dewater residual solids on-site and dispose in landfill or discharge to the WWTF for handling.

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Remaining Work for Pilot Plant Project

- Finalize selection of pretreatment system.
- Determine best method for handling residual solids.
- Finalize cost and energy evaluations.
- Publish the project report.

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Questions?

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Extra Charts

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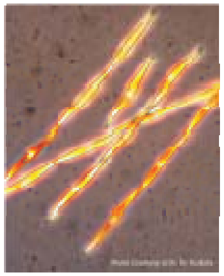
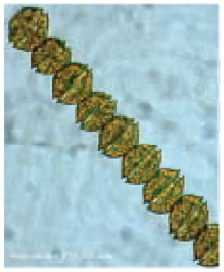
Algal Toxins

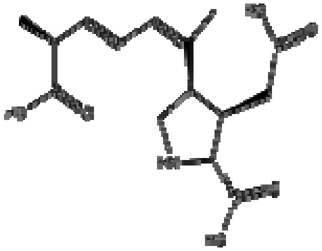
- Two algal toxins in Monterey Bay are:
  - Domoic acid produced by Pseudo-Nitzschia.
  - Saxitoxin produced by Alexandrium.
- Toxins not typically found in Monterey Bay at high enough concentrations for human toxicity
- Monitoring for algal toxins performed during pilot study but none detected.
- Therefore, spiking test performed with Kainic acid at concentration of 40 ppb (1000x naturally occurring concentrations)



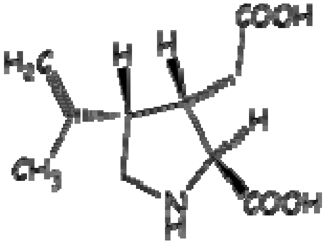
Pseudo - Nitzschia
(Domoic Acid Producer)
Length: 20-40 microns
Width: 18-32 microns



Alexandrium Cantella
(Saxitoxin Producer)
Length: 40-175 microns
Width: 4-8 microns



Domoic Acid (DA)
(Amnesic Shellfish)
Molecular Weight: 311



Kainic Acid (KA)
(Model Compound of DA
Used for Spiking Test)
Molecular Weight: 231

Kainic Acid Spike Results

Sample Description	*Feed Concentration (µg/L)*	*Outlet Concentration (µg/L)*	*Percent Removal*
RO Train 2 (99.5% SR)	39.9	Not detected[2] (<0.017)	>99.9%
RO Train 4 (99.2% SR)	43.2	0.074	99.8%
Slow sand filter (variation in dose due to limited mixing)	20-36.6	2.23	89-94%
Zenon UF w/o coagulation & clarification	22.1	20.1	9%
Clarification step	22.9	17.6	23%
Norit UF with coagulation and clarification	21.1	16.7	28%
Granular media filter with coagulation and clarification	21.1	17.5	24%

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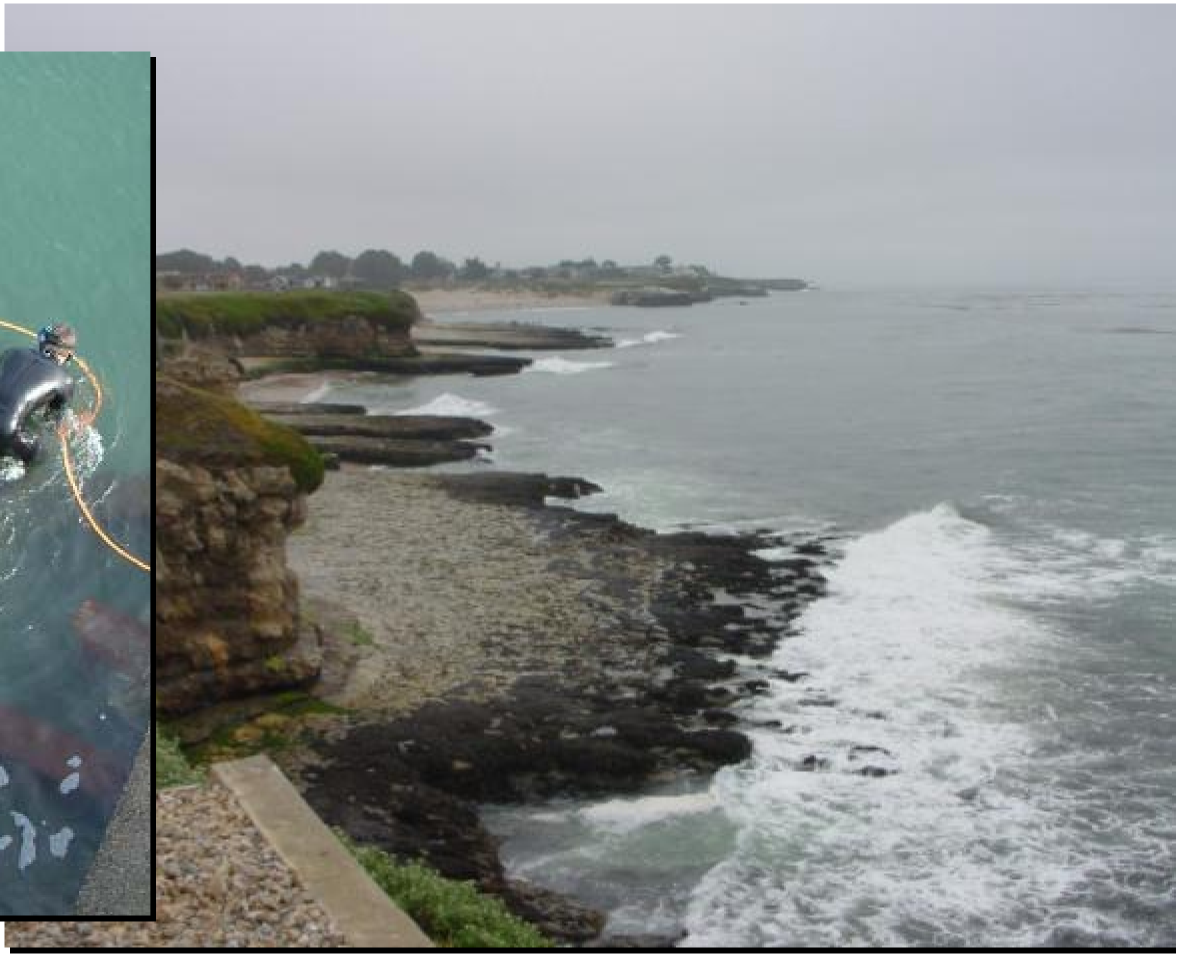
Summary on Removal of Algal Toxins

- Domoic acid detected at 2 ppb in source water at West Basin & Carlsbad pilot plants, but not detected in permeate.
- Not certain if/what the regulatory standard will be in drinking water.
- Pilot plant results similar to other pilot plant and full-scale plant results world-wide.
- RO is the preferred technology for removing algal toxins.

Existing Open Ocean Intake at Long Marine Lab



Nine Major Project Investigations

- Compare pretreatment systems.
- Compare RO systems
- Remove boron.
- Remove algal toxins and emerging contaminants.
- Evaluate on-line methods for monitoring RO membrane integrity.
- Pretreatment without chemicals or disinfectants.
- Limit disinfection by-products.
- Limit iron, lead and copper release in the distribution system.
- Evaluate the toxicity of the RO concentrate and WWTF effluent blend.

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Source Water Quality

- Salinity: 35,000 to 36,000 mg/L
- Temperature: 11 to 16 degrees C
- pH: 7.9 to 8.0
- Three distinct periods of water quality:
  - normal (low turbidity and low concentrations of algae)
  - storm events (high turbidity)
  - red-tide events (high concentrations of algae).

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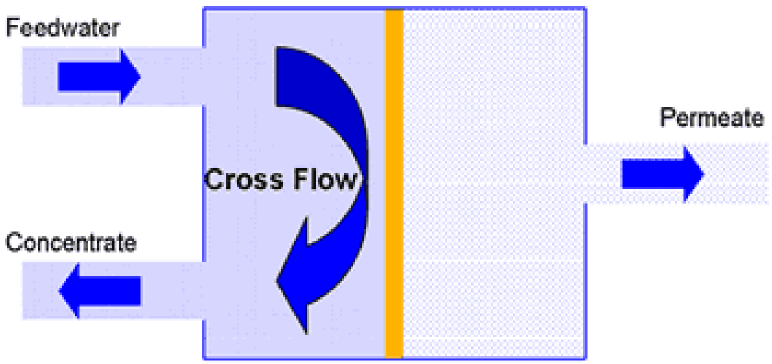
Flocculation and Sedimentation Basins
(could be used before granular media filters and UF)

Pretreatment Conclusions

- Slow sand filters, granular media filters and ultrafiltration (UF) can provide successful pretreatment for seawater RO desalination.
- Slow sand filters are simple and effective, but require a larger footprint.
- Granular media filters require more careful optimization than UF or slow sand filters.
- A treatment step to remove algal cells upstream of granular media filters or UF will further reduce biological fouling of RO membranes.

Commercial Reverse Osmosis Membranes

- Commercial membranes use a **cross flow mechanism** where the surface of the semi-permeable membrane is continually flushed.
- The inlet is known as the **feedwater** and the outlets are the **permeate** (pure water) and the **concentrate** (reject water).



Inside View of Reverse Osmosis Membrane

- Approximately 50% of source seawater becomes potable product water

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Preliminary Findings on Plant Cost and Land Requirements

- **Capital cost** - $55 to $60 million in today's dollars. This includes land, engineering and construction costs.
- **Annual operation & maintenance cost** - $2.1 to $2.4 million. This includes labor, chemicals, power, and solids disposal.
- **Plant land requirements** – 2.5 to 3.5 acres. This assumes mechanical dewatering of solids.

Energy Requirement of Alternatives RO Configurations*

- **Single stage SWRO configuration** – 9.7 kW-hours per 1000 gallons of permeate.
- **Single stage SWRO with partial 2nd pass** – 10.5 kW-hours per 1000 gallons of permeate.
- **Two stage LPRO and SWRO configuration** – 10.4 kW-hours per 1000 gallons of permeate

* Energy requirement after energy recovery step

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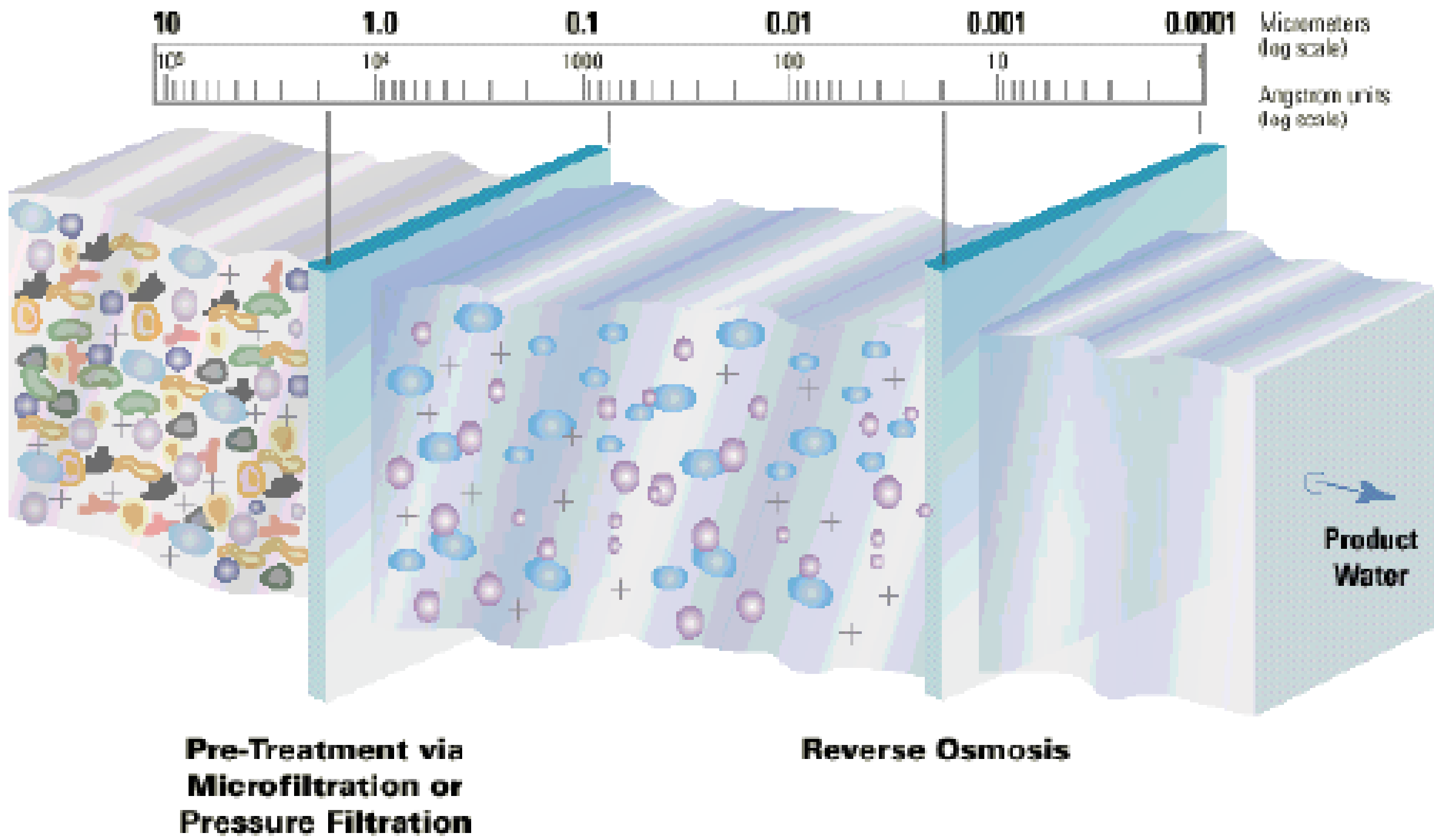
What is removed by treatment?



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