Orange County Water District

Multiple Barriers for Water Quality Protection

June 5, 2002

Briefing Summary

- Reliability of GWR System process train:
  - Source Control Program
  - OCSD Treatment Facilities
  - Microfiltration (MF)
  - Reverse Osmosis (RO)
  - Advanced Oxidation Process (AOP) using ultraviolet (UV) light and hydrogen peroxide (H_2O_2)

Briefing Summary *(cont.)*

- RO expertise of OCWD staff and consultants
- RO thin-film composite (TFC) membrane
  - Overall advantages
  - Removal of NDMA & 1,4-Dioxane
  - Removal of pharmaceuticals & endocrine disruptors
- RO removal mechanisms
- Computer modeling prediction of RO performance

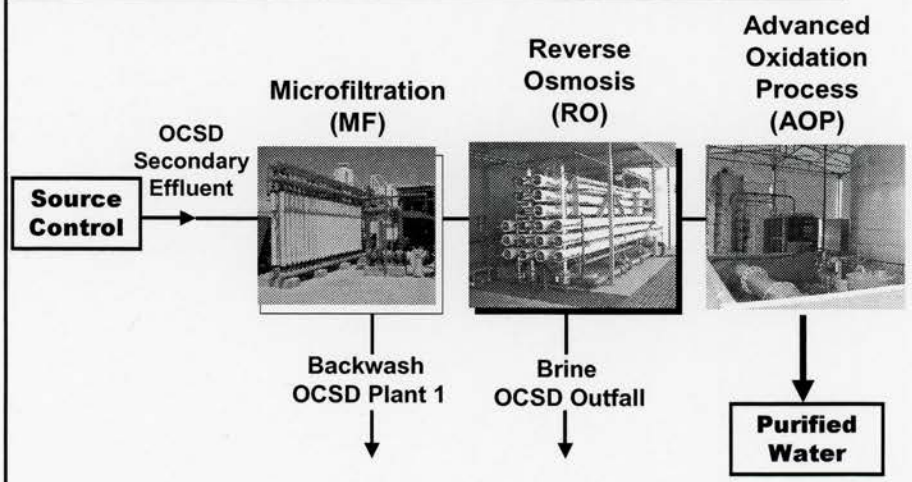
RO Expertise of OCWD GWR System Team

- Bill Everest
  - 20 years RO experience
  - MWD Groundwater RO Program
  - Preliminary Design – WF-21 expansion
- Mehul Patel & Shivaji Deshmukh
  - GWR System development experience
  - Pilot testing program
  - Industry experts
- Bill Dunivin & Staff
  - Over 20 years of experience in operating WF21, Arlington, Tustin, Chino & OCWD R&D

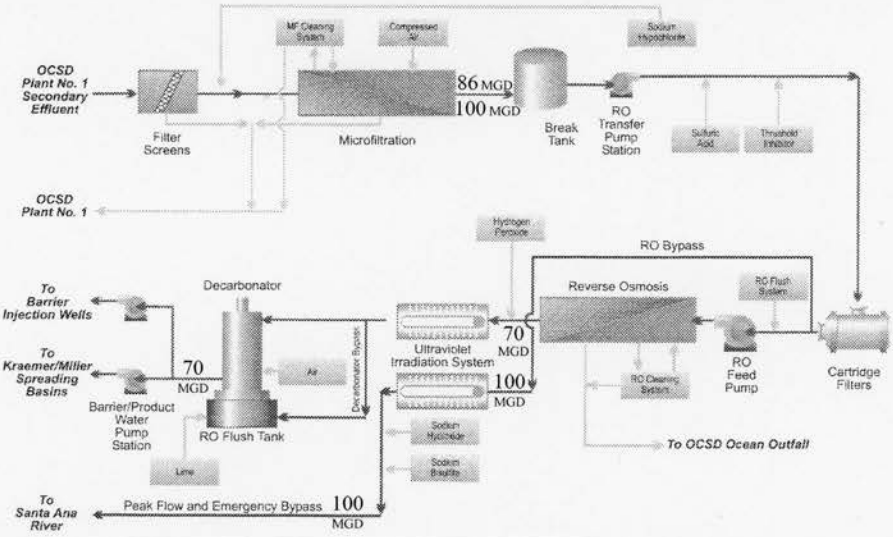
RO Expertise of OCWD GWR System Team

- OCWD Water Resources & Technology Group
  - Mike Wehner, Harry Ridgway, Don Phipps & others
- Separation Processes, Inc.
  - Designed majority of RO projects in California
  - GWR System development experience
  - Dick Sudak: President
  - Kevin Alexander: Project Manager

GWR System Advanced Water Treatment Flow Diagram



GWR System Phase I Dry & Wet Weather Flows



OCSD Treatment Facilities

Prior to delivery of treated wastewater OCSD:

- **Provides secondary treatment**
- **Conducts extensive effluent monitoring**
- **Monitors pollutants of concern**
- **Reduces pollutants by 40% to 80% by secondary treatment**

OCSD Source Control Program

- Regulates over 1300 industrial and commercial facility discharges
- Annually collects 4,500 wastewater samples and performs 22,000 analyses
- Enforces wastewater discharge ordinance to control pollutants of concern (e.g., heavy metals, NDMA, 1,4-Dioxane)
- OCSD influent metals reduced 88% in the 90's
- Received four EPA National Pretreatment Excellence awards

OCSD Source Control Enhancements

- NDMA and 1,4-Dioxane showed us that source control needed to do more
- OCSD is committed to "reinventing source control"
- Source control will now include all compounds of concern in drinking water
- Expanded monitoring to detect more compounds coupled with better communications with industry will help prevent future problems for GWRS

Mechanics of the RO Process

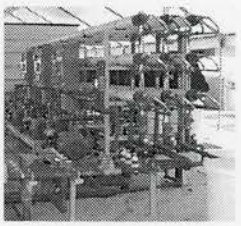
- **Solute Transport Mechanism**
  - **Solution-diffusion is most widely accepted**
  - **Demonstrated with predictive modeling and testing**
  - **Solution-diffusion used by membrane manufacturers considered for GWR System**

Solution-Diffusion Mechanism for Salt

- **Each constituent in a pressurized solution dissolves in the membrane.**
- **Flow of water and salt is uncoupled and water flows through membrane at a more rapid rate than the salt**

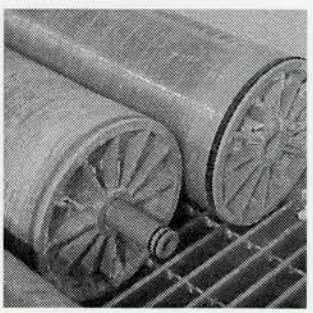
RO Mechanics with Organics

- **Rejection of Organics is More Complex**
  - **Size Dependent (Molecular Weight and Shape)**
  - **Charge Dependent-Positive, Negative or Neutral**
  - **RO Membrane Properties**



RO Process Using Cellulose Acetate Membrane

- **Membrane Used in WF-21 for 25 years**
- **Used with Lime Pretreatment**
- **10% Rejection of NDMA (West Basin and OCWD)**
- **20% Rejection of 1,4 Dioxane (OCWD)**
- **96% Rejection of salt**



RO Process Using Thin-Film Composite Membrane

- **Demonstration Tested at WF-21**
- **Lower pressure; better rejection**
- **50% Rejection of NDMA (West Basin and OCWD)**
- **90% Rejection of 1,4 Dioxane (OCWD)**
- **98% Rejection of salt**

TFC RO Removal of Pharmaceuticals

	GWR System Concentration (ng/L)	
Constituent	**Influent**	**Product**
Ibuprofen	2300	ND
Naproxen	1800	ND
Gemfibrozil	4600	ND
Diclofenec	200	ND
Ketoprofen	47	ND

Occurrence of Endocrine Disruptors

Source	Constituent	Concentration (ng/L)
Wastewater	Total Estrogen	64-350
Drinking Water	Total Estrogen	3-50
Groundwater	Estradiol	0.1-3.2
Repurified Wastewater (San Diego)(TFC RO Permeate)	Total Estrogen	<0.1

Next Issue: Removal of "TICs"

"TICs": Tentatively-Identified Compounds

- **Recently completed identification of TICs in GWRS feedwater**
- **Pilot testing completed for MF/RO/AOP**
- **Lab analyses being reviewed to determine percent removal**

Volatile and Semi-Volatile Organics Identified

Parameter	GWRS Feed Detections
Methylene Chloride (Dichloromethane)	6.2 ug/L
MTBE	3.6 ug/L
Chloroform	2.3 ug/L
Bromodichloromethane	0.55 ug/L
Dibromochloromethane	0.63 ug/L
1,4-Dichlorobenzene	1.9 ug/L
Bis (2-Ethylhexyl) phthalate	5.5 ug/L

TICs Identified GWR System Feedwater

1,1'-Oxybis-2-propanol	5.7 ug/L
1-(2-Methoxy-1-methylethoxy)-2 propanol	5.0 ug/L
2,3-Dimethyl-2-pentanol	8.2 ug/L
Hexadecanoic acid	9.6 ug/L
Hexanedioic acid, dihexyl ester	5.9 ug/L
Octadecanoic acid	9.0 ug/L
Phosphate (3:1)-2-butoxy-ethanol	5.6 ug/L
3,7,11-Trimethyl-2,6,10-dodecatrien-1-ol	6.7 ug/L
Coprostan-3-one	5.2 ug/L
1,1'-Oxybis-2-propanol	5.1 ug/L
2-Methoxy-2-heptanol	8.5 ug/L
1-(2-Methoxypropoxy)-2-propanol	8.5 ug/L

UV with Hydrogen Peroxide Is an Advanced Oxidation Process (AOP)

- Some compounds like NDMA are directly photolyzed by UV light
- Other compounds like 1,4-Dioxane require an Advanced Oxidation Process (AOP)
- UV with hydrogen peroxide is an AOP that acts by producing hydroxyl radicals

Expert Panel Convened by West Basin MWD Recommended AOP with UV-Peroxide

- Expert panel included: Michael McGuire (Chair), Harvey Collins, Perry McCarty, Dennis Williams and David Jenkins.
- Panel stated that:
  - The hydroxyl radical formed by UV-peroxide "is the most powerful oxidant that can be formed in water"
  - "Hydroxyl radicals will oxidize organic compounds that are not removed by the previous unit processes"
  - "The Panel has advised the inclusion of this final oxidation step as a final barrier against as yet unknown organic compounds"

Conclusions

- GWRS will rely on multiple barriers to protect water quality
- Source control is being "reinvented" to prevent contaminants from entering the source water
- MF will better prepare the water for RO treatment

Conclusions (cont.)

- RO treatment with TFC membranes is the core of the GWRS treatment train
- OCWD has over 25 years experience with RO
- RO will remove most organic compounds, especially larger molecules
- Testing documents removal of pharmaceuticals and endocrine disruptors (more testing continues)

Conclusions (cont.)

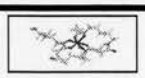
- **AOP with UV and peroxide will destroy compounds that are not removed by RO**
- **Research is underway to model removal of lower molecular weight compounds through RO**
- **Continuing research is needed to verify removal of emerging contaminants and lead to development of better membranes with better rejection**

Computer Modeling of RO Membrane Rejections for Organics

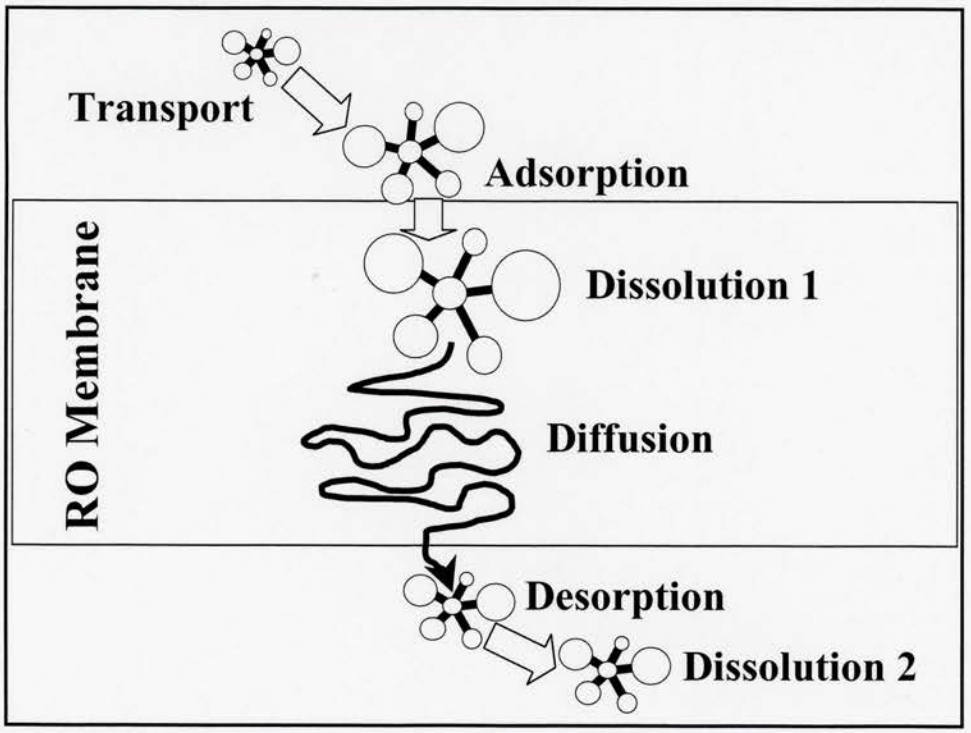
Program Goal:

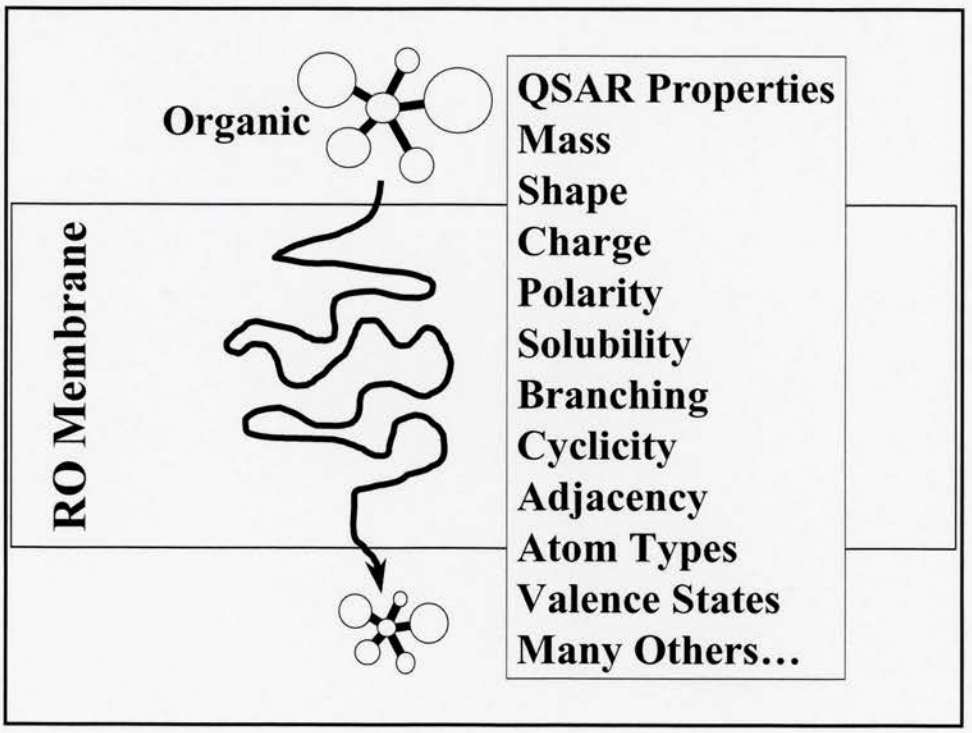
Develop computer models that predict organics rejection by different membranes.

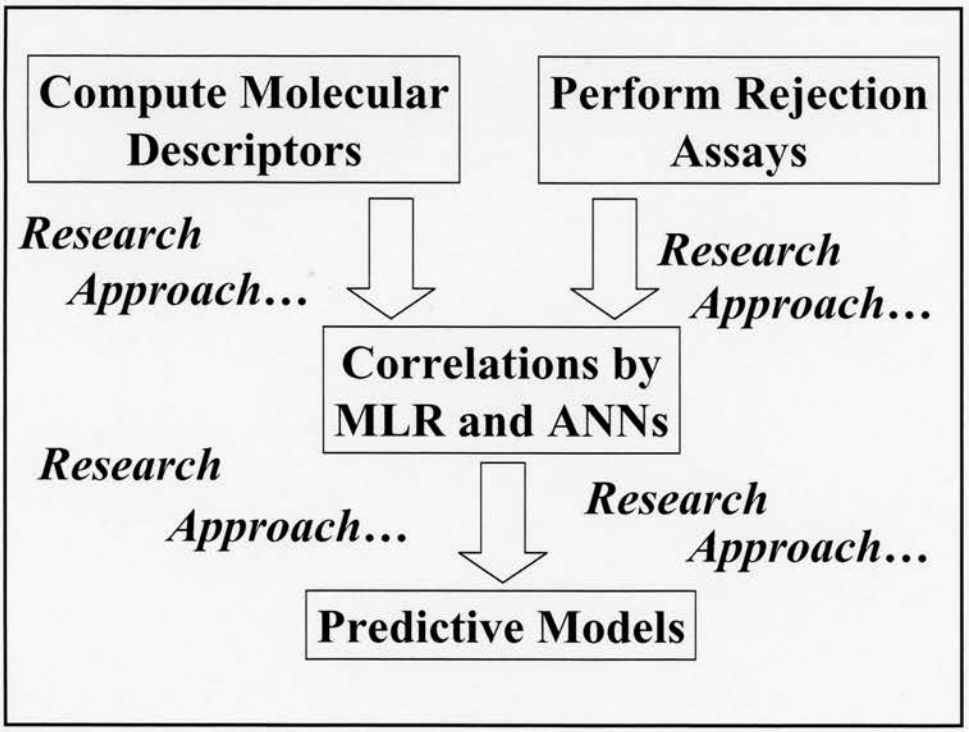
Premise:

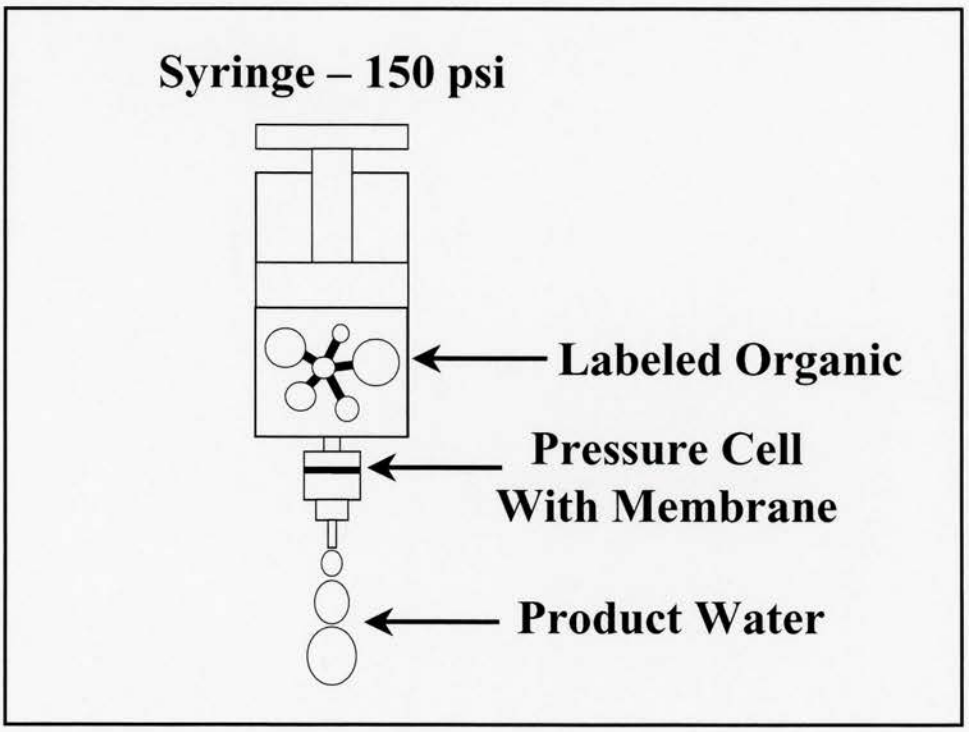


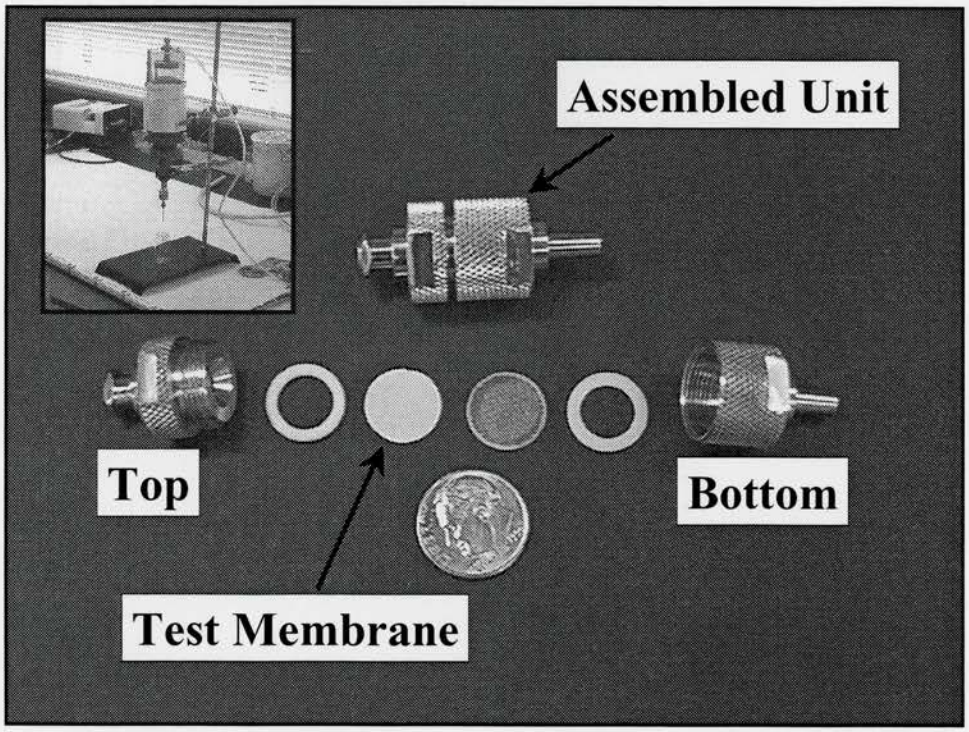
Transport is governed by the structure and reactivity of the compound of interest.

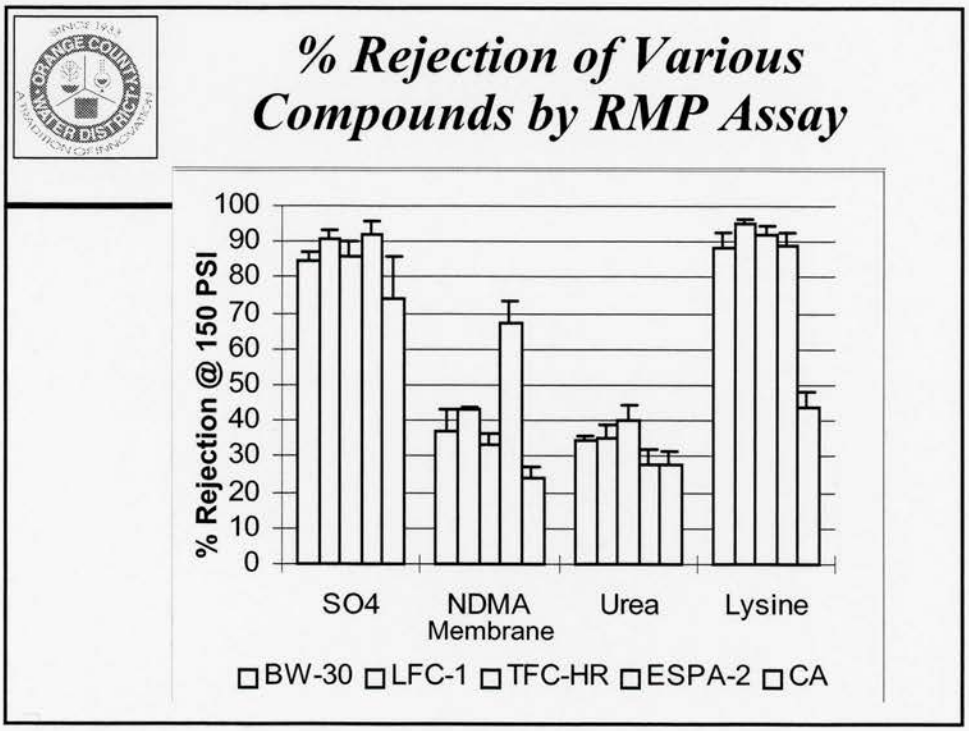

Transport
Adsorption
RO Membrane
Dissolution 1
Diffusion
Desorption
Dissolution 2


Organic
RO Membrane
QSAR Properties
Mass
Shape
Charge
Polarity
Solubility
Branching
Cyclicity
Adjacency
Atom Types
Valence States
Many Others…


Compute Molecular Descriptors
Perform Rejection Assays
Research Approach…
Research Approach…
Correlations by MLR and ANNs
Research Approach…
Research Approach…
Predictive Models


Syringe – 150 psi
Labeled Organic
Pressure Cell With Membrane
Product Water


Assembled Unit
Top
Bottom
Test Membrane


% Rejection of Various Compounds by RMP Assay
% Rejection @ 150 PSI
100
90
80
70
60
50
40
30
20
10
0
SO4
NDMA
Urea
Lysine
Membrane
BW-30 LFC-1 TFC-HR ESPA-2 CA

Factors Decreasing Membrane Organics Rejection:

Lower operating pressures. Trade-off of rejection for lower energy costs.

Bio-organic fouling of the membrane surfaces (polarization + degradation).

Seasonal temperature variations or variations in feed quality.

Funded Projects:

EPA Project – Focuses on methods development and initial model formulation. ~1 year remaining.

NWRI/GWRS/WBMWD Project – Focuses on model development for endocrine disruptors, antibiotics and other regulated compounds. To 2/02.

NSF STC with Stanford and UIUC – Focuses on rejection prediction from first principals molecular modeling. Estimated 5-year life.