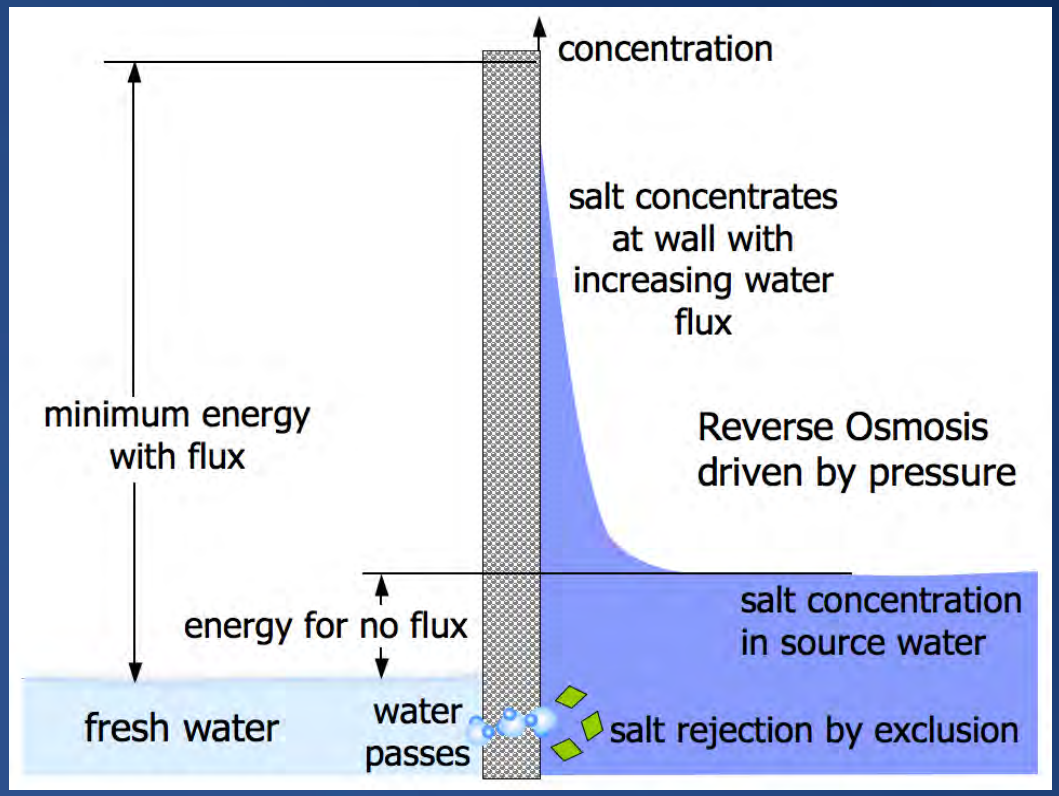
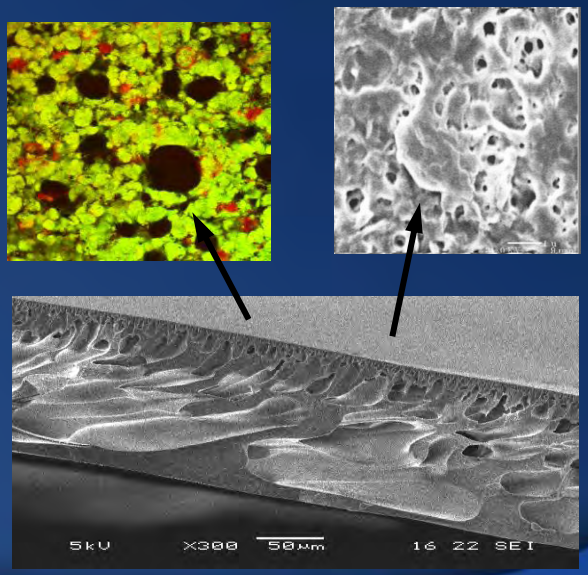
Problems with Reverse Osmosis



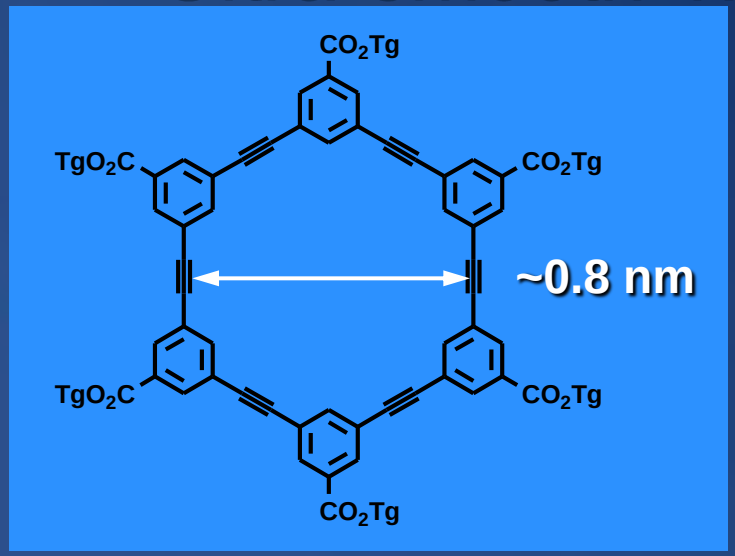
RO membranes are essentially a nanotechnology, but can still see large improvements from nanotechnology

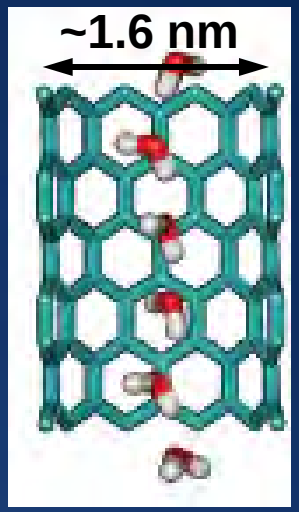
Surfaces and pores plug



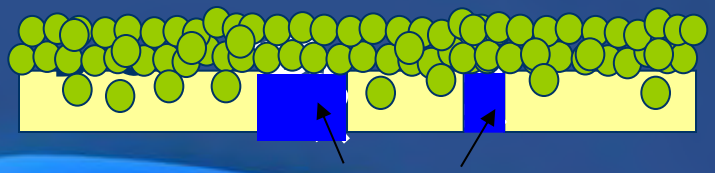
Low maximum flux, polarization also limits flux, and membranes foul. Nanocatalysts to reduce fouling.

Super-Flux with Ultra-thin (<1 nm) Functionalized Rigid Star Amphiphiles and Ultra-smooth 1.6 nm Carbon Nanotubes





RSA active layer

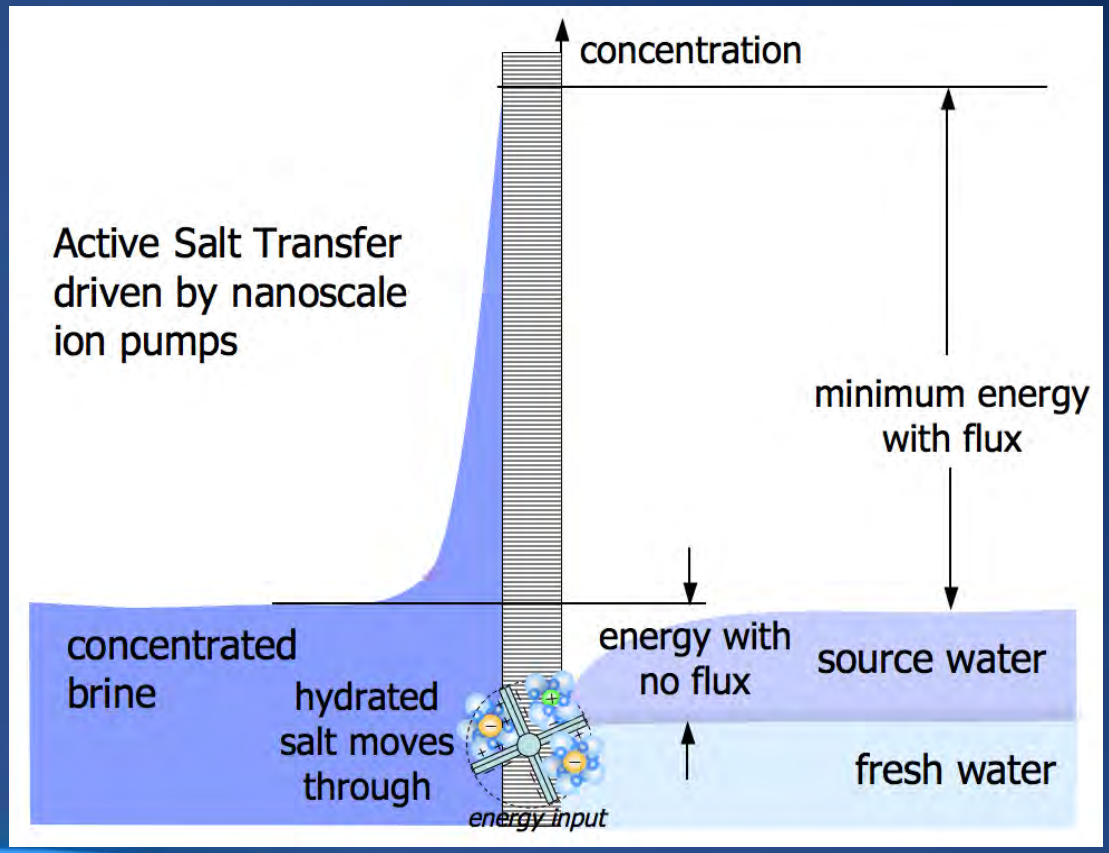


Moore and Mariñas 2007

Comparison to commercial NF membranes

- RSA membranes (RSAMs) had 2x higher water permeability and comparable rejection.
- LLNL CNT membranes have an **order of magnitude higher flux** do to its hydrophobicity and atomic smoothness

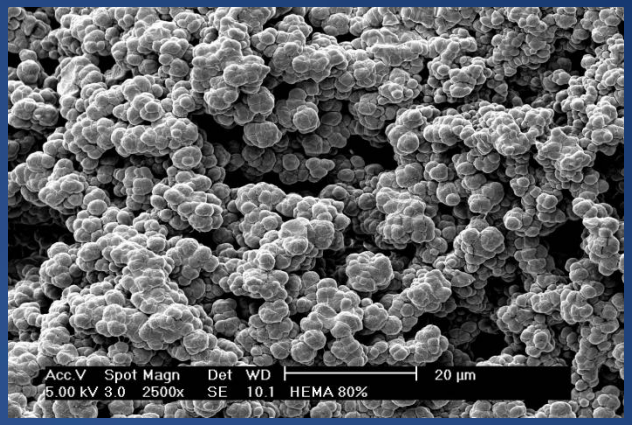
But Even a "Perfect" Membrane Still Slowed by Polarization Impedance

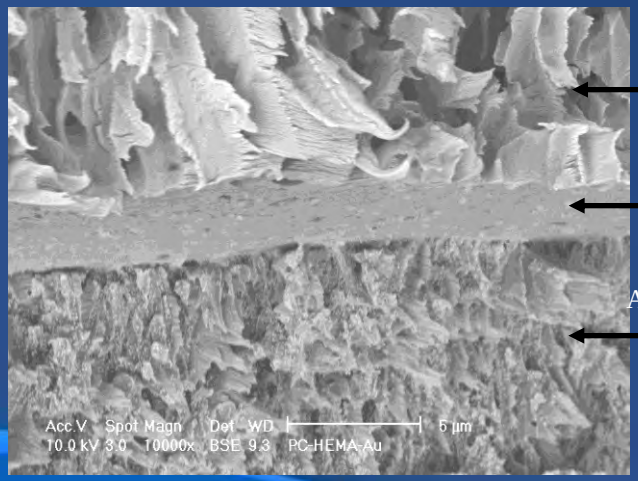


Active nano-channel ion pumps being developed to solve polarization impedance problem, BUT MUST BE NANOFLUIDIC FLOW, where electric double layers interact.

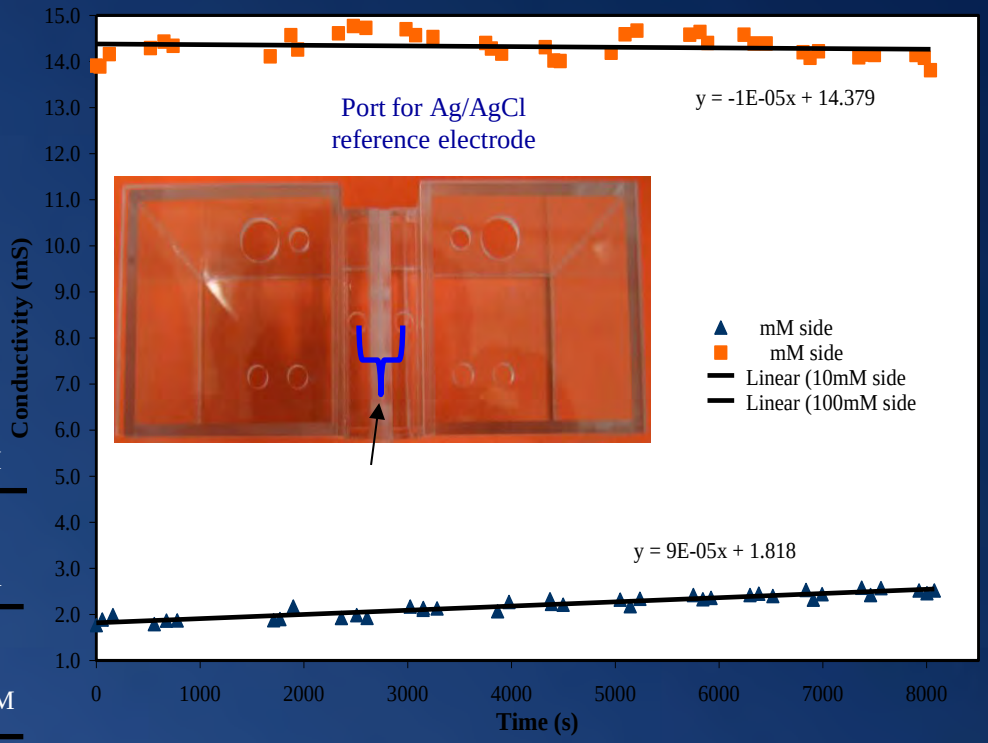
Shannon et al., *Nature* 20 March 2008

Active Membrane System - Key Dimensions are < 1 nm to 100 nm





Assembled 3-layer stack



Prakash, Rutgers
Shannon, UIUC

Distribution System Issues

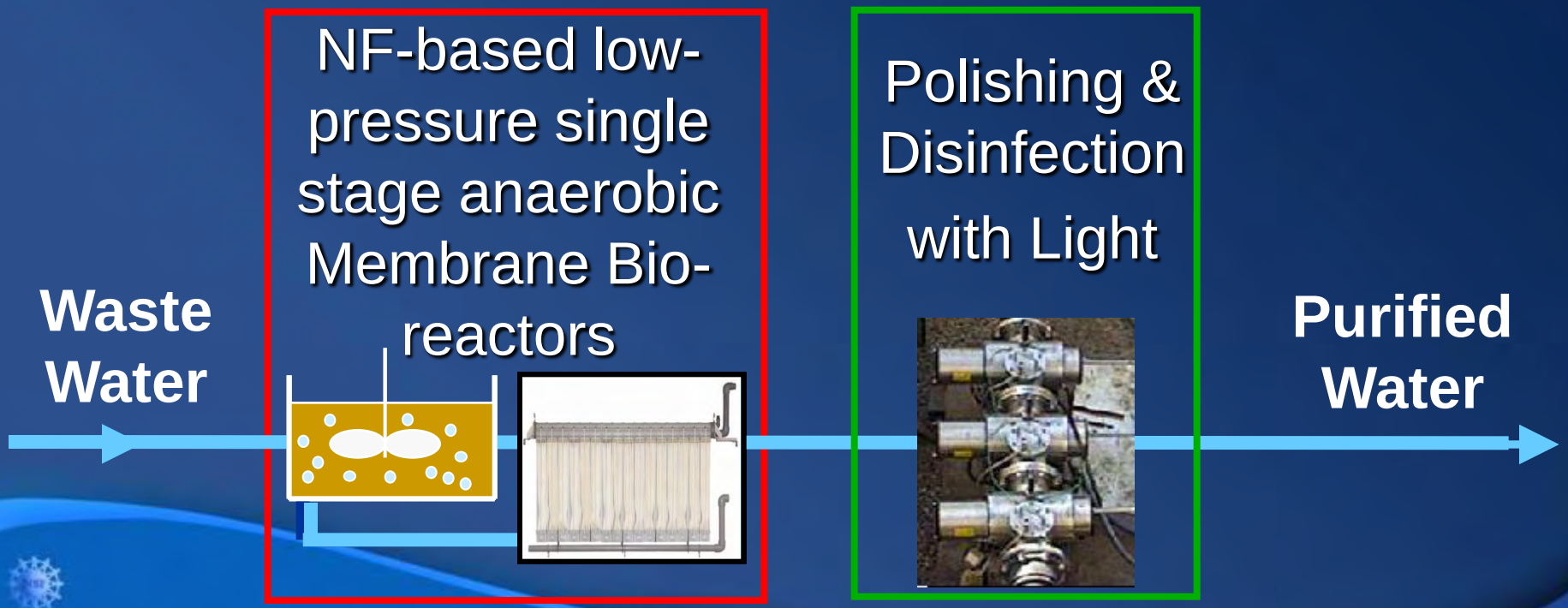
- Distributions systems expensive to install and maintain. They are failing all over the world due to age and neglect.
- Distribution systems can be a source of transmitting disease. New pipes connected to an older system, particularly in peri-urban areas, rapidly degrade and cause disease.

Hard water struvite

- Point-of-source and point-of-use treatment systems can be much lower cost. Point-of-use treatment can prevent disease of contaminated distribution systems.
- But these Point-Systems need the efficacy of large controlled systems, without oversight of trained personnel. Robustness needed similar to the air break and chlorine.

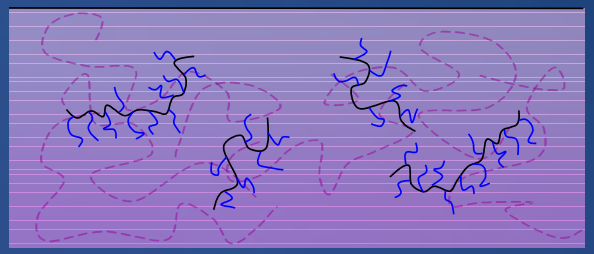
Recovery and Reuse of Water Creates an ENORMOUS RESOURCE

- Can be used for Point-of-Discharge to recharge aquifers
- Membrane Bio-reactors can generate valuable energy & chemicals, rather than consuming energy to purify water
- Ensures absolutely the highest quality and safety

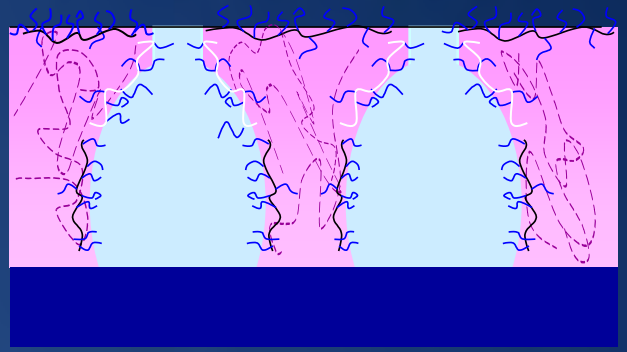


Create Nano-Segregated Compounds within Membrane that Resist Fouling

graft copolymer added to casting solution



segregate and self-organize at membrane surfaces



PEO brush layer on surface and inside pores

Combined hydrophilic/phobic nanofiltration membrane

Fouling Resistance

Asatekin, A., S. Kang, M. Elimelech, and A.M. Mayes, *Jour. Membrane. Sci.*, in press..

To Directly Reuse Water, We Need to Know How to Take Toxic Compounds Out

- Small hydrocarbon molecules can taste and smell bad, and cause water to be colored.
- Low levels of toxic compounds such as heavy metals (As, Pb, Hg, U, Cd), pesticides, herbicides, petroleum distillates, and disinfection byproducts are hard to know if they are in water, and to remove in a high background of organics and potable compounds.
- We must make absolutely sure pathogens are not in the product water.

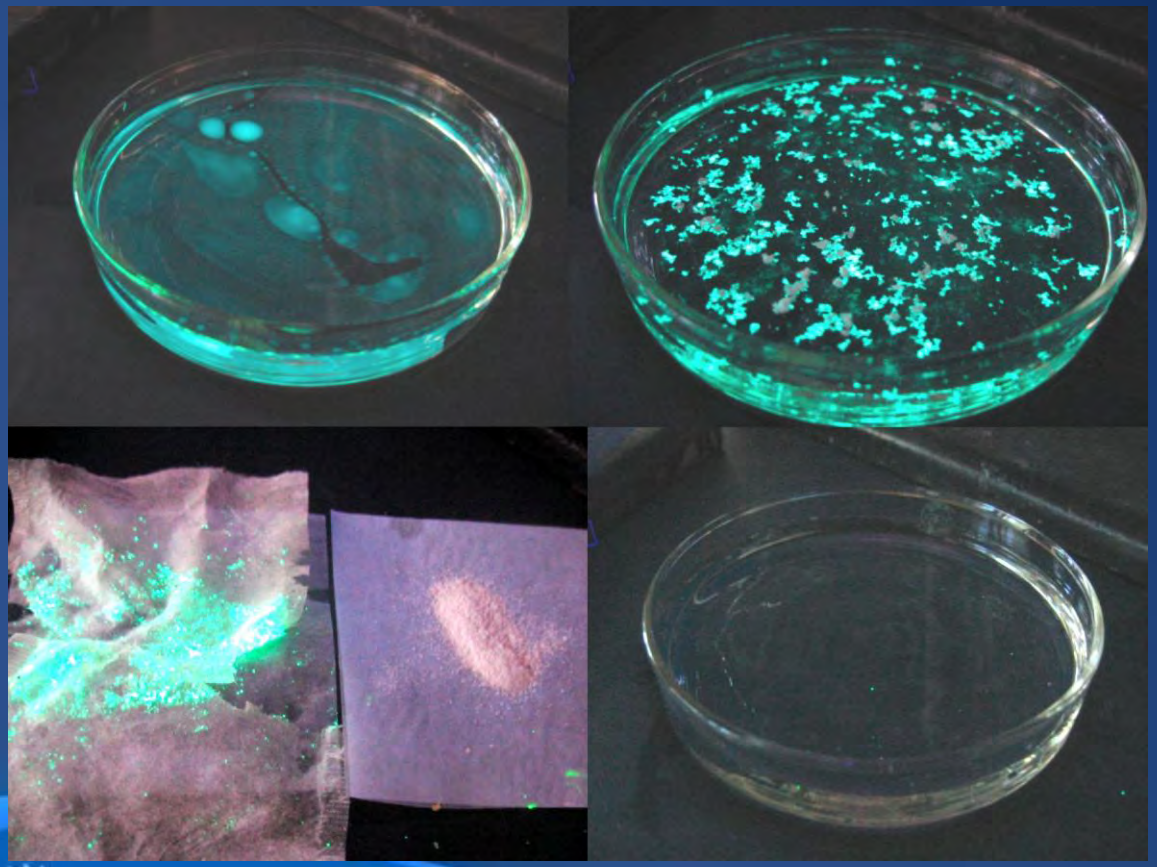
Speciation Matters!

Methyl mercury thousands of times more toxic than elemental mercury.

Nitrosoamines: Carciogenic

Removing Petroleum Byproducts from Water with Nanostructured Materials

"Organic–Inorganic Hybrid Materials that Rapidly Swell in Non-Polar Liquids: Nanoscale Morphology and Swelling Mechanism," Burkett, Underwood, Volzer, Baughman, and Edmiston, Chemical Materials 2008



New low-cost absorbable glass can remove virtually all petroleum byproducts like benzene, distillates, and oil from water. Can be used over and over again. Large numbers of people are sickened by these compounds.

Disinfection of Hard to Treat Pathogens, Without Intensive Chemical Treatment

- Use of materials to trap pathogens, including viruses
- Use particles, catalysts, and photocatalysts with plentiful, free light to kill pathogens in water
- Disinfect water WITHOUT using chlorine or other powerful oxidants that can themselves form toxic compounds

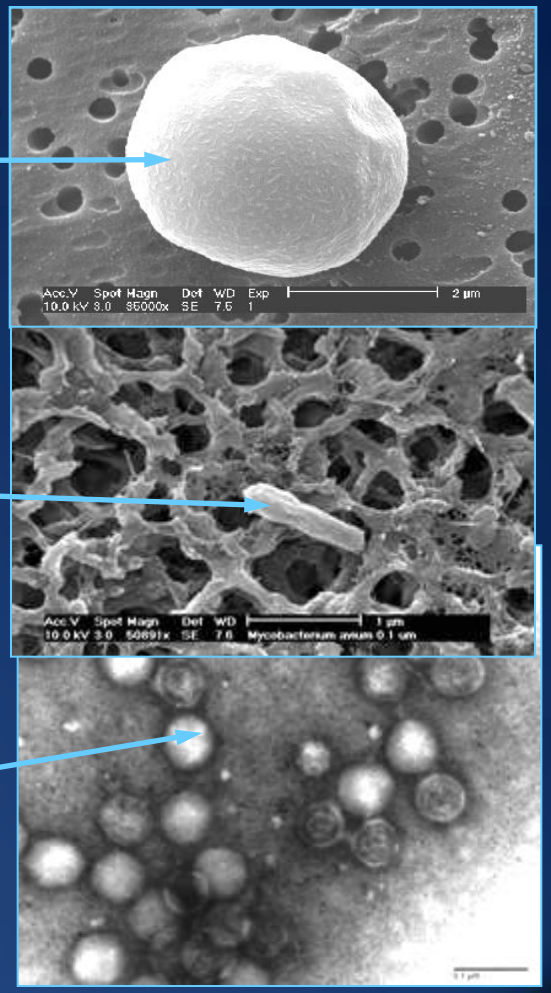
Cryptosporidium parvum
Trap on Nanopore membranes

Mycobacterium avium

Inactivate on surfaces

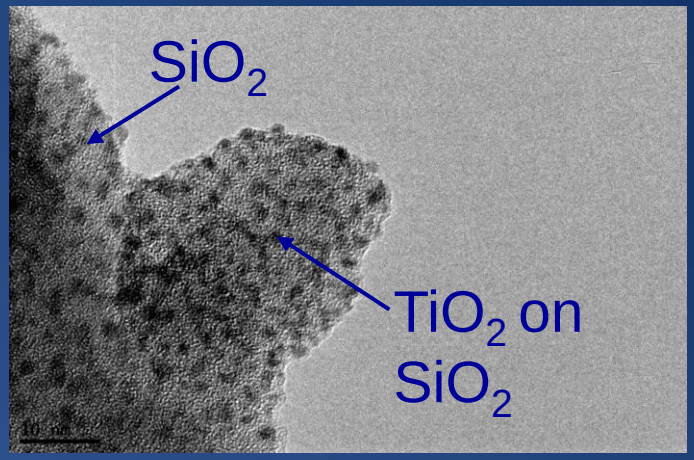
Adenoviruses

Use nanocatalysts

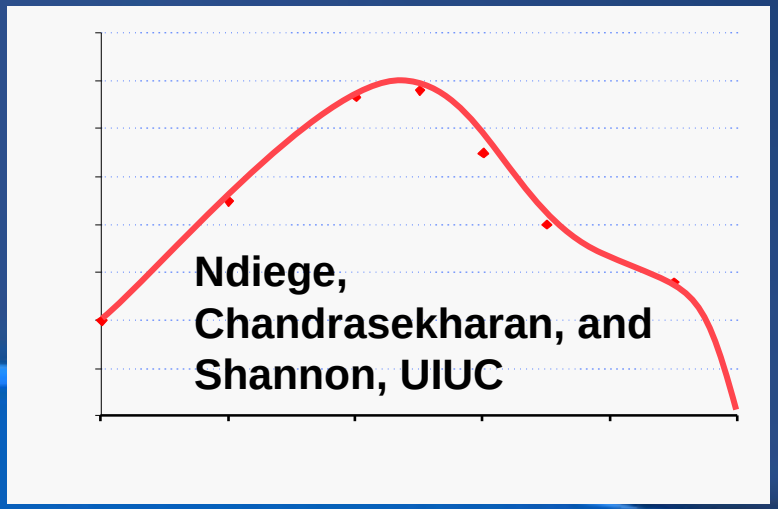


Benito Mariñas, UIUC

Destroy Pathogens and Organics with Nanoscale Photocatalysis



TEM micrograph of 2 nm diameter TiO_2 on 20 nm diameter SiO_2 particles



Can use low-cost treated silica (sand) to remove all organic compounds from water at high rates using free sunlight. Can remove carciogens, toxic compounds, and pathogens too, all without using chlorine.

Sustainable Water Point-Source/Point-Use Disinfection Approaches

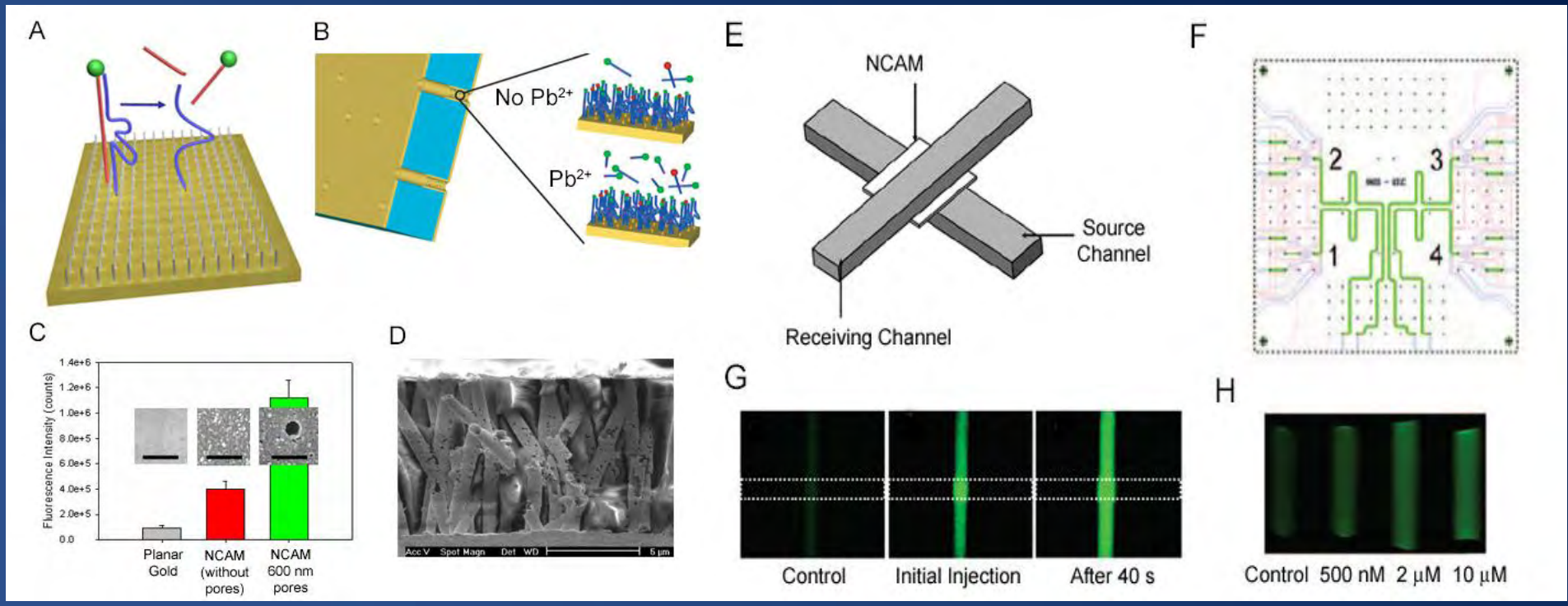
- Point-of-Use Technologies for Rural Areas (photo taken by *WaterPURE* student Maren Somers at Enugu, Nigeria)
- Silver nanoparticle coated ceramic water pots for transporting and storing water (Fullbright Fellow Gordon Nangmenyi in S. Africa)

- **SoChlor Process**: Synergistic combination of visible light (solar disinfection or SODIS) and low-doses of combined chlorine
- **Coagulation with Moringa seeds**: Removal of pathogens with available non-chemical coagulant

Robust Sensing of Contaminants in Real Time: Can be a Game Changer

- New business model: Put knowledge into people's hand
- Most sensing today done in batch mode and sent to lab periodically: Difficulties in getting reliable results
- Low levels of toxic compounds are hard to both sense in a high background of organics and potable compounds
- Need ability to detect pathogens, including viruses
- Fouling stops even simple sensors from working after a relatively short time
- World is moving to ppb and ppt concentrations for regulation
- High cost in treating all waters all the time, when need may be much less

Utilizing Catalytic DNA in Molecular Gates to Sense Trace Amounts of Lead



Molecular Gates Devices

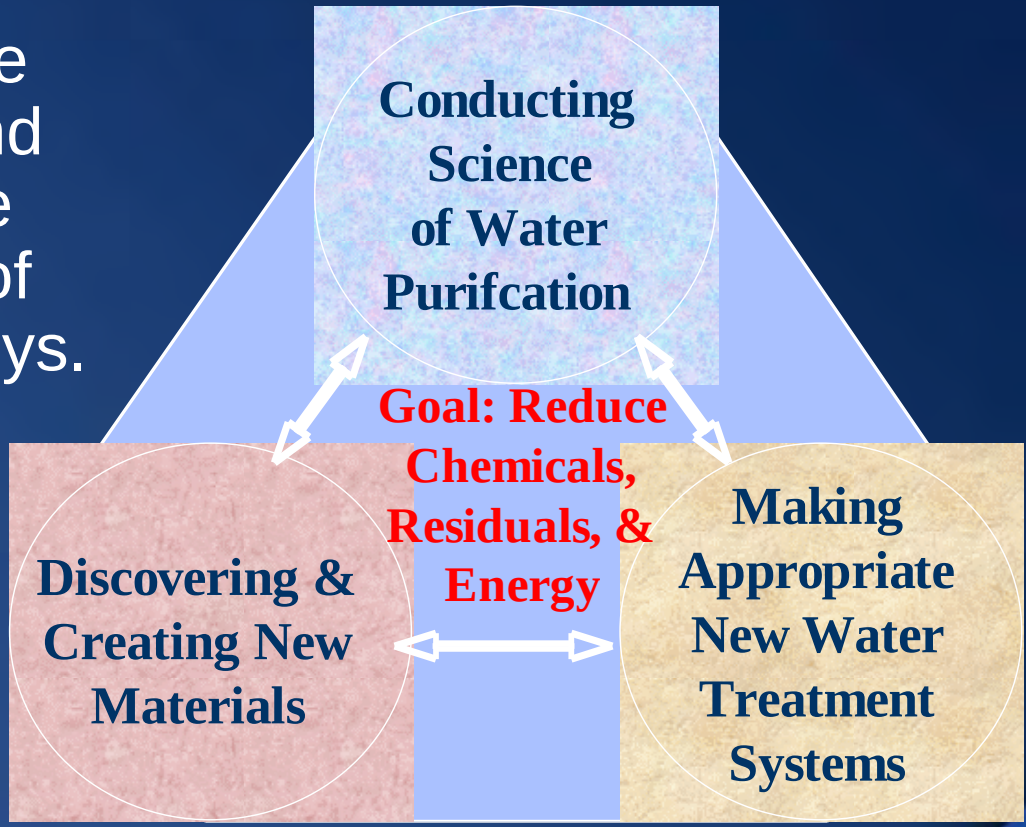
- Time integrated signals
- Controlled sample delivery
- Enhanced reaction efficiency

- Increased signal-to-noise ratio
- Reduced detection limit: from 2 ppb to 0.2 ppb
- Long-term sensor storage and regeneration/reuse

D. P. Wernette, C. B. Swearingen, D. M. Cropek, Y. Lu, J. V. Sweedler, and P. W. Bohn, *Analyst* 131, 41-47 (2006).
D. P. Wernette, C. Mead, P. W. Bohn and Y. Lu, *Langmuir*.

How to Enhance Use of Nanotechnology for Water Purification

- Enable researchers to develop a wide number of solutions.
- Enable businesses to put solutions into markets.
- Have governments reduce impediments to testing and verification, with formative and summative analysis of efficacy of nanotechnologys.
- Develop new business model to finance water purification solution and enable appropriate technologies to be put into practice.



Questions and More Information

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WaterCAMPWS:
http://waterCAMPWS.org