Challenges for Water Resources & Treatment

AECOM Imagine it. Delivered.

– *YuJung Chang, Ph.D.*

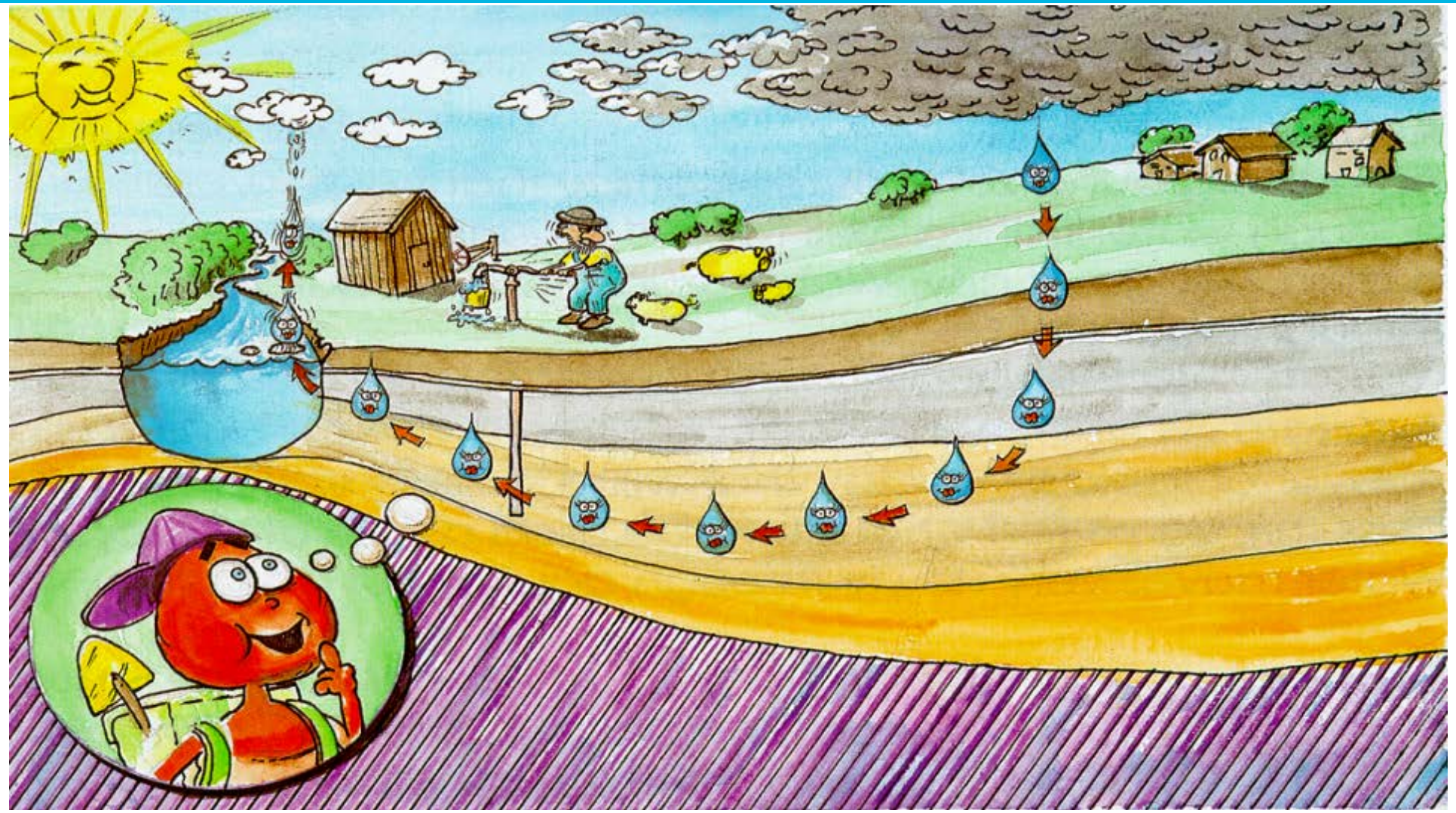
– *AECOM, Bellevue, WA*

Challenges to the World's Water Problem

- Think BIG

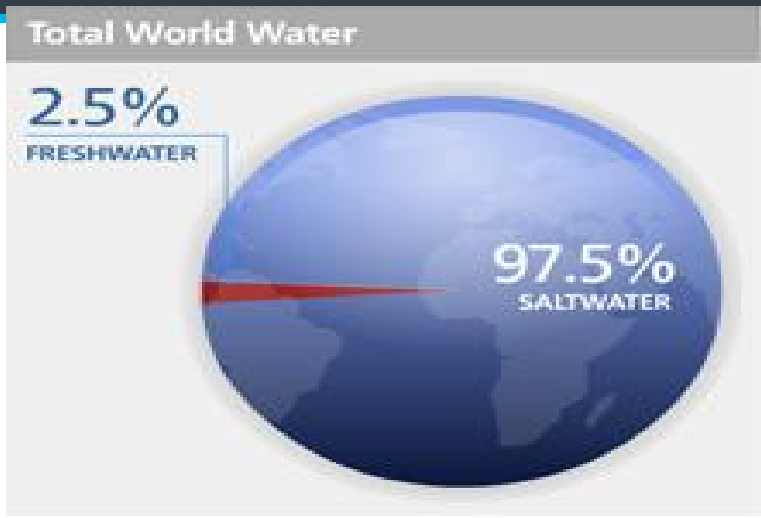
- Think Outside the Box

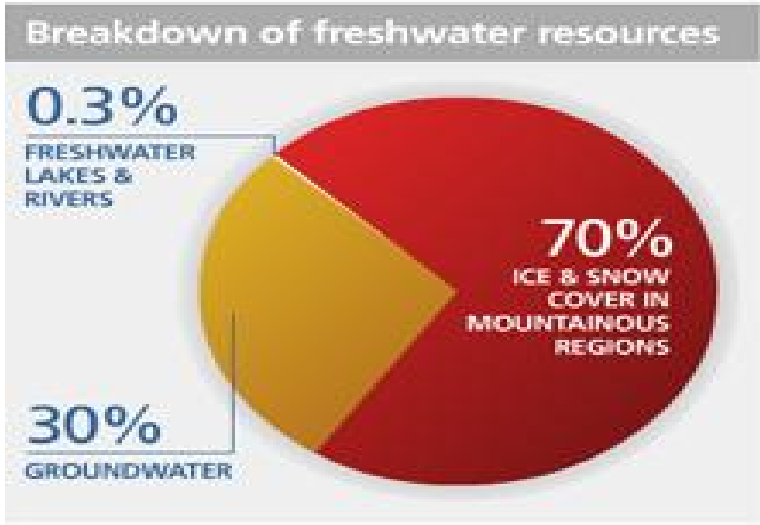
Hydrologic Cycle



World's Water Distribution

- Total Water on Earth
  - 3.7 x 10^{20} Gal
  - 1,135 Trillion Acre-ft
- Saltwater: 97.5%
- Fresh Water: 2.5%
- Fresh Water (28.4 Trillion Acre-ft)
  - 0.3% Surface Water
  - 30% Groundwater
  - 70% Ice/Snow





Fast Facts: Water Consumption Trends

- ***"7 billion people in 60 countries will face water scarcity by 2050."***

"Climate change will account for 20% of global water scarcity."

- U.N. World Water Development Report

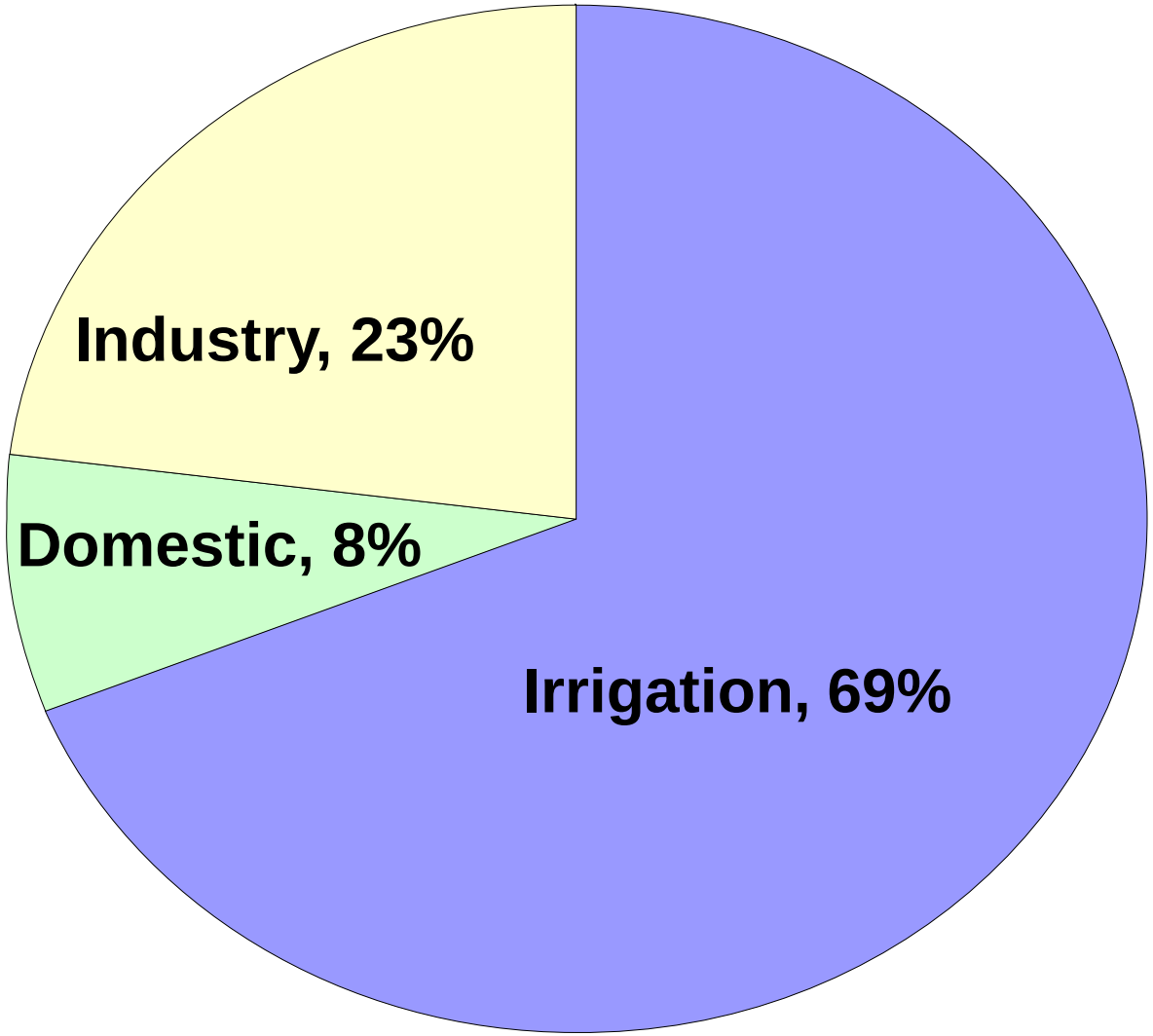
"By 2028 humans will use 70% of available freshwater"

- Global Water Policy Project, Amherst MA

- **"*35% of world population – short of water in 2028"***

- Johns Hopkins University

Fast Facts: General Freshwater Usage



Water Challenges

- Quantity
  - Reduction in freshwater resources
  - Increase in demand (population, agriculture, industrial)
- Water Rights
  - Who gets the water?
  - How much water do you get?
  - When do you get the water?
- Quality
  - Chemicals (Inorganics, organics)
  - Pathogens
  - Salts

Reduced Snow/Ice Coverage (storage)

South Cascades Glacier, North Cascades National Park

Photos courtesy of the USGS.
Source: http://nsidc.org/sotc/glacier_balance.html

Groundwater Depletion

- Groundwater has been heavily taped for agriculture usage
- Groundwater recharge is not feasible in most places in the world since surface water is limited

Water Challenges

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Global Perspective: Population

Global Population

1930: 2 Billion
2003: 6.3 Billion
2008: 6.69 Billion
2010: 6.81 Billion
2018: 7.6 Billion
2050: 10 Billion people projected

Countries with the highest population

China: 1.336 Billion
India: 1.179 Billion
USA: 309 Million
Indonesia: 232 Million
Brazil: 193 Million
Pakistan: 169 Million

Water Challenges

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There is Still Enough Water In the World. The Challenges are…

- Get the water to where it is needed
- Provide just enough water that's needed
- Provide water when it is needed

Not Enough Water

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Too Much Water

Country with Most Freshwater Withdraw

Country	Total Freshwater Withdrawal (km^3/yr)	Per Capita Withdrawal ($m^3/p/yr$)	2005 Population (millions)	Domestic Use (%)	Industrial Use (%)	Agricultural Use (%)
India	645.84	585	1,103.37	8	5	86
China	549.76	415	1,323.35	7	26	68
USA	477	1,600	298.21	13	46	41
Pakistan	169.39	1,072	157.94	2	2	96
Japan	88.43	690	128.09	20	18	62
Indonesia	82.78	372	222.78	8	1	91
Thailand	82.75	1,288	64.23	2	2	95
Bangladesh	79.4	560	141.82	3	1	96
Mexico	78.22	731	107.03	17	5	77
Russian Federation	76.68	535	143.2	19	63	18
Iran	72.88	1,048	69.52	7	2	91
Vietnam	71.39	847	84.24	8	24	68
Egypt	68.3	923	74.03	8	6	86
Brazil	59.3	318	186.41	20	18	62
Uzbekistan	58.34	2,194	26.59	5	2	93
Canada	44.72	1,386	32.27	20	69	12

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Water Challenges

- Quantity
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  - Pathogens
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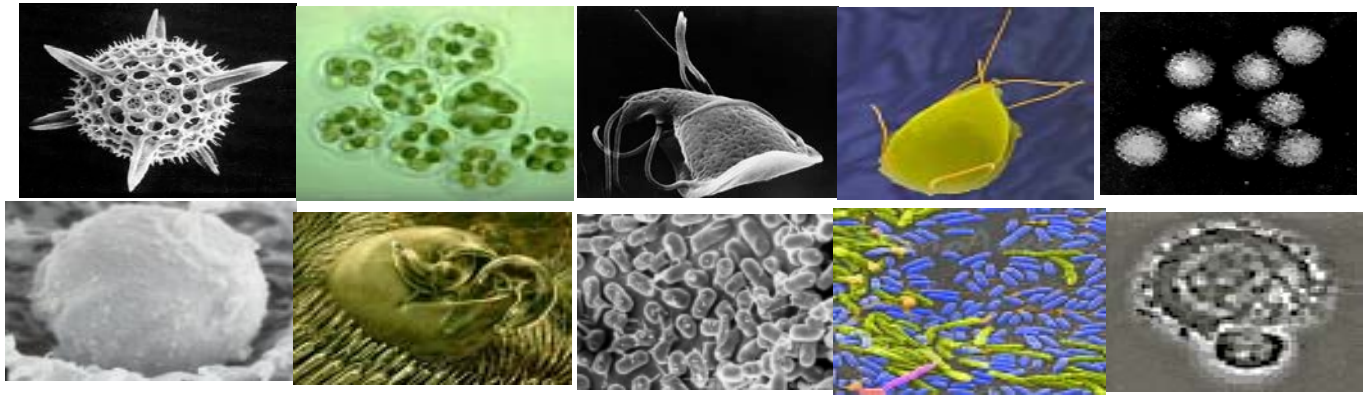
Water Quality Challenges

- Most of the water impurities and life-threatening pathogens can be easily removed with simple treatment processes
- Simple treatment process is still an unaffordable luxury in many areas in the world



Percentage of Population with Access to Safe Drinking Water (in 185 Countries)

- 100% 34
- > 95% 26
- > 90% 25
- > 80 % 31
- > 70% 22
- > 50% 30
- < 50% 12

New Water Sources

Iceberg

Ocean Water

Brackish Water

Rain Water

Grey Water

Reuse Water

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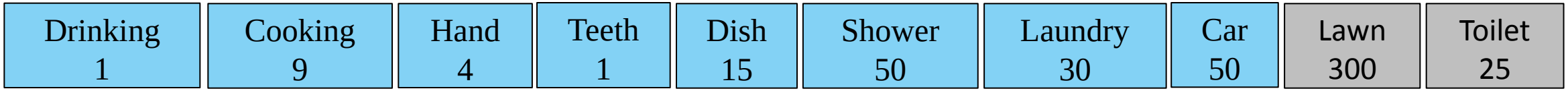
Fast Facts: Water Consumption Trends

- **During the 20th Century, water consumption grew at double the rate of population growth.**
- **Average Daily Usage**
  - **USA = 153 gpcd**
  - **England = 88 gpcd**
  - **Asia = 23 gpcd**
  - **Africa = 12 gpcd**
- **Minimum usage for human life = 13 gal/day/cap**

Typical Water Consumption for Daily Activities in US

Activity	Gallon
Drinking (each time)	0.1
Cooking a meal	3
Washing face or hands	1
Taking a shower with standard/low flow shower head	50 / 25
Taking a bath	40
Brushing teeth with/without water running	2 / 0.25
Flushing the toilet with standard/low flow toilet	5 / 1.5
Running a dishwasher	15
Doing a load of laundry	30
Watering lawn	300
Washing car	50

Type of Water Can be Used for Daily Activity



Drinking Water

Grey Water / Reclaimed Water

Unit: Gallon

Rain / Storm Water

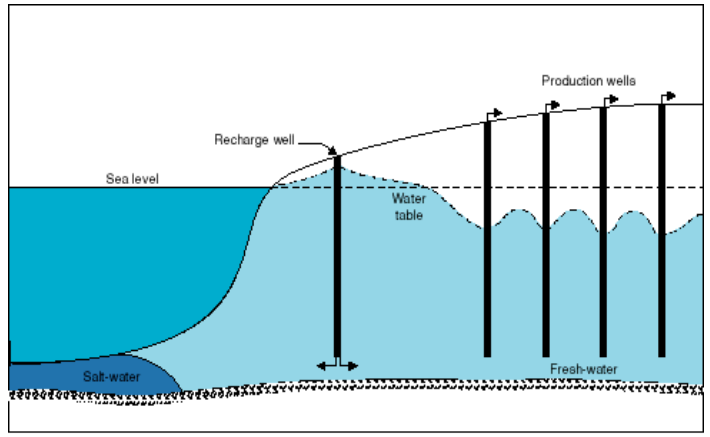
- Who owns the rain?
  - Some states/countries not allowed
  - WA allows 5,000 gal rainwater harvesting
- Primarily used for personal use
- With proper treatment, rainwater could be used for potable water
- Regular maintenance required

Greywater System

- Mostly for small-scale applications
- Require different plumbing system
- Disinfection required for microbial control
- Local building code required
- Regular maintenance required
- Potential esthetic concerns

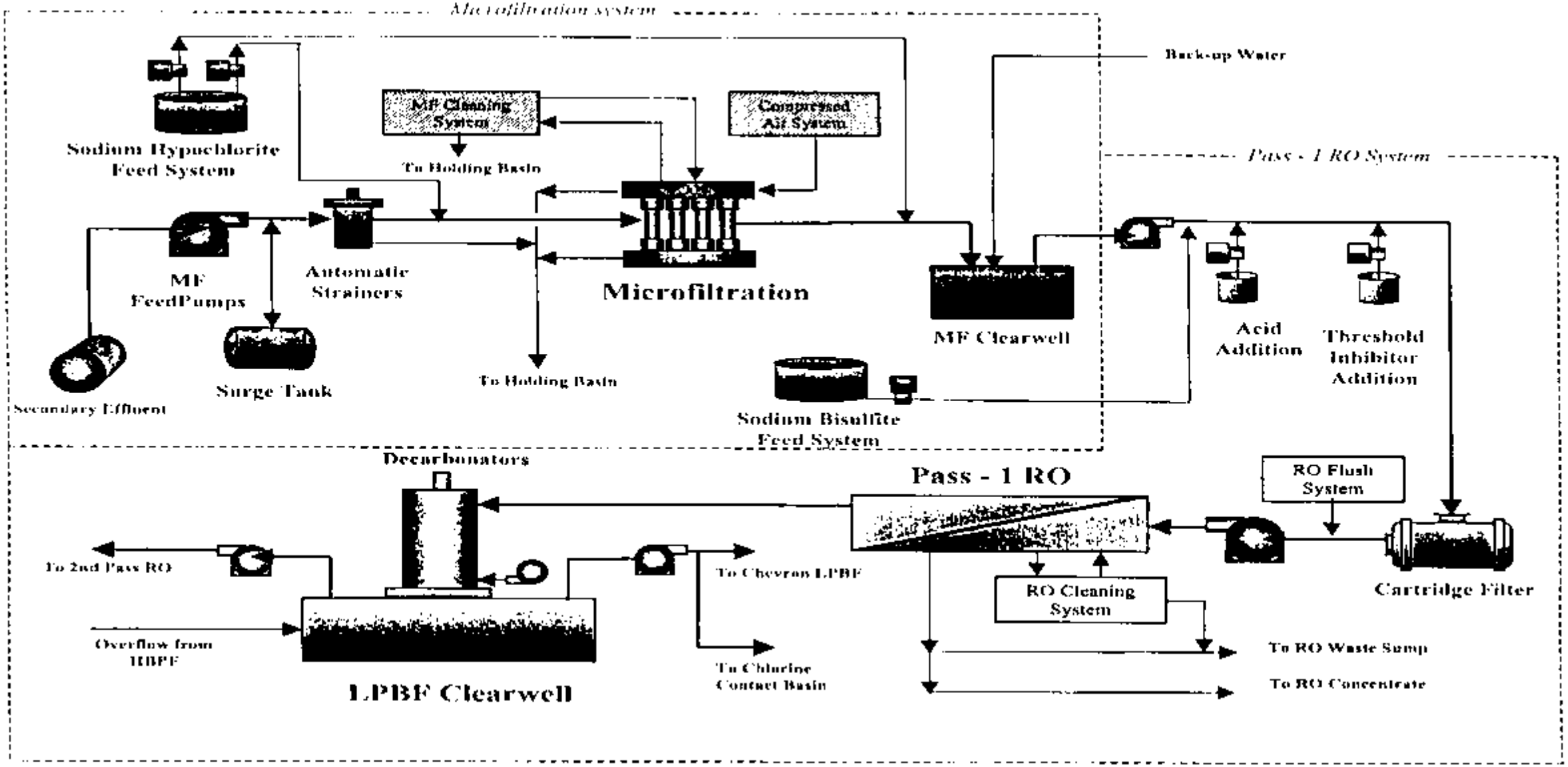
Water Reuse /Reclaim

- Reclaim water require substantial treatment
  - Different end users require different finished water quality
- Direct potable water reuse is acceptable in some countries
- Indirect potable reuse (groundwater recharge or in-stream discharge) and seawater intrusion barriers are the most common applications in US



Deep recharge well creates groundwater ridge.

Example of Water Reuse at West Basin, CA

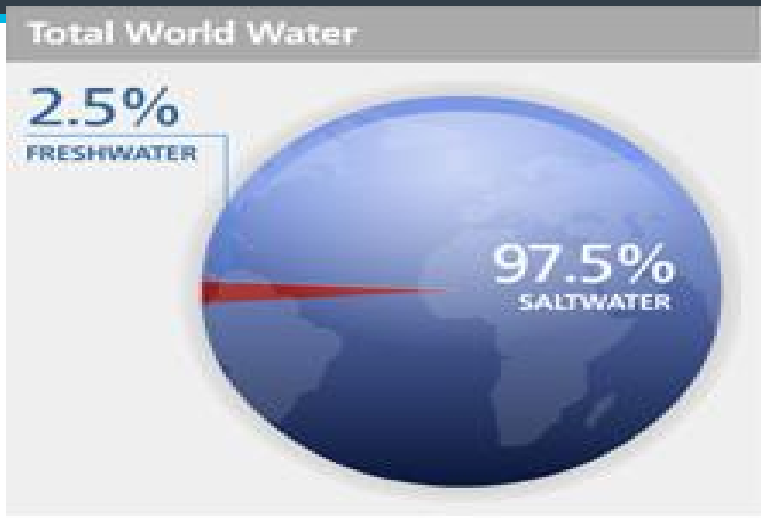


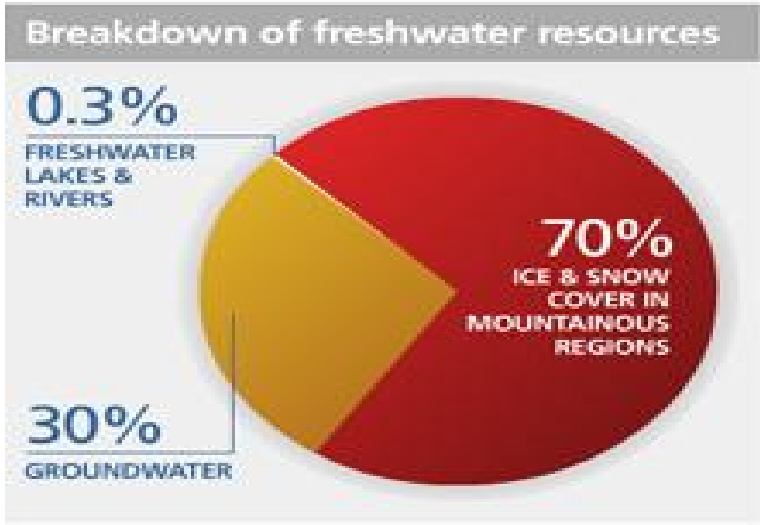
Challenges in Water Reuse

- Repulsion to the concept of “toilet-to-tap”
- The presence of Endocrine Disruptors (EDC) or Pharmaceutical & Personal Care Products (PPCP)
- Require dedicated pipelines

Desalination

- Brackish surface water/groundwater is limited, but treatment technology is well developed (reverse osmosis)
- Ocean water desalination taps into the rest of 97.5% of water on earth
- Seawater desalination requires enormous amount of energy





Energy Required for Treatment Processes

- Typical Surface Water: 0.1 – 0.2 kWh/kgal
- Brackish Water RO: 2.7 – 7 kWh/kgal
- Municipal WW Reclaim: 3.3 – 4 kWh/kgal
  - Seawater RO: 12 – 18 kWh/kgal
  - Seawater Thermal: 57 – 68 kWh/kgal

Seawater Thermal Desalination

Seawater RO Desalination

Seawater Desalination Challenge

Thermal Dynamic Barrier – Thermal Process

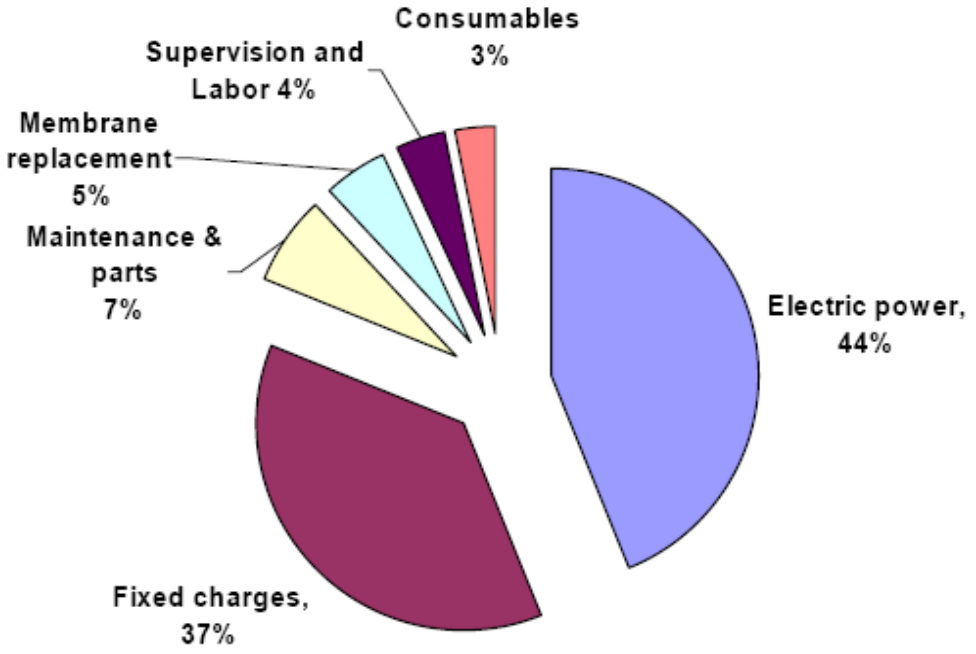
- It takes 3 kWh of energy to boil 1 gal of water (20 C)
- It takes 2630 kWh to evaporate 1,000 gal of 100 C water
- Effective heat recovery can substantially reduce energy

Thermal Dynamic Barrier – Reverse Osmosis

- Osmotic Pressure (35,000 mg/L TDS): 27.8 bar (403 psi)
- It takes 2.92 kWh (theoretical minimum) to produce1,000 gal of water
- Much higher pressure (800 – 1180 psi) is needed

How Much is Energy Cost?

- Energy cost: $0.075/kWh
- Seawater RO energy cost: $1.125/kgal
- Energy Comprises 30 – 44 % of the SWRO Cost
- Treatment cost is ~ 20 – 40% of water rates



Country/City	Water Rate $/1000 gal
Germany	$6.74
Italy	$2.73
US/Australia	**$2.05**
South Africa	$1.62
Canada	$1.42
Seattle	$5.16

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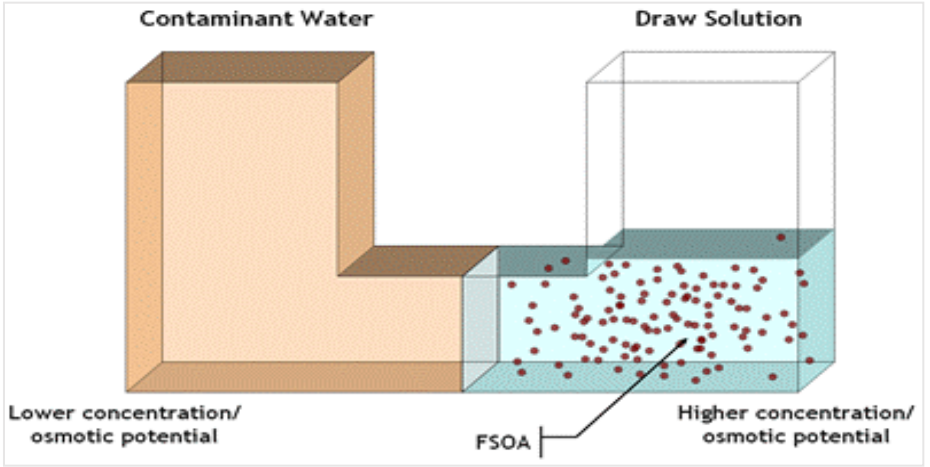
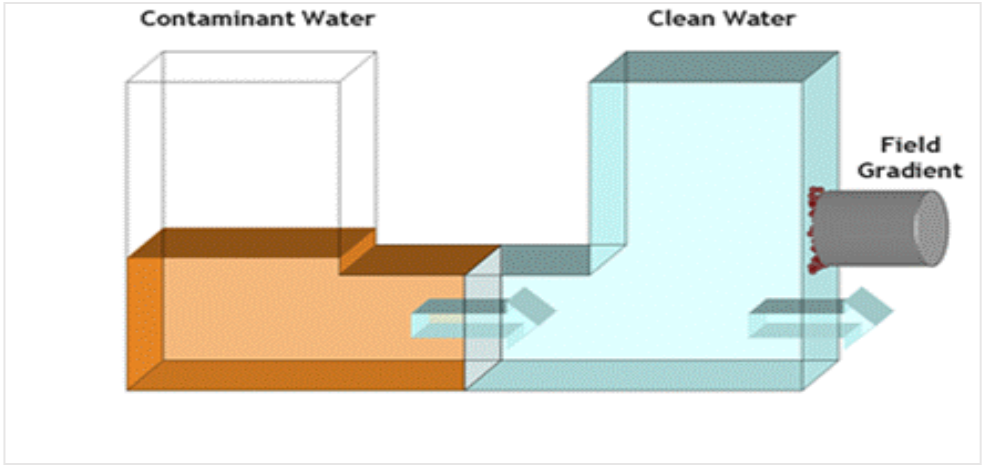
Emerging Technology

- Forward Osmosis
  - Use Osmotic Agents in the Draw Solution
  - No Feed Pressure Required





AQUAFORTUS Forward Osmosis for Zero Liquid Discharge

AQUAFORTUS Forward Osmosis ZLD/纽西兰正渗透零排放工艺

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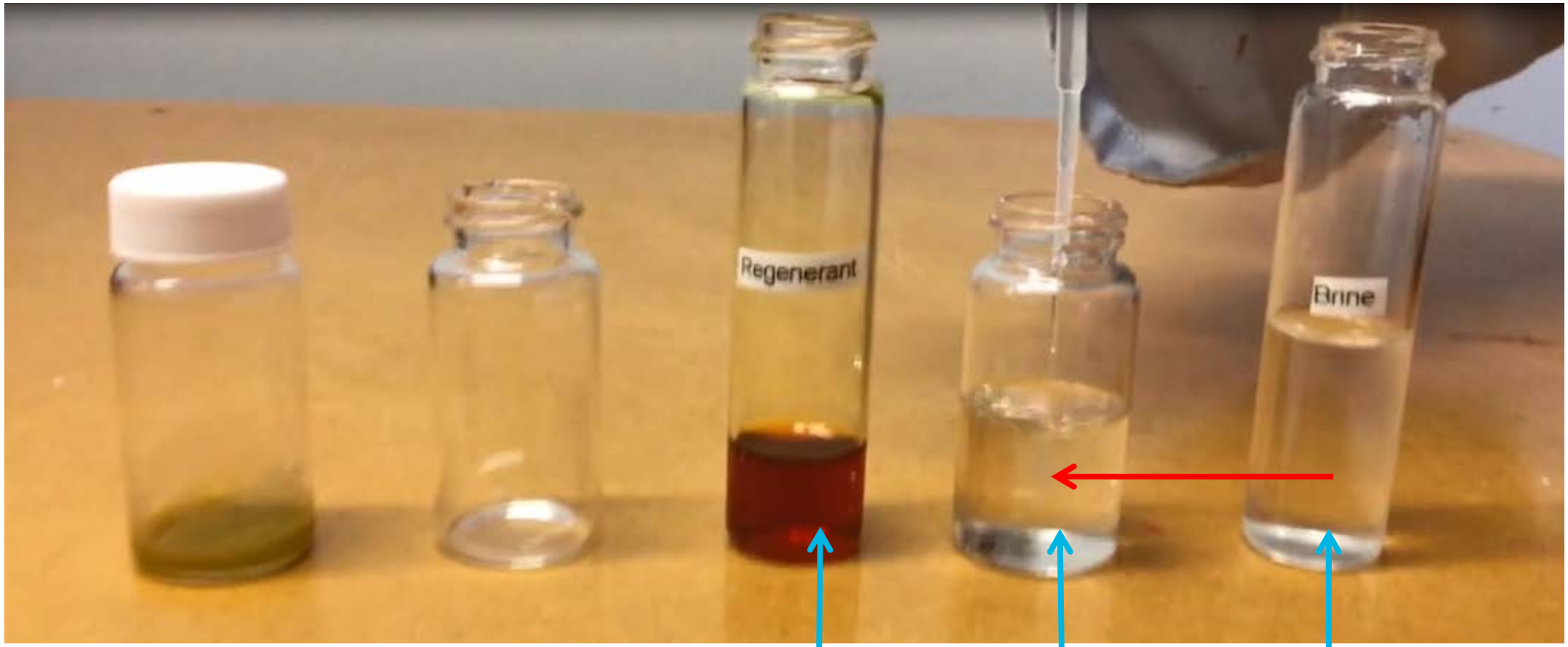
AQUAFORTUS Forward Osmosis ZLD/正滲透零排放

Step 1. Add RO Brine to FO solution



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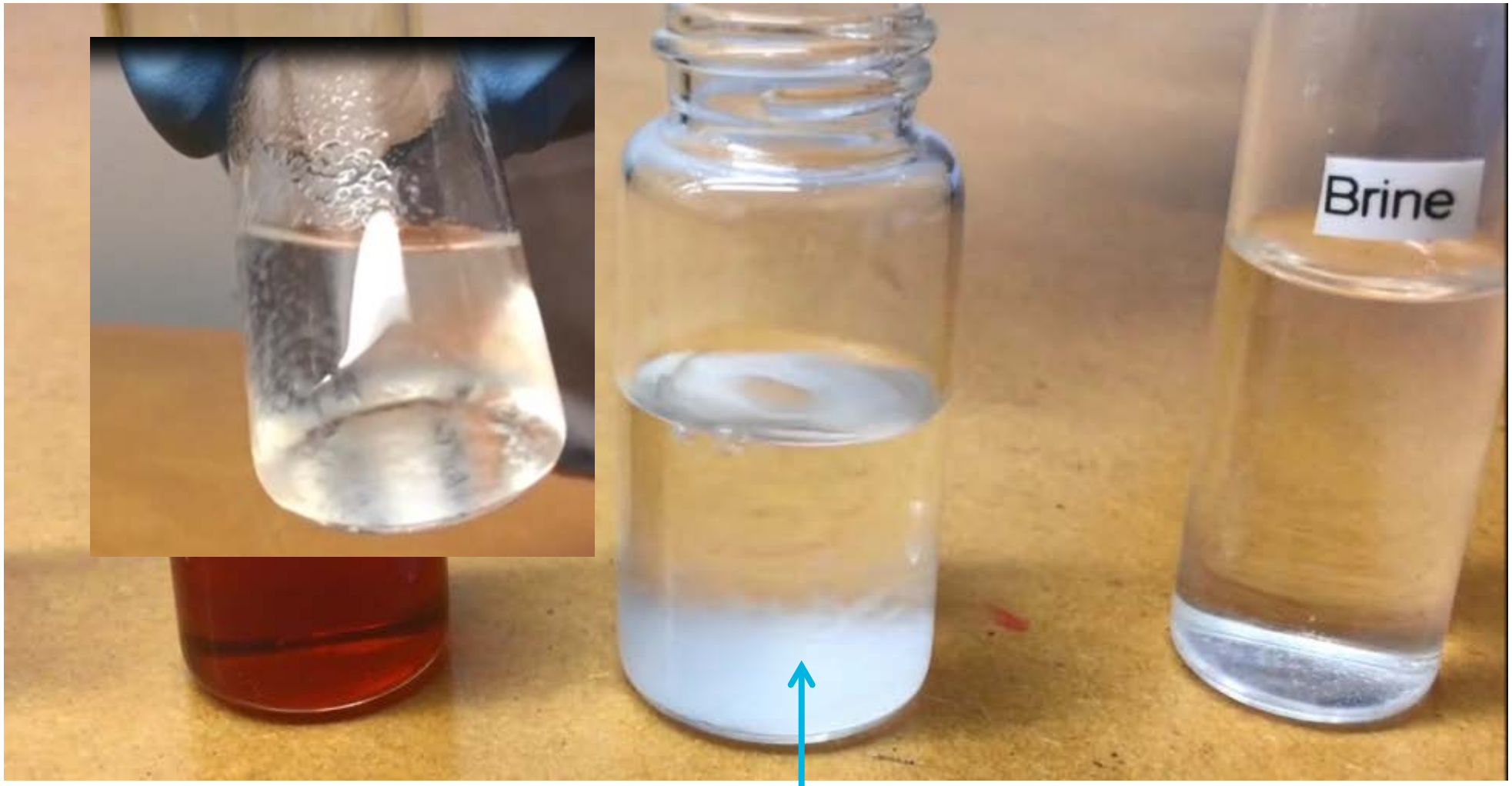
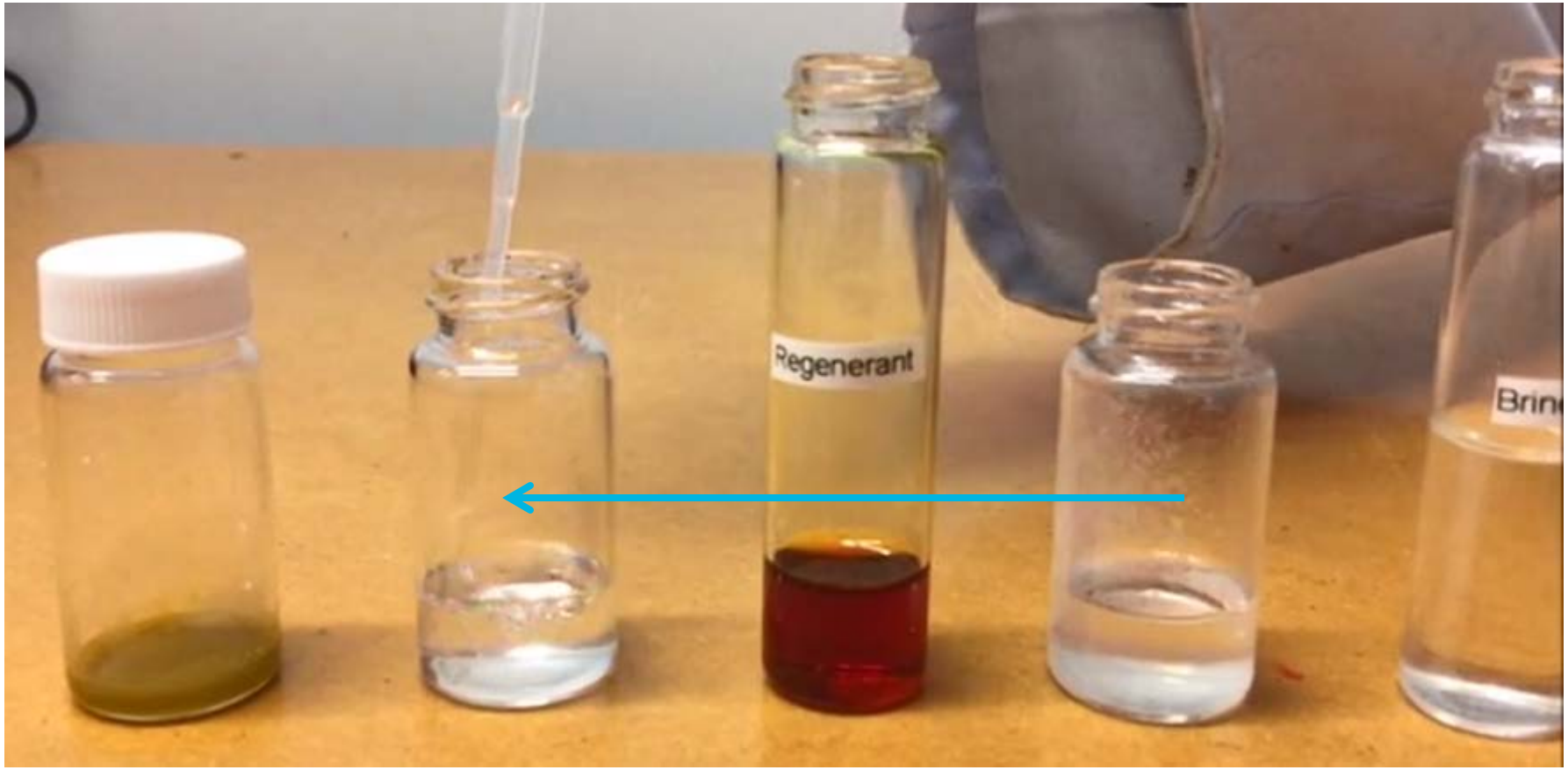
AQUAFORTUS Forward Osmosis ZLD/正滲透零排放



AQUAFORTUS Forward Osmosis ZLD/正滲透零排放

Transfer Water-Enriched FO Solution to Another Vial



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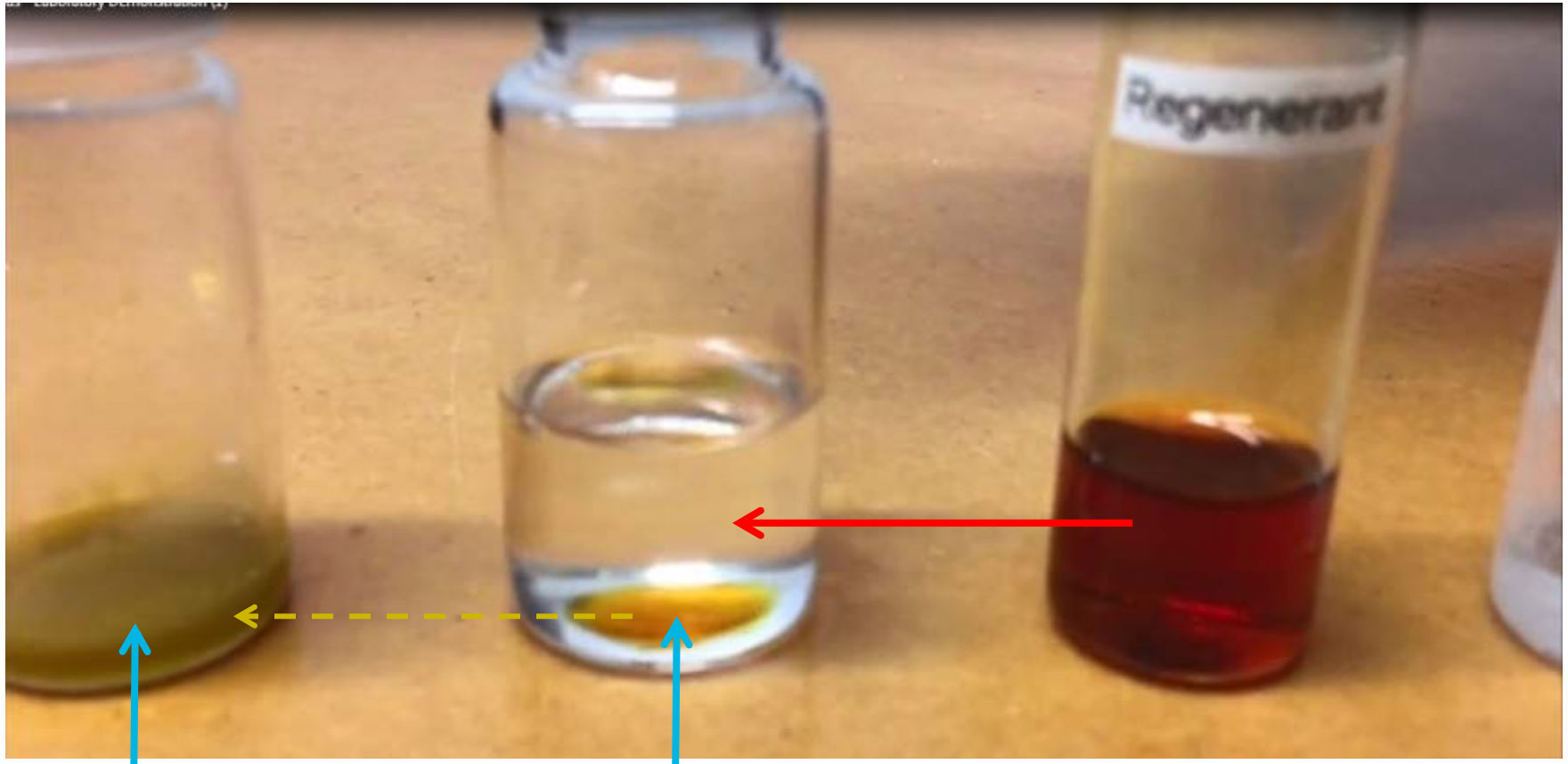
AQUAFORTUS Forward Osmosis ZLD/正滲透零排放

Step 2. Add Regenerant to remove water from FO solution



Collected used regenerant

FO solution bound with Regenerant

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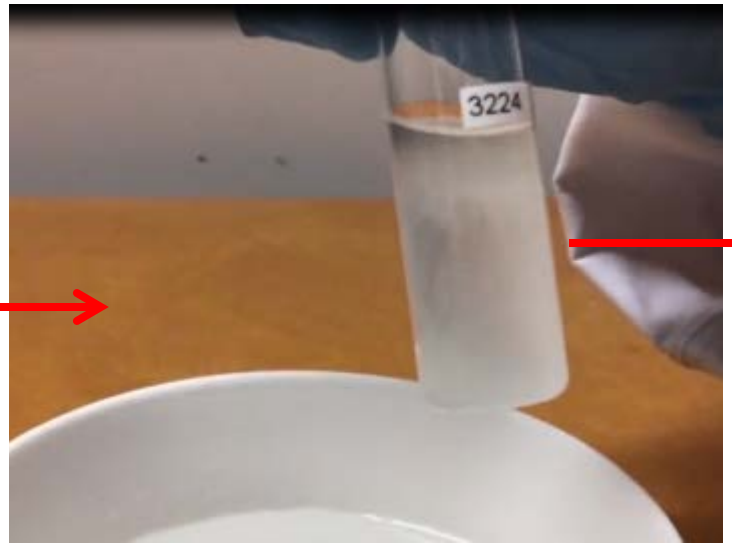
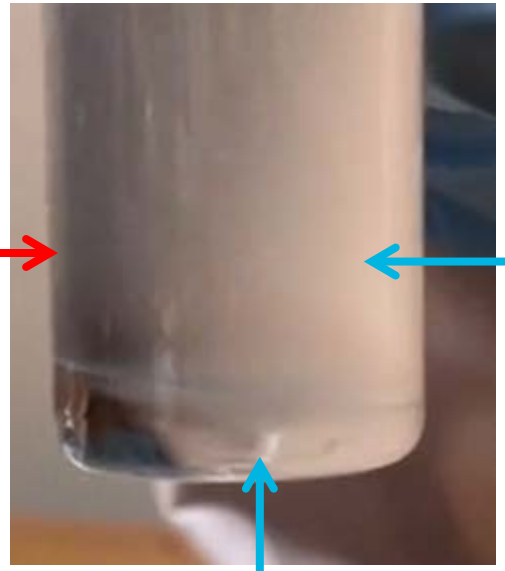
AQUAFORTUS Forward Osmosis ZLD/正滲透零排放

Step 3. Add Regenerant to remove water from FO solution & Recover FO solution





FO solution

Increase Temperature by 4 ^{o}C

Water

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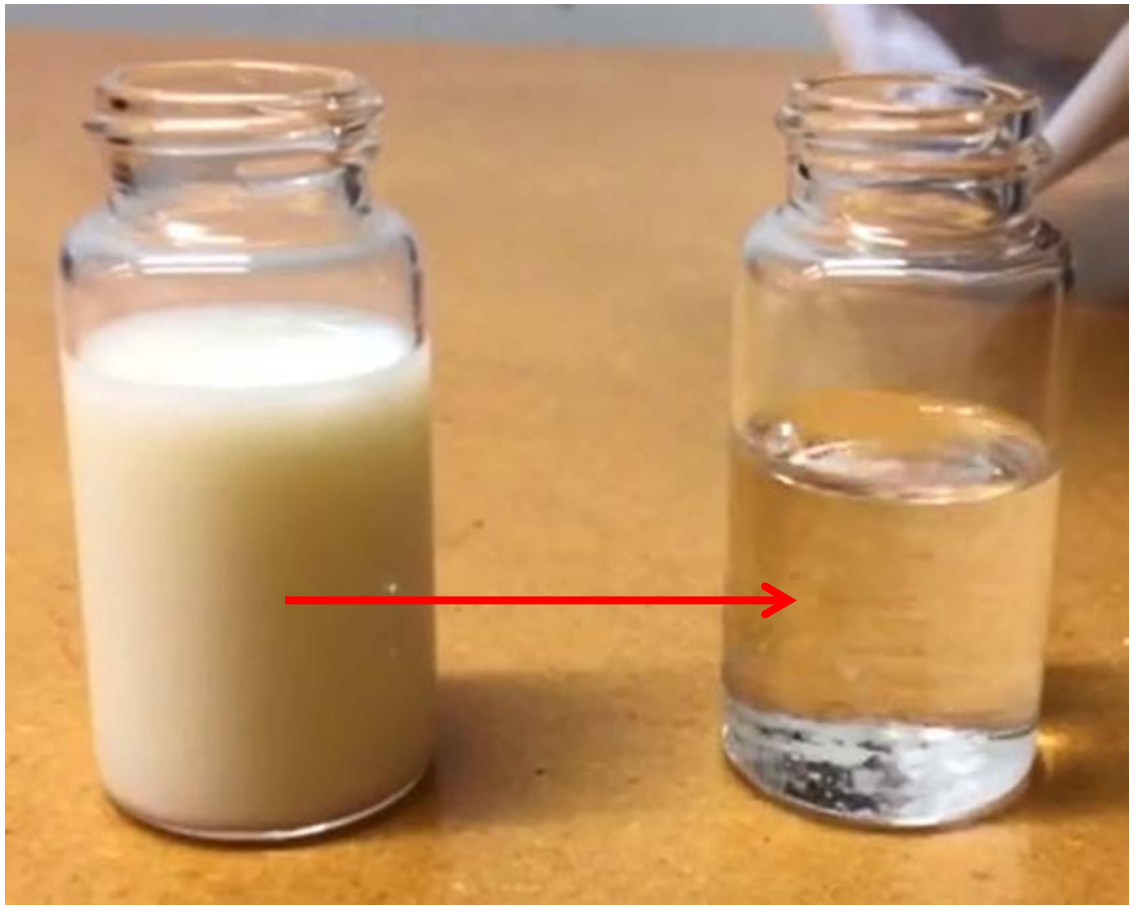
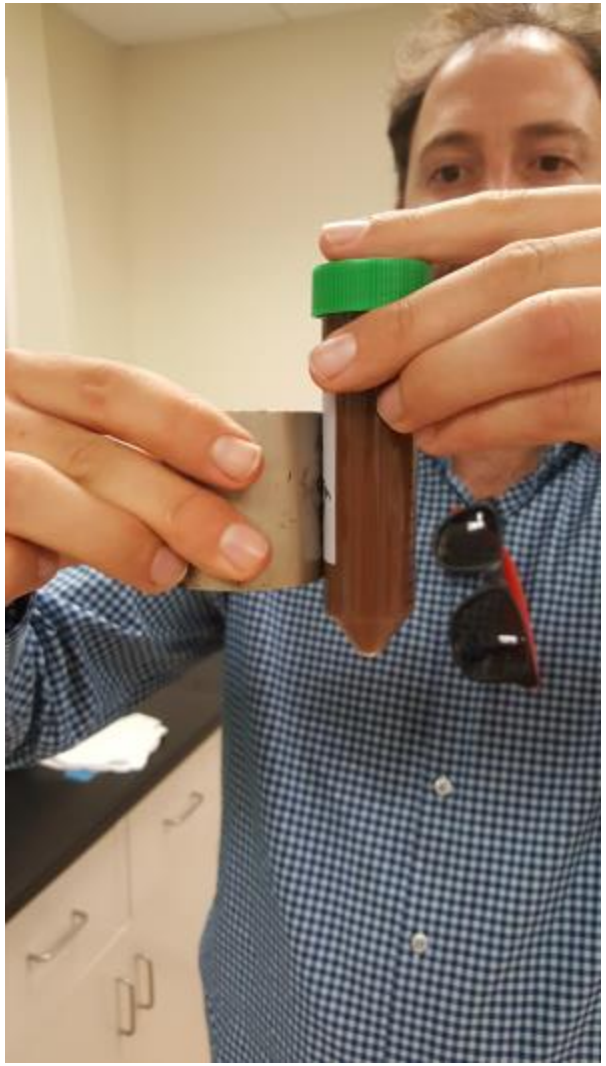
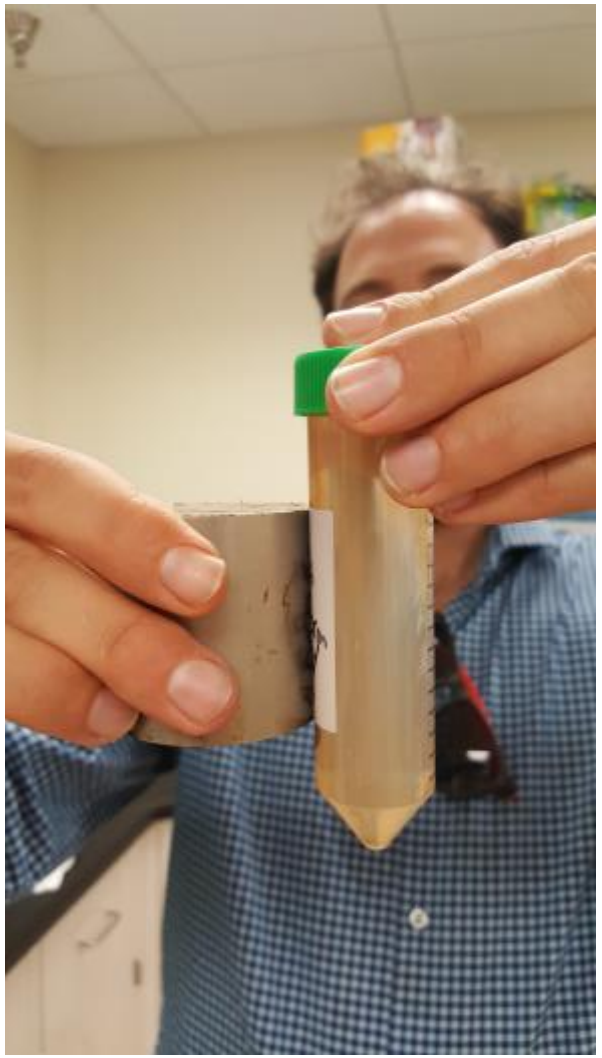
AQUAFORTUS Forward Osmosis ZLD/正滲透零排放

Experiment with Milk to form Milk Powder



Advantages (ADS) Demonstration for Selenium Removal





Desalination with Renewable Energy Source

- Solar Energy
- Wind Power

Wind Power & Desalination

- Wind power is used to provide part of desalination energy in Australia (Denham, Shark Bay), United Arab Emirates (Sir Bani Yas Island), Spain and Scotland


Shark Bay


Spain


Sir Bani Yas Island


Scottish North Sea

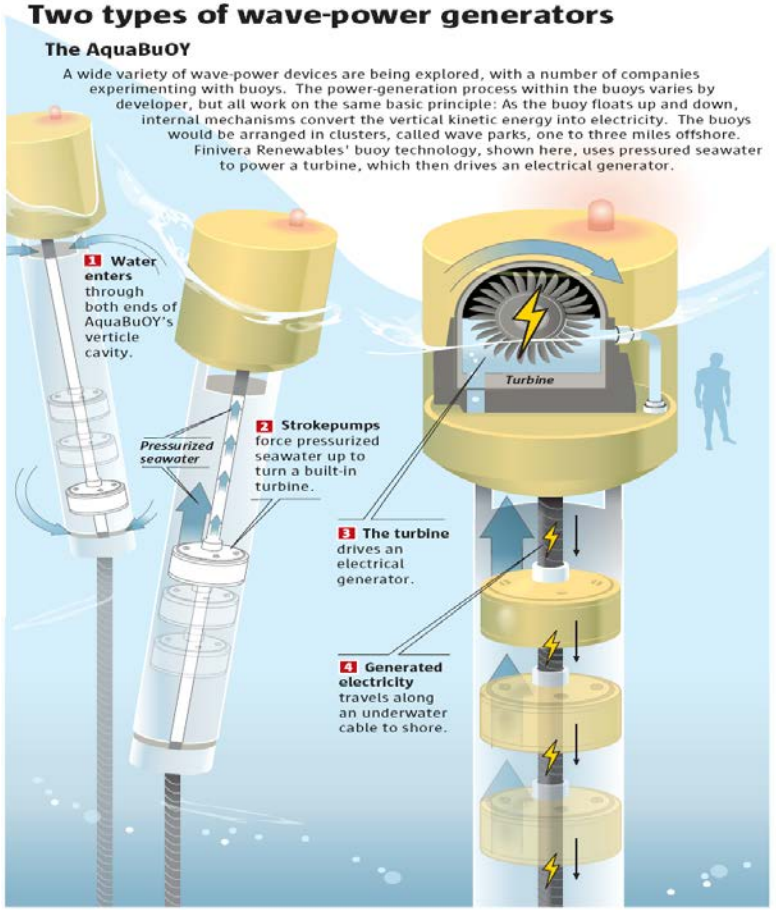
Taping Tidal Energy: The Wave of the Future

The Seattle Times
seattletimes.com
Sunday, October 7, 2007 - Page updated at 02:04 AM

Two types of wave-power generators

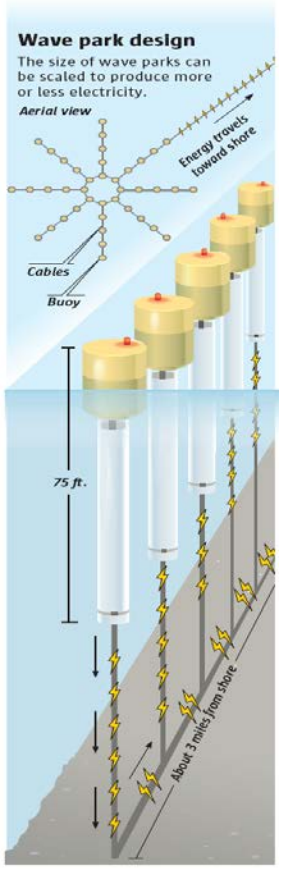
The AquaBuOY

A wide variety of wave-power devices are being explored, with a number of companies experimenting with buoys. The power-generation process within the buoys varies by developer, but all work on the same basic principle: As the buoy floats up and down, internal mechanisms convert the vertical kinetic energy into electricity. The buoys would be arranged in clusters, called wave parks, one to three miles offshore. Finivera Renewables' buoy technology, shown here, uses pressured seawater to power a turbine, which then drives an electrical generator.



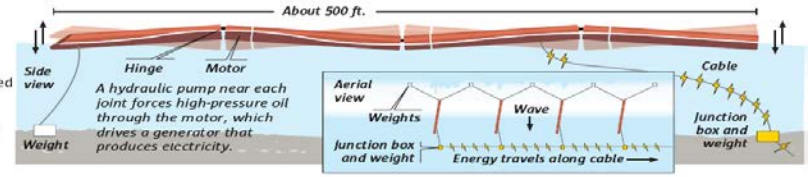
Wave park design

The size of wave parks can be scaled to produce more or less electricity.



The Pelamis

This snake like power converter generates electricity with three hydraulic pumps activated by hinged pontoons that move with passing waves. The Pelamis is loosely anchored so that most of the wave motion is absorbed by the device and converted to electricity.

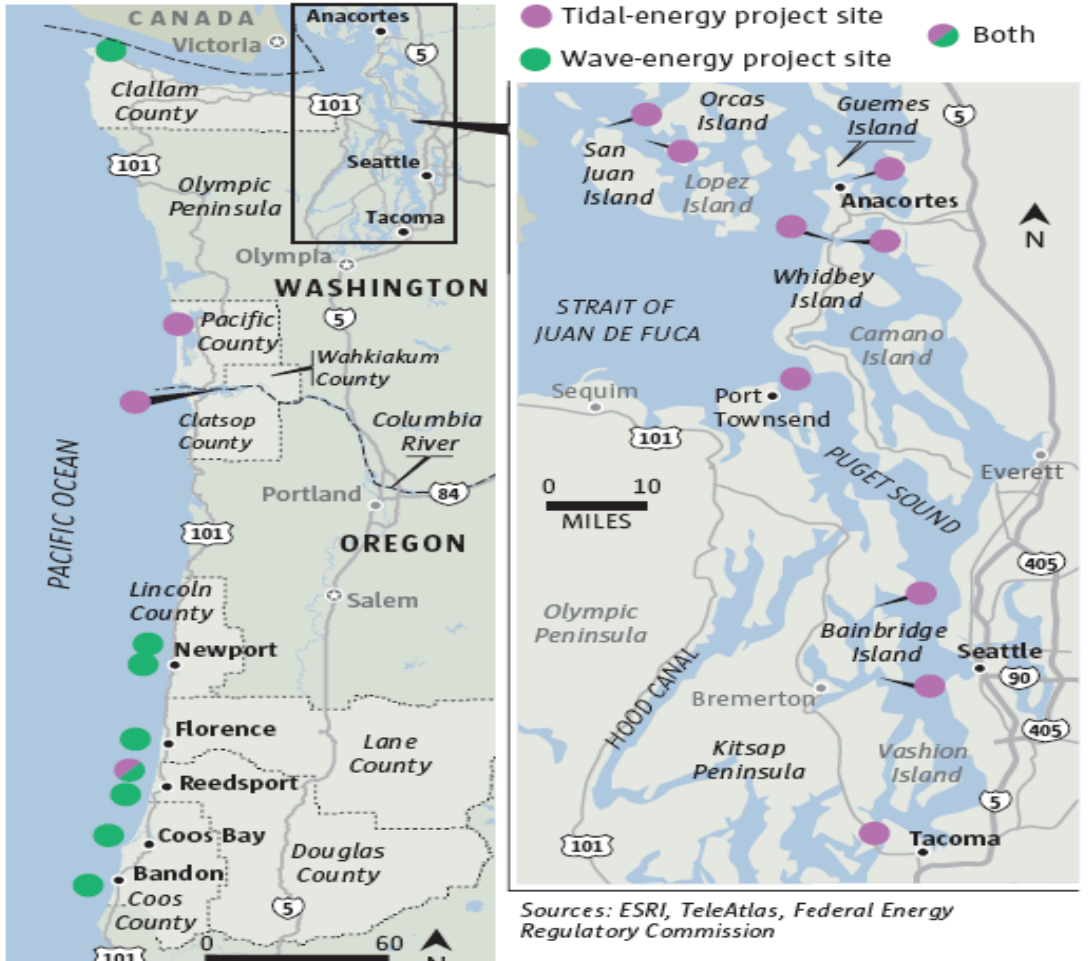


ources: Finavera; Ocean Power Delivery, Ltd.

graphic by KRISTOPHER LEE, research by WHITNEY STENSRUD/THE SEATTLE TIMES

The rush is on to tap the ocean for power

Locations for nearly 20 proposed tidal or wave-energy power-producing projects in the Northwest:



Sources: ESRI, TeleAtlas, Federal Energy Regulatory Commission

MARK NOWLIN / THE SEATTLE TIMES

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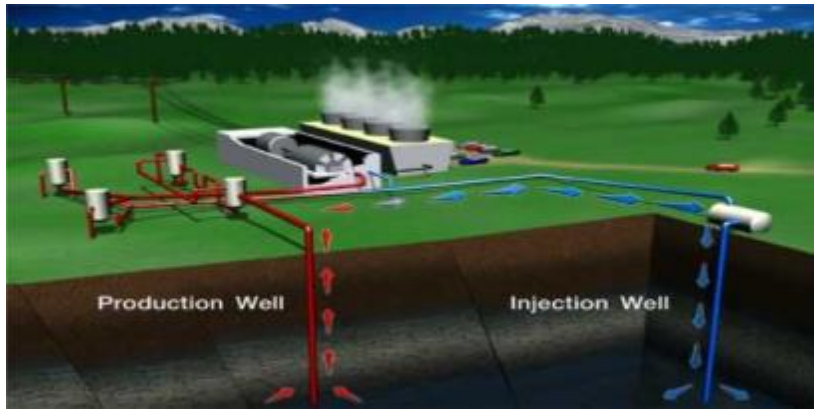
Other Major Challenge for Seawater Desalination…

- Water is not always at the location where people need it. A long, expensive conveyance pipeline could be needed

- Environmental Impact (permitting)

Think Outside the Box

- Precipitation control (weather modification)
  - Cloud seeding
  - Rain delay
- Geothermal energy
- Get water out of the salt (instead of getting salt out of water)
- Greywater/Blackwater separation
  - Indefinite close-loop reuse
- Agricultural water conservation
- Industrial water conservation & reuse



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Summary

- **Water challenges are real and serious**
- **Water crises will escalate in the near future as global warming, population, and water consumption habits continue to grow**
- **Before weather modifying technologies become feasible, fundamental breakthrough in desalination technology will be the key to solving world-wide water shortage problem**
- **“Blue Gold” is the commodity for the 21st Century**