Aqua Access™

Innovations in Water Technology

On Site Generation of Oxidants

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OSG Is Completely Benign

Salt + **Water** + **Electricity** → **Liquid Chlorine**

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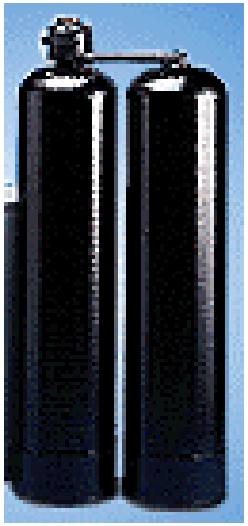
On Site Generator

Water

Salt

Oxidant Storage Tank



Chlorine Solution

Application

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K1 and K2

- **Treatment Capacity** – Produces a strong chlorine disinfection solution in a continuous batch operation. Runs until the bottom solution tank is full and then goes to standby until the tank level drops
- **Power –** 110/220 VAC single phase power
- **Long-Term Functionality** – No consumables to replace. No parts to replace. 10 year shelf life
- **Convenient Size** – 26” Dia x 42” High. Convenient height for loading a bag of salt in the upper salt tank
- **Sustainable** – only consumable is common salt and electricity
- **Reduces Chlorine Taste** – mixed oxidants have less chlorine taste than chlorine gas of sodium hypochlorite
- **Ease of Operation** – Fully automated operation. Simple display with indicator lights for all functions. No pumping or clogging
- **Residual Disinfectant** – prevents recontamination of water by maintaining a chlorine residual while providing enhanced oxidation with mixed oxidants
- **Economic Model –** For village, community or light industrial applications. Capacities of 1 or 2 kilograms of chlorine production per day. Can be produced locally at low cost using rotationally molded low density polyethylene

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K Series

•Can be configured for either 3, 5, 7, or 11 kilograms per day of free available chlorine production
• Stainless steel passivated enclosures to operate in any industrial environment.
• Includes separate power supply and fluid controls cabinets.
• External heat exchanger cools the control cabinet.
• Feed water temperature is maintained above 10^0C by an integral resistance heater thereby allowing feed water temperatures as low as 1C.
• Requires a water softener, brine generator tank, an oxidant storage tank, and a mode of injection.

	K Series
Capacity	3, 5, 7, or 11 kg/day FAC
Power	208 VAC, 1 ph, 50/60 hz, 30A
FAC Concentration	4,500 mg/L
Flow Rate	25 to 91 LPH
Feed Water Temp	>1°C < 30°C
Feed Water Pressure	3 bar minimum
Dimensions	0.7m W x 1.8m T x 0.25m D
Weight	140 kg

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K22-33-44

- Can be configured for either 22, 33, or 44 kilograms per day of free available chlorine production
- Stainless steel passivated enclosures to operate in any industrial environment.
- Includes separate power supply and fluid controls cabinets.
- Heat exchanger cools the control cabinet.
- Feed water temperature is maintained above 10^0C by an integral resistance heater thereby allowing feed water temperatures as low as 1C.
- Requires a water softener, brine generator tank, an oxidant storage tank, and a mode of oxidant injection.

	K22	K33	K44
Capacity	22 kg/day FAC	33 kg/day FAC	44 kg/day FAC
Power	2 circuits at 440 VAC, 3 ph, 50/60 hz, 25A OR 208 VAC, 3ph, 50/60 hz, 50A	3 circuits at 440 VAC, 3 ph, 50/60 hz, 25A OR 208 VAC, 3ph, 50/60 hz, 50A	4 circuits at 440 VAC, 3 ph, 50/60 hz, 25A OR 208 VAC, 3ph, 50/60 hz, 50A
FAC Concentration	5,000 mg/L		
Flow Rate	204 LPH	306 LPH	408 LPH
Feed Water Temp	>1°C < 30°C		
Feed Water Pressure	4 bar minimum		
Dimensions	1.2m W x 1.5m H x 0.7m D		
Weight	650 kg	680 kg	710 kg

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MIXED OXIDANTS
VS
ON-SITE HYPOCHLORITE

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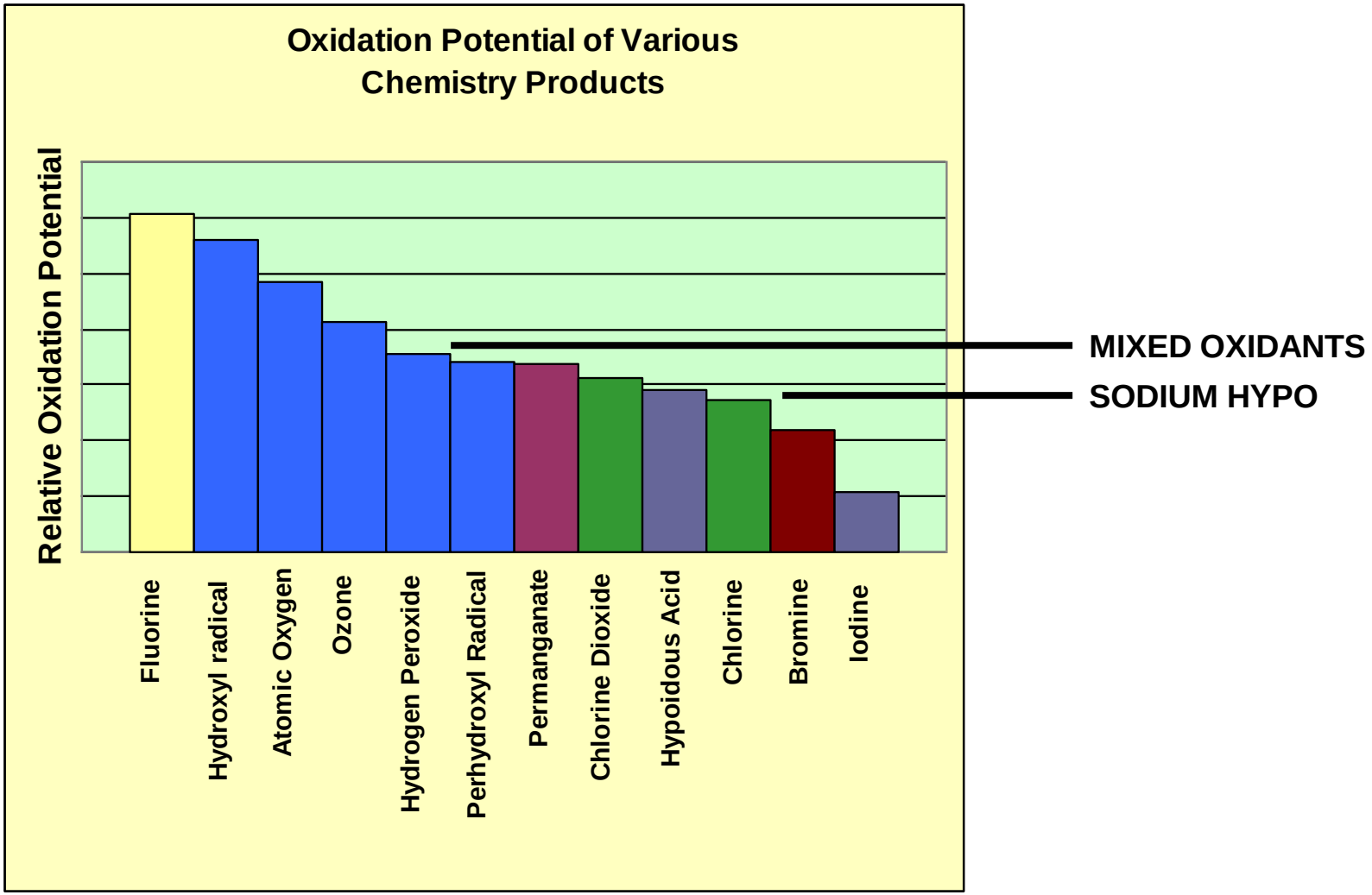
Oxidation Potential Correlates with Energy

The higher the energy applied, the stronger the oxidant produced



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Studies Show Mixed Oxidants Have Better Disinfection Efficacy

- Effective against a wider range of organisms
- Highly effective against biofilm
- Several orders of magnitude (logarithmic) higher inactivation
- Faster kill rate
- Reduced CT values (Contact x Time)

Aqua Access knows how to optimize OSG design for mixed oxidants or on-site hypo

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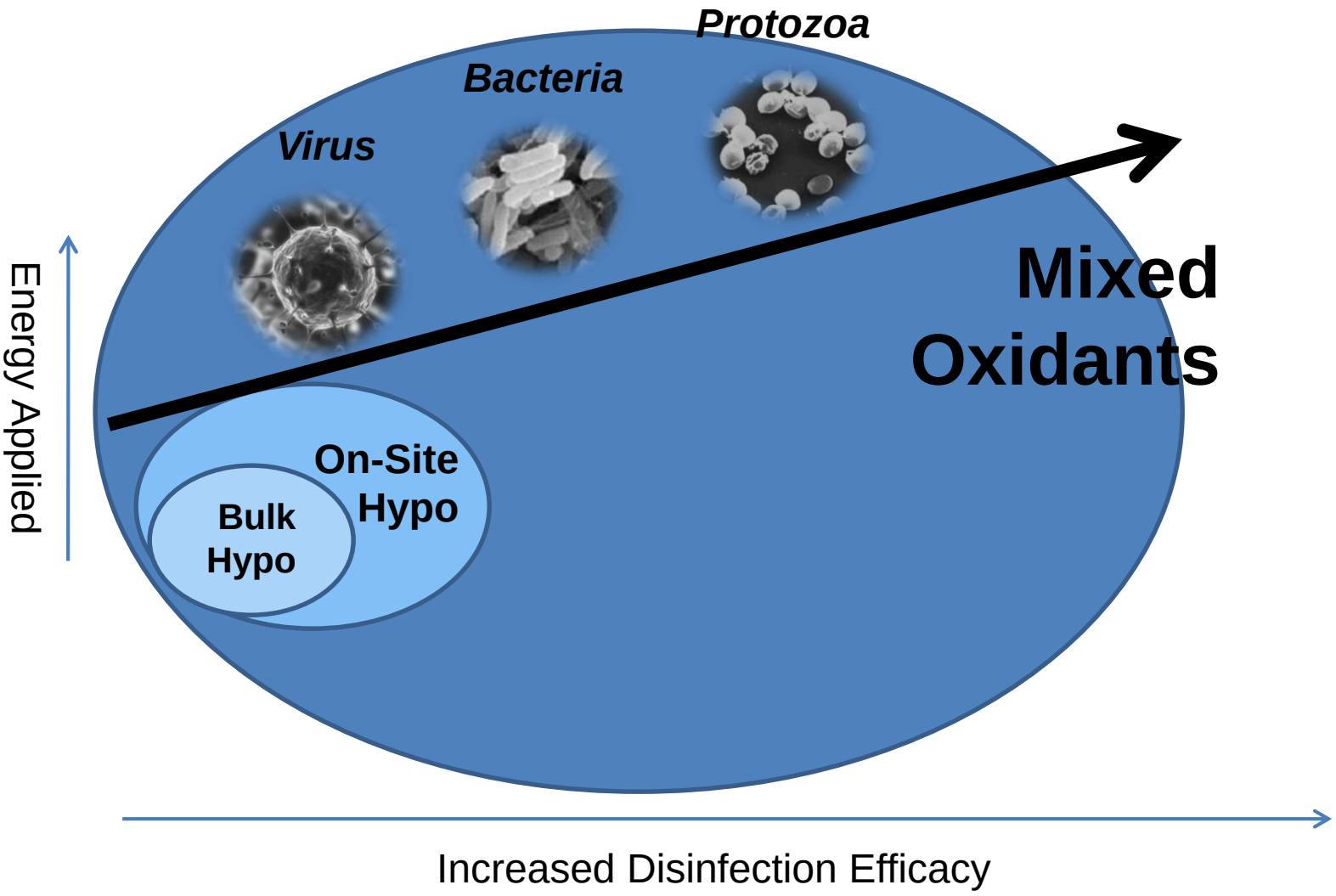
Mixed Oxidants Are Stronger than On-Site Hypo, which is Stronger than Bulk Hypo



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COST

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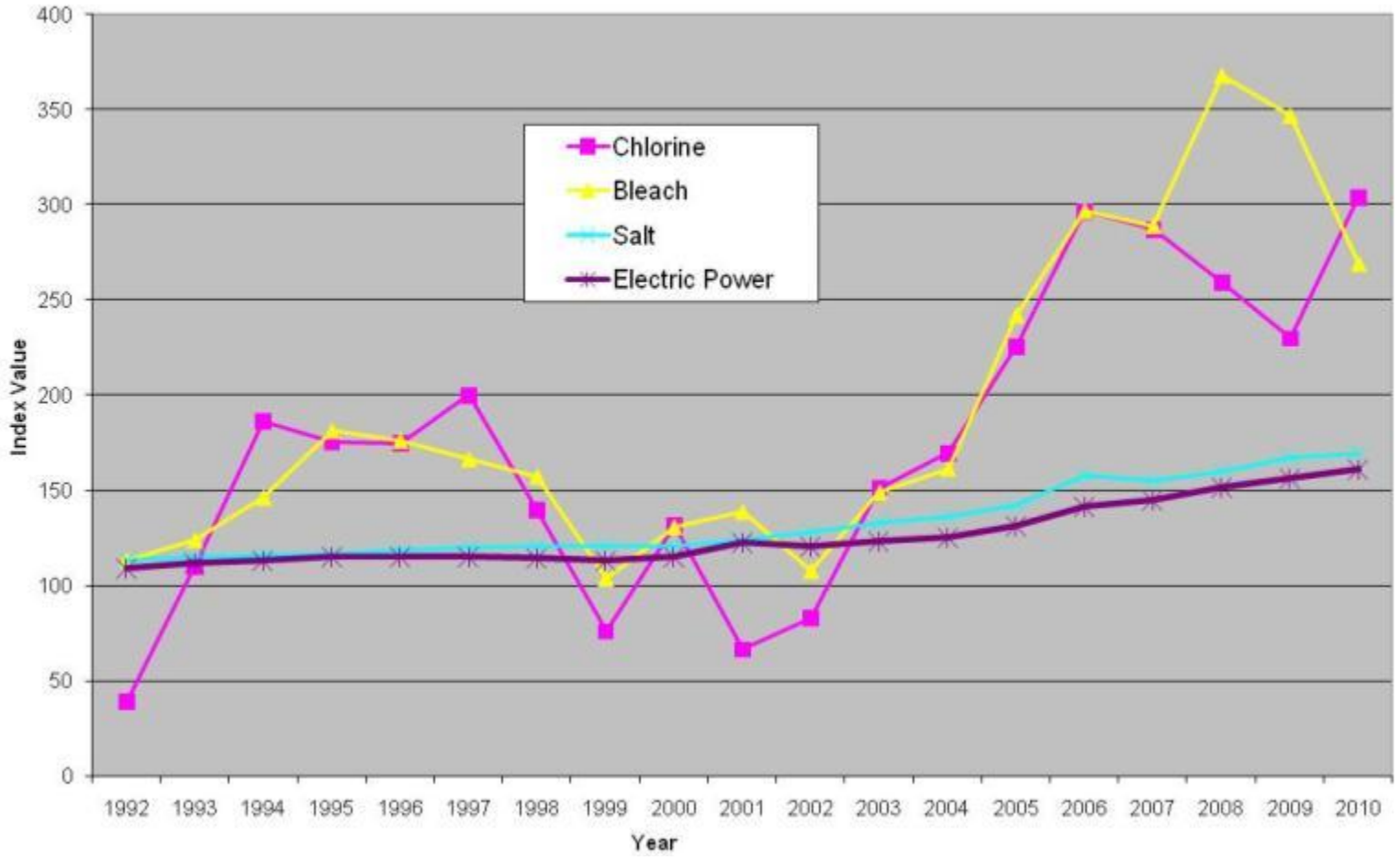
Chemical raw materials costs are rising, while OSG feedstocks are more stable



Producer Price Index, U.S. Department of Labor, Bureau of Labor Statistics

Bulk hypo estimated from chlorine and caustic soda prices (excludes transportation costs); Chlorine gas compressed or liquefied; Salt evaporated or solar; and Electric power

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OSG Cost Structure

- Higher upfront capital cost, but lower operating and maintenance costs
- ROI typically occurs in 1 to 3 years
- Costs associated with other processes are often reduced
  - Reduced pH adjustment chemicals
  - Longer filter runs
  - Reduced alum / polymer consumption
  - Reduced sludge handling
  - Reduced corrosion

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Delivery of Salt Is 4X More Efficient than Delivery of Bulk Hypo

	Hypo Tanker	Salt Tanker
Tanker Capacity	15,000 L (18,500 kg)	21,800 kg
Notes	1L of 12.5% hypo weighs 1.2 kg by mass, but only generates 0.12 kg FAC	1.2 kg of salt generates ~0.4 kg FAC – the same mass of salt offers 3.4X more capacity than hypo
FAC Capacity per kg Mass	0.100 kg FAC	0.333 kg FAC
FAC Capacity by Load	**1,800 kg FAC**	**7,200 kg FAC**
Style of Truck		

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OSG Reduces Transport, Logistics, and Fuel Requirements

Transport requirements are reduced 75% with on-site hypo and 83% with mixed oxidants

	Bulk Hypo	On-Site Hypo	Mixed Oxidants
Days of Supply	40	160	229
Deliveries per Year	9.1	2.3	1.6
Delivery Reduction	---	75%	83%

(Assuming that bulk hypo and salt are transported the same distance)

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MAINTENANCE

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Maintenance is Easier with OSG than with Bulk Hypo

- No dilution to maintain chlorine stability – disinfectant is < 1% FAC, and is generated on demand and used in 24 hours
- Logistics are minimized – OSG salt storage can be designed for long time periods
- OSG pH is near neutral, so acid addition is reduced or eliminated
- Corrosion is virtually eliminated since there is no off-gassing
- No scaling of pumps, backpressure devices, rotometers, or piping

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OSG Maintenance

- Brine tank fill (manual vs. automatic) – occurs weekly to yearly, depending on size
- Water and brine filter changeout – monthly to quarterly, depending on water and salt quality
  - Takes 10 min. per changeout
- Acid-washing cell – quarterly to annually, depending on salt quality
  - Takes 30 min. per acid wash
  - There is NO membrane in the cell, minimizing cell maintenance requirements

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SAFETY

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OSG is Safer than Conventional Biocides

- **Biocides** - bleach, sodium bromide, bromines, proprietary biocides, and various others
- **OSG** - uses only salt

	Biocides	Salt
NFPA Safety Rating	2 or 3	0
Spills reportable	Yes, often	No
Pressurized lines	Yes, often	No
Storage issues	Yes, often	No

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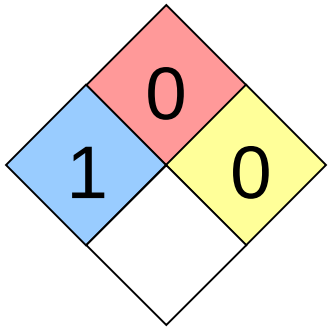
OSG Is Safer Than Bulk Hypo

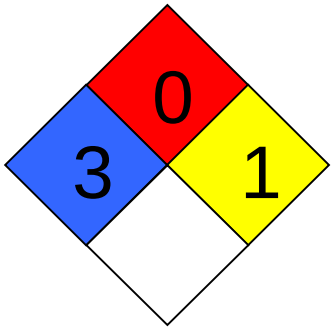
- Cannot form chlorine gas if acid is accidentally added to hypo tank (due to rapid drop in pH)
- Accidents with bulk hypo are actually *more* prevalent than with chlorine gas
- 90% of hypo accidents are attributed to customer storage or process error
- Any safety risks with OSG are easily controlled – do not rely on operator intervention

OSG



vs.

Bulk Hypo



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OSG Safety

- Hydrogen Venting
  - All electrolytic processes generate hydrogen gas
  - Hydrogen is lighter than air and can be easily vented to prevent concentration
  - Passive engineered vent systems maintain hydrogen at <1% (the Lower Explosive Limit (LEL) is 4.1%)
  - Automated dilution blower systems available
- Electrical Safety
  - Small OSG systems are low voltage
  - Higher voltage systems use electrical interlocks
  - Maintenance can be performed without any risk of lethal shock

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ENVIRONMENTALLY FRIENDLY

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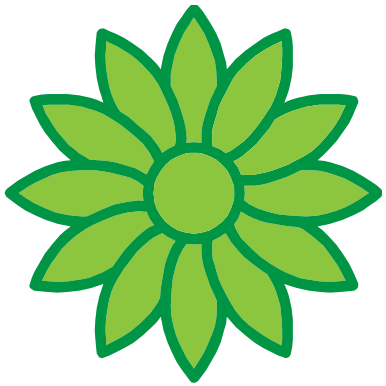
OSG Is A Green Technology

- Eligible for green certifications
- Eliminates transport, decontamination, and disposal of empty chemical drums
- Reduces fuel consumption and transportation logistics
- Reduces carbon emissions
- Reduces road damage
- Improves thermal efficiency
- Reduces energy requirements



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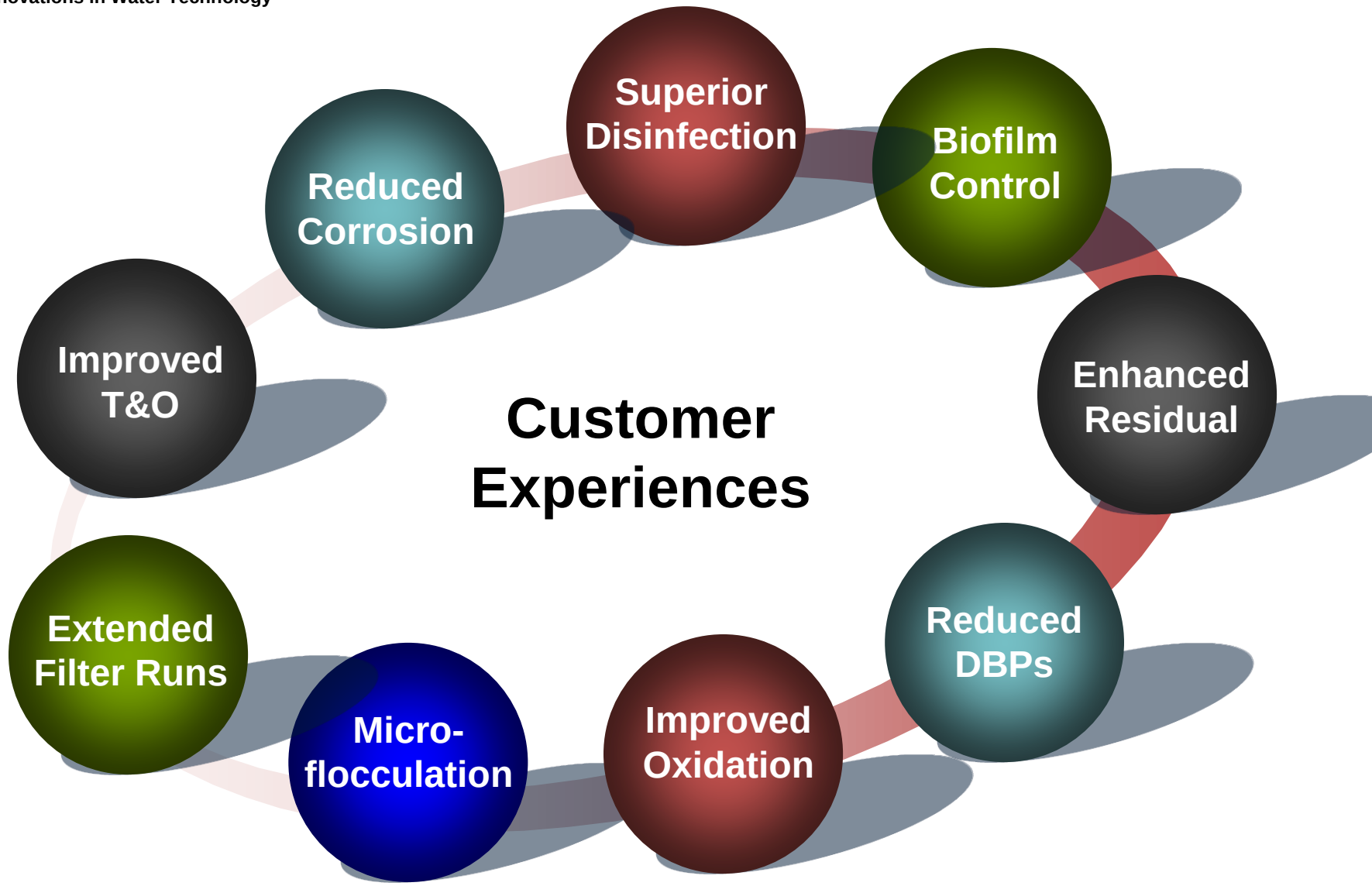
Advantages of Mixed Oxidants



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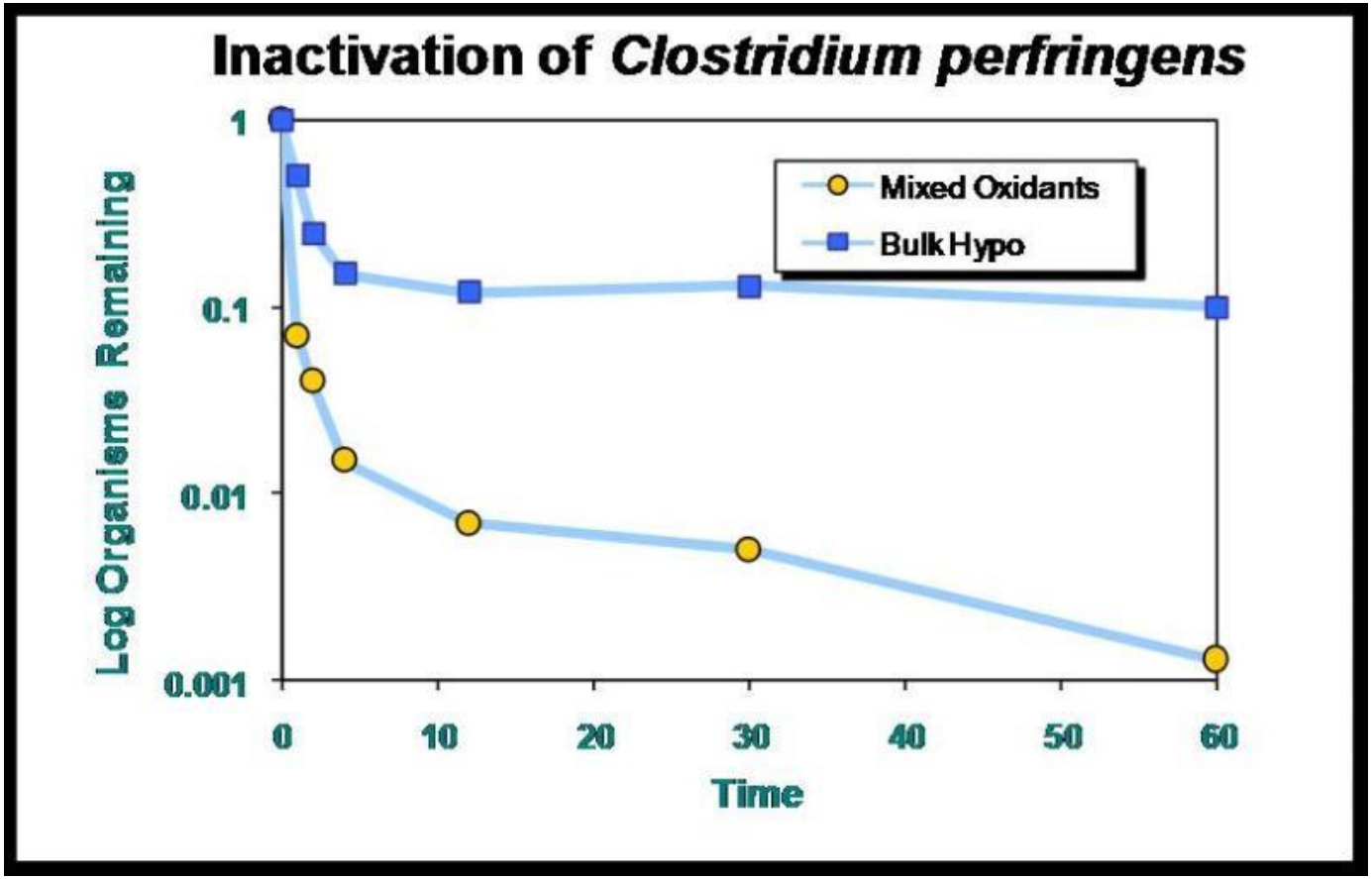
Superior Disinfection



Dr. Linda Venczel, University of North Carolina

Ref: Venczel Dissertation

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Biofilm Elimination

Bulk Hypo

Legionella resides in biofilm - the facility was not in compliance with health standards

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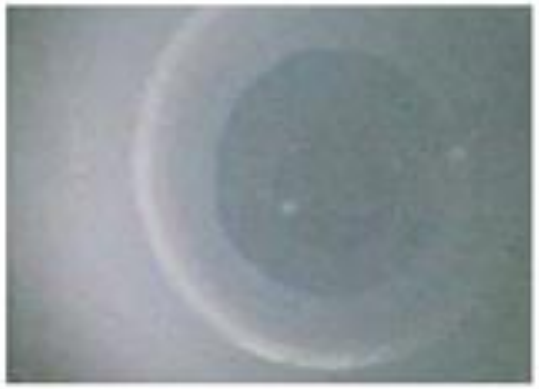
Mixed Oxidants



In 6 days most biofilm was removed. Completely removed in 22 days.

Inono Hot Springs, Japan

Bore Scope Camera Video Tape by NSP

Courtesy: NSP Corporation

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Longer-Lasting Chlorine Residual in the Distribution System

- **Can dose 30% less at the plant to achieve the same chlorine residual in distribution**
- **Can dose the same as with chlorine gas or sodium hypo as before, but maintain a higher chlorine residual in the distribution system**
- **Can maintain a chlorine residual value much further out in distribution**
- **Can maintain a chlorine residual value for a much longer time in the distribution system**

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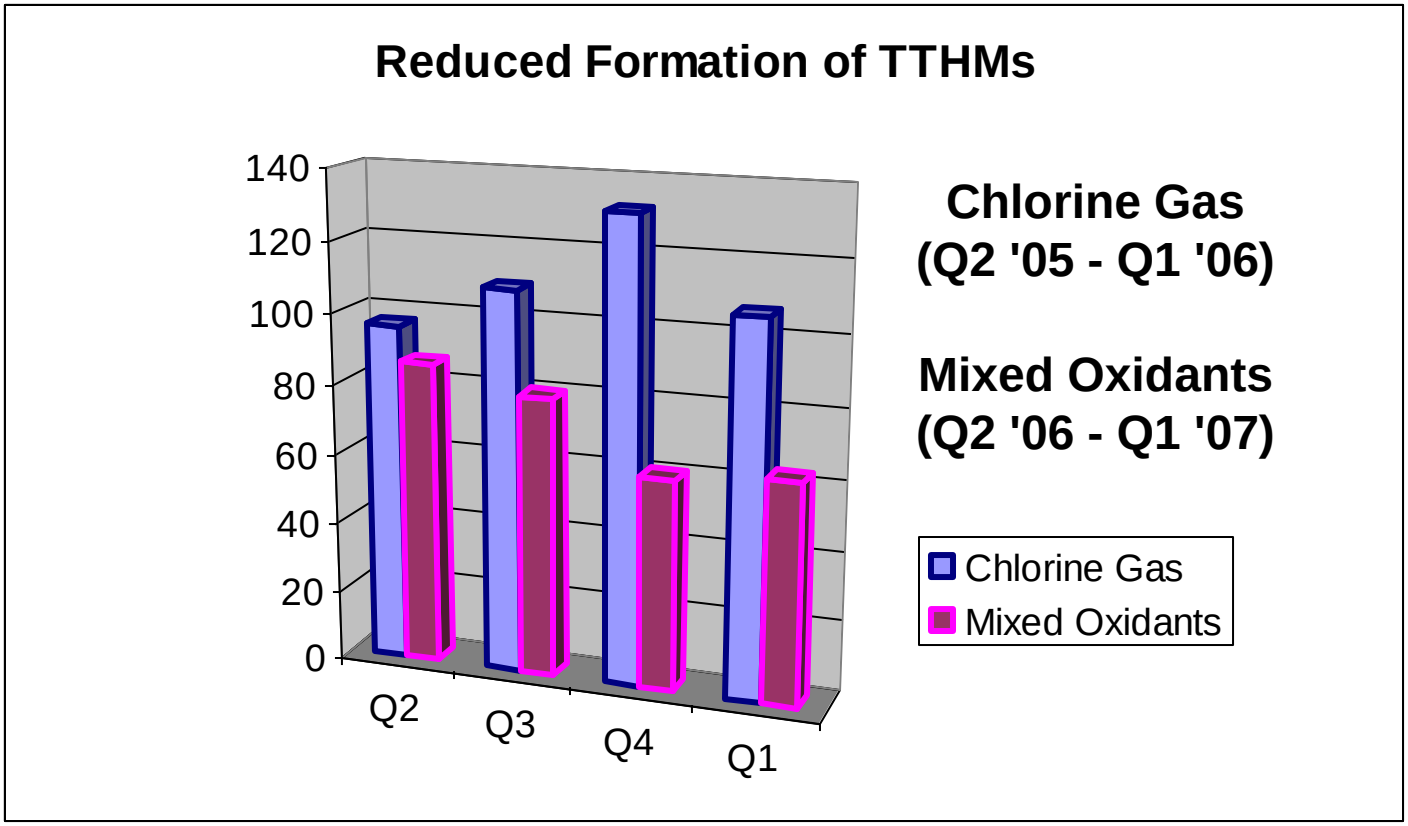
Disinfection By-Products Reduced by 35%



Coto Laurel, Puerto Rico

Ref: AWWA Journal

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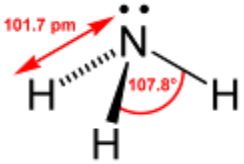
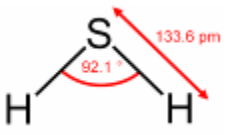
More Rapid Oxidation

- ***Iron (Fe)***

- ***Manganese (Mn)***



- ***Ammonia (NH_3)***



- ***Hydrogen Sulfide (H_2S)***

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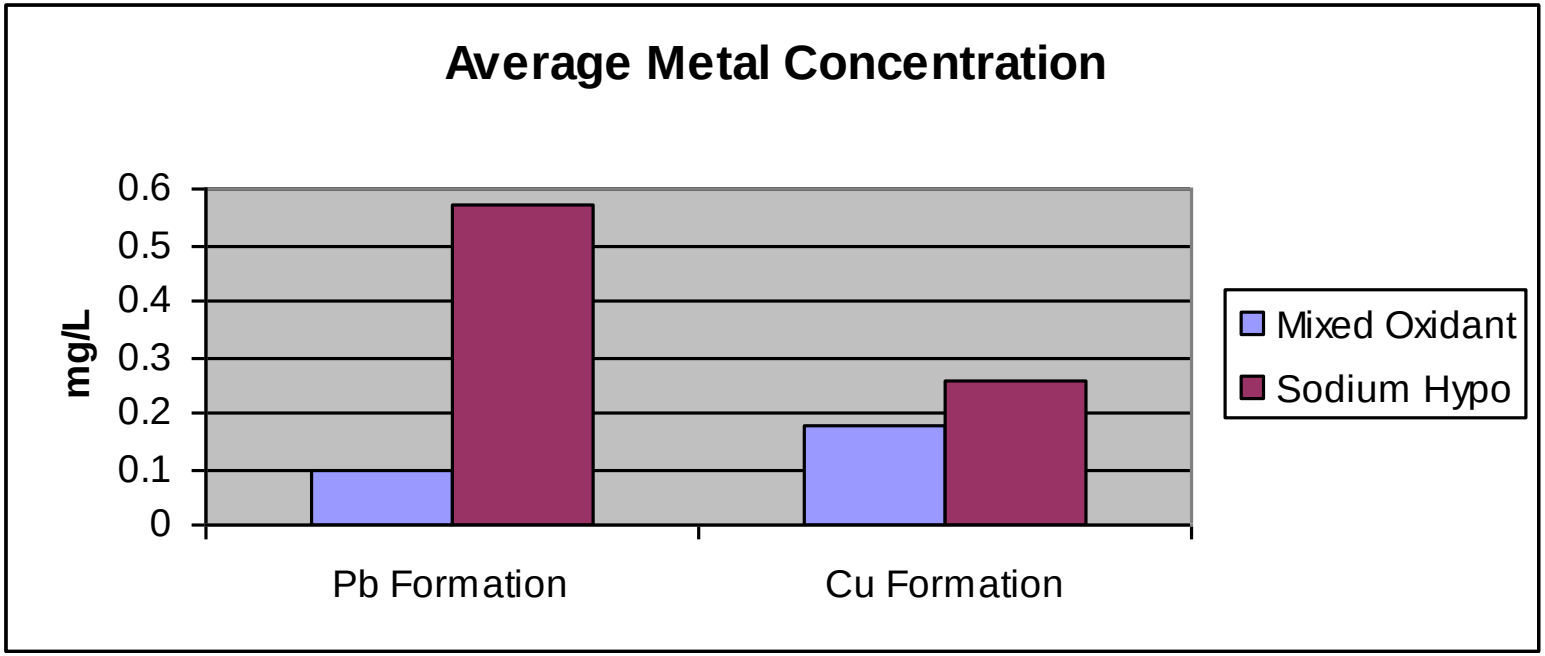
Corrosion Is Reduced

Mixed oxidants form only 18% of Pb levels and 69% of Cu levels in pipelines versus levels formed by sodium hypo



4 weeks exposure, 1 mg/L FAC Residual

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Comparison of Chlorine Alternatives

	Chlorine Gas	Bulk Hypo	On-Site Hypo	Mixed Oxidants
Low Lifecycle Cost	Yes	No	Yes	Yes
Green	No	No	Yes	Yes
Safe	No	Maybe	Yes	Yes
Easy to Maintain	Yes	Maybe	Yes	Yes
Superior Disinfection	No	No	No	Yes
Biofilm Control	No	No	No	Yes
Enhanced Residual	No	No	No	Yes
Reduced DBPs	No	No	No	Yes
Improved Oxidation	No	No	No	Yes
Microflocculation	No	No	No	Yes
Extended Filter Runs	No	No	No	Yes
Improved T&O	No	No	No	Yes
Reduced Corrosion	No	No	No	Yes

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MIXED OXIDANT BENEFITS BY APPLICATION

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Potable Water Benefits

- Biofilm Control
  - Much more durable chlorine residual – possible elimination of booster stations
  - Reduced chlorine demand (30%)
  - Reduced TTHM by-product formation (30%)
  - Improved filter backwash cycle (100%)
- Enhanced Oxidation
  - Reduced alum and polymer consumption (40%)
  - Reduced sludge removal (20%)
  - Better tasting water
- More Neutral pH
  - Reduction in lime / acid requirements (50%)
  - Reduced pipe corrosion (80% for lead, 30% for copper)

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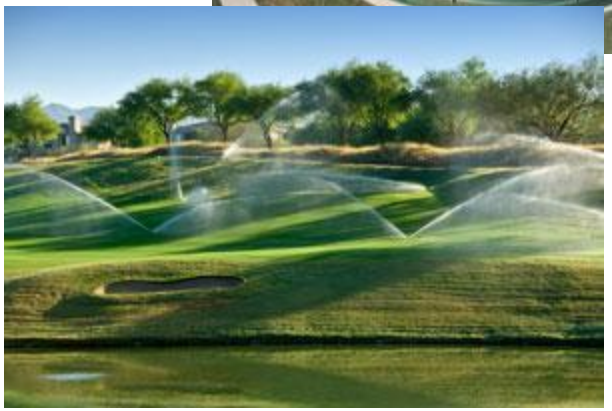
Wastewater / Water Reuse Benefits

- Wastewater
  - Reduced chlorine demand
  - More stable dechlorination requirements
  - Reductions in dechlorination chemicals



- Water Reuse
  - Biofilm control
  - Improved water quality for irrigation, cooling water, or other reuse applications
  - Chlorine residual required

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Cooling Tower Benefits

- No algae growth – easier to maintain
- Effective at a high pH
  - Can reduce or eliminate acid requirements

- More thorough disinfection
- Biofilm removal
  - Maximizes thermal efficiency
  - Eliminates *Legionella*

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Aquatics Benefits

- Better bacterial control
  - No shocking required
  - Less maintenance – reduces algae and biofilm formation
- Reduced chlorine demand
- Better water quality
  - No itchy eyes
  - No burning skin
  - Improved water clarity
- Better air quality
  - Less chlorine odor
  - Potential to reduce asthma occurrences
  - Less corrosion of facility structures
- Neutral pH reduces need for adjustment chemicals

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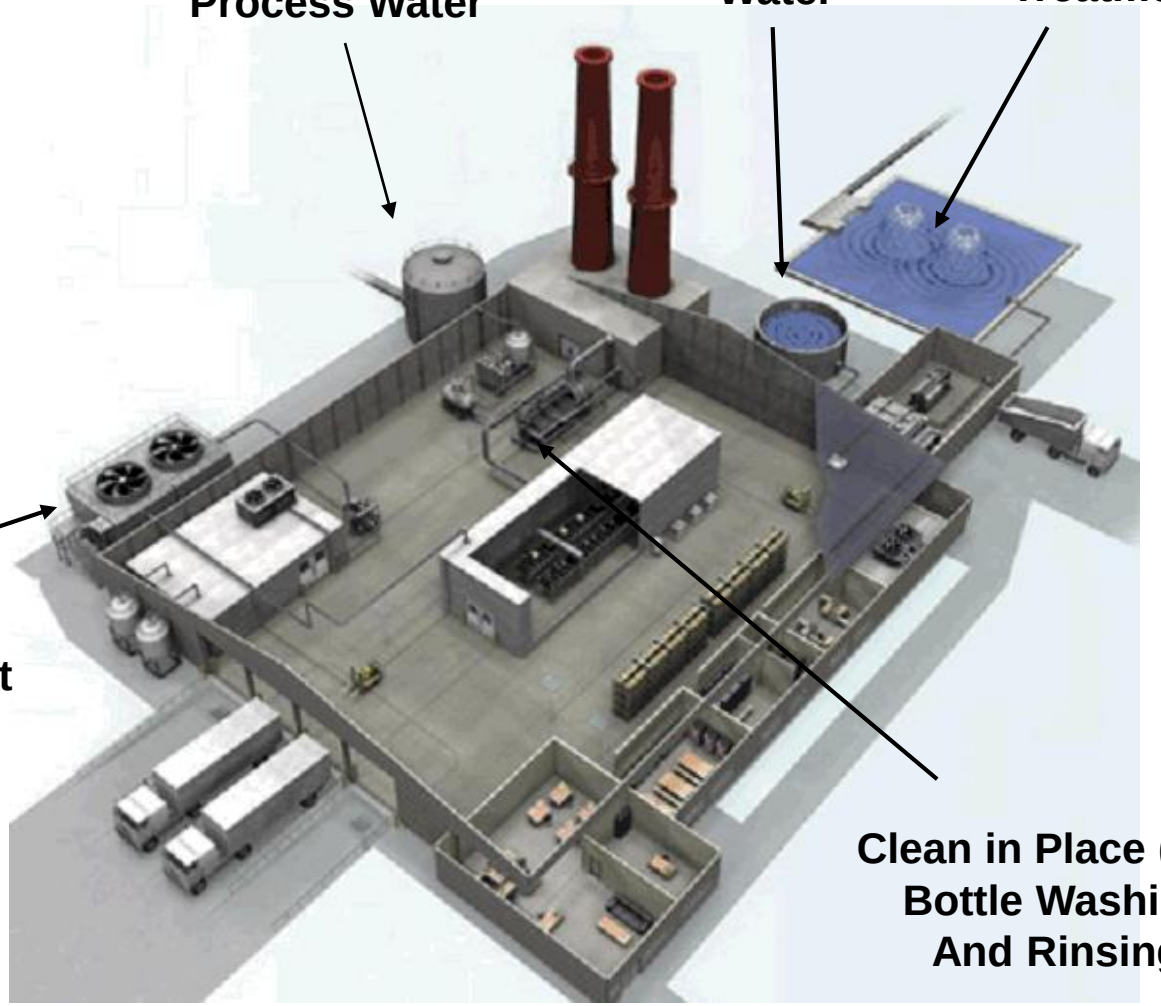
OSG Food and Beverage Applications



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Beverage Processing Benefits

- Better microbial control
  - Improved compliance
  - Reduced risk of shutdown
  - Reduced microbial-induced corrosion (MIC)
- Reduction of CIP cycles
  - Increased time for production
  - Reduced energy consumption (cleaning method is non-thermal)
  - Cost savings
- Can be used in each step of plant process
  - CIP, cooling towers, process water, wastewater

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Mixed Oxidants Enhance Productivity via Reduced CIP Time

Traditional Process: more steps mean less beverage production time

90 Minutes

Mixed Oxidants: requires only 3 steps, significantly increases beverage production time

50 Minutes

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Individual Water Purifier

"Safe Water for the Price of Salt"

Markets

RETAIL:

Hikers, campers, and outdoorsmen want the best technology for “found” water sources.

GOVERNMENT:

Disaster victims

Relief workers

Marines

Soldiers

DEVELOPING WORLD:

1.2 billion people without safe water.

Half of the hospital beds in developing countries occupied by people with water-borne disease.

According to WHO 3.4 million people die each year from waterborne disease.

The WHO has proven that chlorine saves lives.

Overview

h2go™ purifier

- 4 ounce, low cost, hand held water purifier
- Uses only salt – no replaceable components
- Produces chlorine and peroxide.
- Kills all classes of microorganisms.
- Treats 300 liters on one charge. Recharge internal battery 1000X.

Includes brine bottle, charger, and chlorine test strips

Solution

An Innovative Reverse Osmosis Membrane Technology

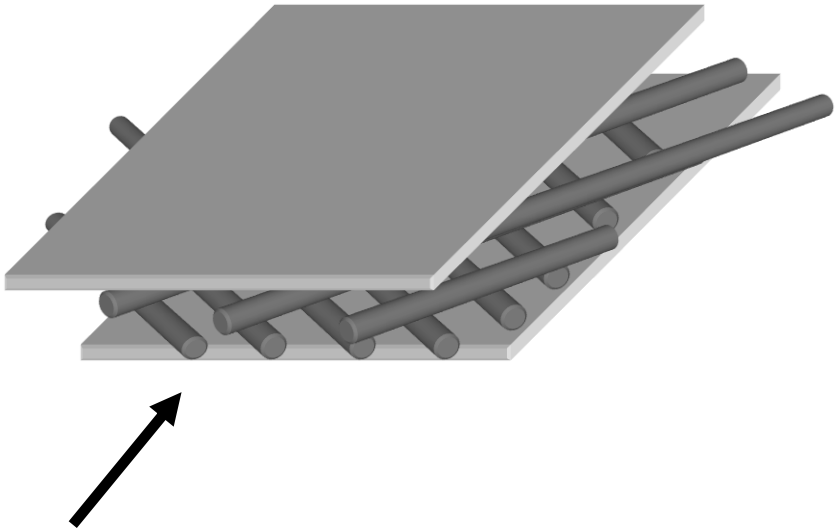
A Multi-billion Industry and Growing

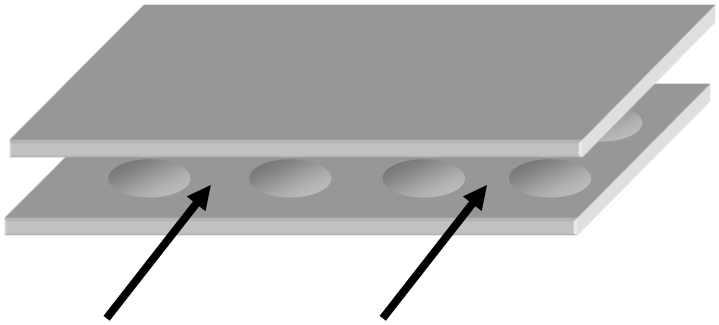
Large Commercial Seawater Systems

Under Counter System

RO Hand Pump

Hypothesis: Water Filtration Membrane Elements Can Be Significantly Improved with Embossed or Printed Feed Spacers



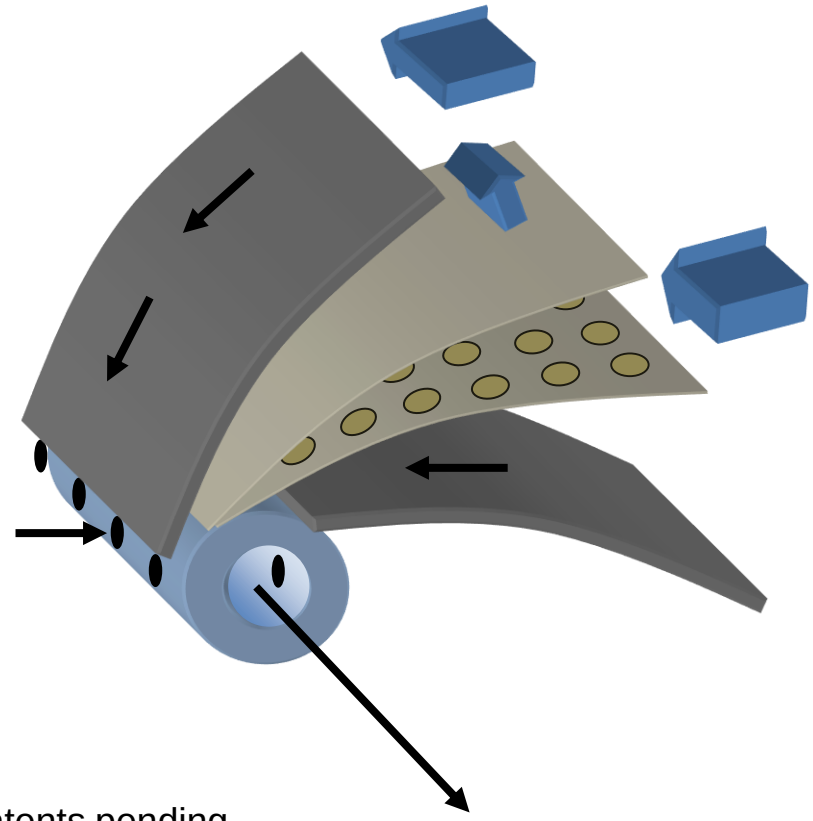


Conventional membrane elements use a mesh material to space membranes apart, but traps particles and creates biofouling – the leading cause of membrane failure and plant maintenance

Innovative Thin Feed Spacer Designs can be spaced much closer together (more surface area in the same size element) and fouling potential is significantly reduced

Patented and patents pending

Spiral Wound Element Design with Embossed or Printed Spacer

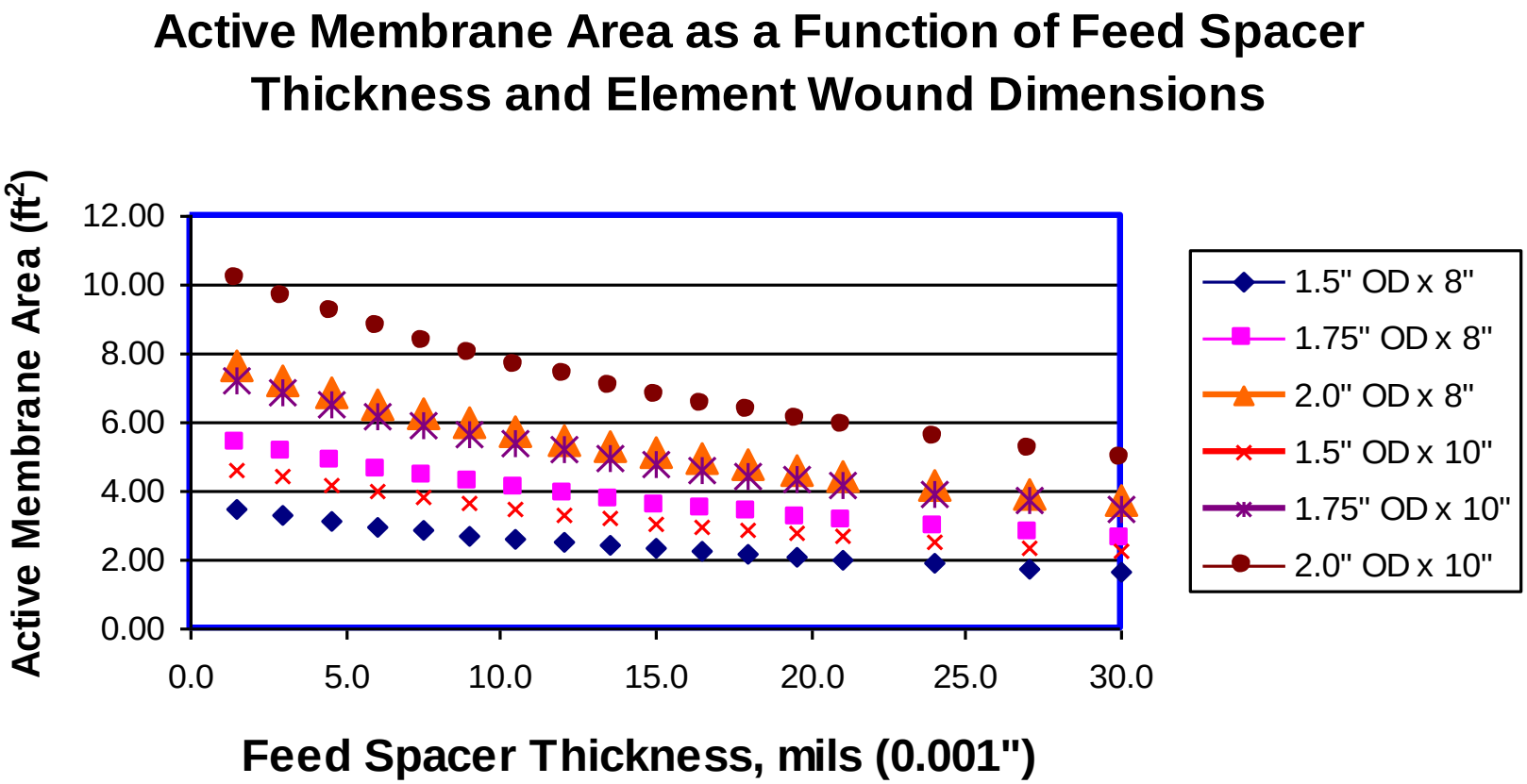


Patented and patents pending

Potential Advantages of Innovations Shown in this Presentation

- Up to twice as much permeate flow in the same housing size
- Scale Control
- Reduced fouling from biofilm and higher micron pre-filtration requirements
- Higher recovery to reduce reject flow
- Simplify under counter or industrial systems by increasing permeate flow sufficient to eliminate the pressure vessel

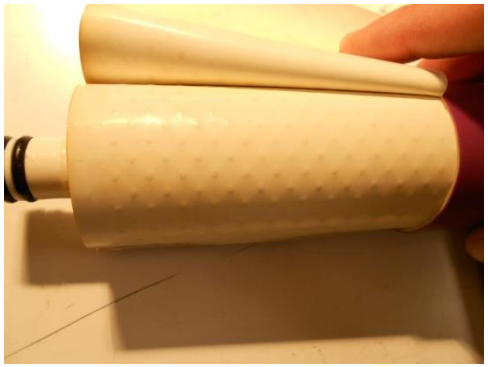
A Thinner Feed Spacer Allows More Membrane Area in the Same Volume Housing



Membrane Length Effects

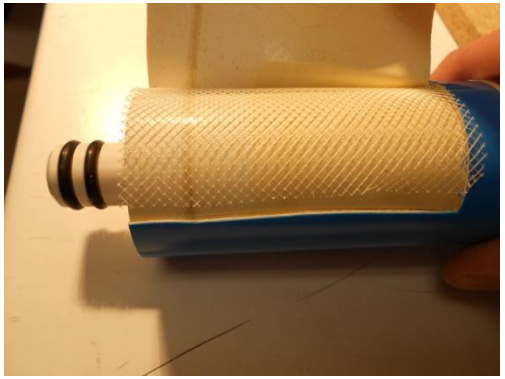
- 12” long elements at .003 inch feed spacer height have been demonstrated in testing with low pressure drop along length of element
  - At .003 in. feed spacer height vs. .025 in. conventional mesh spacer, twice as much membrane area can be wound in the same size element – twice the permeate production
- For 40” long elements, spacing will have to increase to not more than .010 in. to avoid significant pressure drop.
  - At .010 in. feed spacer height vs. .025 in. conventional mesh spacer, 50% more membrane can be wound in the same size 8” diameter element – 50% more permeate production.

2013 - Embossed and Direct Print Membranes have been Demonstrated



Embossed Membrane

Spacer Printed Directly on Membrane – Note Posts to the Right of Stripes



Conventional Mesh Spacer

Direct printing or embossing the membrane produces a thin feed spacer with less resistance to flow and reduced biofilm potential

Patented and patents pending

Membranes are Not Damaged by Embossing or Printing

- Swatch testing has been conducted by two membrane element manufacturers and Aqua Membranes
- There is a limit to embossing depth before rejection is affected, but the depth limit is well above that needed to maintain low pressure drop across a 40” element
- Flux and rejection test results for embossed vs un-embossed controls are statistically and practically insignificant in the operational regime.
- Rejection tests for printed membranes are the same as non-printed controls
- Flux rates for printed membranes on a unit area basis are reduced by less than 3% for print patterns needed for practical applications. Additional surface area greatly overcomes the small loss in area from the printed pattern

"Membrane fouling is the leading cause of membrane system failure and contributes significantly to maintenance requirements"

Concentration Polarization and Scale Formation

- Key limiting factor: As ion concentration increases along the length of the element, ions will precipitate out of solution and form scale on the membrane surface.
  - This has two bad effects:
    - Restricts flow through the membrane
    - Allows formation of biofilm and blockage of flow in the feed spacer.

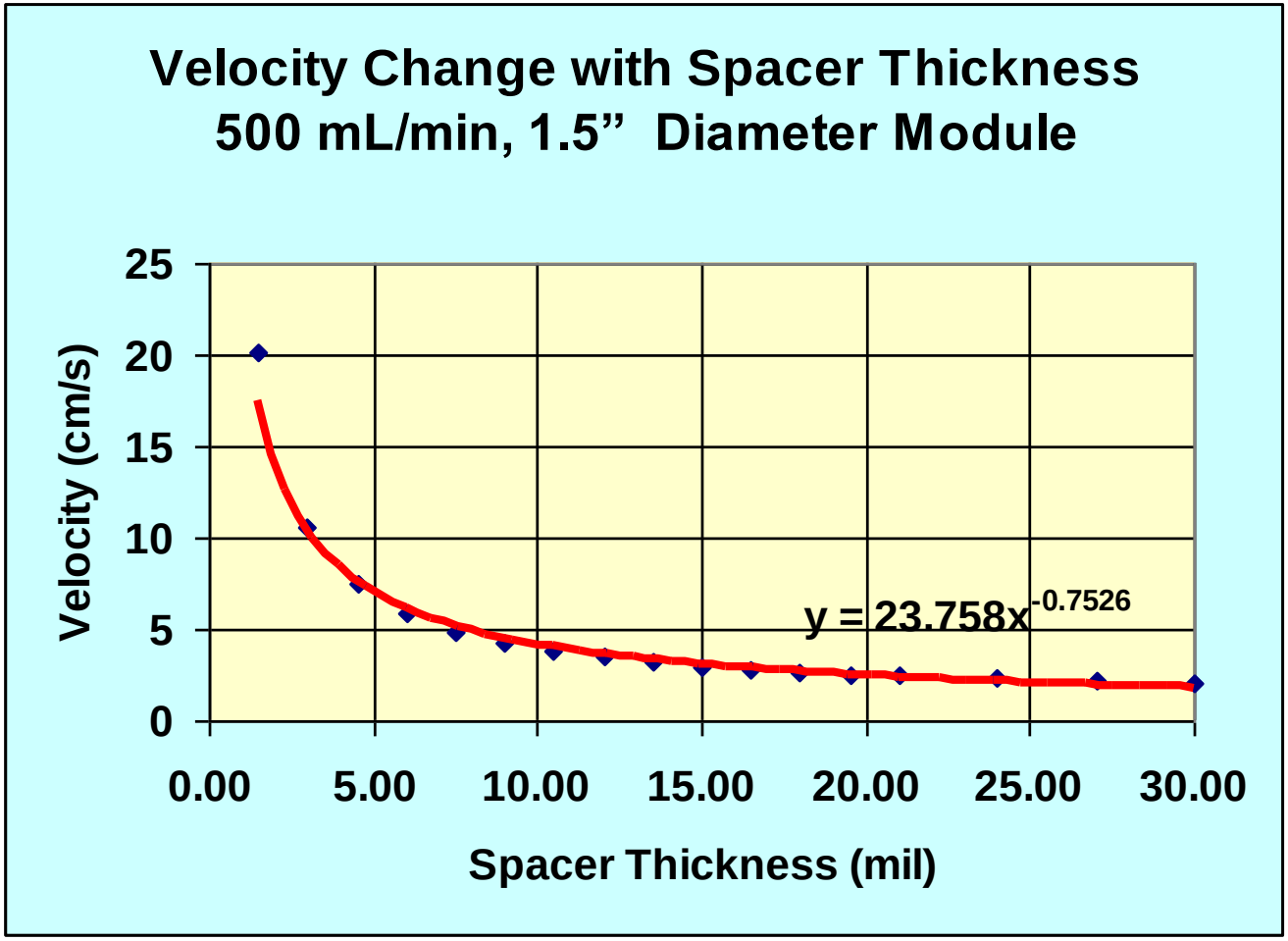
Diffusion Effect Reduces Concentration Polarization

Attributed initially to "…the increased [TDS] concentration gradient at the channel wall reducing the concentration polarization and, hence, increasing the permeate flow."

$$\text{Salt Flux} = -D(dc/dy)$$

$$\partial C/\partial t = -D\,\partial/\partial y(\partial C/\partial y)$$

Increased Fluid Velocity Decreases Concentration Polarization and Improves Performance



Thin Feed Spacers Improve Shear that Reduces Scale Formation

- Decreased membrane spacing increases shear in the fluid stream
- Studies by A.G. Fane – “Critical flux phenomena and its implications for fouling in spiral wound modules” demonstrates positive influence of fluid shear for reduction of membrane fouling.
- With thin feed spacer modules, fluid velocity increases exponentially with thinness.

Biofilm Control in Membranes

- Open channels eliminate the mesh material that hides and traps biofilm.
- Open channels facilitate backwash cleaning to allow materials to be easily removed from the membrane space.
- Open channels allow narrow spaces that increase shear and reduce the chance for biofilm formation.
- Open channels can significantly reduce pre-filtration requirements further reducing capex and energy costs.

Aqua Membranes LLC and Sandia National Laboratory

- Aqua Membranes LLC was awarded an assistance contract with Sandia National Laboratory from the New Mexico Small Business Administration (NMSBA) in 2011 and 2012.
  - Assisted with printing techniques, processes and sources
  - Printing does not damage membrane surfaces
- Aqua Membranes LLC is currently working with Sandia on a third NMSBA grant to study biofilm studies on thin feed spacer membranes.

Summary - Membrane Element Benefits

- Open channel flow and elimination of feed spacer mesh reduces fouling potential
- Feed channels are much closer together providing significantly more membrane surface area per element - up to 2X depending on element length – higher permeate flow per given element size
- Improved shear and diffusion that helps control effects from concentration polarization
- Allows higher recovery that reduces reject flow – more efficient operation – less waste
- High product flow from the same size element reduces plant capex costs.