What Is the ZLD Pilot?
And Does CCSD Want to Participate?

Background:

- **Much of the U.S., and Much of the World, Are Rapidly Running Out of Fresh Water**
- Desalinating Impaired Water Sources is Often Suggested as a Possible Solution
- **However, the Cost of Brine Disposal (not the Cost of the Desalination itself) Destroys the Economics of Almost Every Inland Desalination Project in the U.S. – whether for Farmers or for Cities**
- **Disposing of RO Brine Can Cost as Much as 200x More Per Cubic Meter than Desalination Itself**
- For Cambria – Trucking Brine to Oceano for Disposal Costs around **$.25 per Gallon** – Trucking 50,000 Gallons per Day of RO Brine Would Cost **$375,000 for just 30 Days of 24 hr. RO Plant Operation**
- **Cambria Needs a Radically More Affordable Brine Solution if It Ever Wants to Use Existing RO Plant**
- Our Company – **Global Water Innovations** (GWI) – Was Specifically Formed 6 Years Ago to Figure Out How to Make Desalination Affordable for Agriculture – Because Food Production is Starting to Severely Impacted
- We Became One of the First Two Founding Industry Partners of the **National Alliance for Water Innovation**
- **NAWI** – Over 400 of the top U.S. water researchers belong now - https://www.nawihub.org/about/who-we-are/
- We advised **NAWI's Ag Committee** on their Ag Roadmap. And we have spoken before Congressional Committee staff on the Growing Ag Water Issues - https://vimeo.com/461006426
- Out of our Work with NAWI, we began to work to advance a handful of companies with promising **Zero Liquid Discharge (ZLD) technologies** to recover all the water in Brine cost effectively – with only salts left

Background on the NAWI Grant GWI Just Selected For

- **NAWI** Released the First Round of the Application for this Grant in January of ‘22.
- **GWI** Began Lining Up Piloting Sites in February of 2022, Telling Each Site that We Had No Assurances We Would Pass, But If We Did Win, Was There Interest in Participating?
- We Reached out to John Weigold in February of 2022, and Strong Interest (Subject to More Detail) Was Expressed in Pilot Participation, if in fact GWI won Grant
- Five Other Sites across California Expressed Strong Interest in Participating
- We Kept Alerting Pilot Sites that We Were Still in the Running After Each Round of Competition
- Three Rounds Later, on 1/19/23, **GWI**, and our **ZLD Technology Partner** - **Trevi Systems** - were Selected for Grant Negotiation.
- The Grant Paperwork is Expected to be Finalized with the DOE in 60 days.
- **This Grant is NOT with Cambria**. It is with Global Water Innovations.
- The Federal Funding for this Grant is **Primarily for Building the needed two Mobile Pilot Units to Demonstrate this Technology**
- The Federal Portion of Funding will only cover 42.5% of the Cost. However, the California Department of Water Resources Thought This Piloting Application so Important to California’s Water Future that They Offered to Put Up 50% of the Total Cost if This Particular Pilot was Funded.
- Apart from the Build Budget, the Grant Allocates $40,000 per Pilot Site to Carry Out the Pilots. Our Actual Costs - Trucking Equipment in, Having Engineering & Operational Staff on site, Lodging and Food Expenses, Equipment Rental, Chemicals, etc. will be more & we fully expect to lose money carrying out the pilots.

NAWI National Alliance for Water Innovation

Department of Energy Announces Pilot Project Selections for Secure, Reliable, and Affordable Freshwater Supplies for the U.S.

By: Lauren Nicole Core
January 19, 2023

The U.S. Department of Energy (DOE) and the National Alliance for Water Innovation (NAWI), in collaboration with the California Department of Water Resources, today announced the selection of 11 projects for negotiation that will pilot breakthrough technologies and systems that will allow for more reliable and affordable freshwater supplies for the United States. The projects will also contribute to the decarbonization of the water and wastewater sectors through investments in technologies that enhance the efficient use of energy in the use, treatment, and distribution of water.

The selected pilot projects will process non-traditional source waters from a range of locations and produce water in real-world environments. In some cases, projects will partner directly with communities and groups that have historically been underserved by existing water supplies. The research will help to bolster a circular water economy by supporting water reuse and valorizing constituents we currently consider to be waste. Each project will also generate a range of data sets usable by other researchers seeking to advance the field of data analysis and automation, and fault detection in water treatment systems.

The collaborative project teams of industry, academic, national laboratory, and other stakeholders will deliver impact aligned with NAWI's pipe parity metrics. Pipe parity is defined as technology solutions for treating and reusing nontraditional water sources that are competitive with conventional water sources for specific end use applications.

These pilot systems will directly address the highest priority research needs and technical knowledge gaps outlined in the NAWI Roadmap Publication Series, which was published in 2021.

The selected projects include:

- **Switchable Solvent ZLD Process for Solving the Inland Desalination Brine Problem**

Desalinating and reusing municipal, industrial and agricultural wastewater is an attractive approach for improving the reliability and resilience of water resources. But the presence of dissolved minerals that can plug RO membranes and modules (a process called scaling) limits the amount of water that can be recovered using membrane processes such as RO. This project aims to integrate a novel, high-efficiency process for removing scale-forming ions from brine concentrates, enabling much higher amounts of water recovery and smaller volumes of waste brine. The mobile testbed will demonstrate high-recovery desalination at five sites in California.

Partners: Global Water Innovations, Inc. (lead); Trevi Systems, Inc.

RFP #: NAWI-3-2022 – Switchable Solvent ZLD Process for Solving the Inland Desalination Brine Problem

Team Members, Partners, and Organizations

Clark Easter/Global Water Innovations – Pilot Lead
John Webley/Trevi Systems, Inc – Technical Lead
Cambria CCSD – Site Partner
City of Oxnard – Site Partner
Houweling's Tomatoes – Site Partner
Cat Canyon Resources – Site Partner
Existing RO Brine Pond in SLO – Site Partner

Once the Grant Contract is Finalized with the DOE, GWI will work to Get a Pilot Agreement in Place with Each Interested Site Partner.

GWI will then Work with Each Site Partner to Support Them in Getting Any Needed Permits, Figure Out all Logistics for the Pilot, etc.

Project Summary

This project will build off of Trevi's first generation SSWS ZLD technology – a stationary 5 GPM batch process unit – and proceed to design/construct a second gen mobile 10 GPM continuous process unit. This unit will be combined with the next gen version of Trevi's osmotically assisted brine concentration skid.

Once ready, the team will pilot these technologies at 5 different inland desalination sites to test performance on varied RO and EDR brines – laying the foundation for full commercialization.

RFP #: NAWI-3-2022 – Switchable Solvent ZLD Process for Solving the Inland Desalination Brine Problem 2C

Clark Easter – Global Water Innovations, Inc.

Current Challenges & Value Proposition:

- Desalination Brine costs from 20 to 90x more per cubic meter to deal with than desalination itself ($.40/$m^3$).
- This extraordinary high-cost ruins the economics of most inland desalination projects
- **The current project is aiming to demonstrate the ability to achieve ZLD with inland RO or EDR brines at a cost of around $5.00 per cubic meter - 80% less than current thermal ZLD technologies.**
- This price point will open up the vast brackish groundwater reserves in the West for agricultural use

Envisioned Treatment Process:

- Organic molecule bubbled into brine under pressure
- Hydrophilic nature causes water molecules to release bonds to dissolved salts
- **Up to 90% of sparingly soluble salts simply drop out**
- Water and brine heated 30º F to switch solvent back to gas for reuse
- Softened brine can then be squeezed up by a proprietary blend of hydraulic and osmotic pressures
- 97%+ water recovery, with final brine concentration 400,000 ppm and higher, depending on incoming brine salinity

Research Plan:

- Start from the current fixed, 5 GPM batch SSWS ZLD process just completed by Trevi Systems
- Design & build the next generation of it - a 10 GPM continuous process in mobile shipping containers
- Optimize performance with Trevi's osmotically assisted RO Brine Concentration Skid
- Carry out at least 5 pilots on different RO/EDR brines
- **Use the results and operational experience to build first commercial units.**

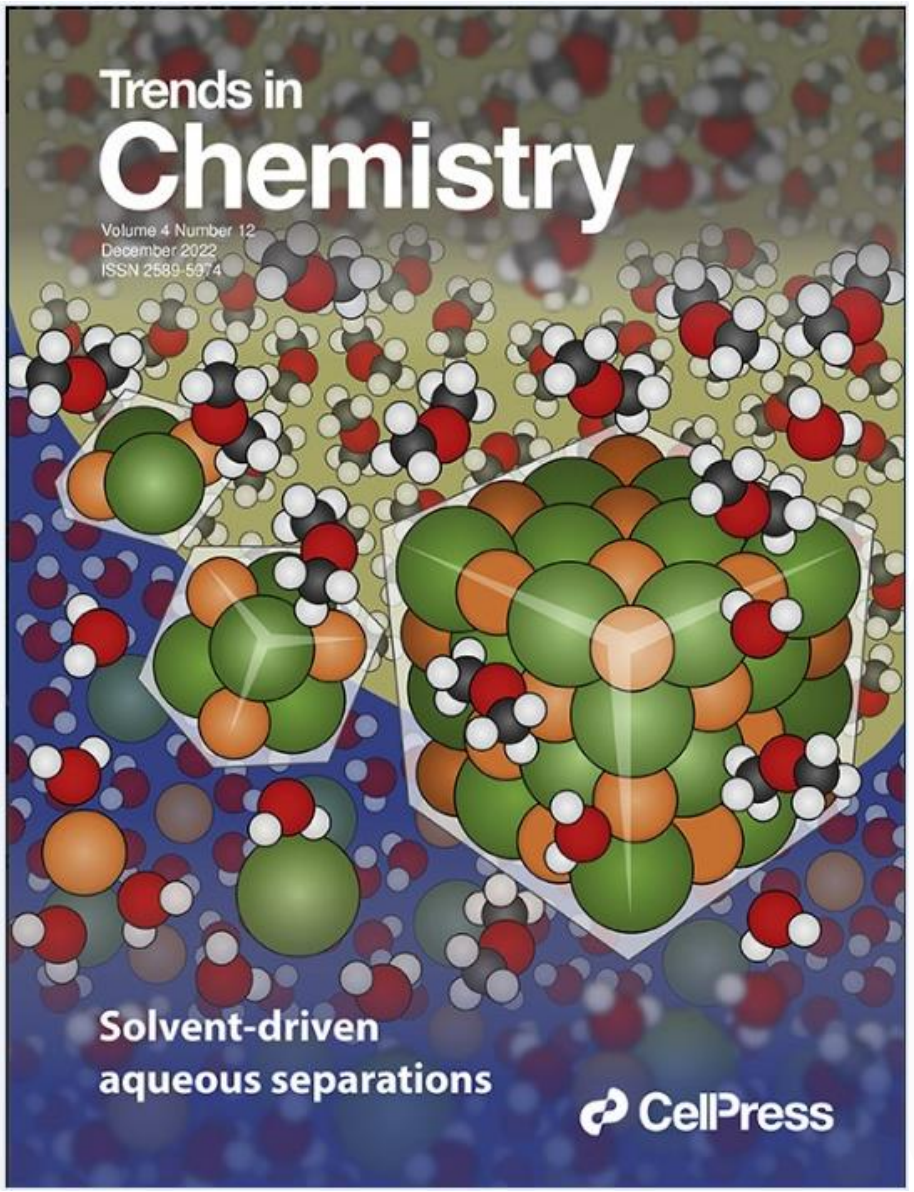
Impacts & Benefits:

- First cost effective ZLD Process for Agricultural sites
- Blended price of First Stage Desal + ZLD of brine will be able to drop down under $.65 per cubic meter for many inland brackish groundwater projects
- Growing food requires lots of water – this innovation will bring desperately needed water resiliency to agriculture, relieving pressure on fresh water supplies
- **Many cites also need an affordable brine solution for their desalination projects!**
- This breakthrough will spur inland desal deployments.

NAWI

RFP #: NAWI-3-2022 – Switchable Solvent ZLD Process for Solving the Inland Desalination Brine Problem

2C



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Trends in
Chemistry

Feature Review

Solvent-driven aqueous separations for hypersaline brine concentration and resource recovery

Zi Hao Foo,[1,7] Caleb Stetson,[2,7] Elizabeth Dach,[3,7] Akshay Deshmukh,[1] Hyeonseok Lee,[2] Akanksha K. Menon,[4] Ravi Prasher,[5,6] Ngai Yin Yip,[3] John H. Lienhard,[1,*] and Aaron D. Wilson[2,*]

Solvent-driven separation processes can extract water and high-value minerals from high salinity or contaminated brines, simultaneously reducing the environmental impact of brine disposal and enabling resource recovery. The efficient dewatering of hypersaline brines is essential for the sustainable minimal and zero liquid discharge processing of industrial wastewaters. Fractional crystallization can selectively extract ions from contaminated waste streams, allowing critical materials to be recycled, including transition and lanthanide metals required for renewable energy generation and storage. Mass transfer in solvent-driven water extraction occurs across a liquid–liquid interface, eliminating the scaling and fouling of membrane and heat exchanger surfaces and limiting the need for extensive pretreatment. Solvent-driven fractional crystallization can leverage sequential treatment and control of process conditions to rapidly recover salts without requiring evaporation of water. Despite promising applications, the principles and potential of solvent-driven aqueous separations remain poorly understood. This critical review explores the opportunities presented by solvent-based aqueous separations from the molecular to process scale, evaluating the chemistry of solvation and system design in the broader context of desalination, resource recovery, water softening, and mineral production.

Highlights

Solvent-driven aqueous separations enable resource recovery and zero liquid discharge desalination from hypersaline or contaminated aqueous brine, mitigating environmental impacts of brine disposal.

Promising solvents include thermo-responsive and volatile organic solvents, which selectively solvate water while dissolving minimally into the aqueous retentate; critical materials, including transition and lanthanide metals, may be recovered simultaneously through fractional crystallization.

Effects of intermolecular interactions and phase kinetics that control macroscopic separation efficacy are identified to elucidate key process-level design considerations for energy-efficient solvent-driven aqueous separations.

Solvent regeneration processes bypass traditional limitations associated with direct water vaporization and membrane separation. Process optimization is evaluated in terms of recycled sensible heats, reducing net energy consumption while mitigating solvent depletion.

Motivations for solvent-driven separations

Population growth, climate change, and rising economic standards are rapidly exacerbating resource scarcity [1]. Globally, water stress has a cascading impact on several critical resources, including the irrigation of farmland for food production, the manufacturing of photovoltaics for clean energy generation, and the extraction of metals for batteries and magnets. Aqueous water–salt and ion–ion separations play a central role in alleviating water scarcity, by augmenting and protecting freshwater supplies and by maximizing resource recycling from industrial waste streams. Sustainable water management and resource recovery systems must be energy, atom, and carbon efficient, to minimize environmental impact [2].

Freshwater supplies can be augmented using nontraditional sources, including saline aquifers, high **total dissolved solids (TDS)** (see Glossary) surface waters, municipal wastewaters, and aqueous industrial wastes. Fresh water can be produced from these sources with membrane systems such as **reverse osmosis (RO)**, the most widely used and generally the most energy efficient **desalination** technology [3]. Currently, RO is extensively employed in brackish and seawater desalination. However, the hydraulic pressure limitations of conventional RO restrict the feed TDS levels to be under ~70 000 ppm, although emerging variants of RO may accept

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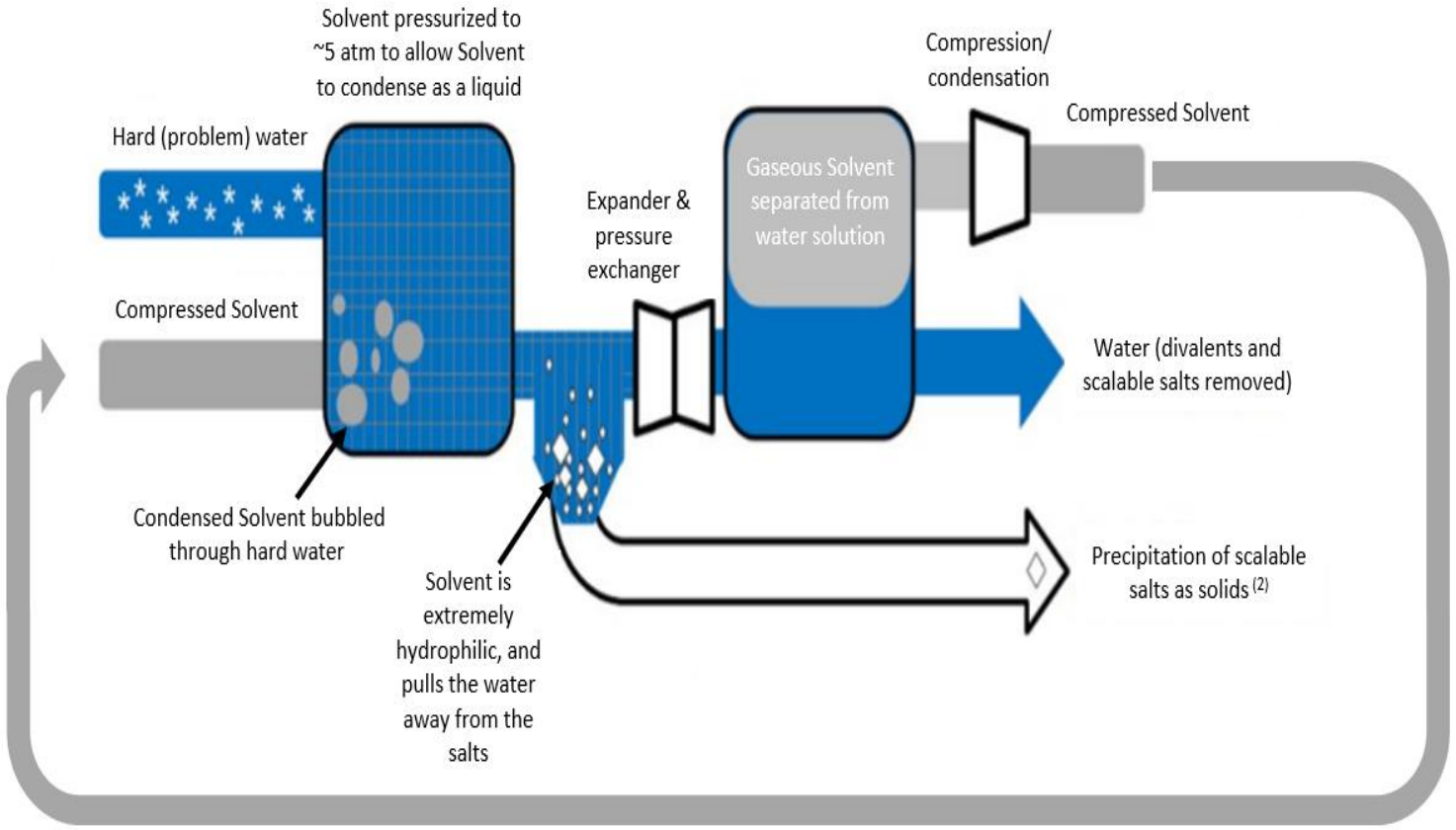
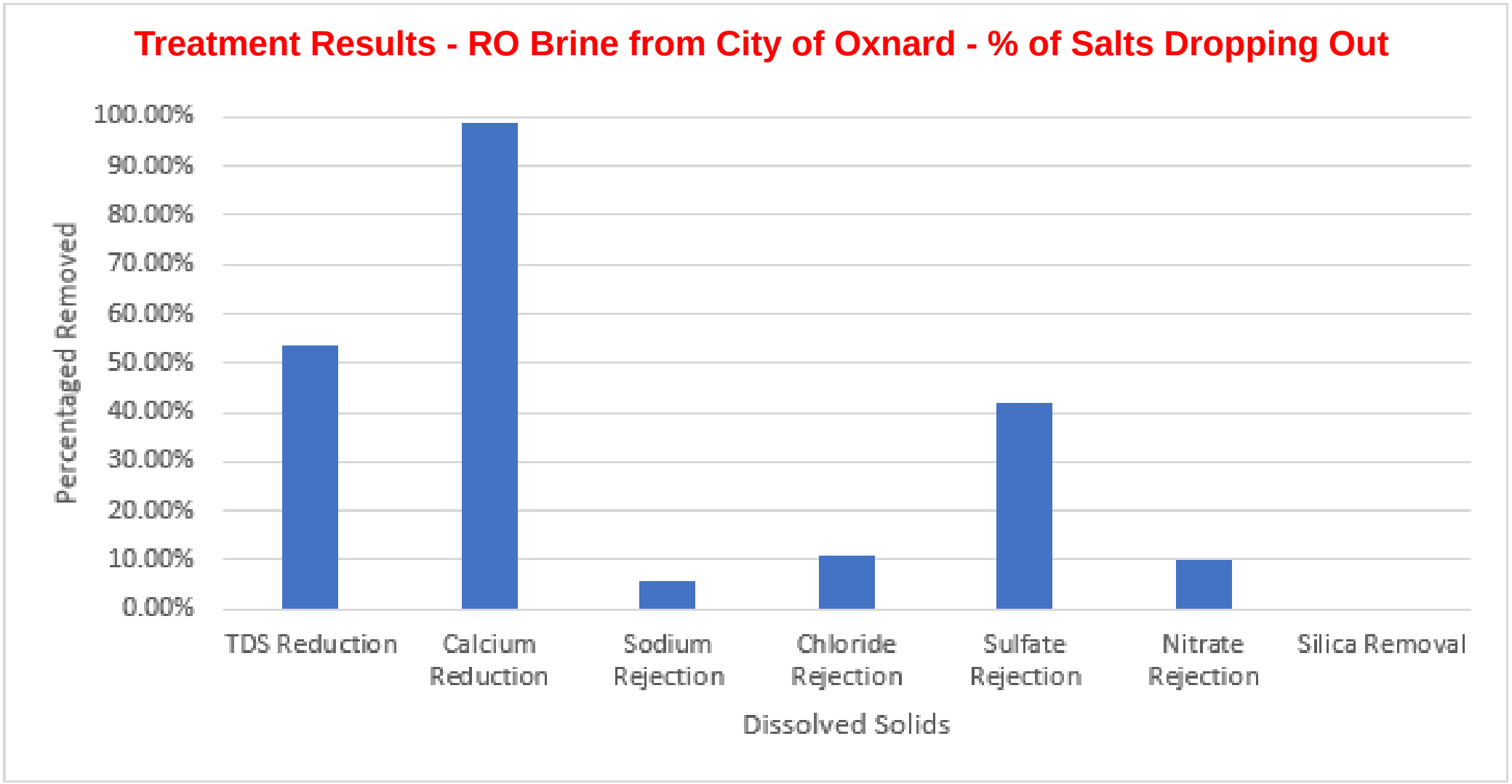
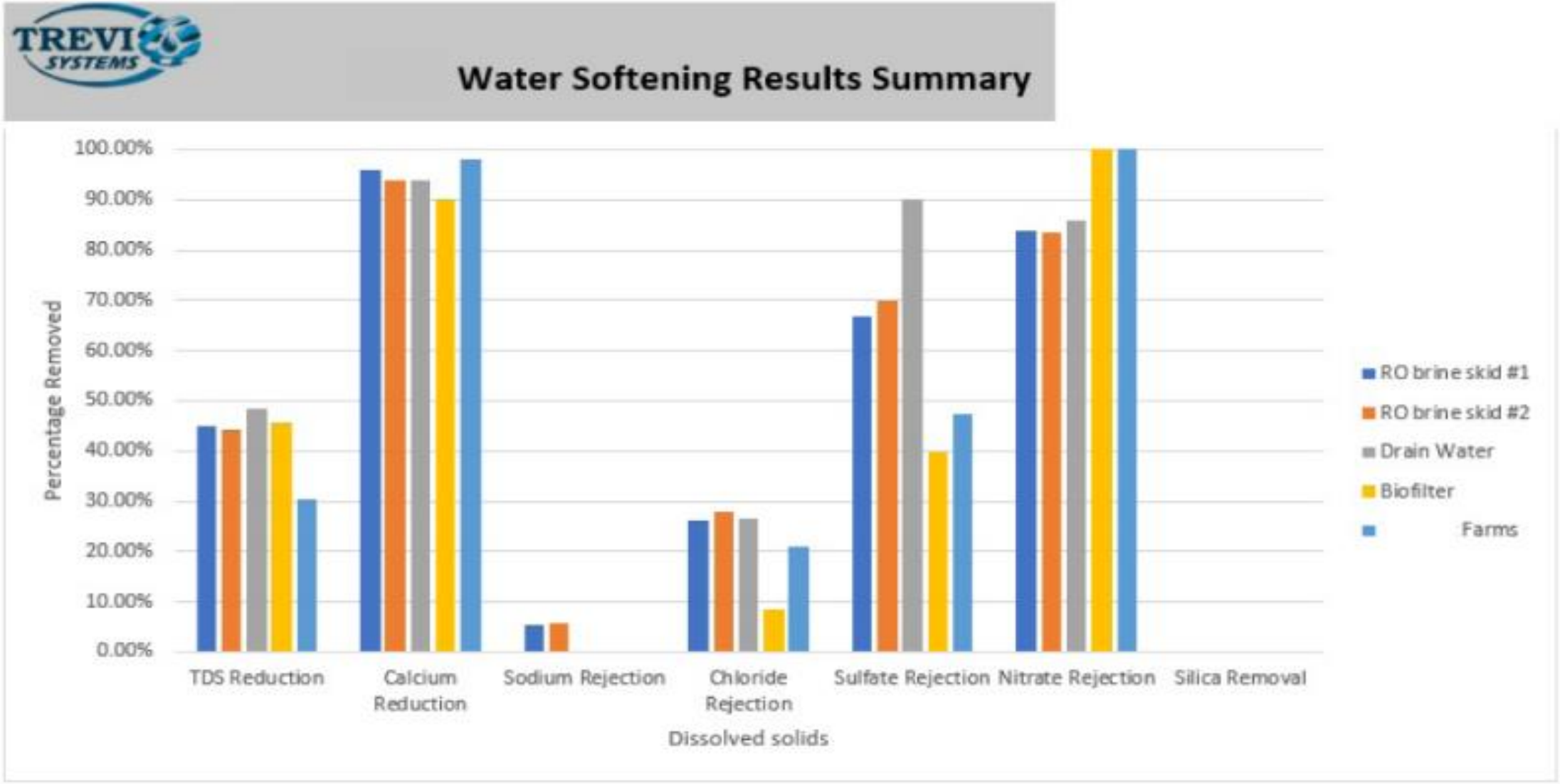
[4]G. W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA

SSWS TECHNOLOGY EXPLAINED

SWITCHABLE SOLVENT WATER SOFTENING KEY TO ZERO LIQUID DISCHARGE (1)




Treatment Results - RO Brine from City of Oxnard - % of Salts Dropping Out
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Percentaged Removed
TDS Reduction
Calcium Reduction
Sodium Rejection
Chloride Rejection
Sulfate Rejection
Nitrate Rejection
Silica Removal
Dissolved Solids



Treatment Results on 4 Different Water Sources at Santa Barbara Co. Farm Site

The Softened Brine from the Prior Treatment Stage Allows Much Higher Brine Concentrations to be Subsequently Reached – by Using Trevi's Proprietary Osmotically Assisted SWRO Process

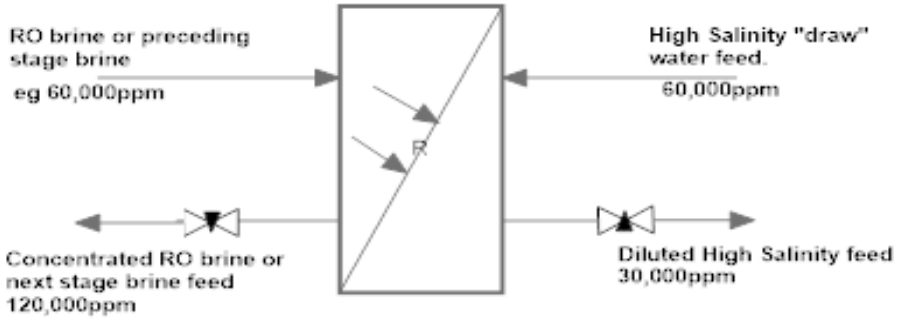


Fig 1. Simplified PFO membrane element

97%+ Water Recovery Can Be Achieved - with the Final Brine Concentration Expected to be over 400,000 ppm. This is 6x Higher than Can Normally Be Achieved with Membranes

The Goal of this Pilot is to Show that Cambria's RO Brine can be Treated, with the Water Fully Recovered, at a Cost of < $.025 per Gallon – 1/10 the Cost of Trucking that Brine off as Waste.

What Will the CCSD Pilot Be Designed to Do?:

- Recover 97%+ of the Water from the Existing RO Brine. The Recovered Water will Meet the Same Standards as the Existing RO Permeate and will be suitable for Groundwater Recharge under the Same Permit.
- The Salts in the Remaining Brine will be Highly Concentrated – over 400,000 ppm. They will be the consistency of Oatmeal – and can be Safely Disposed of in a Lined Landfill.
- Cambria Has First Pick on Time Slot for Pilot – **From October 1st On…**
- The Pilot Length for Cambria Anticipated To Be **8 to 10 Days Total**
- **Two to Three Days to Get all the Equipment Assembled Onsite, Hooked Up, and Tuned In**
- **Four to Five Days of Onsite Operation - Treating 10 GPM of Brine** from Cambria's Existing RO Unit. Continuous Data Gathering Will Take Place
- **One Day to Demobilize Units** and Ready Them for Transportation to Next Pilot Site

Questions?

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