Innovative Cost-Effective Pre-treatment for Desalination

M.H. Lean, J. Seo, A. Kole, A.R. Völkel, N. Chang, and K. Melde

Palo Alto Research Center, Palo Alto, CA, mlean@parc.com

ABSTRACT

This paper describes an innovative technology to pre-treat seawater for desalination, resulting in extremely high quality feed water for RO systems. An inline coagulation-flocculation-separation (CFS) system is detailed that does not require filtration or sedimentation and is able to operate in continuous flow mode. The innovation is the use of hydrodynamic separation, invoking relatively gentle fluidic forces that can also address neutrally buoyant suspensions. Rapid process time is achieved by reducing floc aggregation time and eliminating sedimentation time. Advantages include: scalability, modularity, rapid processing, low energy, and low maintenance. In comparison with conventional and membrane pre-treatments for a 20 MGD installation, this technology may allow reductions in capital cost by 30-70%, operations and maintenance cost by 30-40% and land use by 58-77%.

Keywords: hydrodynamic separation, neutral buoyancy, continuous flow, membrane-less

1 INTRODUCTION

This paper describes an innovation to water treatment that will impact current infrastructure deficiencies – inefficiencies and ineffectiveness contributing to energy and resource intensive treatment processes. Technical details of this innovation covering proof of concept and preliminary validation data have been previously discussed [1,2,3]. Data generated with a bench-scale R&D prototype system are used to indicate technology capability in pre-treatment of seawater for RO. Design and operational parameters are used to develop the conceptual design which is validated with external experts and used to generate estimates of cost, energy, and space advantages. This technology is extensible for treatment of brackish and surface waters. Improvements to the water treatment process train include: technology enhancements to the clarification step, replacement of sedimentation or filtration by rapid hydrodynamic separation, and selective removal of metals by a pre-conditioning step. The treated effluent is flowed through a cartridge filter as insurance against abnormal operation. The replacement interval for a 5µm filter has been shown to be extended by 28X for pre-treatment of seawater before RO. Higher water recovery can be accomplished by cascading two stages of spiral separation, each with 80:20 split, and combining the effluent streams to reclaim up to 96% of the input water. Compactness, scalability, modularity, and low system maintenance contribute to future implementation in a wide gamut of application scenarios ranging from small community to large urban cities. Operational improvements include: <2 psi pressure drop for mixer-conditioner, 1 minute floc aggregation time, gravity-fed separation (<2 psi pressure drop), and overall process time of <10 minutes.

2 INLINE CFS SYSTEM

This novel two-step clarification approach combines innovations in both a mixer-conditioner and the downstream hydrodynamic separator. The 90 degree entrance angle at the inlet of the mixer-conditioner ensures chaotic mixing. The first two turns of the spiral mixer are designed for turbulent flow where channel width limits

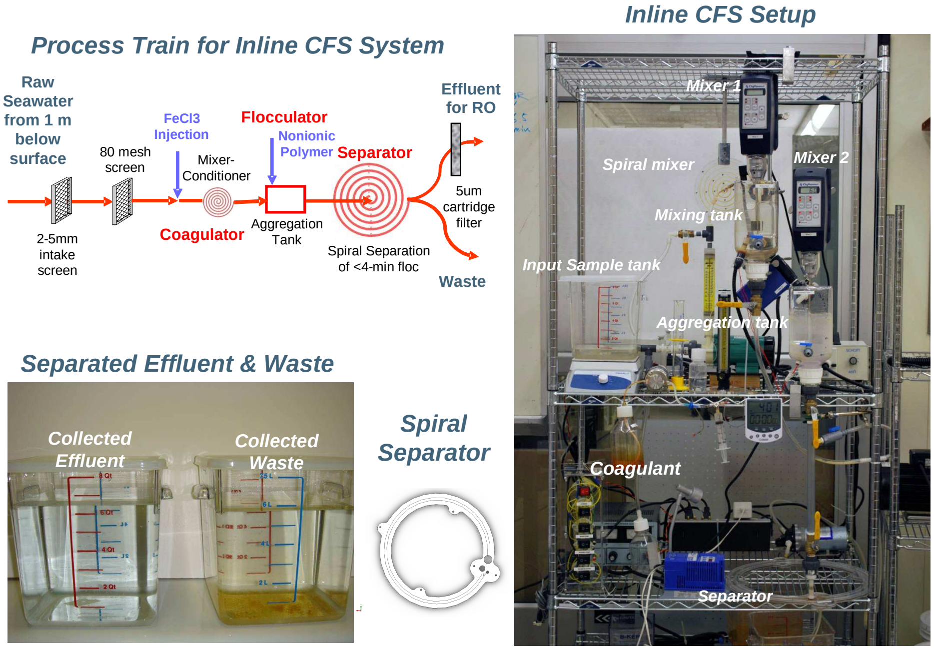
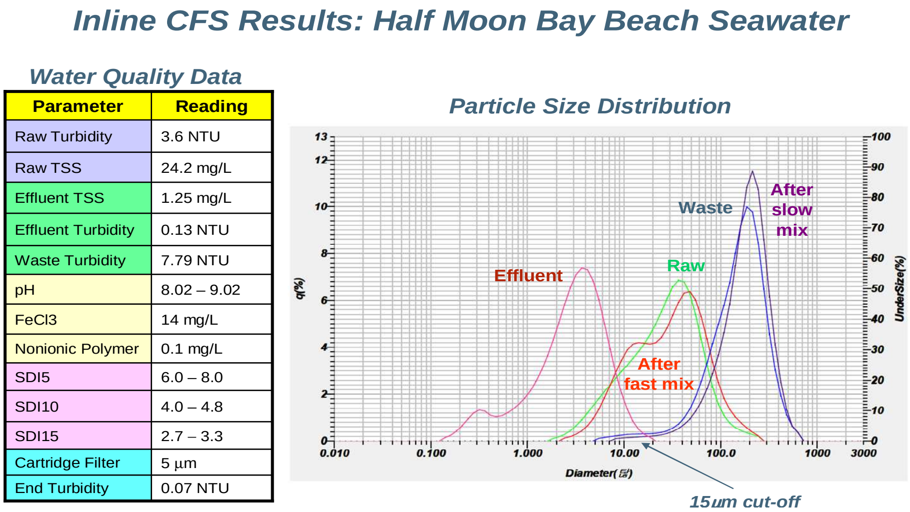


Figure 1: Inline CFS system: process train (top left); prototype (right); collected effluent and waste streams (bottom left); and top view of 19" diameter separator.

diffusion time to assure thorough mixing. The remaining turns of the mixer-conditioner have a designed shear rate to limit rapid growth of loose floc thereby conditioning floc growth to result in dense uniformly sized aggregates. The innovation in the hydrodynamic separator targets separation of neutrally buoyant suspensions. This is accomplished by the novel use of centrifugal force to set up the transverse flow patterns that serve to sweep suspensions to a new force equilibrium location, resulting in band focusing along a side wall with a very low relative G force (<2). In contrast, traditional hydrocyclones and centrifuges require high relative G forces to move suspensions relative to the suspending fluid based on density difference. In general, the smaller the density difference, the higher the relative G force required. This technology is also directly relevant to almost any instance where reduction of TSS loading reduces clogging and extends the time between cleaning for many MF and UF filtration membranes.



Inline CFS Results: Half Moon Bay Beach Seawater

Water Quality Data

Parameter	Reading
Raw Turbidity	3.6 NTU
Raw TSS	24.2 mg/L
Effluent TSS	1.25 mg/L
Effluent Turbidity	0.13 NTU
Waste Turbidity	7.79 NTU
pH	8.02 – 9.02
FeCl3	14 mg/L
Nonionic Polymer	0.1 mg/L
SDI5	6.0 – 8.0
SDI10	4.0 – 4.8
SDI15	2.7 – 3.3
Cartridge Filter	5 µm
End Turbidity	0.07 NTU

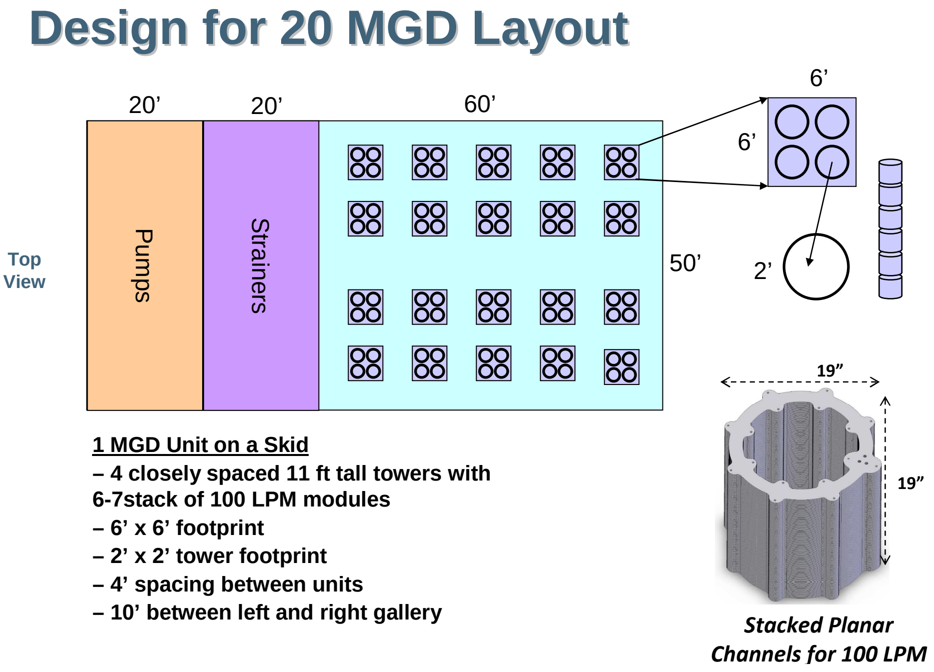
Figure 2: Conceptual layout for 20 MGD installation showing space for pumps, strainers, and separators. The spiral mixer-conditioner may be stacked above the separators, further reducing space.

3 SAMPLE RESULTS

The right side of Fig. 1 shows the CFS setup with the separator on the lowest shelf. A 3-ft drop from the aggregation tank on the second shelf is sufficient for gravity-fed separation where the collected effluent and waste steams are shown in the lower left. The single-turn separator is 19” in diameter. Fig. 2 shows the water quality tested using beach water from Half Moon Bay in Northern California. The low and high values of the SDI range are taken after and before the 5µm cartridge filter. The final turbidity is 0.07 NTU. Curves for the particle size distribution measurements are superimposed to show the progressive growth of aggregates after slow mix, and their sharp and distinctive separation with a 15µm cut-off device. The water quality achieved is remarkable considering that the cartridge filter is used only as insurance against abnormal events. SDI15 of 3 generally indicates uninterrupted operation for many months.

4 CONCEPTUAL DESIGN AND COST

Fig. 3 shows a compact layout for a 20 MGD treatment plant with space allocated for pumps, strainers, and separators. The spiral mixer-conditioners are stacked on top of the separators to further reduce space use.



Design for 20 MGD Layout

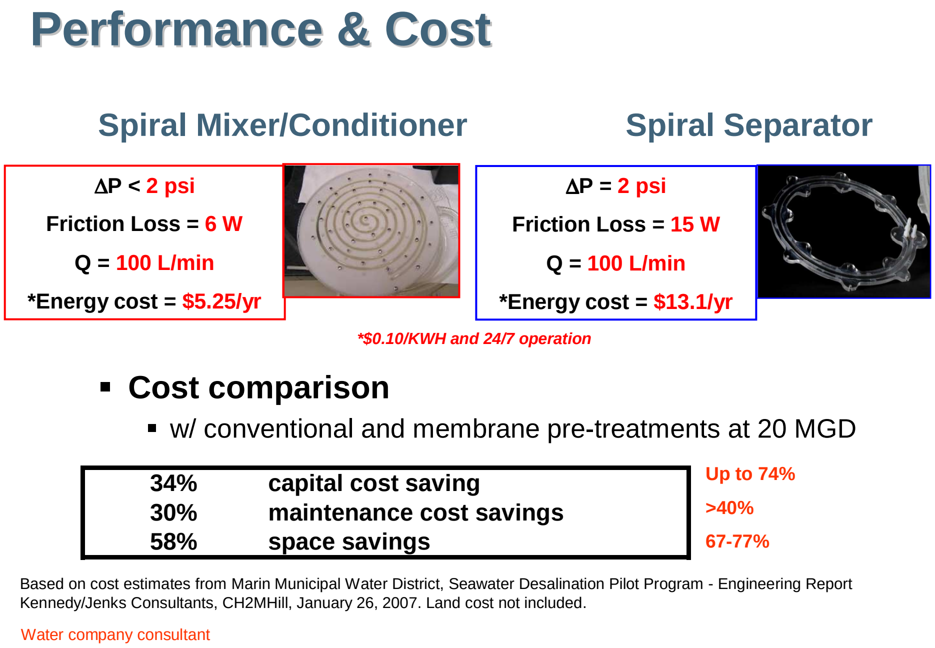
1 MGD Unit on a Skid

- **4 closely spaced 11 ft tall towers with 6-7stack of 100 LPM modules**
- **6’ x 6’ footprint**
- **2’ x 2’ tower footprint**
- **4’ spacing between units**
- **10’ between left and right gallery**

Stacked Planar Channels for 100 LPM

Figure 3: Conceptual layout for 20 MGD installation showing space for pumps, strainers, and separators. The spiral mixer-conditioner may be stacked above the separators, further reducing space.

The 20 MGD is comprised of 20 single MGD skids, each consisting of 4 towers of separators, taking up 6’x6’ area. Each tower consists of 6 to 7 100 LPM base modules; each fitting within a 19” cube. The compactness of the base module allows for flexible configuration and throughput scaling. Scalability will facilitate retrofits of existing installations to accommodate increased demand, especially in space limited settings. Fig. 4 shows device parameters and best estimates of cost calculations for the 20 MGD layout of Fig. 3. In comparison with conventional and membrane pre-treatments, this technology may allow reductions in capital cost by 30-70%, operations and maintenance cost by 30-40% and land use by 58-77% compared to the two referenced sources.



Performance & Cost

Spiral Mixer/Conditioner

ΔP < 2 psi
Friction Loss = 6 W
Q = 100 L/min
*Energy cost = $5.25/yr

Spiral Separator

ΔP = 2 psi
Friction Loss = 15 W
Q = 100 L/min
*Energy cost = $13.1/yr

*$0.10/KWH and 24/7 operation

- Cost comparison
  - w/ conventional and membrane pre-treatments at 20 MGD

34%	capital cost saving	Up to 74%
30%	maintenance cost savings	>40%
58%	space savings	67-77%

Based on cost estimates from Marin Municipal Water District, Seawater Desalination Pilot Program - Engineering Report Kennedy/Jenks Consultants, CH2MHill, January 26, 2007. Land cost not included.

Water company consultant

Figure 4: Pressure drops and energy usage are provided for the multi-turn spiral mixer and single-turn separator. Cost estimates are computed for a 20MGD installation, and shows reduction in capital cost by 30-70%, operations and maintenance cost by 30-40% and land use by 58-77% compared to the two referenced sources.

5 CONCLUDING REMARKS

This paper has described an innovative and disruptive technology that can serve as a platform for many types of water purification beyond desalination. For example, dissolved contaminants may be selectively precipitated, aggregated to the preferred size, and immediately removed in a continuous flow manner. Applications are defined by the contaminant of interest which could include the multivalent metal ions (such as Ca, Mg, Ba, Sr, Fe, Mn), dissolved Silica, and so forth. Conventional chemistry would be adapted for use in the curved channels offering opportunities to reduce dosage (due to enhanced mixing and reduced diffusion time) and increased rates of reaction. The ability to handle neutral buoyancy imply that algae and other organics prevalent in most waters may be removed in a benign manner without lysing of the organisms and resultant leeching of their toxic contents which have been shown to contribute to bio film development and contamination on membranes. For example, the use of this device at the point of water intake with subsequent discharge of the waste stream containing the organics will allow for ecologically friendly operation in a manner that does not contribute to environmental problems. Polysaccharide secretions of the organics such as TEP (transparent exopolymeric particles) and EPS (exopolymeric secretions) have been shown to contribute to major contamination issues as they are able to penetrate sub-micron membranes even at low TMP (transmembrane pressure). This technology will be able to aggregate and remove them gently.

Energy, cost, and footprint requirements are extremely competitive compared to those of the conventional alternatives.

REFERENCES

[1] M.H. Lean, J. Seo, A. Kole, A.R. Völkel, N. Chang, and H.B. Hsieh, “High Throughput Membrane-less Water Purification”, Proc. SIWW, 2008.

[2] M.H. Lean, A. Kole, J. Seo, A.R. Völkel, N. Chang, H.B. Hsieh, and K. Melde, “Innovative Hydrodynamic Clarification for Water treatment”, Proc. SIWW, 2009.

[3] M.H. Lean, A. Kole, N.Chang, A.R. Völkel, J. Seo, and H.B. Hsieh, “Curved Fluidic Structures to Improve Aggregation Kinetics in Municipal Water treatment”, Proc. WQTC, 2008.