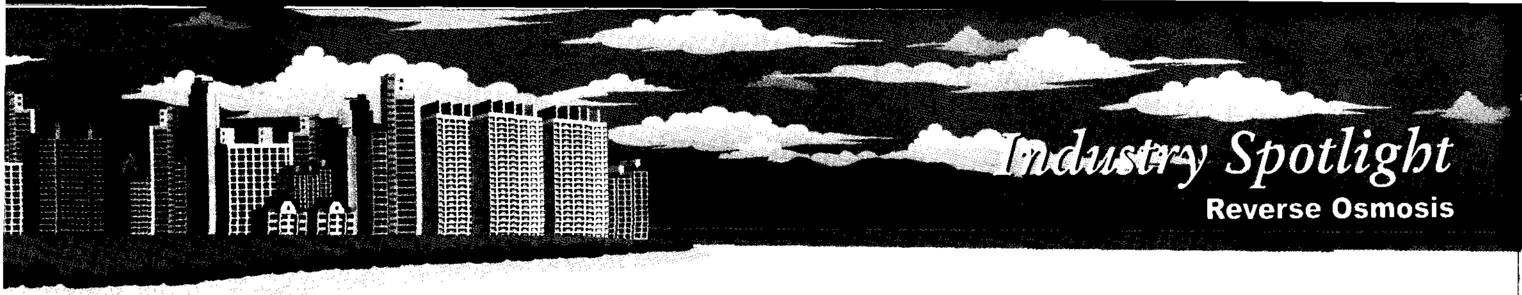
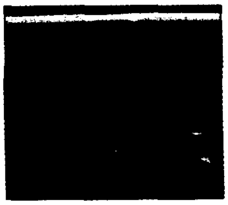



*The article discusses recent VSEP pilot trial results and compares the vibrating membrane filtration system to other methods of brine reject disposal currently being employed or considered.*



# VSEP RO Treatment for Brackish Well Water

**By Greg Johnson, Larry Stowell and Michele Monroe**

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## VSEP advantages

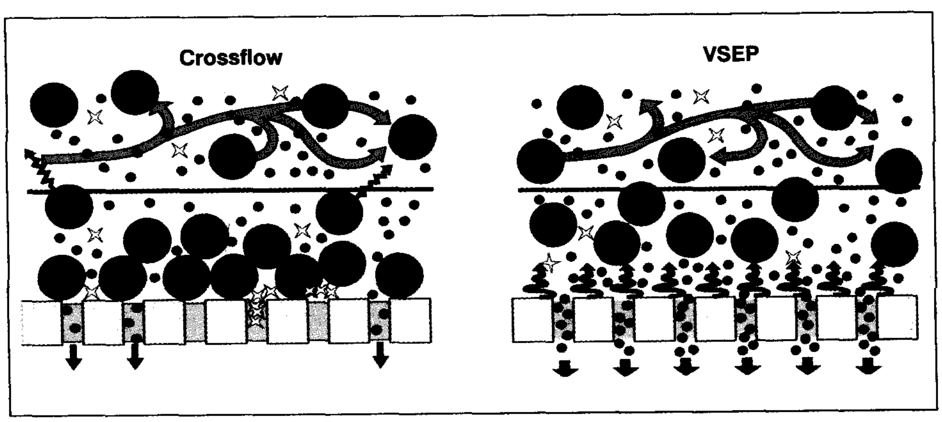
VSEP employs torsional vibration of the membrane surface, which creates high shear energy at the surface of the membrane. The result is that colloidal fouling and polarisation of the membrane due to concentration of rejected materials are greatly reduced. Since colloidal fouling is avoided due to the vibration, the use of pre-treatment to prevent scale formation is not required. In addition, the throughput rates of VSEP are 5-15 times higher in terms of GFD (gallons per square foot per day) when compared to other types of membrane systems. The sinusoidal shear waves propagating from the membrane surface act to hold suspended particles above the membrane surface allowing free transport of the liquid media through the membrane.

The VSEP membrane system is a vertical plate and frame type of construction where membrane leafs are stacked by the hundreds on top of each other. The result of this is that the horizontal footprint of the unit is very small. As much as 2000 square feet (185m$^2$) of membrane is contained in one VSEP module with a footprint of only 4' x 4'.

VSEP employs torsional oscillation at a rate of 50Hz at the membrane surface to inhibit diffusion polarisation of suspended colloids. This is a very effective method of colloid repulsion as sinusoidal shear waves from the membrane surface help to repel oncoming particles. The result is that suspended solids are held in suspension hovering above the membrane as a parallel layer where they can be washed away by gentle tangential crossflow. This washing away process occurs at equilibrium. Pressure and filtration rate will determine the thickness and mass of the suspended layer. Particles of suspended colloids will be washed away by crossflow and at the same time new particles will arrive. The removal and arrival rate will be different at first until parity is reached and the system is at a state of equilibrium with respect to the diffusion layer (also known as a boundary layer). This layer is permeable and is not attached to the membrane but is actually suspended above it. In VSEP, this layer acts as a nucleation site for mineral scaling. Beneath the hovering suspended solids, water has clear access to the membrane surface.

Mineral scale that precipitates will act in just the same way as any other arriving colloid. If too many of the scale colloids are formed, more will be removed to maintain the equilibrium of the diffusion layer. As documented by other studies, VSEP is not limited when it comes to TSS concentrations as conventional membrane systems are.

Conventional membrane systems could develop cakes of colloids that would grow large enough to completely blind the conventional membrane. In VSEP, no matter how many colloids arrive at the membrane surface, there are an equal number removed as the diffusion layer is limited in size and cannot grow large enough to blind the system. In fact VSEP is capable of filtration of any liquid solution as long as it remains a liquid. At a certain point, as water or solvent is removed, the solution will reach a gel point. This is the concentration limitation of VSEP.




*Fluid Dynamics Comparison between VSEP and conventional crossflow filtration*

In the VSEP membrane system, scaling will occur in the bulk liquid and become just another suspended colloid. One other significant advantage is that the vibration and oscillation of the membrane surface itself inhibits crystal formation. The lateral displacement of the membrane helps to lower the available surface energy for nucleation. Free energy is available at perturbations and non-uniform features of liquid/solid interfaces. With the movement of the membrane back and forth at a speed of 50 times per second, any valleys, peaks, ridges, or other micro imperfections become more uniform and less prominent. The smoother and more uniform a surface, the less free energy is available for crystallisation. In the absence of any other nucleation sites, this would lead to a super-saturated solution. In actual fact, what happens is that nucleation occurs first and primarily at other nucleation sites not being on the membrane, which present much more favourable conditions for nucleation.

Crystals and scale also take time to form. The moving target of the membrane surface does not allow sufficient time for proper germination and development. The solids in the bulk fluid present a much more favourable nucleation site. Whereas, with conventional static membranes, scale formation on the membrane is possible and has plenty of time to develop and grow. Another feature of VSEP is that filtration occurs at a dramatically higher rate per $m^2$ than with conventional membranes due to the suspension of colloids above the membrane. Studies have shown as much as a 15 times improvement in flux per area. The result of this is that as much as 1/15th of the membrane area is required to do the same job as a conventional crossflow membrane. This is beneficial for many reasons one of which is hold-up volume of feed waters.

The result is that filtration occurs quickly and the length of travel of feed waters over membrane surfaces is reduced by as much as 15 times. This means that there is much less time for scaling and crystal formation within the membrane system. Crystal formation is a function of time, especially with respect to silica, which is very slow to grow. If scaling is to occur within the system, it will more likely occur at high-energy nucleation points and not on the membrane. In addition to that, the high filtration rate is capable of making a super saturated solution, which may not even have residence time sufficient to react within the membrane system itself and may wait until it has been discharge to complete the equilibrium process.

Since VSEP is not limited by solubility of minerals or by the presence of suspended colloids, it can actually be used as a crystalliser or brine concentrator and is capable of very high recoveries of filtrate. The only limitation faced by VSEP is the osmotic pressure once dissolved ions reach very high levels. Osmotic pressure is what will determine the recovery possible with a VSEP system.

## Validation testing

New Logic has pilot tested several projects where the objective was to volume reduce reject from a spiral RO membrane system. This section will illustrate the performance of pilot tests conducted recently all pertaining to high TDS brine concentration. The first example is not a case of spiral reject, rather it is a case of VSEP treating saline water from an oil production well known as produced water. This test case illustrates the capabilities of the VSEP system. Onsite pilot trials were conducted for several months at an oil production site in Central California. The objective was to treat the water from the oil production wells using RO so that the treated water could be re-injected into the drinking water aquifer for pressure stabilisation.

The results with respect to the primary objective of generating permeate of a quality that reaches the goals for re-injections to the aquifer were met. The water treated was very high in chlorides and because of the very low limits for discharge; two stages of RO filtration were required. In this case, VSEP RO was used as a primary stage with the RO filtrate being polished in a 2nd stage using a conventional spiral RO system. The analytical results from this test were:

| Component: | Chloride | Sulfate | Nitrate | TDS | Boron | Sodium |
|---|---|---|---|---|---|---|
| Initial Feed | 3285 mg/L | 304 mg/L | 4 mg/L | 7314 mg/L | 23.4 mg/L | 2900 mg/L |
| VSEP Permeate | 628 mg/L | 25 mg/L | 0 mg/L | 1617 mg/L | 5.4 mg/L | 614 mg/L |
| Spiral Permeate | 11 mg/L | 0 mg/L | 0 mg/L | 51 mg/L | 0.39 mg/L | 25 mg/L |
| Discharge Limit | 127 mg/L | 127 mg/L | 4.3 mg/L | 510 mg/L | 0.64 mg/L | 85 mg/L |

This test illustrates the ability of VSEP to treat water that is very high is TDS and in other scale forming components. In fact, in this case, silica, carbonates, and sulphates were at saturation with respect to solubility.

## VSEP for brackish water reject from an existing spiral system

Pilot trials on reject wee conducted from an existing membrane system installed in

Southern California. The primary objective was to treat the reject water to minimise reject from the water plant. The result is that disposal costs would be reduced and the yield of clean water could be increased. The primary objectives were to meet limits for colour, TOC and other taste related organics. The customer had previously tested other UF membrane systems for treating this reject and the results were poor regarding flux rate and recovery. The purpose of this test was to see how well VSEP could perform as compared to conventional UF membrane systems. Since VSEP is not limited by solubility and since meeting primary drinking water standards would be a benefit, a tight NF membrane was used. The filtrate from the existing plant and the VSEP 2nd stage concentrator system would be blended, so the better the quality from the VSEP, the more flexibility there would be when it comes to blending.

After scanning several NF membranes, a 90% NaCl reject NF membrane was chosen for further study. Concentration and flux vs time studies were completed and the results were excellent. During a concentration study, the system was started up first in re-circulation mode and also set to the optimum pressure and expected process temperature. The system was run for a few hours to verify that the flux was stable and the system had reached equilibrium. Then, the permeate line was diverted to a separate container so the system is in batch mode. The permeate flow rate was measured at timed intervals to determine flow rate produced by the system at various levels of concentration. The performance during the concentration study was:

| Ave Flux | Initial Flux | Ending Flux | Pressure | Initial Solids | Ending Solids | % Recovery |
|---|---|---|---|---|---|---|
| 65.2 gfd | 144.5 gfd | 11.47 gfd | 450 psi | 0.3% | 11.8% | 98.8% |

Based on the data, the NF membrane was found to be suitable because it provided a high, stable permeate flux with no solids or colour in the permeate. It also met the process objectives for % recovery and demonstrated good performance over time. In this case, the maximum % recovery achieved was 98.8 %, which yielded an average flux of 65.2gfd. (gallons/sq ft/day) The final results of testing were:

| Membrane | % Total Solids | Conductivity | pH | Volume |
|---|---|---|---|---|
| Initial Feed | 0.3% | 1,570 µS | 8.68 | 100% |
| Final Permeate | 0.0% | 145.4 µS | 8.98 | 98.8% |
| Final Concentrate | 11.8% | 44,900 µS | 9.35 | 1.2% |

The results exceeded expectations as the VSEP was able to produce greater than 98% recovery of treated water. In addition, the customer had previously tested other UF membrane systems that had flux rates of about 20gfd. VSEP, using a much tighter NF membrane, was able to achieve a very high flux rate of 65gfd (gal/sq ft/day).

Following are the complete analytical results from grab samples collected during the pilot trails. The purpose of testing was to confirm compliance with primary and secondary EPA drinking water standards related to health issues and aesthetic considerations. By using VSEP to treat the current reject from the installed NF system, 99% recovery of treated water was achievable, leaving only 1% of the volume to be disposed of as reject. The following is a process schematic of the final system design.

## Other VSEP water installations

### VSEP treats river water

New Logic installed its VSEP in July, 1997 at a major international electronic disk manufacturing facility at Hokkaido Island in Northern Japan. The system is used for treatment of river water for ultra-pure water production at this facility. It uses an UF membrane module and is able to treat river water in order to remove or reduce humic substances, colour, turbidity, permanganate consumption and total iron to below the required limits.

The application of VSEP membrane technology to treat river water for ultra-pure water production at electronic disk fabrication facility was found to be an attractive economic alternative to the conventional sand filter water treatment technology. Concentration of the raw river water ranges from 5-10mg/L of TSS. Permeate from the VSEP has less than 1mg/L TSS. VSEP also reduced colour from 67 colour units to less than 1 colour unit, from 2NTU turbidity to less than 0.1NTU and from 0.1mg/L iron to less than 0.05mg/L of total iron.

### Commercial drinking water case study

New Logic has installed a nearly 1MGD water filtration system for a major bottling company. The filtrate from this system is purified and disinfected using an UF membrane and then sent on to the bottling process where it becomes a consumer product for consumption. In this case, aesthetic improvement was the goal due to a large number of taste complaints. Reduction of TOC causing poor taste has been effectively reduced by the use of a 30,000mwco UF membrane. One other benefit of the filtration is the near complete removal of all bacteria and other organisms. Normally, MF could be used with higher throughput per SF of membrane, but in this case TOC reduction required the use of a UF membrane.

The previous system design consisted of a multi-media filter feeding a carbon filter. Normal operation involved frequent recharging or disposal of the carbon media. In addition, the water quality led to numerous taste complaints. The addition of VSEP to the process improves taste, reduces TOC and allows the carbon filters to run trouble free.

**Brine treatment method comparisons**
There are many methods of treatment currently being used for brackish water RO reject. Some of these methods include:

- Disposal
- Evaporation pond
- Deep well injection
- Disposal at sea
- Reclaimed use for industry or irrigation
- Blending with POTW discharge
- Advanced thermal evaporation methods

The treatment method selected will vary depending on the site conditions. For example, if a willing party can take the reject water and benefit from it; this would be the easiest solution. However, willing recipients may be hard to find. Disposal at sea would only be possible if in close proximity to the coastline. This option is not available to places like El Paso. Even if disposal at sea were considered, some discharge limits would apply and may not be met without further treatment. A single treatment method does not fit all scenarios, however, the more that the reject volume can be reduced, the better the choices for final disposal. The primary options for brine reject disposal are:

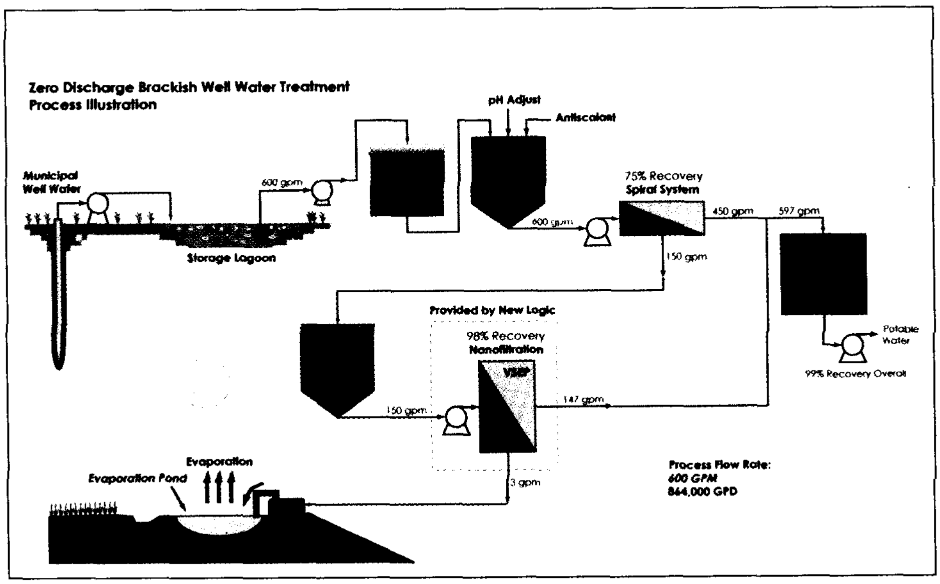
**Evaporation ponds -** Evaporation pond or solar pond use is limited to regions where the evaporation rate exceeds the annual precipitation. Desalination plants located in arid areas such as the southwest United States could consider such treatment methods. The design of the evaporation pond should include liners, leakage monitoring and accurate sizing calculations. The sizing calculation can be complicated as several competing factors must be evaluated including inflow rate, annual precipitation, and evaporation rates. Sufficient excess capacity must be provided.

The cost of construction will vary quite a bit depending on the terrain and site conditions. Once installed, the actual operating costs are relatively small, however, one cost often overlooked is the closure of the pond at the end of the life.

**Deep well injection -** Deep well injection is used for many difficult to deal with waste streams. However, the option of deep well injection is limited by the underlying geology. Any deep well discharge must be protected against mixing with drinking water aquifer supplies.

The permitting process can also be long and arduous. Usually deep well injection is a last resort since it is more difficult and time consuming than other methods of disposal. Costs for disposal wells are mostly related to permitting, drilling and logistics. Very often, disposal well locations are not in the same area as well water supply for drinking water. This means that brine reject would need to be piped and pumped dozens of miles to a suitable location with porous rock formations. One other factor is that in many areas of the United States, oil wells are becoming depleted. Such spent wells are candidates for disposal wells. There are some costs involved in converting the well to a disposal well, but overall there are cost savings if existing wells can be used for this purpose.

**Advanced thermal evaporation methods** - Thermal evaporation methods include brine concentrators and crystallisers. Brine concentrators are used extensively for wastewater applications and employ a falling film evaporator with vapour recompression. Once started, operating costs are manageable. The vapour recompression provides much of the needed thermal energy. The system must be protected against scaling and fouling of the heat exchange surfaces. These systems are capable of reaching up to 15% total solids in the final brine slurry. Crystallisers rely on thermal evaporation of dissolved solids. As the water is flashed off, the solids will begin to crystallise in the unit and are then purged for disposal.




*VSEP Process Schematic for Recently Pilot Tested RO Reject Application*

## Vibrating membranes as an option for brine treatment

With new regulations as part of the Clean Water Act and with the advent of new technologies to address this problem, many municipal facilities are re-evaluating their existing methods. One of the new developments includes the new open channel plate and frame type polymeric membrane filtration systems. Competition and scientific advances have greatly reduced the cost of membrane systems making them more attractive for treating a variety of wastewaters.

RO was previously not appropriate due to solubility limits. Now with this limitation removed, the wide channel flow membrane modules like VSEP, RO membranes offer an excellent alternative to increase overall yield of drinking water and reduce the reject volume to be handled. RO VSEP membranes can be used in parallel and in series to handle any flow and produce nearly any water quality needed.

The VSEP filtration system incorporates a modular design, which makes it compact. Because the basic design is vertical rather than horizontal, the needed floor space per unit is inherently less than other types of dewatering systems. The VSEP does require up to 17' in ceiling clearance. In most industrial applications ceiling clearance is ample but it is floor space that is limited.

Benefits of the VSEP compact design:

- Easily added into an existing system to enhance performance
- Can be installed in areas where space is at a premium
- Is easily portable and can be moved from plant to plant
- Can be installed as multiple stage system or as single stage
- Can be "chain linked" to any number for any process flow demand.

Very often floor space is so limited, or the system being designed is so large that a separate structure is built to accommodate the treatment system. In such cases, the fact that the VSEP units are vertical and compact, it may be able to fit into an existing area of the building or it will reduce new building costs by requiring less space. Construction costs of $80-$120 /square foot for new industrial buildings can add up and are a consideration when figuring the overall cost burden of a completed system. In addition to the limited space required for the mechanical components, the actual filter area has been designed in such a way as to be extremely compact and energy efficient. In the largest model, the "Filter Pack" contains 2,000 square feet of membrane surface area, about the size of a medium size house. This 2000 SF of membrane has been installed into a container with a volume of about 15 cubic feet.

In the case of brackish RO reject treatment, the primary benefits are the increased treated water yield and the volume reduction of reject for disposal. In the test case shown earlier, only 3gpm of reject would be left out of an initial 600gpm of feed flow to the treatment plant. The reject volume would be 150gpm, without the VSEP. Since the cost of zero discharge will hinge on the final disposal of brine, reduction of the reject volume is critical.

## VSEP process conditions

When a VSEP system is added on as a second stage, the well water is fed through the multi-media filter and then the water is pH adjusted and antiscalant is added. The water is then fed to a spiral membrane system at the rate of 600gpm. The spiral system produces 450gpm of treated water and 150gpm of brine reject. This brine reject would be then sent to the VSEP treatment system at a rate of 150gpm and a pressure of 450psig. Industrial scale VSEP units, using NF membranes are installed to treat the spiral reject flow.

The final reject stream after VSEP of 3gpm would be discharged to an evaporation pond or other disposal method. VSEP generates a permeate stream of about 147gpm which is blended with the stage one filtrate from the RO. The permeate contains approximately 1mg/L of TSS and a low level of TDS, all well below the standards for drinking water. Membrane selection is based on material compatibility, flux rates (capacity) and permeate quality requirements. In this example, the TSS reduction is over 99%. The permeate quality from the VSEP can be controlled though laboratory selection from more than 200 membrane materials available to fit the application parameters.

## Economic value

The VSEP systems provide an alternative approach for brackish RO reject treatment applications. In a single operation step, VSEP will provide ultra-pure water and reduce TOC, TSS, TDS and colour to provide a high quality filtrate free of harmful micro-organisms. The justification for the use of VSEP treatment system in your process is determined through analysis of the system cost and benefits including:

- Large land area for evaporation ponds not required as would be without VSEP
- Simple automated treatment system requiring little operator involvement
- Small system footprint
- No chemical pre-treatment addition required
- Non-thermal process with low operating costs.

The VSEP capital and operating costs shown above correspond to the case that was recently pilot tested and described above. Actual VSEP results can vary depending on the make up of the brackish water feed source. Pilot testing should be done to verify system throughput and the resulting capital and operating costs.

Due to the lack of need for pre-treatment, the VSEP technology has been shown to be competitive with conventional spiral membrane systems and could even replace the spiral system completely yielding up to 98% recovery of treated water. A desalination plant composed entirely of VSEP would be a very cost effective alternative to existing conventional membrane plants. However, in such cases where an existing spiral membrane system is operating and where additional yield of treated water is desired, VSEP can be used as a complimentary technology. Compared to all other brine disposal methods, VSEP is much less expensive to own and operate.

## Conclusion

Arid regions of the United States such as the southwest states of California, Arizona, New Mexico and Texas are rapidly growing in population. Local Water Utilities are scrambling to come up with economical sources of drinking water. There has been a lot of research on this subject and this prospect poses a challenge for creative engineers working on the project. Due to competition and scientific advances, membranes are becoming a much more economical method of delivering drinking water from any source.

The VSEP technology has been used for more than a decade in the chemical processing industry. This unique opportunity for treatment of RO reject from desalination plants comes at a time when the VSEP technology is mature, proven, and very cost effective compared to other competing methods.

Addition of a VSEP membrane concentrator system would significantly reduce the volume of brine reject that needs disposal. The reduction of the volume to be treated greatly simplifies the choices for final disposal. In the test case described above, an evaporation pond would only need to be 2% of the size it would be without the VSEP brine concentrator. Reducing the size of the evaporation ponds not only reduces the costs, but has aesthetic and political benefits as well. In addition to helping to solve the brine disposal problem, addition of the VSEP system to an existing desalination plant will increase the yield of treated water to as high as 98% as shown in the case described above.

**About the Authors**

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