WHITE PAPER

HTI'S SEAWATER DRIVE OsMBR:

Truly Sustainable Wastewater Treatment Design for a Changing World

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Climate change and depleted fossil fuel resources threaten the design basis for clean water infrastructure world wide, but particularly in the most densely populated and desirable locations for people to live, i.e. near our oceans or on the shores of bays, estuaries and river deltas. When it comes to the most populous, desirable and threatened human habitats, current discussions focus on overpopulated coastal habitats and the looming sustainability crises at the water power nexus, but who is designing new technology to specifically and comprehensively address these issues?

Hydration Technology Innovations (HTI) is developing the technology solutions that address many of these issues and can demonstrate an attractive return on investment that can justify implementation today!

The Seawater Drive MBR is a comprehensive solution to urban sustainable design at the water's edge. At the core of this technology is HTI's proprietary forward osmosis (FO) driven Membrane Bio-Reactor (MBR), together known as the OsMBR™. The optimal operation of the OsMBR is achieved when it is being driven by the osmotic potential of seawater. For example, a seawater draw solution driven OsMBR receiving a feed of 100 parts by volume of waste water will yield 80 parts by volume of RO quality permeate and 20 parts by volume of sludge bleed. However, the 20 parts (by volume) of sludge bleed contains 98 percent of the nutrients such as N (Nitrogen), P (Phosphorus), and K (Potassium). This nutrient rich bleed can be sent to reduced footprint wetland ponds where algae efficiently consume it. This is illustrated in Figure 3.

Traditional membrane bioreactors (MBR) introduced in the early 1990s offered a significant improvement in treated water quality over conventional Return Activated Sludge (RAS) plants. The microfiltration (MF) or ultrafiltration (UF) membranes used in MBRs serve as a barrier for suspended solids and bacteria while allowing operation at high mix liquor suspended solids (MLSS), and do so within a smaller plant footprint. MBR filtrate is superior to effluent from RAS plants with respect to BOD, TSS and total coliform (pathogens). It is suitable for reuse as reclaimed water for toilet flushing and after disinfection can be used for agricultural or golf course irrigation, but is well below potable reuse standards without substantial advanced treatment.

The MF/UF membrane pore size in an MBR is not small enough to reject total nitrogen (T-N) or total phosphorus (T-P). However, with the optimum application of nitrification and denitrification in an MBR, T-N in MBR permeate can be reduced significantly. Also, T-P can be reduced by physical separation through membranes (NF and/or RO) after addition of precipitating agents such as ferric salts.

Over the past 15 years, there have been numerous advances in MBR technology in performance, operation, membrane module design and membrane characteristics. Even though conventional activated sludge plants continue to be cheaper than MBRs, the price of MBR technology has dropped considerably over the last 15 years so that the higher cost of MBRs can be justified by improved permeate quality in many cases.

HTI's Seawater Drive OsMBR™ targets this cost point in a unique and game-changing way that could extend to currently unserved markets. It does this by giving the MBR the ability to largely power itself using osmotic potentials, while exploiting the ultra-low fouling characteristics of FO, to provide superior treatment performance and lowered O&M/cleaning related costs simultaneously.

HTI's Seawater Drive OsMBR™ must compete favorably against all potential secondary+ wastewater treatment operation options in any relevant brackish water environment subject to secondary and/or tertiary treatment effluent standards, not simply the gold standard for treatment set by MBR/RO based systems. Also, it must out-compete standard secondary treatment on N-P-K, pathogen and EDC (endocrine-disrupting compounds) rejection for any confined saltwater environment, and do so in an affordable way.

HTI's OsMBR™ achieves this by providing the following:

A. MBR/RO level treatment of wastewater at a fraction of the power of conventional secondary treatment followed by NF/RO.

B. MBR/RO level treatment of wastewater at the same or better level of treatment and capital cost of MBR/RO or MBR/NF, but at a fraction of the power and O&M cost.

C. MBR/RO level treatment while not producing RO/NF related waste streams.

D. Reduced waste from cleaning chemicals and modified composition to match the needs of existing natural system treatment capabilities.

E. Nitrate nitrogen, phosphorus and potassium removal to the level of RO rejection by the FO membrane within the MBR regardless of MBR biological treatment efficiency and without fouling upsets.

F. EDC control roughly equivalent to RO, but without RO level power consumption.

G. Integration into various bay, estuary and salt marsh constructed wetland in a way that leverages current capabilities and footprint to treat up to 5 times more water while minimizing changes in the working ecology.

H. Greatly reduced life cycle cost compared with other membrane post treatments for MBRs and other biological secondary treatment plants (conventional RAS).

Forward Osmosis as the Critical Leveraging Technology for MBRs:

HTI has developed an innovative OsMBR to utilize a semipermeable osmotic membrane in the MBR system, thus overcoming many of the disadvantages in present-day MBR systems. As opposed to using a pressure or vacuum driven process employed by present-day MBRs, HTI uses a process called Forward Osmosis (FO) to extract water out of the mix liquor. FO provides some specific and unique advantages in treatment in this application.

Forward osmosis is a process by which water passes from a solution at lower concentration towards a solution at higher concentration when the two solutions are separated by a semipermeable membrane. In nature, membrane mediated osmosis is responsible for the ability of plants to absorb water through their roots and human beings to absorb water through their digestive system. It is also the mechanism by which biological cells regulate the transport of water in and out of the cell. The cell can be regulated by the concentration of either inorganic salts (electrolytes) or sugars in the cellular fluid, and is mirrored in the range of draw solution used in various HTI products and processes.

HTI is the leading provider of FO technology. We have successfully demonstrated the use of Forward Osmosis in applications such as fruit juice concentration, treatment of wastewater produced during natural gas extraction and hydration products for military and disaster relief applications. HTI is the only commercial manufacturer and supplier of FO semi-permeable membranes.

HTI's Seawater Drive OsMBR™ technology applies the process of forward osmosis in MBRs. It uses an infinite draw solution (seawater), which is a concentrated solution of organic and inorganic solutes (dominated by NaCl/salt) with high osmotic pressure, and circulates it on one side (draw side) of the FO membrane while the other side of the FO membrane (feed side) is in contact with the mix liquor in the activated sludge tank. Since the osmotic pressure of the mix liquor suspended solids (feed side) is significantly lower than that of the draw solution (seawater), water passes from the activated sludge through the FO membranes into the draw solution. The diluted draw solution goes back to the bay or estuary from which it was drawn, as a diluted (fresher water) stream. The effect is a salt-water stream that is diluted by the fresh water in the effluent but with a contaminant reduction effect similar to RO.

Justifying Sustainable Design through Immediate Return on Investment:

Unlike many of today's emerging sustainable technologies, HTI's Seawater Drive OsMBR™ technology is sustainable technology that equates to an accelerated payback of the investment.

Conventional thinking would simply compare and position Seawater Drive OsMBR™ against conventional secondary treatment followed by NF and/or RO or current MBR technology. But there is a problem. Utilities have a hard time justifying the cost of these high-grade water treatment solutions. Utilities are called upon to address climate change futures and alternative energy mandates, total energy efficiency mandates, and other long term sustainability concerns. But these mandates are accompanied by sales pitches for technologies that simply are not economic today and don't make sense in the resource-constrained environment, so how can they be justified as sustainable? The Seawater Drive OsMBR must out perform all current options as both a sustainable design tool and current cost cutting measure for the real world utility operator today - and it does.

Currently, the cost of MBRs followed by advanced membranes separation (RO) is prohibitive despite the obvious advantages of the process from the effluent quality perspective. This is because thermodynamics dictates that treating water to a high quality and then dumping it into the sea, while beneficial locally for marine habitat preservation, can never be justified by the cost of the power and resources at the global market or ecology level. **The Seawater Drive OsMBR™ turns the second law of thermodynamics completely around from the membrane processes perspective and harnesses the power of the salt in the sea to provide energy to the wastewater treatment process instead of the treatment process requiring power from us.**

By placing a subtle mass transfer device by the edge of the sea, we let Mother Nature pump both the digester and the tertiary treatment membrane (FO) at the same time. The slow gentle diffusion results in an ultra-low fouling separation process that requires less frequent cleaning and the use of less harmful chemicals than any other membrane separation (including UF) while simultaneously substantially lowering the power consumption by reducing the air scouring needed to keep the membranes clean. Thus, the process truly lowers the carbon footprint because less electrical power is required to treat wastewater than a conventional secondary treatment or first generation MBR plant; a "win-win" for the operator and for the environment.

Traditional membrane filtration processes typically reject a high strength stream, which often includes unproductive contaminates and cleaning chemicals, generating additional waste challenges. The Seawater Drive OsMBR will by-pass a similar amount of wastewater by volume, but this volume is digester/reactor reject with the N-P-K selectively concentrated. The result is the FO membrane selects 80% of the nutrient and pathogen free water for placement into the local environment, while balancing and redirecting the nutrient rich reject stream into a reduced footprint natural biological treatment system best suited to manage it sustainably.

The comparison is given below for conventional treatment (Fig 1), current "natural" (constructed wetland or pond) treatment (Fig 2) and the Seawater Drive OsMBR™ option (Fig 3). The effect of OsMBR is to right size the wetland or ponds for secondary treatment at 1/5th its current footprint requirement through a membrane system that nearly completely powers itself. This combines the advantages of both the high rate conventional approach and the low O&M "Natural" treatment approach, thus producing a truly "sustainable", i.e. "cost effective", sustainable treatment plant.

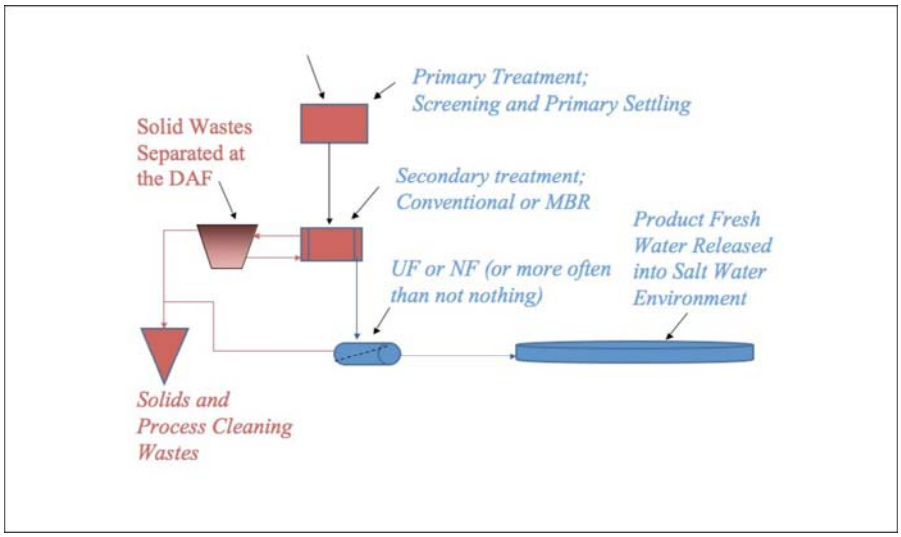

Figure 1: Conventional wastewater treatment plant process

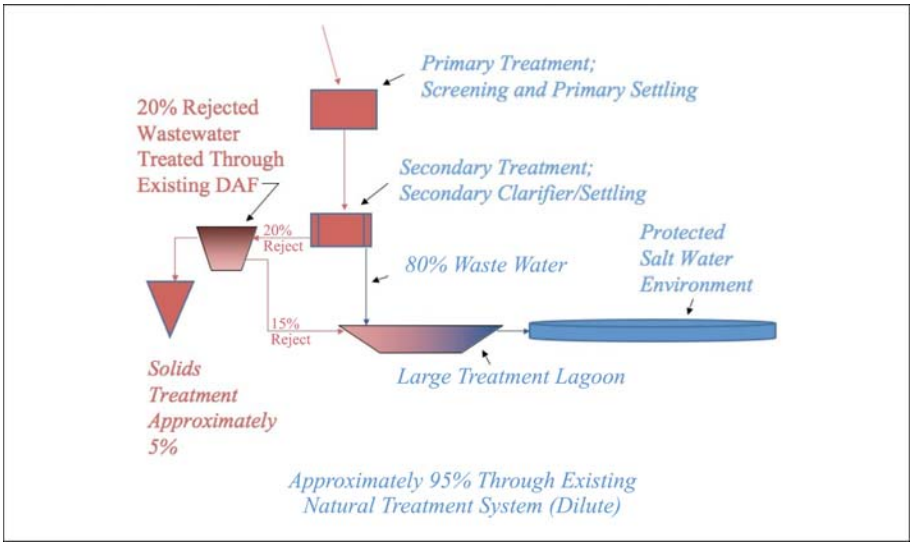

Figure 2: Current "Natural" treatment lagoon model for constructed wetland and pond dependent plants

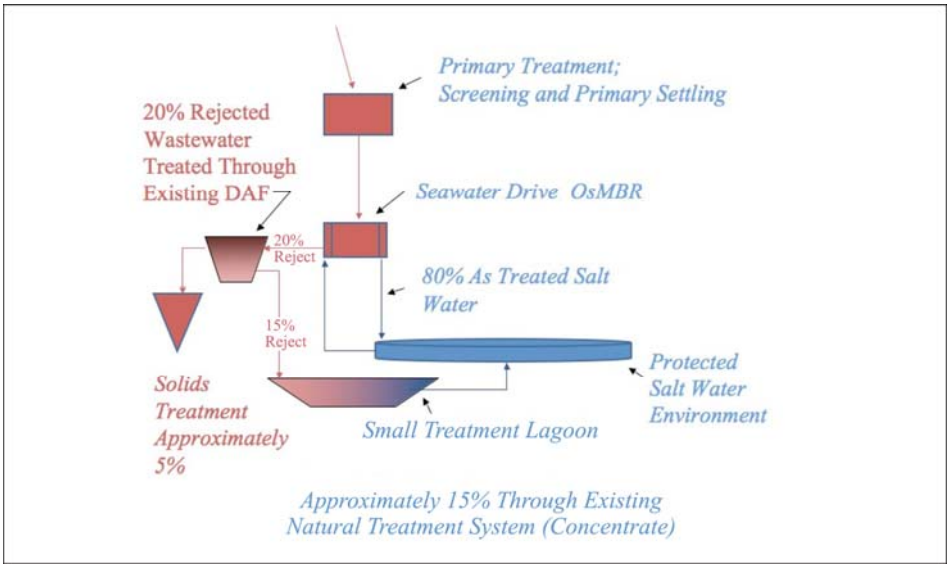

Figure 3: The Seawater Drive OsMBR™ optimized natural treatment system for bays and estuaries

The comprehensive utility to the HTI Seawater Drive OsMBR™ approach should be clear to currently land constrained constructed wetland and lagoon system operators.

HTI's OsMBR technology uses a semipermeable membrane to overcome the limitations associated with present-day MBR technologies that use MF/UF membranes. The following table shows how the disadvantages associated with MF/UF membranes explained earlier is overcome by HTI's Seawater Drive OsMBR™ technology.

Table 1: MBR/OsMBR Comparison

DISADVANTAGES Of current MBR technology using MF/UF membranes	ADVANTAGES Of HTI's OsMBR™ technology using semipermeable FO membranes
Particulate/colloidal fouling of MBR membranes	• Minimal or non-fouling due to the difference in pore size and properties when compared with MF/UF (semipermeable FO membranes) • Low backwash and cleaning frequency resulting in low maintenance, low downtime and higher net permeate flow • Osmotic backwashing performed with minimal or no use of chemicals
Energy cost for membrane scouring	• Lower aeration requirements due to minimal or absent particulate fouling potential • Fine bubble air diffusers can be used to augment oxygen transfer into mix liquor
Backwash and cleaning efficiency	• Surface fouling (as opposed to pore fouling) is easier to clean with lower concentration of cleaning chemicals and lower cleaning time
Phosphorus removal	• Semipermeable FO membranes provide high rejection of phosphorus without chemical addition • Permeate T-P levels meet stringent discharge criteria while improving phosphorus recovery without producing chemical sludge
Removal of virus and endocrine disruptors	• Semipermeable FO membranes reject viruses as well as endocrine disruptors

DISADVANTAGES Of current MBR+RO technology using MF/UF membranes	ADVANTAGES Of HTI's OsMBR™ technology using semipermeable FO membranes
RO concentrate disposal	• No concentrate stream is produced • No RO concentrate disposal cost • Net treated water production is ~ 20% higher than MBR+RO using MF/UF membranes
RO fouling after upset in upstream MBR	• In the event of bio process upset, semipermeable FO membranes block passage of colloidal particles/nutrients

HTI's Seawater Drive OsMBR™ technology is one of the most recent radical and game-changing innovations in MBR technology if not in bioreactor technology in general. It can significantly improve MBR operation while providing superior permeate quality and eliminating the need for concentrate disposal encountered in MBR+RO systems.

For more information on HTI's OsMBR technology, please contact

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