A STUDY OF EFFICIENCY IN CURRENT POINT OF USE WATER TREATMENT SYSTEMS

OR – "HOW MUCH WATER IS MY POU SYSTEM WASTING TO DRAIN EVERY TIME IT MAKES ANOTHER GALLON OF TREATED DRINKING WATER?"

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A STUDY OF EFFICIENCY IN POU SYSTEMS

Executive Summary –

The LINX system demonstrated superior efficiency in this study comparing typical and enhanced RO systems and a capacitive deionization system. The public is generally unaware of the amount of water a typical home RO system sends to waste when making product water. This study characterizes various Point-of-Use (POU) systems with a focus on the efficient use of water.

Study Purpose and Scope –

The testing plan is designed to evaluate the efficient use of water in several types of Point-of-Use (POU) treatment systems under various conditions. All POU systems in this study have the ability to reduce total dissolved solids (TDS). All the systems direct different amounts of waste water to drain in the process of making reduced TDS product water.

The efficiency and other data provided in this study characterize the essential performance of each of the different types of systems. A large scale POU efficiency test project could be developed for public awareness. Ideally this would be done as an independent University type of report with wide distribution to scientists and consumers.

Background -

All TDS reduction technologies must have a way to dispose of the cations and anions accumulated during the process of making reduced TDS product water. Reverse osmosis systems send waste water to drain whenever the membrane is producing water. Deionization systems make product water until a pre-determined exhaustion point. They then stop making product water to enter a regeneration cycle that disposes of the ions the treatment media has removed. When regeneration is complete the system is ready to deliver another batch.

Reverse Osmosis technology and materials have advanced from the first commercial systems to generic consumer appliances in less than 50 years. They are available from water treatment dealers, big box stores, internet sales, etc. Cost for a generic system at a big box is under $150. This low price point means there is an affordable RO for the masses.

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RO system providers acknowledge their systems create a waste stream. However, the websites and the data they provide are miles from the reality of actual efficiency when a system is operated in a household environment. Sites like those cited below state that waste per gallon of product is in the range of 3 to 4 gallons per gallon of product water produced. However, the data that supports this claim is done without the use of a storage tank exerting back pressure on product water production. In real world use, home RO systems don't get used without a storage tank. Our testing with a generic storage tank and typical product draws at various pressures showed waste from 8 – 10 gallons at higher pressures and up to 18 gallons on water pressure of 20 psi.

Typical website claims on efficiency -

AllAboutWater.org
Reverse osmosis, although it is less wasteful than distillation, is still an incredibly inefficient process. On average, the reverse osmosis process wastes three gallons of water for every one gallon of purified water it produces.

RO Water Systems Incorporated
The membrane used in the ROPure5 series will use an average of 3.5 gallons of tap water for every gallon of Reverse Osmosis water produced.

The in-home water meters utilities and water managers used in the past were not sensitive enough to register the very slow waste rates of consumer RO systems. The more advanced electronic meters of today now have the sensitivity to record such slow flow rates. The magnitude of the RO waste water issue is becoming more evident to users and regulators.

In water challenged areas the reduction of RO waste could have a greater impact on water savings than low-flush showers and toilets combined.

Electronic POU systems that have similar TDS reduction performance characteristics offer an alternative to RO systems. Our testing shows systems like the LINX 140 have the ability, under actual operating conditions, to produce a gallon of product water creating as little as 0.4 gallons of waste on waters with an inlet TDS of less than 400 ppm.

In an example of just one gallon used per day, this represents a potential savings of over 1000 gallons per year at 40 psi verses a conventional home RO system.

Methodology –

- All POU systems were operated per the manufacturer's instructions.
- The water source was a softened municipal supply. TDS 140–150 ppm.
- Pressures were adjusted to 20, 40, 60, and 80 psi for testing
- Temperature was monitored in-line
- Projections of RO performance at other temperatures were taken from correction charts provided by membrane suppliers.

NSF/ANSI Standard 53 describes the methodology of a lengthy 7 day test for RO systems. An efficiency calculation (% recovery) comes from this data. The method is very specific for home RO type systems and does not fit the electronic type of POU systems evaluated for this report. The use of water in any POU system can still be readily measured to arrive at a comparable efficiency values.

The basic calculation for efficiency is simple for any POU system --

% Recovery= (Product Water / Product Water + Waste Water) X100

BASIC TEST –

1. Run system at set conditions until the storage tank is full
2. Draw measured amounts of product water from each system
3. Collect and measure the amount of water sent to drain at each draw amount until the system returns to full tank status

*Data on TDS and flow rates was also collected to characterize the POU systems

Instrumentation and Equipment -

Myron L TDS Triple Scale
Myron L Model T2/pH
H&M Digital Dual Range In-Line TDS meters
NIST Traceable TDS Calibration Standards – 15, 150, 300 ppm
Liquid-filled Pressure Gauges 0-160 psi
Watts 560 Pressure Regulator
Digi-Flow 8000T Flow Meter
WX Minute Minder Timers
Nalgene Graduated Cylinders - Various

System Description and Technology

All the devices evaluated are designed to be operated as point of use (POU) water treatment systems. All systems are capable of reducing total dissolved solids (TDS). This distinguishes these POU devices from other physical filters, carbon filters, faucet filters and pitcher filters that do not reduce TDS. All systems tested had pre and post filters installed except the EWP system.

1. LINX 140 NT– Pionetics

- Technology
  - Uses a form of ion exchange to attract and hold dissolved ions
  - Regenerates using only electricity.
  - Stores product water in a captive air tank.
- Power
  - Requires a continuous 120 volt power supply. 6 amp.
- Operation
  - Service – Recharge – Return to Service
- Performance
  - Efficiency (% Recovery) - Averaged 72% (20 psi to 80 psi)
  - Rejection – At "Full" setting rejection rates were up to 95%
  - Temperature - - No significant impact on efficiency
  - Pressure - No significant impact on efficiency

- Other
  - Product water delivery to the faucet varies slightly depending on the amount in the air tank and incoming water pressure.
  - Regeneration is initiated by total product volume delivered
  - Different regeneration frequencies can be set according to TDS level of supply
  - Delivers 3 gallons of product water before regeneration on supply water TDS less than 400 ppm
  - TDS reduction has a customer adjustment to allow the customer to leave in some TDS to change the taste.
  - TDS level on first draw after long idle periods is slightly elevated

2. Typical Home RO

- Technology
  - Uses a generic Thin Film Composite (TFC) membrane in simple housing.
  - Stores product water in a captive air tank.
- Power
  - None required. Can use optional battery powered monitor.
- Operation
  - Service – Refill/Service – Service

- Performance
  - Efficiency (% Recovery) - 5% at 20 psi to 14% at 80 psi
  - Rejection – Rejection rates were up to 95%
  - Temperature – Efficiency reduced by 1.5–2% per degree F
  - Pressure - Impacts efficiency by 1% for each 10 psi reduction

- Other
  - Product water delivery to the faucet varies slightly depending on the amount in the air tank and incoming water pressure.
  - Recharge, refill of the storage tank, is initiated after more than 64 ounces have been withdrawn regardless of TDS, Temperature or Pressure
  - TDS rejection rates are not adjustable
  - TDS level on first draw after long idle periods is slightly elevated

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3. NEXT RO Enhanced RO System

- Technology
    - Uses a generic Thin Film Composite (TFC) membrane in simple housing.
    - Stores product water in a “water on water” tank that uses incoming water pressure to push it back out for delivery. This reduces tank backpressure.
- Power
    - None required. Can use optional battery powered monitor
- Operation
    - Service – Refill/Service – Service
- Performance
    - Efficiency (% Recovery) - 22% at 20 psi to 31% at 80 psi
    - Rejection – Rejection rates were up to 95%
    - Temperature - Efficiency reduced by 1.5–2% per degree F
    - Pressure - Pressure impacts efficiency by 1.5% for each 10 psi reduction

- Other
    - Product water delivery is essentially constant for the entire cycle at a given incoming water pressure.
    - Recharge, refill of the storage tank, is initiated immediately whenever product water is delivered regardless of TDS, Temperature or Pressure
    - TDS rejection rates are not adjustable
    - TDS level on first draw after long idle periods was only slightly elevated

4. EWP – Aqua EWP

- Technology
  - Uses capacitive deionization to attract and hold ions from the water electrically.
  - Regenerates by stopping and reversing charge.
  - Stores product water in a captive air tank.
- Power
  - Requires a continuous 120 volt power supply. 1 amp.
- Operation
  - Service – Static – Change Polarity/Flush – Shunt - Service
- Performance
  - Efficiency (% Recovery) – 45% at 20 psi to 35% at 40 psi
  - Rejection – Rejection rates were less than 50%
  - Temperature - - No significant impact on efficiency
  - Pressure - No significant impact on efficiency

- Other
  - Product quality is strongly influenced by flow rate. At very slow flow rates the system showed rejection of up to 95%
  - The EWP system has a maximum pressure rating of 50 psi
  - Product water delivery to the faucet varies slightly depending on the amount in the air tank and incoming water pressure.
  - Recharge, refill of the storage tank, is initiated immediately whenever product water is delivered regardless of TDS, Temperature or Pressure
  - TDS rejection rates are not adjustable
  - TDS level on first draw after long idle periods was only slightly elevated

5. **Low Cost RO – China (Enhanced Home RO)**
This test was done with the same Low Cost RO characterized in #2. To enhance performance a device called the "Permeate Pump" was used. This device uses the pressure energy of the waste stream to push the product water into the storage tank. By eliminating the backpressure of the storage tank, the system efficiency is improved. In this testing, the efficiency more than doubled at each pressure.

- Technology
  - Uses a generic Thin Film Composite (TFC) membrane in simple housing.
  - Stores product water in a captive air tank using the Permeate Pump device to reduce backpressure
- Power
  - None required. Can use optional battery powered monitor.
- Operation
  - Service – Refill/Service – Service
- Performance
  - Efficiency (% Recovery) – 13% at 20 psi to 23% at 80 psi (NOTE: The device doubled the efficiency of #2.)
  - Rejection – Rejection rates were up to 95%
  - Temperature – Efficiency reduced by 1.5–2% per degree F
  - Pressure - Impacts efficiency by 1% for each 10 psi reduction
- Other
  - Product water delivery to the faucet varies slightly depending on the amount in the air tank and incoming water pressure.
  - Recharge, refill of the storage tank, is initiated after more than 64 ounces have been withdrawn regardless of TDS, Temperature or Pressure
  - TDS rejection rates are not adjustable
  - TDS level on first draw after long idle periods is slightly elevated

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Discussion of Systems –

LINX 140NT

- The LINX claim of 70% recovery was verified at pressures from 20 to 80 psi.
- The LINX claim of >85% rejection was verified at pressures from 20 to 80 psi.

The LINX system out performed all the other systems tested. Rejection performance was improved with the storage tank added. The tank allows for ample flow at the faucet and the DI cartridges can operate at a reduced flow rate.
The data show that dispensing rates at the faucet were doubled at the same pressure using a storage tank. Other advantages of using the tank include the blending of product water and water available during regeneration of the cells.

It is possible to operate the LINX 140 without a storage tank. The system will deliver a continuous flow of product water for 3 gallons from 20 to 80 psi. In a configuration that provides this "no tank" feature, the system is too costly to compete effectively. Generic home RO systems can be purchased at retail for under $150 and they have rejection rates well over 90%. A configuration using one smaller cell to slowly fill a storage tank for on-demand use could potentially bring costs down and save millions of gallons lost to home RO waste.

LINX Percent Efficiency Projections verses Temperatures and Pressures

Pressure and Temperature	**20 PSI**	**40 PSI**	**60 PSI**	**80 PSI**
77 F	72	72	71	71
70 F	72	72	71	71
64 F	72	72	71	71
60 F	72	72	71	71
54 F	72	72	71	71
48 F	72	72	71	71
40 F	72	72	71	71

Low Cost RO (LC RO)

- The LC RO makes no direct claims for recovery or quality.
- There is a section with the statement, "Product water quality and production of RO systems is dependent on pressure and temperature."

The LC RO is representative of the generic home RO systems found at retail, through a water dealer or over the internet. These systems are simple enough for a do it yourself handyman.

Recovery (efficiency) was only 5% at 20 psi and 8% at 40 psi. At 5% recovery, 19 gallons of waste water is sent to drain to make 1 gallon of RO product water.

RO membrane production is typically rated at standard conditions – 77 F and 60 psi – discharging to atmosphere. RO production declines about 1.5% for every one degree decline in temperature. RO production declines 0.5 - 1% for every one pound decline in pressure.

Example: RO system producing 50 gallons per day at 77 F and 60 psi
At 48 F and 60 psi = 25 gallons per day
At 77 F and 30 psi = 35 gallons per day
At 48 F and 30 psi = 20 gallons per day

Note: Subtract storage tank backpressure from these driving pressures and the production is even less.

Recovery goes down when RO production goes down. This is due to the use of a fixed restrictor in the waste line of this type of RO system. The waste will flow at the <u>same rate</u> even if the module in colder water is making product water at only half the rated capacity.

LC RO Efficiency Projections over a range of Temperatures and Pressures

Pressure and Temperature	**20 PSI**	**40 PSI**	**60 PSI**	**80 PSI**
77 F	7	10	12	14
70 F	6	9	10	13
64 F	5	8	9	11
60 F	5	7	8	10
54 F	4	6	7	9
48 F	4	5	6	8
40 F	3	4	5	6

<u>NEXT RO</u>

- The NEXT claim of 33% recovery was verified at pressures above 60 psi
- The NEXT makes only a “soft” claim on rejection, “Highest rejection”. TFC RO membranes typically have rejection specifications of over 90%. Testing verified >90% rejection.
- The NEXT claim of 500% less waste than a conventional home RO is true.

This system is an enhancement over a generic home RO system. NEXT RO addresses the backpressure problem of a captive air tank by using a water-on-water design. Line pressure is directed to “squeeze” the bladder of product water when the faucet is turned on. Then the squeeze water is sent to drain leaving the bladder with no backpressure energy. This line pressure energy pushes the water to the outlet dispensing water instead of the energy in an air bladder. The result is that the RO membrane can produce more water when it doesn’t have to overcome the energy of the tank backpressure. It can make product water faster so the waste stream is on for a shorter time.

Waste water is created from both the use of squeeze water and the reject from the RO membrane process. The design seems inherently limited to less than 50% efficiency. Water is a non-compressible fluid at these conditions. It takes 16 ounces of squeeze water to push 16 ounces of product water to the outlet. That is 50% efficiency before considering any RO reject waste.

NEXT RO Efficiency Projections over a range of Temperatures and Pressures

Pressure and Temperature	**20 PSI**	**40 PSI**	**60 PSI**	**80 PSI**
77	27	32	40	36
70	24	29	37	33
64	22	26	34	30
60	20	25	32	28
54	18	22	28	25
48	15	19	25	22
40	12	15	20	17

EWP

- The EWP claim of 75% recovery was not verified. Testing data show that a recovery rate of 58% is possible.
- The EWP claim of 80% "purification" was not verified. Testing data show rejection as low as 66% on this design.

The EWP system is limited to a maximum pressure of 50 psi. The system sent for testing has the appearance of a hand built prototype. This manufacturer would like to focus on selling the capacitive DI cells and leave system production to OEMs. The system as tested was only intended to reduce TDS to 50-75 ppm per the supplier.

This system needs changes to be a viable POU product when compared to the superior rejection rates the others tested. Product quality is strongly influenced by flow rate. Test data confirm that over 90% is possible if the flow is slowed down sufficiently. The system flow rate is adjusted by changing the inlet flow rate. The system times could revised to extend the service cycle without fear of scaling in the flush cycle. This is particularly true when the source is softened water. Alternately an additional cell in series or changes to the power source would improve rejection performance.

We believe it should be possible to achieve 50 - 80% recovery and 90% rejection with this technology if designed properly. Further testing with a constant inlet flow control still failed to verify the inventor's claim of 75% recovery. That performance would place it in the performance range of the LINX system.

EWP Efficiency Projections over a range of Temperatures and Pressures

Pressure and Temperature	20 PSI	40 PSI	60 PSI	80 PSI
77 F	58	56	Max @ 50 psi	
70 F	58	56		
64 F	58	56		
60 F	58	56		
54 F	58	56		
48 F	58	56		
40 F	58	56		

LC RO with Permeate Pump

- The Permeate Pump claims as much as a 400% improvement in recovery. Testing data show it doubled the recovery rate from 20 psi to 80 psi. The math would call that a 100% improvement.
- The Permeate Pump claims as much as an 80% reduction in waste water. Test data verify this claim.

The Permeate Pump (PP) uses the wasted energy of the RO reject water pressure to drive the product water into the storage tank against the back pressure of the air bladder. This enables the product water to be made against little to no backpressure. The storage tank is filled 2 to 4 times faster with the PP and this shuts off the RO reject sooner saving water. The PP also fills the storage tank closer to the feed line pressure providing more stored product water and a faster delivery rate to the faucet.

The PP can be retrofitted on most home RO systems and cut water usage in half. Earlier models had a clicking noise that has been resolved with newer models.

LC RO Efficiency Projections over a range of Temperatures and Pressures
With Permeate Pump added to system

Pressure and Temperature	20 PSI	40 PSI	60 PSI	80 PSI
77 F	16	14	24	28
70 F	14	12	22	25
64 F	13	16	20	23
60 F	12	10	18	21
54 F	10	9	16	19
48 F	9	8	14	16
40 F	7	6	11	13

Comments

Storage Tanks –

The backpressure of a captive air tank directly decreases the driving force of the RO membrane process. The NEXT RO system and the Permeate Pump option are both designed to improve RO membrane performance by reducing the backpressure that steals energy from the driving force.

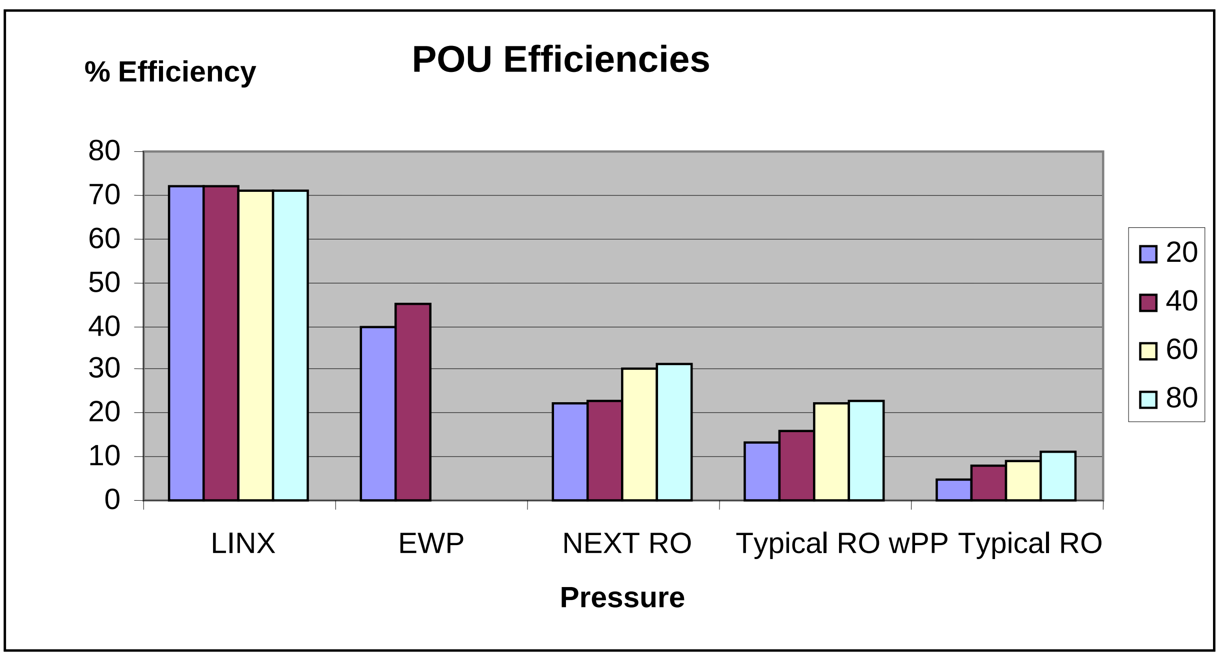
The LINX and EWP systems do not suffer the same impact since they do not rely on pressure to drive the TDS reduction process. Testing data show that the process performance is not impacted strongly by pressure. In either system, a slower flow rate helps to lower product TDS. The use of a storage tank to hold product water for use while letting the system slowly refill it will result in the smallest, low cost system.

Microbiological –

Commercial RO technology is recognized as an effective barrier against biological contaminants. Many medical water systems use a double pass RO configuration. Home RO systems with carbon filters, storage tanks and low flow rates are not sold with any biological claims.

There is data showing that the LINX and EWP technologies may also provide excellent performance against microbiological materials. Could this capability be designed into a home system with biological reduction claims? A final polishing filter may be needed to secure a certified claim.

EFFICIENCY COMPARISONS



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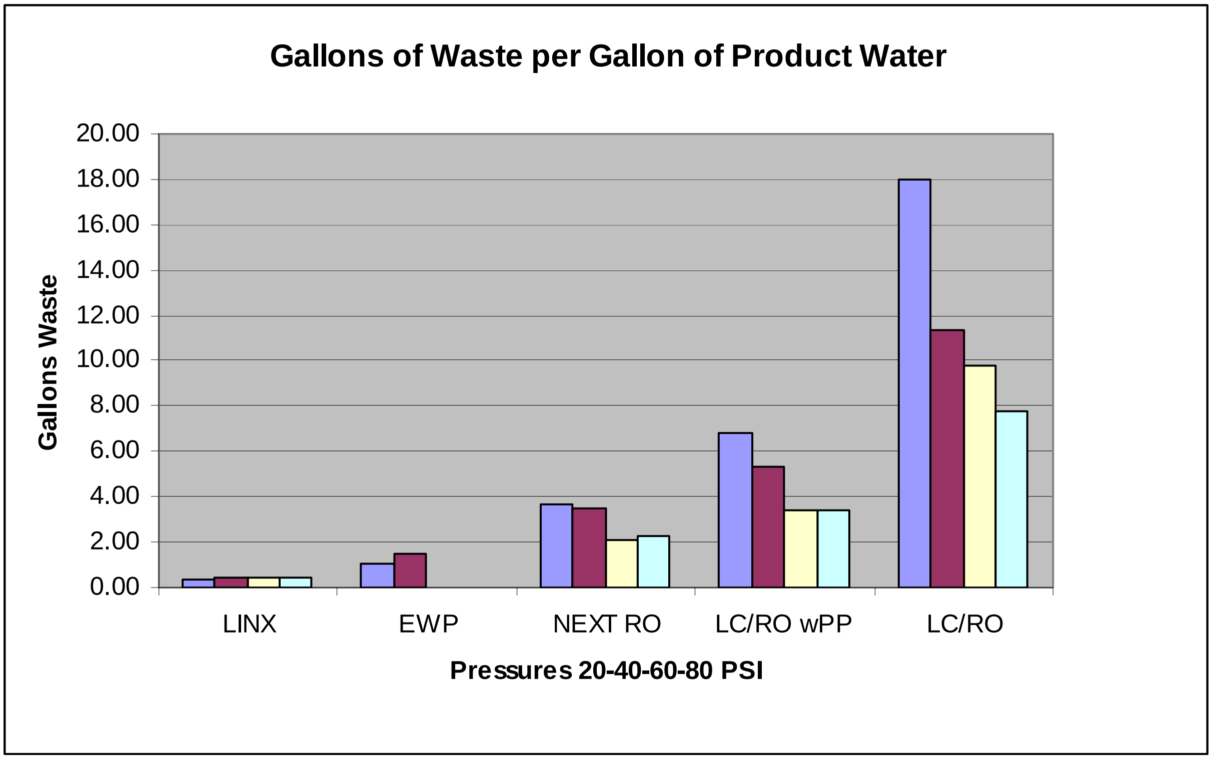

Real World Efficiency Example:

Annual waste to drain at 40 PSI from a family using one gallon of product water each day and the height of a 12” diameter filled with that waste amount –

POU SYSTEM	Waste Per Year	Height of 12” Column
LINX	145 gallons	25 feet
EWP	548 gallons	93 feet
NEXT RO	1277 gallons	218 feet
LC/RO w/Permeate Pump	1948 gallons	332 feet
LC/RO	4152 gallons	707 feet

Conclusions

- The LINX 140NT system performance was superior to the other POU systems tested.
- The public is generally unaware of the volume of water wasted by low cost home RO systems.
- In a cost driven world the low cost RO is the current king.
- A retrofit program with Permeate Pumps has the potential to immediately cut RO waste by 50%
- The EWP technology needs design refinement over the unit tested to achieve its full potential as a competitive POU system.
- The microbiological capability of electronic systems may provide a key advantage verses an RO system.
- A large scale University test protocol could follow to methodology used in this study. The differences in efficiency are very clear.

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Introduction Bio for John Van Newenhizen

John Van Newenhizen is President and founder of Van Newenhizen and Associates, Inc., providing expert consulting on water treatment issues and equipment to a wide range of global clients.

Mr. Van Newenhizen has 37 years of experience in the water treatment field. He spent 30 years at Culligan International in the technical management of all product lines. In numerous positions he played an integral role in directing Culligan's industry leading research and development (R&D) efforts, supervising new product design, regulatory affairs, analytical services and overall quality for household, commercial and industrial markets. As Director of Custom Engineering, John also has extensive experience in the engineering design and manufacturing of specialty water treatment equipment.

An active member of the Water Quality Association, John is currently serving on the Water Sciences Committee. Other affiliations include AWWA, the Water Reuse Association and the National Groundwater Association. He is professionally known for an ability to translate complex subjects into meaningful concepts for stakeholders at all levels.

Mr. Van Newenhizen received a Bachelor of Sciences degree in chemistry and physics from Lake Forest College, holds numerous product patents and has traveled to China, South America and Europe to give technical presentations on water treatment.

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