Membrane Filtration of Commercial Drinking Water

V✧SEP, An effective and economical solution

New Logic Research manufactures a proprietary vibrating membrane filtration system that is uniquely suited for treatment of commercial and domestic drinking water. The use of a vibrating membrane mechanism to avoid membrane fouling is new and is just the kind of improvement needed to make the use of membrane filtration an effective and economical treatment solution for drinking water. New Logic has completed several surface and well water facility installations using this vibrating membrane system for treatment to produce ultra-pure water.

The results have demonstrated many advantages of this new membrane technology when compared to the conventional treatment methods. This new membrane system is know as V✧SEP which is an acronym for Vibratory Shear Enhanced Process and is manufactured by New Logic Research at its factory in Emeryville California near San Francisco.

Water Treatment

Most well water and surface waters contain varying amounts of suspended solids, including silt, clay, bacteria, and viruses. It is necessary to remove these prior to distribution to the domestic or industrial consumer. Suspended solids not only affect the acceptability of the water; they also interfere with the conventional disinfecting process using chlorine. The principal treatment processes used to remove suspended solids are sedimentation and filtration. Sedimentation alone is rarely adequate for the clarification of turbid waters and is of little or no value for the removal of such very fine particles as clay, bacteria, and colloidal materials.

In many plants that treat surface waters, there is a pre-sedimentation reservoir ahead of the treatment units. The reservoir allows the larger particles to settle as well as to provide a volume buffer against changes in water quality. Further treatment involving conventional filtration would require significant pre-treatment with chemical flocculation and precipitation prior to the filters. Neither rapid sand filters nor mixed media filters remove appreciable quantities of colloidal particles without chemical pre-treatment. While these can act as a barrier to unsafe water, the effluent can be as colored or turbid as the incoming water. The use of V✧SEP and polymeric membranes can effectively reduce color and reject colloids, organics, and organisms without chemical pre-treatment. This complete removal is not possible with sand filtration even with chemical flocculation.

Standards for Health:

Total Organic Carbon, TOC	5.0 mg/L
Arsenic	0.025 mg/L
Barium	1.0 mg/L
Cadmium	0.005 mg/L
Chromium	0.05 mg/L
Cyanide	0.2 mg/L
Fluoride	1.5 mg/L
Lead	0.01 mg/L
Mercury	0.001 mg/L
Selenium	0.01 mg/L
Uranium	0.1 mg/L
Vinyl Chloride	0.002 mg/L

Giardia Protozoa, (15 micron) a toxic microorganism that must be monitored in drinking water supplies

Water Standards

Drinking water is monitored to conform to acceptable levels of many harmful chemicals and organisms. Setting of standards is a continual process as more is learned about the potential harmful effects of various constituents. In addition to monitoring for health risks, water quality is controlled for aesthetic and operational purposes. For example, water high in sulfate, while not toxic can have a laxative effect. Water high in iron can lead to hardness and staining in laundering. Water high in organics can have a foul taste. Recent fatalities involving toxic microorganisms have renewed standards review when it comes to monitoring and treatment to prevent harmful bacteria from entering the distribution network. The following list summarizes some of the targeted undesirable ingredients to drinking water.

Dissolved Organic Carbon

Organic Carbon is an indicator of biological growth. Water quality can deteriorate during storage as bio-film dwelling bacteria grow and as a result affect taste and odor.

Arsenic

Arsenic is present at very low levels in all surface waters. It is a naturally occurring chemical found in mineral deposits and will go through a natural dissolution process bleeding it into waterways. Arsenic is a carcinogen and must be controlled in drinking water sources.

Chromium

Trivalent Chromium is the naturally occurring state of Chromium and is not considered toxic. However, naturally occurring Chromium can be oxidized in raw water to make the more toxic form of Hexavalent Chromium. Other sources of Hexavalent Chromium are from paint and plating wastewater contamination of waterways.

Cyanide

The human body detoxifies small amounts of Cyanide. Lethal toxic affects can occur if the levels are above certain limits and the detoxification mechanism is overwhelmed. Chlorination is normally sufficient to oxidize Cyanide and reduce it to low levels.

Lead

Lead is a naturally occurring metal. It can also leach from piping and solder. Lead can be harmful to pregnant women and young children.

Selenium

Selenium is an essential trace element for human consumption. The exact toxic effects of it are not known and its interaction in the human body is very complex. In order to provide safety factor, levels of Selenium are controlled in drinking water so that over-exposure to Selenium does not occur.

Uranium

The naturally occurring form of Uranium is as the Uranyl Ion UO_2^{++}. Uranium, while it may be radioactive, is actually more serious as a toxin to the kidney. At high enough levels, it can cause permanent kidney damage.

Vinyl Chloride

Vinyl Chloride is a man made substance and is not found in nature. It is a synthetic chemical that has been classified as a carcinogen. The toxic affects come from the monomer of vinyl chloride and the polymerized form as found in PVC pipe is not toxic.

Microorganisms

Microorganisms are the biggest challenge when it comes to drinking water treatment. Algae and protozoa can cause problems with taste and odor. Nematodes, while not a health risk by themselves, can harbor viruses and bacteria and shield them from standard methods of disinfecting like Chlorination. Most organisms can be removed using conventional treatment methods and Chlorination. However, nuisance organisms can be difficult to control once they have become established and can become resistant to Chlorination or may be protected by slime and debris. The population of organism can be controlled in many ways including reducing nutrients, eliminating invertebrates, covering reservoirs, and maintaining residual chlorine.

Another very effective method of organism removal is by polymeric membrane filtration. Sub-micron membranes can completely eliminate protozoa and bacteria, especially Cryptosporidium and Giardia, two known lethal bacterial organisms. Membrane filtration can also effectively eliminate Escherichia Coli (E. Coli) and other fecal coliforms that can come from sewage contamination or livestock run-off contamination. Bacteria and other toxic organisms are especially problematic if surface water is used for water supplies. Well water, while initially free from organisms can decay as it is stored and microorganisms once rooted can take hold and cause problems here as well. Sub-micron membrane filtration of drinking water can effectively remove protozoa, which are in the range of 10-15 micron in size.

Membrane filtration is the only effective means of nearly total log removal of bacteria and harmful organisms. Tastes and odors in surface waters result from the action of biological organisms. Chlorination and oxidation can significantly reduce the amounts of microorganisms, but membrane filtration is much more effective and can virtually eliminate even the heartiest microorganism.

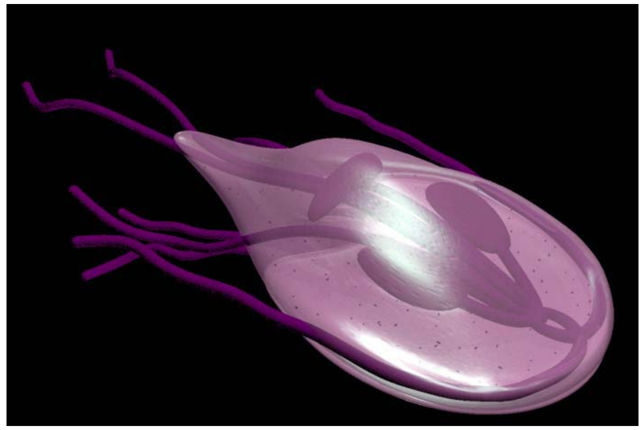


Illustration of Giardia Protozoa

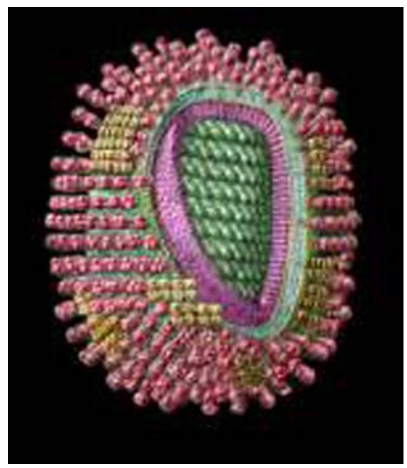
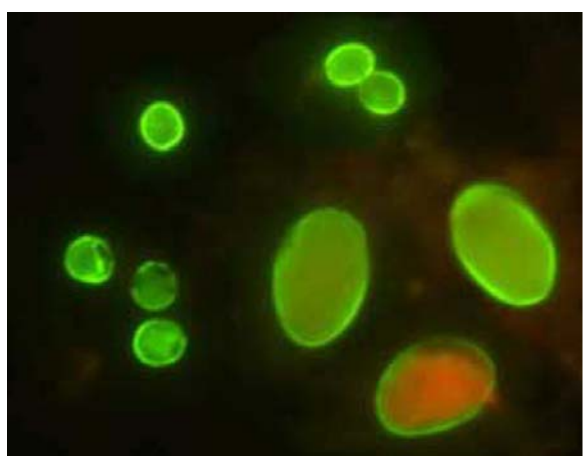


Illustration of Influenza Virus



SEM Photo of Giardia & Cryptosporidium

Cryptosporidium

Cryptosporidium (Crypto) is a parasite commonly found in surface waters such as lakes and rivers, especially when the water is in contact with animal wastes and sewage. Cryptosporidium is very hard to kill with chlorine, which is the current treatment. Although watersheds are closed to the public and have no sewage discharges within them; they are natural areas that wildlife inhabit. Even a well-operated water treatment system cannot ensure that drinking water will be completely free of this microorganism. Cryptosporidium is not a new microorganism, but was first recognized as a health threat in 1976. Presumably low levels of Cryptosporidium have been in our raw water supply for many years. This microorganism is not completely understood. To give this lack of knowledge some perspective, it helps to note the history of human experience with this organism:

1976 - First identified report of infection and illness in humans - a single case in Africa.
1981 - 7 human cases known, worldwide.
1983 - 58 human cases known, worldwide.
1984 - First waterborne outbreak occurs, Braun Station, TX, 47 cases.
1987 - Carrolton, GA, waterborne outbreak, 13,000 cases.
1992 - Jackson County, OR, waterborne outbreak.
1993 - Milwaukee, WI, waterborne outbreak, 403,000 cases.

The federal government and local public health professionals are conducting independent and collaborative research. There are currently no regulations regarding Cryptosporidium in public drinking water. Public water providers, especially those that use surface water, use multiple barriers to reduce the number of oocysts and kill Cryptosporidium in water. Since Cryptosporidium are resistant to traditional disinfecting using chlorine, the best protective practices start with the protection of watersheds from contamination and include the use of optimized filtration and ozonation. Currently, watersheds are protected through the restriction of access by the general public. Deer, elk, and other animals that can be carriers of Crypto inhabit the watersheds. The Center for Disease Control and Environmental Protection Agency have developed more specific guidance regarding Cryptosporidium for the immuno-compromised population.

Water districts recommend that Immuno-compromised individuals should:

1] Bring their drinking water to a rolling boil for one minute for killing the parasite.
2] Use point of use filters that remove particles one micron or less in diameter
3] Use bottled waters derived from protected groundwater supplies, such as protected wells and protected springs that are less likely to be contaminated by Cryptosporidium.
4] Use bottled water treated by distillation or reverse osmosis before bottling

Giardia Lamblia

Monitoring since 1988 has sometimes found small concentrations of Giardia cysts in the water prior to treatment. Disinfecting with chlorine is effective in reducing Giardia concentrations in water. This is the current treatment method. Additional treatment processes are expected to be added in the future to provide additional layers of water quality protection. Giardia Lamblia is a microscopic protozoan which, when ingested, can cause giardiasis. Giardiasis is a gastro-intestinal disease manifested by diarrhea, fatigue, and cramps. Symptoms can last anywhere from a few days to months. Warm blooded animals, such as elk, deer, muskrats, beavers, domestic or farm animals, and humans can be hosts for this protozoan. Giardia is excreted into the environment from the fecal material of the warm-blooded hosts. It is then washed into lakes, rivers, and streams. For this reason, consumption of untreated water while hiking, camping or at any time is not recommended. Giardia can also be spread in day care or health care settings from inadvertent fecal/oral contact (diaper changing, food preparation, etc.). Travelers often contract giardiasis in foreign countries, as well.

Current water treatment regulations, specifically the Surface Water Treatment Rule (SWTR), have been developed to ensure that public water systems provide adequate disinfecting to reduce Giardia concentrations

Controlling Water Quality

The presence of metals and other naturally occurring chemicals will be very stable and predictable. Standard methods of oxidation and treatment are quite effective at reducing the toxicity of these constituents. Once a water source has been selected and characterized, a suitable treatment method can be developed which will be reliable and predictable. While Reverse Osmosis or Nanofiltration membranes can be used also to remove heavy metals, pesticides, and other ionic species, these are in very small concentrations and conventional treatment methods are reliable and inexpensive. The more difficult problem for conventional methods has to do with controlling microorganisms. Blooms can occur as water temperature rises or as nutrient levels increase. Blooms can also occur from pollution by livestock waste or other cross contamination. Older systems are subject to sequestered organisms that are resistant to treatment. Arsenic is getting a lot of public attention, but problems with Arsenic have not lead to any lethal effects and are easily controlled. However, blooms from microorganism have lead to many deaths due to the unpredictable nature of the control of toxic microorganism like Giardia and Cryptosporidium.

Membrane Filtration of Drinking Water

There has been a trend in recent years towards the use of polymer membranes for treatment of potable water for domestic and industrial use. The first sand filter used for clarifying drinking water was installed in Paisley Scotland in 1804. Since then some advances have been made in sand filter design and in the use of coagulation prior to filtration. However, the basic concept has remained the same for nearly 200 years. There have been significant advances in polymer chemistry within the last 20 years and the use of membranes is becoming more widely accepted. In addition to the membrane itself, significant advances have occurred with respect to the delivery system. New technologies are appearing all the time and membrane systems now offer an effective competitive treatment method option. There are four basic types of membranes having to do with pore size or rejection characteristics. Microfiltration is the most open media with pore sizes from 0.05 micron and larger. Ultrafiltration membranes have pores ranging in size from 0.005 micron to 0.05 micron. These are typically rated according the minimum nominal molecular weight size that the membrane will reject. This range for UF membranes is from 2,000 mwco (molecular weight cut off) to 250,000 mwco. Nanofiltration and reverse osmosis membrane don't have pores as such and work by diffusion. Ionic charge and size play a role in the permeation through the membrane.

Sedimentation Rate as a Function of Particle Diameter

Spherical Radius	Particle	Sedimentation Rate
10 mm	Gravel	0.3 seconds
1 mm	Coarse Sand	3 seconds
100 µm	Fine Sand	38 seconds
10 µm	Silt	33 minutes
1 µm	Bacteria	55 hours
100 nm	Colloid	230 hours
10 nm	Colloid	6.3 years
1 nm	Colloid	63 years

Table Showing that only coarse particles can be removed using settling alone

Monovalent ions will pass more freely than multivalent or divalent ions. For the purpose of drinking water filtration, Microfiltration is generally good enough. There is a correlation between pore size and throughput. Generally, the larger the pore, the higher the flow rate through a given area of membrane. Since filtration is needed to remove silt, suspended particles, bacteria, and other microorganisms, a Microfilter is normally used, as it will provide the highest throughput and best economics. If the water source is especially colored or turbid or if taste complaints are a problem, Ultrafiltration can be used which is tighter than Microfiltration. UF membranes can remove very small organic matter, humic substances, and even viruses. UF membranes can improve color, taste, and odor of the drinking water. In the case of commercial bottled water, a premium is charged theoretically due to the better quality of the water. Ultrafiltration is appropriate in this case where taste and color will be a big issue. For domestic water, much of it is used for operational duties like irrigation, laundry, bathing, and such. A very small percentage is actually consumed.

Ultra Filtration Membrane

Composition	Cellulose
Nominal Pore Size	30k mwco
Operating Pressure	0-140 psi
Continuous pH Range	2-12
Max Flat Sheet Temp	60ºC

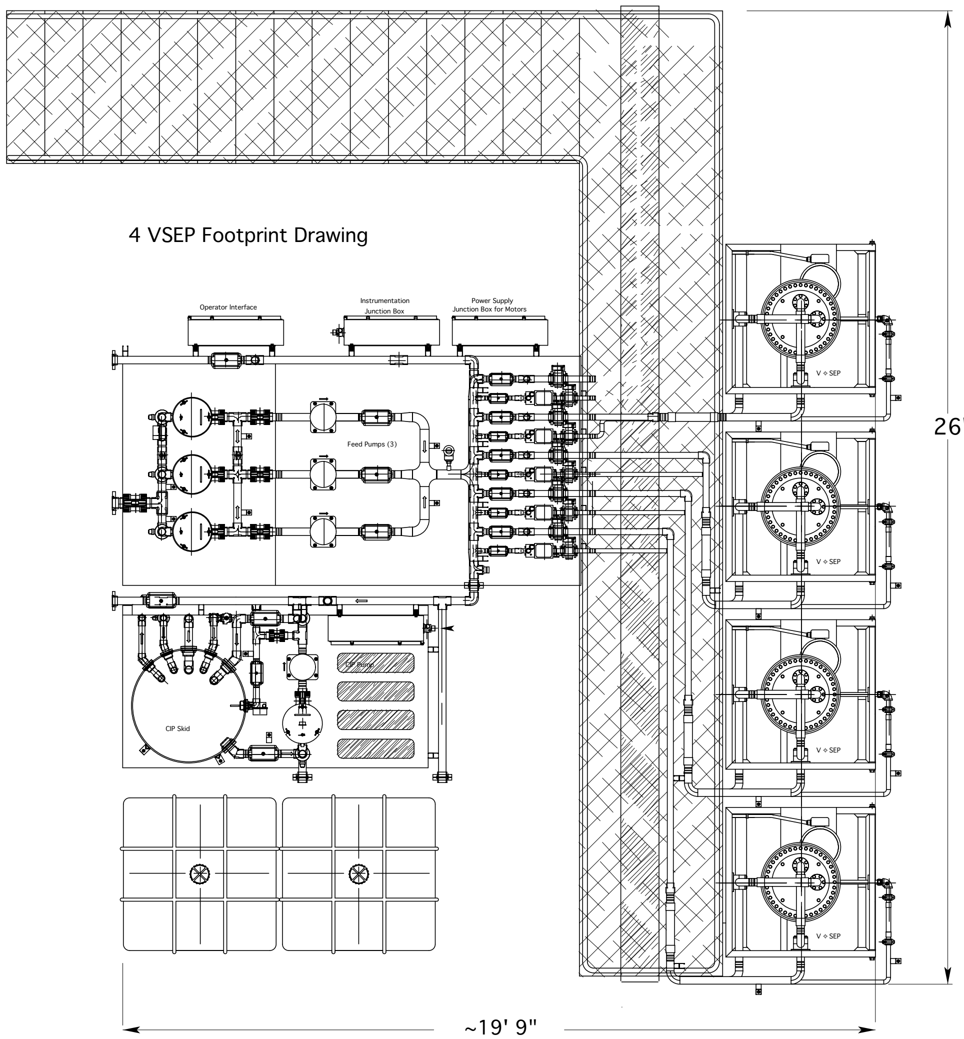
UF Membrane Specifications for this Case Study

V✧SEP Advantages

V✧SEP 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 polarization of the membrane due to concentration of rejected materials are greatly reduced. Since colloidal fouling is avoided due to the vibration, the use of pretreatment to prevent scale formation is not required. In addition, the throughput rates of V✧SEP 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 V✧SEP 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 (185 m2) of membrane is contained in one V✧SEP module with a footprint of only 4' x 4'.

Conventional membranes are subject to colloidal fouling as suspended matter can become attached to the membrane surface and obstruct filtration. Crossflow is used to reduce the effects of this accumulation. Just as conventional membranes have limits on TDS due to the solubility limits of the various constituents, they also have limits on TSS, as colloidal fouling will occur if these levels are too high. V✧SEP employs torsional oscillation at a rate of 50 Hz at the membrane surface to inhibit diffusion polarization 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 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 parody is reached and a state of equilibrium is reached with respect to the diffusion layer. (Also known as a boundary layer) This layer is permeable and is not attached to the membrane and is actually suspended above it. 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, V✧SEP 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 V✧SEP, no matter how many arriving colloids there are, an equal number are removed as the diffusion layer is limited in size and cannot grow large enough to blind the system.



Footprint Drawing of a 4 Unit VSEP Filtration System producing nearly 1 Million Gallons per day of Commercial Water for Drinking

V✧SEP Treats River Water

New Logic installed its Vibratory Shear Enhanced Processing (V✧SEP) in July, 1997 at a major international electronic disk manufacturing facility at Hokkaido Island in Northern Japan. The V✧SEP system is used for treatment of river water for ultra-pure water production at this facility. The V✧SEP system uses an ultrafiltration membrane module and is able to treat river water in order to remove or reduce humic substances, color, turbidity, permanganate consumption and total iron to below the required limits. The application of V✧SEP 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 to 10 mg/L of TSS. Permeate from the V✧SEP has less than 1 mg/L TSS. VSEP also reduced color from 67 color units to <1 color unit, from 2 NTU turbidity to <0.1 NTU, and from 0.1 mg/L Iron to <0.05 mg/L of total Iron.

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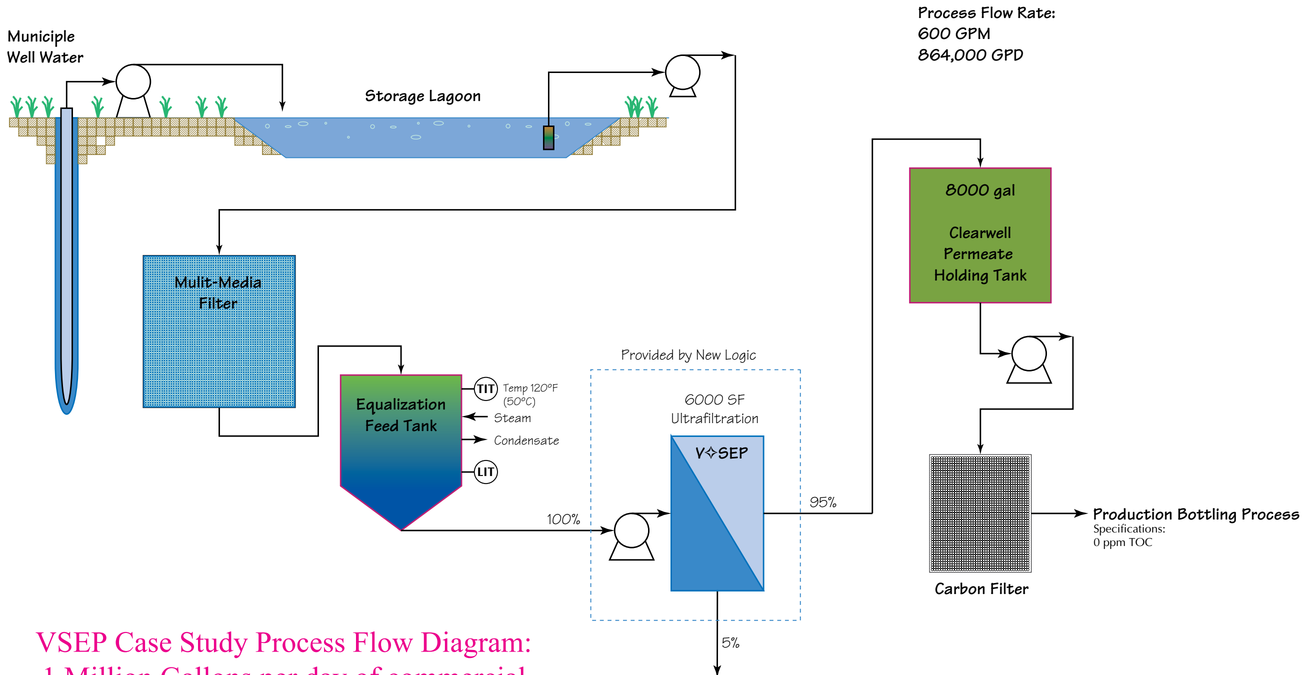

VSEP Case Study Process Flow Diagram: 1 Million Gallons per day of commercial drinking water

Commercial Drinking Water Case Study

New Logic has installed a nearly 1 Million Gallon per day water filtration system. The filtrate from this system is purified and disinfected using an Ultrafiltration 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 30,000 mwco UF membrane. One other benefit of the filtration is the near complete removal of all bacteria and other organisms. Normally, Microfiltration could be used with higher throughput per SF of membrane, but in this case TOC reduction called for 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 V✧SEP to the process improves taste, reduces TOC, and allows the Carbon filters to run trouble free.

Process Conditions

A process schematic for the project is presented in the figure shown above. The well water is fed through the existing Multi Media filter and then to the V✧SEP treatment system at a rate of 600 gpm and a pressure of 100 psig. Four industrial scale V✧SEP units, using Ultra-filtration membranes are installed to treat the total flow. The reject stream of 30 gpm is sent to sewer. V✧SEP generates a permeate stream of about 570 gpm which is sent on to the existing Carbon Filter for polishing. The permeate contains about ~ 1 mg/L of total suspended solids (TSS), and a low level of total dissolved solids (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 V✧SEP can be controlled though laboratory selection from more than 200 membrane materials available to fit the application parameters.

V✧SEP ... A New Standard in Rapid Separation

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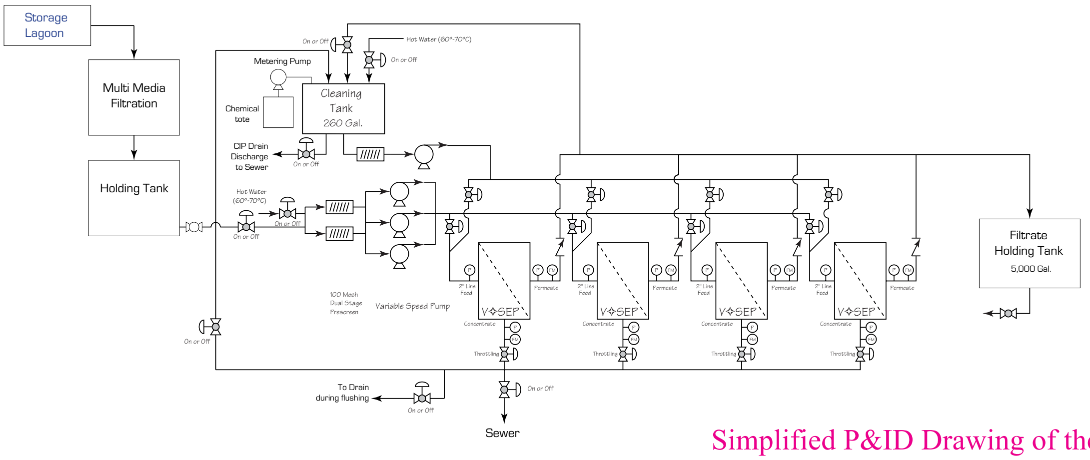


Simplified P&ID Drawing of the Commercial Drinking Water VSEP Installation

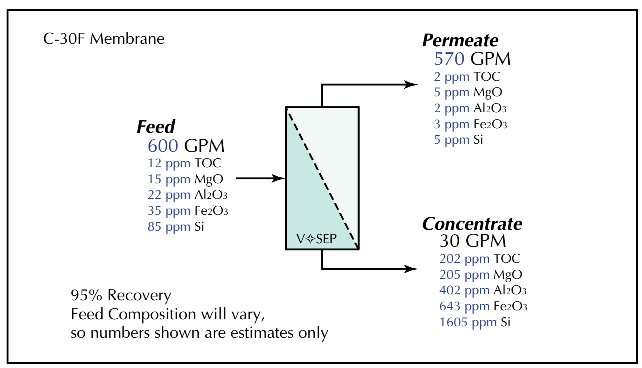
Compact Design

The V✧SEP Machine 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 separations systems. The V✧SEP does require up to 17' in ceiling clearance. In most industrial applications ceiling clearance is ample, it is floor space which is limited.

Benefits of V✧SEP Compact Design:

1] Easily added to existing system to boost performance
2] Can be installed in areas where space is at a premium
3] Easily portable & can be moved from plant to plant
4] Can be installed as multiple stage or as single pass
5] Can be "chain linked" to any number
6] More units can be installed as production grows.

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 V✧SEP 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 to $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 2000 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!!



Block Drawing showing relative performance across the membrane for Commercial Drinking Water

Economic Value

New Logic's V✧SEP system provides an alternative approach for drinking water treatment applications. In a single operation step, V✧SEP will provide ultra-pure water and also reduce BOD, COD, TSS, TDS and color to provide a high quality filtrate free of harmful microorganisms. The addition of V✧SEP can eliminate conventional treatment equipment including the need for chemical treatments. The justification for the use of V✧SEP treatment system in your process is determined through analysis of the system cost and benefits including:

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Commercial Drinking Water - V✧SEP Operating Costs

Description	Description
V✧SEP System Power Consumption*	$ 22,418
System Maintenance & Cleaning	$ 2,555
Annual Filtrate Production (at 144 gfd)	315,360,000 gal./yr

*based on 0.04 $/kW electricity cost

V✧SEP Cost Benefits:
Large land area not required as would be with Clarifiers
Water quality and appearance much better than existing.
Fewer taste complaints.
Elimination of harmful microorganisms
Simple automated treatment system
Small system footprint
No Chemical addition.

Your New Logic Sales engineer can assist with economics analysis for your project and can demonstrate operating cost savings and Return on Investment calculations. The Table above shows the operating costs associated with the commercial drinking water project mentioned previously. The units are modular, so the operating costs are proportional to the number of V✧SEPs installed.

Summary

New Logic Research has supplied V✧SEP separation technology successfully into many industrial processes. The availability of new membrane materials and V✧SEP technology make it possible to economically treat commercial and domestic drinking water.

Contact a New Logic representative to develop an economic analysis and justification for the V✧SEP in your system. For additional information and potential application of this technology to your process, visit New Logic's Website @ http:/www.vsep.com or contact New Logic Research.

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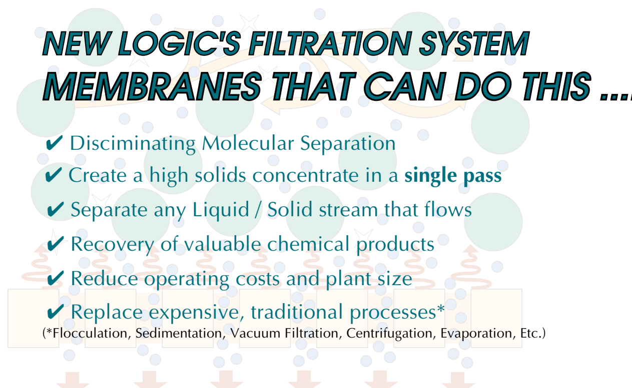

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