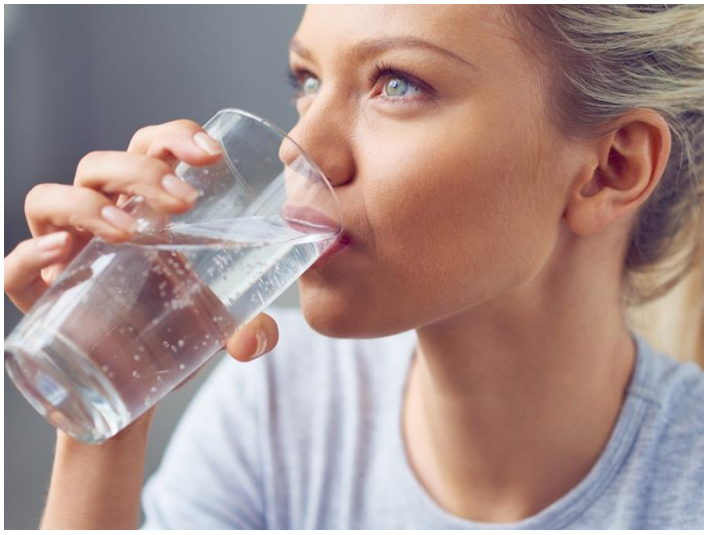
VSEP Vibes Newsletter

Welcome to the New Logic Research Newsletter

100 Million People in the US Drink Water with PFAS

Polyfluoroalkyl Substances, or PFAS, are a very wide range of fluorinated chemicals that have been made since the 1940s. These substances do not decompose and are easily able to migrate through the environment. They are found in soil, surface waters, ground water, and even rain water in Florida. PFAS is suspected to have adverse health consequences for humans and aquatic life. The EPA recently started evaluating how to regulate the discharge of these chemicals. The EPA is working on rules for sewage treatment plant discharge to protect aquatic life and drinking water supplies. They are also developing rules for landfills where significant amounts of PFAS chemicals are found in the leachate. Normally this leachate would be transported to a local sewage treatment plant, but that will likely change since POTWs will be restricted on the amount of PFAS they can discharge.

Very significantly, the EPA has finalized rules for drinking water distributed by public water systems. There is also the issue of private wells and this has not been addressed. Most people with private wells have no idea if their water is safe or not. The EPA estimates that more than 7000 public water systems serving more than 100 million people in the United States have PFAS levels that are too high. PFAS is also being reported at unsafe levels in our own Reno Drinking water that comes from the beautiful Truckee River. The EPA has designated PFAS as a hazardous material. The lawsuits have already begun even while industries and public works did not even know there was a problem just one year ago. There are dozens of PFAS chemicals and the actual health risk and safe level is not fully known. But the entire group is suspected of being harmful. Even though there are dozens of PFAS chemicals that are potentially unsafe, the EPA has outlined an



implementation plan to limit only five of these including PFOA,PFOS, PFHxS, PFNA, and HFPO-DA. The enforceable limits in drinking water for PFOA and PFOS are 4 parts per trillion (ppt) and 10 ppt for the other three chemicals. More than 7000 public water systems are not in compliance with those limits.

Public water systems must monitor for these PFAS chemicals by 2027 and must report to the public what the levels are in their drinking water. By 2029, public water systems must implement solutions that reduce PFAS levels to below the limits. After 2029, any water distributed with levels exceeding the limit will be considered a violation and must be reported to the public. This rule is earth shaking and has not been discussed much or even known to the public. 7000 public water systems have four years to completely change their water source or implement a new water treatment system. The conventional method of water treatment is clarification and disinfecting with Chlorine or Chloramine. This method is completely ineffective in removing PFAS. These public water systems will be looking for solutions that work. PFAS chemicals are very small

and cannot be removed by ion exchange or adsorption. Membrane filtration would seem like the only solution. This will be a very expensive retrofit for these treatment plants. For more than 10 years, New Logic has supplied RO membrane systems for industrial clients with PFAS in their discharge. More recently, landfills have approached us since they see the coming rules on leachate discharge. We have recently completed fabrication of a landfill leachate system bound for Minnesota

Chiquita Canyon Landfill

Last spring a landfill near Los Angeles experienced a common problem which is chemical reactions deep in the pile of trash. Sometimes this can results in an underground fire that is very difficult to extinguish. In this case some sort of chemical reaction is causing heat and this is boiling the liquid leachate causing it to erupt and leak at the ground level. Sometimes these releases have been like geysers.

Leachate in general is very toxic with heavy metals, PFAS chemicals, and other pollutants. Landfills are required to line the bottom of the trash pile and capture that leachate that accumulated and then properly dispose of it. Because of the heat generated in this case volatile substances like Benzene are escaping and leaking on the ground. It is unknown how or when the heat generating reaction will be stopped. Meanwhile, the landfill is collecting the above surface leachate and transporting it for offsite disposal. Normally this could be discharged at a local municipal sewage treatment plant. But, because of the Benzene, hazardous waste disposal which is very expensive is required.

Storage Tankers for Leachate at Chiquita Landfill

There are also concerns about air emissions and the possibility of rainwater runoff carrying pollutants to local surface waters. At first the leachate erupting was about 20,000 gallons per day (gpd). But, this has increased and is now estimated to be 200,000 gpd or about 140 gallons per minute.

This is another reason why maintaining a safe level of moisture in a landfill is important. Some moisture is helpful to decompose the trash. But too much moisture can lead to runoff pollution or other problems.

New Logic has installed more than 20 landfill projects and can effectively treat this kind of leachate. The landscape for landfills is changing since the discovery of PFAS chemicals in leachate is limit or prevent discharging at local POTW locations. More and more, landfills will need to install onsite treatment equipment in order to continue operations. There is currently litigation occurring where the focus is on shutting down this particular landfill. Onsite leachate treatment would insure against this kind of risk.

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A Multi-Color River in Buenos Aires

Recently a canal in Argentina mysteriously turned bright red. Residents near the water body were awakened by the strong stench. This happened to the Sarandi Canal which is located is a suburb of Buenos Aires. This canal flows into the Rio de la Plata river which flows from Argentina and Uruguay to the Atlantic Ocean. Residents have also observed the water in many other colors at different times including yellow, green, pink, and purple with a greasy oil on top. There are textile factories nearby and it is suspected that illegal discharges form these plants may be the cause. The Ministry of the Environment has taken water samples to confirm if the color is coming from organic dyes used at the textile plants. Unfortunately, illegal discharge at night is a common problem in many places around the world.

Sarandi Canal in Buenos Aires

Textile effluent is difficult to treat because of the high concentration of dissolved solids. While these industries use clean water for processing, the chemicals used by these industries including wetting agents, soda ash, caustic soda, peroxides, sodium hypochlorite, bleaching powder, common salt, acids, dye stuffs, soap oil and, fixing and finishing agents make the waste water very harmful to the environment. Textile mills also require a lot of clean water. For every kilogram of yarn, approximately 20-30 liters of water is used.

There are methods for removing color from the effluent, but the high level of TDS would require membrane use. A common method of effluent treatment is to combine the dye effluents into an EQ tank and then aerate to lower BOD and COD. Then the water is passed to a clarifier where lime, Ferrous Sulfate, and polyelectrolyte are added to remove color. Sludge is removed and evaporated. The clarified de-colored water is discharged, but is very high in dissolved solids. The benefit of using membranes to treat the effluent is that the treated water can be recycled instead of being discharged.

New Logic has installed its VSEP system at Textile plants to remove organic dyes and salt using RO membranes. The system requires very little pretreatment and has a small footprint. The VSEP concentrate can be evaporated and a total zero liquid discharge can be accomplished so that no discharge happens and therefore regulatory compliance is not needed. New Logic has also done work with inorganic pigments such as Indigo used to color blue jeans. For this kind of effluent, VSEP on average has a throughput rate of about 60 gallons per square foot per day (GFD) and can recover about 80% of the volume as clean water for reuse.

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Carbon Capture – Fact or Fiction

When a hydrocarbon like coal, gasoline, or natural gas is burned, Carbon Dioxide (CO_2) is produced. Every human and every animal also exhales Carbon Dioxide during respiration. Plants and trees do the opposite. They take in CO_2 and expel Oxygen. But, plants and trees including rainforests only produce about 28% of the earth's oxygen. The rest comes from plant life in the ocean. Mostly, about 50% of the earth's oxygen comes from phytoplankton. These tiny plant like organisms consume carbon dioxide and use sunlight for energy to convert this to Oxygen.

Ratcliffe Power Plant in Mississippi

Even though coal is the most economical fuel for producing electricity for households and electric vehicles, it has become the target for those at war with carbon. The Environmental Protection Agency (EPA) has been applying ever tightening regulations on coal fired power plants. In the 1970s, these power plants could exhaust their flue gas containing Sulfur Dioxide. This lead to acidification of clouds and led to acid rain. Then these plants were required to install scrubbers on their flue gas to remove Sulfur. This is done by spraying a mist of lime water at the top of the stack and as the water drops down, it absorbs the Sulfur and other contaminants. Then the EPA applied very strict rules on the discharge of this effluent requiring treatment to reduce Mercury, Arsenic, and Selenium. More recently, the EPA is proposing a rule that would require sequestration of CO_2 to remove this from the flue gas. But is it technically feasible at a commercial scale?

10 years ago, I was invited to give a presentation on VSEP treatment of coal power plant scrubber water at the EPA headquarters in Washington DC. At the time, the EPA was formulating the rule for treating scrubber water (FGD Effluent). But in order to make a rule and require power plants to comply, they had to be sure that the rule could be met with existing technology. From this, they would recommend treatment options as the best available technology. During my presentation, I described the results of more than a dozen pilot tests that we had completed to treat FGD effluent. I also showed the analytic results where we easily met all of the requirements for discharge of the water including less than 5 parts per trillion for Mercury. The EPA told me that they cannot consider pilot scale results and VSEP could only be considered if we had a full-scale system performing. This was a problem for a couple of reasons. First, no customer needed our system for this application because there was no rule at the time. Second we did have a full-scale installation but were not allowed to discuss it due to NDA restrictions. All I could tell them was that we did have a full-scale VSEP in operation, but I could not disclose results. Eventually, the EPA figured out where the VSEP was and after that, they included VSEP as the best available technology for FGD effluent and finalized the rule.

After the EPA used very strict discharge requirements for FGD effluent as a way of inducing coal-fired power plants to switch to natural gas, it became clear that by using VSEP, these power plants could comply and it could be possible to continue to use

coal. So, then, the EPA began proposing a rule that CO_2 must be captured and removed from the flue gas at these plants. Carbon capture has been worked on by many companies, but there have been no successful commercial scale projects where this has been done. So while the EPA required us to prove feasibility at full-scale for VSEP in order to make a rule for FGD effluent, in this case the full-scale requirement did not apply and only the possibility of carbon capture actually working was all that was needed.

In about 2010, Mississippi Power, a subsidiary of Southern Company, began construction of a "clean coal" power plant known as Plant Ratcliffe. The plant took 5 years to build and was supposed to cost $2.4 billion dollars and ended up costing 7.5 billion dollars. This was for a 582 megawatt powerplant. The design included a gasification of Lignite coal and a carbon capture technology developed by Southern Company. The carbon that was captured as Sodium Carbonate was to be sent through a 30 mile pipeline and then injected into underground storage pits or into old oil wells that needed to be pressurized to produce more oil. The initial plan was for rate payers to pay for the estimated $2.4 billion dollar capex. But the costs soon began to skyrocket. The power plant was able to get an increase for rate payers to $3.2 billion. But in 2018, after the capex costs had tripled and after there were operation problems with the gasification and carbon capture, the decision was made to abandon these and convert the power plant to natural gas. The enormous gasification and carbon capture facility and building was demolished. While several other power plants are attempting to get carbon capture working successfully, the largest power company in the US was not able to do that even after spending $7.5 billion. VSEP was able to solve the FGD effluent problem for only a few million dollars. There are questions about whether carbon capture can work even with an extremely high cost that would be passed on to rate payers.

In 2007, New Logic pilot tested a project for a company with a patented process to capture carbon. The process would involve heat and addition of sodium hydroxide. This would convert the CO_2 into Sodium Carbonate or Baking Soda. However, the process produced large volumes of water containing dilute Sodium Carbonate. In order to produce a baking soda product it would need to be dewatered and dried. The starting Sodium Carbonate concentration was about 5%. The solubility limit is about 13%. So VSEP was used to precipitate the Baking Soda. The osmotic pressure that needed to be overcome was very high. New Logic designed a special high pressure filter and ran the pilot test at 1200 psi. We were able to precipitate the Sodium Carbonate.

A 500 megawatt power plant will produce about 926 tons of CO_2 per day. When converted this would be 1,760 tons of Sodium Carbonate. This would equate to 35,000 m3/day or about 9.3 million gallons per day of liquid that would need to be dewatered or disposed of. VSEP is less expensive to operate than evaporation. Spiral membranes are not able to precipitate solids during filtration. So while VSEP would be the most economical solution, with a flux rate of 10 GFD, it would require a VSEP system having 650 modules. So, the carbon capture scrubber would cost about $400 million and VSEP would cost about $200 million just for equipment. The turn-key project could cost 4 times that amount. Then there is the question about how the power plant would get the 8.8 million gallons per day of water required and how they would discharge that much filtrate. Phytoplankton consume massive amounts of CO_2 at no cost. Perhaps a better way to capture carbon would be to grow more phytoplankton

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If it's not Broken, Don't Fix it

The initial days of VSEP were very interesting. The evolution in design took a while until we had a reliable machine that would vibrate 50 times per second and would pull 100 Gs each time the oscillation reversed. Engineers are taught that vibration is bad and it should be avoided at all costs. Brad Culkin, the inventor of VSEP, took the vibration challenge to the extreme. Not only did he want vibration, he wanted vibration on steroids. Designing a machine that can do this took a lot of work and trial and error. The first torsion spring of a VSEP was a coil spring from a Mazda car. The VSEP prototype hopped across the floor like a helicopter out of control. It took about 5 years, but eventually we nailed it.

After the design was perfected and VSEP systems started to make it into the market, it caught the attention of many large process equipment companies. One of these was Pall Filtron, a multi-billion dollar filtration company. Their management expressed an interest in promoting this equipment because they immediately saw the benefit if shear and vibration after struggling with fouling for many years. Then, 30 years ago, Pall signed a technology transfer and license agreement for food and beverage applications with New Logic to deploy their version of VSEP which they called Pallsep. As part of the technology transfer, New Logic disclosed the design details of the VSEP and also met with them regarding manufacturing procedures. The VSEP does look very simple and we have had potential customers look at it and say that they could build that in their garage. But as we learned in the proving ground days, it is not that easy. Pall is a large company and as soon as their engineers got ahold of our design, they set about to change the whole design and put their signature on it. We warned them about that, but they insisted on their superior engineering knowledge. What we have learned over the years is that changing anything no matter how small can have extreme effects that you could never imagine. We ourselves have tried "design improvements" only to find that there were unintended consequences. Pall learned this the hard way. They did build the Pallsep for several years and sold many systems especially to breweries in Europe. Their design did suffer from some of the first generation design problems. They decided not to renew the license agreement and stopped producing the Pallsep. This left dozens of customers with equipment that they could not service. Some of these customers have converted to VSEP.

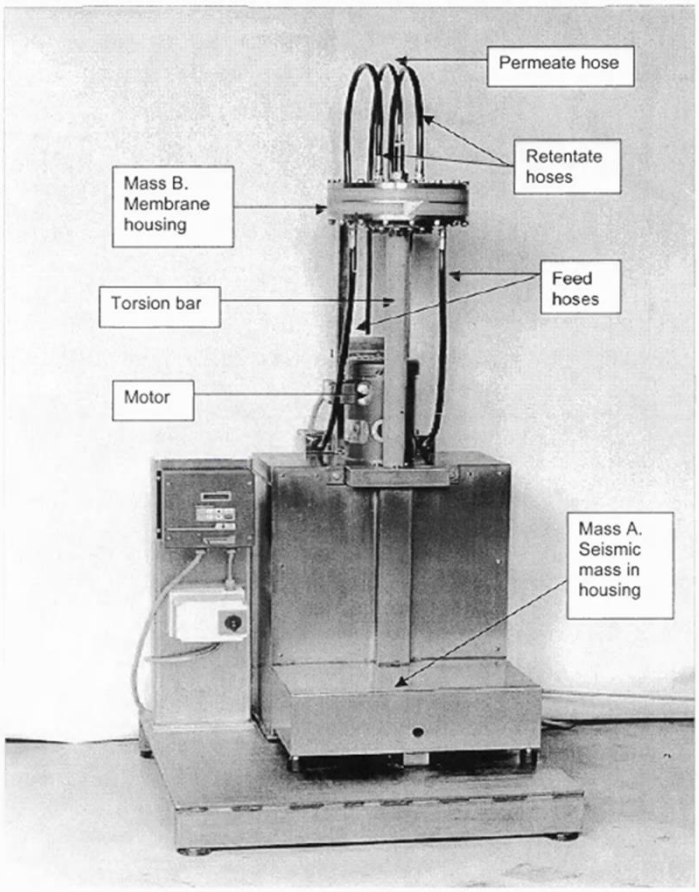

Figure 1.4 – PallSep PS10 (membrane area 0.1 – 1 m^2).

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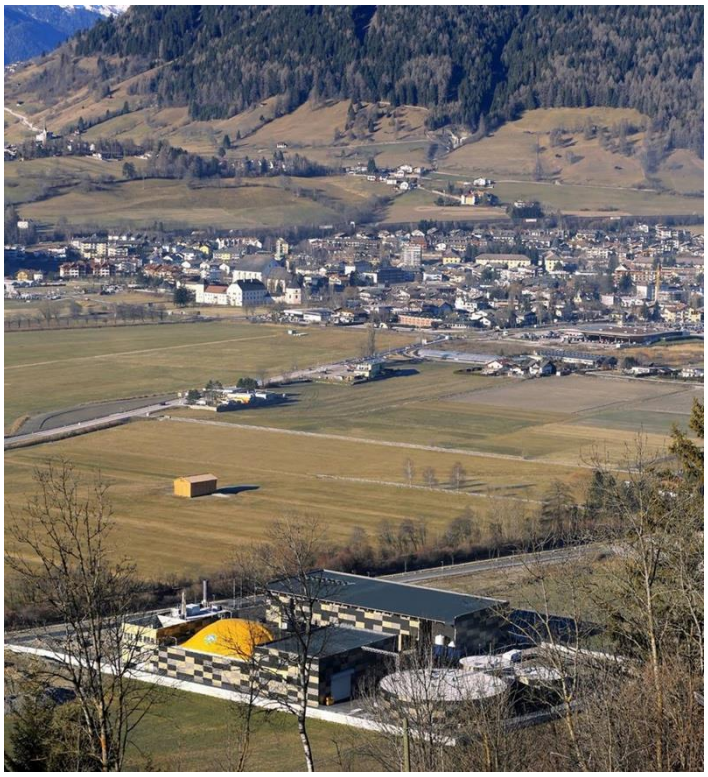
New Biogas Investment Subsidies

There are currently about 2400 biogas facilities in the United States. Some have speculated that there could be as many as 24,000 in the future. Biogas facilities use manure, food waste, or other organic biomass that can generate volatile solids that can be converted to methane. The methane produced can be fed into a natural gas pipeline after cleaning, or it can be burned to make electricity that is put on the grid. The economics of operating a biogas plant are very difficult. New Logic has installed 26 VSEP systems to treat biogas effluent and more than half of these projects have gone out of business. Government subsidies both in the US and in Europe are key to being able to launch a profitable biogas facility.



The US government announced production credits and investment credits for "clean energy" projects in 2022. Just recently on November 17th 2024, the outgoing Biden administration announced that biogas facilities will qualify as "clean renewable energy" projects and would be eligible for these credits. This is a new offer for projects that are commissioned in 2025 and beyond. The government subsidy includes a 30% investment credit for qualifying projects that meet certain criteria. Additionally, the private investments in the project can be depreciated over a short 5 year period instead of the normal 20 years further reducing the economic burden on investor to start these projects. This represents a huge incentive and could lead to the construction of many biogas projects going forward. There is some discussion about whether Biogas should be classified as clean energy especially given the huge volume of effluent that is generated. The same controversy applies to Ethanol where some claim that it requires more energy to produce Ethanol that Ethanol itself can deliver. Biogas, also known as renewable natural gas, is "renewable" in the sense that humans and animals will keep producing waste. But we should not encourage generating more waste for the sole purpose of creating more biogas. After all, though capturing and using methane is better than allowing it to escape to the atmosphere, burning the gas still has an impact. So there are risks with biogas, so it is an imperfect answer. The production of biogas can generate Hydrogen Sulfide, Siloxanes, and Ammonia gas. These must be removed from the methane before use. Natural gas extracted from the ground does not require much cleaning. Raw Biogas production generates about 60% methane and 39% carbon dioxide (CO2). So in addition to the CO2 that is created upon combustion of methane, the production process itself generates additional CO2. A better more sustainable biogas facility would not only recover the methane, but also dewater and dry the nutrient fertilizers in the effluent.

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Fly Ash – A value added byproduct of Coal

Fly ash is the residual particulate matter left after coal is burned to make electricity. The fly ash rises with the flue gas and solidifies and is then caught with bag filters. Because the fly ash contains many of the same minerals as Portland cement such as Silicon Dioxide, Aluminum Oxide, and Calcium Oxide, it can be used a replacement or partial replacement for Portland cement. This has value and can be sold as a product. About 50% of fly ash is recycled in this way. The rest is sent to landfills. Unbeneficiated fly ash can be used as a filter replacement for sand in concrete. Coal fired power plants will store this material onsite in large quantities until it can be moved offsite. These storage piles should be lined and protected so that releases to the environment cannot occur. The fly ash can contain trace amounts of heavy metals including Arsenic, Beryllium, Cadmium, Chromium, Selenium, and Mercury. So, when it rains, the water will absorb these pollutants and the leachate is not suitable for discharge and must be treated. This is called fly ash leachate. If the moisture content of the fly ash pile is not maintained at a safe level, a containment berm can fail and release to the environment can occur. Such a release happened in 2008 when a containment failure occurred at a Tennessee Valley Authority's Kingston fossil plant in Roane County Tennessee. The

spill resulted in 1.1 billion gallons and leachate flowing into nearby waterways including the Emory and Clinch river.

Fly ash is not regulated as much as the flue gas scrubber water, but it is an environmental concern and a liability. As with any landfill, the water balance must be maintained or a berm failure can result. New Logic has experience in treating fly ash leachate. For example in 2018, New Logic pilot tested this leachate for a coal fired power plant in Indiana. The effluent had 0.77% total solids and a conductivity of 9,500 µS. The water also had about 170 parts per billion (ppb) of Selenium and 21 ppb of arsenic. The concentrations of heavy metals will vary depending on the source coal that is use. With just a single pass with VSEP RO, we were able to produce clean water that would be suitable for discharge or reuse. The VSEP was able to recover 93% of the volume as clean water with a conductivity of 365 µS. The final concentrate was 5.7% total solids and most of these were precipitated and crystallized during filtration. Even with the high recovery rate and high ending solids, the VSEP had a flux rate of 28 gallons per square foot per day (GFD). VSEP with no pretreatment and direct RO was able to demonstrate its ability to dewater the fly ash and allow for maintenance of the water balance for the fly ash storage.

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VSEP vs 38,000 Pigs' Manure

The European Union has created very strict rules that went into effect at the end of 2016. The Nitrate Directive Guidelines are an integral part of the Water Framework Directive that regulates agricultural activities to protect water sources. In Europe, Pig and Cow farming has been done for thousands of years. In many cases the farms have land applied their manure waste on the same land during that same period. This has led to Nitrates getting into the water supplies. Also manure has a low N:P ratio and more Phosphorous is applied to the land than the crops can use. So this has led to high P levels in the soil which leads to eutrophication and poor water drainage leaving the soil muddy.

The EU has been very aggressive when it comes to climate change and believes it is an immediate threat. They claim that animal farming is responsible for 18% of global greenhouse gas. Land applied manure can release Ammonia, Nitrous Oxide, and Nitric Oxide gas to the atmosphere. In addition to these gas emissions, the applied manure can release Nitrates, Ammonium, and Nitrates into the ground threatening groundwater and surface water in overfertilized areas. However, some agricultural areas do not have large livestock populations and are deficient in nutrients. So a more even distribution of nutrients would be beneficial, but transportation distances make this difficult.

To tackle these problems, several Milan University professors and staff published an article about a VSEP RO system what was installed to dewater and concentrate pig manure. The article titled Pig Slurry Management Producing N Mineral Concentrates discusses how the VSEP system removes clean water and captures and concentrates the nutrients so they can be transported more easily to regions that are deficient in nutrients.

The article also goes in depth about how specifically this improves water and air emissions that cause pollution and global warming.

The VSEP system analyzed took up only 200 m2 and was installed at a pig farm with a production cycle of 38,000 pigs. The process starts with a screw press to remove large solids followed by a vibrating wire mesh screen to capture remaining solids that are >100 microns. Then, the screened manure is fed to a two module 84" VSEP RO system. The VSEP permeate goes to two stages of spiral RO polishing to make clean water with very low levels of Nitrogen.

During the process, 19% of the volume is removed by the screw press and vibrating screen. 48% of the volume is removed as clean water and 33% of the volume is left as an exportable liquid nutrient slurry. So because the volume of the liquid concentrate is only 33%, hauling costs are 1/3rd of what they would be without the VSEP system. The project was installed in 2020 in Tezze sul Brenta in the Northeast of Italy. The customer has recently requested a quote for replacement filters after 4 years of use.

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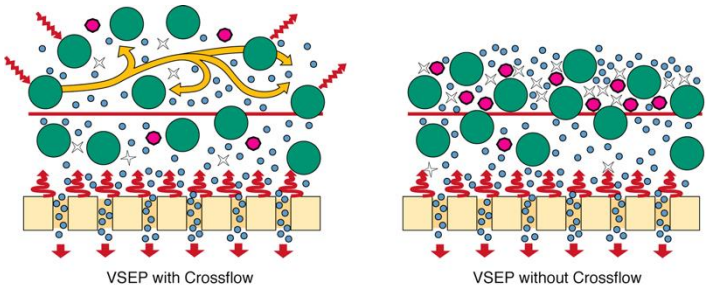
The Power of Shear plus Crossflow

During membrane filtration, liquids are able to pass through the membrane and solids are rejected. Much of membrane science has been dedicated to keeping rejected solids from getting in the way so they reduce water transport rates. Spiral membranes rely only on aggressive laminar flow to create turbulent shear to "wash" away rejected solids. This method of operation is known as "Crossflow". New Logic's VSEP employs torsional vibration of the membrane, which creates high shear energy. The result is that shear is created right at the membrane surface rather than on the backside of the rejected solids boundary layer in the bulk flow. The combination of this shear at the membrane and laminar crossflow are far superior to crossflow alone.

The reduction of throughput due to solids impedance is broadly referred to as "fouling". In fact, there are many ways that solids present themselves once rejected. Fouling simply refers to the fact that they are there and are impacting performance. Minimizing fouling or the presence of solids at close proximity to the membrane is the key to membrane system optimization. The solids can be held in place by convection as the liquid flow is rapid and toward the membrane surface. The analogy here is similar to a piece of paper being held against a chain link fence by the wind. Shear at the membrane surface can inhibit solids deposition by simple convection. It can also have some reducing effect on solids that are able to migrate close enough to the membrane for form chemical bonds. One other mechanism that is often thought of as fouling is when rejected materials are basically congregating near the membrane surface like when a large number of people are trying to exit a theater with only one

door. These solids are rejected by the membrane and are hovering or floating near the membrane. With no shear at all, solids can become densely impacted and form a layer of concentrated dissolved solids very near the membrane or even form a scale on the membrane. With the addition of shear, these particles or solids stay away from the membrane, but can still form a densely packed layer known as a boundary layer that is suspended above the membrane. If this layer builds to significant density, it can act as a resistor in series with the membrane that will reduce throughput.



In addition to shear and crossflow for solids removal, there are some other naturally occurring phenomenon. There are "back diffusion"

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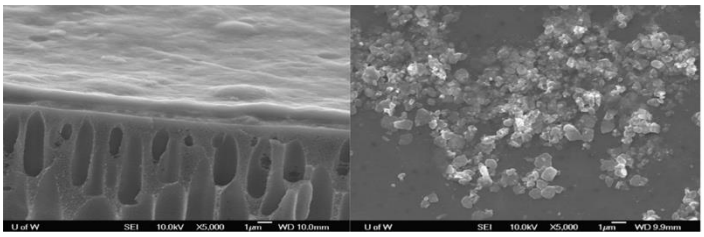
mechanisms that will occur naturally. The back diffusion transport mechanisms for small molecular substances are different than large macromolecules. Large macromolecules are back transported by shear waves. With no shear, macromolecules will not move. Small molecules will disperse evenly due to Brownian motion. In nature, small particles will naturally disperse and create a solution with equal dispersion of ions throughout all of the liquid body. Small molecules are in constant irregular motion with a velocity proportional to the square root of temperature. Small particles are buffeted about by collisions with other molecules in the fluid. As these collisions occur, small molecules are transported in different directions and are constantly in motion. Equilibrium occurs when the particles and number of collisions are equally spaced. The result is an even dispersion of small molecules in a fluid body.



SEM Image – No Vibration Left, w/Vibration Right

Vibration shear plus crossflow is better than just vibration or just crossflow alone. The shear waves created by the VSEP are very intense at the membrane surface at about 120,000s^{-1} However, this shear energy dissipates as the shear waves travel out into the bulk fluid. Once out in the bulk fluid, no shear would exist without crossflow. Shear at the membrane surface can back diffuse the molecules and expel them only to a certain distance from the membrane. After that, crossflow is needed to completely convect these away from the boundary layer. An equilibrium is reached when crossflow washes solids away at the same rate as new solids are arriving.

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