NEW LOGIC RESEARCH

Technical Article

Membrane Filtration of Landfill Leachate

Advances in Module Designs Enhance Landfill Effluent Treatment

Introduction

Some recent breakthroughs in the membrane filtration industry have now made it possible for the treatment of some previously difficult separation applications. New "plate and frame" type membrane modules can tolerate very high levels of TSS, organics, and COD. Previous conventional membrane modules with tight feed channels and limited crossflow capabilities were not able to effectively handle the high fouling and plugging applications like Landfill Leachate. Now, with more open high turbulence membrane modules that are resistant to fouling and plugging, membranes are becoming a preferred option for treating Landfill Leachate when compared to conventional methods that have been used for many years.

This article discusses the new membrane technologies and how they compare to the existing methods used at Municipal Landfills in the United States.

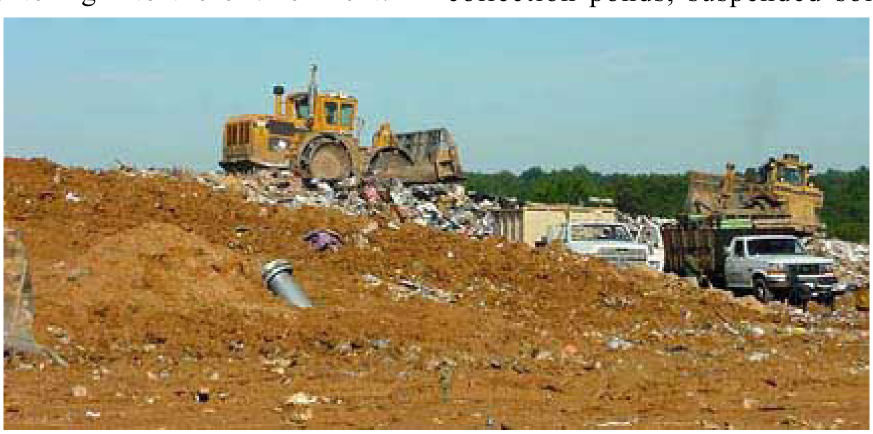
Landfill Operations

The reason for having a landfill is to contain waste and prevent it from entering into the environment. In modern landfills, the waste is actually encapsulated and sealed off to prevent migration of pollutants and pathogens. The key part of landfill design is the bottom liner on top of which the solid waste is piled and compressed. The liner is made of a rugged puncture resistant material like high-density polyethylene. The liner is also surrounded by compacted clay soil, geo-fabrics, and other layers of protection.

There are two ways for liquid to enter into the landfill. One is in the trash itself. Landfills regulate the moisture content that is allowed when dumping solid waste. Slump tests and paint filter tests are used to measure moisture contents. Rainwater also can soak into the landfill and will result in leachate that must be treated. It is important to keep the landfill as dry as possible to reduce the amount of leachate.

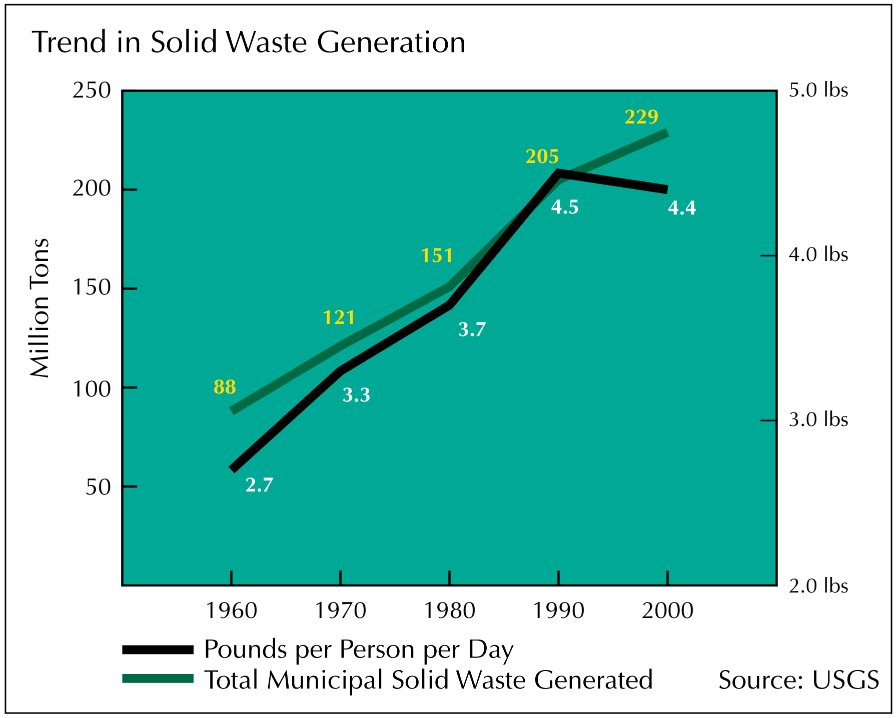
Surface run-off is collected using ditches and catch basins and is diverted away from the covered landfill cells. The ditches are either concrete or gravel-lined and carry water to collection ponds. In the collection ponds, suspended soil particles are allowed to settle and the water is tested for leachate chemicals. Once settling has occurred and the water has passed tests, it is then pumped or allowed to flow off-site.

Since the cover of the landfill is porous, water does leach into the landfill area. The water percolates through the trash and picks up contaminants along the way. The decomposition process breaks down the solid waste and the introduction of water acts as a solvent to dissolve digesting materials.



This water that contains dissolved contaminants is called landfill leachate and eventually reaches the bottom of the cell where it starts to accumulate. If the level of leachate saturating the bottom layer of soil rises, the hydraulic pressure on the liner also increases. This pressure must be relieved to prevent leaks and the leachate is pumped out via drainage piping that is perforated.

Leachate Control Methods



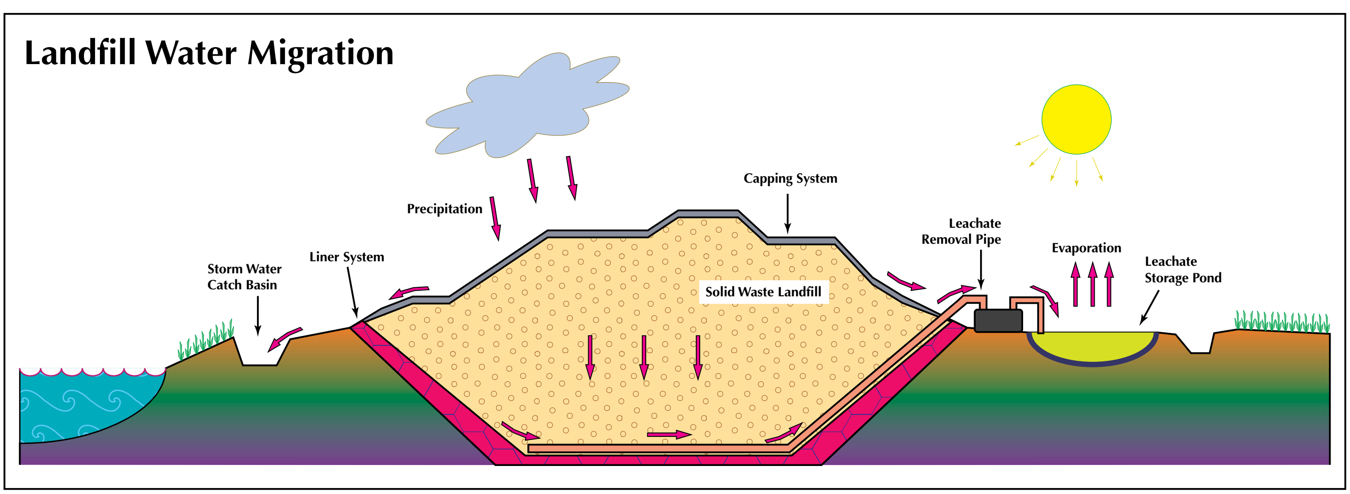
The leachate is directed to a separate leachate collection pond. Leachate can be pumped to the collection pond or flow to it by gravity. A leachate collection pond is designed to catch and isolate the contaminants that can get into the environment. The leachate in the pond is tested for acceptable levels of various chemicals (biological and chemical oxygen demands, organic chemicals, pH, calcium, magnesium, iron, sulfate and chloride) and allowed to settle. After testing, the leachate must be treated like any other sewage/wastewater. The treatment may occur on-site or off-site. The options for treatment include recirculating the leachate back to the landfill, treating for sanitary sewer discharge, or treating for local surface water discharge.

Because leachate may contain contaminants from the buried solid waste, it must be prevented from going outside the landfill boundaries or down into the groundwater. Through a complex combination of landfill liners, monitoring wells, piping, pumps, and capping of the landfill, leachate flow is restricted and captured. The wetter the climate, the more potential risk there is for leaks and attenuation of toxic substances. Paint, pesticides, batteries, and automotive products deposited in landfills contribute to the toxic contaminant levels in the leachate.

The EPA estimates that 7.1 billion gallons of wastewater was generated at landfill facilities domestically in 1992. EPA has proposed to regulate the following landfill sources of wastewater: leachate, gas collection condensate, truck/equipment wash water, drained free liquids, laboratory wastewaters, and contaminated stormwater.

Regulations

EPA has published its proposed regulations for Landfills as part of the Clean Water Act. The new effluent limitations are based on "Best Available Technology " (BAT) methods that have been surveyed and



Municipal Landfills in the United States

Alabama	28	Montana	82
Alaska	217	Nebraska	21
Arizona	59	Nevada	56
Arkansas	67	New Hampshire	33
California	278	New Jersey	14
Colorado	72	New Mexico	79
Connecticut	11	New York	42
Delaware	3	North Carolina	114
Florida	67	North Dakota	12
Georgia	159	Ohio	63
Hawaii	10	Oklahoma	94
Idaho	37	Oregon	88
Illinois	61	Pennsylvania	47
Indiana	32	Rhode Island	4
Iowa	77	South Carolina	37
Kansas	58	South Dakota	13
Kentucky	12	Tennessee	81
Louisiana	29	Texas	678
Maine	27	Utah	54
Maryland	25	Vermont	61
Massachusetts	106	Virginia	152
Michigan	54	Washington	25
Minnesota	26	West Virginia	22
Mississippi	14	Wisconsin	46
Missouri	30	Wyoming	59

Source EPA

Total 3,536

reviewed. Non-hazardous landfills are regulated under Subtitle D and hazardous landfills are regulated under Subtitle C of the "Resource Conservation and Recovery Act" (RCRA). The proposal would also establish pretreatment standards for the introduction of pollutants into Publicly Owned Treatment Works (POTWs) associated with the operation of new and existing Hazardous landfills regulated under Subtitle C of RCRA.

EPA has identified several trends in the waste disposal industry that may increase the quantity of leachate produced by landfills. More stringent RCRA regulation and the restrictions on the management of wastes in general have increased the amount of waste disposed at landfills as well as the number of facilities choosing to send wastes off-site to commercial facilities in lieu of pursuing on-site management options. This has increased the amount of solid waste and also the amount of leachate requiring treatment.

The landfills affected by the new regulation include 158 non-hazardous landfills discharging wastewater directly into local surface waters. In addition, there are 6 hazardous landfills that discharge to POTWs that are affected by the new regulation. Many of the remaining landfills have their own in-situ wastewater treatment systems and do not discharge waste to surface waters or to POTWs

Treatment Method Comparisons

There are many methods of treatment currently being used for landfill leachate. The treatment technologies include physical/chemical treatment and biological treatment. Some of these methods include:

- Chemical precipitation
- Aerobic biological
- Anaerobic biological
- Carbon adsorption
- Multimedia filtration
- Reverse osmosis
- Air stripping
- Sludge dewatering

Even though the treatment methods vary, the most common conventional methods used include various forms of aerobic biological systems. These include aerated lagoons, activated sludge systems, and sequential batch reactors. Biological methods have been successful, but do have some

Leachate Treatment Technology Comparisons

		Initial Raw Feed ppm (mg/l)	Precipitation plus Biotower 4626	Sequence Batch Reactor 4721	Activated Sludge 4759	2 Stage RO Membrane 4687
Arsenic	**As**	584		223	312	**2**
Barium	**Ba**	280	3			**1**
Chromium	**Cr**	415	123	222	82	**2**
Copper	**Cu**	139		54	76	**1**
Molybdenum	**Mo**	13,260		13,260	13,127	**27**
Nickle	**Ni**	2,060		1,976	1,879	**10**
Selenium	**Se**	178		138	178	**0**
Tin	**Sn**	908		886	723	**5**
Titanium	**Ti**	23	738	2	2	**0**
Zinc	**Zn**	126	11	42	47	**1**
Boron	**Bo**	1,808	1,220	1,728	1,540	**101**
Cyanide	**Cn**	3,990			271	**20**
Lithium	**Li**	266		266	239	**1**
Silicon	**Si**	4,362	3,677	3,969	4,362	**353**
Strontium	**Sr**	1,406	39	1,232	467	**14**
Ammonia	**NH4**	58,480	351	234		**292**
Total Nitrogen	**TKN**	209,400			155,584	**1,047**
Total Suspended Solids	**TSS**	171,800	3,436	47,932	126,101	**2**
Total Dissolved Solids	**TDS**	2,478,000		2,438,352	2,373,924	**9,912**
Biological Oxygen Demand	**BOD**	1,182,000	41,370	62,646	28,368	**5,910**
Chemical Oxygen Demand	**COD**	1,526,000	61,040	424,228	360,136	**10,682**
Total Organic Carbon	**TOC**	642,600		216,556	101,531	**3,213**
Oil and Grease	**O&G**	37,333		5,563	9,333	**37**
Benzoic Acid		7,685	23	69	**8**	38
P-Cresol		797		37	**2**	4
Pheonol		1,262	19	8	**3**	6
Tolulene		376	3	3	28	**2**

Source: Development Document - Proposed Part C EPA Office of Water

Table 8-6.8-5, 8-4, 8-2

drawbacks. The retention times are long in order to enhance performance. The microbiology is sensitive to toxic heavy metals, loading rates, and temperature variations. In addition, very often, several treatment technologies must be used in a train of unit operations in order to meet effluent limits.

With new regulations as part of the Clean Water Act and with the advent of new technologies to address this problem, many municipal facilities are re-evaluating their existing methods. One of the new developments in wastewater treatment includes the new open channel plate and frame type polymeric membrane filtration systems. There are several types including the Disk Tube Module made by Rochem and the VSEP (Vibratory Shear Enhanced Process) made by New Logic Research of Emeryville, California.

Reverse Osmosis was previously not appropriate due to narrow feed channels. Now with this limitation removed as in the wide channel flow

membrane modules, RO membranes offer an excellent alternative to biological systems. RO membranes are capable of very selective separations and can achieve filtrate quality better than any biological system. These membranes can also be used as a single unit op to handle the raw leachate flow and produce clean water in one step. RO membranes can be used in parallel and in series to handle any flow and produce any water quality needed. Therefore, they are not subject to the loading rate, toxic metals, and temperature limitations of biological systems.

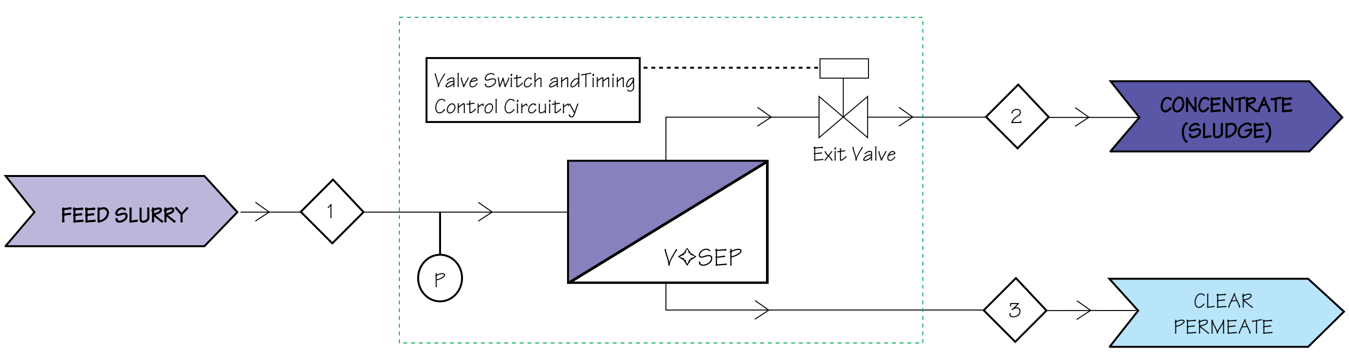
These plate and frame type membrane filters are installed in dozens of landfills worldwide and are becoming more and more accepted as an industry standard.

Polymeric Membranes

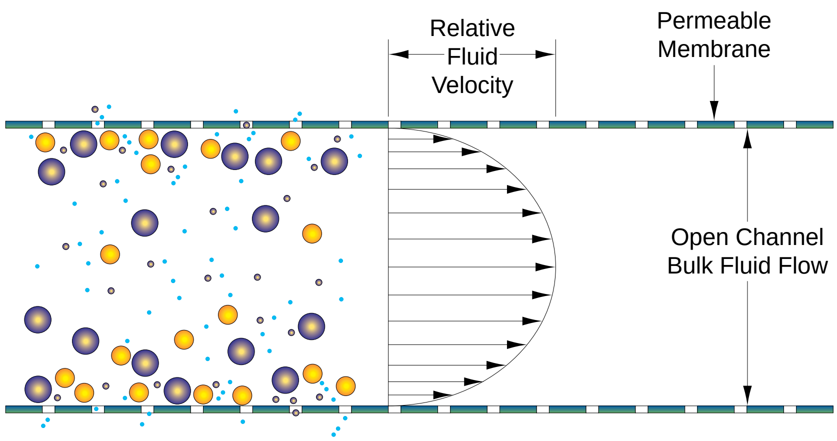
While Reverse Osmosis is a fairly mature technology, the use of it for wastewater is a relatively new advance. First used in the 1950s and 60s, they were primarily used for seawater desalination and brackish water applications. The advance of membrane chemistry and especially the invention of new thin film composite membranes has widened the use of membranes. These new membranes can tolerate a broader pH range, higher temperatures, and harsher chemical environments than the previous Cellulose Acetate membranes. This change has only occurred as recently as the 1980s.

The driving forces for advancements in membrane technology are the compelling advantages of RO membranes over traditional separation technologies. RO membranes are pressure driven processes and don't involve energy intensive phase-changes or expensive solvents and adsorbents. The RO process is inherently simple to design and operate. In one piece of equipment, simultaneous separation and concentration of both inorganic and inorganic compounds are possible.

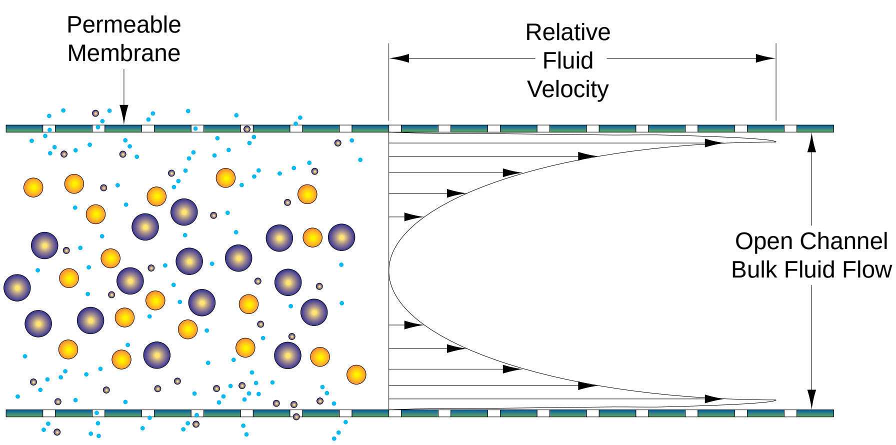
The new Thin Film Composite membranes are composed of two or more layers of selective polymers cast onto a porous backing cloth. The top layer is very thin and is what controls the selectivity and flux through the membrane. Membranes are formed by a phase inversion or polymer precipitation process. In the process, polymer precipitates in a polymer rich solid phase that forms the membrane and a polymer poor liquid phase that forms the pores. Then cast onto this is another thin solid film of polymer that forms the membrane surface and is where diffusion filtration occurs.



Tangential Flow Pattern in Crossflow Membrane Systems



Tangential Flow Pattern in Vibratory V✧SEP Membrane Systems



Module Design

Just as membrane chemistry has evolved, the hardware to deliver the membrane has also advanced. There have been several generations of membrane module design as the industry continues to adapt to new applications and demand for selective membrane filtration. Currently, there are several types of membrane systems, just as there are several types of biological systems. As with biological systems, one size does not fit all. Conventional spiral wound membrane modules are relatively inexpensive and can be used for polishing of water for discharge or reuse. However, these have narrow feed channels and are subject to limitations on the quantity of some chemical components that can be present in the water. For this reason, the feed water needs to be pretty clean already and these units are normally associated with some kind of pretreatment, which may be chemical injection or pre-filtration by UF or MF membranes.

To alleviate the limitations on solids entering a membrane system, new open channel type plate and frame membrane modules have been developed. Two leading designs include the Disk Tube Module by Rochem and the VSEP by New Logic. Rochem's module contains multiple leaf layers of membranes stacked in a column with spacer setting the gap between them. Rochem relies on high turbulence and high crossflow to keep the membrane surface clear of suspended solids cakes and other formations that would blind the membrane.

New Logic's VSEP, employs the same stacked column of membrane trays with spacers setting the gap. The VSEP also utilizes high crossflow and high turbulence to keep the feed liquid homogenous and evenly concentrated. One main advantage of VSEP is that it also employs torsional oscillation of the membrane stack. The membranes are vibrated in resonance at a frequency of about 50 hz (times per second) and the membrane displacement is equal to 3/4" peak to peak at the perimeter.

The industrial VSEP machine contains many sheets of membrane, which are arrayed as parallel disks separated by gaskets. The disk stack is contained within a Fiberglass Reinforced Plastic (FRP) cylinder. This entire assembly is vibrated in torsional oscillation similar to the agitation of a washing machine. The resulting shear is 150,000 inverse seconds, which is ten times greater than the shear in crossflow systems. High shear has been shown to significantly reduce the fouling of many materials. The resistance to fouling can be enhanced with membrane selection where virtually any commercially available membrane materials such as polyamide, polypropylene, polyester, polysulfone and Teflon can be used.

Each Series i system contains up to 2000 square feet of membrane filtration area. A single VSEP unit is capable of processing from 5 to 200 U.S. gallons per minute while producing crystal clear filtrate and a concentrated sludge in a single pass. This large throughput capability can be accomplished with a system, which occupies only 20 square feet of floor space and consumes 15 hp.

Scaling Resilience of VSEP

Torsional oscillation is a very effective method of colloid repulsion as 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 boundary layer.

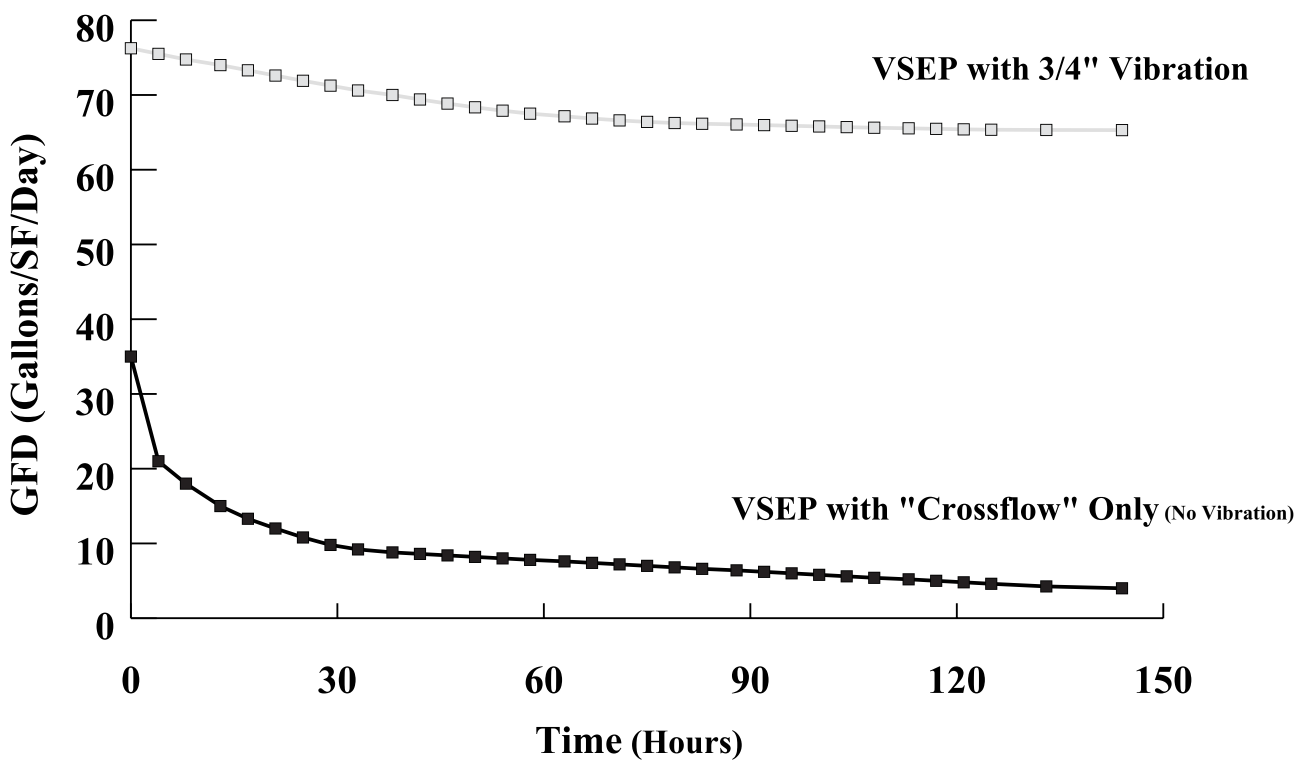
This layer is permeable and is not attached to the membrane and is actually suspended above it. In VSEP, this layer acts as a nucleation site for mineral scaling. Mineral scale that precipitates will act in just the same way as any other arriving colloid. If too many of the scale colloids are formed, more will be removed to maintain the equilibrium of the diffusion layer. Conventional membrane systems could develop cakes of colloids that would grow large enough to completely blind the membrane. In VSEP, no matter how many arriving colloids there are, and equal number are removed as the diffusion layer is limited in size due to the gravitational pull (G forces) of the vibrating membrane.

One other significant advantage is that the vibration and oscillation of the membrane surface itself inhibits crystal formation. Just as a stirred pot won't boil, lateral displacement of the membrane help to lower the available surface energy for nucleation. Free energy is available at perturbations and non-uniform features of liquid/

RO Vibration Study on Saturated $CaSO_4$

Using VSEP (Vibratory Shear Enhanced Process)

Test Conditions: 400 psi, 25ºC, Saturated Calcium Sulfate Slurry



solid interfaces. With the movement of the membrane back and forth at a speed of 50 times per second, any valleys. Peaks, ridges, or other micro imperfections become more uniform and less prominent. The smoother and more uniform a surface, the less free energy is available for crystallization. Crystals and scale also take time to form. The moving target of the membrane surface does not allow sufficient time for proper germination and development. Other stationary features within VSEP present a much more favorable nucleation site. Whereas, with conventional membranes that are static, scale formation on the membrane is possible and has plenty of time to develop and grow.

Performance Results

VSEP's Reverse Osmosis membrane module is capable of treating Landfill Leachate Drainage and providing a filtrate, which is free from suspended solids and low in COD and Heavy Metals. The VSEP process does not involve any chemical addition and meets the process engineer's needs for automated PLC controlled production. VSEP modules containing about 1900 SF (176m2) of filtration media are modular and can be run in parallel as needed to meet any process flow requirements. Each 104" VSEP module can produce 40 gpm of clean water from the leachate pond. Since the units are modular and can be used in parallel or in series, the number of VSEPs needed can be calculated based on the amount of material to be processed, (GPD or GPM). System throughput is a function of the extent to which the feed is concentrated and will vary from site to site. The VSEP module is also uniquely capable of high recovery of filtrate due to its scaling resistance. Recoveries of up to 96% of the landfill leachate as clean filtrate are possible. Depending on the concentration of the leachate, two stages of RO filtration may be required.

Summary

Though membranes have experienced great advances in the past twenty years, their use in leachate treatment has only been explored recently. With more stringent regulations placing greater emphasis on leachate treatment, the industry is seeking new technologies to solve the problem. Offering economic and operating advantages, VSEP is a leading technology for treating landfill leachate and will continue to revolutionize the use of membranes in the industry.

VSEP Leachate & Groundwater Applications

Acid Mine Drainage
Phosphate Cooling Pond Water
Radioactive Groundwater
Arsenic Removal
Landfill Leachate
Agricultural run-off
Produced Water from Oil Drilling

Company Profile

New Logic is a privately held corporation located in Emeryville, CA approximately 10 miles from San Francisco. New Logic markets, engineers, and manufactures a membrane dewatering and filtration systems used for chemical processing, waste streams, pulp & paper processing, mining operations, and drinking water applications. The VSEP technology was invented by Dr. Brad Culkin in 1985. Dr. Culkin holds a Ph. D. in Chemical Engineering and was formerly a senior scientist with Dorr-Oliver Corporation.

About the Author: Greg Johnson, Chief Operating Officer, has been with New Logic Research since 1992 and has a Chemical Engineering background. He is responsible for engineering and design of the patented VSEP Vibratory Membrane System.

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