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Disruptor®
Non Chemical Water Purification Technology

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Disruptor®* - A new filtration technology!

Welcome to the world of Disruptor®, a unique and broad spectrum water filtration technology!

The development of this electroadsorptive technology started nearly 10 years ago with fundamental research by Fred Tepper of the Argonide Corporation. His early work was partially funded by an SBIR grant from NASA for the development of water filters to be used on space exploration vehicles.

As part of our innovation process, Ahlstrom identified this technology as having the potential to be a true "game changer" in nearly every aspect of water filtration. In 2006, Ahlstrom became the exclusive licensee of the electroadsorptive technology now known as Disruptor®.

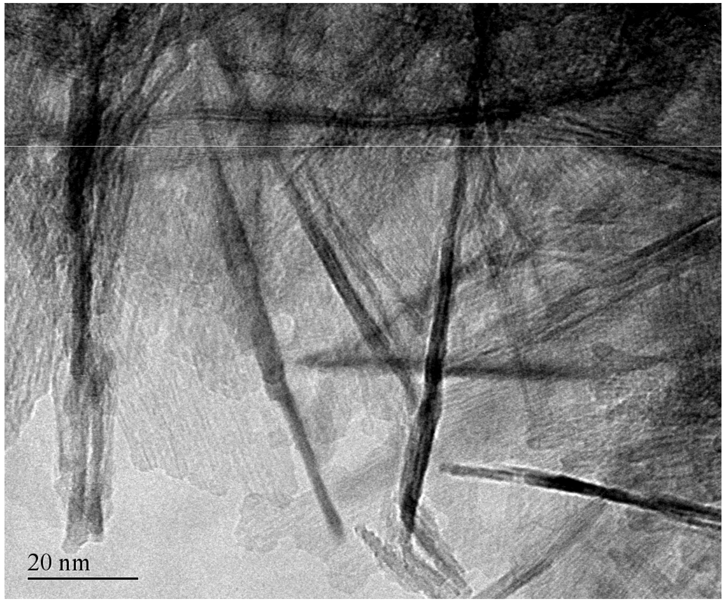
This technology is beginning to fundamentally change how the world thinks about the filtration of water. This is because Disruptor® is not a mechanical filter media. Instead, it removes many submicron pathogens and inorganic contaminants through electroadhesion and ion exchange. Disruptor® technology makes it possible for a nonwoven media to produce filtration efficiency comparable to nanofiltration membranes but at very low pressure drop, with high flow rates and high loading capacity. Disruptor® and Disruptor® PAC are extremely efficient, cost effective media that work equally well in fresh, brackish and salt water providing significant benefits to many filtration systems.

Systems designers are embracing the new opportunities created by this non-mechanical filter media to generate high efficiency filtration that results in energy savings as compared to membrane filters. It also improves our environment, making life better for us all.

*Ahlstrom's trademark registered in the U.S. Patent and Trademark Office

Active ingredient is a natural mineral fiber

Disruptor® technology is based on the mineral pseudoboehmite, AlO(OH) or more specifically, aluminum oxide hydroxide . The active fibers are 2 nm in diameter and approximately 250 nm in length. The crystal structure of the mineral creates a natural electrokinetic potential of Al+++ on the surface of the fiber. With fibers so small in size they have tremendous surface area! A single gram of alumina fiber has greater than 500 square meters of surface area.



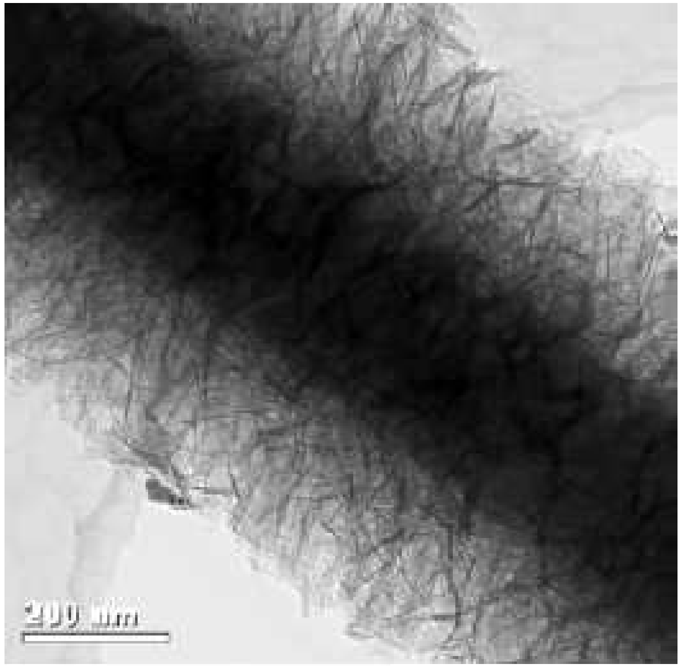
R.Ristau, IMS, UCONN

Since the electropositive charge is derived from the crystal structure of the mineral, it is not an electrostatic charge but a charge potential. Therefore it cannot be dissipated by immersion in isopropyl alcohol. The charge potential maintains its integrity between 5–9.5 pH equally well in salt, brackish or fresh water.

The available hydroxyl group in each fiber will also exchange protons with many electropositive colloids to retain them through a form of ion exchange.

Creating water filter media

Disruptor® technology is protected by multiple patents granted in the US, EU, Russia, China, India and other countries of the world. These patents protect both the manufacturing process for the alumina fibers as well as the method of attaching these small fibers to microglass carrier fibers.



R.Ristau, IMS, UCONN

Other patents protect the use of the media in a range of filter devices and for the inclusion of additives that can enhance the performance of the media for specific contaminants.

The alumina coated microglass fibers (as seen in this image) are easily produced into a depth filter media using standard wet laid, nonwoven manufacturing technology. The base media is laminated between layers of spunbond to provide both strength and pleat support.

Disruptor® is heat sealable and can be made into virtually any size filter cartridge.

Disruptor® media has 2um average pore

Shown below are three, 0.65 micron microglass fibers coated with alumina that form a pore approx 3 x 2 microns in size. Such a large pore allows for high flow rate at very low pressure drop but as a mechanical filter, has only about 2-3 micron initial efficiency. There are approximately 400 such pore structure layers in the Disruptor® filter media to produce an excellent depth filtration media.

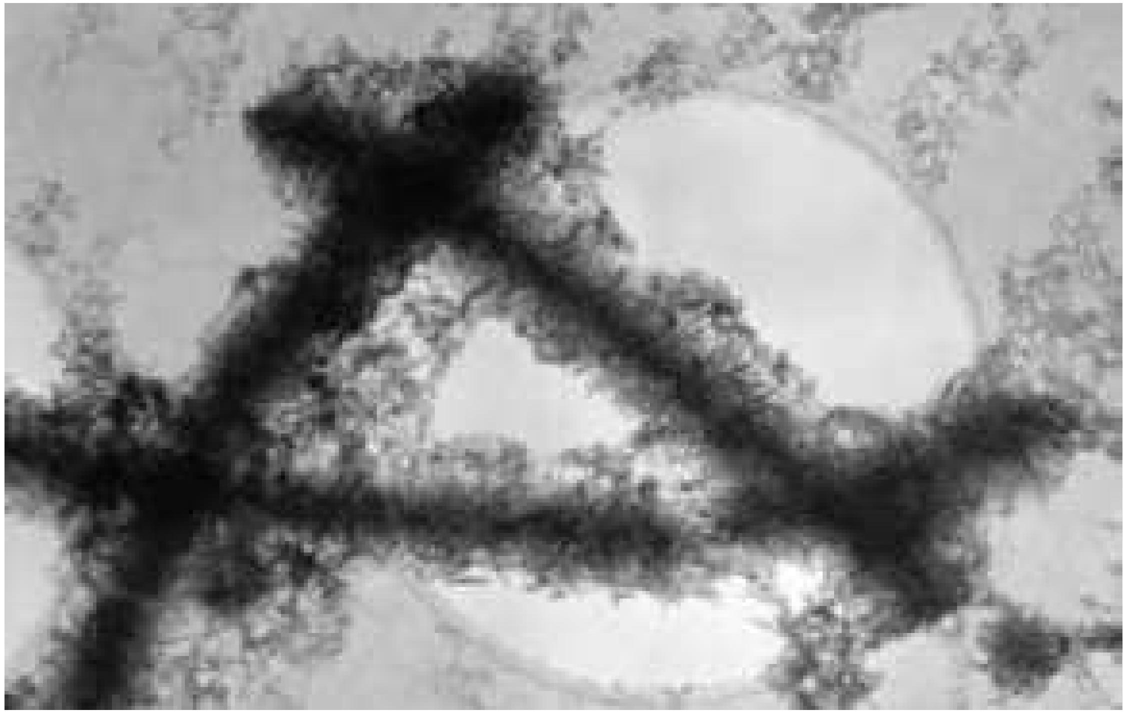


Photo courtesy of R. Ristau, IMS, Univ. of Conn

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Disruptor® is an electroadsorptive media

When exposed to water between pH 5 – 9.5, a charge potential is generated by the natural crystal structure of the alumina fibers. The resulting charge field radiates to a maximum distance of 1 micron from the fibers as represented by the red shaded area.

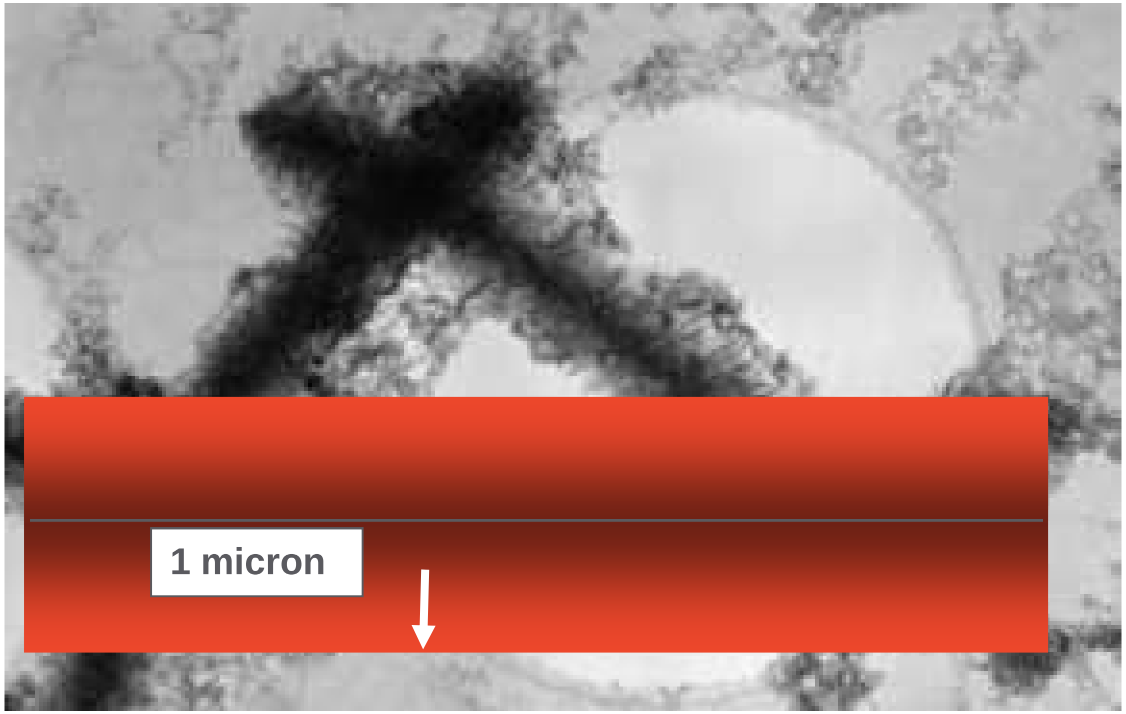


Photo courtesy of R. Ristau, IMS, Univ. of Conn

Expressed as streaming zeta potential, the charge field of Disruptor® has been consistently measured as greater than 53 millivolts at pH 7.2.

Total void volume charge field coverage

Disruptor® has been specifically engineered to have an average pore size of 2 microns and a mean flow pore of 0.7 microns. This allows the charge field created by the alumina fibers to effect the total volume of the individual pores as well as virtually the entire void volume of the filter media itself!

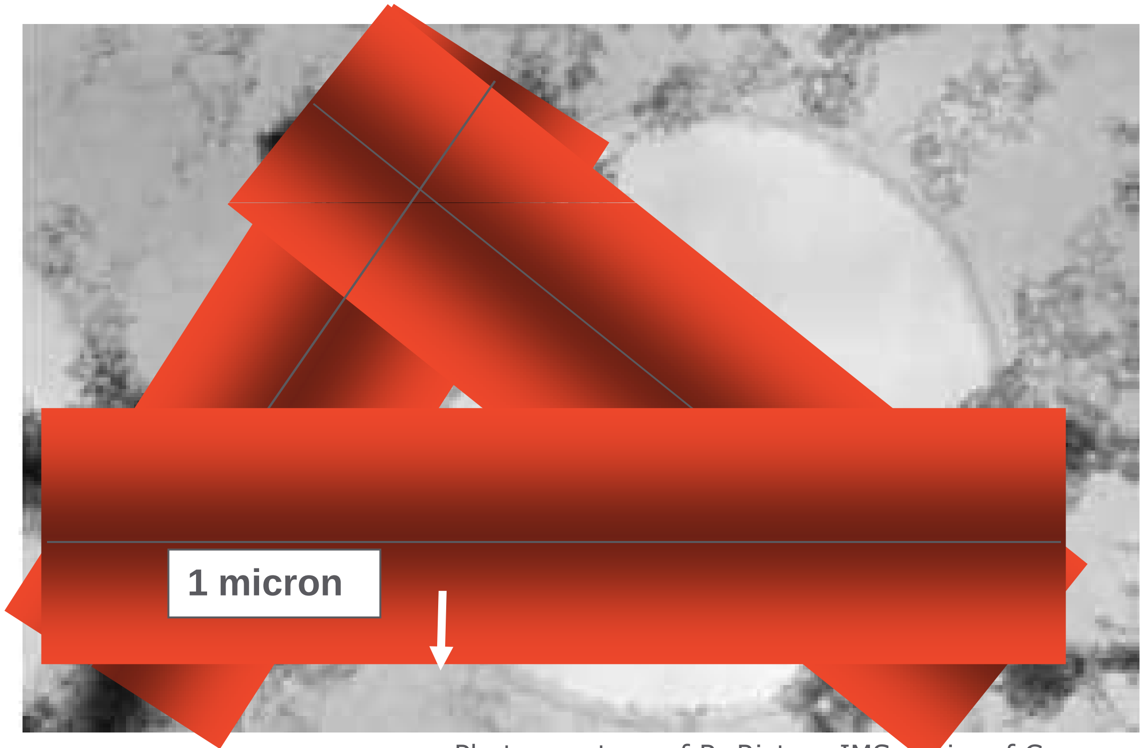
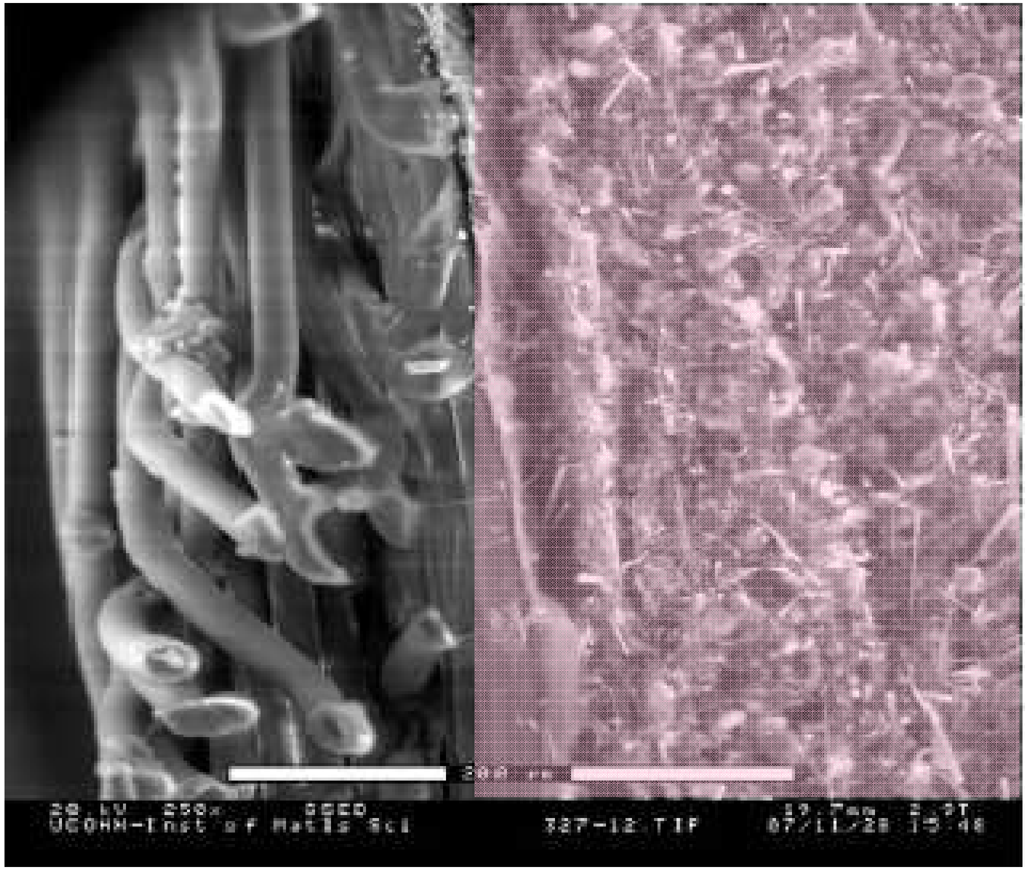


Photo courtesy of R. Ristau, IMS, Univ. of Conn

Disruptor® media has more than 400 individual pores making up the average sheet thickness of 0.8 mm.

Contaminants are removed by being exposed to a torturous path through the media, depth and the powerful electropositive charge field generated by the alumina fibers.

Edge view of Disruptor® PAC



Contaminants are removed through a combination of the powdered activated carbon, a torturous path through the media, the thickness of the media and the powerful charge field generated by the alumina fibers.

Disruptor® has “ion exchange” properties

The pseudoboehmite fibers are composed of layered octahedral crystals held together by hydrogen bonding. Therefore the surface chemistry of the pseudoboehmite in water is difficult to quantify or exactly predict as it is altered by both the contaminant make-up and pH of the water.

At low pH (below about 5 pH) the protons of the OH group are tightly bound making them unavailable for proton bonding. As the pH increases to > pH 6 the proton bonding within the mineral to be weakened, allowing the exchange of protons from many positively charged colloids.

Since the mineral/water interface is constantly changing it is difficult to clearly define the adsorption mechanism as being either purely charge related, through ion exchange or some combination of both processes.

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Removal Capabilities

Virus adsorption by Disruptor®

The following chart compares the removal capability of Disruptor® to 3M Virasorb® using MS2, a 25 nm bacteriophage. In the test, 10 ml aliquots were taken at 3 intervals. Samples were filtered through one thickness of a 25 mm disc at a flow rate of 10cc per square cm per minute.

The data shows that as TDS, pH and salinity are increased there is a significant performance deterioration of Virasorb® as compared to Disruptor®.

Work by Mark D. Sobsey and others confirm the high removal efficiency of virus by Disruptor® in sea water and other high salinity environments.

This feature makes Disruptor® highly effective in: virus concentration, water sampling, potable water filtration, aquaculture and many other demanding applications.

MS2 retention comparison

Media	Thickness mm	Basis Wt g/m^2	Challenge Water			MS2 Removal, %		
			pH	TDS g/L	MS2, PFU/ml	0-10 ml	60-70 ml	130-140 ml
Disruptor®	0.8	200	7.2	0	$3 \cdot 10^5$	99	98	94
			9.2	0	$6 \cdot 10^5$	90	90	
			7.2	30	$5 \cdot 10^5$	97	97	
			9.2	30	$4 \cdot 10^5$	96	88	
3m Virasorb®	0.8	210	7.2	0	$6 \cdot 10^5$	99	92	62
			9.2	0	$3 \cdot 10^5$	60	13	
			7.2	30	$5 \cdot 10^5$	4	6	
			9.2	30	$4 \cdot 10^5$	0	0	

Data courtesy Argonide Corp

Note the loss of efficiency by the Virasorb® media with increased volume, salinity or phi

Study on virus removal from sea water

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ORIGINAL ARTICLE

Evaluation of positively charged alumina nanofibre cartridge filters for the primary concentration of noroviruses, adenoviruses and male-specific coliphages from seawater

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Keywords
adenovirus, coliphage, concentration, electropositive filters, norovirus, water.

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Abstract

Aim: To evaluate the electropositive, alumina nanofibre (NanoCeram) cartridge filter as a primary concentration method for recovering adenovirus, norovirus and male-specific coliphages from natural seawater.
Methods and Results: Viruses were concentrated from 40 l of natural seawater using a NanoCeram cartridge filter and eluted from the filter either by soaking the filter in eluent or by recirculating the eluent continuously through the filter using a peristaltic pump. The elution solution consisted of 3% beef extract and 0·1 mol l^{-1} of glycine. The method using a peristaltic pump was more effective in removing the viruses from the filter. High recoveries of norovirus and male-specific coliphages (>96%) but not adenovirus (<3%) were observed from seawater. High adsorption to the filter was observed for adenovirus and male-specific coliphages (>98%). The adsorption and recovery of adenovirus and male-specific coliphages were also determined for fresh finished water and source water.
Conclusion: The NanoCeram cartridge filter was an effective primary concentration method for the concentration of norovirus and male-specific coliphages from natural seawater, but not for adenovirus, in spite of the high adsorption of adenovirus to the filter.
Significance and Impact of the Study: This study demonstrates that NanoCeram cartridge filter is an effective primary method for concentrating noroviruses and male-specific coliphages from seawater, thereby simplifying collection and processing of water samples for virus recovery.

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Bacteria removal by Disruptor®

The following chart compares the removal capability of Disruptor® as to 3M Virasorb® using B. diminuta, a 0.3 micron X 1 micron bacteria commonly used to evaluate the performance of sterilization membranes.

In this test, 10 ml aliquots were taken at 3 intervals. Samples were filtered through one thickness of a 25 mm disc at a flow rate of 10cc per square cm per minute.

As with the MS2 data, this work shows that as TDS, pH and salinity are increased there is a significant performance deterioration of Virasorb® as compared to Disruptor®.

It is important to note that although Disruptor® and Disruptor® PAC both remove bacteria from water neither product will inactivate the bacteria without the addition of another material. We also offer both products that contain a silver treated zeolite that inhibits the growth of bacteria retained by the media.

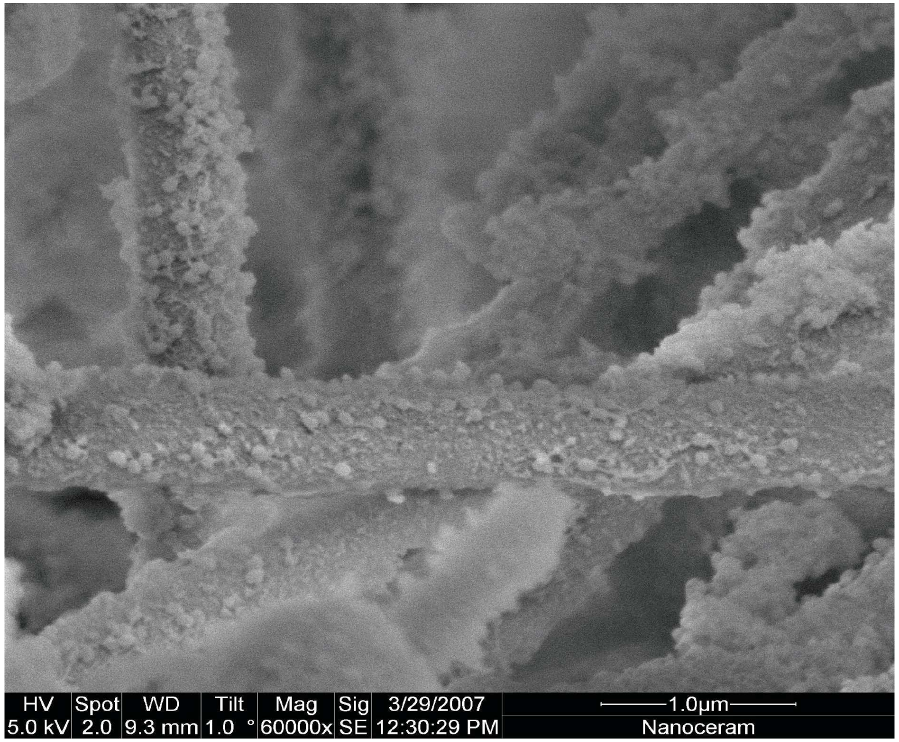
B. diminuta retention by Disruptor® media

Media	Thick-ness mm	Basis Wt g/m^2	Challenge Water			B. Diminuta Removal, %		
			pH	TDS g/L	CFU/ml	0-10 ml	60-70 ml	130-140 ml
Disruptor ®	0.8	200	7.2	0	$7 \cdot 10^5$	99.997	99.97	99.93
			9.2	0	$1.3 \cdot 10^6$	99.99	99.9	
			7.2	30	$1.2 \cdot 10^6$	99.9	99.7	
			9.2	30	$5.1 \cdot 10^5$	99	98.5	
Reference	0.8[d]	210[d]	7.2	0	$7 \cdot 10^5$	98.6	97.7	97.7
			9.2	0	$1.3 \cdot 10^6$	93.8	73	
			7.2	30	$1.2 \cdot 10^6$	92	72	
			9.2	30	$5.1 \cdot 10^5$	92	84	

Data courtesy Argonide Corp

Samples were filtered through one thickness of a 25 mm disc at 10cc per square cm per minute.

T4 bacteriophages retained by Disruptor®



Elisbeth Helmke Alfred Wegener Institute

The images shows the structure of microglass fibers coated with alumina nanofibers retaining T2 phages, which are the white spots seen on the surface of the fibers. T4 is an enterobacterio phage with an icosahedral head and hollow tail. It is approximately 90 nm wide and 200 nm in length.

Bacteria testing with 5289 PAC with silver

# weeks	Date	Silver initial	Silver after flush	E. coli (col/100 mL) before	E. coli (col/100mL) after	Total coliform (col/100mL) before	Total coliform (col/100mL) after	Days Run	Estimated Calculated Liters
1 start	12/01/2010	0.036	0.021	nd	nd	12	nd	0	0
2	12/08/2010	-	0.027	3	nd	32	nd	7	47
3	12/15/2010	-	not tested	1	nd	22	nd	14	95
4	12/22/2010	-	0.015	nd	nd	14	nd	28	142
5	12/29/2010	-	0.036	nd	nd	10	nd	35	189
6	01/05/2011	-	nd @ .0020	nd	nd	14	nd	42	236
7	01/12/2011	-	0.019	nd	nd	8	nd	49	284
8	01/19/2011	-	0.01	nd	nd	9	nd	56	331
9	01/26/2011	-	0.0071	nd	nd	1	nd	63	378
10	02/03/2011	-	0.0046	nd	nd	2	nd	70	425
11	02/09/2011	-	0.0022	nd	nd	41	nd	77	473
12	02/16/2011	-	nd @ .0020	nd	nd	>201	nd	84	520
13	02/23/2011	-	0.0038	nd	nd	101	nd	91	567
14	03/02/2011	-	nd @ .0020	nd	nd	12	nd	98	614
15	03/09/2011	-	nd @ .0020	nd	nd	18	nd	105	662

Silver is a secondary contaminant. Limit = 0.10 mg/L

Flow average ~ 7 liters per day

Endotoxin removal

Methods typically used for removal of endotoxins:

- Ion exchange chromatography
- Ultrafiltration
- Distillation
- Acid-base hydrolysis
- Oxidation using hydrogen peroxide
- Sodium hydroxide treatment
- Extreme heating (250C for 30 minutes)
- Electropositive charged filters

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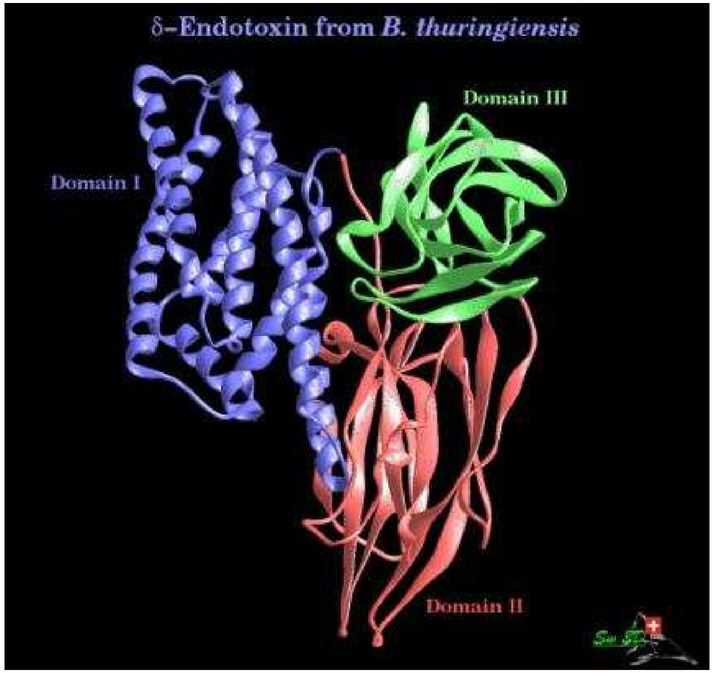
Endotoxin reduction

Endotoxins are polymeric secretions and lipopolysaccharide cellular fragments of Gram-negative bacteria that are generally electronegative. When introduced into the human body they can cause fever, changes in white blood cell counts, low blood pressure, increased heart rate, and in some cases, lead to death. The molecular weight of endotoxins is highly variable, ranging from 10,000 to 1,000,000 Da. Due to this large variation in molecular weight, levels of endotoxin in solution are measured in endotoxin units or EU.



Endotoxins are heat stable and insensitive to changes in pH. For instance, boiling for 30 minutes does not destabilize them.

One EU = 100 pg of E. coli lipopolysaccharide which is the amount present in around 105 bacteria. Humans can develop symptoms when exposed to as little as 5 EU/kg of body weight.

Endotoxins are efficiently reduced through proper use of Disruptor® filter media.

Endotoxin removal

Methods typically used for removal of endotoxins:

- Ion exchange chromatography
- Ultrafiltration
- Distillation
- Acid-base hydrolysis
- Oxidation using hydrogen peroxide
- Sodium hydroxide treatment
- Extreme heating (250C for 30 minutes)
- Electropositive charged filters

Endotoxin removal comparison

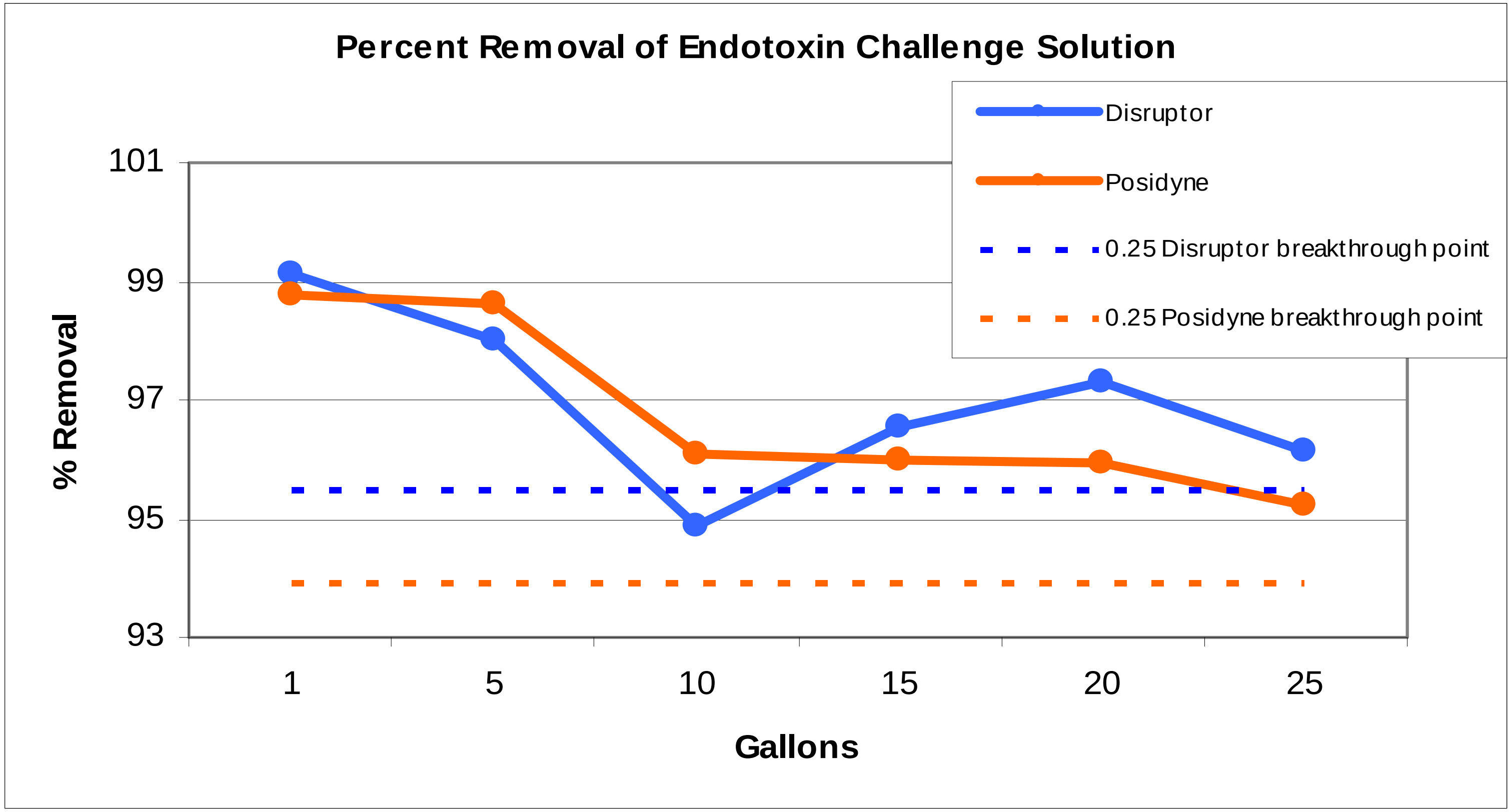
The following slide is based on data from a study that compared the removal of endotoxin between Pall Posidyne® a two-layer, charged, nylon membrane and Disruptor® filter media.

The Posidyne® media was challenged with water containing 4.11 EU/ml of endotoxin while the Disruptor® was challenged with water containing 5.52 EU/ml of endotoxin.

Both products exhibited similar removal efficiency and capacity across a 25 gallon challenge. The Disruptor® filter exhibited 97% average removal of the challenge solution while the Posidyne® filter exhibited 96.7% average removal.

It is important to note that throughout the testing the Disruptor® media filtered at a much higher flow rate and with much lower pressure drop than the Posidyne® membrane media.

Endotoxin-long term comparative study



Disruptor® breakthrough point (0.25 EU/ml) is at 95.5% while the Posidyne® is at 94%
Disruptor® endotoxin challenge was higher 5.52 vs. 4.11.

Removes trace hydrocarbons from water

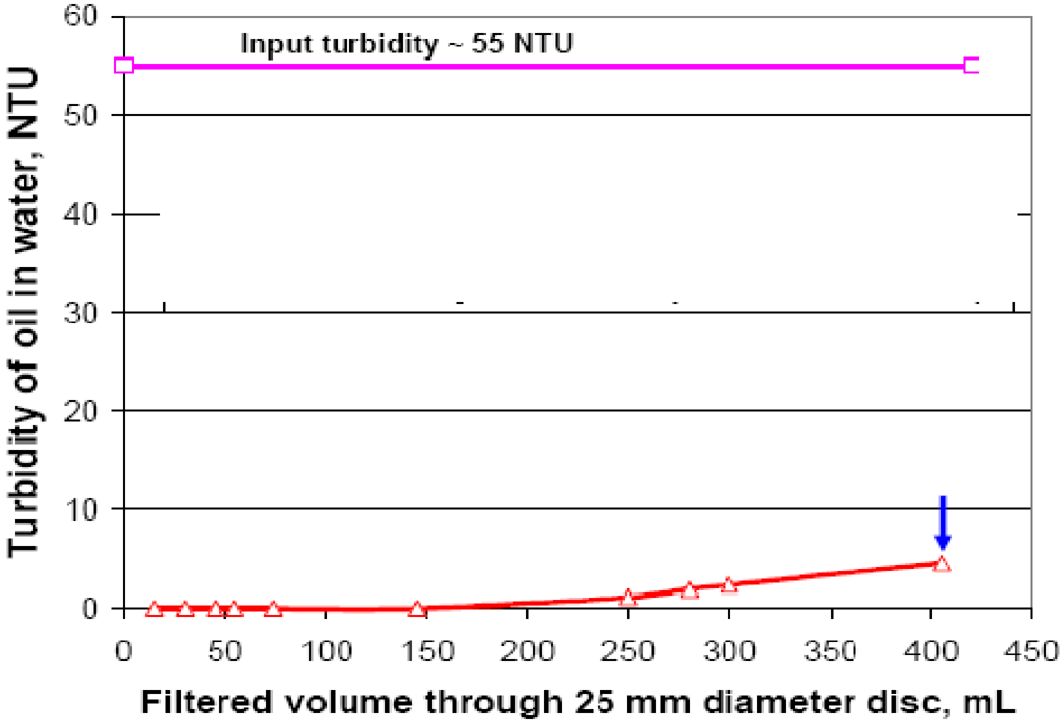
Trace amounts of emulsified oil below 10 ppm are very difficult to remove from water. Emulsified oils are highly problematic in causing fouling on RO membranes. They are also difficult to remove from water produced by oil or gas wells or when treating bilge water to meet environmentally safe discharge standards.

Disruptor® has the ability to effectively remove trace amounts of emulsified hydrocarbons to protect RO membranes from fouling and our environment from hydrocarbon contamination. It has been found to be especially effective in retain the lighter hydrocarbons that are quite difficult to remove using typical filtration techniques.

When combined with appropriate prefiltration to remove the bulk hydrocarbons from water, Disruptor® is an effective polishing filter for those difficult to remove, trace hydrocarbons.

The following slide shows the result of challenging Disruptor® with a 55 NTU solution of emulsified mineral oil. Note the significant reduction in effluent turbidity.

Emulsified oil removal



Disruptor® exhibits the capability of removing trace and emulsified hydrocarbons from water with a capacity of up to 50 grams of hydrocarbon per square meter.

Data courtesy Argonide Corp

Cartridge filtration

Disruptor® filter media has over 42,000 square meters of alumina fiber surface area per square meter of finished filter media. This is more than the combined area of 7 football fields! This massive surface area gives Disruptor® media huge loading capacity for the adsorption of submicron particulates.

The following two slides illustrate both the capacity and efficiency of the media under different test conditions.

The first slide shows the NTU of water from a municipal source, filtered by Disruptor® along with the corresponding flow rate and pressure drop of the media. This filter had a surface area of approximately 0.7 square feet (0.64 m2).

It is important to note that the influent was at 1.2 NTU and the filtrate NTU was below detectable levels. A pressure drop below 2 bar (30 psi) existed for approximately 20,000 liters or 5,300 gallons.

The second slide shows the loading capacity of Disruptor® using AC fine test dust. This test does not represent the best use of Disruptor® media but shows it is very efficient with contaminants greater than 1 micron as well.

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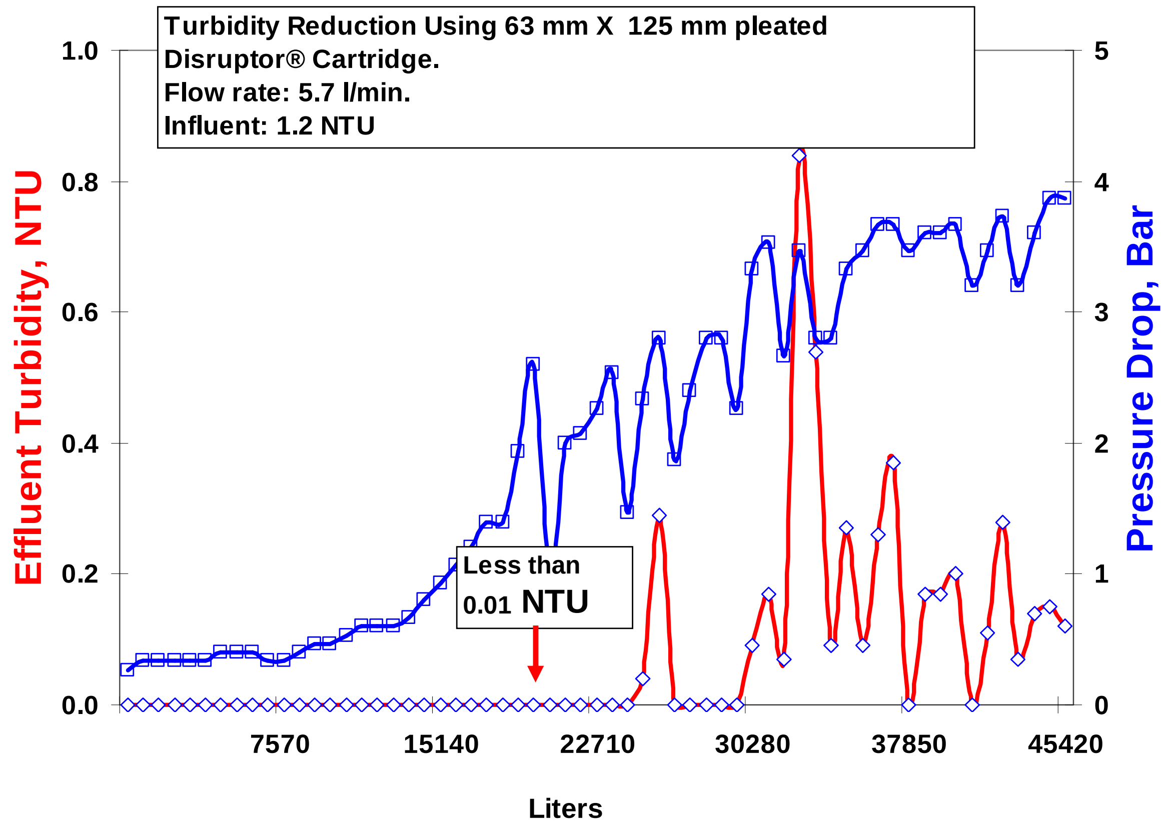
Long term cartridge life



This pleated Disruptor® cartridge retained all colloidal particles for more than 22,000 liters at 5.7 l/min flow rate with no detectable turbidity . NOTE: Influent NTU is 1.2 and off the top of the scale.

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Data courtesy Argonide Corp

Dirt holding capacity, A2 fine test dust

Photo and data courtesy of Argonide Corporation

Key Details

- 62 mm X 250 mm pleated cartridge after cycle testing with 20 NTU A2 fine test dust
- Initial flow 16 lpm, final 4 lpm, 1.5 min on, 1.5 off through 618 cycles
- Disruptor® core weight = 72 g before testing
- Final dust load of 177 g or 2.46 times it's weight with no breakthrough

Trace metals removal - selected metal reduction data

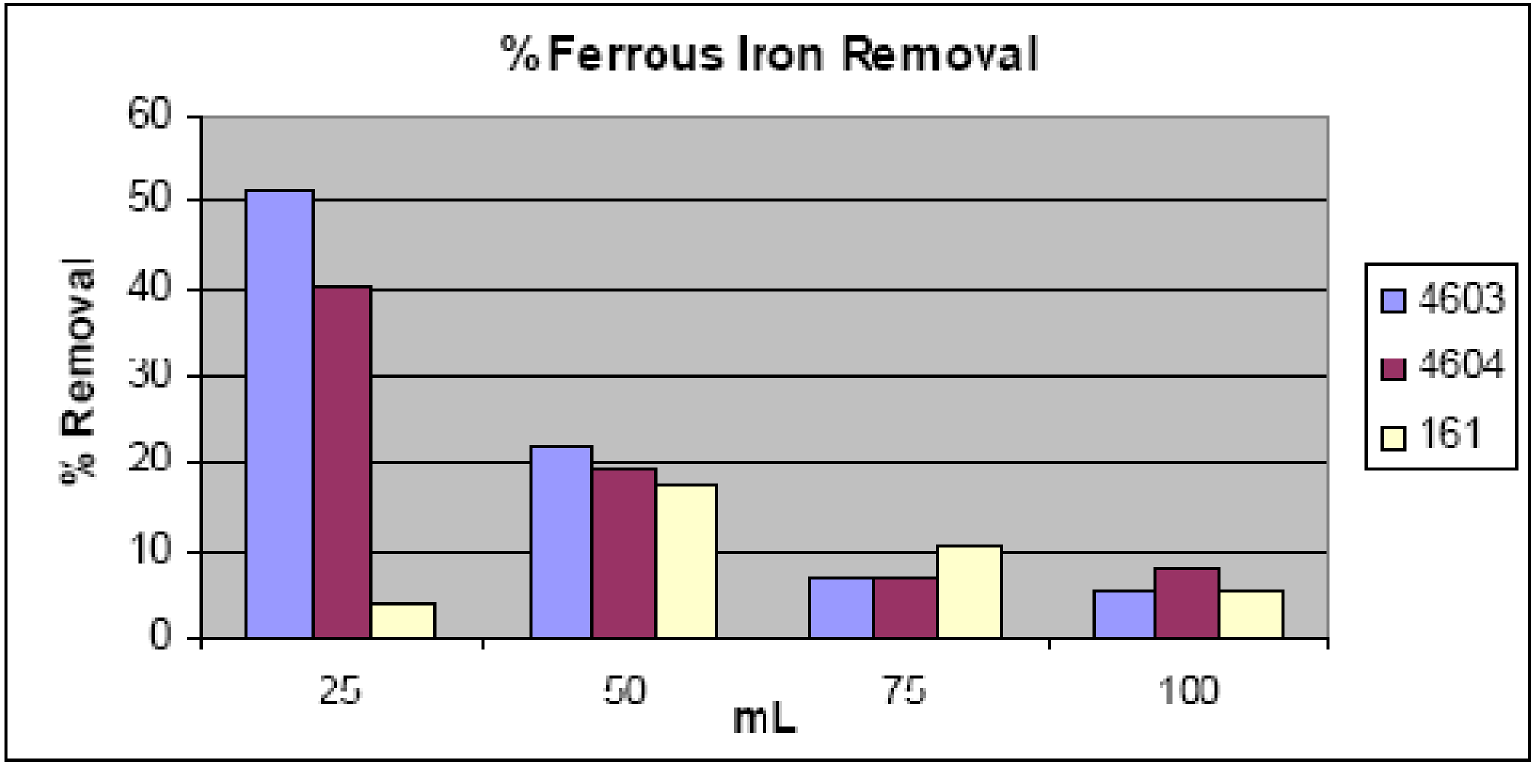
The following chart shows the removal of capability of Disruptor® for a variety of colloidal metals. It does not work equally well on all metals but does show very good affinity for removing or reducing levels of lead, iron, tin, chrome III, aluminum, copper and nickel.

Testing was performed using 47 mm discs having an effective surface area of 8.2 square centimeters. The flow rate for all testing was 60 ml/minute. Testing was terminated on certain samples when the pressure drop exceeded 42 psi across the media.

Metal	Input concentration ppm	pressure drop, psi		Output concentration in a given aliquot[a], ppm					
		Initial	Final	0-0.25 L	0.5-0.75L	1-1.25 L	2-2.25 L	3-3.25L	4-4.25 L
Pb	3.6[b]	3	3	0.00018	0.00020	0.00038	0.00036	0.00038	0.00038
Hg	4.9	4	4	3.2	4.6	4.7	4.7	4.8	4.7
Au	5.0	4	4	4.2	4.9	4.8	4.9	4.9	4.9
Sn	1.4	4	7	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
Ag	0.14	4	5	0.0028	-	0.11	0.11	0.11	0.11
As III	1.9	4	8	1.8	1.8	1.8	1.8	1.8	1.8
As V	2.4	4	4	1.3	2.1	2.2	2.2	2.3	2.3
Cu	1.3	4	4	0.00067	0.00037	0.00037	0.00053	0.071	0.33
Ni	1.4	4	4	0.0086	0.98	1.2	1.3	1.3	1.3
Fe	1.7	5	42	0.014	0.014	0.014	0.014[b]		
Cr III	1.3	4	8	0.00059	0.0026	0.054	0.19	0.22	0.24
Cr VI	1.8	4		1.0	1.8	1.8	1.8	1.8	1.8

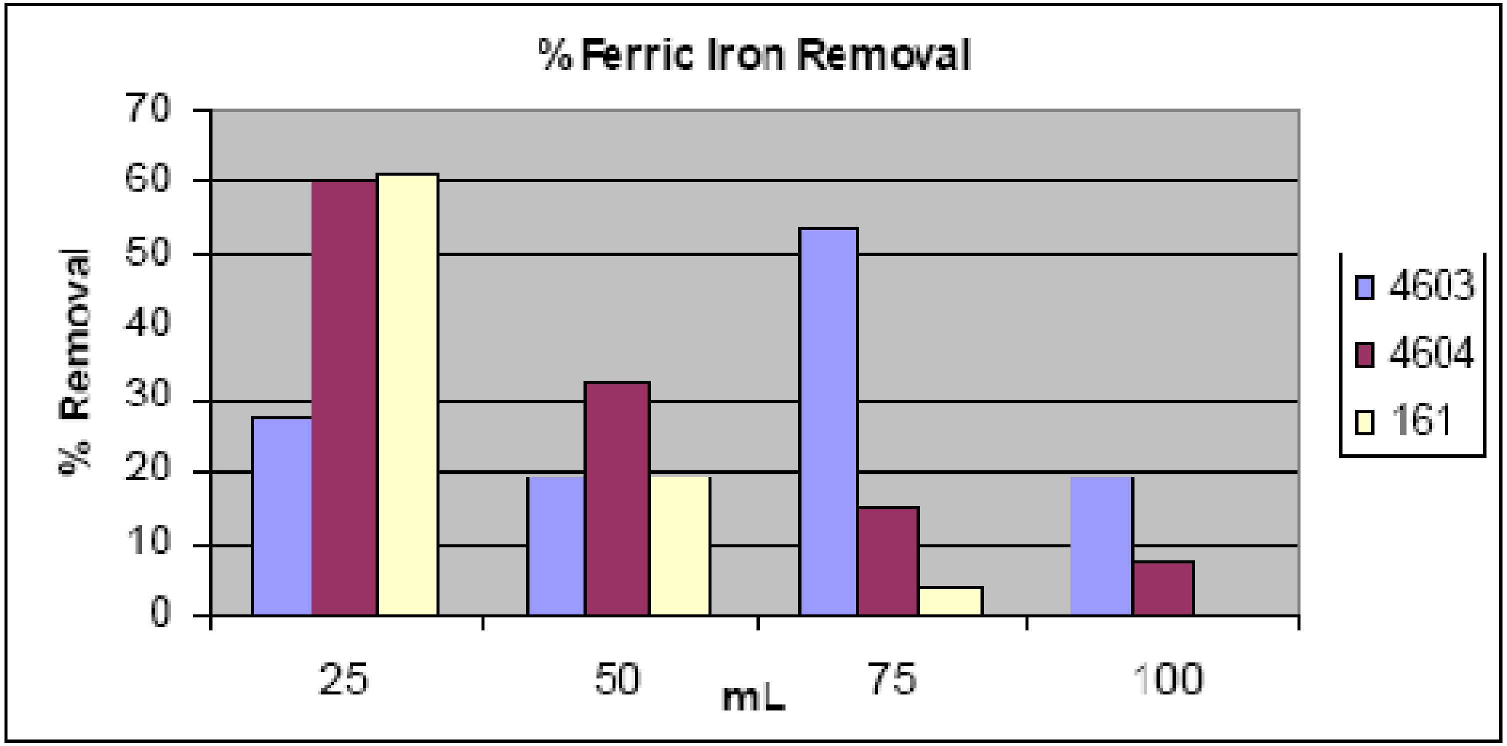
Data courtesy Argonide Corp

Ferrous iron removal (Fe++)



Disruptor® grades 4603 and 4604 are the active center layer our standard and PAC versions respectively. At the start of the test they removed over 10 times the amount of soluble iron than the 161 microglass filter media having a similar pore size.

Ferric iron removal (Fe+++)



In the calculated ferric iron test, the 161 glass filter initially performed as well as the carbon Disruptor® version at capturing the insoluble particles, but both Disruptor® versions were able to out perform the glass in removing insoluble particles by the conclusion of the test.

Lab testing and custom data clearly show that Disruptor® should be seriously evaluated as a component to increase the iron capability of nearly any sized filtration system.

Disruptor® PAC

Features of Disruptor® PAC

Disruptor® PAC (Powdered Activated Carbon) contains carbon particles where 90% of the particles will pass through a 625 mesh screen. The PAC is retained by the electoadsorptive charge field during the wet laid paper making process. This aspect of Disruptor® allows it to retain smaller particles of carbon, than is possible by mechanical entrapment as is typical with other nonwovens containing granular activated carbon (GAC).

Using carbon with a very high surface area to mass ratio, Disruptor® PAC produces extremely rapid reaction kinetics for removing chlorine, iodine and VOCs.

Disruptor® PAC has similar particulate retention, flow rate and pressure drop as our “standard’ Disruptor® but also improves the taste, odor and safety of water through the absorptive power of PAC.

Disruptor® PAC is heat sealable and easily pleats to fit standard cartridge sizes.

Silver treated zeolites can be added to Disruptor® PAC to inhibit growth of bacteria retained by the media.

Chlorine removal data

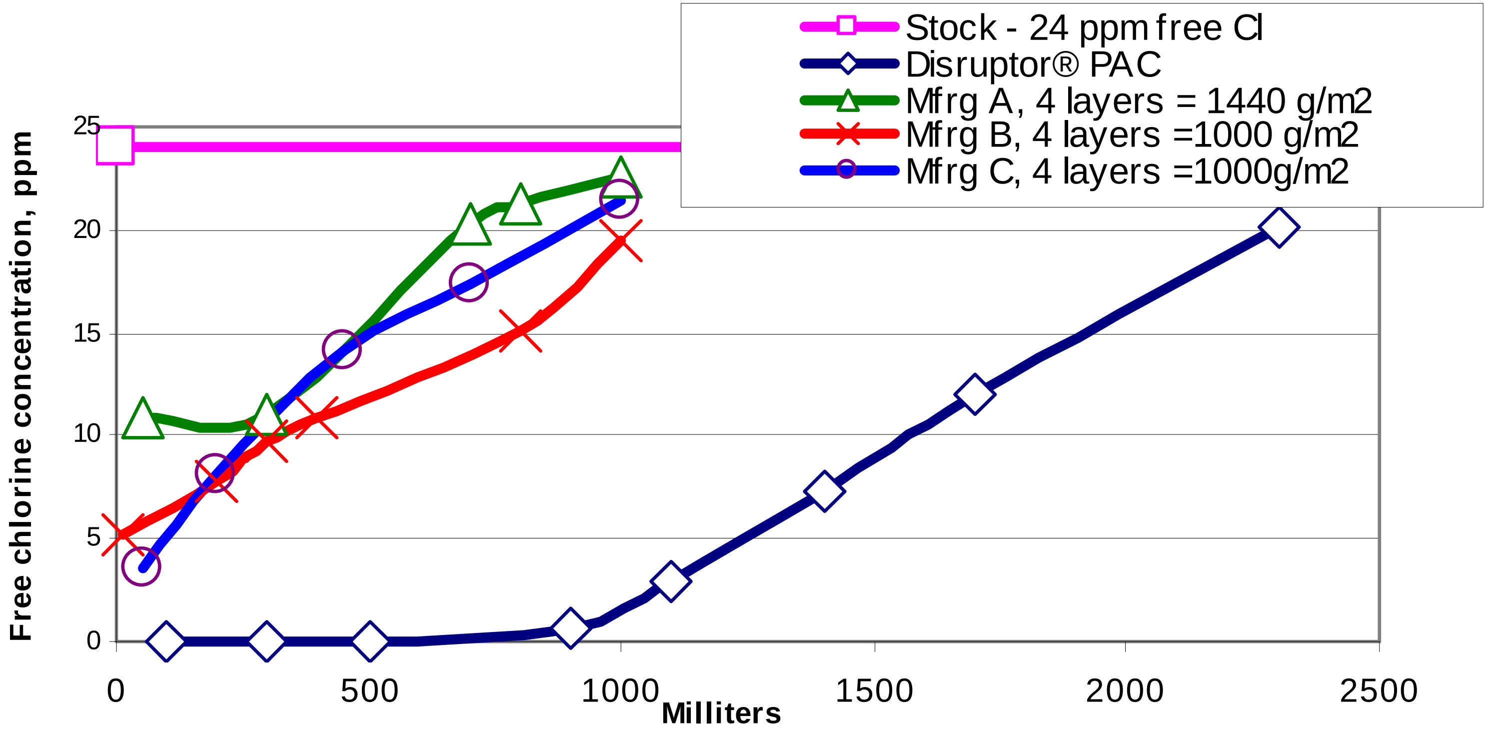
The following slide show data from a chlorine removal test.

The test was a comparative challenge of typical granular nonwoven media obtained from commercially available carbon filters. In all cases, the competitive media contains more carbon by weight than the Disruptor® PAC.

When the test was performed using only one layer of competitive media, the breakthrough was instantaneous making it impossible to generate a breakthrough curve. Four layers finally had to be used to obtain breakthrough data for the competitive products. Although the chlorine challenge concentration was high, the objective of the test was to show the remarkable difference in reaction kinetics between granular and powdered carbon.

Since Disruptor® retains the PAC with a charge field, there are no added binders or resins used to retain the particles as with many other carbon nonwovens. This allows all of the surface area of the carbon to be available for contaminant removal and not occluded with substances from the manufacturer.

Chlorine removal – high concentration



Data courtesy Leo Kaledin, Argonide.

Tested with LaMotte Chlorine Tracer using 4 layers of 3.7 cm2 of carbon nonwoven media at flow rate of 40 ml/min and free chlorine input concentration of 24 ppm.

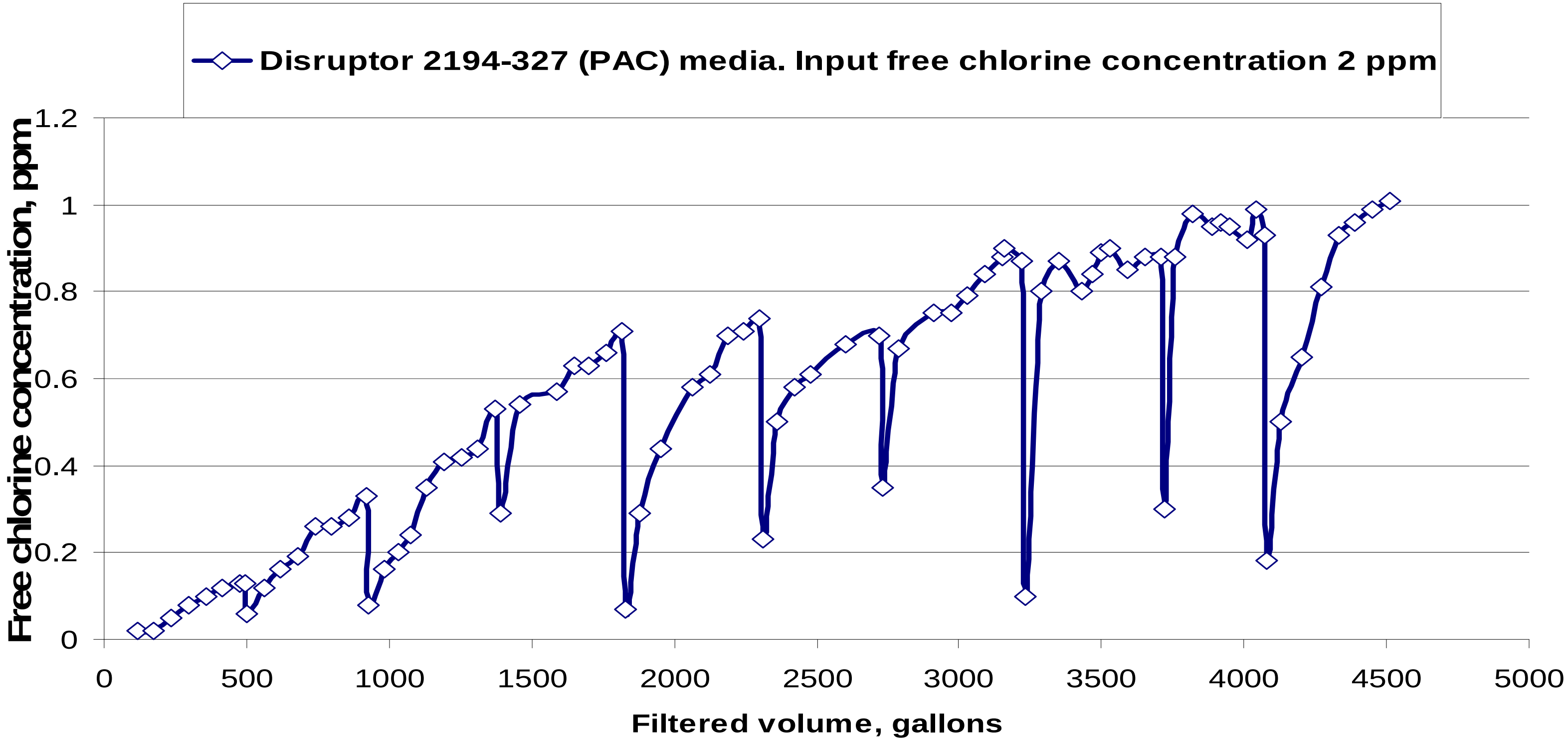
Chlorine capacity of Disruptor® PAC

The following test was conducted with a pleated cartridge containing approximately 24 grams of PAC.

A total 17,000 liters (4,500 gallons) of water was used, having an input concentration of 2.25 ppm. Testing was considered complete when the output concentration reached 1.01 ppm or half the input concentration.

The result corresponds to adsorption of approximately absorption of 958 mg of free chlorine per gram of PAC.

PAC cartridge tested at 2 ppm chlorine



Data courtesy Leo Kaledin, Argonide.

Simulation of EPA protocol for Cl removal from drinking water with stagnation points using a 2.5” X 10” pleated cartridge with a surface area of approximately 0.32 square meters.

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PCB removal by Disruptor® & Disruptor® PAC

Congener Group	ng/L influent	5284 ng/L effluent	5283 ng/L effluent
Total monochloro biphenyls	158	2.36	0.377
Total Dichloro Biphenyls	629	0.85	nd
Total Trichloro Biphenyls	1260	nd	nd
Total Tetrachloro Biphenyls	4490	nd	nd
Total Pentachloro Biphenyls	4870	nd	nd
Total Hezachloro Biphenyls	4460	nd	nd
Total Heptachloro Biphenyls	2460	nd	nd
Total Octachloro Biphenyls	1810	nd	nd
Total Nonachloro Biphenyls	473	nd	nd
Decachloro Biphenyls	187	nd	nd
Total PCBs	20797	3.21	0.377

Polychlorinated biphenyls (PCBs) are man made organic chemicals that are known for their toxic effects. Independent testing has shown Disruptor® and Disruptor® PAC to be effective in removing PCBs from water as indicated by the above chart.

Residential Products

AquaSure®


AquaSure®
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PROTECTION
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Visual result

Comparison of raw water and after being filtered through Unilever Purit, Tata Swach and Eureka Forbes AqauaSure

OKO water bottles

Preventing Membrane Fouling

Membrane biofoulants

- Typical biofilm constituents:
  - Virus, bacteria, cell debris, protiens, colloids, natural organic matter (NOM), iron and silica
- Other known biofoulants include cellular compounds such as:
  - Lipids (hydrophobic and hydrophylic)
  - Phospholipids
  - Amino acids
  - Carbohydrates
  - Glucose – mono and poly saccharides
- These biofoulants are removed to a significant degree by Disruptor®

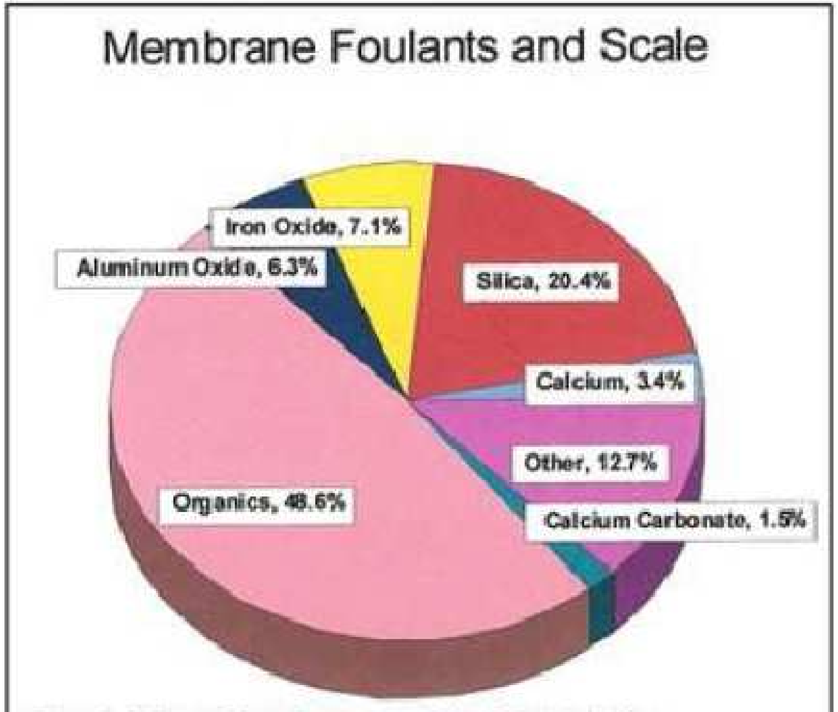


Figure 2. Different foulants that cause membrane fouling and scaling.

Ultrapure Water April 2010 Jane Kucera, Nalco.

Membrane fouling

Biologic contamination is a contributing factor in greater than 45% of all membrane fouling. Typical biofilm constituants include; Virus, bacteria, polysaccharides, protiens, colloids, organic acids, iron and silica.

Polysaccharides are becoming recognized as the initiator of primary biofouling. They are also known as Transparent Extracellular Particles or TEP. TEP is produced by bacteria and other microscopic organisms to protect their outer membrane. TEP is found in all surface water and in many underground water sources that contain microscopic life.

Like human skin, as new TEP is generated, the old TEP sloughs off into the water. TEP is "sticky" and electronegative. The TEP will come together to create agglomerate particles from 0.4 to > 200 microns in size as seen in the following slide.

TEP itself can become a host food source for bacterial growth and act as a transport mechanism for bateria and other foulants.

TEP is largely transparent to sand filters and most mechanical prefiltration techniques but can be removed by RO and NF membranes as evidenced by chronic biofouling.

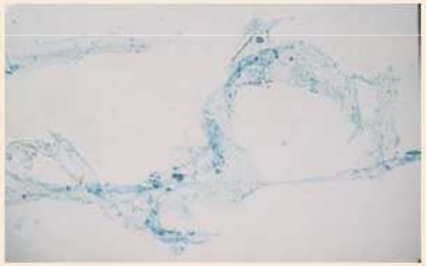
Source and properties of TEP

TEP is produced by bacteria, diatoms, phytoplankton, shellfish and possibly other organisms

Physical properties include:

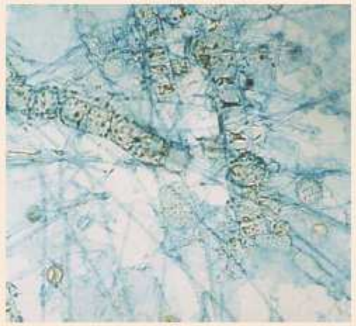
- Discrete amorphous particles to macro gels 0.4 to 100 microns in size
- Highly deformable
- Large surface area
- Transparent
- Electronegative
- Sticky
- Difficult to detect

small particles



large webs

TEP, The "Dark Matter" of surface water!

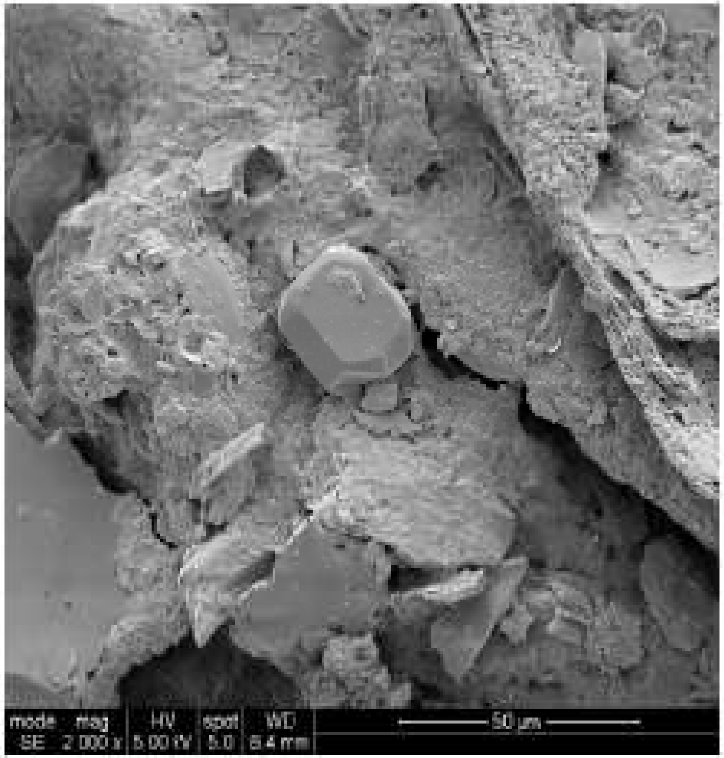


matrix of aggregates

Images courtesy of Uta Passow

SEM of Disruptor® - New and fouled

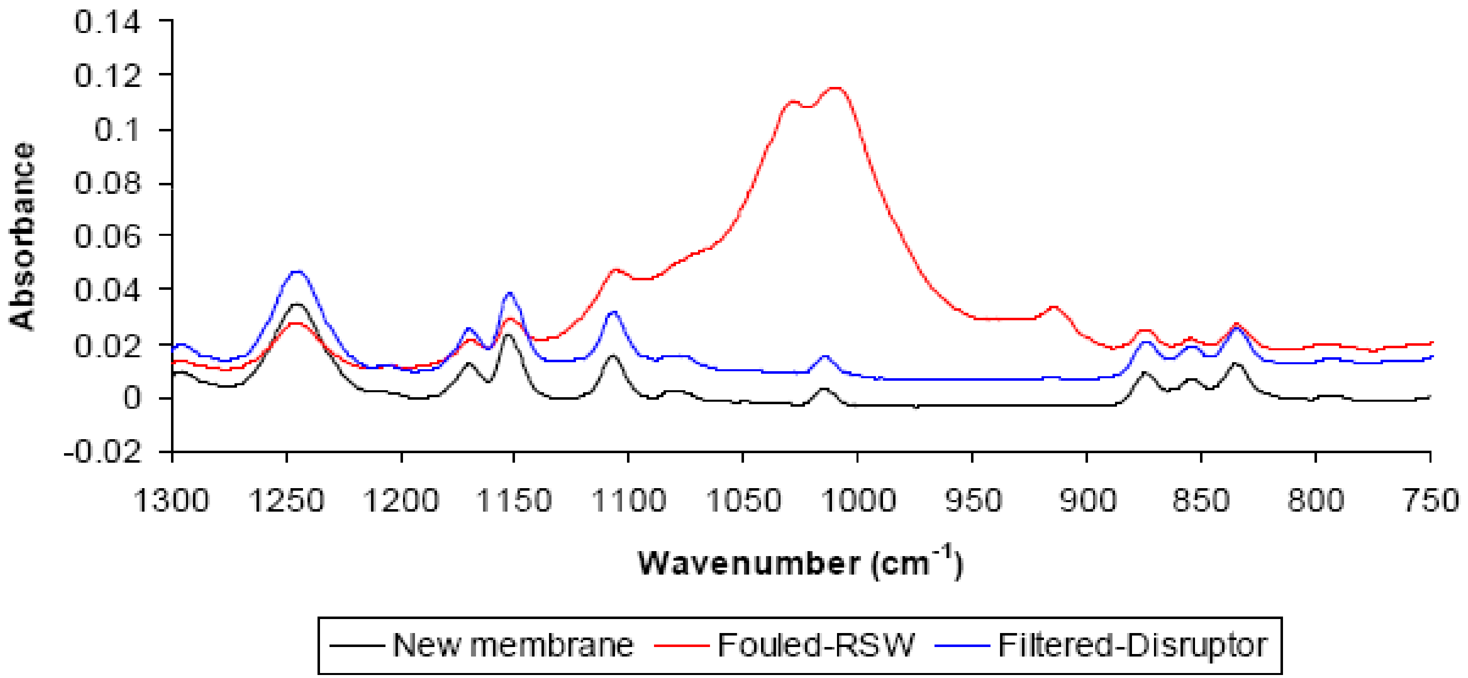
The scanning electron microscope image on the left is of the surface of a new sample of Disruptor® with the image on the right being of Disruptor® fouled with polysaccharides. This test was done using water from the North Sea.



Images courtesy of Ibrahim El-Azizi, and Robert J. G. Edyvean, University of Sheffield, UK.

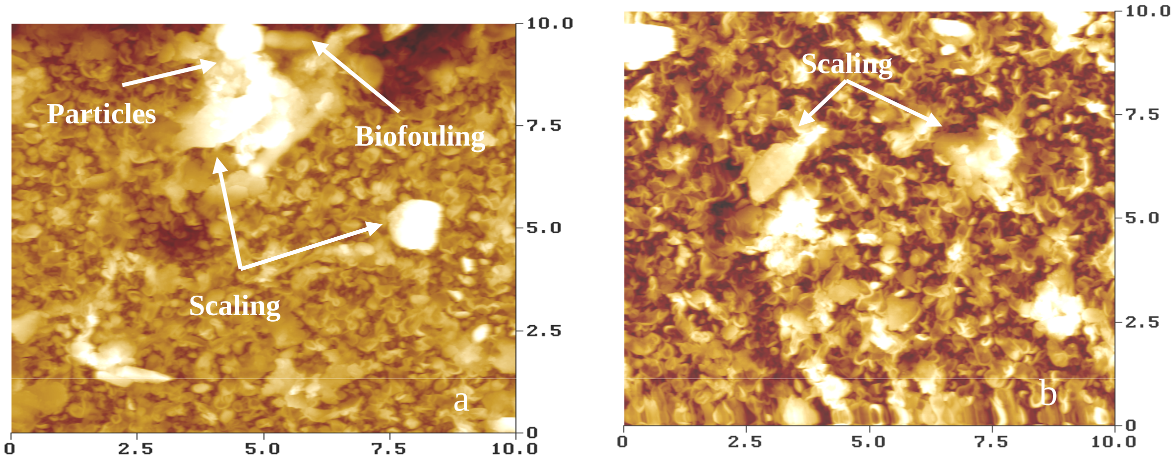
FTIR spectrum of foulants

The FTIR peak is from the surface of a fouled RO membrane not protected by a Disruptor® prefilter. The other lines show a new membrane and one protected by Disruptor® that were essentially equivalent after filtration using water from the North Sea. Materials in this wave number range of the red peak indicate the presence of silicates and polysaccharides.



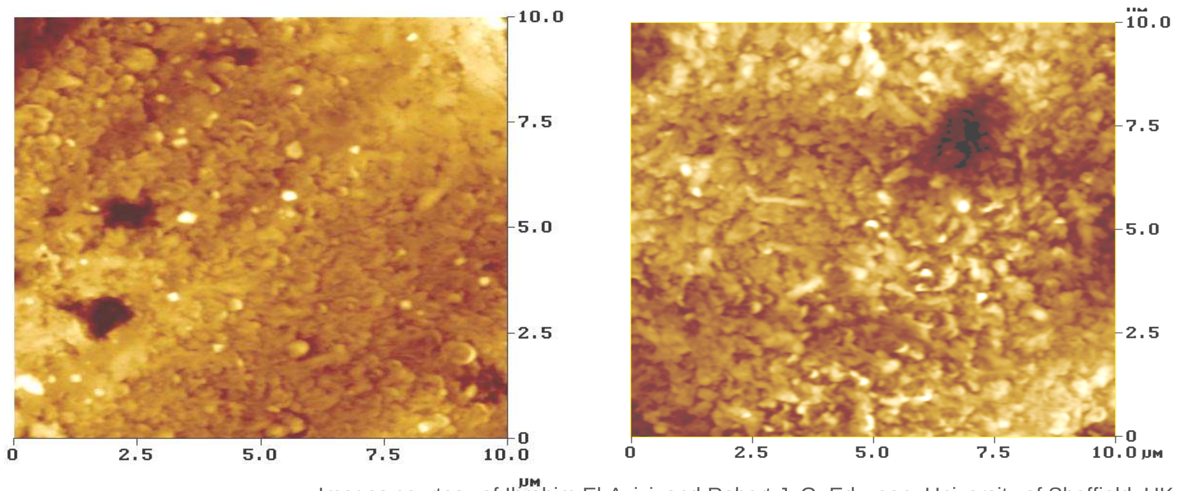
Data courtesy of Ibrahim El-Azizi, and Robert J. G. Edyvean, University of Sheffield, UK.

AFM images of membrane surfaces



RO membrane surface images after filtration with North Sea water.

Membrane on left was protected by a 5 um prefilter while the membrane on the right was protected with a 1 um prefilter



RO membrane surface images. Image on left shows membrane protected by Disruptor® after filtration using North Sea water.

Image on right is of the surface of a new, unused RO membrane.

Images courtesy of Ibrahim El-Azizi, and Robert J. G. Edyvean, University of Sheffield, UK.

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Transparent exopolymer particles (TEP)

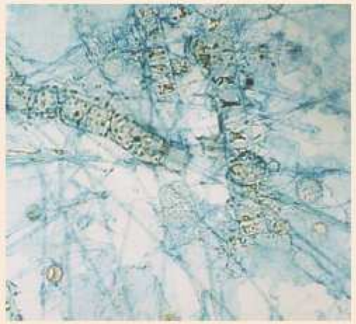
TEP is produced by bacteria, diatoms, phytoplankton, shellfish and possibly other organisms

Physical properties include:

- Discrete amorphous particles to macro gels 0.4 to 100 microns in size
- Highly deformable
- Large surface area
- Transparent
- Electronegative
- Sticky
- Difficult to detect

small particles

large webs



matrix of aggregates

Images courtesy of Uta Passow

January 2011

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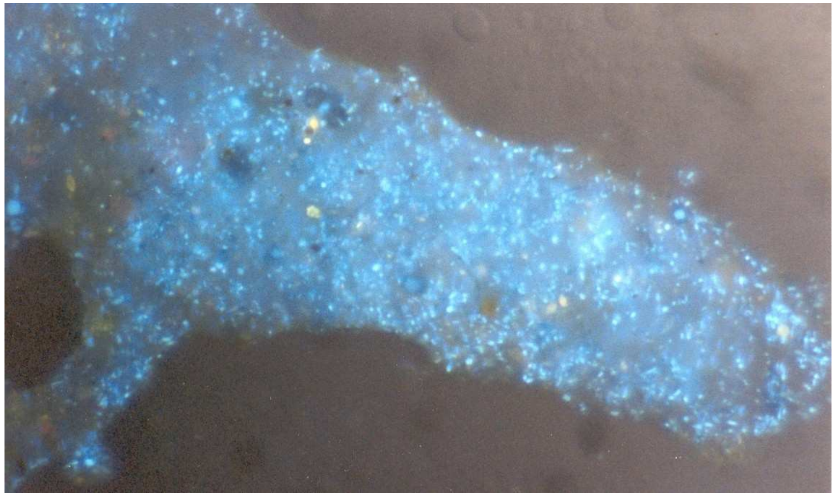
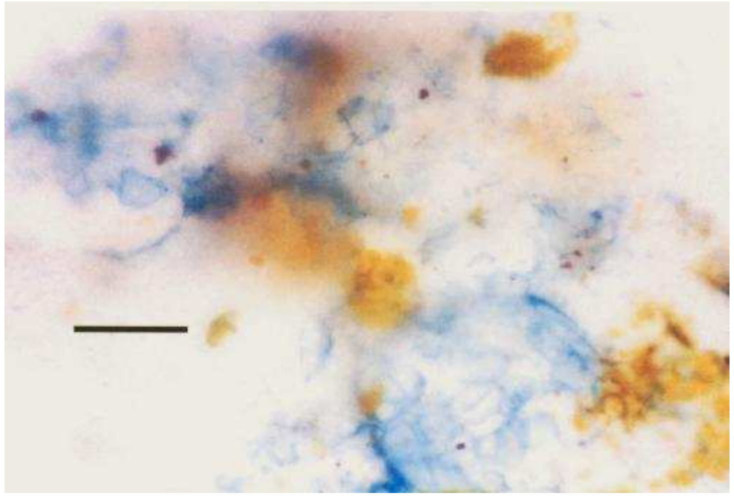
TEP as carrier mechanism

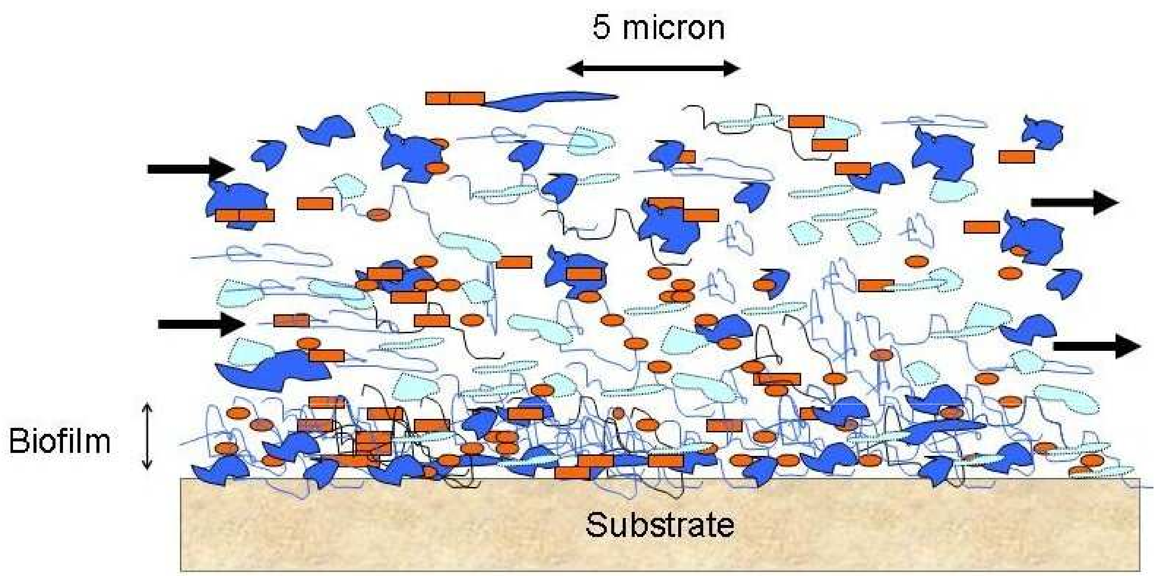
The left image shows TEP coated with bacteria stained with a combination of DAPI and alcian blue. The second images shows TEP that is carrying inorganic material shown as brown.





Images courtesy Tom Berman and Uta Passow

Initial biofouling on membrane



Images courtesy Tom Berman and Uta Passow

TEP shown as blue, bacteria shown as brown. It is postulated that the TEP with attached bacteria can provide the primary conditions for biofouling with continued growth by bacteria contributing to biofilm build up. Other colloidal material shown as light blue also becomes entrapped by the gelatinous TEP/bacteria build up.

TEP fouling on membrane

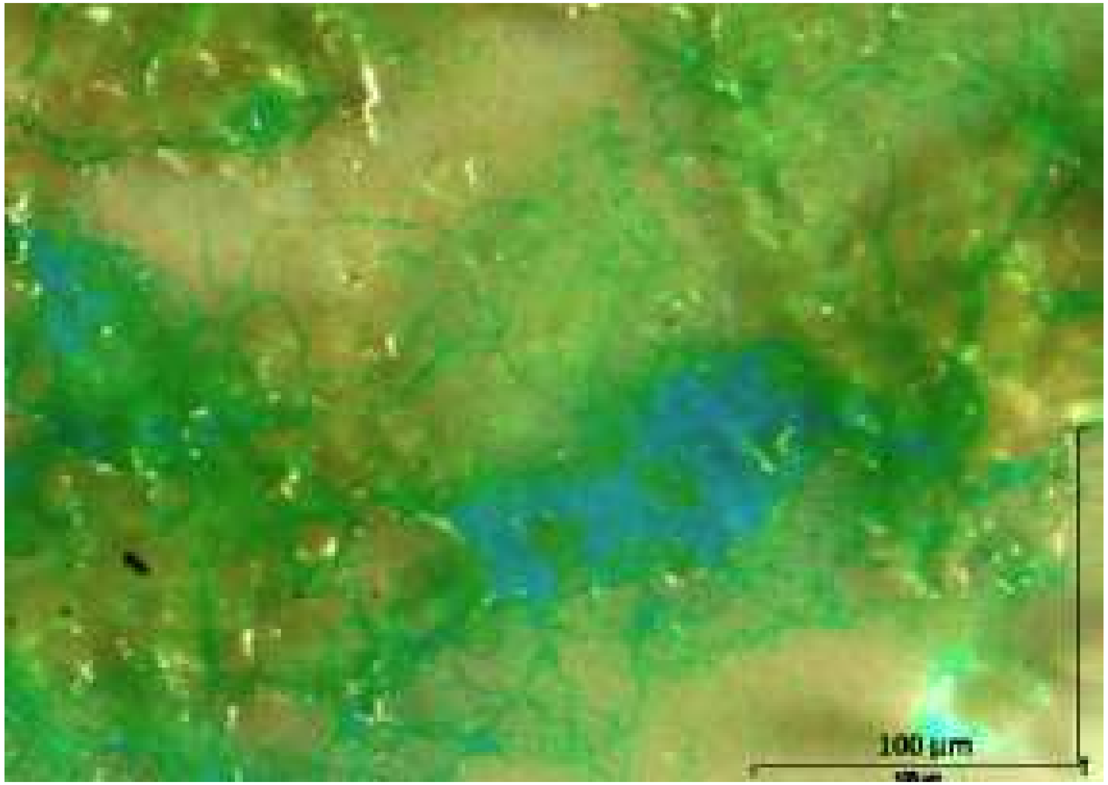


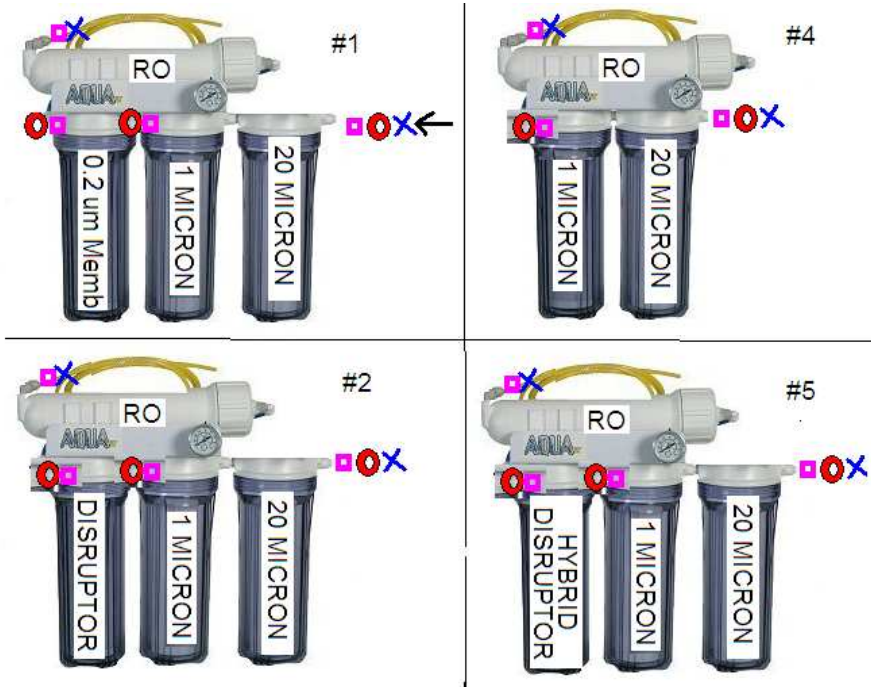
Image Credit Loreen Villacorte

This image shows the membrane as the brown colored material in the background. TEP can be seen on the surface of the membrane after staining as green and blue. Without the staining, the membrane surface appears a solid brown.

TEP extracted from water

RO Pre-filtration Study

RO pre-filter study



A RO prefiltration study was conducted fro 24 days using source water that simultaneously fed four domestic RO units using identical membranes. Each unit was protected by a different prefilter.

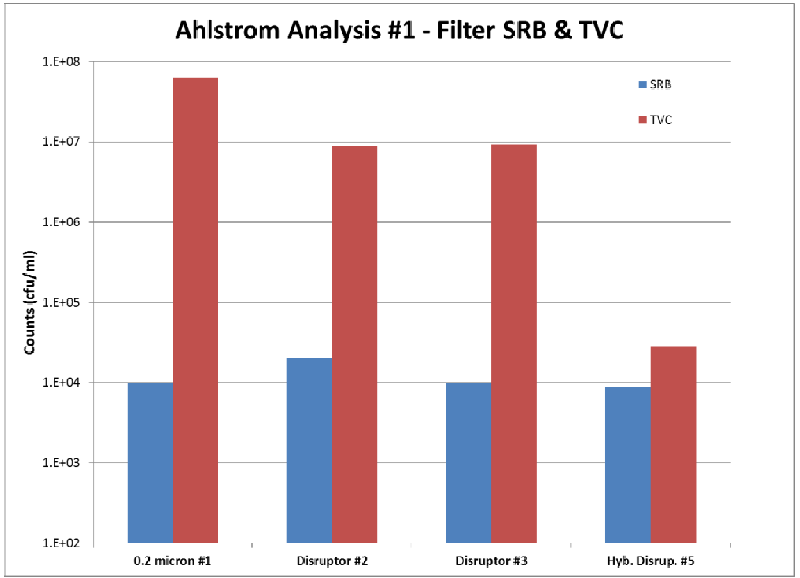
This trial was to attempt to determine the relative benefit of membrane protection delivered by a 0.2 micron pleated membrane, a 1 micron meltblown filter, a Disruptor® pleated filter and a specially designed Disruptor® hybrid filter.

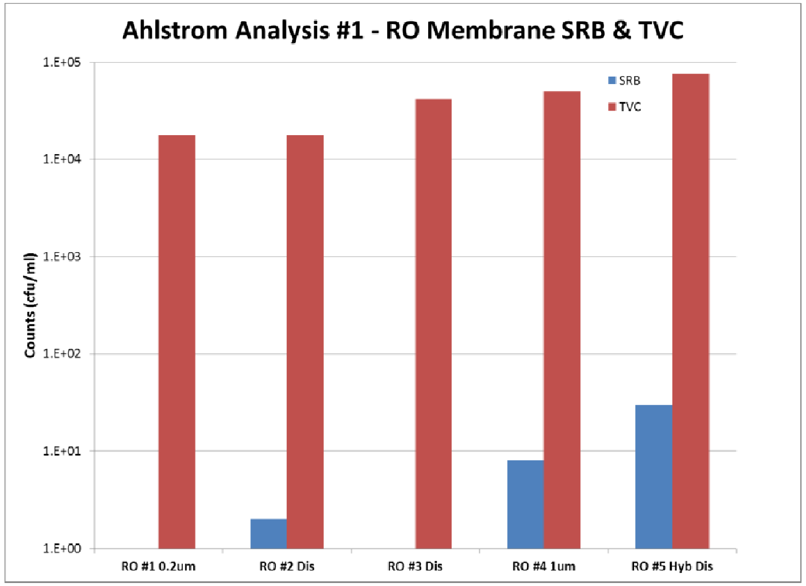
Test data is available upon request.

Basic water characteristics

Parameter	Result	Units
Ca	34	mg/L
Mg	5.4	mg/L
Na	17	mg/L
Fe	ND	mg/L
Mn	ND	mg/L
SO_4	5.6	mg/L
SiO_2	9.2	mg/L
TOC	2.5 - 14	mg/L
TDS	135-180	mg/L
Turbidity	8.3	mg/L

Comparison of microbial content – prefilters and RO



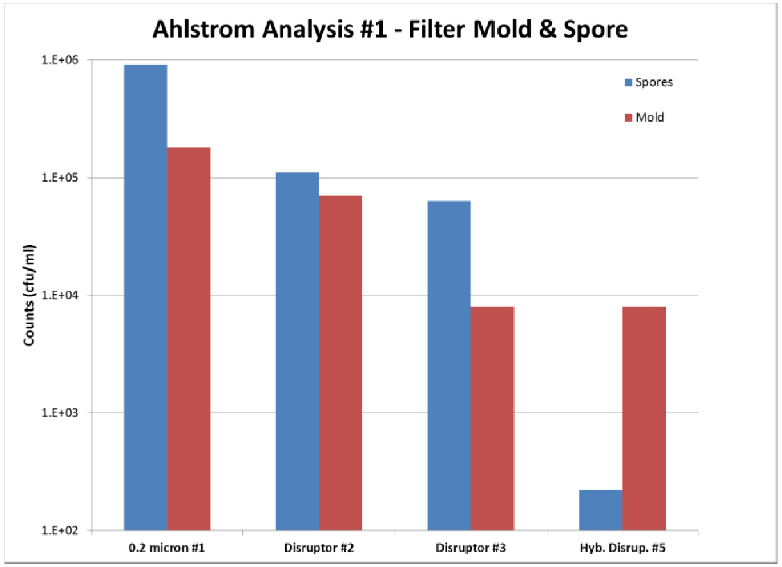


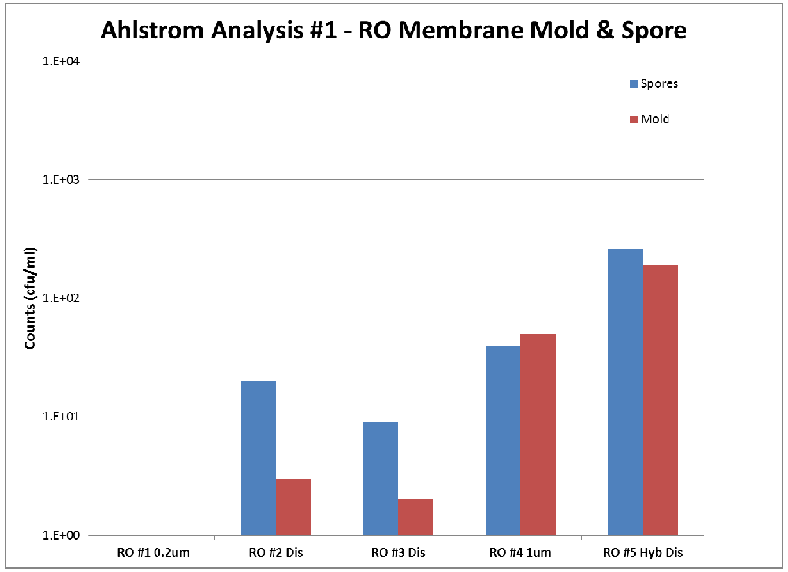
- SRB content was similar
- SRB content was high – significant fouling
- TVC content was similar except Hybrid. Disruptor®
- Hybrid Disruptor® retained lower TVC

- SRB were identified only in #2, #4 & #5
- SRB content was highest in Hybrid Disruptor®
- TVC content was similar on all RO's

Membrane analysis courtesy NALCO

Comparison of microbial content – pre-filters and RO





- Spore content was highest in #1
- Spore content was lower in #2, #3, #5
- Mold content was highest in #1 than others
- Mold & Spore content is indicative of retention

- Spore & mold were not identified in #1
- Counts were similar in #2, #3, #4
- Content was highest in Hybrid Disruptor®
- Content is most likely a passage from pre-treatment

Membrane analysis courtesy NALCO

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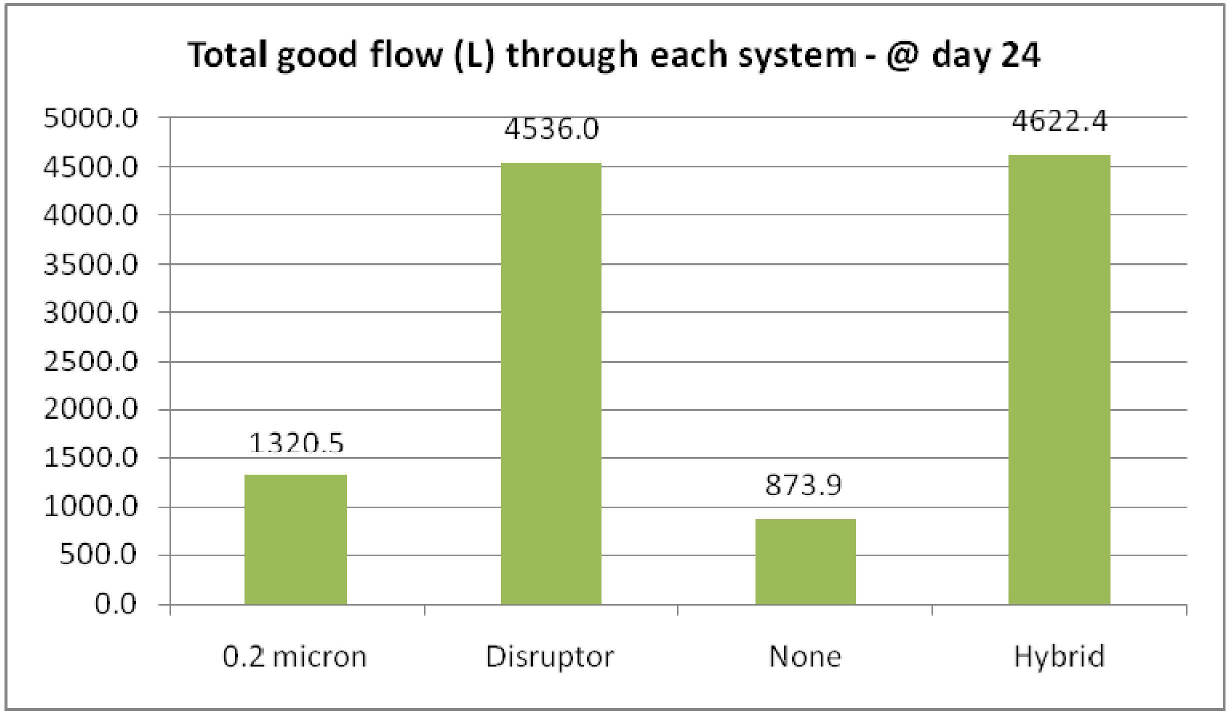
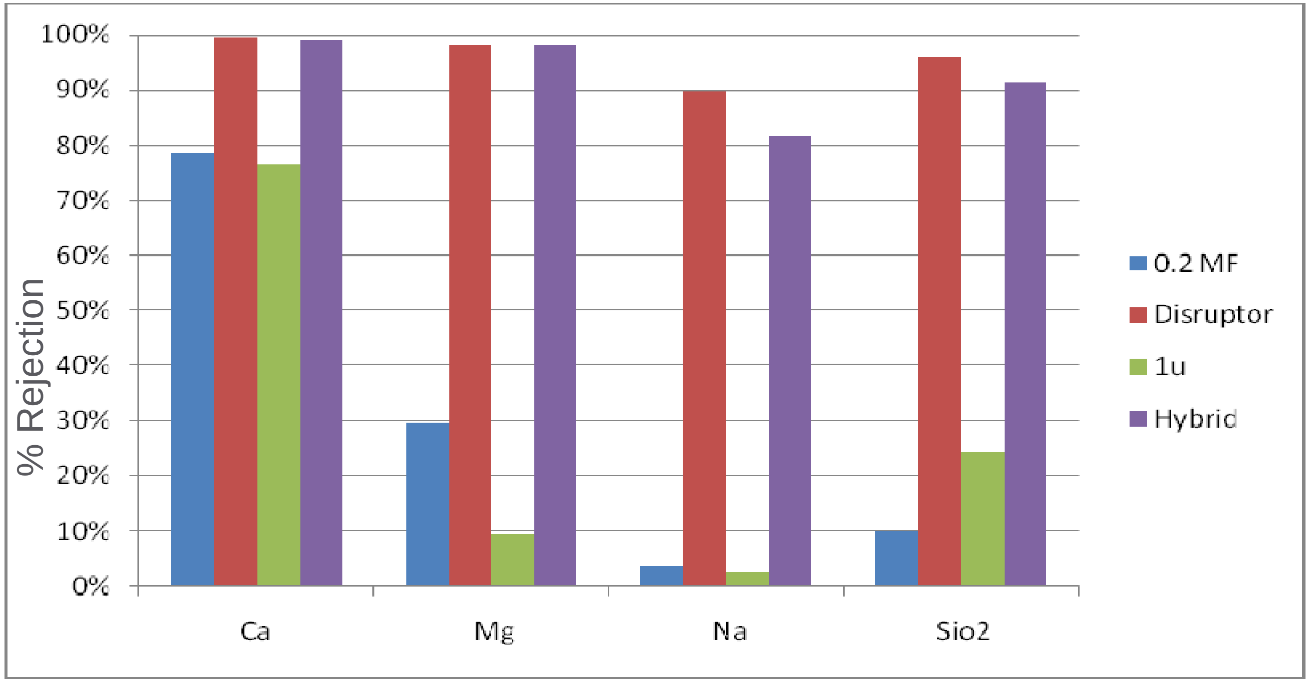
Total filtrate volume for trial



Data from the trial shows the amount of filtrate produced by the four different systems after a 24 day trial with same influent, system flow rate and incoming pressure. Clearly the Disruptor® and Disruptor® hybrid filters far outperformed the protection provided by the other prefilters that are typically used in RO prefiltration.

Ca, Mg, Na, SiO_2 rejection by RO systems



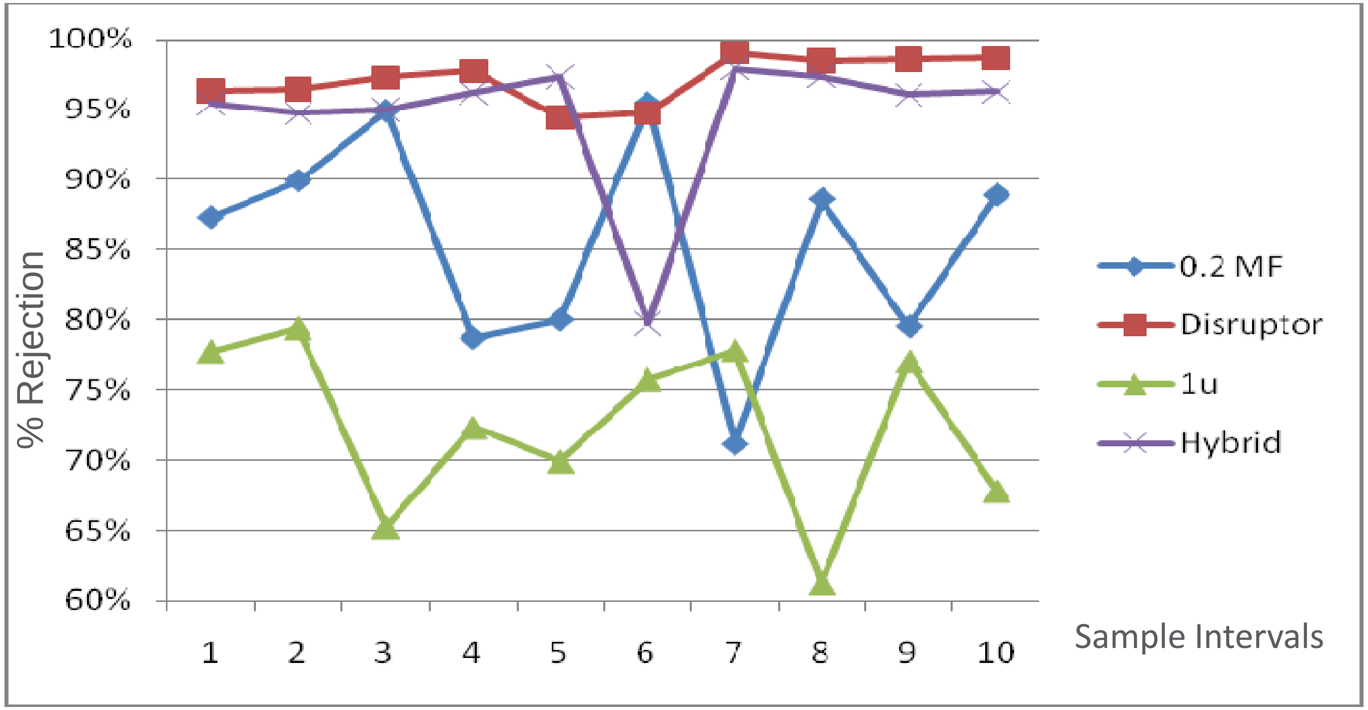
- RO membranes pre-filtered with Disruptor® showed significantly higher rejection rates for Magnesium, Sodium, and Silica
- Calcium rejection levels were similar-slightly higher with Disruptor®

Increases rejection of Ca, Mg, Na, SiO_2

- Data indicated the use of Disruptor® filters to protect RO membranes from fouling may also allow the membranes to perform more effectively to reject Ca, Mg and Na

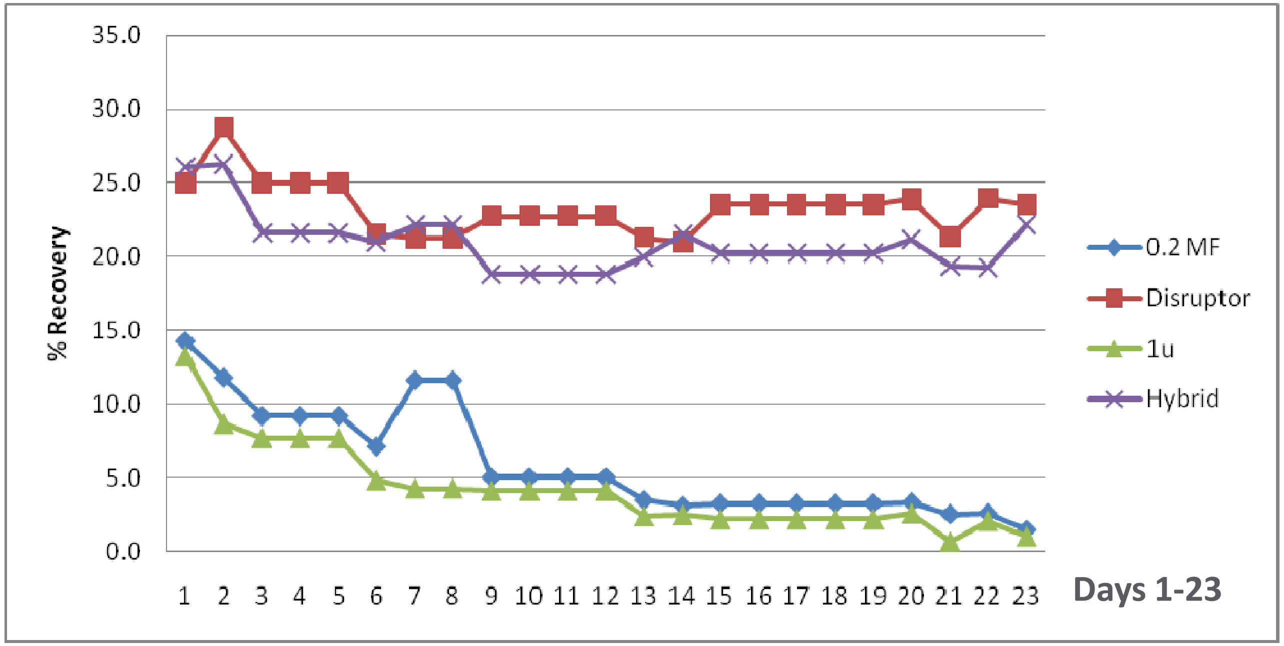
	Silica	Calcium	Magnesium	Sodium
initial	9.1	33.7	5.4	16.9
after sediment #1	9.2	33.3	5.3	16.8
after sediment #2	9.2	34.4	5.5	17
after sediment #4	9.2	34	5.4	16.7
after sediment #5	9.2	34.3	5.4	17
after 0.2 micron #1	9.1	33.1	5.3	16.7
after Disruptor #2	9.1	33.6	5.4	17
after Hybrid # 5	9.1	34	5.4	16.7
After RO #1 – O.2 micron	8.2	7.2	3.8	16.3
After RO #2 - Disruptor	0.37	0.17	nd	1.7
After RO #4 – 1 micron	6.9	7.9	4.9	16.5
After RO #5 – Disruptor Hybrid	0.78	0.31	nd	3.1

Disruptor® improved TDS rejection



- Higher TDS rejection levels were recorded with the Disruptor® prefilters
- TDS rejection was more consistent with the Disruptor® throughout the test
- TDS rejection data recorded from the other trains were lower and more erratic

RO performance - % recovery



- The percent recovery is the percentage of total influent that was turned into permeate by the membranes in each test system.
- RO membranes pre-filtered with the 0.2u polymeric and the 1u exhibited significantly lower initial permeate recovery and declined significantly over the study period.

Disruptor® reduces RO fouling

- Known foulants reduced by Disruptor® technology:
  - Virus, bacteria, colloids (Iron, manganese, silica, etc)
- Cellular debris also reduced:
  - Lipids (hydrophobic and hydrophylic)
  - Phospholipids
  - Protiens
  - Carbohydrates
  - Glucose – mono and poly saccharides (TEP/EPS)
- Preliminary data suggestsDisruptor® adsorptive filter media could produce a significant improvement in membrane performance, life and reduce overall operating costs by reducing fouling caused by TEP and other contaminants.
- Data indicates that reduction of membrane fouling contributes to better membrane perfromance in rejection of dissolved salts.
- The study also indicates better membrane performance at low transmembrane pressure that could produce significant energy savings in applications such as SWRO desal.

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Disruptor® vs competing technologies*

	Disruptor®	NF	UF/MF	Pyrolusite Greensand	GAC	Ion Exchange
Flow	1 MGD	1 MGD	1 MGD	1 MGD	1 MGD	1 MGD
Capital $	$42,000	$1 MM	$600,000	$350,000	$250,000	$290,000
Foot Print	2.5' x 7'	12' x 15'	12' x 15'	20' x 40'	12' x 24'	12' x 24'
Δ P (PSI)	2-3.5	70-80	15-20	20-25	15-20	20-25
Chemicals	No	Yes	Yes	Yes	No	No
Complexity	Low	High	High	High	Low	Low
Operational Costs ($/Kgal)		$0.40-0.45	$0.20-0.40	$0.08-0.10	$0.18-0.25	$0.20-0.25
Installed Costs	Minimal	$400,000	$300,000	$500,000	$180,000	$180,000
5 year PV	$512,245	$2.09 MM	$1.5 MM	$1.04MM	$817,812	$928,549

This table provides a general comparison of several aspects of different filtration systems. Note the difference between the relative square footage, installed cost, operating cost and payback comparison for each type of system . This shows that Disruptor® could provide significant cost avoidance when considering new installations or lower operating costs when used to protect or enhance membrane systems.

*This information is presented for general comparison purposes only. It is not meant to be an indication of actual installed cost as it does not include many important factors.

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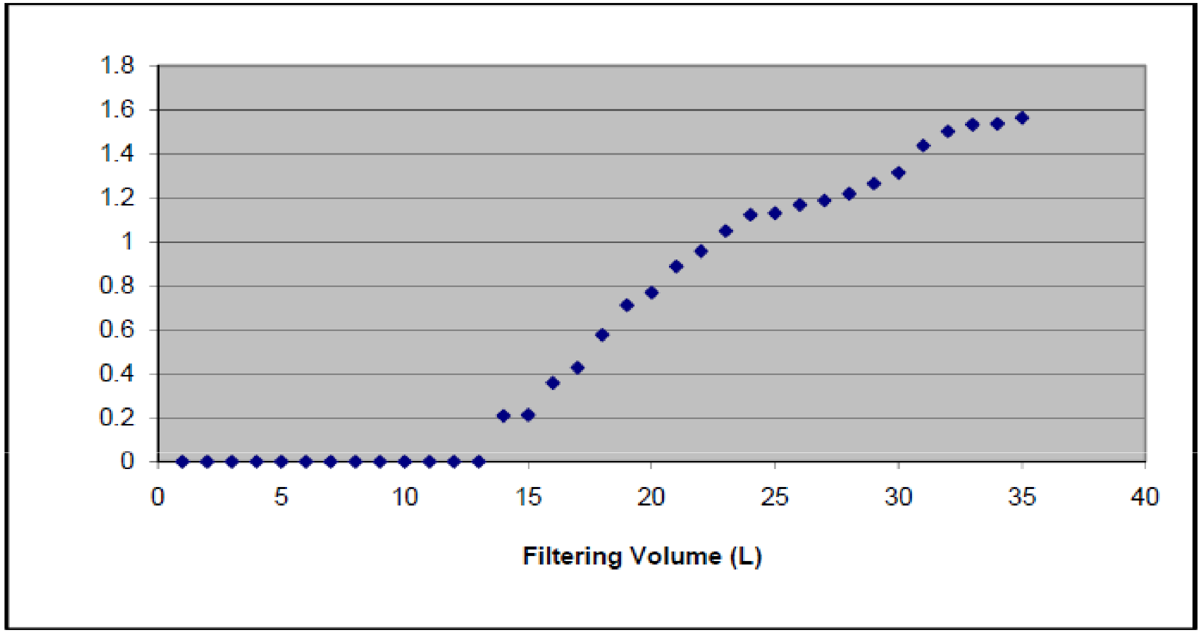
Trace Contaminant Removal

Micro contaminant removal

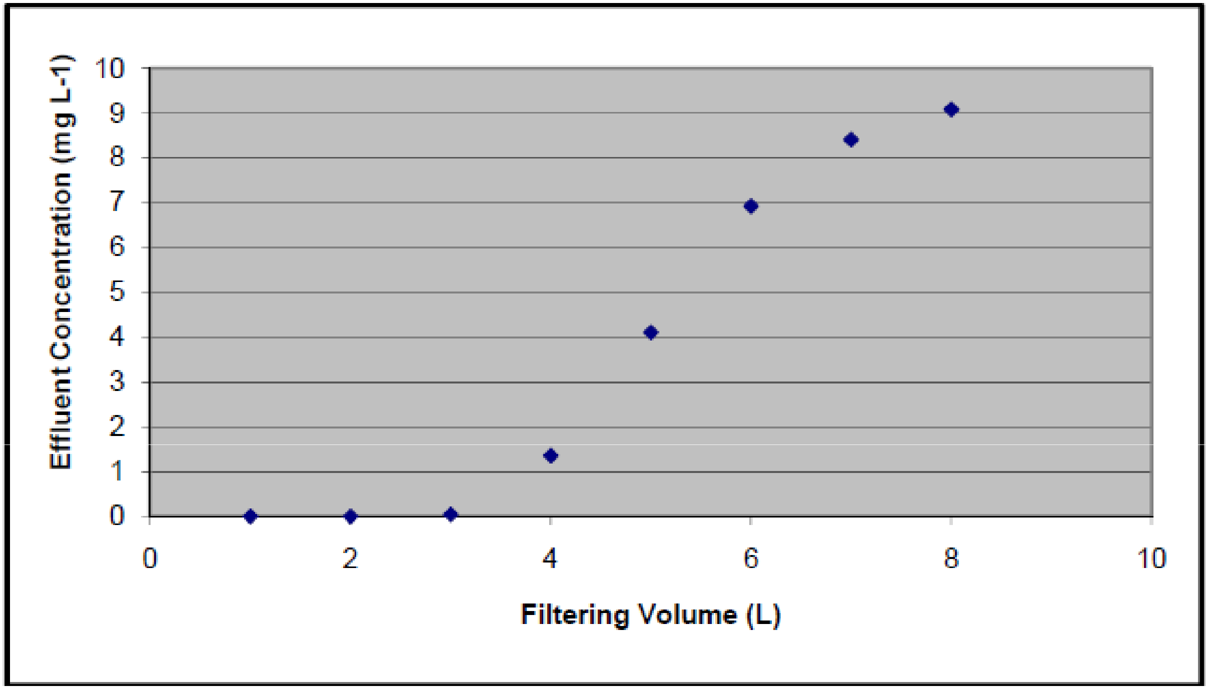
- Microcontaminants of many types are now being detected in many waste water and in some potable water sources.
- The dangers these contaminants present to humans and the environment are not well understood
- Reduction of removal of these compounds from both waste and potable water is a concern to many health authorities and agencies
- Independent testing by the University of California Irvine has shown Disruptor® to be effective in removing trace levels of Penicillin G, Bisphenol A (BPA) an endocrine inhibitor and the antibiotic Flumequinean
- The following three slide show the contaminant removed an well as the capacity for removal with Disruptor® PAC technology.

Penicillin G removal



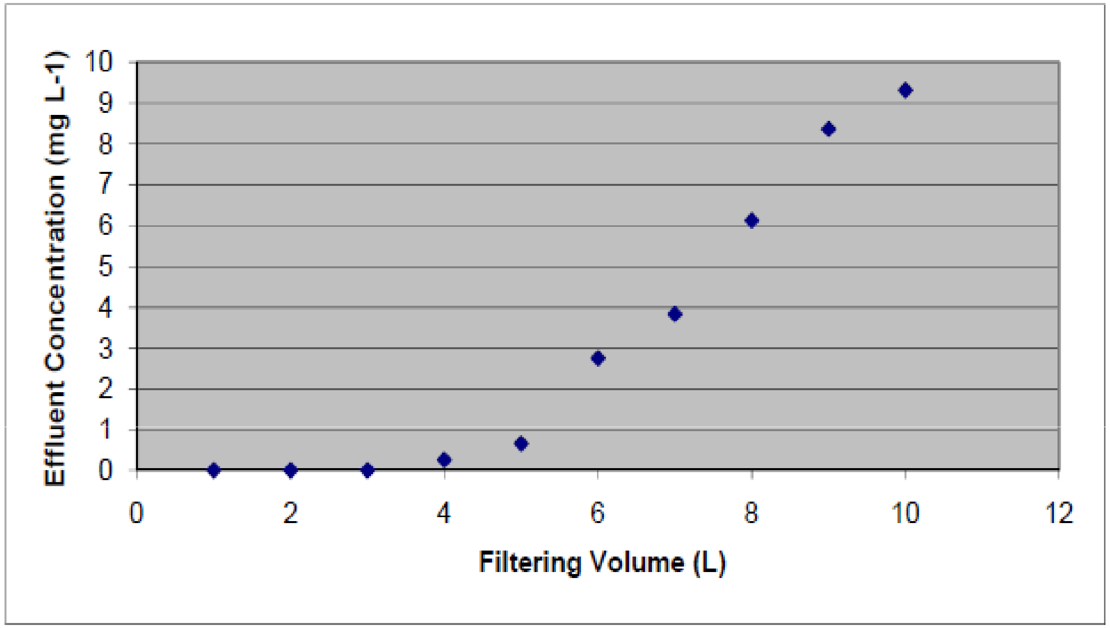
Penicillin G was used as a representative antibiotic. It was first studied using a challenge solution of 2 mg.l. This slide shows that the entire antibiotic was removed from 13 liters of water. At more typical concentration in the range of 2 micrograms per liter, a square foot of Disruptor® PAC could theoretically process more than 900,000 liters of water if it were free of other contaminants.

Bisphenol A (BPA) removal



BPA is monomer used in the manufacture of polycarbonate and epoxy resins. It is know to be estrogenic and is controversial and well studied in conjunction with many health related issues including: reproduction, heart disease and diabetes. The data shows complete removed from 3 liters of water having a concentration of 10 mg/L. At more typical concentration in the range of 2 micrograms per liter, a square foot of Disruptor® could theoretically process more than 1 million liters of water if it were free of other contaminants.

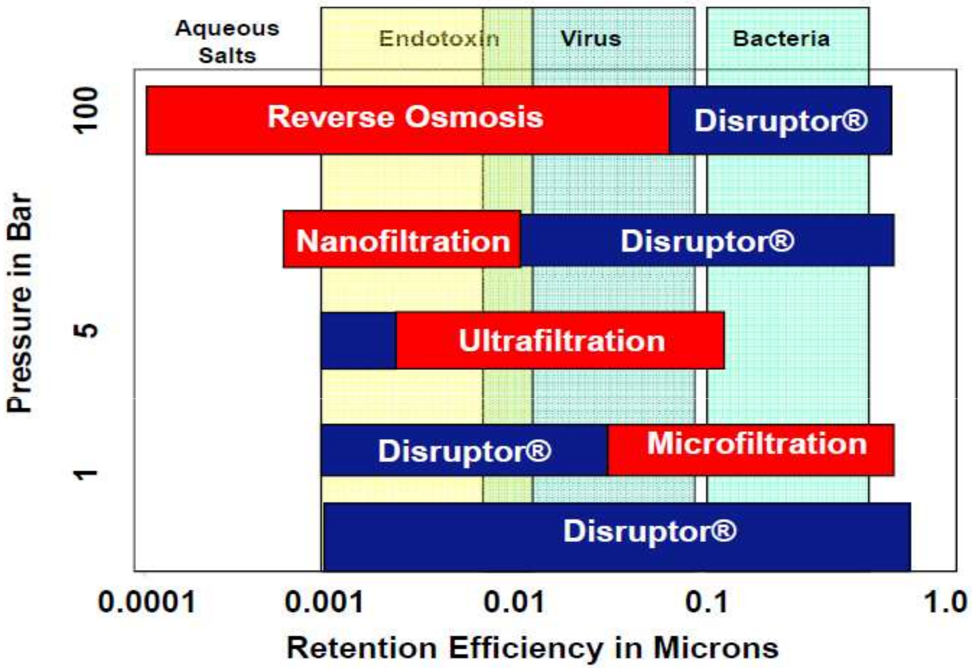
Flumequine removal



Flumequine is a chemotheraputic antibiotic implicated in tendon rupture, DNA damage and anaphylactic shock. It has been taken off the market but is representative of the flumequine drug class. The data shows complete removed from 3 liters of water having a concentration of 10 mg/L.   At more typical concentration in the range of 2 micrograms per liter, a square foot of Disruptor® could theoretically process more than 1 million liters of water if it were free of other contaminants.

Summary and conclusions

Value of Disruptor® in water filtration



Disruptor® technology represents a dramatic leap forward in filtration technology.

Disruptor® wet laid, nonwoven filter media can compete with polymeric membranes in removal efficiency but does so at a higher flow rate and lower pressure drop.

Depending on the quality of the influent water and volume being filtered, Disruptor® can perform as a stand-alone filter or be used in conjunction with other membrane systems to enhance their performance. When used downstream of MF or UF membranes as a post filter, Disruptor® can improve the filtrate quality by reducing virus, organic acids, TEP, and many colloids that may pass through these membranes. When used as a prefilter to RO and NF membranes Disruptor® can minimize biofouling. This feature helps to increase the flux rate of the membranes, decrease cleaning cycles and decrease energy use.

Many new applications in water filtration

- Disruptor® can be used in nearly any aspect of potable or waste water filtration or purification
  - Personal filters – water bottles, canteens, water bladders, back packs
  - Point of Use- tap filters, pitchers, gravity flow devices, refrigerator filters, water coolers, etc
  - Point of Entry – residential and commercial filters
  - Municipal – potable and waste water applications in conjunction with membranes
  - RO Prefiltration to reduce biofouling and improve filtrate production
  - Alternative to many MF and UF membranes
- Sampling, testing and concentration of contaminants
  - Virus sampling of municipal water or sea water for aquaculture purposes
  - Test kits for pesticides, virus, bacteria and other contaminants
- Endotoxin reduction
  - Hospital water, pharmaceutical manufacture, ultrapure water
- The following slides show some of the new uses and applications that are being developed using this exciting new technology!

Pesticide detection

Technology Licensing Opportunity

UNIVERSITY of GUELPH

Bioactive paper for detection and removal of organophosphates and lactones

Patent Status:

PCT patent application filed

A) Bioactive paper (enzyme +)

B) Control paper (enzyme -)

Bioactive paper containing a thermostable enzyme capable of degrading organophosphate, organosulfur, and acylhomoserine lactone compounds

Potential Markets:

1. Organophosphate Pesticide Detection

- Organophosphate based pesticides constitute 50% of the insecticides used in North America. In Canada, there are approximately 100 pesticides registered that contain organophosphates as their active ingredient, with another 24 product applications currently pending.
- Some of the organophosphate pesticides have been associated with adverse health effects such as paralysis, respiratory failure and even death.
- In 2004, a study from Environmental Canada revealed that 10 of the 13 organophosphates analyzed were detected in Lake Erie.
- There is a need for a simple biosensor that can be used to detect organophosphate pesticides in the field.

Applications:
- Qualitative biosensor for organophosphate compounds

Norovirus concentration

Anion exchange filtration for Norovirus surrogate concentration from foood samples prior real-time RT-PCR detection

Rapid separation and detection of Norovirus surrogate from food samples by anion exchange filtration and real-time RT-PCR

Rocío Morales-Rayas[a,b], Petra F.G Wolffs[b,c] and Mansel W. Griffiths[a,b]*

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[b] Canadian Research Institute for Food Safety, 43 McGilvray St., Guelph, ON, Canada N1G2W1.

[c] Department of Medical Microbiology, University Hospital of Maastricht. Peter Debyelaan 25, P.O. Box 5800, 6202 AZ, Maastricht, The Netherlands.

Rotavirus detection

KONKUK UNIVERSITY

Detection and quantification of Rotavirus (RV) from fresh produce by Real-time RT-PCR and cell culture

Konkuk University, Seoul, Korea
Ji-Yeon Hyeon

Removing aerosolized virus from air

Aerosol Science 40 (2009) 65 – 71

Contents lists available at ScienceDirect

Aerosol Science

journal homepage: www.elsevier.com/locate/jaerosci

ELSEVIER

Removal and retention of viral aerosols by a novel alumina nanofiber filter

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A R T I C L E   I N F O

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Keywords:
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MS2
Removal efficiency
Filter quality
Extracted fraction

A B S T R A C T

Nanomaterial, due to its unique physical, chemical and biological properties compared to its bulk counterparts, has the potential to provide a product superior to its bulk predecessor. In this study, a novel alumina nanofiber filter was assessed for its removal and retention capability for MS2 aerosol. Its physical removal efficiency in the 10–400 nm range was 94.35%, while its viable removal efficiency was 98.87%, which was slightly lower than three conventional HEPA filters tested. However, its pressure drop was much lower than HEPA filters, yielding a higher filter quality than HEPA filters. The average extracted fraction from the nanofiber filter was $8.64\times10^{-4} \pm 7.00\times10^{-4}$, which is three orders lower than other HEPA filters, demonstrating that the viruses were effectively retained in the nanofiber filter. Furthermore, the performance of the nanofiber filter showed no dependence on relative humidity. In conclusion, this novel alumina nanofiber filter presents advantageous potential for removal and retention of viral aerosol agents.

Reducing RO biofouling

The University Of Sheffield.

Study of a Depth Filter (Disruptor^{TM}) for the Novel Application of Reducing SWRO Membrane Fouling

Ibrahim M. El-Azizi
The University of Sheffield - UK

EPA virus testing publication

http://cfpub.epa.gov/si/si_public_record_report.cfm?direntryid=196983

Last updated on Wednesday, August 12th, 2009.

Science Inventory

You are here: EPA Home Science Inventory Record Report

A New Electropositive Filter for Concentrating Enterovirus and Norovirus from Large Volumes of Water - MCEARD

Citation:

Karim, M., E. RHODES, N. BRINKMAN, L. J. WYMER, AND G. FOUT. A New Electropositive Filter for Concentrating Enterovirus and Norovirus from Large Volumes of Water - MCEARD. Presented at ASM Annual Meeting, Boston, MA, June 01 - 05, 2008.

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Description:

The detection of enteric viruses in environmental water usually requires the concentration of viruses from large volumes of water. The 1MDS electropositive filter is commonly used for concentrating enteric viruses from water but unfortunately these filters are not cost-effective for routine viral monitoring. In this study, an inexpensive electropositive cartridge filter, the Nanoceram® filter, was evaluated for its ability to concentrate enterovirus and norovirus from large volumes of water. In initial experiments, one hundred liters of deionized water

Reducing iron from industrial water

Electropositive Filtration Technology
in
Automobile Manufacturing Applications

By

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USAPHC fact sheet

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Alumina Nanofiber Filters in Drinking Water Treatment

FACT SHEET 31-015-0211

What are Alumina Nanofibers?

Alumina nanofibers are very small fibers made from aluminum metal or aluminum containing materials. The fibers range in size from 1-100 (nm) in diameter and can be up to several micrometers in length (reference 1). To give perspective, a sheet of paper is about 100,000 nanometers thick. Alumina nanofibers consist of either aluminum oxide (Al_2O_3) or aluminum hydroxide, such as aluminum oxide hydroxide (AlOOH), commonly referred to as boehmite, or aluminum trihyroxide [$Al(OH)_3$], commonly referred to as gibbsite, bayerite or nordstrandite (reference 1).

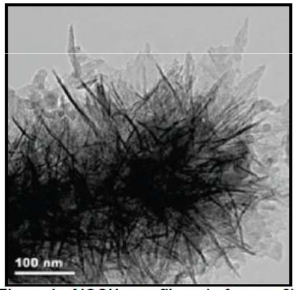

Figure 1. AlOOH nanofibers (reference 2).

How can Alumina Nanofibers be used for Treating Drinking Water?

Alumina nanofibers have been incorporated into cartridge filters to increase their ability to remove contaminants. The nanofibers have two particular attributes that make them attractive for use in drinking water filters – the proven capability of alumina to adsorb various contaminants in conjunction with the extremely high surface areas of the nanofibers allow for potential adsorption of significant amounts of contaminants (references 3, 4). This could extend the life of a filter. The electrostatic attraction allows for the potential adsorption (and thus removal) of viruses which are on the submicron and nanoscale. This would improve a filter's microbial pathogen removal capabilities. Research has shown the potential for Al_2O_3 alumina materials and Al_2O_3 alumina nanofibers to remove or reduce virus concentrations in water (references 5-8).

Currently, one company uses alumina nanofibers for drinking water treatment. The nanofibers are aluminum oxide hydroxide, or boehmite (AlOOH). The boehmite nanofibers are about 2 nm in diameter and 200-300 nm in length (Fig. 1). The nanofibers are incorporated onto submicron glass fibers which are then bonded onto a pleated filter medium (references 9, 10). The resulting filter has pore sizes of about 2-3 micrometers. However, due to the electrostatic attraction much smaller particles (e.g., viruses) could potentially be removed through adsorption, effectively making the filter function as though it had much smaller, submicron pore sizes similar to a membrane filtration technology such as ultrafiltration. With an actual pore size of about 2-3 micrometers, the filter could allow a high rate of flow with a low pressure drop compared to membrane technologies – an advantage over traditional membrane technologies. Some research shows Al_2O_3 alumina nanofiber filters of similar design to this company's filters performing effectively at high flow rates (references 8, 11).

Do Alumina Nanofibers used for Treating Drinking Water Pose any Human Health or Environmental Health Risks?

Alumina nanofibers used in drinking water treatment could be shed from a filter and be ingested or enter the environment.

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Conclusions

Disruptor® is the first new filter technology to be commercialized since the advent of polymeric membranes. It represents a new category of filter media that removes contaminants through electroadhesion and ion exchange, not mechanical filtration.

Disruptor® efficiently retains inorganic particulates and organic materials - cell debris, endotoxins, virus, proteins, many colloids, bacteria and inorganic submicron particulates

Benefits over microglass, resin bonded and chemically charge-modified filter media include:

- Finer particle retention
- Higher loading capacity
- Greater efficiency in salt, brackish and fresh water
- Wider pH operating window

Benefits over polymeric NF, UF or MF membranes include:

- Higher flow rate = Faster filtration
- Low pressure drop = Low operation energy demand
- High loading capacity = Long life
- Very low installation cost and smaller footprint than traditional systems

And it is commercially available today to help your business stay ahead tomorrow!

AHLSTROM

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Unleashing better performance in everything we do.

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Thank you

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