

**A NEW APPROACH TO ORGANIC
REMOVAL FOR MAKE-UP AND
WASTEWATER TREATMENT IN
MEMBRANE SYSTEMS**

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A New Approach to Organic Removal for Make-up and Wastewater Treatment in Membrane Systems

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Abstract:

The application and potential of MYCELX™ technology will be discussed in relation to reducing organic loading and subsequent fouling on membrane systems. Additional data will be present on MYCELX™ hydrocarbon removal capabilities in various water treatment processes.

What is MYCELX™?

MYCELX™ is a patented polymeric compound formed as a synthesis product of a natural drying, semi-drying, and non-drying oil with a synthetic polymer [Composition Patent(s): 5,437,793 and 5,746,925 / Chemical Abstract Service (CAS) #173967-80-1 and #173967-81-2]. MYCELX™ is infused into a variety of substrates so that it is homogeneously dispersed and cured throughout the base materials. As hydrocarbon pollutants come in contact with the MYCELX™, they are dissolved and bonded into the infused material, making hydrocarbons hydrophobic and thickening them so they will not re-disperse into solution. MYCELX™ infused filters are engineered to remove hydrocarbons ranging from oil to gasoline from water in a single-pass without significant pressure drop or clogging.

MYCELX™ binds all phases of hydrocarbon compounds together, keeping them from separating and emulsifying. MYCELX™ can remove oil/water and water/oil mixed emulsions. It is proven effective in removing Alkanes, Alkenes, Cycloalkanes, Aromatic Hydrocarbons, Crude Oils, Tallow and other animal fats, Vegetable Oils, Complex Monomers, Polymers, Organo-metallics, PCBs, MTBE, Chlorinated Organics and mixed emulsions.

MYCELX™ is a non-hazardous / nontoxic material that will not dissolve or migrate into water. It has been declared compliant to section 300.915 of the NCP by the EPA. MYCELX™ infused materials will not absorb water when used to remove oil and other pollutants from the water. Normally, oil sorbents absorb 10 times their weight in water when they are used in an oil spill application. That water costs a lot of money to haul off. MYCELX™ materials only absorb hydrocarbon based pollutants so when saturated, only the MYCELX™ material and the pollutant is left (i.e. no water).

MYCELX™ infused filters and media are easily disposed of by incineration. They have an extremely low water drag-out and ash content resulting in a clean burning waste with a BTU value comparable to alternative fuels. The hazardous nature of the saturated MYCELX™ filters are dictated by the absorbed/adsorbed contaminates. In many cases, the filters can be land filled with other petroleum-saturated materials (i.e. oily rags, sorbents and oil filters).

MYCELX™ Hydrocarbon Removal Applications

A. Pretreatment for Membrane Systems

Membrane systems, i.e., Reverse Osmosis (RO), Nano-filtration (NF), Ultrafiltration (UF), are used in a variety of water treatment applications. Almost half the cost of water filtration arises from clearing clogged and fouled filtration membranes (*Business Week*; February 26, 2001). Membrane technologies work as molecular sieves and through size exclusion, and remove organics and inorganic larger than a given pore size.

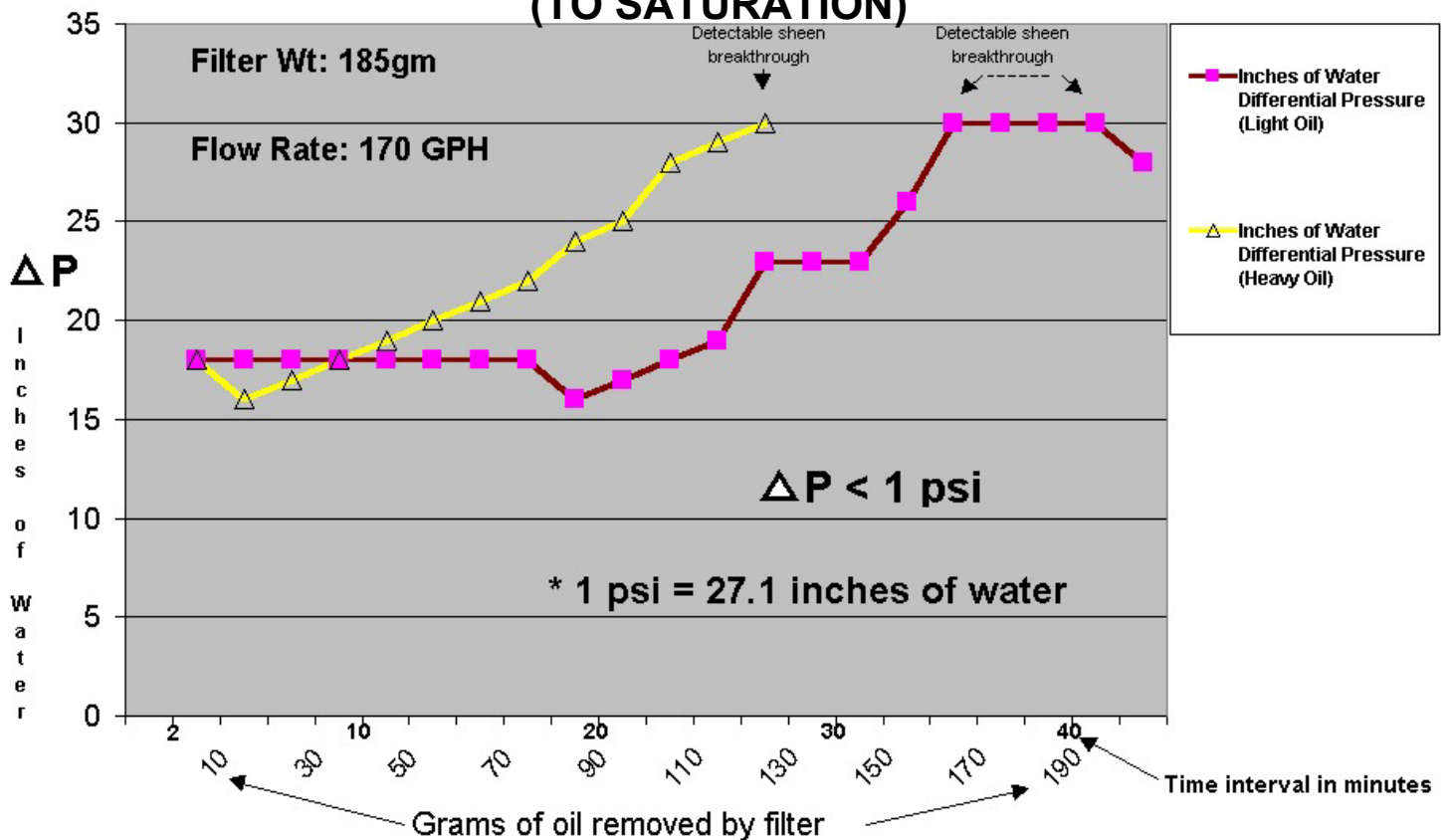
Membrane systems are often on-line for long periods of time processing large volumes of water. Even trace amounts of organics retained by the membrane can accumulate over time and reduce permeate flow, increase differential pressure and cause contaminant slippage into the permeate. Organics foul membranes because the organic foulant and the membrane materials are similar. Like attracts like. As a result of incipient and chronic organic fouling of membrane systems, they must be periodically cleaned. Cleaning “organic fouling is more problematic because chemicals that are effective in removing the organic fouling agents tend to denature and damage the membranes. This is because the membranes are chemically similar to the foulants themselves.”⁽¹⁾ The control of organic fouling in membrane systems really depends on reducing organic contaminants prior to the membrane system rather than post fouling cleaning.

As mentioned above, one of the basic properties of many filtration membranes is that they are composed of hydrophobic polymers. This causes them to attract and attach hydrophobic molecules, i.e. oils, and other organic compounds. Attempts have been made to solve this problem using oleophilic prefiltration but have been largely unsuccessful due to the high-pressure drop across these filters after they have captured and clogged with hydrophobic organic compounds and oils. The prefilter pressure drop increase is due to the swelling of the polymer/organic foulant coagulate. Generally, the result has been prefilter organic fouling as opposed to cross flow membrane fouling, but due to the large volume of water processed by membrane systems, membrane fouling still occurs.⁽¹⁾

To address the problem of increasing pressure drop on membrane system prefilters, MYCELX Technologies developed an oleophilic filter, which exhibits insignificant pressure drop even as it saturates with viscous organics (Reference Figure 1 – Pressure Drop Curve). This works as follows: the MYCELX™ oleophilic polymer can be permanently cured into practically any filter substrate. What makes this molecule novel, aside from its high affinity for organic compounds, is that the polymer itself and its coagulate product with oil is viscoelastic. Generally, viscoelastic materials become more viscous and denser with shear. Essentially, the opposite of swelling occurs. Viscoelastic materials actually contract when sheared, as is the case when water flows through a filter. This is a very important fact because as water passes through the filter, the coagulate contracts allowing for essentially zero pressure drop across the filter to saturation (less than 0.5 psig @ saturation). The saturation point of these filters is approximately ¾ of filter weight with oil/hydrocarbon before breakthrough (generally with 99.99 percent first pass efficiency).

Figure 1

LOW DIFFERENTIAL PRESSURE (TO SATURATION)



Case Study 1.0 – Government Contractor Installation - Complete

A major industrial manufacturing plant extensively uses RO to recover process water due to its location in the desert where water is scarce. This facility initially attempted recovery of process waters utilizing membrane technology. They found that maintenance, cleaning and replacement of membranes only gave them 50 percent of their initial projected yield. The system was deemed effective but uneconomical. Consequently, viscoelastic polymeric surfactant (MYCELX™) filters were deployed as RO membrane prefilters. After processing nearly a million gallons of water the facility has found that membrane service life has extended ten-fold, resulting in a 50 percent decrease in cost to treat. This has allowed the plant to re-use their process water – a precious resource in this case.

Case Study 2.0 – Machining Operation – In Progress

MYCELX filters (MX-4), i.e. 4 x 30” PP Septa, were installed on semi-fouled NF membranes. The MX unit significantly reduced the rate of NF membrane fouling and preserved the NF system's percent recovery. Preliminary indications are that the MX unit will extend the NF membrane service-life by a factor between 5-7 times, as well as reduce annual energy requirements, maintenance and downtime.

Current System Configuration:

UF → MX-4 → Holding Tank → NF → RO

System Details:

- The Ultrafiltration (UF) system consists of "Sintered Stainless Steel (0.1 Micron) Membranes". The UF system intermittently discharges between 20 & 80 ppm emulsified lube oil @ 40 gpm.
- The MX-4 polishes this residual emulsified lube oil. The MX-4 unit captures on average 2.64 kilograms of hydrocarbon and treats between 85,000-100,000 gallons (this works out to roughly 0.36 cents/gallon over 100,000 gallons, but the cost-to-treat totally depends on inlet concentration of oil). Typical operating pressure drops across the MX-4 vessel are between 2.5 psi (initial) and 3.0 psi (final). The filters are changed when visible sheen breaks through to the Hold Tank.
- The NF system consists of spiral-wound polymer membranes ("TriSep/Filmtec NF70 type") and flows 40 gpm as well.
- The NF system feeds two 20-gpm RO systems with different brands of spiral-wound membranes. The first are Filmtec BW30 membranes & the second consists of Hydranautics' equivalents.

(1) Article June 2001 issue of *Environmental Protection*, Vol. 12, No. 6, p. 34. Title "Protection from Organic Fouling"; Co-Authors: Hal Alper and Kirk Abbott

B. Oil / PCBs / Chlorinated Hydrocarbon Removal

Case Study 1.0 – Electric Utility – Work Complete

The utility industry – like many others seeking to protect the environment while at the same time reducing their risk of fines, costly cleanup efforts and unwanted public scrutiny – is striving to prevent oil and PCB contamination of soil and water.

For utilities, the problem occurs primarily in manholes and in transformer yards where storm water is exposed to old transformers and capacitors that may still have/had oil or fluids that contain some PCBs. In order to perform maintenance, the storm water (containing traces of oils, lead and PCBs) must be

pumped out of the manholes or retention wells and be treated before it can be discharged to the environment or municipal sewer systems – an expensive process for any organization.

For one utility, this practice – excluding pumping and transportation of the water to a treatment facility – cost 25 cents per gallon. JoDAN Technology, LTD (JDT) was asked to develop a treatment system to address the oil/PCB/contaminant concerns. In cooperation with an electric utility JoDAN developed the JMOR™ System consisting of particle filtration and MYCELX filtration technology.

In June 2000, JDT designed, built and began testing the first JMOR™ system. This JMOR™ system used particulate bag filters followed by an MX-12 (12 x 30" MYCELX™ -infused filters). The first field trial with the JMOR™ system produced excellent results. After 4 months of operation the JMOR™ system processed 1,300,000 gallons of manhole wastewater at a cost of 2.8 cents per gallon. The system removed PCBs, oil and grease, copper, and hydrocarbons to Below Detectable Limits (BDL). As an unexpected bonus, the filter system also reduced the particulate lead from the effluent water. See Table 1.0.⁽²⁾

Table: 1.0 Results from treating 1,300,000 gallons of manhole water.

	PCB1254 ppb	TPH ppm	Oil&Grease ppm	Lead Avg. ppm	Copper ppm
MYCELX Effluent	<1.0	<5.0	<5.0	0.020	<0.01
Avg. Influent	3.74	367.9	17698	33.0	11.6
Max. Influent	40.0	21400	141000	150.0	87.0

- Values presented are from the utility’s analysis of influent and effluent samples
- The lead and copper removal was due to the metals being tied up as organo-metallics
- All PCB samples were analyzed as PCB Aroclors
- PCB effluent samples were all < 1.0 ppb
- Some PCB influent samples had LLDs greater than 1.0 and were incorporated as absolute values

Case Study 2.0: Pump Manufacturer – Work Complete

A pump manufacturer had eleven drums of PCB contaminated water, which resulted from the decommissioning of electrical equipment containing PCB contaminated capacitors. Cost to have the 11 drums shipped off site and treated was \$11,000 dollars. They contacted JoDAN Technologies, LTD and utilized an MX-1 (10" x 2.5") MYCELX™ treated PP cartridge with a 5 gpm submergible pump (Cost \$350.00). All 11 drums were process within 1 week and disposed of as a clean waste. The results are reported in Table 2.0

Case Study 3.0: Land Fill Discharge – Testing In Progress

An owner of a landfill requested support to remove PCBs from landfill run off water. An MX-1 (10" x 2.5") MYCELX™ treated PP cartridge was placed down stream of a 1µm cartridge filter and sand filter and flowed at 2.5 gpm. Results from the 1st trial are listed in Table 2.0

Table 2 Results for PCB Case Study 2 and 3

	Land Fill (Filter MYCLEX Standard Formulation) PCB 1254 2.5 gpm single 10" cart	Pump Manufacturer (Filter MYCLEX Standard Formulation) PCB 1254 5 gpm single 10" cart
Influent	129 ppt	174 ppb
Effluent	BDL(<0.65 ppt)	BDL (<1.2 ppb)

Case Study 4.0: Chlorinated Hydrocarbon Removal – Complete

Laboratory test completed by a client:

Test Conditions:

Centrifugal pump -> MX-1 (10" MYCELX™ Cartridge)

Flow Rate: 1.35 gpm, Single Pass through Cartridge

Results:

Compound + Initial Concentration	Results
1,1,1 Trichloroethylene 50 ppm (mg/l)	< BDL
Perchloroethylene 50 ppm (mg/l)	< BDL
Tetrachloroethylene 50 ppm (mg/l)	< BDL

BDL = < 1.0 PPM Using EPA Method 608

(2) Article January 2001 issue of *Environmental Protection*, Title "PCB Gone"; Co-Authors: Hal Alper and Phil D'Angelo

C. BTEX Removal From Surface Water –Case Study 1.0

Removal of Benzene & Toluene from Contaminated Groundwater

Initial water test 31 May 2001 by Advanced Analytical Associates, Bozeman, Montana:
 Sample #1005114 Well Head: Benzene 11 ug/L Toluene 5.3 ug/L
 Sample #0105115 Inside Sample: Benzene 27 ug/L Toluene 11 ug/L
 Both initial samples had ND as result for MTBE, Ethyl benzene, Xylenes and Naphthalene.

SAMPLE ID	LAB ID	Target Analytes	
		Benzene	Toluene
		ug/L	ug/L
WELL HEAD	105114	11	5.3
INSIDE	105115	27	11
BLANK	BW0530	ND	ND

Single-Pass MYCELX™ Filter Results

PETROLEUM SCREEN FOR FILTERED WELL SAMPLES ¹		EPA 524/525
Volatile Organic Compounds ²	None Detected	EPA 524/525
Synthetic Organic Compounds	Negative	EPA 524/525
Total Polvaromatic Hydrocarbons	Negative	EPA 524/525
Total Diesel Range Organics	Negative	EPA 524/525
Total Motor Oil Range Organics	Negative	EPA 524/525

1 PQL = Practical Quantitation Limit = 0.5 ug/l

2 Volatile Organic Compounds determined non-detect by USEPA Method 8021

D. BTEX + MTBE Removal From Surface Water – Case Study

Removal of BTEX and MTBE from Contaminated Surface Water (ppm)

<u>Sample ID</u>	<u>MTBE</u>	<u>Benzene</u>	<u>Toluene</u>	<u>Ethyl benzene</u>	<u>Xylene*</u>
Inlet #1 **	87	2.0	12	3.8	24
Discharge #1	0.18	0.004	0.016	0.002	0.012
Knockdown #1	99.8%	99.8%	99.9%	99.9%	99.9%

<u>Sample ID</u>	<u>MTBE</u>	<u>Benzene</u>	<u>Toluene</u>	<u>Ethyl benzene</u>	<u>Xylene*</u>
Inlet #2	17	0.92	3.2	0.48	2.6
Discharge #2	0.21	0.034	0.14	0.030	0.14
Knockdown #2	98.7%	96.3%	95.6%	94%	95%

•*Average of all Isomers

•**USEPA Method 8020 – Volatile Aromatic Hydrocarbons

E. Emulsified Truck-Wash Wastewater Treatment – Case Study

Removal of TPH and Copper in Emulsified Truck Wash Waste Water

SAMPLE ID #1: Before MYCELX™ Filter					
PARAMETER	RESULTS	UNITS	PQL	METHOD #	DATE ANALYZED
Total Copper	1.58	mg/L	0.02	200.7	02-19-02
C ₆ - C ₁₂ Hydrocarbon	43.0	mg/L	5.0	1005	02-18-02
C ₁₂ - C ₂₈ Hydrocarbon	85.0	mg/L	5.0	1005	02-18-02
C ₂₈ - C ₃₅ Hydrocarbon	28.0	mg/L	5.0	1005	02-18-02
C ₆ - C ₃₅ (TPH)	156	mg/L	10.0	1005	02-18-02

E. Truck Wash - Waste Water Treatment

SAMPLE ID #2: After MYCELX™ Filter (Single Pass)					
PARAMETER	RESULTS	UNITS	PQL	METHOD #	DATE ANALYZED
Total Copper	0.778	mg/L	0.02	200.7	02-19-02
C ₆ - C ₁₂ Hydrocarbon	9.0	mg/L	5.0	1005	02-18-02
C ₁₂ - C ₂₈ Hydrocarbon	<5.00	mg/L	5.0	1005	02-18-02
C ₂₈ - C ₃₅ Hydrocarbon	<5.00	mg/L	5.0	1005	02-18-02
C ₆ - C ₃₅ (TPH)	9.0	mg/L	10.0	1005	02-18-02

*** TPH Knockdown = 94.2%**

PQL: Practical Quantitative Limit

mg/L: Milligrams per Liter

Test Methods: Methods for Chemical Analysis of Water and Waste, EPA 600/4-79-020, Rev. March 1983
Standard Methods for the Examination of Water and Wastewater, 18th Edition 1992