California Surface Water Treatment Alternative Filtration Technology Demonstration Report*

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Contents

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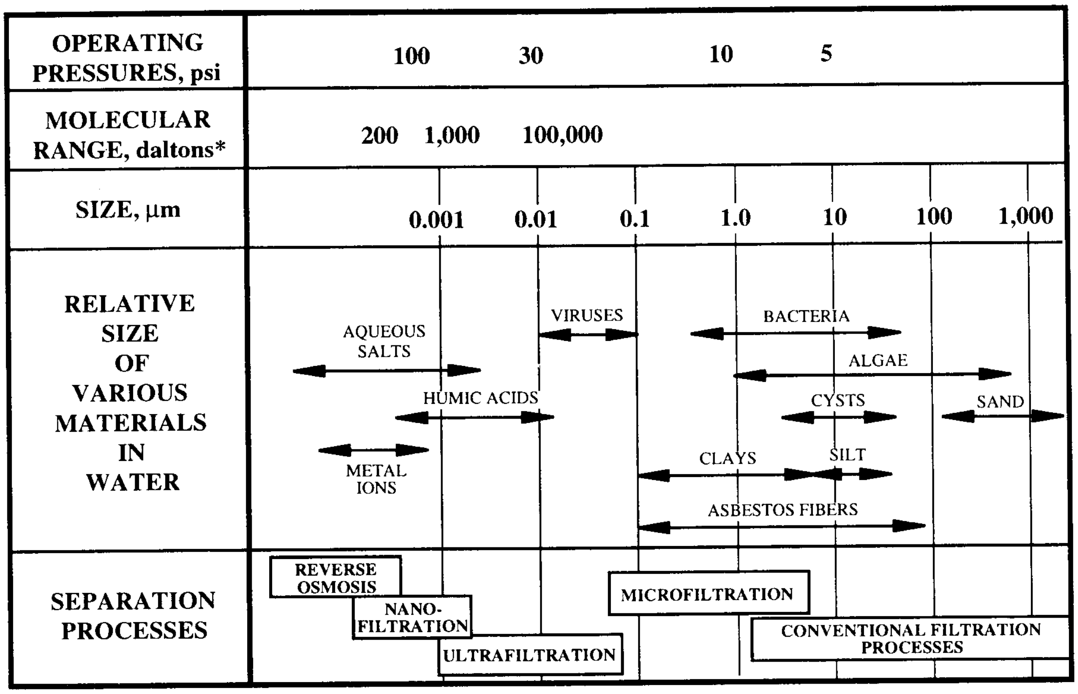
Preface

In using this document the reader should keep in mind that it is important to review all of the sections and documentation pertaining to any given technology to ensure that all conditions pertinent to evaluating the technology are applied. One should not rely solely on Table 1 or the individual summary tables that precede the narrative discussion of each technology to provide adequate material for permit provisions. Finally, this document is not intended to be a comprehensive design manual for alternative filtration technologies. The report is only intended to aid the Department's Drinking Water Program field staff in developing domestic water supply permit provisions and assessing the adequacy of operation plans submitted as a requirement of the domestic water supply permit.

The intent of providing the narrative sections is to supply field staff with material so that site specific permit provisions could be written to ensure reliable operation of the alternative technology or to evaluate the need for further pilot studies. The narrative summary in the document is intended to provide field staff with a summary of the testing conditions so that appropriate recommendations can be made to the utilities considering alternative technologies to either replace existing facilities or to comply with the Surface Water Treatment Rule (SWTR). When the conditions of testing do not match site-specific water quality parameters, it may be appropriate for the Department's field engineer to recommend additional pilot testing.

The reader should also note that the testing conducted to demonstrate the efficacy of an alternative filtration technology is limited to the equipment supplied by the manufacturer. This equipment is often turned over to an independent third party, who conducts the tests. As such, this testing does not cover deficiencies that might be inherent in manufacturing practices. Any utility purchasing equipment should address manufacturing and quality control issues as part of their equipment specifications, e.g., post manufacturing or preinstallation testing of the individual membrane modules. Utilities may also want to limit their selection to manufacuturers that have manufacturing quality control and quality assurance protocols in place and are certified as adhereing to minimum manufacturing quality control and quality assurance protocols (e.g., ISO 9000, 9001).

As a reminder of the potential performance variability resulting from the difference in pore sizes and pore size distribution between technologies, the reader is directed to Figure 1. This figure shows a number of means to "classify" membranes. Regardless of the mean used to classify a membrane, the figure also illustrates the industry's broad nature of the general "definitions" for microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. The ranges that categorize the different membranes serve to illustrate the difficulties in drawing strict boundaries between the membrane classifications. The variability in pore size and distribution between membranes of the same classification may be part of the reason for performance differences between membrane systems of the various manufacturers. However, this does not rule out the possibility that some other component (other than the membranes) may be the cause of poor performance (e.g., gaskets or seals between the product water and the source water), as it is the "system" that is being tested, not the membrane itself.



* Dalton is an unit of mass which designates 1/16 mass of the lightest and most abundant isotope of oxygen

Figure 1. Relationship Between Separation Processes Based on Pore Size or Molecular Size (Jacangelo, Adham, and Laine, 1997).

If supplemental information is required, the reader is directed to the references listed in each section, the one-year operating reports, and the appendices. As noted previously, this document is intended to be a summary performance report and is not a design document.

The acceptance of any membrane technology is specific to the technology tested. Should the manufacturer make any changes in the physical attributes or character of the membrane or system, it is the responsibility of the manufacturer to notify the Department in order to determine whether the modification will require additional testing.

Although this document is updated periodically, Department field staff should be aware that additional alternative technologies might have received a conditional letter of acceptance from the Department. As alternative technologies are found to be acceptable by the Department's SWTR committee, a memo notifying field staff of the acceptance will be sent to all Field Operations Branch Chiefs, Regional, and District Engineers.

Field staff may want to consider working with a utility by offering to issue conceptual approvals at various points in the project (e.g., design, construction, installation, and startup) up to the point at which a domestic water supply permit is issued. Issuing the domestic water supply permit is point at which the alternative technology is approved for use at a given site. As part of this process it may be worthwhile to consider recommending a commissioning study on the plant to ensure the performance of the system, as constructed and installed, meets the design, equipment specifications, and pertinent regulatory requirements.

The use of trade names, trademarks, or commercial product names in this document does not constitute endorsement by the state of California, the California Department of Health Services, or any of their agents.

A. Introduction

The filtration technologies presented herein have completed a demonstration of filtration effectiveness to satisfy the requirements of the California Surface Water Treatment Rule (CCR, Title 22, Chapter 17, Section 64653(f)) (CSWTR), as alternative filtration technologies. The demonstration studies were designed and conducted in accord with the California Department of Health Services, Division of Drinking Water and Environmental Management, Drinking Water Program (DWP).

B. Appropriate Permit Provisions

The CSWTR specifies certain requirements only for the four recognized conventional filtration technologies. For alternatives to these technologies, technology specific requirements are set in the individual water supply permit. Examples of appropriate permit provisions, addressing all performance standard related issues in the CSWTR that apply to alternative technologies follow, with the numerical component given as an alphanumeric variable. This example is written in a form that can be applied directly to a conventional media filter. The field engineer shoud carefully review the example permit provisions and the text of the provisions and modify as appropriate for the respective alternative filtration technology. The values for the alphanumeric variables can be found in the summary provided in Table 1.

Section 64653(c) equivalent for these technologies

The turbidity level of the filtered water shall be equal to or less than **A** NTU in 95 percent of the measurements taken each month and shall not exceed **B** NTU at any time.

When using a grab sampling monitoring program the turbidity level of the filtered water shall not exceed **C** NTU in more than two samples taken consecutively while the plant is in operation. When using a continuous monitoring program the turbidity level of the filtered water shall not exceed **C** NTU for more than eight consecutive hours while the plant is in operation.

Section 64660(b)(6) equivalent for these technologies

When any individual filter is placed back into service the filtered water turbidity of the effluent from that filter shall not exceed any of the following:

(a) **D** NTU.

(b) **E** NTU in at least 90 percent of the interruption events during any consecutive 12-month period.

(c) **A** NTU after the filter has been in operation for 4 hours.

Section 64655(b) and (d) equivalent for these technologies

To determine compliance with the turbidity performance standards specified, the turbidity level of representative samples of the combined filter effluent, prior to clearwell storage, shall be determined at least once every **four** hours that the system is in operation. Small water systems may demonstrate compliance by collecting grab samples once per day provided the system has been properly evaluated after installation and it has been documented that the daily sample is representative of system operation. Monitoring shall be conducted in accordance with the approved operations plan.

Section 64663(a & b) equivalent for these technologies

The supplier shall notify the Department within 24 hours by telephone whenever: a) the turbidity of the combined filter effluent exceeds **B** NTU at any time; or b) more than two consecutive turbidity samples of the combined filter effluent taken every four hours exceed **C** NTU.

Table 1. Recommended Alternative Filtration Technology Requirements for Water Supply Permits.

	Permit Provisions				
	A	B	C	D	E
Filtration Technology					
Conventional†, direct filtration, diatomaceous earth filters	0.5	5.0	1.0	2.0	1.0
Slow Sand	1.0	5.0	1.0		
Alternative Filtration Technology					
USFilter/Memcor Microfiltration	0.1	1.0	1.0	NA	NA
Pall Microza	0.1	1.0	1.0	NA	
Advent Membrane System	0.1	1.0	1.0	NA	NA
Hydranautics Hydracap	0.1	1.0	1.0	NA	NA
Koch PMPW	0.1	1.0	1.0	NA	NA
Zenon Zeeweed 500a, 500c, and 1000	0.1	1.0	1.0	NA	NA
Desal DK-5	0.1	1.0	1.0	NA	NA
EPD Alternative Filtration Technology	0.2	5.0	1.0	2.0	1.0
Trident, Pacer II, Advent Package Water Treatment System for 2-log *Giardia* and 1-log virus removal	0.5	5.0	1.0	2.0	1.0
Trident, Pacer II, Advent Package Water Treatment System for 2.5-log *Giardia* and 2-log virus removal	0.2	5.0	1.0	2.0	1.0
Multitech	0.5	5.0	1.0	2.0	1.0
Sverdrup/Serck Baker Hi-Rate Pressure Filtration Drinking Water Plant	0.2	1.0	0.5	1.0	0.5
USFilter Model ELB-921∇	0.2	1.0	0.5	1.0	NA
Rosedale Bag Filtration System	0.2	1.0	0.5	1.0	NA
3M Bag and Cartridge Filtration∇	0.2	0.5	0.2	0.5	

† The USEPA has promulgated the Interim Enhanced Surface Water Treatment Rule, which lowers the turbidity requirements. The intent behind this regulation is to improve filter performance so that some degree of *Cryptosporidium* removal is affected in the treatment process train. The removal credits cited in this report do not reflect the fact that these same technologies may be in the "tool box" of the stage 2 long term SWTR or LT2SWTR. Consequently, the Department makes no claims as to the applicability of the technologies or the removal credits cited in this document and applied to the LT2SWTR. The California statutes will be updated to reflect the changes in the federal drinking water quality standards. However, the values in this table reflect current statuatory requirements.

	Permit Provisions				
	A	B	C	D	E
3M Bag and Cartridge Filtration for systems serving less than 500∇	0.2	0.5	0.2	0.5	

∇ The acceptance for the use of this technology has been rescinded as 3M no longer provides the replacement products. Existing systems may continue to operate and use 3M products purchased prior to December 31, 1999 until all cartridges have been used, or until December 31, 2001, whichever occurs first. By December 31, 2001 acceptable replacement equipment must be in use.

C. Guidelines

The Office of Drinking Water (predecessor to the Drinking Water Program within the California Department of Health Services) published the "Surface Water Treatment Staff Guidance Manual" on May 15, 1991. Chapter 2 of the manual includes guidelines for evaluating three alternative technologies, non-conventional coagulation and/or rapid rate filtration processes, physical straining processes, and natural filtration processes.

Non-conventional coagulation and/or rapid rate filtration processes

The guideline states that, for non-conventional coagulation and/or rapid rate filtration processes (e.g., contact clarification systems), "Credit for newly designed facilities without an operating history should be based on the results of pilot plant test, or full scale demonstrations with a 1 log safety factor. For example, if the pilot plant test indicated an average turbidity performance and 4 μm particle removal equivalent to 3 log removal, then the plant should be given 2 log removal credit with a disinfection system designed to provide the additional 1 log reduction."

Physical straining processes

For physical straining processes (e.g., membranes) the guidelines recommend that, "The credit allowed for cyst removal for these types of processes should be dependent on the demonstrated effectiveness in removing particles greater than 4 μm in diameter. For example, if the process reliably (at least 95% of the time) removes 90% of the particles, a 1-log credit can be given." The guidelines further recommend that no credit for virus removal be given unless the manufacturer clearly demonstrates otherwise. Consequently the Department has taken the position of granting, "log removal credit" to membranes based on their performance in pilot studies. Credit is granted based on the performance using the 5^{th} percentile log removal (plotting the log removals from the lowest to the highest) as being a measure of reliable process performance. This means that 95% of the time the process is achieving the credited log removal or better.

Mulitple Barrier

The USEPA SWTR guidance manual (Section 5) states, "*In all cases*, a minimum of 0.5 log reduction of *Giardia* should be achieved by disinfection *in addition* to the removal credit allowed for by other treatment (emphasis added)." This statement follows section 4 in which the following statement appears: "Reverse osmosis is a membrane filtration method which is used for desalination and/or the removal of organic contaminants. The treatment process is effective for the removal of *Giardia* cysts and viruses and no demonstration is necessary." This point is reemphasized in Section 5 in which the RO membrane is given 3 and 4 log *Giardia* and virus removal credit respectively. However, federal SWTR guidance appears to be quite clear on requiring a minimum of 0.5 log reduction of *Giardia* by disinfection, in addition to the log removal credit given the treatment technology, even if full treatment credit is granted to the individual unit process.

Under California's Surface Water Treatment regulations (CSWTR) a water supplier is required to provide "multibarrier treatment" or a series of water treatment processes that provide for removal and inactivation of waterborne pathogens. Just providing a single barrier for a given pathogen is not considered to be acceptable treatment of a surface supply source. The Department has established a policy, which recommends that, at a minimum, an additional 0.5 log giardia or 2 log virus inactivation be supplied following filtration. The more restrictive disinfection requirement based on the disinfectant used is followed. If disinfection by-products are a significant issue, then that must be included in an evaluation of the disinfection practices.

Removal Credit versus Demonstrated Performance

While performance of any unit process is assumed to be at steady state for the purposes of modeling or design, most processes show some degree of variability in output over time. At present, alternative filtration technologies are assigned a log removal credit based on the minimum log removal that can be achieved 95% of the time. Ranking the log removals and plotting them on log-probability graph paper, provides a graphical means of determining the lowest log removal that could be achieved an estimated 95 percent of the time (with the seeding being conducted over an operational cycle of the system, e.g., for membranes this is between chemical cleanings).

It has been noted by the SWTR Committee that the basis for assessing the minimum pathogen removal demonstration (CCR, Title 22, Chapter 17, Section 64653(f)) is not specified in regulation. As noted in the previous paragraph, the finished water from the operation of alternative filtraiton technologies can vary over the operational cycle of the membrane. Therefore, while demonstrated performance may cover a range of log removals, credit is issued based on the degree of performance that can be consistently and reliably achieved. Consequently, it is the opinion of the Committee that an alternative technology may demonstrate pathogen over a wide range, but may be credited with some lower degree of pathogen removal. It is the credit that should be used to establish compliance with the overall removal/inactivation requirements of the CSWTR.

D. Technology Summary Sheets and Discussion of Demonstration Results

Microfiltration

1. **USFilter/Memcor Microfiltration**
   (Richard Sakaji)

Product: Company: Contact:	**USFilter/Memcor Microfiltration** **USFilter/Memcor Products** **USFilter/Memcor Products** Dawn Guendert US Filter/Memcor 1214 Plum Tree Road Carlsbad, CA 92009 (760) 804-5844
Technology:	microfiltration, polypropylene hollow fiber, transverse flow,
Study at:	Metropolitan Water Dist. of So. Calif., San Jose WC
By:	Metropolitan Water Dist. of So. Calif., San Jose WC, AWWARF
Systems using:	MWD of SC, SJWC, several others
Raw Source:	Colorado River Aqueduct, others
	The turbidity typically ranged from 0.5 to 20 NTU.
Removal Credit:	4-log *Cryptosporidium*, 4-log *Giardia*, **0.5-log virus removal**[+].
Performance Std:	A=0.1 NTU, to be met 95% of time
	B = 1.0, C = 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: 110 Lph/m^2 (66.9 gfd) Transmembrane pressure (psi): 15
Operation plan:	establish air integrity test frequency

[+] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must *demonstrate* that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. A 1.5 log removal of virus was demonstrated, on average. However, due to uncertainties in methods and test protocols, a 1 log safety factor was applied to the log virus removal credit giving the technology a 0.5 log virus removal credit. The balance of the removal/inactivation can be achieved by disinfection.

Product: Company: Contact:	**USFilter/Memcor Microfiltration** **USFilter/Memcor Products** **USFilter/Memcor Products** Dawn Guendert US Filter/Memcor 1214 Plum Tree Road Carlsbad, CA 92009 (760) 804-5844
Technology:	microfiltration, polypropylene hollow fiber, transverse flow
Study at:	Carmichael Water District, San Jose Water Co.
By:	San Jose Water Co., Montgomery-Watson for Carmichael Water District
Systems using:	Carmichael Water District, San Jose Water Co.
Raw Source:	American River, SJWC Creek
Removal Credit:	4-log *Cryptosporidium*, 4 log *Giardia*, **0 log virus removal**[+]
Performance Std:	A=0.1 NTU, to be met 95% of time
	B = 1.0, C = 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: 160 Lph/m^2 (93.6 gfd) Max. transmembrane pressure (psi): 17
Operation plan:	establish air integrity test frequency

[+] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. There were no virus seeding studies conducted in conjunction with the testing at the higher flux. In order for this technology to be used in systems serving more than 500 persons, the 90 percent virus removal requirement must be waived and the utility must, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed.

Product: Company: Contact:	**USFilter/Memcor Microfiltration** **USFilter/Memcor Products** **USFilter/Memcor Products** Dawn Guendert US Filter/Memcor 1214 Plum Tree Road Carlsbad, CA 92009 (760) 804-5844
Technology:	microfiltration, polyvinylidene fluoride hollow fiber, transverse flow
Study at:	Cucamonga County Water District's Arthur H. Bridge water treatment plant
By:	Montgomery Watson
Raw Source:	Cucamonga Creek
Removal Credit:	4-log *Cryptosporidium*, 4 log *Giardia*, 0.5 log virus removal
Performance Std:	A=0.1 NTU, to be met 95% of time
	B = 1.0, C = 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: 85 Lph/m^2 (50 gfd) Flow: outside-in; flux based on hollow fiber external surface area Max. transmembrane pressure (psi): 29
Operation plan:	establish air integrity test frequency

Polypropylene Membrane

The initial acceptance of the USFilter/Memcor microfiltration technology was based on limited *Giardia* and MS-2 bacteriophage seeding studies conducted by the Metropolitan Water District of Southern California (MWDSC) for their Desert Pumping Plants (Coffey 1992) using Colorado River water. These studies were conducted using a maximum flux of 110 Lph/m^2 (0.50 gpm/m^2) and introduced a coagulant into the feed stream for the evaluation of organics removal. No coagulant was added during the pathogen seeding studies. In addition to the 3-log *Giardia* removal credit, the transmembrane pressure (TMP) was limited to 15 psig, as the TMP in the studies did not exceed 15 psig.

These studies showed a consistent >4.4-log removal of *Giardia* (n=3). The three virus seeding runs conducted on the pilot plant showed log removals that ranged from 1.65 to 2.87 (average = 2.16). Since the technology of conducting pathogen-spiking studies was still evolving in 1992, there were questions about the variability in the performance of these membranes. In addition there were analytical questions (recovery, accuracy, and precision) that were not sufficiently addressed by the MWDSC study.

In reviewing the MWDSC report (Coffey 1992), it was apparent that virus challenges had been conducted after several days of operation following or preceding a chemical cleaning. Consequently, the study also did not address the issue of variability in membrane performance over time, i.e., during operational cycles. The membrane surfaces could have been fouled prior to the virus challenge in the MWDSC study thereby improving the log removal performance of the membrane system. While these studies show that on average the USFilter/Memcor can achieve greater than 1 log removal of bacteriophage, the results are consistent with USFilter/Memcor MF performance after a period of operation. The most vulnerable period of operation is the time immediately following a chemical cleaning or when a clean membrane is challenged with a very “clean” water (e.g., distilled or deionized). A USFilter/Memcor unit (with clean membranes) tested by Jacangelo *et. al*. (1997) showed less than 0.5 log removal of MS-2 bacteriophage when challenged with deionized water at pH 7 spiked with MS-2. The membrane was challenged 8 times and the results were very reproducibile. So, while the MWDSC study demonstrated greater than 1 log removal of virus (on average), the technology was only credited with 0.5 logs of virus removal for the purpose of calculating the overall degree of removal achieved using microfiltration to meet the SWTR requirements.

Recent studies (Carmichael Water District and San Jose Water Co.) were used to grant an increased flux to this alternative technology (Sakaji 1998). The USFilter/Memcor microfiltration technology has been accepted for use at a flux of 160 Lph/m^2 (0.7 gpm/m^2) and transmembrane pressure of 17 psig. However, at this flux, the technology has been granted a 3-log *Giardia* removal credit and 0-log virus removal credit (no virus removal credit was given because virus removal at this flux was not evaluated) and can only be used on surface waters demonstrated to be free of a virus hazard or in systems serving less than 500 service connections. The increased flux for the USFilter/Memcor microfiltration technology was accepted by the SWTR committee on April 30, 1998 and approved by Executive Staff on July 28, 1998.

Generally the operatonal transmembrane pressure (TMP) is restricted to documented conditions of operation as the impacts of TMP on membrane or membrane system performance are not fully evaluated. TMP is analogous to headloss in conventional filtration. However, the operating theory behind conventional filters differs from that of membrane filtration. Unlike granular media filtration, which relies on collector mechanisms that require particulate and filter media interaction, membrane filters restrict passage of particulates primarily by sieving or size exclusion. It is recognized that the TMP increases as the membranes foul, due to the formation of a fouling layer on the membrane surface. This fouling layer can reduce the effective pore size of the membrane thereby improving particulate removal. However, during a period immediately after backwashing or chemical cleaning the fouling layer on the membrane has been removed and particulates, including some pathogens, can pass through the membranes.

Concerns that increased TMP may lead to premature breakthrough of this membrane by pushing pathogens through the membrane have been raised. Unlike colloids that have some rigidity to their structure, the elastic cell wall or capsule (protein coat) of pathogens allows them to be reshaped so that they can squeeze through holes smaller than their actual physical size. As shown in Figure 1-1 the virus log removal from seeding studies decreases when the TMP exceeds 17 psi (the presently allowed TMP for a flux of 160 Lph/m^2). It is not possible to evaluate fully the impact of the increased TMP on the membrane performance since this is only a single data point and from a review of the report there is no indication of the fouling state of the membrane when this data point was collected. Since operation of the membrane at TMPs up to 17 psi is coupled with particle counting information, this would seem to provide a reasonable indication that membrane performance has not been compromised. Therefore, operation of the unit is restricted to below 17 psi until additional studies are conducted.

Upon reviewing the historical water quality information and uncertainty surrounding the initial acceptance of this technology, the SWTR Committee decided to grant the polypropylene USFilter/Memcor microfiltration technology with a 4-log *Giardia* and 4-log *Cryptosporidium* log removal credit. USFilter/memcor was notified of this action by a letter to Dawn Guendert on October 19, 1999.

Membrane Integrity. As long as the membrane remains intact, the performance of the membrane as a physical barrier to pathogens is not in question. However, any breach in the integrity of the membrane can allow the passage of pathogens through the membrane as holes or broken membranes may allow particulates to follow the path of least resistance. Therefore, the system operator must detail a monitoring program that will ensure the integrity of the membranes and membrane unit.

Filter Backwash. The backwash from the USFilter/Memcor microfiltration process can be returned to the headworks of the filtration plant for recycling. The backwash recycle flow should not exceed 10% of the total flow into the treatment plant. All other backwash recycle criteria apply (see *Cryptosporidium* Action Plan, Appendix K of the California SWTR Guidance Manual, Ten States Standards (1997), and Partnership for Safe Water Documents for additional guidance).

Membrane Cleaner (chemical). The chemical cleaner used to remove foulants from the membrane surface can be recycled and reused, if the manufacturers instructions are followed. The rinse water from the chemical cleaning procedure should be disposed of, but not recycled.

NSF has certified the Memclean chemical cleaning agent under their standard 61 (Johnson 1998). However, the NSF certification is based on the manufacturer’s claims, that were subsequently confirmed by the testing required for NSF standard 61 listing.

There have been questions raised regarding the adequacy of the rinsing operation. Under the NSF certification procedure pH was used to indicate when the cleaning agent had been flushed from the system so it could be returned to service. However, there was no correlation established between the concentration of surfactant and the pH. As the alkalinity or buffering capacity of the rinse water can impact the pH readings, residual surfactant and cleaning chemicals can continue to bleed out of the filtration system even after the manufacturer's recommended "return to service" pH levels had been reached.

At present, the presence of foaming or surface active agents, as measured by Methylene Blue Active Substances (MBAS), is covered by a secondary standard (aesthetic). However, the MBAS test only covers cationic surfactants. Since the memclean solution is a nonionic surfactant, the MBAS test is not appropriate to use for determining surfactant residuals in the rinse water. There are no simple field tests for anionic or nonionic surfactants at present although other types of analytical methods are available, such as *Standard Method* 5540 for nonionic surfactants.

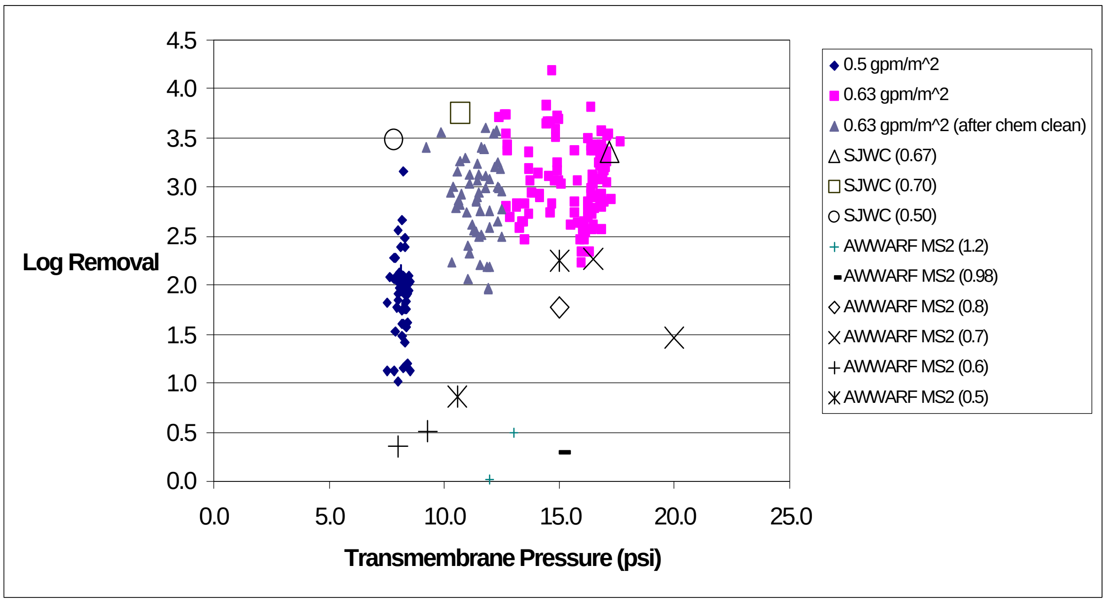


Figure 1-1. Transmembrane Pressure and Log Removal for Particle and MS-2 seeding studies (polypropylene membrane). Flux rates in parentheses are given in mixed english and metric units of gpm/m^2, as reported in Jacangelo *et al*. (1997).

PVdF Membrane

Specific information on the Polyvinylidene Fluoride (PVdF) membrane tested can be found with a summary of the testing results in the report "Final Report California Department of Health Services Certification Testing For US Filter PVdF Membrane" (Montgomery

Watson 2001). The summary contained herein provides a short review of the testing results‡.

This chlorine tolerant membrane is available in both pressure-driven and submerged (vacuum-driven) configurations. The commercial designation for the pressure-driven configuration is M10V and the commercial designation for the submerged configuration is S10V. The nominal pore size of the membranes is 0.1 μm with an absolute pore size of 0.2 μm. Testing of the pressure-driven PVdF membrane system manufactured by US Filter was conducted in July, and October thru December of 2000 at the A.H. Bridge Plant in Rancho Cucamonga, California. The source of supply for this study was the Cucamonga Creek whose typical water quality characteristics are summarized in Table 1-1. The source and product water quality characteristics during the course of the study are summarized in Table 1-2. The membrane system was operated at a flux rate that did not exceed 50 gfd, based on the external surface area of the membrane.

Table 1-1. Typical Cucamonga Creek Water Quality (1982 to 1993).

Parameter	Unit	Average	Minimum	Maximum
Turbidity	NTU	1.8	0.1	11.6
Temperature	°C	12	8	18
pH	Units	8.3	7.9	8.7
Total Alkalinity	mg/L	148	139	162
Total Hardness	mg/L as Ca CO_3	149	130	164
TOC	mg/L	<0.5	<0.5	<0.5
Total coliform	MPN/100 mL	580	50	1600

‡ The U.S.Filter/Memcor technology was accepted earlier as an alternative filtration technology (October 24, 2000) based on preliminary work (Montgomery Watson 2000) submitted to the Department. Since the preliminary report did not contain the results or data indicating virus seeding challenges had been conducted, the original acceptance of the PVdF technology was restricted to applications serving less than 500 persons or to populations served of greater than 500 if the watershed was found to be free of a virus hazard.

Table 1-2. USFilter PVdF Membrane System Summary of Water Quality Data During CDHS Testing

			Feed Water			**Permeate**	
Parameter	Unit	Count	Median	Range	Count	Median	Range
Temperature	Deg C	13	14	7. 7-16	3	17	15.9-17
Turbidity	NTU	13	0.30	0.19-0.74	12	0.031	0.026-0.034
TSS	mg/L	8	<10	<10-<10	8	<10	<10-<10
TOC	mg/L	8	0.9	0. 8-1.1	8	0.8	0. 8-1.3
pH		7	8.2	7.8-8.2	7	8.2	8.0-8.3
HPC	cfu/mL	6	300	7-500	8	<1	<1-5
Total Coliform	MPN/100 mL	7	50.0	26-2800	8	<1.1	<1.1-<1. 1
Fecal Coliform	MPN/100 mL	7	13.0	<2-80	8	<1.1	<1.1-<1. 1

Based on the performance of this membrane as outlined in the Montgomery-Watson report, this membrane was granted a 4-log *Giardia* and 4-log *Cryptosporidium* removal credit. The technology was also granted a 0.5 log virus removal credit. The flux (gfd, based on the external surface area of the membrane) and TMP (psi) for this technology is restricted to below 50 gfd and 29 psi, respectively.

Membrane Cleaning. Chlorine (sodium hypochlorite) was added to the feed water at a dose of approximately 0.3 – 0.5 mg/L to control fouling. Chlorine was not added to the feed water during virus seedings. No chemicals were used during backwash, beyond any chlorine that might be present in the feed water. Citric acid (8 lb) and chorine solutions (200 – 400 mg/L) were used to clean the membrane.

Membrane Integrity. The use of a pressure hold test was demonstrated to be effective at detecting one broken fiber in 43,000. However, the pressure hold test requires all or a portion of the membrane modules to be taken off-line. Turbidity or particle counters are often used to monitor the performance of the membrane systems on-line and in “real” time. In this case, the report (Montgomery Watson 2001) states that the demonstration of particle counters to ensure membrane integrity was not conclusive due to the low source water particle concentrations.

References

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Johnson, P.

Memclean study results, USFilter/Memcor letter, June 11, 1998.

Montgomery Watson

“Preliminary Report California Department of Health Services Certification Testing For US Filter PVdF Membrane” Montgomery Watson, Pasadena, CA, August 2000.

Montgomery Watson

“Final Report California Department of Health Services Certification Testing For US Filter PVdF Membrane” Montgomery Watson, Pasadena, CA, January 2001.

Sakaji, R.

“Amend Flux and Transmembrane Pressure Criteria for Memcor Microfiltration Alternative Technology,” California Department of Health Services Memo, dated May 8, 1998.

Sakaji, R.

Letter to Dawn Guendert, October 19, 1999.

2. Pall Microza

(Richard Sakaji)

Product: Company: Contact:	**Microza (Pall XUSV 5203 Membrane)** Pall Corp. JBI Bob Zaiser 17 Muirfield Trabuco Canyon, CA 92679 (949) 766-2600 FAX: (949) 766-2609
Technology:	Microfiltration
Study at:	Aqua 2000 Research Center
By:	Montgomery-Watson
Systems using:	
Raw Source:	Colorado River
Removal Credit:	4-log *Cryptosporidium*; 4-log *Giardia*; 0.5-log Virus
Performance Std:	A= 0.1, B= 1.0, C= 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: ≤88 Lph/m^2 (51.7 gfd) Flow: outside-in; flux based on hollow fiber external surface area Max. transmembrane pressure (psi): 36
Operation plan:	Require one particle monitor per 638 ft^2 of membrane (o.d.) surface area Remove the module from service and conduct air pressure hold test after backwashing.
Study:	Aqua 2000 Research Center

Specific information on the membrane tested can be found with a summary of the testing results in the report "Final Report California Department of Health Services Certification Testing for Pall Microza Microfiltration Membranes" (Montgomery Watson and the City of San Diego 1999). The summary contained herein provides a short review of the testing results.

Table 2-1 is a summary of the raw source water quality conditions during the study. The water for this study comes from the San Diego Aqueduct and is supplied from Lake Skinner. Typically the water in the lake is a 70/30 blend of Colorado River and State Project waters. This source water was used during the same period of time for the Hydranautics and Zenon testing summarized in later sections of this report.

Table 2-1. Raw Source Water Quality

Parameter	Median	Range	Method
pH	8.2	7.9-8.3	4500H
Temperature, °C	15.5	9.7-22.0	2550B
Turbidity, desktop, NTU	1.92	1.12-4.80	2130B
Turbidity, on-line, NTU	1.70	1.29-4.66	
TSS, mg/L	<10	<10-16	2540D
TOC, mg/L	2.32	2.17-2.50	5310C
Total coliform, MPN/100 mL	<20	<2-50	9221B
Fecal coliform, MPN/100 mL	2	<2-<20	9221B
HPC, cfu/mL	190	180-800	9215B

Table 2-2 summarizes the permeate water quality characteristics for parameters other than the pathogens.

Table 2-2. Microza Permeate Water Quality

Parameter	Median	Range	Method
pH	8.2	7.9-8.3	4500H
Temperature, °C	16.4	13.5-21.0	2550B
Turbidity, desktop, NTU	0.042	0.035-0.087	2130B
Turbidity, on-line, NTU	0.026	0.023-0.058	
TSS, mg/L	<10	<10-<10	2540D
TOC, mg/L	2.23	2.10-2.48	5310C
Total coliform, MPN/100 mL	<2	<2-<2	9221B
Fecal coliform, MPN/100 mL	<2	<2-<2	9221B
HPC, cfu/mL	<1	<1-<1	9215B

Based on the particle counting results from the Montgomery Watson/City of San Diego report (1999) the log removals of *Cryptosporidium* and *Giardia* size particles are about 3 log or better 95 percent of the time. Normally this would result in a 3-log removal credit for *Cryptosporidium* and *Giardia* being given to the technology. However, as part of the testing direct challenges using *Cryptosporidium* oocysts and *Giardia* cysts were conducted. The results from these challenge studies showed consistently greater than 6 logs of removal for both *Cryptosporidium* oocysts and *Giardia* cysts. However, the SWTR Committee has agreed that the credit granted any membrane technology would not exceed 4-log. Therefore, the final credit extended the system is 4 log *Cryptosporidium* and 4 log *Giardia* removal.

Based on the MS2 challenges reported in the Montgomery Watson/City of San Diego report (1999), the Pall Microza membrane was credited with 0.5 log virus removal.

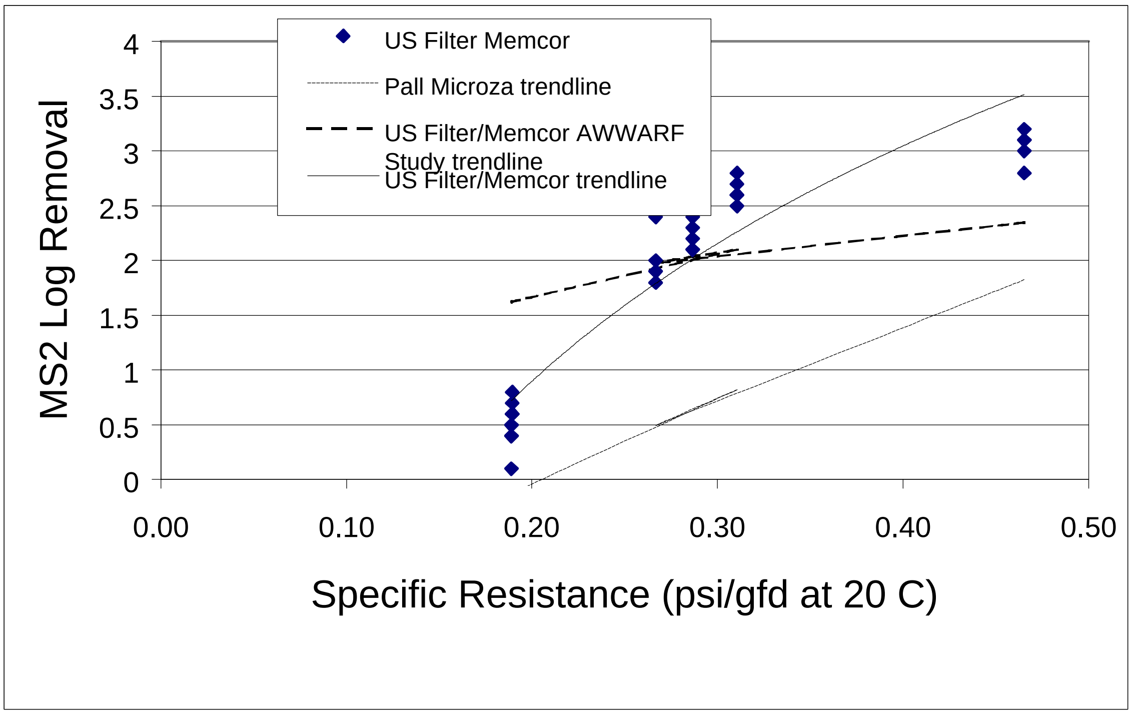

Figure 2-1. Comparison of Specific Resistance to MS-2 Log Removal for Pall Microza and US Filter/Memcor MF Technology.

Membrane Integrity. Based on the integrity testing conducted in San Diego, one particle counter per 1.6 modules (≈7600 fibers each 0.7×1.3mm [id × od]) should be sufficient to detect a single fiber break while operating. This calculation does not account for a partial tear, but does not preclude the use of nondestructive “off-line” testing (e.g., diffusive air flow test) could be used for these situations.

The number of particle counters needed to detect one broken fiber is rated on the basis of active membrane surface area so that the number of particle counters can be properly apportioned to systems with greater or lower surface area in a given module (element). This will allow more flexibility in membrane module design. Of course, this assumes that the dimensions of the hollow fiber do not change appreciably. A manufacturer wanting to place additional membranes in the module to increase surface area may do so, but must maintain the ratio of particle counters to membrane surface area to provide assurance that the membrane fibers are intact. Alternatively, a new more sensitive technology may come along to replace the current generation of particle counters. When such technology becomes available it can be demonstrated as an alternative to the current generation of particle counters.

References

Coffey, B.M.

“Conceptual Design Report for Desert Pumping Plant Domestic Water Systems,” Metropolitan Water District of Southern California, Water Quality Division, September **1992**.

Jacangelo, J.G.; Adham, S.; Laine, J.-M.

“Membrane Filtration for Microbial Removal,” American Water Works Association Research Foundation, Denver, CO **1997**.

Montgomery Watson and the City of San Diego

“Final Report California Department of Health Services Certification Testing for Pall Microza Microfiltration Membranes,” Montgomery Watson, Pasadena, CA **1999**.

Ultrafiltration

3. Aquasource Ultrafiltration
(Richard Sakaji)

Product: Company: Contact:	**Advent Membrane System** Aquasource North America, LLC Michael A. Dimitriou 2924 Emerywood Pkwy PO Box 70295 Richmond, VA 23255-0295 (804) 672-8160
Technology:	ultrafiltration, cellulosic esters hollow fiber, crossflow, membrane manufactured by Lyonnaise Des Eaux
Study at:	East Bay MUD, Contra Costa WD
By:	AWWARF, East Bay MUD, Contra Costa WD, Montgomery-Watson
Systems using:	Pardee Recreational Area (East Bay MUD)
Raw Source used in testing:	Mokuelumne R. and Delta
Removal Credit:	4-log *Cryptosporidium* 4-log *Giardia*, 4-log virus removal
Performance Std:	A = 0.1 NTU, to be met 95% of time
	B = 1.0, C = 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: 136 Lph/m^2 (80 gfd) flux. Flow: inside-out; flux based on hollow fiber internal surface area 29 psi maximum transmembrane pressure Backwash when transmembrane pressure reaches 22 psi in recirculation filtration mode and 18 psi when operating in dead-end filtration mode Backwash once every three hours Clean membranes using manufacturers instructions once every six months. Operate in deadend mode for raw water turbidities up to 1 NTU, in recirculation mode without a bleed to waste for raw water turbidities up to 5 NTU, and in recirculation mode with a bleed to waste when raw water turbidities exceed 5 NTU.

On the basis of the James M. Montgomery report (1991) the SWTR committee granted the then Infilco-Degremont Advent UF membrane a 3-log *Giardia* and 4-log virus removal credit. The study reported particle removals (geometric mean) for *Giardia* size particles (7-14 μm) on the order of 3.1 log (81 particles/mL in the Mokelumne source water to 0.06 particles/mL in the permeate) and 3.6 log (194 particles/mL in the Delta source water to <0.04 particles/mL in the permeate). Slightly better log removals on the same source waters were reported for particles in the *Cryptosporidium* size range (4-7 µm). The geometric mean log removal was 3.4 for Mokelumne water (249 particles/mL in source water and 0.10 particles/mL in the permeate) and 3.9 (512 particles/mL in the source water and 0.06 particles/mL in the permeate) for Delta water. Other source water quality parameters for this study are summarized in Table 3-1.

Since this report was issued, additional studies using this membrane have been conducted in California and elsewhere (Jancangelo et al. 1997) confirming the results from earlier studies. The log removal credits granted the technology have not changed. However, based on demonstrated virus removal (greater than 95 percent of the time), the committee felt that additional *Giardia* and *Cryptosporidium* log removal could be granted to the technology without additional study. Because of the high degree of MS-2 removal, the membranes should provide a barrier to the passage of larger organisms, such as *Giardia* or *Cryptosporidium* that are several orders of magnitude larger in diameter. Hence the membrane is now credited with 4-log *Giardia* and 4-log *Cryptosporidium* removal at the higher flux rate.

Table 3-1. Source Water Quality (Mean values with ranges reported in parentheses).

Parameter	Mokelumne Water	Delta Water
pH	9.0 (6.8-9.5)	8.1 (7.5-9.1)
Alkalinity, mg/L as $CaCO_3$	23 (21-24)	71 (43-103)
Hardness, mg/L as $CaCO_3$	22 (20-24)	106 (52-150)
Turbidity, NTU	0.49 (0.1-2.5)	9.0 (1.9-47)
Total Organic Carbon, mg/L	1.7 (1.3-2.6)	3.6 (2.4-8.9)
Temperature, °C	17 (10-27)	17 (9-27)
Particle Density >1 µm, # $\times 10^3$/mL	5.4 (0.3-20)	111 (24-332)
Total Coliform, MPN/100mL	<2.8 (<2.2-170)	86 (2.2-1600)
HPC Bacteria, CFU/mL	141 (1-8600)	1289 (25-7500)

Table 3-2. Lyonnaise des Eaux-Dumez (Aquasource) Ultrafiltration Specifications

	1991 (James M. Montgomery *et al*. 1991)	1997 (Jancangelo *et al*. 1997)
Configuration	Hollow fiber	Hollow fiber
Material	Cellulosic derivative	Cellulosic ester
Molecular Weight Cutoff (Daltons)	100,000	100,000
Maximum Temperature (°C)	30	35
pH Range	4-8.5	4-8.5
Maximum transmembrane pressure (psi)	29	5-29
Specific Flux (L/h/m^2/bar)	271-345	100 (20°C)
Surface Area (m^2)		Bench-scale: 0.07 (20 membranes) Pilot-scale: 7.1 (2060 membranes)

Table 3-3. Virus and Giardia Seeding Study Results (James M. Montgomery et al., 1991).

Pathogen	Delta Log Removal	Mokelumne Log Removal
Virus (MS-2)	7.2 (21)[+]	7.0 (12)
Total Coliforms	7.4 (4)	7.1 (3)
Giardia	5.1 (3)	4.7 (7)

[+] number of batch tests in parentheses.

The study results from Jancangelo et al. (1997) provide additional information on the effectiveness of the Aquasource membranes on specific pathogens. Table 3-2 summarizes the manufacturer's specifications published in 1991 and 1997. With only three exceptions, the slightly higher maximum operating temperature, lower specific flux, and the composition of the membrane, the specifications for the membrane have not changed. The results from the 1997 report provide additional validation of the Aquasource membrane technology. As with any membrane based technology, as long as the membranes remain intact, the Aquasource membrane provides a strong physical barrier that prevents the passage of pathogens.

We do not have log removal cumulative probability distributions from the Jacangelo *et. al*. study, but the pathogen seeding challenges conducted in the 1997 study were conducted with freshly cleaned (chemical) or new membrane modules. Since previous studies have led us to believe that a clean membrane surface is one of the times when the membrane barrier can be compromised, the log removals reported in Table 3-4 should be fairly indicative of membrane performance during its most vulnerable period of operation. Therefore, it would be reasonable to assume that the log removal performances listed in Table 3-4 should easily occur at least 95 percent of the time. However, due to uncertainties with the experimental protocols and apparent absence of controls, the previous credit granted the process was not changed.

With the exception of the *Giardia* removal results, the seeding studies conducted in 1997 were very similar to those achieved in 1991. The higher log removals reported in the 1997 report are probably due to improvements in the techniques used to spike or seed the pathogens into the source water. This work was conducted on several source waters, all of which were outside California except the San Jose Water Company Lake Elsman supply (water quality data reported in Table 3-5).

This study also examined the effect of pH on virus removal and found none. Virus removals during filter runs conducted at a pH or 5 and 9 showed no significant difference in performance over runs conducted at ambient pH.

Change in Flux Rate. Based on work conducted in San Diego at the Aqua 2000 facility, the Aquasource Advent membrane can be used at a higher flux rate (136 Lph/m^2 [80 gfd]) (Montgomery Watson, City of San Diego 2000) than listed in the original membrane acceptance report (113 Lph/m^2). The results of this testing showed no degradation in membrane performance at the higher fluxes (the water quality summary for the source and product water during testing are summarized in Table 3-6). Seeding studies using *Giardia*, *Cryptosporidium*, and MS-2 bacteriophage showed >4, >6.6, and >6 log removal of these microbes. Although particle count data appears to indicate lower removal of particles in the *Giardia* (5-15 µm) and *Cryptosporidium* (2-5 µm) size ranges 2.4 and 2.8 log removal or better (95 percent of the time), it was the opinion of the SWTR Committee that this data reflected the limitations of the analytical technique and did not reflect the performance of the membrane system. Due to the low concentration of particles in the source water, it was not possible to attain higher log removals or particles in these size ranges. The MS-2 seeding studies also indicated greater than 6 log removal of the virus during periods in which 2.4 logs of *Giardia* size particles were removed. Since the MS-2 bacteriophage is several orders of magnitude smaller than either *Giardia* or *Cryptosporidium* (on the order of 0.025 µm), it seemed counterintuitive to expect such low log removal of *Giardia* and *Cryptosporidium* size particles while concomitantly achieving such high log removal of the much smaller MS-2. Based on these observations the SWTR committee agreed to accept the use of the Aquasource Advent membranes at a higher flux rate of 136 Lph/m^2 with a maximum transmembrane pressure of 21 psi.

Membrane Cleaning. Since the original testing under which the Department accepted the use of the Aquasource membrane, the issue of membrane cleanliness following chemical cleaning has arisen. While several membrane manufacturers use chemicals to clean their membranes, most rely on simple water quality parameters, such as pH, to determine whether the chemical cleaners have been thoroughly flushed from the system. Since surfactants may interact with the membrane matrix differently than those compounds that determine the pH of the solution, it is possible that pH alone would not be adequate to determine when the system was free of cleaning chemicals. Work done by Montgomery Watson and the City of San Diego shows that a simple water quality parameter, such as chlorine residual or pH would not be sufficient to determine whether or not surfactant continued to "bleed" off the membrane after chemical cleaning. Their work shows that free chlorine residual is easy to measure, but is flushed out of the system at a quicker rate than the surfactant. In the two modules examined, the surfactant was rinsed out of the system at a noticeably slower rate. Since the components of pH would behave more like the free chlorine residual, one should not depend on pH or free chlorine residual to determine when a system should be returned to service. Since no specific surfactant data was provided, it appears as though 2.5 to 5 specific volumes[§] are required to obtain nondetectable concentrations of surfactant in permeate. The operations plan should incorporate this information to determine optimal membrane cleaning procedures.

Membrane Integrity. Prior acceptance of the Aquasource membrane did not include results from any membrane integrity testing. Results from membrane integrity testing (Montgomery Watson, City of San Diego 2000) show that the pressure hold test is very good at detecting one cut fiber out of 4100 fibers. The report also estimated that, under certain water quality and operating conditions, a particle counter for every 20 modules would be sufficient to detect the presence of one broken fiber.

[§] The specific volume is the volume of water used to flush the cleaning chemical normalized to the membrane surface area employed in the pilot study. The volume of water used to flush the pilot unit after chemical cleaning is measured and divided by the total membrane surface area installed on the pilot (which can include more than one module). Thus, the specific volume accounts for the total number of membrane modules in the system.

Table 3-4. Aquasource Pathogen Seeding Study Results (Jacangelo et al. 1997)

Pathogen	n	Log Removal	
Heterotrophic Plate Count	12	140 to 2.1 /mL	Pilot
MS-2	4	>6.9	Bench, pH 7.9, turbidity 3 NTU , new module
Giardia	3	>7.0	Pilot
Cryptosporidium	3	>6.7	Pilot

Table 3-5. Lake Elsman Water Quality Summary (Jacangelo et al. 1997)

-	Average	Range
Turbidity	3.4	0.3-100
pH	7.9	7.1-10
Temperature (°C)	13	7-23
Alkalinity (mg/L as $CaCO_3$)	140	84-194
Hardness (mg/L as $CaCO_3$)	160	92-234
TOC (mg/L)	2.6	1.5-6.8
UV254	0.06	0.03-0.25
Color	5	2-25
HPC	1885	270-12,000
Total Coliforms (MPN/100mL)	13	1-460

Table 3-6. Summary of Water Quality Data During DHS Testing of the Aquasource Membrane System (Montgomery Watson, City of San Diego 2000)

			Feed Water			**Permeate**	
Parameter	Unit	Count	Median	Range	Count	Median	Range
pH		68	8.3	7.9-8.5	65	8.3	7.7-8.5
Temperature	deg ºC	136	17	7.0-24	65	17	7.0-25
Desktop	ntu	136	1.3	1.0-2.2	32	0.047	0.042-0.058

Turbidity							
Online Turbidity	ntu	136	1.3	1.0-2.1	32	0.029	0.028-0.039
TSS	mg/L	7	9.1	1.8-15	6	<1	<1-<1
TOC	mg/L	5	3.5	2.6-4.1	5	2.5	2.2-3.6
Total Coliform	MPN/100 mL	8	8	<2-80	7	<2	<2-<2
Fecal Coliform	MPN/100 mL	8	3	<2-20	7	<2	<2-<2
HPC	cfu/mL	8	115	2-290	8	2	<1-83

References

James M. Montgomery Consulting Engineers, Inc., Lyonnaise Des Eaux-Dumez

“Pilot Investigation of Membrane Technology for Particulate Removal in Drinking Water Treatment,” James M. Montgomery Consulting Engineers, Inc., Pasadena, CA, February **1991**.

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“Low Pressure Membrane Filtration for Particle Removal,” AWWA Research Foundation, Denver, CO, **1992**.

Jacangelo, J.G.; Adham, S.; Laine, J-M.

“Membrane Filtration for Microbial Removal,” Report No. 90715, American Water Works Association Research Foundation, Denver, CO February 1997.

Montgomery Watson; City of San Diego

“ California Department of Health Services Certification Testing for Aquasource Ultrafiltration Membrane,” Montgomery Watson, Pasadena, CA, September 2000.

4. Hydranautics Hydracap

(Richard Sakaji)

Product: Company: Contact:	**HYDRAcap™** Hydranautics John Wammes 401 Jones Rd. Oceanside, CA 92054 (760) 901-2565
Technology:	Ultrafiltration
Study at:	Aqua 2000 Research Center
By:	Montgomery-Watson
Raw Source:	Colorado River
Removal Credit:	4-log *Cryptosporidium*; 4-log *Giardia*; 4-log Virus
Performance Std:	A= 0.1, B= 1.0, C= 1.0, D = n/a, E = n/a
Operation criteria:	Max. flux: 119 Lph/m^2 (69.3 gfd) Flow: inside-out; flux based on hollow fiber internal surface area Maximum transmembrane pressure (psi): 18
Operation plan:	Need one particle sensor for every 4320 ft^2 of membrane surface area. Need to establish frequency of membrane integrity checks.
Study:	Aqua 2000 Research Center

Specific information on the membrane tested can be found with a summary of the testing results in the report "Final Report California Department of Health Services Certification Testing for Hydranautics (HYDRAcap™) Ultrafiltration Membranes" (Montgomery Watson and the City of San Diego 1999). The summary contained herein provides a short review of the testing results and provides the SWTR Committee's reasoning behind the log pathogen removal credit.

This membrane was tested in a single membrane module configuration, i.e., a single bunch of hollow fiber membranes per pressure vessel. Hydranautics has a pressure vessel that can accommodate a series of hollow fiber bundles in much the same way an RO unit is setup. Acceptance of the HYDRAcap™ membrane does not extend to the high-pressure vessel containing a series of UF bundles.

Table 4-1 is a summary of the raw source water quality conditions during the study. The water for this study comes from the San Diego Aqueduct and is supplied from Lake Skinner. Typically the water in the lake is a 70/30 blend of Colorado River and State Project waters. This source water was used during the same period of time for the Pall and Zenon testing summarized in other sections of this report.

The cumulative probability distribution for the virus seeding studies shows that 95 percent of the time this membrane module is able to affect a 4.5 log virus removal. However, the SWTR Committee has agreed that the credit granted any membrane technology will not exceed 4-log. Therefore, the final credit extended the system is 4 log virus removal.

The cumulative probability distribution diagram for log reduction of *Giardia*-size particles shows that this technology could remove 3 logs or better 95 percent of the time. It was the opinion of the SWTR committee that the removal of particles in this size range was limited by the concentration of particles in the source water, i.e., the concentration of particles was not sufficient to demonstrate greater than 3-log removal. Based on the virus seeding results the committee felt that since pathogens at least two orders of magnitude smaller than *Giardia* or *Cryptosporidium* could not pass through the membrane, the larger pathogens also would not pass. Therefore, the Hydranautics HYDRAcap™ membrane was credited with 4-log *Cryptosporidium* and 4-log *Giardia* removal credit.

Table 4-1. Raw Source Water Quality

Parameter	Median	Range	Method
pH	8.2	7.9-8.3	4500H
Temperature, °C	15.5	9.7-22.0	2550B
Turbidity, Desktop, NTU	1.92	1.12-4.80	2130B
Turbidity, On-line, NTU	1.70	1.29-4.66	
TSS, mg/L	<10	<10-16	2540D
TOC, mg/L	2.32	2.17-2.50	5310C
Total coliform, MPN/100 mL	<20	<2-50	9221B
Fecal Coliform, MPN/100 mL	2	<2-<20	9221B
HPC, cfu/mL	190	180-800	9215B

Table 4-2. HYDRACAP™ Permeate Water Quality

Parameter	Median	Range	Method
PH	8.2	8.0-8.4	4500H
Temperature, °C	16.0	13.5-22.0	2550B
Turbidity, Desktop, NTU	0.043	0.037-0.084	2130B
Turbidity, On-line, NTU	0.022	0.022-0.033	
TSS, mg/L	<10	<10-<10	2540D
TOC, mg/L	2.35	2.26-3.97	5310C
Total coliform, MPN/100 mL	<2	<2-<2	9221B
Fecal Coliform, MPN/100 mL	<2	<2-<2	9221B
HPC, cfu/mL	<1	<1-1	9215B

Membrane Integrity. Based on the membrane integrity testing conducted at Aqua 2000, 16 modules containing a total of 160,000 fibers (each module contains about 10,000 fibers 0.8 × 1.3 mm id × od) can be connected to a single particle counter and still detect a single broken membrane. This is an estimate based on the model developed by Montgomery-Watson as cited in their report (1999).

5. Koch PMPW Membrane

(Richard Sakaji)

Product: Company: Contact:	**PMPW membrane** **Koch** Eveyln Scibelli 850 Main Street Wilmington, MA 01887 (978) 694-7195 Brian M. Kilcullen Same address as above (978) 694-7144
Technology:	Ultrafiltration Polysulfone membrane
Study at:	Aqua 2000 Research Center
By:	Montgomery-Watson
Systems using:	
Raw Source:	Colorado River
Removal Credit:	4-log *Cryptosporidium*; 4-log *Giardia*; 4-log Virus
Performance Std:	A= 0.1, B= 1.0, C= 1.0, D = n/a, E = n/a
Operation criteria:	Max. Flux: 173 Lph/m^2 (102 gfd) Flow: inside-out; flux based on internal surface area Max. transmembrane pressure (psi): 35
Study:	Aqua 2000 Research Center

Specific information on the membrane tested can be found with a summary of the testing results in the report "Final Report California Department of Health Services Certification Testing for Koch Ultrafiltration Membrane" (Montgomery Watson and the City of San Diego 1999). The summary contained herein provides a short review of the testing results.

Table 5-1 contains a summary of the raw source water quality conditions during the study. The water for this study comes from the San Diego Aqueduct and is supplied from Lake Skinner. Typically the water in the lake is a 70/30 blend of Colorado River and State Project waters. This source water was used during the same period of time for the Hydranautics and Pall testing summarized in previous sections of this report.

Table 5-1. Summary of Water Quality Data During DHS Testing KOCH Membrane System.

			Feed Water			Permeate	
Parameter	Unit	Count	Median	Range	Count	Median	Range
pH		77	8.3	8.0-8.4	64	8.3	8.0-8.4
Temperature	deg C	112	27.4	20.3-40.7	68	29.2	20.5-40.6
Desktop	Turbidity ntu	119	1.1	0.4-3.8	60	0.04	0.04-0.11
Online	Turbidity ntu	110	1.2	0.5-3.8	30	0.03	0.03-0.10
TSS	mg/L	5	7.8	1-27.2	7	<1	<1-1.4
TOC	mg/L	7	3.13	2.61-5.94	7	2.98	2.55-4.38
Total	Coliform MPN/100 mL	7	2	<2-23	7	<2	<2-<2
Fecal	Coliform MPN/100 mL	7	<2	<2-<2	7	<2	<2-<2
HPC	cfu/mL	7	140	44-240	7	2	<1–30

The cumulative probability distribution of the virus seeding results shows that 95 percent of the time the Koch membrane system was capable of achieving at least 5 log virus removal. However, the SWTR Committee has agreed that the credit granted any membrane technology will not exceed 4-log. Therefore, the final credit extended the system is 4 log virus removal.

The cumulative probability distribution for the turbidity data shows that 95 percent of the time the turbidity from the system should be capable of producing less than 0.035 NTU. The SWTR committee believes that consistent turbidities above 0.10 NTU are probably an indication of catastrophic membrane failure and loss of membrane system integrity. Based on the Department's experiences, it is possible to encounter situations in which smaller size particles (submicron) comprise the majority of turbidity. In this case the turbidity performance standard may be increased without reducing the effectiveness of the protozoan pathogen barrier.

The nominal MWCO for the Koch PMPW membrane is reported to be 100 kD the absolute cutoff is not reported. With this membrane there are measurable concentrations of MS-2 in the permeate, but 95% of the time the membranes can affect about a 5.5 log removal of the virus. Note that the Hydranautics HYDRACAP® membrane with a reported nominal 150 kD MWCO corresponding to a reported 0.015 µm nominal pore size only achieved a 4.5 log virus removal 95% of the time. According to the nominal MWCO data the Koch membrane should outperform the Hydranautics membrane and it does.

Some of the disparity in virus removal results, may be based on membrane structural characteristics, however, some of the variation in results may be traced to the tests used to characterize membrane pore structure. None of these tests, either MWCO or pore size is standardized with respect to the compounds used, testing conditions, etc. However, the variability may also reflect the integrity of the membrane modules as the module is challenged by the virus seeding, not just the membrane. This may be used as an indication that we do not want to rely solely on absolute MWCO or pore size information on which to base membrane removal credit.

Membrane Integrity. Results from pressure hold tests indicate that one fiber in 6500 can be detected. Based on water quality characteristics and operational considerations one sensor per 12 modules should be sufficient to detect a broken fiber.

Membrane Cleaning. According to the Montgomery Watson, City of San Diego report (2000), a solution of 2% citric acid followed by a 0.05% caustic containing 200 mg/L of free chlorine is used to clean the membranes. Following the procedures outlined by the manufacturer the free chlorine residual and pH are back to normal when the membranes are returned to production. The free chlorine and pH measurements on the permeate all appear to be normal when the unit is returned to operation.

Montgomery Watson and the City of San Diego

"Final Report California Department of Health Services Certification Testing for Koch Ultrafiltration Membrane," Montgomery Watson, Pasadena, CA **2000**.

6. Zenon Zeeweed (500 series and 1000)
(Richard Sakaji)

Product: Company: Contact:	**ZeeWeed® 500a and 500c (OCP membrane)** **ZeeWeed 1000 (E 1000 membrane)** Zenon Environmental, Inc. Paul Johnson 24912 Via Lopez Ct. Ramona, CA 92065 (760) 788-9744
Technology:	Ultrafiltration
Study at:	Aqua 2000 Research Center
By:	Montgomery-Watson
Raw Source:	Colorado River (OCP Membrane), Otay Lake (E 1000)
Removal Credit:	OCP Membrane: 4-log *Cryptosporidium*; 4-log *Giardia*; 2-log Virus E 1000 Membrane: 4-log *Cryptosporidium*; 4-log *Giardia*; 3.5-log Virus
Performance Std:	A= 0.1, B= 1.0, C= 1.0, D = n/a, E = n/a
Operation criteria (E 1000 Membrane):	Flux: 51 Lph/m^2 (30 gfd) Flow: outside-in; flux based on hollow fiber external surface area Transmembrane Pressure (psi): 10
Operation criteria (OCP Membrane):	Flux: 85 Lph/m^2 (49.8 gfd) Flow: outside-in; flux based on hollow fiber external surface area Permeate vacuum (in Hg): 9-24
Operation plan:	For the OC membrane: need a particle sensor for every 27,780 ft^2 of external membrane surface area. Need to establish frequency of membrane integrity checks.
Study:	Aqua 2000 Research Center

Zenon ZeeWeed® 500 series.

Specific information on the OCP membrane tested can be found with a summary of the testing results in the report "Final Report California Department of Health Services Certification Testing for Zenon (ZeeWeed®) Membrane" (Montgomery Watson and the City of San Diego 1999). The summary contained herein provides a short review of the testing results.

Table 6-1 is a summary of the raw source water quality conditions during the study. The water for this study comes from the San Diego Aqueduct and is supplied from Lake Skinner. Typically the water in the lake is a 70/30 blend of Colorado River and State Project waters. This source water was used during the same period of time for the Hydranautics and Pall testing summarized in previous sections of this report.

Table 6-1. Raw Source Water Quality

Parameter	Median	Range	Method
pH	8.2	7.9-8.3	4500H
Temperature, °C	15.5	9.7-22.0	2550B
Turbidity, desktop, NTU	1.92	1.12-4.80	2130B
Turbidity, on-line, NTU	1.70	1.29-4.66	
TSS, mg/L	<10	<10-16	2540D
TOC, mg/L	2.32	2.17-2.50	5310C
Total coliform, MPN/100 mL	<20	<2-50	9221B
Fecal coliform, MPN/100 mL	2	<2-<20	9221B
HPC, cfu/mL	190	180-800	9215B

The cumulative probability distribution of the virus seeding results shows that 95 percent of the time the Zenon Zeeweed process was capable of achieving at least 2.5 log virus removal. It was the opinion of the SWTR committee that the removal demonstration of particles in the 2-5 μm size range was limited by the particle concentration in the source water, i.e., the concentration of particles was not high enough to be capable of demonstrating more than 3-log removal of *Giardia* size particles. However, the committee recognized that particles two orders of magnitude smaller (MS-2 bacteriophage) were being being used to challenge the membranes and some degreee of removal was being affected by the membranes. This physical demonstration of particle removal capability along with the membrane pore size distribution data submitted to the committee by the manufacturer persuaded the committee to increase the log removal of *Giardia* size particles to 4 logs.

The cumulative probability distribution for the turbidity data shows that 95 percent of the time the turbidity from the system should be capable of producing less than 0.1 NTU. The SWTR committee believes that consistent turbidities above 0.1 NTU are probably an indication of catastrophic membrane failure and loss of membrane system integrity. Based on the Department's experiences, it is possible to encounter situations in which smaller size particles (submicron) comprise the majority of turbidity. In this case the turbidity performance standard may be increased without reducing the effectiveness of the protozoan pathogen barrier.

The nominal MWCO for the Zenon Zeeweed membrane is reported to be 100 kD with an absolute cutoff of 120 kD. The reported nominal pore size for the membrane is 0.035 μm with a reported absolute pore size of 0.1 μm. With this membrane there are measurable concentrations of MS-2 in the permeate, but 95% of the time the membranes can affect a 2.5 log removal of the virus. Compare this to the 4.5 log virus removal 95% of the time performance of the Hydranautics HYDRACAP® membrane with a reported nominal 150 kD MWCO corresponding to a reported 0.015 μm nominal pore size. According to the nominal MWCO data the Zenon membrane should outperform the Hydranautics membrane, but the performance is reversed.

Some of the disparity in virus removal results, based on membrane structural characteristics may be traced to the tests used to characterize membrane pore structure. None of these tests, either MWCO or pore size is standardized with respect to the compounds used, testing conditions, etc. However, the variability may also reflect the integrity of the membrane modules as the module is challenged by the virus seeding, not just the membrane. This may be used as an indication that we do not want to rely solely on absolute MWCO or pore size information on which to base membrane removal credit.

Membrane Integrity. By the Montogomery Watson calculations, 60 modules containing 282,000 fibers (0.75 ×1.95 mm) could be connected to a single particle counter and single broken fiber could be detected.

500a versus 500c. On March 15, 2001 Zenon (Thompson 2001) submitted a letter regarding a modification to their Zenon ZeeWeed® 500 technology, which had previously received acceptance as an alternative filtration technology to meet the requirements of the Surface Water Treatment Rule. According to their letter, this change resulted in a 20% increase in the surface area packed into the module, but that there had been no other changes to their manufacturing process with respect to the membranes or modules. The only modification to the technology appears to be in the manner in which the membranes are potted. Consequently, they requested that their ZeeWeed® 500 acceptance as an alternative filtration technology be extended to the new module now designated the ZeeWeed® 500c, with the “old” module being designated as the ZeeWeed® 500a.

On May 9, 2001 the Department’s Surface Water Treatment Rule (SWTR) Committee in reviewing their submittals agreed to not require additional testing of the ZeeWeed® 500a system. Based on the information submitted, the committee felt that it was reasonable for us to accept the use of the Zenon ZeeWeed® 500a system, as it was the committee’s understanding that the physical characteristics and properties of the membranes used in the 500a and 500c systems are identical.

Therefore, based on the data submitted, the SWTR Committee granted the Zenon ZeeWeed® 500a conditional acceptance for meeting the requirements of the SWTR in California. The terms and conditions of the acceptance of the Zenon ZeeWeed® 500a will be same as those for the Zenon ZeeWeed® 500c (the original technology). A letter was sent to Zenon informing them of the committee's decision. The letter also reminded them that should they make any changes in the physical attributes or character of the membrane or system, the Department was to be immediately notified so that we can determine whether the modification will require additional testing in an expeditious method.

Table 6-2. ZeeWeed® 500c Permeate Water Quality

Parameter	Median	Range	Method
pH	8.3	7.9-8.4	4500H
Temperature, °C	16.0	10.2-22.0	2550B
Turbidity, desktop, NTU	0.051	0.036-0.138	2130B
Turbidity, on-line, NTU	0.030	0.024-0.146	
TSS, mg/L	<10	<10-<10	2540D
TOC, mg/L	2.36	2.14-2.43	5310C
Total coliform, MPN/100 mL	<2	<2-<2	9221B
Fecal coliform, MPN/100 mL	<2	<2-<2	9221B
HPC, cfu/mL	<1	<1-2	9215B

Montgomery Watson and the City of San Diego

"Final Report California Department of Health Services Certification Testing for Zenon (ZeeWeed®) Membrane," Montgomery Watson, Pasadena, CA **1999**.

Thompson, Doug

"Advisement of modification to the configuration of the ZeeWeed® 500 membrane module," Letter to the Department of Health Services, March 15, 2001.

Zenon ZeeWeed® 1000

Specific information on the OCP membrane tested can be found with a summary of the testing results in the report "Draft Final Report California Department of Health Services Certification Testing For Zenon ZeeWeed 1000 Membrane" (Montgomery Watson and the City of San Diego 2001). The summary contained herein provides a short review of the testing results.

Table 6-3 is a summary of the raw source water quality conditions during the study. The water for this study comes from Lake Otay. Some of the permeate water quality values are summarized in Table 6-4.

The cumulative probability distribution of the virus seeding results shows that 95 percent of the time the Zenon Zeeweed 1000 process was capable of achieving at least 3.5 log virus removal. It was the opinion of the SWTR committee that the removal demonstration of particles in the 2-5 μm size range was limited by the particle concentration in the source water, i.e., the concentration of particles was not high enough to be capable of demonstrating more than about 3-log removal of *Giardia* size particles. However, the committee recognized that particles two orders of magnitude smaller (MS-2 bacteriophage) were being being used to challenge the membranes and these membranes were relatively efficient at removing the MS-2. Therefore, the committee was willing to assign a 4-log *Cryptosporidium* and 4-log *Giardia* removal credit to the membrane.

Table 6-3. Lake Otay Source Water Quality during Testing

				Feed Water		**Permeate**	
Parameter	Unit	Count	Median	Range	Count	Median	Range
Temperature	deg C	12	13.4	12.5-13.6			
Turbidity	NTU	11	2.0	1.69-2.59	10	0.07	0.05-0.09
TSS	mg/L	5	<10	<10-<10	5	<10	<10-<10
TOC	mg/L	5	6.5	5.2-6.7	5	5.5	4.9-6.0
pH		5	8.0	8.0-8.3	5	8.0	7.9-8.0
HPC	cfu/mL	7	126	46-800	7	<1	<1-350
Total Coliform	MPN/100 mL	7	23	8-50	7	<2	<2-<2
Fecal Coliform	MPN/100 mL	9	5	<2-17	7	<2	<2-<2

Table 6-4. ZeeWeed® 1000 Permeate Water Quality

Parameter	MCL	Raw Water	Filtrate
Turbidity	0.5	2.0, 1.7-2.6	0.07, 0.05-0.09
Total Coliforms	5%	23, 8-50	<2, <2-<2
Fecal Coliforms	0%	5, <2-17	<2, <2-<2
Lab pH	6.5-8.5	7.4	7.5
Total Hardness as $CaCO_3$ by ICP		177	177
Sodium, Total, ICAP		73	65
Calcium, Total, ICAP		38	38
Potassium, Total, ICAP		4.3	3.8
Magnesium, Total, ICAP		20	20

Membrane Integrity. The results of cutting a fiber, illustrated the pressure decay test could detect a single broken fiber in 90,000. However, based on their model a particle counter would have to be installed on every three modules to detect a single broken fiber. This makes the use of particle counters for monitoring membrane integrity at the level of one compromised fiber, impractical.

Montgomery Watson and The City of San Diego

"Draft Final Report California Department of Health Services Certification Testing For Zenon ZeeWeed 1000 Membrane," San Diego, CA April 2001.

Nanofiltration

7. DESAL DK-5 Thin Film Nanofiltration Membrane
(Bob Hultquist and modified by Rick Sakaji)

	Systems using **"Desal DK-5"** membrane, i.e., any well designed and constructed treatment system using this membrane
Product: Company: Contact: Product: Company: Contact: Product: Company: Company: Contact: Company: Contact	Mem-Clear Tri-Valley Water Services 5989 McCauley Rd. Valley Springs, CA 95252 Bing Stanley, (209) 772-0446 Mem-Brain™ Waste Water Management Int'l. Bert Baker, (209) 277-1475 H Series ATP Manufacturing (California Sales) 479 Mason St., Suite 221D Vacaville, CA 95687 Mark Clausen, (707) 447-5076 or ATP Manufacturing Unit 1 attn: Ernie Mee or Bud Haney 2595 McGillivray Blvd Winnipeg, Manitoba CN R3Y1J5 (204) 888-2292 Eagle Environmental Technologies Ltd. PO Box 999 Angels Camp, CA 95222 Brian Wilmot (209) 736-4530 Clear Water Resources PO Box 2221 Sparks, NV 89432-2221 Jerry Wilmot (775) 560-8002
Technology:	Nanofiltration, spiral wound sheet
Study at:	Solano Irrigation District
By:	Summers Engineering
Systems using:	Marconi Conference Center, Tracy Pumping Plant, various Thousand Trail Campgrounds
Raw Source (Study):	Putah South Canal. The source water turbidity typically ranged from 8 to 15 NTU. Two filter runs were spiked to 150+.
Removal Credit:	3-log *Giardia*, 2-log virus removal for all sources, *Cryptosporidium* oocyst challenge demonstrated >5-log removal
Performance Std:	A = 0.1 NTU, to be met 95% of time
:	B = 1.0, C = 1.0, D = n/a, E = n/a

Acceptance given in November 9, 1995 SWTR committee minutes.

American Water Technologies Inc. (now Tri-Valley Water Services) and Waste Water Management International Inc., using a filtration system provided by Waterite Inc. (now ATP Manufacturing Ltd.) that incorporates a DESAL DK-5 membrane element completed a demonstration. The filtration technology tested consisted of a Desalination Systems Inc. DESAL DK-5 thin film nanofiltration element as part of a complete filtration system.

The demonstration was conducted on the Putah South Canal source of Solano Irrigation District. The source water turbidity usually ranged from 8 to 15 NTU during the study. The turbidity was artificially increased to 150+ NTU using native sediment for two short runs. The demonstration was made using particle counts, turbidity, and a virus challenge. The test protocol and performance of the filtration system is documented in a report from American Water Technologies and Waste Water Management International dated February 7, 1994. The demonstration study was intended to evaluate the suitability of the technology for point of entry treatment. This report only deals with the filtration technology acceptance issue.

The filtration system successfully demonstrated the ability to reliably achieve a 99.9% (3-log) *Giardia* cyst removal and 99% (2-log) virus removal. A Cryptosporidium oocyst challenge demonstrated a >99.999% removal. The filtration system was able to comply with a 0.5 NTU turbidity performance standard in at least 95% of all measurements made over the length of a filter run. The effluent turbidity was reliably below 0.2 NTU when measured by grab sample. Continuous turbidimeter measurements often ranged up to 0.5 NTU, presumably due to air bubbles. The effluent turbidity did not appear to vary with raw water turbidity or operational conditions.

The DESAL DK-5 membrane element successfully demonstrated that it could achieve the required organism removals while reliably producing an effluent with a turbidity of 0.2 NTU. It is not known whether a DESAL DK-5 membrane filtration system would meet the same organism removal efficiencies while producing a higher turbidity effluent.

The filtration system must be designed and operated in conformance with the Desalination Systems, Inc. recommendations for the DESAL-5 membrane except those regarding formaldehyde (see below).

The design of a filtration system using the DESAL DK-5 must include an element containment vessel that will provide a tight seal with the DESAL element over the expected range of operating pressures. A Payne Mfg. Co. vessel was used in the demonstrated device and is satisfactory. The system design must provide instrumentation and control features to regulate the recirculation rate and fast flush cycles. Sample taps must be provided for raw water and permeate monitoring. There must be provision in the design for verifying that the membrane element in the system is a DESAL-5. The system must be designed to minimize the potential cross-connections between raw and finished water.

An operations plan for this filtration technology should address how loss of membrane integrity will be identified when raw water turbidities are low. An alarm triggered by a high particle index is acceptable. The plan must also address the frequency and method of element cleaning. The trigger for element replacement must be identified. To prevent degradation of the membrane, and resulting loss of organism removal efficiency, the operation must observe the recommended operating pH range of 4-11, the cleaning pH range of 2-11.5, and the chlorine tolerance of 2000 ppm-hours. Manufacturers recommendations regarding other oxidants must be observed.

Several documents from the DESAL Engineers Catalog: Product Specifications, DESAL-5; Bulletin E-15, Cleaning and Sanitizing; and Bulletin E-22, Cleaners/Sanitizes were attached to the original acceptance memo and should be used by field engineers reviewing proposals to use this technology. The manufactures Bulletin E-15 recommends flushing the membrane with a formaldehyde solution to control biological growths when reduced permeate flow or increased differential pressure indicates a problem. **<u>Formaldehyde or solutions containing formaldehyde should not be used</u>**. Bulletin E-15 suggests 0.1% sodium bisulfite as an option and the permit should specify use of this chemical for cleaning.

Attempts by the Department to resolve operational questions regarding the adequacy of the manufacturers chemical cleaning and flushing procedures remain unresolved at this time. The Department has not received a written study protocol or evidence to verify that the flushing procedures recommended by the manufacturer are adequate to prevent the cleaning chemicals from entering the potable water supply. The Department has also requested information on NSF 61 certification of the cleaning chemicals with no response to date. Since the presence of surface-active agents (e.g., MBAS) is handled through a secondary standard (an aesthetic standard), the lack of this information does not preclude the use of this technology to meet the SWTR requirements, at this time.

This DESAL DK-5 membrane is an acceptable filtration technology for use on any approved surface source when used as the core of a complete and well designed, constructed, and operated filtration system.

American Water Technolgoies, Inc. On September 28, 1999 the Department received a letter from Tri-Valley Water Services. The letter indicates that Paul Chapman no longer has an interest in American Water Technologies, Inc. or any ownership of AWT Mem-Clear Products. According to a letter from the Chavez-Ochoa Law Offices Tri-Valley Water Services purchased American Water Technologies on or about July 4, 1998. Therefore, all references to American Water Technologies have been removed from this report and replaced with Tri-Valley Water Services.

Contact Clarification

8. Contact Clarification/Filtration
(Bob Hultquist)

Product: Company: Contact:	**Trident** Microfloc Mike Brunell, (916) 939-0728
Product: Company: Contact:	**Pacer II** Roberts Filter Co. Lee Roberts (610) 583-3131
Product: Company: Contact:	**Advent Package Water Treatment System** Infilco Degremont Inc. Rick Jaccarino, (804) 756-7600
Technology:	contact clarification/filtration
Study at:	numerous in U.S.
By:	
Systems using:	numerous
Removal Credit:	2-log *Giardia*, 1-log virus removal for all sources where direct filtration would be a suitable technology; 2.5-log *Giardia*, 2-log virus removal for some sources/operational criteria
Performance Std:	A = 0.5 NTU for 2/1-log removal, A = 0.2 NTU for 2.5/2-log removal, to be met 95% of the time B = 5.0, C = 1.0, D = 2.0, E = 1.0
Operation criteria:	Same as for conventional or direct filtration technology.
Design criteria:	Same as for conventional or direct filtration technology.
Operation plan:	Same as for conventional or direct filtration technology.

9. Multitech

Product: Company: Contact:	**Multitech** Culligan USA (USFilter) Dr. Frank Brigano, (708) 205-5964
Technology:	contact clarification/filtration
Study at:	Freestone, others in U.S.
By:	
Systems using:	Freestone, June Lake
Removal Credit:	2-log *Giardia*, 1-log virus removal for all sources where direct filtration would be a suitable technology
Performance Std:	A= 0.5 NTU, to be met 95% of time
	B = 5.0, C = 1.0, D = 2.0, E = 1.0
Operation criteria:	Same as for direct filtration technology.
Design criteria:	Same as for direct filtration technology.
Operation plan:	Same as for direct filtration technology.
Study:	

There are several companies marketing a filtration technology that consists of a coarse media bed, providing some flocculation and solids removal, followed by a filter. This filtration technology is not among the recognized technologies identified in the Surface Water Filtration and Disinfection regulations. The technology does not qualify as direct filtration because it does not provide flocculation comparable to that defined by accepted industry design criteria (AWWA/ASCE Water Treatment Plant Design, Ten States Recommended Standards for Water Works, and water treatment process design text books). The filtration technology must, therefore, be authorized for use by a public water system according to the process established in SWF&DR Section 64653(f), (g), (h), and (i).

The DHS Drinking Water Program (DWP) has adopted the term contact clarification - filtration to identify this technology. A contact clarifier is a bed of granular fine to medium gravel sized media. The bed is preceded by coagulant addition and high energy mixing. Flocculation and solids retention occurs within the bed. The bed is periodically washed to waste by maintaining hydraulic flow or backwashing while applying a vigorous air scour. The wash should be triggered by excessive head loss, effluent turbidity, or length of run. The filter accompanying the contact clarifier should conform with accepted industry filter design criteria.

Contact clarification/filtration systems having demonstrated effective filtration through studies may be accepted without further study on all waters where the median total coliform MPN is less than 500 per 100 mL and the turbidity is less than 15 NTU (where direct filtration is appropriate according to the USEPA and California surface water treatment guidance manuals). Additional pilot plant studies should not be necessary except to ascertain the ability to deal with source specific water quality problems and identify the best coagulant and optimum dose.

A substantial number of particle count and organism challenge studies have been completed with treatment systems designed in conformance with this technology. The studies demonstrate that the technology, as executed by the specific systems involved in the studies, meets the removal efficiency and effluent turbidity requirements of Section 64653(f). These systems can, therefore, be readily accepted for use on a variety of sources. Other companies with similar systems must provide evidence of compliance with Section 64653(f).

The only systems known to qualify for acceptance at this time are the Microfloc Trident, Roberts Pacer II, Infilco Degremont Advent Package Water Treatment System, and Culligan Multi-Tech. These systems should be granted credit for 2-log *Giardia* cysts and 1-log virus removal when operated in compliance with a performance standard of 0.5 NTU in the effluent 95% of the time; in conformance with the performance, monitoring, design, reliability, and operational requirements appropriate to direct filtration; and the plant operations plan. As with any alternative filtration technology the performance standards, performance standard monitoring schedule, requirements for Department notification in the case of performance standard violation, and operating criteria must be stated in permit provisions.

Higher Removal Credit. The filtration technology as implemented by Microfloc, Roberts, and Infilco Degremont has successfully demonstrated organism and/or particle removal performance equivalent to that achieved by conventional treatment on waters with turbidities as shown in the Table 8-1 for various combinations of temperature and alkalinity. For these conditions you may allow a credit of 2.5-log *Giardia* cyst removal and 2.0-log virus removal when operated in compliance with a performance standard of 0.2 NTU in the effluent 95% of the time. The other requirements are as stated for the previous situation except that the appropriate turbidity limit after the filter has been in operation for four hours is 0.2 NTU.

Table 9-1. Successfully Treated Raw Water Turbidities

Temp. (°F)	Alkalinity as $CaCO_3$ (mg/L)								
	70	80	90	100	110	120	130	140	170
30				10-20					
40									
50	1								
60			2-20			1-40		20-130	1
70			2	30-70	30-70				
80		20-30	20-30						

Pressure Filters

10. EPD Alternative Filtration Technology
(Bob Hultquist)

Product: Company: Contact:	**EPD Alternative Filtration Technology** Environmental Products Division (EPD) of Hoffinger Industries, Rancho Cucamonga,California Michael Stockton, (800) 266-4740
Technology:	in-line, high-rate, dual-stage pressure filters using 12 inches of Garnet media in each stage (d_{10} = 0.27 mm [UC = 1.7] and d_{10} = 0.18 mm [UC = 1.61]), cationic polymer coagulant.
Study at:	Yucaipa Valley Water District, 1993
By:	EPD, Dr. Hendricks, Co. St. Univ. for organism challenges
Systems using:	Yucaipa Valley Water District, Miners Oaks CWD, Banning Heights Mutual, Havasu WC
Raw Source:	The source water alkalinity ranges from 64 to 190 mg/L as $CaCO_3$ and the temperature from 9 to 15 °C. The turbidity typically ranged from 0.4 to 6 NTU. One filter run was spiked to 21 NTU
Removal Credit:	2-log *Giardia*, 1-log virus removal Two *Cryptosporidium* oocyst challenges demonstrate oocyst removal efficiencies comparable to *Giardia* cyst removal.
Performance Std:	A = 0.2 NTU, to be met 95% of time
	B = 5.0, C = 1.0, D = 2.0, E = 1.0
Operation criteria:	treat up to 6 NTU at 12 gpm/ft^2 treat up to 20 NTU at 5 gpm/ft^2
Design criteria:	filter-to-waste required
Operation plan:	identify best coagulant for source backwash at 14 psi headloss

The filtration technology tested consisted of in-line, high rate, dual stage, pressure filters using 12 inches of Garnet media in each stage (d_{10} = 0.27 mm [UC = 1.7] and d_{10} = 0.18 mm [UC = 1.61]), and a General Chemical CLARION A410P cationic polymer coagulant. The coagulant feed and filter-to-waste valves were automatically controlled by raw and filtered water continuously reading turbidimeters.

The demonstration was conducted on the Oak Glen source of Yucaipa Valley Water District, Yucaipa, California (Hendricks 1993; Bowman *et. al.* 1993). The source water alkalinity ranges from 164 to 190 mg/L as $CaCO_3$ and the temperature from 9 to 15 °C. The turbidity typically ranged from 0.4 to 6 NTU. One filter run was spiked to 21 NTU. The demonstration was made using *Giardia* lamblia cyst, Cryptosporidium parvum oocyst, and MS-2 coliphage virus challenges, and particle counts.

The filtration system successfully demonstrated the ability to reliably achieve a 99% (2-log) *Giardia* cyst removal and 90% (1-log) virus removal. Two Cryptosporidium oocyst challenges demonstrate oocyst removal efficiencies comparable to *Giardia* cyst removal. The filtration system was also able to produce an effluent with less than 0.5 NTU in at least 95% of all measurements made over the length of a filter run. This demonstration was performed with hydraulic loading rates up to 12 gpm/sq ft. Increasing the rate to this level did not noticeably degrade performance with this raw water at a turbidity of 6 NTU. There is data to show that turbidities of 20 NTU can be adequately treated at 5 gpm/sq ft. The filters did meet the required filtration efficiencies in two filter runs without the addition of a coagulant, but the data is insufficient to authorize coagulant free operation. It was shown that the use of a coagulant significantly enhanced particle removal efficiency. The use of a cationic polymer either pre-first stage or pre-second stage was shown to be effective. Backwash was usually initiated at a head loss of 14 psi. Filter to waste was utilized to meet the turbidity requirements after backwash.

The EPD technology successfully demonstrated that it could achieve the required organism removals while reliably producing an effluent with a turbidity of 0.2 NTU. It is not known whether the EPD filtration system would meet the same organism removal efficiencies while producing a higher turbidity effluent.

The EPD filtration system is an acceptable filtration technology for the Oak Glen source at Yucaipa Valley Water District and other sources with similar water quality and treatability characteristics. Coagulant chemical and dose should be optimized for each application. Hydraulic loading rates up to 12 gpm/sq ft may be acceptable when it is demonstrated that the turbidity performance standard will be met. The direct filtration performance, design, reliability, and operation (with the exception of loading rate) requirements of the Surface Water Filtration and Disinfection regulation are appropriate to this technology.

References

Hendricks, D.; Boutros, S.; Sobsey, M.

"Particle Removal Performance of the EPD Hi-Rate Filtration System" August **1993**.

Bowman, G.

"EPD Drinking Water Filtration Plant, an Alternative Filtration Technology Demonstration Study" August **1993**.

11. Sverdrup/Serck Baker Hi-Rate Pressure Filtration
(modified by Kurt Souza)

Product: Company: Contact:	**Sverdrup/Serck Baker Hi-Rate Pressure Filtration** Serck Baker Inc. Houston, Texas Tim Trapani, (713) 586-8400
Technology:	in-line, high rate pressure filters using: 18" top layer of 0.85 mm Anthracite (UC 1.7), 18" middle layer of 0.35 mm garnet (UC 1.32), 13" support layer of 1.45 mm garnet (UC 1.23), air scour.
Study at:	Casitas Municipal Water District, 1995
By:	Sverdrup Civil Inc., Dr. Gerba, U. of Arizona
Systems using:	Casitas Municipal Water District
Raw Source:	The source water alkalinity ranges from 130 to 160 mg/L as $CaCO_3$ and the temperature from 14 to 18°C. The turbidity typically ranged from 0.8 to 3.0 NTU. One filter run was spiked to 8.6 NTU.
Removal Credit:	2-log *Cryptosporidium*; 2-log *Giardia*; 1-log virus removal
Performance Std:	A = 0.2 NTU, to be met 95% of time
	B = 1.0, C = 0.5, D = 1.0, E = 0.5
Operation criteria:	treat up to 9 NTU at 12 gpm/ft^2
Design criteria:	filter-to-waste required
Operation plan:	prechlorination identify best coagulant for source backwash at 15 psi headloss
Required at Casitas:	ferric sulfate and polymer required for 1-log virus removal all filters must be in service if the rate through any filter exceeds 6 gpm/ft^2 NTU (95% of time) and 2-log removal in 5-15 µm particle size performance goals streaming current detector to control coagulant dose full treatment (coagulation, flocculation, sedimentation, and filtration) of all recycled backwash water Recycled backwash returns to the head of the plant

***Cryptosporidium* Removal**. In 1995 the Department's SWTR Committee accepted the use of the Serck Baker Filtration System, the initial pilot study and a portion of full-scale data were reevaluated in 1999 (Souza) to determine the log removal capability on *Cryptosporidium* oocyst. The pilot study included log removal calculations and data for particle size range of 2-4 microns. Included were four test runs including 12 gpm/ft^2, varying flow rates from 3 to 12 gpm/ft^2, high turbidity challenge and recycled flow included in the filter influent. All the pilot test runs show greater than 2 log removal of *Cryptosporidium* sized particles 95% of the time.

Furthermore, the Casitas MWD has provided the District office with one day per week of particle counting monitoring of the influent of combined filtered effluent of their 100 cfs facility. Four random days were evaluated from February 1997 through July 1999. The data clearly provides evidence that the full-scale treatment facility achieves 2 log removal of Cryptosporidium sized particles 95% of the time.

The result of the evaluation was the Serck Baker Filtration System successfully demonstrated the ability to reliably achieve 99% (2-log) Cryptosporidium oocyst removal.

References

Souza, Kurt

“Serck Baker Filtration System – *Cryptosporidium* removal credit,” memo to the SWTR committee, August 12, 1999.

Bag and Cartridge Systems

12. USFilter Model ELB-921
(Bob Hultquist)

The acceptance for the use of this technology has been rescinded. 3M no longer provides the Model 523A product (Mitchell 1998). Existing systems may continue to operate and use the Model 523A product purchased prior to December 31, 1999 until all cartridges have been used, or until December 31, 2001, whichever occurs first. By December 31, 2001 acceptable replacement equipment must be in use.

Product: Company: Contact:	**Model ELB-921** USFilter Municipal Division David Ball 600 Arrasmith Terrace Ames, IA 50010 (515) 232-4121
Technology:	a prefilter (Memtec 1 μm poly cartridge filter - Filterite "1U30U"), followed by a primary *Giardia* barrier (<u>3M Model 523 bag filter</u>♦ with USFilter Permaseal), integrated into package plant, granular media prefilter is necessary when source water turbidities exceed 1 NTU.
Study at:	Fern Valley Water District
By:	
Systems using:	Fern Valley
Raw Source:	Low turbidity (< one NTU), protected (minimal virus hazard) The source water alkalinity ranges from13 to 25 mg/L as $CaCO_3$ and the temperature from 8 to 11°C. The turbidity typically ranged from 0.054 to 0.634 NTU. No spiked filter run.
Removal Credit:	2.0-log *Giardia*, 0-log virus removal♣
Performance Std:	A = 0.2 NTU, to be met 95% of time
	B = 1.0, C = 0.5, D = 1.0, E = na
Operation criteria:	
Design criteria:	pressure relief to protect bags from an excessive pressure surge and possible bag rupture
Operation plan:	
Study:	

♦ The Department has been informed that 3M does not intend to continue providing the Model 523 product beyond December 31, 1999. This acceptance will be rescinded at that time, although existing systems may continue to operate until all cartridges have been used, or until December 31, 2001, whichever occurs first.

♣ Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. The 90 percent virus removal requirement can be waived, at the request of the supplier, under Section 64653 (g) if the supplier can, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed.

USFilter, using their Model ELB-921 at Fern Valley Water District, has completed a demonstration of filtration effectiveness. The filtration technology tested consisted of a prefilter (Memtec 1 µm poly cartridge filter - Filterite "1U30U"), followed by a primary *Giardia* barrier (3M Model 523 bag filter with USFilter Permaseal). The ELB 921 is a skid mounted unit containing the necessary piping, valves, cartridge and bag vessels, hydraulic instrumentation and controls, pumps, and turbidity sampling taps to constitute a complete filtration process.

The demonstration was conducted on a well protected low turbidity surface source at Fern Valley Water District, Idyllwild, California using a full size ELB-921. The source water turbidity ranged from 0.05 to 0.63 NTU during the study. The virus removal requirement was waived for this source per SWF&DR Section 64653(g). The demonstration was made using particle count and turbidity data. Performance of the filtration system is documented in a report entitled: Report on the Performance of the Model ELB-921 *Giardia* Removal Filtration System at Fern Valley Water District by Fern Valley Water District and USFilter. The technology had previously been accepted for use in Washington State on the basis of *Giardia* challenges (median 4.1 log removal).

The filtration system successfully demonstrated the ability to reliably achieve a 99% (2-log) *Giardia* cyst removal. This organism removal was achieved while an effluent turbidity of 0.2 NTU or less was observed in at least 95% of all measurements. It is not known whether the ELB-921 filtration system would meet the same organism removal efficiencies while producing a higher turbidity effluent.

The design of an ELB-921 must include pressure relief to protect bags from an excessive pressure surge and possible bag rupture.

An operations plan for this filtration technology should address how loss of bag or seal integrity will be identified. An alarm triggered by a drop in headloss or high particle index is acceptable (both headloss and particle monitoring should be continuous). The plan must make it clear that the rinse of vessels at bag or cartridge change is done with treated water. The plan must identify the maximum flow through each cartridge and bag (not to exceed 50 gpm for the bag), and the maximum headloss across each cartridge and bag (not to exceed 30 psi for the bag). The plan must specify the triggers for cartridge and bag replacement and the replacement procedures. The plan shall identify the minimum supply of replacement cartridges and bags that will be maintained on site and justify this number in light of the anticipated rate of use and availability. A record must be kept of cartridge and bag purchases to be used to verify that they are not being reused.

A multi-media roughing filter is available for the ELB-921. This unit was not tested at Fern Valley because the source turbidities were consistently low. The ELB-921 could be used on sources with turbidities in excess of one NTU if prefiltration were provided and operated to meet a one NTU performance standard. An existing non-complying filter plant may serve this purpose. The pre-filter cannot be expected to provide virus removal and this option is restricted to sources with limited virus contamination.

This USFilter ELB-921 filtration system is an acceptable filtration technology for protected sources where the virus removal requirement can be waived and the turbidity is less than one NTU.

13. Rosedale Bag Filtration System

(Bob Hultquist; modified by Paul Gilbert-Snyder, Kurt Souza and Grant Manning)

Product: Company: Contact:	**Rosedale Bag Filtration System** Rosedale Products of California John Bush, (209) 683-6854
Technology:	two-stage bag system: prefilter (GD-PO-523-2), followed by a primary *Giardia* barrier (GLR-PO-82502), integrated into package plant, granular media prefilter as necessary
Study at:	Cactus CalTrans rest stop
By:	
Systems using:	
Raw Source:	Colorado R. Raw water up to 2 NTU (this technology can be used on source water with higher turbidities, but the source must be pretreated to 2 NTU)
Removal Credit:	1.0-log *Cryptosporidium*; 2.0-log *Giardia*; 0-log virus removal[+]
Performance Std:	A = 0.2 NTU, to be met 95% of time, not to exceed 0.5 NTU
	B = 1.0, C = 0.5, D = 1.0, E = na
Operation criteria:	head loss not to exceed 10 psi up to 10 gpm per bag with prefilter less than 3 gpm without prefilter
Design criteria:	pressure relief to protect bags from an excessive pressure surge and possible bag rupture filter to waste (FTW) after installation of new bag
Operation plan:	gradually increase flow FTW for a minimum of 5 minutes after installation of new bag.
Study:	

[+] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. The 90 percent virus removal requirement can be waived, at the request of the supplier, under Section 64653 (g) if the supplier can, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed.

The filtration technology tested consisted of a prefilter (a GD-PO-523-2 nine layer polypropylene bag, supported by a stainless steel basked, in a 8-30-2F-2SP-150-N-S-N-FG-S-B-DP bag housing) followed by a primary *Giardia* barrier (a GLR-PO-82502-20+ layer polypropylene bag rigid outer shell supported by a stainless steel basket, in a 8-30-2F-2SP-150-N-S-NFG-S-GB-Dp bag housing). The Rosedale Bag Filtration System contains the necessary piping, valve, bag vessels, hydraulic instrumentation and controls, and turbidity sampling taps to constitute a complete filtration process.

The demonstration was conducted on a low turbidity surface source at Cal-Trans Cactus Reststop, California using a full size Rosedale Bag Filtration System. The source water turbidity ranged from 0.40 to 2.5 NTU during the study. The virus removal requirement was waived for this source per SWF&DR Section 64653 (g). The demonstration was made using particle count and turbidity data. Performance of the filtration system is documented in a report entitled : Cal-Trans Cactus City Filtration Demonstration Study Results.

The filtration system successfully demonstrated the ability to reliably achieve 99% (2-log) *Giardia* cyst removal. This organism removal was achieved while an effluent turbidity of 0.2 NTU or less was observed in at least 95% of all measurements. It is not known whether the Rosedale Filtration System would meet the same organism removal efficiency while producing a higher turbidity effluent. Virus removal efficiency was not included in this study. The particle count data indicate a 90% (1-log) Cryptosporidium oocyst removal capability.

The prefilter was not used during all test runs and is not required for the organism removal credit. The prefilter is required only for high hydraulic loading rates (see subsequent discussion) and is desirable to extend the life of the *Giardia* barrier.

The appropriate permit provisions that addresses notification, Section 64663 (a & b), for this alternative technology, might read: "The supplier shall notify the Department within 24 hours by telephone whenever the turbidity of the combined filter effluent exceeds 1.0 NTU at any time."

To prevent possible bag rupture the installation of the Rosedale Bag Filtration System must include pressure relief to protect the *Giardia* barrier from a pressure surge that would cause a pressure differential across the bag in excess of 30 psi.

An operations plan for this filtration technology should address how loss of bag or seal integrity will be defined. An alarm triggered by a drop in headloss is acceptable (headloss monitoring should be continuous). The plan must make it clear that the rinse of vessels at bag change is done with treated water. The plan must identify the maximum flow through each *Giardia* barrier (not to exceed 3 gpm without a prefilter, 10 gpm with a prefilter bag) and the maximum operating headloss across each bag not to exceed 20 psi for the prefilter and 10 psi for the *Giardia* barrier. The plan shall identify the minimum supply of replacement bags that will be maintained on site and justify this number in light of the anticipated rate of use and availability. A record must be kept of bag purchases to be used to verify that they are not being reused. The system must filter to waste for five minutes upon startup of each new bag.

The Rosedale Bag Filtration System is effective for raw water turbidities up to two NTU. The Rosedale Bag Filtration System could be used on sources with turbidities in excess of two NTU if additional prefiltration were provided and operated to meet a two NTU performance standard. An existing non-complying filter plant may serve this purpose. The additional prefiltration cannot be expected to provide virus removal.

The Rosedale Bag Filtration System is an acceptable filtration technology for protected sources where the virus removal requirement can be waived and the turbidity is less than 2.0 NTU.

***Cryptosporidium* Removal Credit**. The Cal Trans Cactus Filtration Demonstration Study Results were evaluated again to determine the log removal capability of the Rosedale Bag Filtration System on Cryptosporidium oocysts. The goal of the evaluation was to determine the log reduction between the raw particle count and the filtered particle count for particles ranging from 2-5 μm in size 95% of the time.

The original data was evaluated and a log removal verses percentile graph was generated. Data from runs 4 and 5 were not included due to problems with the data noted in the study report. Also, any particle count data collected when the pressure differential across the Rosedale filter was greater than 10 psi was not included.

As a result of this evaluation, the Rosedale Bag Filtration system successfully demonstrated the ability to reliably achieve 90% (1-log) Cryptosporidium oocyst removal.

14. 3M Cartridge Model #723A
(Paul Gilbert-Snyder)

The acceptance for the use of this technology has been rescinded. 3M no longer provides the Model 723A product (Mitchell 1998). Existing systems may continue to operate and use the Model 723A product purchased prior to December 31, 1999 until all cartridges have been used, or until December 31, 2001, whichever occurs first. By December 31, 2001 acceptable replacement equipment must be in use.

Product: Company: Contact:	**3M Cartridge Model 723A** 3M Filtration Products Jeffery Mitchell (800) 648-3550
Technology:	723A cartridge
Study at:	San Dimas Experimental Station
By:	Nat'l Park Service
Systems using:	Various National Parks: Bridge Campground, Lassen NF, Juanita Lake Campground, Klamath NF
Raw Source:	0.4 to 3.1 NTU with spikes to 10 NTU May be used on raw water with an average raw water turbidity of 3 NTU. Short duration (1 hour or less) spikes of 10 NTU or less are acceptable.
Removal Credit:	2-log *Giardia*, 0-log virus[+]
Performance Std:	A = 0.2 NTU, to be met 95% of time
	B= 0.5, C= 0.2, D= 0.5, E=n/a
Operation criteria:	Not to be operated beyond 20 psid
Design criteria:	
Operation plan:	
Study:	

[+] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. The 90 percent virus removal requirement can be waived, at the request of the supplier, under Section 64653 (g) if the supplier can, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed.

Date of approval: June 1998 SWTR Committee Meeting minutes.

The United States Forest Service (USFS), in cooperation with R-P Products and the 3M Company, has completed a demonstration of filtration effectiveness to satisfy a requirement of the California Surface Water Filtration and Disinfection Regulation (CCR, Title 11, Chapter 17, Section 64650 et seq.) (SWF&DR), specifically Section 64653(f) dealing with alternative filtration technologies. The demonstration study was designed and conducted with Drinking Water Program participation and approval. The system evaluated was the **3M Model 723A Cartridge Filter with a stainless steel housing unit** provided by R-P Products. Acceptable housing unit model numbers are HE-SS4-F100-LP or HE-SS4-T-100-LP (A or D designations in the model number are irrelevant). The system contains the necessary piping, valve, container vessels, hydraulic instrumentation and controls, and turbidity sampling taps to constitute a complete filtration process.

The demonstration was conducted at the USFS Technology & Development Center in San Dimas, California. Seven filters were tested over a period of three months. The source water was domestic water with an artificially induced suspended solids load producing average turbidities between 0.4 and 3.1 NTU. The system was also challenged with several short duration (1 hour or less) source water spikes of 10 NTU. Particle counters and turbidimeters were used to demonstrate removal of *Giardia* and *Cryptosporidium* sized particles, 5-15 µm and 2-5 µm, respectively. **The system was not tested for virus removal**.[**] Performance of the filtration system is documented in a report submitted to the Department with a cover letter dated March 25, 1998.

The system demonstrated the ability to reliably achieve 99% (2 log) removal of *Giardia* sized particles, while achieving effluent turbidities of 0.2 NTU or less. It is not known whether the system would provide the same removal efficiency while producing a higher turbidity effluent.

At differential pressures of 20 psi or less, the system demonstrated the ability to reliably achieve 99% (2 log) removal of *Cryptosporidium*-sized particles, while achieving effluent turbidities of 0.2 NTU or less. The test protocol was designed to demonstrate filter performance through 20 psid. Testing beyond psid was for reliability purposes only. If a supplier wishes to operate the filter at higher differential pressures an additional study will need to be completed. **(The manufacturer's literature suggests that these units can be operated up to a 35 psid. -Ed.)**

[**] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. The 90 percent virus removal requirement can be waived, at the request of the supplier, under Section 64653 (g) if the supplier can, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed.

For systems serving 500 persons or less, alternative technologies are only required to demonstrate 90 percent *Giardia* removal. Since 3M has not demonstrated a minimum virus removal of 90 percent, this technology can only be used in:

1) systems that have demonstrated, through their sanitary survey, the lack of a virus hazard in the watershed, or

2) systems serving less than 500 persons.

During a portion of the study, the source water experienced an algae bloom that affected system performance. Although 95th percentile removal of *Giardia*-sized particles remained at or above 2 log, the 95th percentile removal of *Cryptosporidium*-sized particles decreased to 1.8 log and the 95th percentile effluent turbidity increased to 0.23 NTU. Although *Giardia* removal requirements were met, the use of this system is not recommended for source waters that may experience algae blooms unless adequate pretreatment is provided. Such conditions may cause the effluent to exceed the 0.2 NTU performance standard and may also significantly shorten the cartridge life.

A prefilter was not used during the study and is not required for the organism removal credit, although a prefilter would be recommended for higher solids (turbidity) loading rates (see subsequent discussion).

An operations plan for this filtration technology should address how loss of cartridge or seal integrity will be defined. An alarm triggered by a drop in headloss or high particle count is acceptable (headloss or particle monitoring should be continuous). The plan must make it clear that the rinse of vessels at cartridge change is done with treated water. The plan must identify the maximum flow through each cartridge, not to exceed 20 gpm, and the maximum operating headloss across each cartridge, not to exceed 20 psi. The system should be equipped with a feed back loop to ensure the differential pressure does not exceed 20 psi, and that the system will divert flow or shutoff if the differential pressure does exceed 20 psi. The plan shall identify the minimum supply of replacement cartridges that will be maintained on the site and justify this number in light of the anticipated rate of use and availability. **A record must be kept of cartridge purchases to be used to verify that they are not being reused**.

The 3M Model 723A is effective for raw water turbidities averaging up to 3 NTU, with short duration (1 hour or less) spikes of 10 NTU or less. The 3M Model 723A could be approved for use on sources with average turbidities in excess of 3 NTU if additional prefiltration were provided and operated to meet the 3 NTU performance standard. An existing non-complying filter may serve this purpose. The additional prefiltration cannot be expected to provide pathogen removal.

The Department's SWTR committee concluded from the demonstration study results that the 3M Model 723A cartridge filter is an acceptable filtration technology for protected sources where the virus removal requirement can be waived and the turbidity is typically less than 3 NTU.

References

Mitchell, J.K.

Letter to Dr. David P. Spath, April 24, 1998.

FOR SYSTEMS SERVING LESS THAN 500 PERSONS

15. 3M Bag and Cartridge Filtration System

The approval for the use of this technology has been rescinded. 3M no longer provides the Model 523A and 744BW products (Mitchell 1998). Existing systems may continue to operate and use the Model 523A and 744BW products purchased prior to December 31, 1999 until all cartridges have been used, or until December 31, 2001, whichever occurs first. By December 31, 2001 acceptable replacement equipment must be in use.

Product: Company: Contact:	**3M Bag and Cartridge Filtration** Filtration Technology Gregg Fisher (208) 336-6611
Technology:	523A bag and 744BW cartridge
Study at:	Sequoia Kings Canyon Nat'l Park Headquarters
By:	Nat'l Park Service
Raw Source:	The turbidity ranged from 0.86 to 4.6 NTU. May be used on raw water up to 4 NTU (higher with prefiltration to 3 NTU)
Removal Credit:	1.5-log *Giardia* (see note under operating criteria), 0-log virus[+]
Performance Std:	A = 0.2 NTU, to be met 95% of time
	B= 0.5, C= 0.2, D= 0.5, E=n/a
Operation criteria:	suitable only for use by systems serving less than 500 persons Not to be operated beyond 20 psi (differential pressure?)
Design criteria:	pressure relief to protect bags from an excessive pressure surge (30 psi) and possible bag rupture

[+] Under the current SWTR regulations, CCR Title 22 Chapter 17 Article 2 Section 64653 (f), alternative technologies must demonstrate that they can provide a minimum of 99 percent *Giardia* cyst removal and 90 percent virus removal to be used in systems serving more than 500 persons. The 90 percent virus removal requirement can be waived, at the request of the supplier, if the supplier can, through their watershed sanitary survey, demonstrate the lack of a virus hazard in the watershed. This technology also meets the minimum 1-log *Giardia* and 0-log virus removal requirements for systems serving less than 500 persons.

Two 3M Systems were evaluated in the study. These systems were the 3M-Brand 523A bag filter with stainless steel housing unit and the 3M Brand 744BW Cartridge Filter with stainless steel housing unit. The 3M Company systems contains the necessary piping, valve, container vessels, hydraulic instrumentation and controls, and turbidity sampling taps to constitute a complete filtration process.

The demonstration was conducted on water from the Middle Fork of the Kaweah River, a low turbidity surface source, at the Sequoia Kings Canyon National Park Headquarters in Three Rivers, California. The source water turbidity ranged from 0.86 to 4.6 NTU during the study. The virus removal requirement was waived for this source per SWF&DR Section 65653(g) as proposed for revision. The *Giardia* cyst removal demonstration was made using particle count and turbidity data. Performance of the filtration system is documented in a report submitted to the Department with a cover letter dated October 24, 1995.

Both filtration systems successfully demonstrated the ability to reliably achieve 97 percent (1.5 log) *Giardia* cyst removal. This organism removal was achieved while an effluent turbidity of 0.2 NTU or less was observed in at least 95 percent of all measurements. It is not know whether the 3M Systems would provide the same organism removal efficiency while producing a higher turbidity effluent. Virus removal efficiency was not included in this study. The particle count data was not evaluated for Cryptosporidium oocyst removal capability.

A prefilter was not used during the study and is not required for the organism removal credit. A prefilter would be required for higher solids (turbidity) loading rates (see subsequent discussion) and is desirable to extend the life of the *Giardia* barrier.

To prevent possible bag rupture the installation of the 3M Systems must include pressure relief where necessary to protect the *Giardia* barrier from a pressure surge that would cause a pressure differential across the bag in excess of 30 PSI.

An operations plan for this filtration technology should address how loss of bag or seal integrity will be defined. An alarm triggered by a drop in headloss or high particle index is acceptable (Headloss or particle monitoring should be continuous). The plan must make it clear that the rinse of vessels at bag change is done with treated water. The plan must identify the maximum flow through each *Giardia* barrier (not to exceed 20 gpm for the 3M Bag (523A and 30 gpm for the 3M Brand 744W Cartridge filter) and the maximum operating headloss across each bag is not to exceed 30 psi for both systems. The plan shall identify the minimum supply of replacement bags or cartridges that will be maintained on site and justify this number in light of anticipated rate of use and availability. A record must be kept of bag or cartridge purchases to be used to verify that they are not being reused. The system must filter to water for five minutes upon each startup.

The 3M Filtration Systems are effective for raw water turbidities up to 3.0 NTU. The 3M Filtration Systems could be approved on sources with turbidities in excess of 3.0 NTU if additional prefiltration were provided and operated to meet a 3.0 NTU performance standard. An existing non-complying filter plant may serve this purpose. The additional prefiltration cannot be expected to provide virus removal.

The Department's review committee concluded from the demonstration study results that the 3M Filtration Systems are an acceptable filtration technology for protected sources were the virus removal requirement can be waived and the turbidity is less than 3.0 NTU.

References

Mitchell, J.K.

Letter to Dr. David P. Spath, April 24, 1998.

Questions regarding the policies contained in this report should be directed to the Surface Water Treatment Rule Committee. Corrections and additions should be sent to:

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Acknowledgments

The SWTR Committee would like to thank all of those who contributed their ideas and thoughts to this report. The importance of the field observations and reports made by the members of the California Department of Health Services' Drinking Water Program Field Office's cannot be overstated. Without such information, the value of this report would be greatly diminished. It is the committee's hope that the value of this document will continue to increase and that any ideas or comments to improve the content or organization should be directed to the editor.

The committee would also like to acknowledge the contributions made by the utilities, consultants, and manufacturers. Your efforts and the reports submitted to this Department have provided this Department with a solid technical foundation from which to move these alternative technologies forward.

Appendix A. First-Year Operation Reports

The Department recognizes that pilot-scale testing alternative filtration technologies provides a limited evaluation of alternative treatment technologies. Temporal variations in water quality cannot always be evaluated during pilot tests. Consequently the Department requires an annual report evaluating the performance of the alternative technology.

Section 64653(i) requires that:

> "Within 60 days following the first full year of operation of a new alternative filtration treatment process approved by the Department, the supplier shall submit an engineering report prepared by a qualified engineer describing the effectiveness of the plant operation. The report shall include results of all water quality tests performed and shall evaluate compliance with established performance standards under actual operating conditions. It shall also include an assessment of problems experienced, corrective actions needed, and a schedule for providing needed improvements."

The following first-year operational reports are known to have been submitted to the Department in fulfillment of the Section 64653(i) requirement.

Water system	Technology
San Jose Water Company and Metropolitan Water District of Southern California	Memcor Continuous Microfiltration System
East Bay Municipal Utility District, Pardee Recreation Area	Advent Membrane Systems, (Aquasource North America, LLC)
Marconi Conference Center	Desal DK5 Membrane: Memclear PC-2
Tracy Pumping Plant	Desal DK5 Membrane: Memclear PC-10
Casitas Municipal Water District	Sverdrup/Serck Baker Hi-Rate Pressure Filtration
Los Angeles Department of Water and Power PP1 and PP2 Water Treatment Plants	Culligan Duplex Multi-Tech Filter System Model MT-30D
Cactus City Rest Area operated by Caltrans	Rosedale Bag Filtration Plant
Castaic Lake Water Agency	Contact clarification and anthracite filtration
Paradise Irrigation District	Roberts Filter Company Contact Clarification Process
Calleguas Municipal Water District	High rate direct filtration plant using ozone for predisinfection

Memcor Continuous Microfiltration System

Two systems (Inverness Public Utility District (2110001) and the Bolinas Public Utility District (2110005)) in Marin Co with Memcor plants report that they are cleaning the membranes much more frequently. They are experiencing a shorter interval (from months to weeks) between a cleaning and TMPs indicating a need for another cleaning as well as a more rapid rise in TMPs at the end of the interval.

They are not repairing fibers (pinning) with any increased frequency so fiber failure does not seem to be a problem. All three plants are at least 6 years old with the original membranes in place. The sources are fairly low in turbidity and low TOC so they may be a best case in terms of raw water quality challenges/impacts to membranes. They are planning a joint purchase of new modules within a year. So it looks the 5-year life of a module estimated by the manufacturer is about right. We should probably ask other plants with Memcor membranes about this issue in our inspections.

Michael J.Finn, P.E. (June 6, 2001)
Associate Sanitary Engineer
San Francisco District

San Jose Water Company Saratoga Water Treatment Plant – Surface Water Treatment Rule Compliance Evaluation – August 30, 1994.

Performance and Operation Report of Memcor Microfiltration Units at Metropolitan Desert Pumping Plant dated April 25, 1995 (Metropolitan Water District of Southern California).

Advent Membrane Systems, (Aquasource North America, LLC)

East Bay MUD- Pardee Recreation Area Ultrafiltration Effectiveness

East Bay Municipal Utility District, Pardee Recreation Area

Ultrafiltration plant provided by Advent Membrane Systems, (Aquasource North America, LLC)

Desal DK5 Membrane: Memclear PC-2

Marconi Conference Center (Michael Finn and Richard Sakaji). The following summary is based on a letter submitted to the Department by the Marconi Conference Center Treatment Plant Supervisor, Chris Hanson (dated October 5, 1998),. The unit was installed in May 1995 and has never performed to their expectations (high operation and maintenance costs associated with frequent membrane cleaning and downtime) although the quality of water produced exceeds our requirements. They have experienced pressure switch and solenoid valve shutdowns for no apparent reasons. Instead of the anticipated manual dismantling and cleaning of the membranes every six months, the system is being cleaned every 2 weeks to keep it operational (see note below). The automatic backwash has not functioned properly as they do not switch back to production mode as designed. Although the influent flow and pressure to the unit are constant at 10 gpm and 35 psi, the filters have never produced treated water at the design flow of 5-8 gpm (actual production is 2-3 gpm). In addition, the installed Chem Trec PM 2500 particle monitor never operated as designed and the system is using daily manual turbidity checks to meet the permit requirements.

Note: "I confirmed that the PC1 units at Marconi were rated at 4gpm per unit or 2 gpm per module (2 modules per package). The sales literature says 3.5 gpm @ 35psi. They never actully ran above 2 gpm per unit because the TMP rose so fast and initiated cleaning so frequenlty that he system could not meet demands." (Mike Finn; August 4, 2000)

Thousand Trails NACO. A county health official reported that a campground (Thousand Trails NACO, 4176 Yuba Gap, Emmigrant Gap, CA) using the Mem-Clear system had run into problems (frequent chemical cleaning required) with the operation of the membrane and called the Department inquiring about getting technical support. Since then a company by the name of Argo Scientific in San Marcos, CA (Mark Warren or Ray Eaton [760] 727-2620) took on the job of examining the membranes in an effort to determine if they could be salvaged by cleaning at the request of the Thousand Trails NACO corporate headquarters located in Dallas TX. (B.J. Thomas). Argo found that the membranes were only achieving about a 50% salt rejection and recommended they buy new membranes. In total about 20 membranes were evaluated by Argo for this one campground.

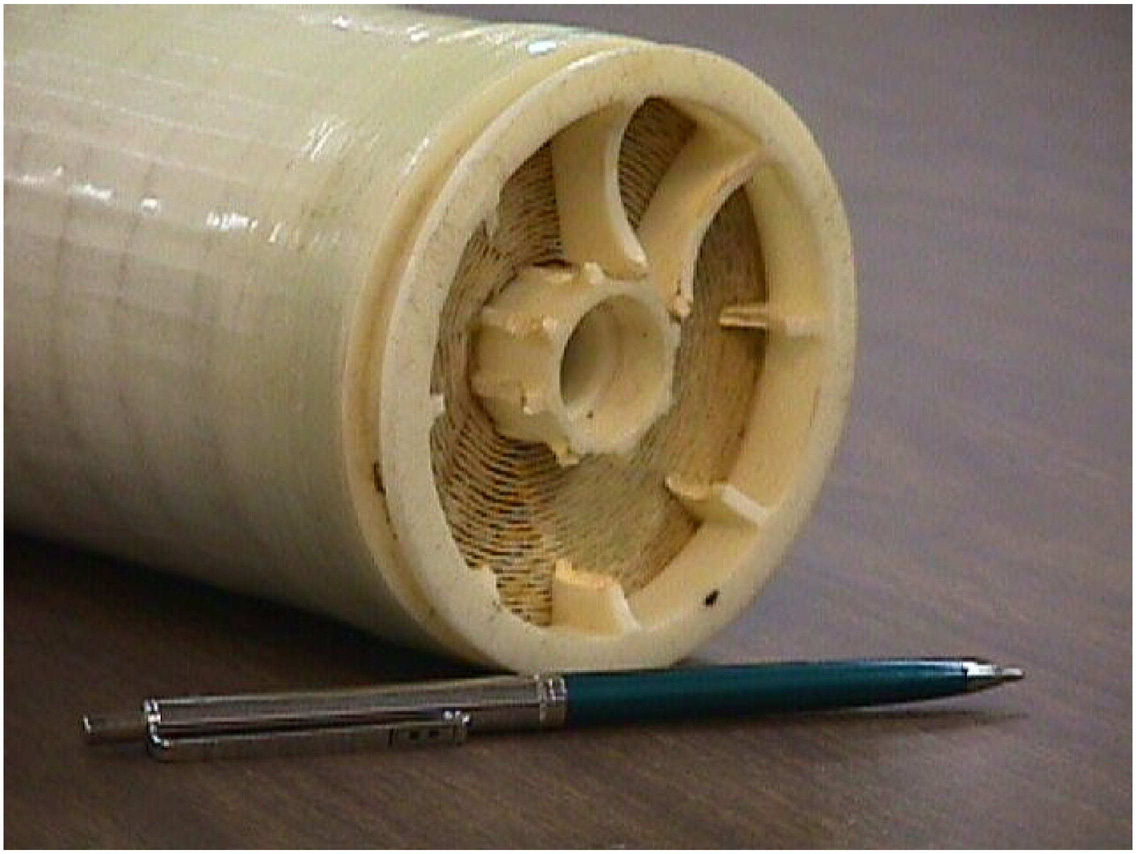

Figure A-1. Desal DK5 Membrane male end and support structure destroyed by improper installation (Photo by Gene Reade).

Thousand Trails Campground in Placer County (Gene Reade). Another incident, reported by Gene Reade, was associated with a Thousand Trails Campgrounds in Placer County. A Mem Clear system equipped with a 0.2 μm cartridge following the membrane was having flow problems. Apparently the cartridge filter was continually plugging. In order to increase flow through the system the cartridge was removed. Without the cartridge the system was not able to meet the turbidity performance standards. Upon removal of the DeSal DK 5 membrane, it was discovered that the seals had been installed backwards and force (hammer blow) was used to "seat" the membrane (see Figure A-1). This action caused the o-ring seals to fail resulting in significant by-pass of inadequately treated water. The data was insufficient to determine how long this problem had gone on or what volume of inadequately treated water had passed through the system.

Sverdrup/Serck Baker Hi-Rate Pressure Filtration

Marion R. Walker Pressure Filtration Plant, Summary Report and Evaluation for the First Year of Operation. April 1998

High rate direct filtration plant using ozone for predisinfection.

Lake Bard Water Filtration Plant Alternative Filtration Technology One Year Report – October 1997. Calleguas Municipal Water District

Contact clarification and anthracite filtration

Alternative Filtration Technology Engineering Report First year of operation – Rio Vista Treatment Plant – Castaic Lake Water Agency – November 1996.

Castaic Lake Water Agency. Contact clarification and anthracite filtration operating at 10 gallons per minute per square foot.

Microfloc contact clarifier and multi-media filtration.

West San Bernardino County Water District

Oliver P. Roemer Water Filtration Facility First Year Operations Report prepared by District staff, December 1996.

It has been reported by field engineers that some of the floating contact clarifier media used by the Trident systems at Fort Bragg and Willits has become coated to the degree that the media is no longer buoyant. There is some loss of contact clarifier effectiveness in this situation. The condition appears to be a associated with source waters high in iron or manganese, or where potassium permanganate is fed. In these cases, washing or replacement of the media has been necessary.

In 1997, the raw source turbidity for the Folsom Prison's Microfloc direct filtration system reached 250-300 NTU (Morehouse 1997). The system could not operate effectively at this high turbidity and the plant was shutdown. A temporary interconnection between the prison and local water system was setup to provide water (two fire engine pumper trucks providing system pressure between fire hydrants located in the respective systems). Bottle water, limited showers, and portable toilets were being used to limit water use.

Morehouse, J.

personal communication, Janaury 4, 1997.

Roberts Filter Company Contact Clarification Process

A file containing field office comments and observations on these systems is available on request.

The Department has been looking into various problems with Roberts Filter over the past several months and identified the following concerns that field staff should bear in mind during their review of plans and specifications and inspections.

1. Review of the plans and specifications should look for and eliminate the use of single wall or common wall construction between the influent and effluent of treatment process steps in all water treatment plants. In addition, the area enclosed by the double wall must drain and must be accessible for inspection.

2. Also noted has been the loss of media from the sedimentation basin under normal operating conditions. This illustrates the need to install screens to prevent loss of media.

3. Visual inspection of systems has noted air binding and boiling in the clarifer that can result in excessively high turbidities from the clarifier. The high turbidity and associated high solids concentration can result in a high solids load to the filters.

Culligan Duplex Multi-Tech Filter System Model MT-30D

Los Angeles Department of Water and Power PP1 and PP2 Water Treatment Plants

Culligan Package Treatment Plant, which includes media clarification followed by multi media filtration and pressure vessels.

Rosedale Bag Filtration Plant

CalTrans-Cactus City Rest Area Water Treatment Plant Engineering Report – August 1997

Cactus City Rest Area operated by Caltrans

There is no evidence that the following systems and technologies have submitted their one-year alternative technology operational reports.

Water System	Technology
Moose Lodge (Solano County)	Desal DK5 Membrane: Memclear PC-2
Hines Nursery (Solano County)	Desal DK5 Membrane: Memclear PC-2
Tracy Pumping Plant	Desal DK5 Membrane: Memclear PC-10
Yucaipa Valley Water District	EPD
Banning Heights Mutual	EPD
Miners Oaks CWD	EPD
Havasu WC	EPD

At this time a central list of operational alternative treatment technologies does not exist. Efforts are underway to create such a list and it is hoped that a future edition of this report will contain the information.

Corrections and additions to this section should be sent to:

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Appendix B. Studies

A. Technology Acceptance (pending)

Pacific Keystone submitted a request for acceptance of their "AC" technology. The SWTR Committee found that the original request for 2.5 log *Giardia* removal credit applied only to contact clarification technologies that have demonstrated to be equivalent to full conventional treatment. The SWTR Committee decided that in order to receive the 2.5 log *Giardia* removal credit Pacific Keystone will need to demonstrate that the AC technology achieves this level of performance. However, the SWTR Committee also recognized that the AC technology could be accepted as being equivalent to direct filtration technology (2-log *Giardia* and 1-log virus removal credit) without any additional studies pending the resolution of several issues.

B. Studies Underway

Ionics/X-Flow Ultrafiltration Membrane: Otay

Hydranautics HYDRACAP: Otay; higher flux.

C. Studies anticipated

The following studies and product evaluations for alternative filtration devices are currently underway:

Harmsco-Product presentation, limited data submitted, but no study protocol submitted for Department consideration, may be testing under the U.S. Forest Service protocol approved for USFS San Dimas Testing Facility.

Kinetico-General protocol received and reviewed by the Department-further protocol review will not be taken until a test site is identified.

LaPointe Industries (Strainrite) ETV testing for a 3M replacment bag.