

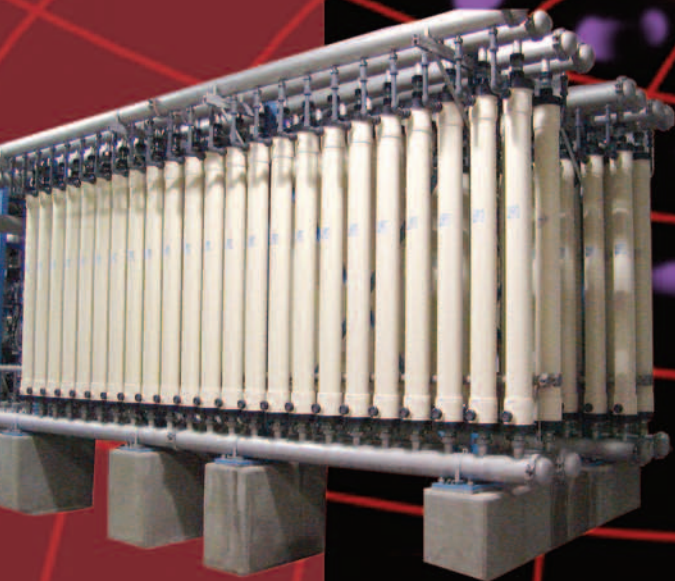


Pall Corporation

Pall Aria™ Systems
for
Water Treatment
Applications Guide



chemical resistance
long membrane life
high efficiency
low fouling



Filtration. Separation. Solution.™

Pall Aria Systems for Water Treatment Applications Guide

With stringent water treatment regulations and a growing demand for safer water, treatment systems must ensure strict compliance with purity standards. Filtration is critical to the success of your water treatment system in meeting purity goals, and traditional filtration methods such as sand and granular mixed media are often inefficient, labor intensive, and costly. The Pall Aria line of water treatment systems uses hollow fiber microfiltration or ultrafiltration membrane technology to produce pure water from any water source. Pall Aria systems remove bacteria, protozoan cysts, viruses, iron, manganese, arsenic, and other solid particulate to deliver water that consistently measures up to even the toughest standards. In fact, the Pall Aria system is the first membrane system to meet NSF International's Standard 61 certification for drinking water purity.

Designed for compliance with government standards

In the United States, the *Safe Drinking Water Act* is the fundamental federal law ensuring the quality of drinking water. This act has required the U.S. Environmental Protection Agency (USEPA) to develop standards and regulations to increase protection of drinking water against contaminants and tighten controls governing chemical disinfection byproducts. The regulations apply to the processing of surface water, groundwater, industrial and municipal wastewater, secondary effluent, and salt water for direct and indirect potable use. The Pall Aria system is designed to produce water that complies with the USEPA regulations listed below.



USEPA Regulations Governing Water Treatment

| Regulation | Mandate |
|------------------------------|---|
| Surface Water Treatment Rule | Water from surface sources or under the direct influence of surface water must meet the mandated limits for <i>Cryptosporidium</i> , <i>Giardia lamblia</i> , bacteria, turbidity, and viruses in drinking water. |
| Disinfection Byproduct Rule | Water that is chemically disinfected for drinking must comply with maximum contaminant levels for disinfection byproducts. |
| Arsenic Rule | Any water distributed to the public must contain no more than 10 µg/L of arsenic. |

Cost effective, efficient, and flexible

At the heart of the Pall Aria system is a highly permeable hollow-fiber membrane with high flow per unit area and a high recovery rate. These features can lower the cost of each gallon of water you treat. Documented test results and actual system performance demonstrate the efficiency of the membrane-based Pall Aria filtration system.

You can purchase the Pall Aria system for stand-alone use or for integration with your existing equipment. Its modular design offers flexibility and allows you to customize your system for your unique process application and integration requirements.

Surface Water Treatment

The quality of surface water entering your treatment system from rivers, lakes, streams, and reservoirs varies with seasonal conditions. The Pall Aria system produces effluent that remains consistent regardless of source water quality.

Applications

Raw water

Raw water treatment removes chlorine-resistant *Giardia* and *Cryptosporidium* to meet the requirements of the Surface Water Treatment Rule. The Pall Aria system's 0.1 µm membranes eliminate the need for you to add chemicals to coagulate these contaminants. Performance data shows that the Pall Aria system achieves a 6 log reduction of *Giardia* and *Cryptosporidium*, with recovery rates that vary from 90-97%, depending on the influent water quality. (Refer to the following table.)

Typical Performance Data for Pall Aria Systems Processing Raw Surface Water

| Avg turbidity (NTU) | TOC avg mg/L | Flux (gal/day/ft ²) | Recovery (%) |
|---------------------|--------------|---------------------------------|--------------|
| <20 | <3 | 75 | 97 |
| <50 | <5 | 53 | 94 |
| Up to 100 | >5 | 32 | 90 |

Nephelometric turbidity unit (NTU) is the unit of measure for the size or concentration of suspended particles based on the scattering of light transmitted or reflected by the medium.

Total organic carbon (TOC) represents the average number of organic particles per liter of water processed.

Flux is a measure of the flow rate in gallons per day per square foot of membrane.

Direct coagulated water

With microfiltration membranes, coagulation can improve the removal efficiency of harmful contaminants such as arsenic, natural organic matter, and phosphorous. When you add coagulant and establish the proper pH, the Pall Aria system can reduce arsenic to well below the maximum level (10 µg/L) specified by the USEPA's Arsenic Rule. This is the case even if your source water contains more than 50 mg/L arsenic.

Disinfection byproducts such as trihalomethanes and haloacetic acids are formed when chlorine reacts with natural organic matter in the feed water. Removal of organic matter reduces these byproducts. Coagulant injected upstream of a Pall Aria system can eliminate 30-60% of the organic matter and attain a recovery rate of approximately 90-95%. It is more cost effective than nanofiltration or reverse osmosis (RO) for this purpose.

Typical Performance Data for Pall Aria Systems Processing Direct Coagulated Surface Water

| Avg turbidity (NTU) | TOC avg mg/L | Flux (GFD) | Recovery (%) |
|---------------------|--------------|------------|--------------|
| <50 | <5 | 75 | 97 |
| <50 | >5 | 51 | 95 |
| Up to 100 | >5 | 35 | 93 |

Surface Water Treatment

Coagulated and settled water

If you use low-quality source waters, an option for increasing flux rates is to allow coagulated materials to settle before feeding the clarified supernatant to the Pall Aria system. This has immediate financial benefits if you have settling equipment in place, but it is still cost effective if you purchase the equipment. Fewer microfiltration modules are needed when settling is part of the treatment process, so the expense of the settling equipment is offset by what you save on the modules.

The following table presents performance data for the processing of coagulated and settled water. The data shows that settling equipment enables Pall Aria system performance to remain relatively stable despite changes in water quality.

Typical Performance Data for Pall Aria Systems Processing Coagulated and Settled Water

| Avg turbidity (NTU) | TOC avg mg/L | Flux (GFD) | Recovery (%) |
|---------------------|--------------|------------|--------------|
| <50 | <5 | 75 | 97 |
| <50 | >5 | 75 | 97 |
| Up to 100 | >5 | 75 | 97 |

Pall Aria installations for surface water treatment

The following table provides information about some Pall Aria system installations that treat surface water.

Sampling of Pall Aria Installations for Surface Water Treatment

| Project Location | Application | Pretreatment | Flux (GFD at 20°C) | Flow (mgd) |
|------------------------------|----------------------|---------------------------|--------------------|------------|
| Abilene, TX | Direct coagulated | Ferric sulfate | 29 | 08.0 |
| Austin, TX Travis Co. #18 | Pretreated & settled | Granular activated carbon | 47 | 03.0 |
| Bakersfield, CA | Coagulated & settled | Polyaluminum chloride | 67 | 20.0 |
| Brushy Creek, TX | Direct coagulated | Ferric chloride | 32 | 06.0 |
| Kernville, CA | Raw water | None | 44 | 00.5 |
| Washington, UT | Raw water | None | 65 | 03.0 |

Typical performance is 75 gal/ft²/day.

San Patricio—Ingleside, Texas

The San Patricio Municipal Water District in Ingleside, Texas was tasked with providing high-quality, potable water for both residential users and a new cogeneration facility. The feedwater for the cogeneration facility came from the Nueces River and Lake Texana. Turbidity, temperature, and hardness were highly variable.

The Water District management decided that the most effective treatment method would involve settling followed by microfiltration. After testing different membrane systems, the Pall Aria microfiltration membrane system was selected. It had the highest flux, excellent performance, and the ability to easily retrofit microfiltration modules with ultrafiltration modules. An official of the San Patricio Municipal Water District explained the decision to choose the Pall system: "We serve an area of rapid growth where the demand for water quality and quantity is a daily concern. The Pall system demonstrated it could give us great performance on both counts and at a cost well within our budget."



Abilene, Texas

In 1999, a heat wave caused the most extensive drought in Abilene's recorded history. The city's two water treatment plants used conventional filtration and could not produce enough drinking water for its residents.

A proposal was made to build a third plant, which would draw water from a remote reservoir. Since the reservoir's water was of poor quality—brackish, hard, with high organic content, and a high level of total dissolved solids—microfiltration followed by reverse osmosis appeared to be the best filtration solution. Direct coagulation would also be included in the treatment process. This step would enhance performance of the RO units, improve the quality of the finished water, and eliminate the need for flocculation tanks and mixing tanks, which would reduce the initial investment and maintenance costs.

The decision to install a Pall Aria system was based on pilot tests that compared the performance of several microfiltration membrane systems. The Pall system proved to be well adapted to direct coagulation and the most efficient, cost effective solution.

Travis County, Texas

To ensure safe drinking water, the Travis County Water Control and Improvement District No. 17 plant was changed over from conventional filtration to the Pall Aria system. The Facility's General Manager said that Pall's proven performance at the San Patricio plant was an important factor in the decision.

Using the Pall Aria system, the water treatment plant has increased production from 4 mgd (million gallons per day) to 8 mgd and reduced disinfection byproducts by 30-40%. Travis County has received other benefits as well.

- Established a water surplus that exceeds federal drinking water standards.
- Increased water output by improving process efficiency.
- Decreased operating expenses by increasing reliability.
- Reduced the formation of disinfection byproducts by eliminating chlorine pretreatment.
- Required less downtime for cleaning, since simple methods such as reverse filtration, air scrub, and enhanced flux maintenance can be used.
- Reduced corrosion, since water treatment is contained within the modules.



Groundwater Treatment

Groundwater has been a preferred source of drinking water because of the general perception that it is of higher quality, less vulnerable to contamination, and requires less intensive treatment than other types of water. In fact, groundwater is susceptible to contaminants such as iron, manganese, and arsenic found in soil and rock.

Applications

Iron and manganese removal

Iron and manganese are secondary aesthetic contaminants in groundwater. They produce red and brown stains, giving the water the appearance of being impure. The consequence is reduced consumer confidence in your product. You can eliminate iron and manganese using an oxidation process that precipitates these dissolved metals into particulate. The particulate can then be filtered out using a Pall Aria system.

Arsenic removal

In the United States, high arsenic levels are common in groundwater. The 2000 Federal Register reports the USEPA finding that roughly 4,000 public drinking water facilities nationwide could require additional treatment to remain within the maximum limit of 0.01 mg/L (*Office of the Federal Register, 2000*).

Naturally occurring arsenic is found in two forms: arsenate [As(V)] and arsenite [As(III)]. Under typical groundwater conditions, arsenate is more common and is easier to remove using coagulation and membrane filtration. An oxidation process can be used to convert arsenite to arsenate for coagulation/filtration. Even when arsenic levels in the feedwater are high, the Pall Aria system can reduce arsenic below the MCL when a coagulant dose of 15 mg/L of ferric chloride and proper pH control is used. When tested at the El Paso, Texas installation and at Fallon Naval Air Station (NAS), Nevada, the Pall Aria system successfully removed arsenic with ferric chloride used as the coagulant.

Pall Aria installations for groundwater treatment

The following table identifies some Pall Aria system installations for groundwater treatment.

Sampling of Pall Aria Installations for Groundwater Treatment

| Project Location | Application | Pretreatment | Flux (GFD at 20°C) | Flow (mgd) |
|------------------|-----------------|--------------------------------------|--------------------|------------|
| Fallon , NV | As removal | FeCl ₃ w/ CO ₂ | 75 | 0.5 |
| Holladay, UT | GWUDI | No | 65 | 2.5 |
| Orleans, MA | Fe & Mn removal | NaOCl & KMnO ₄ | 60 | 3 |

Typical performance is 75-100 gal/ft²/day.



Holladay, Utah

Stricter government regulations and poor quality spring water prompted the Holliday Water Company to build the Spring Creek water treatment plant in 2002. Until then, the 15,000 residents of Holladay, Utah received their potable water from springs that were under the influence of surface waters from seasonal run-off. The spring water had a turbidity of 0.3 NTU, the maximum allowed by the USEPA. The goal was to reduce turbidity below the maximum.

The Pall Aria system was selected for treatment because of its features and its performance during pilot testing. "It was cost effective, modular to fit our limited area, had a quiet backwash, and was capable of filtering prechlorinated water," the plant manager said of the system's performance during the pilot studies.

The full-scale Pall Aria system installed at the Spring Creek plant includes 78 modules, with 50 square meters of effective filtration surface area per module. It processes 1.2 mgd of the feedwater, with 95% recovered. This system accomplished its goal by lowering turbidity from 0.3 NTU to 0.021 NTU, well below the USEPA's upper limit.



Wastewater Treatment



The amount of wastewater produced by municipalities and industry is substantial and, if left untreated, poses a significant threat to aquifers, rivers, lakes, and watersheds. Recycled wastewater and secondary effluent, on the other hand, are potential resources. These resources are especially needed where water is scarce from drought or overpopulation.

The most widely used standard for wastewater recycling across the U.S. is Title 22 of the California Code of Regulations. This regulation, established by the California Department of Health Services, defines suitable uses of recycled water, specifies treatment requirements, and mandates that recycled water achieve a level of purity consistent with its ultimate use. When the Pall Aria system processes wastewater and secondary effluent, the product is of such integrity that you can safely use it for agriculture and industry. This enables water producers to conserve the scarce fresh water for drinking and allows agricultural and industrial users to reduce purchases from the municipal drinking water supply.

Applications

Secondary effluent

Secondary effluent recycling utilizes microfiltration with or without downstream reverse osmosis treatment. When a Pall Aria system is used, the effluent meets the USEPA's National Pollutant Discharge Elimination System requirements for reducing *Cryptosporidium* and *Giardia*. Based on this criterion, the high-quality discharge can be used for irrigation, aquifer injection, recharging of watersheds, and industrial processes. In addition, secondary effluent can be treated for use as boiler feed water and cooling tower water.

Membrane-coupled bioprocess

In recent years, membranes have been used in conjunction with biological treatment, without a secondary clarification step. The Aqua MB Process* couples Pall Corporation's membrane technology with the biological treatment expertise of Aqua Aerobic Systems Inc. to deliver a cost-effective alternative to membrane bioreactor systems. The Pall Aria system is ideally suited to this application since it is pressure driven and uses membranes that are extremely robust and chemically resistant. New wastewater treatment facilities employing this technology will be more efficient, with a smaller footprint, higher quality effluent, and greater throughput. Existing facilities can benefit from greater throughput without altering the current footprint of the plant.

Pall Aria installations for wastewater

The following table identifies Pall Aria system installations used for wastewater and secondary effluent treatment. Installations around the world manage secondary effluent at capacities ranging from 300,000 gallons per day to 4.2 million gallons per day, in some cases using complementary equipment such as RO membranes and UV disinfection systems. Data for wastewater and secondary effluent processing shows that the performance efficiency of the Pall Aria system can vary greatly with the feedwater quality. However, the absolute nature of membranes enables effluent quality to remain consistent regardless of the feedstream.



Sampling of Pall Aria Installations for Wastewater

| Project Location | Type of Wastewater | Treatment | Water Use | Flow (mgd) |
|-------------------------------------|--------------------|-----------|-----------------------------------|--------------------------------------|
| Chandler, AZ | Electronics mfg. | MF + RO | Aquifer recharge | 1.75 mgd (275 m ³ /hr) |
| Luggage Point, Brisbane, Australia | Municipal | MF + RO | Industrial process | 4.2 mgd (670 m ³ /hr) |
| Panel Rey, Mexico (Automotive Mfg.) | Industrial | MF + RO | Industrial process | 0.3 mgd (35 m ³ /hr) |
| Sonoma County, CA | Municipal | MF only | Irrigation & groundwater recharge | 3 mgd (460 m ³ /hr) |

Typical flux is 25-75 GFD.

Sonoma County, California

The Sonoma County Water Agency needed to find a resource to supply local vineyards with water for their drip irrigation systems. The decision was made to use lagoon effluent with a 3 mgd Pall Aria microfiltration system to remove the solids and pathogens.

A process of microfiltration followed by chlorination has enabled Sonoma County vineyards to be supplied with water that meets the California Code of Regulations Title 22 standards for food crop irrigation. The new system has ensured that the vineyards will receive a constant supply of high-quality filtered water with low suspended solids, even when drought conditions exist.

Bedford Hills, NY

Treated secondary effluent is discharged into watersheds that collect and store the public drinking water supply. This water frequently requires further treatment to increase its safety. The New York State Department of Corrections facility in Bedford Hills discharges its processed wastewater into a New York City watershed. This water is not treated at the reservoir, so a Pall Aria system processes the secondary effluent and removes pathogens prior to discharge. The system has achieved removal of *Giardia* and *Cryptosporidium* in excess of 6 logs (99.9999%) and the removal of *Coliform* bacteria in excess of 4 logs.

Fountain Hills, Arizona

The challenge presented to the Fountain Hills Sanitation District was to find a more efficient wastewater treatment system that could recharge the groundwater aquifer. Both treatment process and product had to meet stringent environmental regulations, and total treatment cost had to be reduced.

Based on these factors, the decision was made to upgrade the plant with the AquaMB Process, which incorporates the Pall Aria system. At the conclusion of the process, the water that leaves the Pall Aria system is injected into deep wells to recharge the groundwater aquifer. It is stored during the winter months and becomes available in the summer months, when Arizona can experience severe drought conditions.



Seawater Treatment

Where fresh water is scarce, alternative sources of water are sought for drinking and industrial use. Seawater is a vast and readily available resource, and its desalination is already common in arid areas of the world. The processing of salt water is expected to become more widespread in the near future as fresh water sources and treatment costs decrease.

The use of microfiltration followed by reverse osmosis is becoming the accepted standard for desalination. Seawater can be converted into high-quality fresh water efficiently and cost effectively using the Pall Aria microfiltration system in combination with RO membranes.

Applications

Seawater desalination

Ocean water has an average salinity of 35 parts per thousand. The approximate distribution of dissolved minerals is: chloride, 55%; sodium, 31%; sulfate, 8%; magnesium, 4%; calcium, 1%; and potassium, 1%. When you pretreat with the Pall Aria system followed by reverse osmosis, you can reduce salt content to less than 500 mg/L. Typically, for every 1,000 gallons of seawater, the desalination process produces 300 to 500 gallons of pure water.

Pretreatment processes

Seawater must be pretreated to remove organics, algae, and fine particles that, in most cases, cause RO systems to foul prematurely. Premature fouling can increase your operating costs substantially. The Pall Aria system has a demonstrated ability to prevent premature fouling and clogging of RO membranes. It provides a cost-effective alternative to traditional desalination pretreatment methods such as air flotation, clarification, sand filtration, and cartridge filtration. Microfiltration membranes differ from RO membranes in that they are made of more chemically resistant materials that allow them to be cleaned more aggressively. As a result, fouling of pretreatment membranes is typically not a problem.

During storms, particulate content of seawater from an open intake is variable. The Pall Aria system uses 0.1 μm rated polyvinylidene fluoride membranes to remove even the finest particles from the water. The system has been designed to handle particulate of all types, since even fine particles can foul RO membranes.

When you pretreat with a Pall Aria system, the result is a low concentration of suspended particles, which enables your RO membranes to operate at high flux. The stability of the pretreated water extends the life of your RO membranes, assuring consistently clean feedwater to your RO system. When compared with conventional pretreatment, costs are lower for power, cleaning chemicals, prefilter cartridge changeouts, and labor. Additional cost savings result because fewer pressure vessels and RO membranes are needed.

Pall Aria system performance for desalination applications

The following statistics represent typical Pall Aria system performance for salt water pretreatment. To maintain optimal performance, it is recommended that you conduct a monthly clean-in-place using caustic and chlorine followed by acid.

| Silt Density Index (SDI) | Recovery Rate | Membrane flux |
|-----------------------------------|---|---------------|
| Approx. 1.5 to feed the RO system | Up to 50% combined (Pall Aria system improves RO efficiency) | 59-82 GFD |



Pall Aria installations for salt water treatment

Pall conducted long-term pilot testing at three locations to determine the effectiveness of Pall Aria systems for pretreating Mediterranean seawater prior to reverse osmosis. The tests compared the outcomes of seawater processing under the following conditions: no pretreatment, pretreatment using coagulation with ferric chloride (FeCl₃), and enhanced flux maintenance (EFM) protocol with or without pretreatment.

Summary of Operating Conditions at Three Pilot Sites

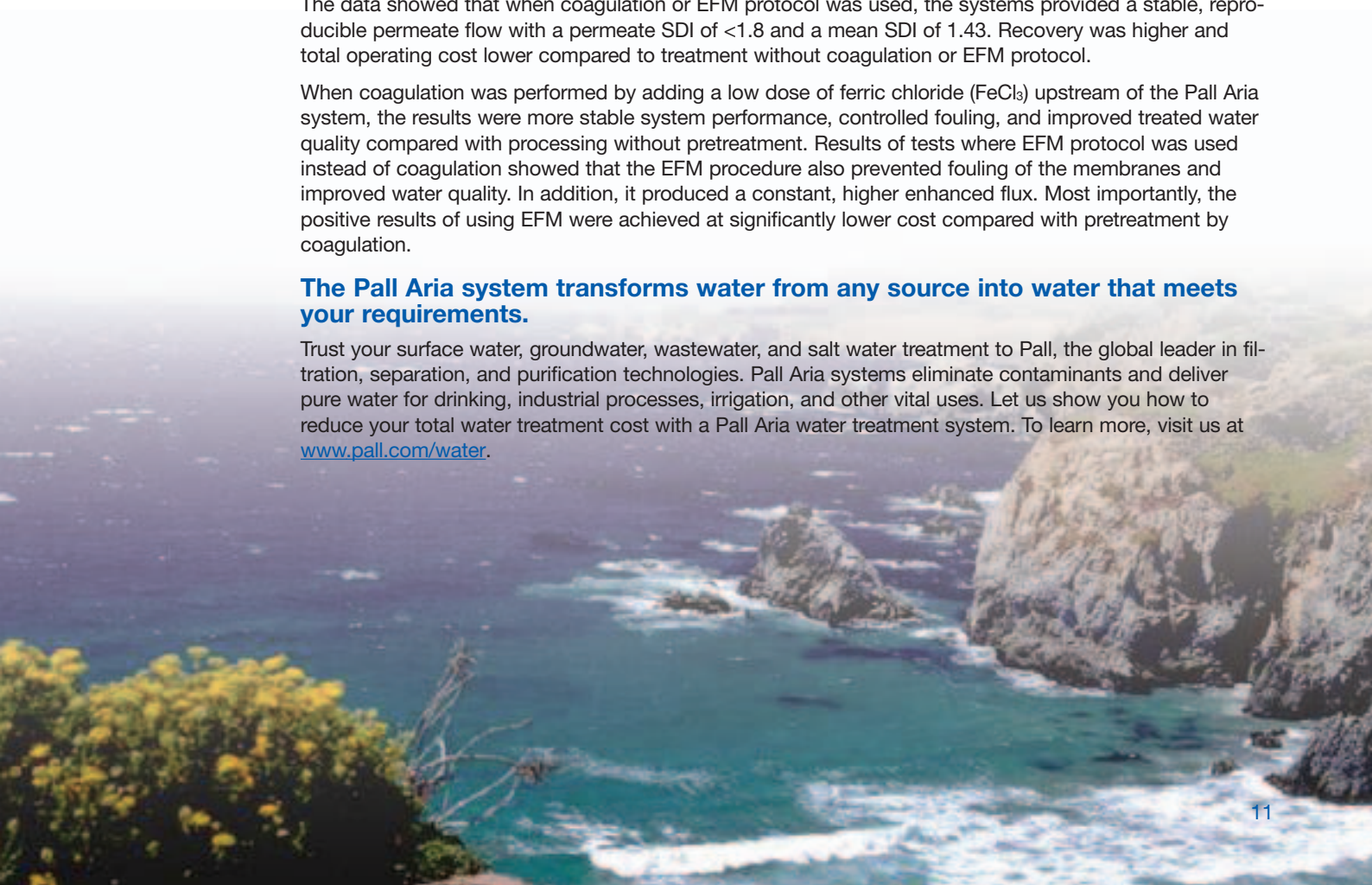
| | Site 1 | | | Site 2 | | | Site3 |
|---|-------------------|-------------------|-------------------|-------------|-------------------|-------|-------------|
| | Test Number | | | Test Number | | | Test Number |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Seawater pretreatment | FeCl ₃ | FeCl ₃ | FeCl ₃ | No | FeCl ₃ | No | No |
| Enhanced Flux Maintenance (EFM) | Daily | Daily | Daily | No | No | Daily | Daily |
| Air Scrub Frequency | 30 | 30 | 30 | 20 | 20 | 20 | 40 |
| Instant flux (L/hm ²) | 60 | 80 | 90 | 100 | 100 | 100 | 117 |
| Normalized flux (L/hm ² @20°C) | 67 | 91 | 103 | 82 | 79 | 91 | 100 |

The data showed that when coagulation or EFM protocol was used, the systems provided a stable, reproducible permeate flow with a permeate SDI of <1.8 and a mean SDI of 1.43. Recovery was higher and total operating cost lower compared to treatment without coagulation or EFM protocol.

When coagulation was performed by adding a low dose of ferric chloride (FeCl₃) upstream of the Pall Aria system, the results were more stable system performance, controlled fouling, and improved treated water quality compared with processing without pretreatment. Results of tests where EFM protocol was used instead of coagulation showed that the EFM procedure also prevented fouling of the membranes and improved water quality. In addition, it produced a constant, higher enhanced flux. Most importantly, the positive results of using EFM were achieved at significantly lower cost compared with pretreatment by coagulation.

The Pall Aria system transforms water from any source into water that meets your requirements.

Trust your surface water, groundwater, wastewater, and salt water treatment to Pall, the global leader in filtration, separation, and purification technologies. Pall Aria systems eliminate contaminants and deliver pure water for drinking, industrial processes, irrigation, and other vital uses. Let us show you how to reduce your total water treatment cost with a Pall Aria water treatment system. To learn more, visit us at www.pall.com/water.





Pall Corporation

2200 Northern Boulevard
East Hills, New York 11548-1289

1.888.428.5597 toll free (only in US)
516.801.9906 phone
516.484.3216 fax
www.pall.com/water

Visit us on the Web at www.pall.com/water

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