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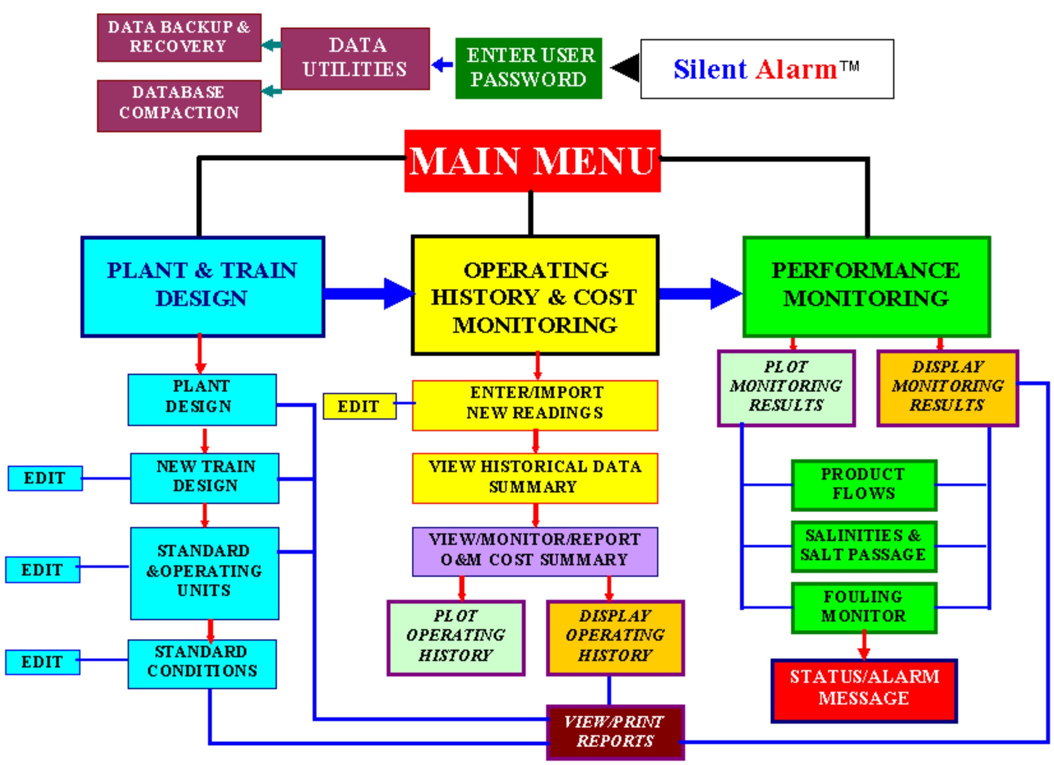
Manufacturer's Case Study

Smart software optimizes membrane plants

Mohamad Amin Saad, MASAR Technologies, Inc., USA

Since the advent of membrane technology applications in commercial and industrial water desalination and purification plants utilizing RO, NF, UF & MF processes, membrane manufacturers, system suppliers and end-users alike have been facing two major problems: how to adequately and reliably monitor membrane system performance and how to detect membrane fouling and scaling development in real time and before significant or irreversible loss of performance and equipment occurs. The current industry-standard membrane performance analysis and evaluation is based on normalization of operating data in accordance with ASTM D-4516 standard method.



WHAT IS AN EARLY-WARNING SYSTEM?

In order for any software or hardware system to be reliably referred to as an **Early-Warning** system, it must be:

- Capable of providing a warning in sufficient time for proper corrective action.
- Affordable (*i.e., cost-effective*).
- Verifiable.
- Reproducible.
- Reliable, producing minimum false positive or negative alarms.
- Simple, requiring low or minimum operator training.
- Comprehensive, covering all potential threats.
- Universal, applicable to most situations in a specific industry.
- Robust, capable of remote operation year-round.

Table 1

What's Wrong with ASTM Performance Trending?

This analytical technique was originally developed by the industry's pioneer and early leader, DuPont, and represents only the membrane performance *trend* from a membrane manufacturer's point of view based on in-house test data and not on real-life site-specific plant's design, operating parameters and other dynamics. By definition, trending requires a statistically valid, and reasonably large amount of operating data records plotted over a long period of time to establish a definite trend. Field experience at a large variety of membrane plants around the world in the past 20 years shows that it is virtually impossible to detect the early development of membrane fouling in a system simply by monitoring a long-term trending analysis. By then, the fouling practically becomes too significant (*i.e., uncleanable*) and often causing irreversible loss in performance and element damage. This is largely due to the fact that fouling is cumulative in nature and builds up over a long period of time, unless it is already too severe from the start, before it starts noticeably exhibiting its physical effects at the plant.

The Fouling Monitor™ (FM)

To address the critical need of RO, NF and other membrane plant operators and owners to detect and measure membrane fouling or scaling development as early as it starts to occur and to monitor the real performance of their membrane systems in real-time, MASAR Technologies, Inc., has developed an innovative and practical new approach – the Silent Alarm™. The new approach was discovered after many years of closely monitoring and trending the flux decline performance of a large RO plant with a biofouling history that exhibited itself suddenly after the first 2 years of operation. Many plants which are prone to fouling typically start exhibiting significant and sudden losses in productivity and/or deterioration in product quality when the ASTM-normalized "trend" in flux decline or salt passage has matured, at which point it is almost too late to save the plant. Significant losses in the plant's performance, availability and consequently, O&M costs, result. The technology is capable of detecting fouling or scaling development at the onset, and quantitatively measure it via a parameter known as the Fouling Monitor™ (FM) representing the percentage differential between the industry-standard ASTM-normalized flow and the corrected-normalized flow of each data point using the new approach, represented by the yellow area on the graph (*Figure 1*). The new monitoring system acts as an ***early-warning*** system and benefits plant owners and end-users in optimizing the total cost of produced water.

Case History A

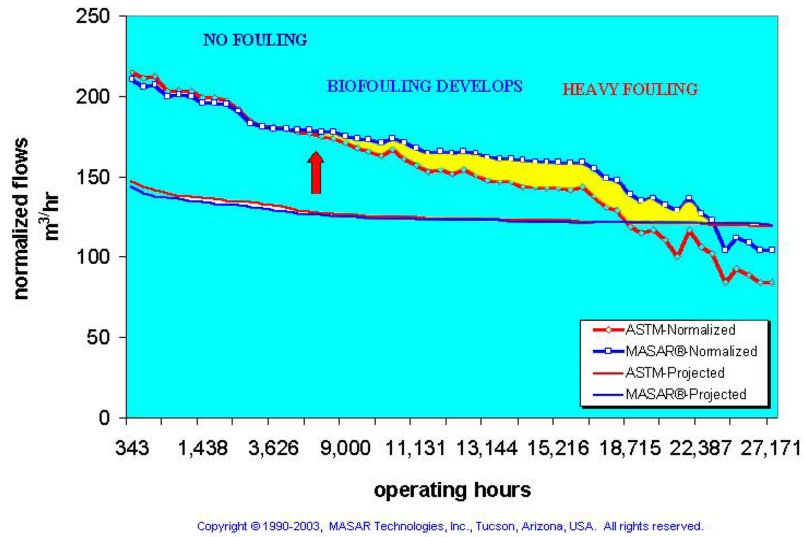


Figure 1.a. Biofouling RO Plant's Flux Decline History

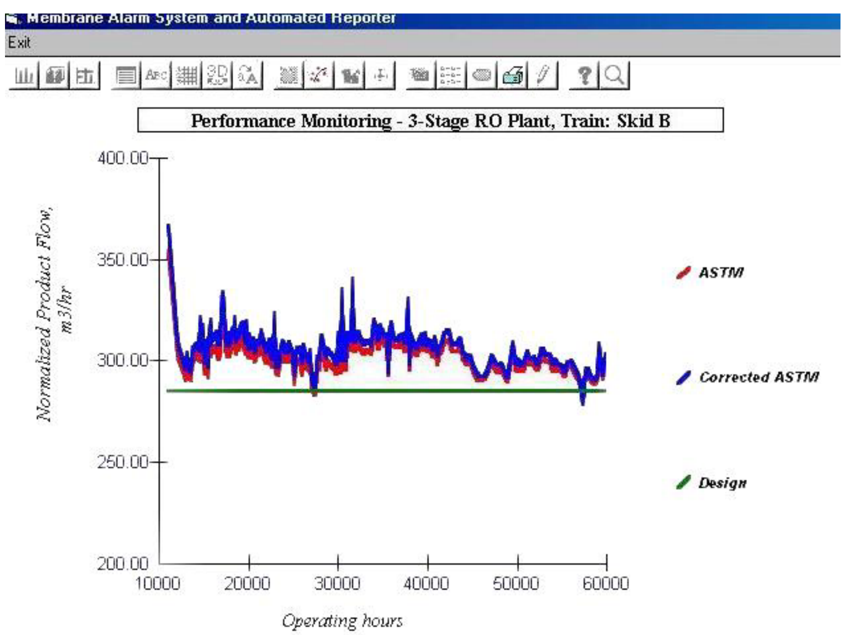


Figure 1.b Non-fouling RO Plant's Flux Decline History

Figure 1.a shows a typical normalized flux decline graph of a large RO plant located in the Arabian Gulf, with DuPont's seawater hollow-fine fiber membranes, (*Ref. 1*).

The plant witnessed a biofouling event that started to be exhibited on site at the end of the second year of operation (*about 17,500 operating hours*). However, the FM shows the start of fouling development almost 9 months earlier (*at the beginning of the split between the two normalized flux decline lines*).

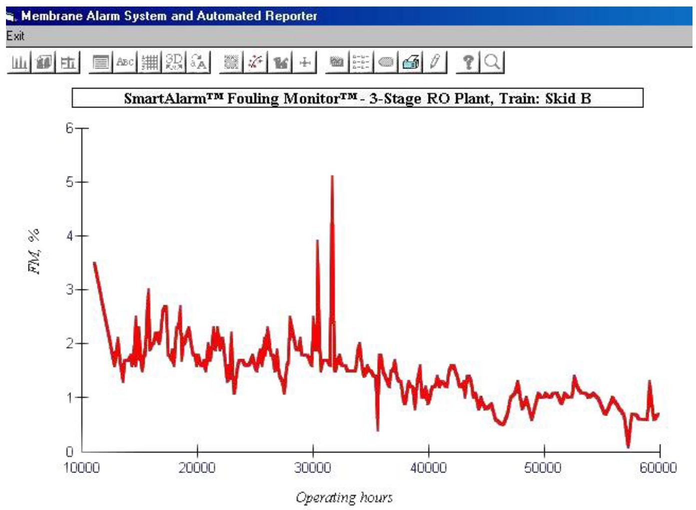


Figure 1.c Non-fouling RO Plant's Fouling Monitor™ History

Because the plant was *apparently* performing so well in terms of productivity and quality, the biofouling went undetected until the flux suffered a sudden drop. Subsequent frantic cleanings proved ineffective and a large number of membranes had to be replaced at a great cost, coupled with loss of plant availability and much lower productivity.

Figure 1.b shows the same plant after correction of the biofouling problem, membrane replacements and other process and operational changes that resulted in sustaining excellent, non-fouling performance for the last 5 years. The average FM for this period was 1.5% (*Figure 1.c*).

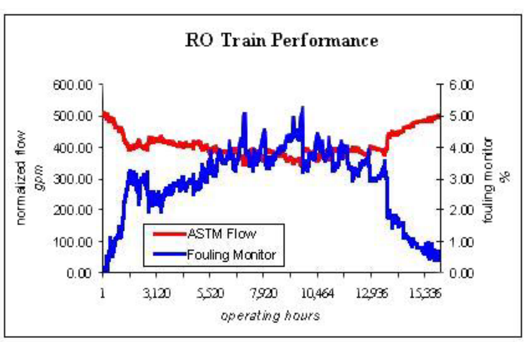


Figure 2.a

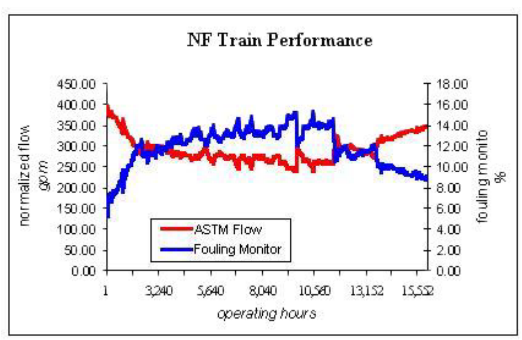


Figure 2.b

Case History B

Figure 2.a shows the ASTM-normalized flux decline trend vs. the Fouling Monitor™ performance of the RO train at the 1.0 MGD Port Hueneme's Brackish Water Reclamation Demonstration Facility near Santa Barbara, California. *Figure 2.b* shows the same graph for the NF (nanofiltration) train at the same plant. Both trains were identical in design and operated side-by-side using the same feed water source and pretreatment system with Dow Filmtec®'s spiral-wound membranes. The plant experienced a history of biofouling from start-up in November 1998 till June 2000 (*about 13,500 operating hours*) when the plant operator switched the major raw water disinfection agent from chorine to chloramine.

Both trains, as monitored by the plant using the standard ASTM normalization, showed equal improvement and restoration of performance in the aftermath of the change in the disinfection method. However, the new approach uniquely showed that the NF train, not only exhibited higher FM values from start-up than the RO train, but it was still behaving differently and has not fully recovered from the biofouling event. The plant later revealed that the NF membrane cartridges in this train also had a manufacturing defect and were all consequently replaced. This would explain the irregular performance of this train that was discovered only by the new technique, based on trial evaluation of operating data over 16,000 hours, even after the biofouling issue was resolved (*Ref. 2*).

Based on the above case histories and many other from different membrane plants around the world, the Fouling Monitor™ satisfies all of the listed requirements as an *early-warning* system for RO, NF, UF & MF membrane water purification and desalination plants (*Table 1*).

Fouling Monitor™ Practical Guidelines

Based on 20 years of plant fouling and performance monitoring field experience around the world, membrane water desalination and purification plants exhibiting FM values under 3% are considered well operated and maintained plants with little or no fouling. As soon as the program indicates an FM increase, within just a few hours or days, the operator is soft-alarmed so that corrective action can be initiated immediately to find the source of fouling while the plant is apparently still performing well and while no panic cleaning, which is often ineffective, is needed.

Silent Alarm™ Software

The universally-applicable and fully-tested software program, the Silent Alarm™, was subsequently developed based on the new *Silent Monitoring and Automated Reporting Technology*. Since its first introduction in 1997 at the IDA World Congress on Desalination & Water Re-use in Madrid, Spain, the software system, a stand-alone Visual Basic application, has been marketed as MASAR® (*Membrane Alarm System and Automated Reporter*). Several versions of the program are available for single-pass RO/NF and UF/MF plants. A version is also available for single-train RO/NF

FM RANGE	FOULING STATUS	RECOMMENDED ACTION
0% - 3%	No significant fouling.	Good operation. Continue to monitor.
3%-10%	Low to moderate fouling may be starting to develop.	Monitor more closely. Consider trouble-shooting if trend rise continues.
10%-20%	Moderate to heavy fouling is in progress.	Start trouble-shooting immediately to identify and eliminate source of fouling.
Over 20%	Heavy to irreversible fouling is occurring.	Significant membrane replacements required due to extensive loss of performance and possible physical damage.

Table 2. Fouling Monitor™ (FM) Guidelines

systems and another customized for double-pass applications, such as UF or MF (as pretreatment) followed by RO or NF for desalination or purification. A monthly in-house plant monitoring and evaluation service is also available requiring only e-mail transmission of train operating data files in order to deliver a full performance evaluation and fouling status report, complete with recommendations for action if required. A early-warning alert is also sent to the plant in case fouling or scaling development is detected.

Program Applications

Serving as a real-time, early-warning performance, fouling and O&M cost monitoring and optimization tool, as well as an integrated plant data management & reporting system, the program's operating data input is based only on the same design & operating data parameters required by ASTM D 4516 - "*Standard Practice for Standardizing Reverse Osmosis Performance Data*" (*Ref. 3*). The new methodology and software program apply universally to any water desalination or purification membrane plant (*for drinking & industrial end-use applications*) with:

- ♦ Brackish, high brackish, seawater & wastewater feed sources.
- ♦ RO, NF, UF or MF membrane process.
- ♦ Single or multi-brine-staged systems.
- ♦ Single & double-pass systems (i.e., UF/RO).
- ♦ Multiple numbers of trains or skids.
- ♦ Any membrane manufacture, model, material (*cellulose acetate, polysulfone or polyamide*), configuration (*spiral-wound and hollow-fine fiber*) and design (*number of membrane cartridges per pressure vessel*).
- ♦ Any system design configuration and layout.

The program is especially valuable for R&D, product development and pilot testing monitoring & optimization, such as those conducted by water treatment chemicals suppliers, academic institutions and industrial research labs. The instant, real-time response of the system is critical in evaluating and monitoring the *true* efficacy of membrane cleanings, chemical dosing systems and impact of on-line changes in design, process or operational parameters in the field. This allows the maintaining of the system dynamics while different process and operating parameters are tested.

The program also monitors and displays, in graphical and report forms, the operating membrane flux (*feed or product flow per unit membrane area*) as well as the MASAR®-calculated flux that serves as another real-time indication of fouling development potential, especially in ultrafiltration and microfiltration membrane systems designed as pre-treatment to RO or nanofiltration plants.

Program calculations incorporate empirical conductivity to NaCl salinity conversions, especially for difficult Arabian Gulf seawater and high-brackish feed waters, as well as the latest salt passage correction standards reflected in ASTM D 4516-00, published in 2000.

Operating Cost Monitoring

The program is currently being upgraded with a major new feature that will help membrane desalination plant owners and operators calculate and monitor their operating and maintenance costs in real-time. O&M costs monitored will include chemicals consumption, membrane replacements and additions, energy utilization and labor. Operators will be able to enter their cost basis data such as chemicals and supply parts prices, price indices, wages & salaries, units, conversions, etc., as well as actual O&M cost data such as chemical dosages & consumption rates, membrane & filter cartridges replacement rates, membrane cleaning frequencies, equipment and spare part purchases, repairs and maintenance, energy usage and other important items. Indirect operating cost items, such as capital cost amortization, financing, interest or cost of long-term investments will not be included in the O&M cost calculations.

Output will consist of a summary of total and itemized O&M costs (on a daily, monthly and annual basis), with corresponding reports and graphs. Cost profiles of major categories, such as chemicals, membranes and energy, may also be plotted against plant productivity, conversion and water quality to give plant operators tangible and realistic correlations to better manage their budgets and optimize their final cost of water.

Conclusion

With membrane technology applications exploding in growth and utility around the globe, the need to address the problem of monitoring and evaluating membrane desalination plants performance, fouling development and operational cost-effectiveness becomes ever so critical. New mega plants are already operating or coming on line, or being designed or conceptualized in the new millennium, such as the 90,000 m^3/d seawater RO plant in Al Jubail, Saudi Arabia, the 142,000 m^3/d seawater

RO plant in Al Fujairah, UAE, the 109,000 m^3/d Point Lisas seawater RO plant in Trinidad, the 24 MGD seawater RO plant in Tampa Bay, Florida (with another 24 MGD plant planned for the same district in the near future), the 25 MDG seawater demonstration plant in Corpus Christie, Texas and the 45 MGD seawater RO plants planned by the Metropolitan Water District of Southern California. Reliable performance and availability of these plants, for example, at minimum operating and maintenance costs are mandatory. The new Silent Alarm™ program can provide these plants and many others a unique tool to help them achieve these objectives on a daily basis.

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About the author

Mohamad Amin Saad has a B.S and M.Sc. in chemical engineering from Georgia Institute of Technology, Atlanta, Georgia, USA. During the past 20 years of his professional career in the water *desalination and membrane technology applications, he has gained tremendous technical and practical field experience in RO plant design, startup & commissioning, operation optimization, performance evaluation, trouble shooting and membrane fouling identification and prevention, particularly in the Middle East, Europe and USA, and published several international technical papers. He has also designed and conducted numerous membrane desalination technology in practice seminars, workshops and courses for plant operators, engineers and managers. Mr. Saad worked as a Senior Technical Specialist with DuPont, as a Membranes Development Manager with Aqua-Chem and as a Technical Marketing Director at Biosphere 2 Environmental Project in Arizona before starting his own consulting, training and plant monitoring software development and marketing firm in Tucson, Arizona. He can be reached by e-mail at mas@masar.com or via the company's web site www.masar.com.*