

THE **SMART**[™] TECHNOLOGY INNOVATION

Real-Time Analytic Monitoring & Optimization of Membrane Desalination System Operation & Performance for Successful Digital Transformation of Water Treatment Plants

SilentAlarm[™] *Early-Warning* Detection, Measurement and Monitoring of Membrane System Fouling & Scaling Development

THE TECHNOLOGY

- Innovative and reliable software application system that measures and monitors the performance and fouling development of all Reverse Osmosis (RO), Nanofiltration (NF), Ultrafiltration (UF) and Microfiltration (MF) membrane systems in brackish water, seawater and wastewater purification plants.
- The **SilentAlarm**[™] software is based on **MASAR**[®]'s proprietary **SMART**[™] (**Silent Membrane Alarm in Real Time**) innovative, unique and field-tested technology, and therefore, it is different than all available normalization programs from membrane manufacturers in that it does not rely on performance trending but rather on measuring its true parameters and fouling potential in **real-time**.
- The **SilentAlarm**[™] calculates and displays a unique membrane system fouling indicator, developed by MASAR Technologies, Inc., called the **Fouling Monitor**[™] (**FM**), which is the difference in normalized flows calculated using both ASTM D-4516-00 method as well as the proprietary corrected The **SilentAlarm**[™] method.
- Monitoring the **FM** allows users to continuously check the membrane system's operational performance and detect the development of any membrane fouling or deterioration trends *long before* adverse symptoms are exhibited, resulting in significant or irreversible loss in performance characteristics. *No additional data collection or system maintenance is required by the **SilentAlarm**[™].*
- This translates into significant reduction in plant's down time, maintenance and operating costs while assuring that plant produces the design quantity and quality of water with maximum efficiency and availability.

The **SilentAlarm**[™] **minimizes your plant's total water production cost and maximizes its availability & efficiency like no other system in the world.**

Your partner in successful transformation of your water treatment plant

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*Consulting * Membrane Plant Services * Training * Software Solutions & Licensing*

SilentAlarm™ Benefits

The **SilentAlarm™** provides a unique, proven and reliable tool to the plant owner and operator that will assure that the plant produces or exceeds the design quantity and quality of desalinated water with maximum efficiency, reliability and availability at lowest possible total cost of water production.

This is how:

- 1. The **SilentAlarm™** MONITORS YOUR PLANT'S OPERATIONAL AND PERFORMANCE, FOULING & COST STATUS RELIABLY IN REAL TIME, NOT AS A LONG-TERM TREND.**
 - By monitoring the **Fouling Monitor (FM)**, the **SilentAlarm™** allows the plant operators to continuously check the membrane system's operation status and detect any adverse performance changes or deterioration, such as biofouling, colloidal fouling, silica or chemical scaling, as early as they develop in the system and long before they are exhibited at the plant.
 - Unlike the standard normalization method (ASTM D 4516), used by all membrane manufacturers and required by them for membrane warranties, the **FM** measures and shows the actual performance of the membrane system on a day-by-day basis (i.e., in real-time), not as a long-term trend that cannot be fully determined or utilized until it is too late (i.e., when severe fouling effects are exhibited at the plant resulting in significant plant performance, availability and cost losses).
- 2. The **SilentAlarm™** DETECTS AND MEASURES FOULING AND SCALING DEVELOPMENT, AND GIVES THE OPERATOR EARLY WARNING AND RECOMMENDS PROPER ACTION BEFORE TOO LATE.**
 - If the system is beginning to foul or scale, The **SilentAlarm™** alarms plant managers, engineers and operators, and prompts them to take immediate corrective action while the plant is still performing according to or above design values, and months before significant or irreversible loss in performance characteristics are experienced.
- 3. The **SilentAlarm™** HELPS YOU ACHIEVE THE MOST ATTAINABLE OPTIMUM CONDITIONS FOR YOUR SYSTEM OPERATION.**
 - If the system is not fouling and performing as designed or better, the **SilentAlarm™** confirms the non-fouling conditions everyday and allows you to determine if the plant is actually running at the most optimum conditions without having to wait for a long-term trend to develop and be analyzed.

- the **SilentAlarm™** helps optimize and achieve the maximum attainable membrane system recovery ratio by monitoring the true fouling potential as the recovery ratio is incrementally increased to the maximum level allowed by feed water chemistry and system limitations. Most RO plants operate well below their maximum recovery ratios because of warranty limitations or fear that the system will react negatively and cause problems.
4. the **SilentAlarm™** SHOWS THE TRUE EFFECT OF DESIGN, PROCESS AND OPERATIONAL CHANGES, MEMBRANE CLEANINGS, ADDITIONS AND REPLACEMENTS AND CHEMICAL DOSING.
- By monitoring and measuring the actual performance of your system on a daily basis, NOT as a long-term trend, the **SilentAlarm™** allows the plant operator to determine the true need for cleanings, membrane additions or replacements, change of disinfectants or anti-scaling chemicals or other process and operational changes.
 - As a truly independent system, the **SilentAlarm™** is especially effective in comparing different membrane performance under the same dynamic plant conditions. When the plant changes the membrane manufacturer and replaces membranes on a train, for example, it will be able to compare the actual performance and fouling tendency of the new membranes versus the old ones, and make an informed decision on which ones work better for this specific application.
 - Most RO plants go by a pre-set schedule for system maintenance, especially for cleanings and membrane replacements or additions, not taking into account the actual system performance at the time, but the **SilentAlarm™** lets you reliably determine if there's a need for such maintenance at any time, and helps save you significant expense from unnecessary or ineffective cleanings, chemicals, labor and other O&M costs.
 - the **SilentAlarm™** is effective in testing the effectiveness of new treatment chemicals such as coagulants, anti-scalants and biocides, either on pilot systems or on actual plant. It also helps test new processes or equipment (such as microfiltration) and their impact on RO performance and cost.
5. the **SilentAlarm™** DIFFERENTIATES BETWEEN FLUX DECLINE CAUSED BY EITHER MEMBRANE COMPACTION OR BY FOULING/SCALING.
- Because the **SilentAlarm™** monitors the **FM**, as the only sensitive indicator of fouling, by taking the difference between two normalized product flows, it actually can tell you if the decline is due only to compaction (i.e., **FM** remains low but the two normalized flux curves decline together), or due to fouling or scaling (i.e., **FM** increases significantly in a short period while

- the two normalized flux curves decline). This is important because most RO plants which monitor their normalized flux decline curves cannot distinguish between the two effects, leading them to believe that they have a fouling problem (and starting unnecessary membrane cleanings, additions, etc.) while the problem is only that the decline is due to membrane compaction higher than projected by the membrane manufacturer or designer.
- A recent case history study showed that the **SilentAlarm™** actually indicated that a set of nanofiltration membranes had a membrane manufacturing defect as compared to an identical RO set that was free of any defects.

6. the **SilentAlarm™ ACTS AS YOUR PLANT'S FULLY-INTEGRATED PERFORMANCE, FOULING, O&M COST MONITORING AND DATA MANAGEMENT & REPORTING SYSTEM.**

- The software system is designed so that the operator can easily and selectively produce professional plant operating and performance history reports and graphs for each train, stage and operating hour range.
- The system maintains 2 user-accessible databases or storing operating data records and for performance data summaries.
- Data entry can be done manually by the operator, downloaded automatically from the plant's data acquisition systems, or transferred directly from any membrane manufacturer's normalization program files.
- The software system is extremely user-friendly and error-proof (i.e., does not accept invalid or erroneously entered data and prompt the user to correct the problem immediately in a simple language to avoid system failure).
- The system applies universally to any membrane-based water desalination or purification plant with any end-use application, feed source, membrane type, material, manufacture, configuration or system array.
- The software expert system is available in 2 license versions to suit most membrane desalination and filtration plant applications:
 1. Single -pass, single-plant, multi-train, multi- stage RO or NF.
 2. Double-pass, single-plant, multi-train, multi-stage UF/MF and RO/NF.
 3. Single -pass, single-plant, multi-train, multi- stage UF or MF (stand-alone).

The software expert system can also be customized to suit your particular application, special design features and data input/output requirements.

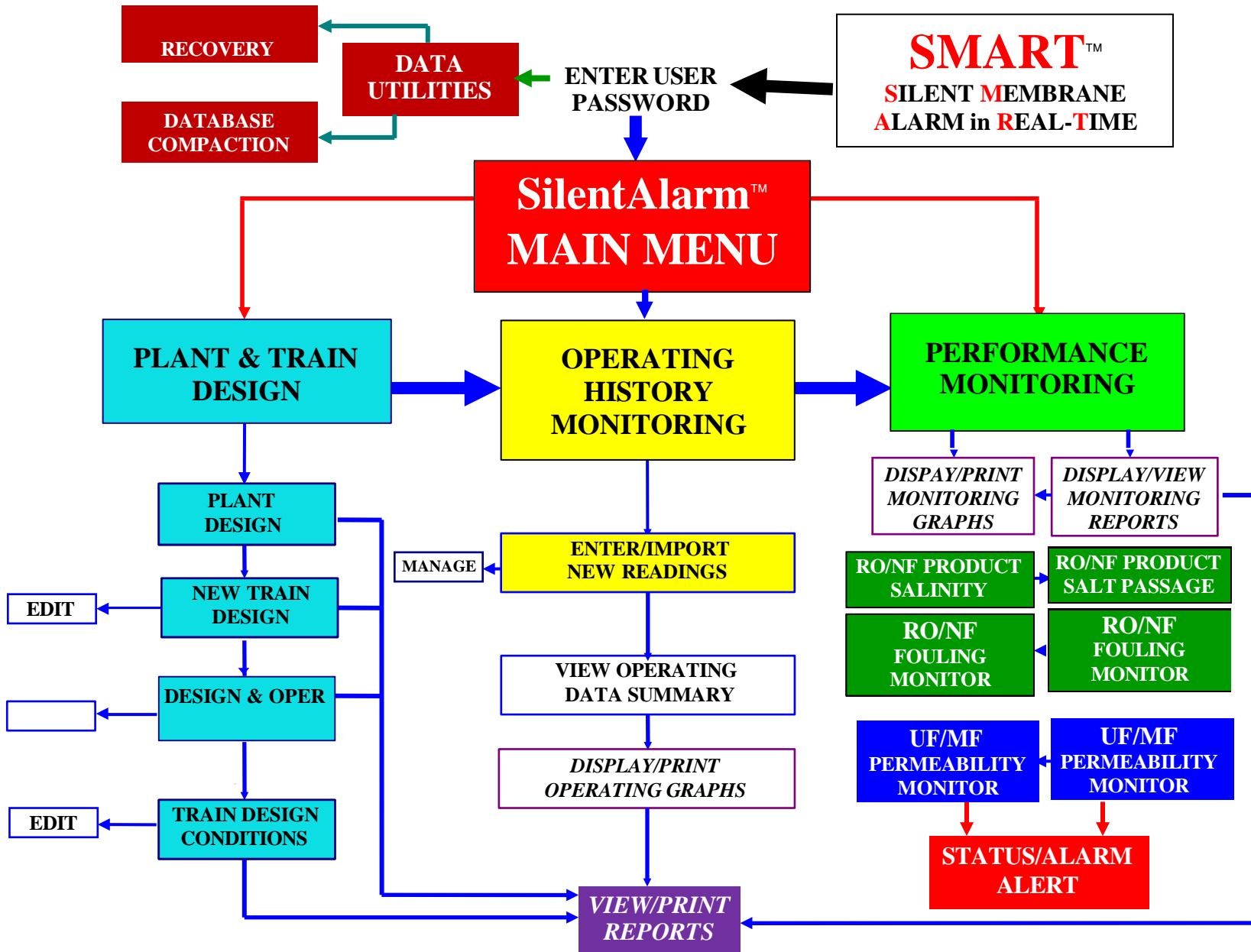
7. The **SilentAlarm™ HELPS YOU OPERATE AND MAINTAIN THE MOST EFFICIENT, OPTIMUM-PERFORMING MEMBRANE DESALINATION PLANT AT THE LOWEST WATER COST WITH:**

- ❖ **A significant reduction in operational downtime.**
- ❖ **A significant reduction in fouling potential.**
- ❖ **A significant reduction in maintenance.**
- ❖ **A significant reduction in O&M costs.**
- ❖ **A significant improvement in plant data management.**

The **SilentAlarm**™ software system has been successfully tested, evaluated, operated or verified at more than 20 membrane desalination plants around the world, and approved for field application by DuPont's Permasep® Products, the pioneering membrane manufacturer that introduced membrane technology applications commercially since 1979, and also wrote the procedures for membrane system performance evaluation that later became ASTM standard method D-4516, the basis for all available normalization software programs, which this innovative technology challenges. It has also been licensed to the Saline Water Conversion Corporation (SWCC) in Saudi Arabia, the largest producer of desalinated water in the world, Saudi ARAMCO, the largest producer of oil in the world, South Australia Water Corp., and others.

RECOMMENDED LITERATURE

1. Saad, M.A., "The SMART Solution to Membrane Fouling Detection, Monitoring & Management", presented at and published in the proceedings of the *IDA World Congress on Desalination & Water Reuse*, San Diego, California, USA, Aug.-Sept. 2015, IDA, Massachusetts, USA.
2. Pelekani, Jewell, and Kilmore, "Design, Operating and Research Experience at the Penneshaw Seawater Desalination Plant, South Australia", presented at and published by the IDA World Congress-Maspalomas, Gran Canaria –Spain October 21-26, 2007.
3. Saad, M.A., Richardson, J., "Real-time Membrane Fouling Monitoring – A Case History", *Proceedings of the World of Water Conference*, Las Vegas, Nevada, USA, December, 2001. Excerpted in *Industrial WaterWorld Journal*, Case Studies, 2002,
4. Saad, M.A., "Manufacturer's Case Study: Smart Software Optimizes Membrane Plants" –*International Desalination & Water Reuse Quarterly*, August/Sept. 2003, Vol. 13/2, pp. 45-49, Faversham House Group Ltd., UK.
5. Saad, M.A., "Real-Time Monitoring of Membrane Fouling", *Waste & Energy Thailand*, March-April 2008, TechnoBiz Communications Ltd., Bangkok, Thailand.



Summary of the **SilentAlarm™** Software System Features

1. Measures & displays a unique, early-warning **Fouling Monitor** for the average train on line and recommendations for action.
2. Needs ONLY your membrane system's design & operating data: *Manually entered, uploaded or transferred from any of your data files.* Selection of American or metric (SI) design and operating units:
Stream salinities/conductivities, flows, pressures and membrane pressure drops.
3. Applies universally to ANY water treatment membrane system: *RO, NF, UF & MF: single & double-pass systems (i.e., UF/RO).* Can be utilized in ANY end-use application:
Drinking, Municipal, Ultrapure & Industrial Wastewater.
4. Incorporates the latest ASTM standards:
 - *Salt passage corrections-ASTM 4516-00 RO data standardization method.*
 - Selection of data view, display, charting and reporting:
By pass, train/skid, stage and operating hour range.
 - Customizable plant record-keeping and reporting system:
operating data entry, editing and validation, screens, reports & graphs. User-friendly, error-proof and menu-driven software: *MSWindows®95/08/2000/NT-compatible; point and click navigation.*
 - User access to design, operating and performance summary data:
Data export, instant plant data backup and emergency recovery capabilities.

SOFTWARE FUNCTIONALITY

Data Entry/Edit

- Plant and Train Design Parameters
- Standard and Operating Units
- Standard Conditions - *by Train and Stage*
- System Operating Data - *by Train, Stag and Operating Hour Range*

Screen Displays— *by Train, Stage/ Overall System and Operating Hour Range*

- Operating Data - *includes bad and duplicate data checks*
- Normalized Product Flows, Salinities and Salt Passage (*ASTM & SilentAlarm™*)
- **Fouling Monitor™ (FM)** - *for each operating record and overall average.*

Graphs (View/Print)

- Plant's Operational History and Water Condition Profiles:
Feed Salinity, Temperature, Pressure and Flow, Product Flow, Conversion and Salinity, Membrane Pressure Drop.
- Performance Monitoring Results: *Normalized Product Flows, Salt Passage and **FM***

Reports (View/Print)

- Plant and Train Design Parameters and Units
- Standard Conditions (*basis for normalization*) - *by Train and Stage*
- Operating Data and Performance Monitoring Results - *by Train, Stage/Overall System & Hours*

OTHER FEATURES

- ◆ User-friendly, point-and-click MSWindows®95/98/2000/NT-compatible software system.
- ◆ Applies to any plant feed source (*brackish, wastewater, seawater*), membrane manufacture (*make and model*) and material, system brine-staging (*1-3 stages*), design configuration and layout (*number of membrane vessels per pressure vessel*).
- ◆ **Single-pass** systems and **Double-pass** system, as well other custom systems (i.e., *triple-pass systems*) are available for ultrapure water and other special applications requiring more than one phase of purification such as SWRO/BWRO or UF/SWRO, etc.
- ◆ Choice of manual data entry, datafile transfer and/or automatic operating data logging (*database compatible with plant data acquisition system if pre-configured as required*). Any combination of all 3 methods can be used.
- ◆ Plant's design and historical operational data conversion and transfer from any electronic data file format (i.e., spreadsheet, database or data files used in all membrane manufacturers' normalization programs) directly into the **SilentAlarm**™'s MSAccess® database to prevent data logging interruption or loss as well as ability to review plant's operating and performance history immediately upon software installation.
- ◆ Operating and performance data selection, display, editing, plotting & reporting by pass, train, stage/overall and operating hour range.
- ◆ Detection of unreliable or erroneously entered data that do not meet actual system limitations and capabilities.
- ◆ User-defined authorized access by password if desired.
- ◆ Customization options for system functionality, data display and report/graph output.
- ◆ Error-proof, user-interface features to ensure reliability of data entry and retrieval.
- ◆ Operating and design data backup, export & recovery in case of system malfunction.

Summary of **SilentAlarm**™ Plant References

The following is a partial list of membrane plant installations worldwide where **MASAR**®'s **SMART**™ innovative membrane system fouling and performance monitoring and optimization technology and the **SilentAlarm**™ software systems, developed exclusively by Eng. Mohamad Amin Saad, have been used or installed, including plants for which the membrane system's performance and fouling history have been evaluated or monitored (either on-site or in-house) using actual historical plant operating data & membrane system design parameters:

1. Abqaiq Brackish RO Plant 500 (Upgraded 17,500 m³/d capacity with Hydranautics and Toray spiral membranes), Saudi Aramco, Saudi Arabia, 2012.
2. Al Jubail Seawater RO Plant (91,000 m³/d capacity with Dupont hollow fiber, and Toray & Toyobo spiral membranes), SWCC (Saline Water Conversion Corporation), Jubail, Saudi Arabia, 2007.
3. Abqaiq Brackish RO Plant (9,000 m³/d capacity with Toray spiral membranes), Saudi Aramco, Saudi Arabia, 2007.
4. Penneshaw Seawater RO Plant (300 m³/day capacity with Koch spiral membranes), South Australia Water Corp., Adelaide, Australia, 2005.
5. E.I. Dupont's *Permasep*® Products RO plants in the Middle East/Arabian Gulf and US Research facilities, 1998 – Testimonial letter, issued by DuPont's Permasep® Products following the conclusion of the 9-month evaluation and testing in the Arabian Gulf and US Research Facilities, agreed with our conclusion that **MASAR**® is "an excellent to monitor plant performance and capable of providing an early warning if membrane fouling is occurring", and recommending its use of the **MASAR**® software technology at RO plants employing DuPont membranes (copy of letter available upon request).
6. Al Fujairah Seawater RO Plant (190,000 m³/d double-pass capacity with Hydranautics spiral-wound membranes), ADWEA (Abu Dhabi Water & Electricity Authority), Fujairah, UAE, 2006-2016.
7. Gabes Brackish RO Plant (22,500 m³/day capacity with Toray spiral-wound membranes), SONEDE, Tunisia, 2003-2004.
8. Pembroke Seawater RO Plant (54,000 m³/d capacity with Dupont hollow fiber membranes), MDS (Malta Desalination Services), Malta, 2003.
9. Industrial Wastewater RO Plant (30,000 m³/d capacity with Dow Filmtec spiral membranes), SUT Sakra Pte., Singapore, 2003.
10. Ras Abu Jarjur High-brackish 3-stage RO Plant (52,500 m³/d capacity with Dupont's hollow fine fiber membranes), Bahrain, 1998-2002.

11. Port Hueneme Demonstration Recycling Facility, brackish RO and Nanofiltration Trains (5,700 m³/d capacity with Dow Filmtec' spiral membranes), California, USA, 1999-2000. See paper entitled "Real-time Membrane Fouling Monitoring – A Case History", presented at and published by the World of Water™ Conference, Las Vegas, Nevada, USA, December 10-12, 2001. Also excerpted in Industrial WaterWorld Journal, Case Studies, PennWell, January 2002.
12. Clifton Brackish Nanofiltration Plant (9,000 m³/d capacity with Osmonics' spiral membranes), Colorado, USA, 2001.
13. Brackish RO Plant – 4 Arrays (264 gpm capacity with Koch Fluid Systems' spiral membranes), USA, 2001.
14. Burrton Brackish Pilot RO Plant (6 gpm capacity with Koch Fluid Systems' spiral membranes), Colorado, USA, 2001.
15. Sajaa Brackish RO Plant (5,700 m³/d capacity with Dow Filmtec' spiral membranes), Sharjah, UAE, 2000-2001.
16. Orange County Water District Brackish RO Pilot Plant (300 gpm capacity with Koch Fluid Systems' spiral membranes), Municipal facility, Southern California, USA., 2000.
17. Motorola's Ultrapure Water Double-Pass RO Plant (350 gpm capacity with Dow Filmtec' spiral membranes), Chandler, Arizona, USA, 2000.
18. Brackish Microfiltration Pilot Plant – Unit 3 (250 gpm capacity with US Filter's Memcor hollow fine fiber membranes), Texas, USA, 2000.
19. Brackish Microfiltration Pilot Plant (25 gpm capacity with US Filter's Memtec hollow fine fiber membranes), Texas, USA, 2000.
20. West Basin Water District Brackish RO Plant (42,600 m³/d capacity with Hydranautics' spiral membranes), Municipal facility, Southern California, USA., 1999- 2000.
21. New Port News Brackish RO Plant (21,600 m³/d capacity with Hydranautics' spiral membranes), Virginia, USA, 1999.
22. Ghar Lapsi Seawater RO Plant (34,000 m³/d capacity with Dupont's hollow fine fiber membranes MDS (Malta Desalination Services), Malta, 1999.
23. Riyadh Water & Sewage Authority's 6 Riyadh Region Brackish RO Plants: Salboukh, Manfouha I & II, Shemaisi, Malaz (160,000 m³/d design capacity with Dupont's hollow-fine fiber membranes) and Buwaib (46,800 m³/d design capacity with Osmonics' spiral membranes) – 1998. The **SilentAlarm**™ was effectively specified as the only system proven to perform "*special calculations to measure the Fouling Index as a function of plant's operating conditions and elapsed time*" - Al Shumaisi RO Plant's Refurbishment Contract, Technical Specifications, General Conditions (page 63).
24. Ad-Dur Seawater RO Plant (45,000 m³/d capacity with Dupont's hollow fine fiber membranes), Bahrain, 1998.
25. Selected SWRO plants with DuPont's Permasep Products membranes in the Arabian Gulf Region, tested and validated internally under Beta Test Agreement (1997-1998).