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The Four Most Common Problems in Membrane Water Treatment Today

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In this article, we will look at the four most common problems currently affecting membrane water treatment units. A membrane water treatment unit refers to a spiral-wound nanofiltration or reverse osmosis unit. The problems are listed starting with the biggest problem. The four most common problems are:

1 – Inadequate Training of Personnel
2 – Inadequate Microbial Control
3 – Inadequate Monitoring
4 – Inadequate Equipment Design

The problem is first defined, then a list of recommendations in an a, b, c, and d format is provided, followed by a more in-depth discussion of each recommendation.

1 Inadequate Training of Personnel

The single biggest problem in the membrane water treatment industry is that too few people have been adequately trained in today's high-tech water treatment technologies. Most of us have gotten into high-tech water treatment by chance or luck, without any formal education or training.

Not everyone requires the same amount of training. There are three general levels of proficiency needed:

a) Knowledgeable **b) Advanced, and** **c) Expert**

As a minimum, every operator, maintenance person, engineer and direct supervisor should be **knowledgeable** about the water treatment system. Each should:

- Have a basic knowledge of how each piece of equipment works and its desirable operating parameters
- Understand the preventive procedures and preventive maintenance required to minimize problems, and
- Know what parameters to monitor in order to be able to tell when a problem is occurring

Additionally, at the discretion of each facility, a few water treatment personnel should possess **more advanced knowledge and skills**, having the ability to troubleshoot the most common upsets that may occur. The most common upsets include scaling, fouling, chemical attack, o-ring leaks, mechanical failures and instrumentation failures. Advanced individuals can provide on-the-job support to less trained and experienced people.

Did You Know?

Water that doesn't have a residual of a biocide present, like chlorine, should be considered biologically active and potentially hazardous to your health. For example, a common treatment scheme is for a plant to purchase chlorinated or chloraminated municipal drinking water as its raw water. It's common to dechlorinate the water before a treatment step like reverse osmosis that could be damaged by chlorine. **Any water downstream of the point of dechlorination should be considered potentially biologically hazardous.**

Finally, two or three key people should be **experts** in the membrane water treatment field. These individuals must have received sufficient training to be able to troubleshoot complex chemical, biological, mechanical and instrumentation multi-point failures; and additionally be able to train and support all other personnel.

2 Inadequate Microbial Control

In order for bacteria to grow quickly enough and extensively enough to cause serious problems, certain conditions must be met in the aqueous environment. These include:

- **a) The presence of food**
- **b) A warm temperature**
- **c) A relatively low flow rate, and**
- **d) The absence of harmful chemicals, such as oxidizing agents**

Food for most microorganisms is organic carbon-containing compounds. The concentration of dissolved organic compounds is measured as Total Organic Carbon or Total Oxidizable Carbon, and commonly abbreviated to TOC. A TOC level of only 1 mg/L may be sufficient to cause a lot of problems. TOC levels of 5-10 mg/L or more are extremely favorable for biofouling.

The ideal temperature range for most water-borne bacteria is 30-40°C (86-105°F). In this temperature range the fastest growth occurs.

Bacteria grow best when a constant supply of food is brought in at a relatively low flow rate. High flow rates minimize growth due to shear force.

Chemicals that kill microorganisms are called *biocides* or *microbicides*. Oxidizing agents are frequently used as biocidal agents. Chlorine is most commonly used.

Except for cellulose acetate membranes, most of today's nanofiltration and reverse osmosis membranes have limited tolerance to oxidizing agents such as chlorine. Therefore, oxidizing agents are typically removed from the feed water just upstream of the membrane unit. This is accomplished either by passing the feed water through an activated carbon bed or by the injection of a reducing agent, usually a sulfite-ion generating compound such as sodium metabisulfite.

Especially for a warm feed water originating from a surface water source, the removal of chlorine, or other biocidal agent, commonly results in the conditions inside of the membrane unit being ideal for bacterial growth. The food, temperature, flow rate and absence of biocide can lead to serious biofouling.

3 Inadequate Monitoring

Many systems don't have sufficient instrumentation to check all of the parameters that must be monitored in order to catch problems at an early stage, when they are most likely to be reversible. Even if the instrumentation *is* adequate, many facilities don't trend the data… and/or no one looks at the data.

While an excellent feed water, like certain ground water, combined with an excellent membrane unit and pretreatment design, may provide a system that seems to "operate on its own", this is frequently not the case. It is important to monitor certain parameters. The most important parameters are:

- **a) Silt Density Index**
- **b) Normalized Permeate Flow**
- **c) Pressure Drop Across each Stage, and**
- **d) Percent Salt Rejection or Percent Salt Passage**

The Silt Density Index (SDI) is a measurement of the fouling potential of the feed water. The SDI procedure measures the amount of fouling that occurs in and on a standard analytical membrane filter pad after a given feed water is passed through the filter pad for fifteen minutes. An SDI of less than 1 is exceptional; less than 3 is good; less than 4 or 5 is usually acceptable. If the SDI is greater than 5, the feed water is generally unacceptable for membrane water treatment. Additional pretreatment is required in order to reduce the SDI.

For many well water sources, an SDI measurement may only need to be taken monthly. For surface water, an SDI measurement should be taken one to three times per day; more frequently during troubleshooting events. For surface water, the data should be entered daily and graphed at least weekly.

Normalized Permeate Flow (NPF) compares the membrane unit's performance today, with the performance that WOULD BE expected if the unit was new, as it was at startup. The NPF equation takes into account changes in permeate flow rate, temperature, feed water salt concentration and various operating pressures. If the Normalized Permeate Flow decreases, this indicates scaling and/or fouling. If the Normalized Permeate Flow increases, this indicates membrane damage or bypass of the membrane. Normalized Permeate Flow data should be recorded daily and graphed at least weekly.

For membrane units, **pressure drop** is a measurement of the pressure into a stage of pressure vessels, minus the pressure out. The pressure drop measurement correlates with the resistance to flow through the stage. With scaling and/or fouling, there is less available space through which water travels, therefore, there is more resistance to a given flow and the pressure drop increases. The pressure drop across each stage should be recorded daily and graphed at least weekly.

Percent Salt Rejection (%SR) typically measures the percentage of feed water conductive substances that are rejected by the membrane. **Percent Salt Passage (%SP)** is the opposite of this; it measures the percentage of feed water conductive substances that pass through the membrane. A conductivity meter on the feed water line and the permeate line are required for real-time measurement of %SR or %SP. Salt rejection decreases and salt passage increases with membrane damage and any condition where the membrane is bypassed, such as an o-ring leak. Scaling also commonly causes the %SR to decrease (or %SP to increase). The %SR or %SP data should be recorded daily and graphed at least weekly.

Every week, a designated person, or persons, should review the Silt Density Index, Normalized Permeate Flow, Pressure Drop, and Percent Salt Rejection or Percent Salt Passage data. The human brain is excellent at quickly seeing whether the trends are stable or there is undesirable performance degradation occurring. Some plants outsource the performance monitoring and evaluation which is also acceptable so long as the evaluations are occurring weekly.

Inadequate Equipment Design

The industrial water treatment industry is booming. There are many new OEMs (Original Equipment Manufacturers) entering the arena, many with little experience. The buyer must be aware. The design of the membrane unit and pretreatment equipment is critical for maximum life and minimum problems.

The design should include the following components:

a) Conservative water flux rates
b) Relatively high cross-flow rates
c) Sufficient instrumentation for adequate monitoring, and
d) An adequate cleaning skid

Water Flux is the amount of permeate that passes through a given amount of membrane in a given amount of time. Water flux is commonly identified as *gfd*, gallons of permeate produced, per square foot of membrane, per day.

For a surface water with adequate pretreatment, 10-14 gfd is a reasonable water flux rate. For an excellent *well* water with adequate pretreatment, 15-20 gfd is OK. For highly pretreated feed water, such as microfiltered, ultrafiltered, or hyperfiltered water, a gfd of 20-30 is typically allowable.

In order to lower bid cost, an OEM may specify fewer membrane elements and pressure vessels than another OEM. This means that the same amount of permeate is being produced by less square footage of membrane. This means that the gfd is higher.

In general, the higher the gfd, the higher the fouling rate. While the initial capital expense may be lower with a higher gfd unit, the overall annual operating and maintenance expenditures may be higher. This added expense occurs every year thereafter.

To calculate gfd for a given unit, multiply the gallons per minute of permeate produced by 1440 minutes per day. This is the total gallons per day of permeate produced. Next multiply the square footage per membrane element times the total number of membrane elements. Standard 8" diameter membrane elements contain 365 to 440 square feet of membrane. Standard 4" diameter membrane elements contain roughly 80 square feet of membrane. You must find out, from the membrane element specification sheet, how many square feet of membrane your elements have. Finally, divide the gallons per day of permeate by the total square footage of membrane to determine a unit's gfd.

For example, let's consider an RO unit that is easy for the brain to understand, not a real RO unit. Let's say that this RO unit has ten 8" diameter, 400 ft^2 membrane elements and produces 50 gallons per minute of permeate.

Fifty gallons per minute times 1440 minutes per day equals 72,000 gallons per day. Ten membrane elements times 400 square feet of membrane each equals 4,000 square feet of membrane. 72,000 gallons per day divided by 4,000 square feet of membrane equals 18 gfd. If this unit was operating on surface water, even municipal drinking water from a surface source, it is likely that fouling is at an unacceptably high rate. Either more membrane elements need to be added, or less permeate needs to be produced to lower the gfd.

Crossflow rates refer to the feed water flow rate that passes across the surface of the membrane. In general, the higher the crossflow rate, the higher the shear force, and subsequently the lower the fouling rate.

If the flow rate exiting each pressure vessel is greater than 25 gpm per 8" pressure vessel, then the crossflow rate is exceptional by industry standards. It is not uncommon for the concentrate flow rate to be less than 20 gpm per 8" pressure vessel. If higher fouling rates than acceptable are seen, this may be one of the contributing reasons.

The need for monitoring *Silt Density Index*, *Normalized Permeate Flow*, and *Percent Salt Rejection* or *%Salt Passage* has been discussed. In order to monitor these parameters, the following instruments are required as a minimum:

- Feed water temperature
- Feed water pressure
- Feed water conductivity
- Permeate flow rate
- Permeate pressure
- Permeate conductivity
- Concentrate flow rate
- Concentrate pressure
- Pressure between each stage

Finally, as a minimum, a good cleaning skid must contain:

✓ A cleaning tank that can hold roughly 2 - 2.5 times the volume of water contained in the first stage pressure vessels.

✓ An adequate mixing system for the cleaning tank so that all chemicals are dissolved prior to initiation of chemical cleaning

✓ A heating element, temperature indicator and temperature controller on the cleaning tank so that the temperature of the cleaning solution may be controlled

✓ A cleaning pump that can deliver up to 40 gpm per pressure vessel of cleaning solution to each stage being cleaned, at a pressure of less than 60 psi.

✓ A cartridge filtration system to remove particulate material

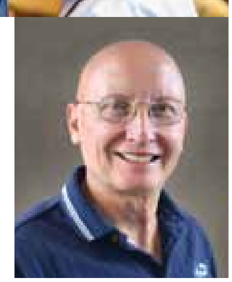
✓ A flow indicator and flow control valve so that the cleaning solution flow rate may be controlled

✓ Pressure indicators at the inlet and outlet of the stage being cleaned so that pressure drop can be monitored and controlled by varying the flow rate

✓ A sample point so that the pH and other parameters of the cleaning solution may be monitored

Conclusion

With the ever-expanding human population, the need for high quality water will not diminish. Membrane water treatment is currently the best available technology for many industrial and municipal applications. The future is bright for trained water treatment people who provide excellent service both to their employer and to their clients.



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- Bill Gates

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