A Fundamental Guide to Industrial

REVERSE OSMOSIS AND NANOFILTRATION MEMBRANE SYSTEMS

A PUBLICATION OF SAMCO TECHNOLOGIES

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TABLE OF CONTENTS

1 What Are Reverse Osmosis and Nanofiltration and How Do They Work?

2 Does Your Facility Need a Reverse Osmosis or Nanofiltration System?

3 Reverse Osmosis and Nanofiltration: Common Problems and How to Fix Them

4 How to Choose the Best Reverse Osmosis and Nanofiltration Systems for Your Facility

5 How Much Do Reverse Osmosis and Nanofiltration Membrane Systems Cost?

Conclusion

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Chapter One

WHAT ARE REVERSE OSMOSIS AND NANOFILTRATION AND HOW DO THEY WORK?

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REVERSE OSMOSIS AND NANOFILTRATION SYSTEMS

What they are and how they work

Reverse osmosis (RO) and nanofiltration (NF) are often discussed in unison as they are similar membrane technologies that solve a variety of process separation and filtration needs. The two technologies are being utilized more and more by industrial facilities looking to recycle and treat water for reuse and conservation. As water scarcity issues continue to increase, these technologies have become a long-term economical solution for avoiding astronomical discharge and water-usage fees in addition to serving other filtration requirements, such as process-water generation and product concentration.

If you are looking for a separation and/or filtration solution, you might be thinking RO/NF is a good fit. **But what are reverse osmosis and nanofiltration, exactly, and how do they work?**

This article will simplify these technological processes so you can get a better understanding of how they might be able to help your facility:

What is reverse osmosis?

Reverse osmosis, also known as RO, is **a membrane technology that uses a semipermeable medium to remove certain ions and particles from a liquid stream.** RO removes contaminants based on their

particle size and charge—generally anything that is 0.0001 µm or larger, including:

- bacteria
- calcium
- colloidal particles
- fluoride
- iron
- manganese
- organic material
- pyrogens
- salt
- viruses

Because of its filtration properties, RO is often used to:

- clean wastewater to acceptable effluent standards or for reuse
- concentrate solvents used in the food and beverage industry, such as whey
- create ultrapure process water streams, such as required in the microelectronics industry
- desalinate seawater or other brine solutions
- generate potable drinking water

RO is **also the reverse process of *osmosis***, a phenomenon that occurs naturally when a lower-solute stream (with a higher water concentration) migrates toward a higher-solute stream (with a lower water concentration) through a semipermeable membrane to achieve concentrate equilibrium.

What is nanofiltration?

While RO and NF are both membrane technologies that use a semipermeable medium to remove certain ions and particles from a liquid stream, they can be distinguished based on the size of particulates that each is able to remove. Comparatively, RO and NF are capable of removing finer contaminants than microfiltration and ultrafiltration, with applications including the removal of:

- hardness
- heavy metals
- nitrates
- organic macromolecules
- radionuclides
- sulfates
- total dissolved solids (TDS)

Nanofiltration, however, delivers slightly coarser filtration than RO, **with the ability to remove particles as small as 0.002 to 0.005 µm in diameter**, including pesticide compounds and organic macromolecules, while retaining minerals that RO would otherwise remove; nanofiltration membranes are capable of removing larger divalent ions such as calcium sulfate, while allowing smaller monovalent ions such as sodium chloride to pass through.

Because of its filtration properties, nanofiltration is often used to:

- concentrate and demineralize valuable byproducts, such as metals from wastewater
- generate potable drinking water
- remove nitrates

- remove pesticides from ground or surface water
- soften water

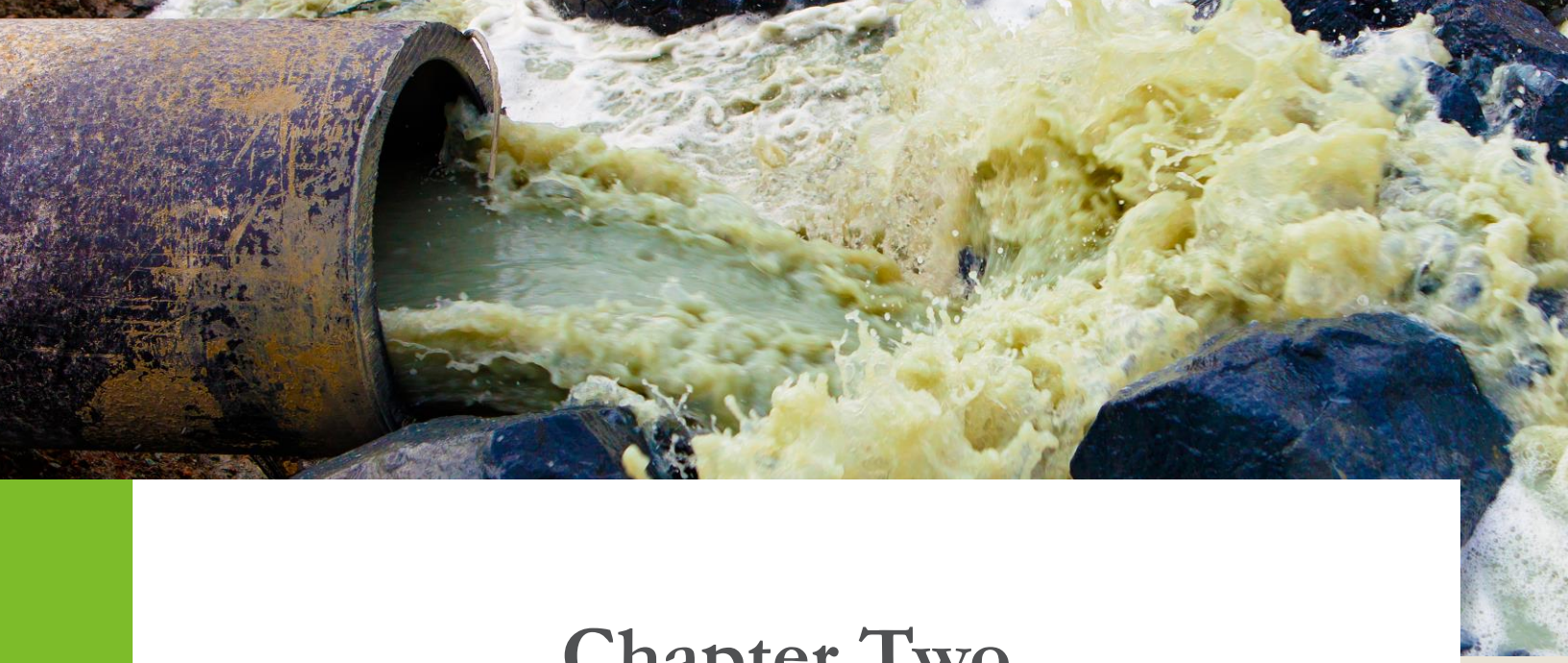
How do they work?

As mentioned above, **RO is the reverse of osmosis, which is a passive, naturally occurring process that happens without the use of energy**. For example, if you were to place a semipermeable membrane in a tub of water then add salt to one side, the water would naturally migrate from the side without salt to the side of the semipermeable membrane where you added the salt to dilute the concentrated, salt-contaminated liquid until the two sides were equally dilute. You would end up with one side having a higher level of water, creating what is known as osmotic pressure. RO and NF function similarly, the difference being what size particulates are being filtered out.

With RO/NF, since you are removing contaminants from a high-solute liquid stream, **energy larger than the naturally occurring osmotic pressure must be applied to force the solvent from the (highly concentrated solution) through the semipermeable membrane in the opposite direction than what would occur naturally and without force**. This causes the permeate to pass through the semipermeable membrane while trapping and filtering out any contaminates larger than the pure water that passes through to the lower-pressure side.

The pressure required to push the solvent through the semipermeable membrane depends on the concentrate of solids. The more concentrated the stream is, the more pressure you need to

apply to overcome the osmotic pressure and force the permeate (filtered water) through. This leaves you with a highly concentrated reject stream that is either used or discarded, depending on the separation/concentration needs of the facility.



Chapter Two

DOES YOUR FACILITY NEED A REVERSE OSMOSIS OR NANOFILTRATION SYSTEM?

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DO YOU NEED AN RO/NF MEMBRANE SYSTEM?

How to know if it's necessary

Implemented judiciously, RO and NF are effective strategies for recycling process liquids, reducing waste water, recovering and concentrating dissolved materials, and generating potable water.

If your industrial facility requires removal of dissolved materials at any point in the process stream, then you may be asking **"Does my facility need a reverse osmosis or nanofiltration system?"**

This chapter will help you understand key applications, benefits, and drawbacks of RO/NF so you can make an informed decision.

RO/NF might be right for your plant if:

You are looking to save on operational costs

RO/NF and conventional treatment processes are capable of removing many of the same contaminants, including hardness, heavy metals, organic molecules, radionuclides, and total dissolved solids (TDS). Conventional separation processes are often complex multi-step systems that demand a variety of operational resources, which can include chemicals, energy costs, and space to accommodate their large footprint. RO/NF, on the other hand, use relatively compact

membrane elements to physically separate substances without the use of coagulant chemicals or energy-intensive heating and cooling. As a result, **RO/NF can be more efficient than conventional treatment systems and occupy a much smaller footprint**.

The downside is that RO/NF systems have historically commanded a steep initial investment, which has generally put them out of reach unless process conditions made them absolutely necessary. But that's starting to change, as growing environmental concerns and advancements in RO/NF membrane technology have recently led to wider adoption and lower upfront costs.

As these trends continue, RO/NF is expected to become increasingly competitive with conventional treatment systems.

Nitrates, sulfates, or organic molecules are present in your process stream

While choosing RO/NF over conventional treatment processes often involves weighing a variety of factors, there are some applications for which RO/NF is uniquely suited.

If your process demands removal of nitrates or sulfates, then RO or NF is likely your best bet. Nitrates and sulfates cannot be efficiently removed through conventional treatment methods, such as coagulation and filtration, thus, to ensure consistent permeate quality and process efficiency, RO/NF is generally the most practical choice.

Likewise, if your process demands removal of dissolved organics, **RO/NF is often far more effective and efficient than alternative separation strategies for removal of organics such as pesticides, agricultural residuals and pharmaceuticals**. For example, RO/NF can operate at room temperature, making it a far less energy-intensive process than distillation for dissolved organics removal. Additionally, RO/NF delivers consistent permeate quality, while microfiltration (MF) or ultrafiltration (UF) must be paired with coagulation, and do not remove dissolved organics as reliably as RO/NF.

Additionally, recent advancements in NF membrane technology have resulted in better resistance to organic solvents, which has spurred the adoption of NF for exchange, separation, and recovery of organic solvents and catalysts.

Your plant experiences scaling

Hardness, or the presence of calcium, magnesium, and other metal cations in water, often leads to scaling in pipes, cooling towers, or equipment, which can negatively impact the efficiency of your process and drive up operational and maintenance costs. While many facilities turn to lime softening or ion exchange technology for water softening, RO/NF is capable of removing problematic divalent ions without the maintenance or waste that other softening strategies can entail. For some applications, RO/NF system maintenance is far more cost-effective than having to regenerate ion exchange resins and/or dispose of concentrated brine waste.

Industry-specific separation needs

RO/NF are used for a wide variety of specialized industrial applications. Some examples of typical RO/NF industrial applications include:

Power

RO/NF are used in the power industry for reliable removal of contaminants and minerals from process streams in order to prolong equipment life, increase cooling tower cycles, and minimize water consumption by facilitating reuse.

Refinery

In the refinery industry, RO/NF are frequently deployed for recovery of valuable materials, such as lithium. While NF is frequently thought of as a means of treating aqueous solutions, the technology can be effectively applied for separation of other process or waste streams as well, including one petroleum plant's large-scale use of NF for oil dewaxing.

Petrochemical and chemical

RO/NF support a variety of specialized chemical processes too numerous to list. RO/NF are typically applied in chemical production for processes that demand consistent quality in the permeate stream. NF in particular is able to process large volumes of liquid relatively quickly.

Oil and gas

RO is used extensively in the oil and gas industry for potable water generation in areas where drinking water is scarce, such as deserts and off-shore oil rigs.

Mining and metals

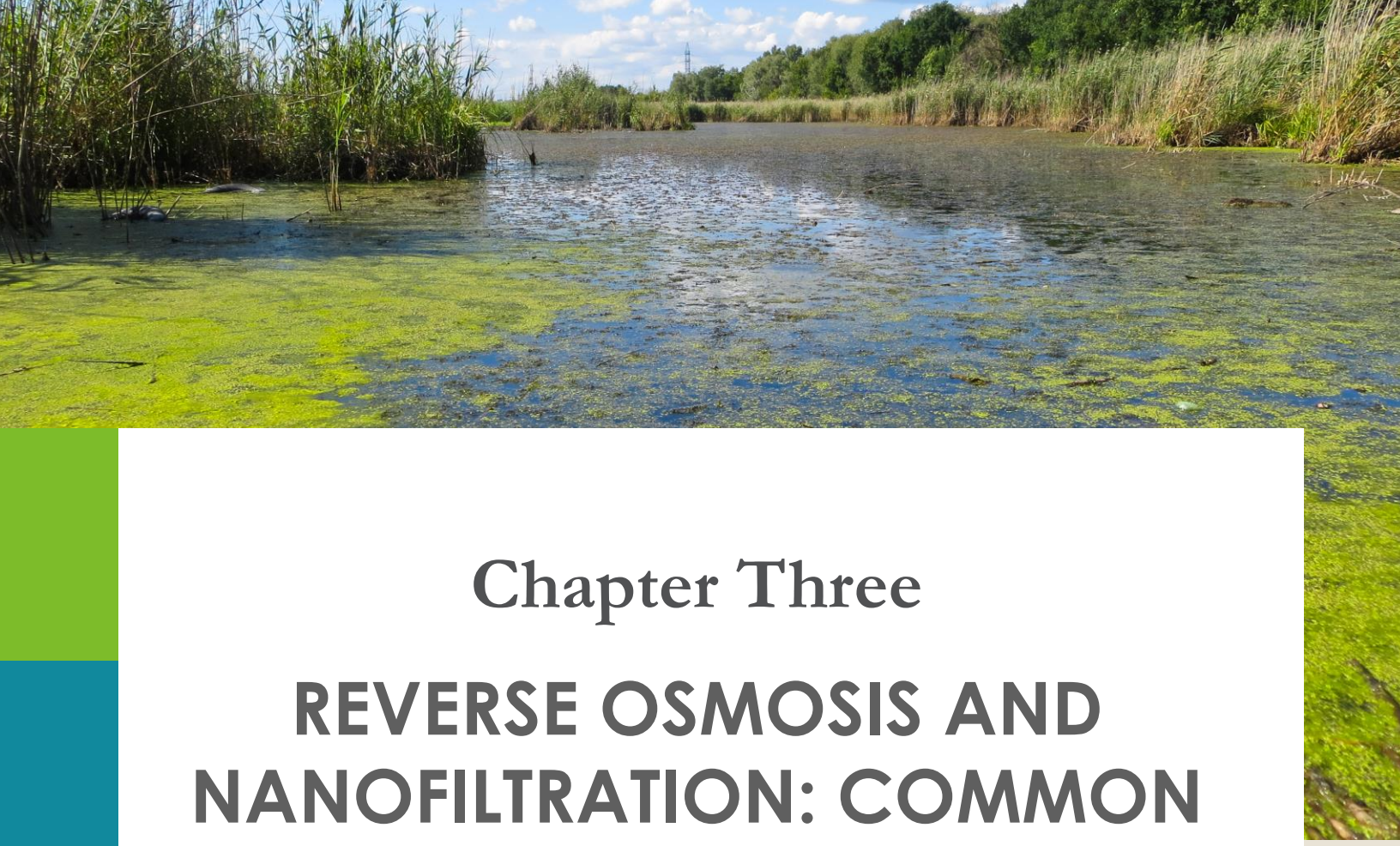
RO/NF is frequently used within the mining and metals industry for treatment and recycling of waste streams generated by mining operations, metal finishing and plating, as well as the recovery of valuable materials.

Food and beverage

Typical applications of RO within the food and beverage industry include the treatment of process water for reuse, and the reduction of biochemical oxygen demand (BOD) in wastewater prior to discharge. The food and beverage industry relies on NF for a variety of specialized applications, including the concentration of sugar and dextrose syrup, the production of alternative sweeteners, degumming of solutions in edible oil processing, and the concentration of whey proteins in dairy industry.

Municipal

RO is used extensively at desalination plants. While RO delivers the purest water possible, NF was developed for removal of larger molecules while allowing desirable minerals to flow through. Increasingly, NF is being used to support a variety of water purification needs, such as removal of residual disinfectants from drinking water.



Chapter Three

REVERSE OSMOSIS AND NANOFILTRATION: COMMON PROBLEMS AND HOW TO FIX THEM

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COMMON REVERSE OSMOSIS AND NANOFILTRATION SYSTEM PROBLEMS

What are they? How do you fix them?

Well-designed RO/NF units are compact and demand relatively little maintenance, making them an attractive alternative to conventional treatment trains.

Even despite the merits of today's efficient RO/NF technologies, it pays to understand common pitfalls associated with them. If your facility currently uses RO/NF or is considering purchasing an RO or NF system, the following information will help you understand the most common problems impacting RO/NF and some possible solutions.

RO/NF membrane fouling

Fouling occurs when contaminants collect on the surface of a filtration membrane and restrict the flow of water through the membrane's pores. With the smallest pore sizes of any membrane filtration technology, RO/NF are particularly prone to premature membrane fouling. Without adequate pretreatment and process monitoring steps in place, **RO/NF membrane fouling can reduce unit service life, compromise permeate quality, and increase operational costs**.

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Preventative steps and/or remediation strategies for membrane fouling depend on the types of contaminants present in the process or waste stream. Common types of fouling include:

Particulate and colloidal fouling

Particulate fouling occurs when solid materials build up on a filtration membrane surface, forming a cake layer that blocks water from flowing through the membrane's pores. In many cases increased pressure differential measurements provide early indication of particulate fouling in RO/NF membranes. Common particulate contaminants include bacteria, viruses, sediment, macromolecules, iron oxides, salts, and colloidal silica. In many cases, particulate fouling of RO/NF units can be prevented by applying appropriate upstream filtration, which can include media filtration, microfiltration (MF), and/or ultrafiltration (UF), depending on the sizes and geometric shapes of particles present.

For streams with colloidal particles, it is sometimes necessary to apply an inorganic coagulant to separate out suspended solids. Commonly-used coagulants include aluminum sulfate, aluminum chloride, sodium aluminate, and ferric chloride, and the use of each will vary depending upon the contaminants present in the feed stream. The use of coagulant chemicals must be monitored closely, however, as coagulants can also lead to RO/NF membrane fouling if allowed to proceed downstream, where they can react with antiscalants or other substances and collect on the membrane.

Biofouling

Biofouling is a process where microorganisms, plants, algae or other biological contaminants grow on RO/NF membrane elements,

forming a layer known as biofilm. As biofilm accumulates on the membrane surface, greater pressure is needed to force water through, resulting in higher energy costs, and eventual damage to the RO/NF membrane element. Key symptoms of biofouling include increased differential pressure from feed to concentrate, and decreased membrane flux.

RO/NF membrane elements tend to provide the warm, low-flow environments suitable to biological growth, making them particularly susceptible to biofouling. Some common solutions for control and prevention of biofouling include:

- biofiltration to remove nutrients from the feed stream
- chlorination to chemically destroy biological contaminants
- fouling-resistant membranes that prevent microbials from clinging to the RO/NF element

Scaling or precipitation fouling

Scaling or precipitation fouling occurs when membrane pores are blocked by crystallized salts, oxides, or hydroxides that have precipitated from solution. Scaling is among the most common forms of fouling in RO/NF elements, especially by divalent calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ions. Like other forms of fouling, scaling and precipitation fouling can compromise the efficiency of an RO/NF unit, and, over time, can irreversibly damage membrane elements.

Control and prevention strategies for scale and precipitation fouling focus on inhibiting crystal growth, resulting in particles that are small enough to be carried away in the reject stream.

Control methods include:

- acid injection to control calcium carbonate scale
- water softening, or the addition of lime to feed water as a means of reducing hardness, alkalinity, and silica to prevent scale crystal formation
- scale inhibition, or the injection of a specialized chemical substance into the feed stream to inhibit the growth of salt crystals

Membrane material compatibility

RO/NF membranes are fabricated from a variety of materials, including cellulose acetate, polyamide, and polysulfone, among others. In order to prevent premature failure, a number of important process factors—including industrial application, pH, substances present, temperature, feed pressure, and biological load—should be considered in the selection of a membrane material. An example of this is the use of polyamide membranes. While widely used in RO/NF units, polyamide membranes are easily damaged by chlorine, making them a poor option in applications where chlorine is needed for disinfection purposes. In order to prevent chemical attack and oxidation, all process characteristics must be carefully considered when selecting a membrane material.

Reject water discharge

While they are extremely effective water purification technologies, RO/NF produce large volumes of wastewater—frequently up to 20-50% of the volume of feed water that they process. Disposal of the

concentrated waste streams produced by RO can be challenging, especially if your facility is subject to zero liquid discharge (ZLD) regulations, or if you face high costs for sewer or surface water discharge. A popular solution to mitigate disposal costs is the reduction of RO waste stream volume through evaporation.

Overall impact of proper design on preventing common problems

Many of the common problems impacting RO/NF can be avoided through careful design that takes process conditions into account. While we've already discussed how pretreatment is essential for minimizing operational and maintenance issues, care must also be given to other system design elements, including:

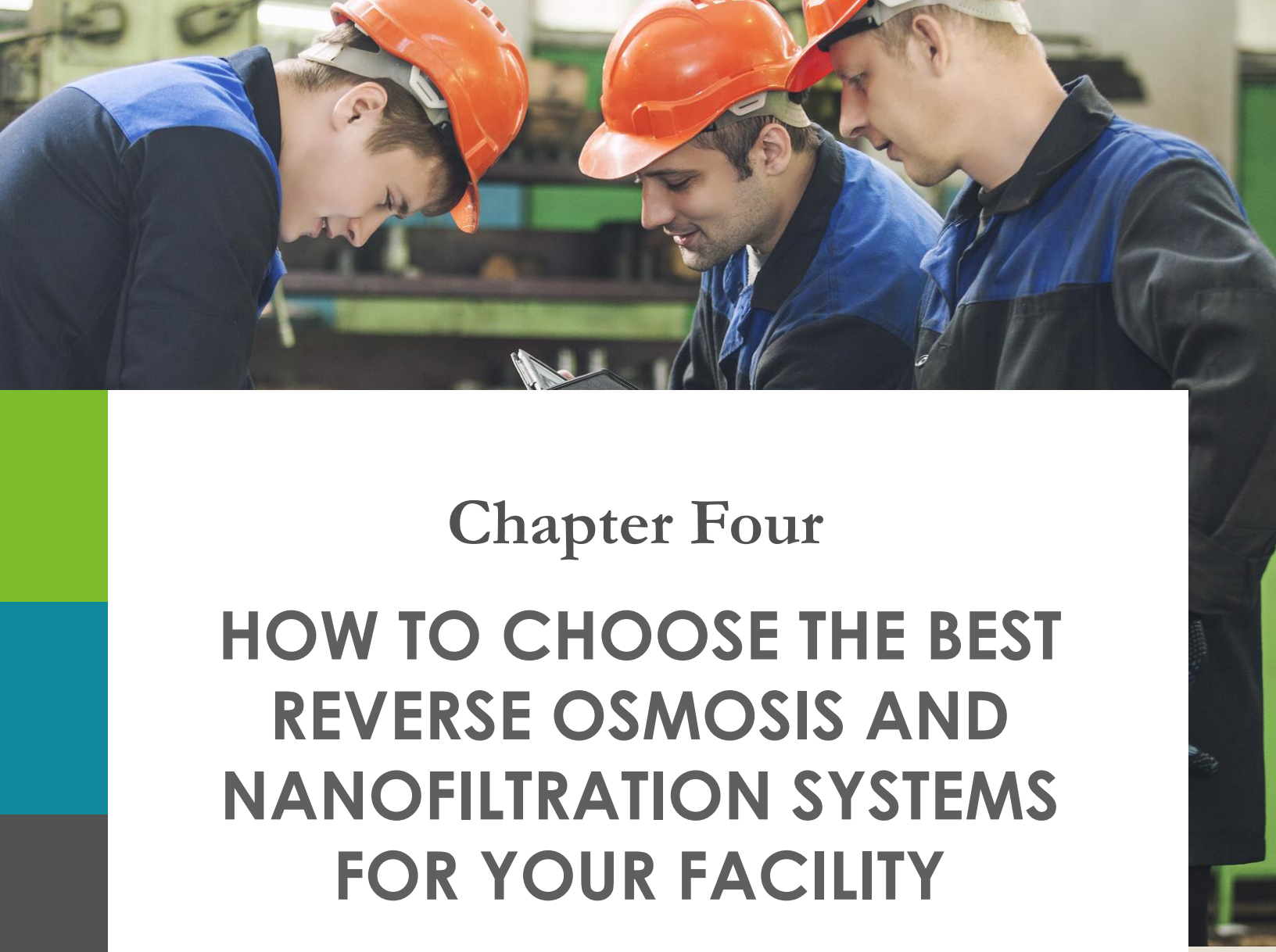
Flux: Flux is the volume of water to pass through a membrane in a given amount of time, often expressed as the number of gallons of water per square foot of membrane per day (GSFD). Flux is used to determine the number of membrane elements needed for an application and is affected by feed water quality, temperature, and salt concentration.

Flow rate: Generally measured in gallons per minute (GPM), feed and permeate flow rates are critical measures for efficient RO/NF operation. Good RO/NF system design takes water source into account, for example, when processing surface waters with high colloids, an optimal flow rate may be 10–14 GPM/ft^2 of membrane.

Array: An array is the physical arrangement of pressure vessels in an RO/NF system. An array can entail multiple stages, with multiple

pressure vessels in each stage. Generally speaking, the higher a recovery rate demanded by a facility, the greater the number of stages in its array.

A trusted engineer can help you to weigh these and other factors to achieve optimal RO/NF performance, maintenance, and energy costs, both immediately and in the long term.



Chapter Four

HOW TO CHOOSE THE BEST REVERSE OSMOSIS AND NANOFILTRATION SYSTEMS FOR YOUR FACILITY

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WHICH RO/NF MEMBRANE SYSTEM IS BEST FOR YOUR PLANT?

Here's how to tell

As global demands for clean water increase, more and more industrial facilities are looking toward membrane filtration solutions, such as reverse osmosis (RO) and nanofiltration (NF), to help manage intake, process, and waste water treatment. Using membrane filtration can help your facility reuse wastewater and virtually eliminate discharge fees, and depending on the industry or required use, it can also help a facility efficiently treat raw and/or process water more efficiently than some conventional treatments.

If you think an industrial plant needs to explore its options regarding RO/NF, you might be wondering **"How Do You Choose the Best RO/NF System for an Industrial Facility?"**

Since there are a variety of options that will depend on what industry the plant serves (oil and gas, petrochemical, food and beverage, etc.), along with which part of the process the filtration is needed and what contaminants need to be removed, this chapter breaks down what to consider when going through the process:

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What is the stream characterization?

When a facility is looking to consider RO/NF membrane filtration as a water treatment solution, they first need to consider **what the quality characterizations of the liquid stream are in addition to the purity requirements of the treated stream.** For example, if a microelectronics facility is looking to use a raw water source, such as a river or lake, to feed their process stream (which requires extremely high-purity water), chances are you are looking at substantial pretreatment process preceding an RO system, followed by ion exchange, which can effectively remove nearly all suspended and colloidal contaminants.

Since RO is the finest of all membrane filtration systems (with extremely small pores capable of removing particles as small as 0.1 nm), it is generally a great fit for microelectronics production, among other processes, such as desalination.

NF delivers slightly coarser filtration than RO, with the ability to remove particles as small as 0.002 to 0.005 µm in diameter, so it might be a better choice for softening hard water. NF is a relatively recent technology that was developed mainly for potable water generation, but,as mentioned in a previous chapter, it removes harmful contaminants, such as pesticide compounds and organic macromolecules while retaining minerals that RO would otherwise remove. Nanofiltration membranes are capable of removing larger divalent ions such as calcium sulfate, while allowing smaller monovalent ions such as sodium chloride to pass through, which makes it a good choice for concentration and demineralization in some dairy-processing facilities.

What type of membrane should you use?

Membrane configurations can vary, but mostly spiral wound and hollow fiber membranes are used. The quality and overall efficiency of the unit can depend on the type of membrane chosen, which can include:

Hollow fiber; more suitable for low-solid liquid streams, these membranes are constructed of thousands of hollow fibers that resemble spaghetti and can be efficiently kept clean with occasional backwashing and clean-in-place (CIP) technology.

Plate and frame; these membranes are placed on top of plate-like structures that collect solids on the inside of the supporting plate. These have low packing densities and can be less efficient than other filtration methods, but they are generally easy to use and clean. Typically used on solutions difficult to filter. They are also among the lower-cost membranes but higher-cost systems.

Spiral-wound; spiral-wound membranes are among the commonly used. They are composed of flat sheets of membrane between mesh-like spacers that are wound around a central tube (this tube collects the permeate after filtration) and placed within a casing. They are relatively compact and can be used in high-volume applications with low suspended solids.

Tubular; several tube-like membranes are placed within a pipe/shell, and as the stream is passed through the tubes, it transfers the permeate to the pipe/shell side. These can be less permeable with a lower packing density and are generally used for hard-to-treat streams, such as those with high TDS, TSS, and oils, greases, and fats.

Are there pre- or post-treatment needs for your RO/NF membrane treatment system?

RO and NF membrane systems are rarely used alone; they are generally part of a technology "train." Since they can foul or scale pretty easily, they usually require some type of pretreatment, such as microfiltration, again, depending on the quality of the incoming stream versus the needed stream quality after filtration.

There is also usually some type of byproduct that needs to be recovered or disposed of after the filtration. When designing your RO/NF system, this should be taken into consideration, as well. For example, sometimes the byproduct might be something valuable (such as silver), or in other cases, it could be something expensive to dispose of. Byproducts are always important to keep in mind when developing a plan for filtration.

What is the result of a treatability study and/or pilot test?

A treatability study is a **study or test that will determine *if* the water stream can be treated for your process and *how* it needs to be treated**. If the study is done correctly, it will clearly identify the contaminants present in your water stream, helping ensure the proper treatment solutions are considered and implemented in your RO/NF membrane treatment system. It can help your facility understand what pre- and post-treatment might be needed, as well as the bypass ratio, amount of recovery the system will yield, and how efficient you can expect the process to be.

This step is **critically important** when choosing the best treatment system for your plant. After having a roadmap of maybe two or three technology platforms that meet your base and operating cost, running an efficient treatability test will help validate the assumptions you've made about possible contaminations and solutions to remove them. This streamlines to process and takes out any guesswork, ensuring your facility is getting the best possible solution for your unique situation.

Also keep in mind that even though the study might seem thorough on paper, **there's nothing better than running pilot testing in the field to validate the treatment/technology assumptions, optimize design,** because during this phase, other problems can arise and be found prior to choosing the components of your system, which can help save you from any process water hiccups or effluent violations down the line.

Chapter Five

HOW MUCH DO REVERSE OSMOSIS AND NANOFILTRATION MEMBRANE SYSTEMS COST?

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WHAT RO/NF MEMBRANE SYSTEMS COST

Pricing, factors, etc.

If your facility requires a separation and/or filtration solution, you might be thinking RO/NF is a good fit. **But how much do reverse osmosis and nanofiltration membrane systems cost?**

Although it can be difficult to pinpoint exactly what you might be spending on an RO/NF membrane system since the solutions and configurations of these systems can be complex, it is possible to simplify and narrow the cost down to a range.

In the following chapter, we break down **what your facility might be spending for a reliable RO/NF membrane system** and outline the various factors that often drive that cost up and down:

What's included in a basic RO/NF membrane system?

For raw water or wastewater, in particular, the configuration of an industrial RO/NF system will depend on the application and characteristics of the waster in relation to the required level of purity. Although each system is typically unique and custom-designed, most RO/NF membrane systems will have some type of:

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- Inlet collection tank
- Feed pump skid and tank
- Filtration system (typically MF/UF for raw water or wastewater)
- Membrane/module rack
- Receiving tank
- Backwash pumps off the receiving tank for MF/UF
- Chemical cleaning systems
- Compressed air for scouring the membrane when MF/UF is cleaned
- Automation instrumentation (such as PLC controls)

The inlet collection tank feeds to a pumping system that normally has two pumps, enabling the system to be run consistently, 24 hours a day. The water then flows to a holding tank large enough for a half hour to an hour's worth of influent, depending upon the nature of the feed stream. If the feed stream has a lot of variability to it, the tank might need to hold more in order to give the stream time to blend out the ups and downs in the feed source.

From there, the water flows through a prefilter to take out particles large enough to plug the internal fibers of the ultrafiltration (UF) filter, which is usually a type of strainer, though there are different types of designs. From there it gets fed to the UF system, which reduces suspended particles, bacteria, and viruses from going into the RO. It's often cleaned several times a day with back pulsing and chemical cleaning (in some cases, chlorination) to keep the module sanitized. Every once in a while, a CIP with intense chemical cleaning is performed (once a month or once a quarter).

The cleaning skid should be included with the UF/RO/NF membrane system, along with backwash pumps, cleaning pumps, air scour blower, etc.

After UF, the permeate is collected in the holding tank. The purpose of the holding tank has two functions: it's used to backwash the filter, and it's also used for forward-flow to the RO unit.

The RO has a cartridge filter housing, and it's followed by the membrane array specifically designed for that application. A typical array is two by one, where the water goes through stage one, then the brine concentrate goes to a stage two. But there are all kinds of different arrays and they are all designed with computerized modeling tools, depending on the facility's required flow rate.

From there, the water goes on to a holding tank that has a substantial amount of storage capacity to store enough water in case you have to take the RO down and clean it, and it's also designed to handle the peak flows to production. So if you have a production that needs 100,000 gallons per day but you use the water over 16 hours, then your storage tank needs to have enough water to cover the 16 hours of consumption. Next are booster pumps that pump the water out of the holding tank to points of use.

On the side of these systems are a separate CIP system for cleaning the RO, and that system is typically also used for cleaning the UF.

The main factors of RO/NF membrane system cost

Water characterization

The main factor that will drive up and down RO/NF membrane system cost is the **characterization of the water**—whether it's surface or well water, and how dirty it is (are there algae, organics, or a lot of metals to cause scaling and fouling?).

With RO/NF, there is usually pretreatment required, but what that treatment entails will depend upon the degree of contaminants. If no pretreatment is used (UF), the RO/NF membranes will likely experience fouling and cause all sorts of problems, possibly even plant downtime.

Flow rates

On both the UF pretreatment and RO/NF devices, there is a linear "scaling up" based on flow (how many are stacked up depend on the flow rate). You can often estimate the cost of the membrane rack by flow rate and the flux rate you're designing it to.

There are two functions that will affect the cost of the system here: flow rate and how much water you want to make from each membrane. The cleaner the water, the higher the flux rate can be (gallons per day per square foot of membrane surface area).

Construction materials

The last factor that will affect the cost of your RO/NF membrane system is the construction materials. In a municipal application where PVC piping is used, its's going to be less expensive than an industrial,

medical, or power application where all stainless-steel piping will add substantial amount to the cost. Piping into the front end of the UF is sometimes PVC or CPVC, whereas piping coming out might be cleaner materials such as polypropylene. PVC piping has chemicals in the makeup material that can leach into the water, so in applications for the pharmaceutical industry, as an example, these pipes require higher end materials to preserve the required purity. Also, some facilities that look to hot-sanitize the piping require stainless steel piping, or piping that can handle the heat.

Other important factors to consider when pricing a RO/NF membrane system

Upfront planning. Developing the concepts, designs, and regulatory requirements for your project is the first step to planning your RO/NF membrane system. The cost of engineering for this type of project can typically run about 10–15% of the cost of the entire project and is usually phased in over the course of the project, with most of your investment being allocated to the facility's general arrangement, mechanical, electrical, and civil design. The lower the equipment cost the higher the percentage. The higher the capital equipment cost the lower the percentage.

Space requirements. When planning for a RO/NF membrane system, the size of your system and your plant location will affect your cost. For example, if your plant is located in a place that is very expensive when it comes to space, you might want to aim for a smaller footprint, if possible.

Installation rates. Another thing to keep in mind is the installation rates in your area. These sometimes also fluctuate by location, so be sure you're aware of the cost to install the system and factor this into your budget. In areas where installation costs are high you may want to consider prepackaged modules versus build-in-place facilities.

Level of system automation needed. When it comes to the level of automation you need for your RO/NF membrane system, there are two options. The first is a higher level of automation where you won't need an operator present for much of the time. With type of automation, you can eliminate much of the human error associated with running the plant, and although this option is more costly upfront (an initial investment in more sophisticated PLC controls and instrumentation), the ongoing labor costs are less. The second option is a lower level of automation with less capital cost, but with added labor, this can end up costing you more in the long run. When deciding whether or not to invest in more costly controls, you need to consider what works for your company and staffing availabilities.

***Turnkey and prepackaged systems*.** If you are able to order your RO/NF membrane system prepackaged, this will typically save you construction time at about the same cost or less. A benefit to having your system prepackaged is that the production facilities and fabrication shops that assemble your system are, more often than not, highly knowledgeable about the type of system they are manufacturing. This results in a quick and efficient fabrication versus build-in-place facilities. Sometimes when you hire a field crew, there is a bit of a learning curve that can add extra time and/or cost to a project. Installation costs will vary, but typically range between

15–40% of the project cost, depending on the specifics of prepackaging and amount of site civil work needed.

***Shipping the system to your plant*.** When having your RO/NF membrane system shipped to the plant, you usually want to factor in about 5–10% of the cost of the equipment for freight. This can vary widely depending upon the time of year you are purchasing your system in addition to where your plant is located in relation to the manufacturing facility. When you are looking to purchase your system, check with your manufacturer to see if there is a facility where the system can be constructed closer to you, if not on-site.

***Operation costs*.** Also keep in mind that particular technology packages cost a certain amount to purchase upfront, but you need to also factor in system operating costs over time. For decisions like these, you need to weigh the pros and cons of initial versus long-term cost investment in addition to what works for your company and staff. You will likely want to look into having someone develop an operating cost analysis so your company can plan ahead for the operating cost over your facility's life cycle. This might help you consider whether or not you want to spend more on your system initially or over time.

Other possible costs and fees. When purchasing a RO/NF membrane system, you might also want to keep in mind what other hidden costs and fees might be. For example: Will there be any taxes on the system or additional purchasing fees? What are your possible utility costs to the installation area? Will there be any environmental regulatory fees and/or permits? Any ongoing analytical compliance testing you need to pay for?

Also consider that there will be costs to treating the secondary waste produced by the system. With stringent environmental regulations, you will need to either treat the waste for hauling away or solidify with a filter press/evaporator and transport to third party disposal firm.

Also be sure to ask your system manufacturer about options that might be cheaper to install. They might be able to shed some light on the more installation-friendly systems with suggestions on how to keep your costs to a minimum.

The bottom line

A **five to 10 GPM** RO/NF membrane system, along with the ancillary equipment (you might add about another $10k with tanks, pumps, and things like that), could be **about $45,000 to $60,000** for a small, commercial-quality unit. When you get into higher industrial qualities, you can double or triple that cost, whereas a **30 to 50 GPM commercial-quality system would be about $200,000**.

A **high-end 100 gallon per minute system** (GPM) with all the top end instruments stainless steel piping (such as for a power plant with) could be a **$1 million system**. For a **commercial-quality system at 100 gallon per minute system**, cost could be as low as **$250,000**.

When you get into bigger systems, such as a **300 GPM, cost could be $2 to $4 million**, depending on what pretreatment type of pretreatment is required.

HOW CAN SAMCO HELP?

SAMCO has over 40 years' experience helping design and engineer some of the most effective RO/NF systems in the industry. For more information about what we offer and how we can help your facility, please visit our website or contact us to schedule a consultation with one of our skilled engineers.

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