An Introduction to

INDUSTRIAL WATER TREATMENT SYSTEMS

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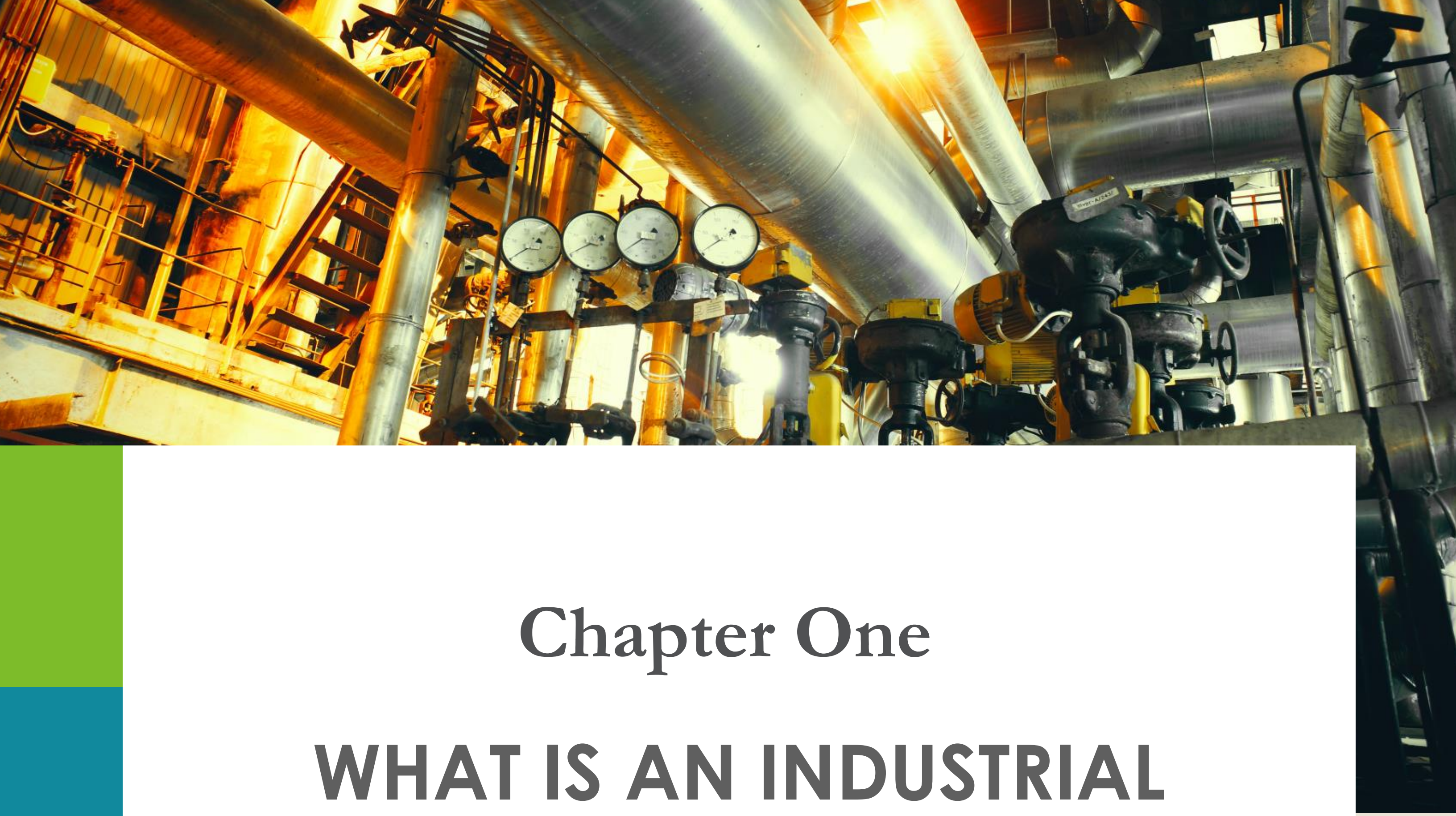

Chapter One

WHAT IS AN INDUSTRIAL WATER TREATMENT SYSTEM AND HOW DOES IT WORK?

INDUSTRIAL WATER TREATMENT SYSTEMS

What they are and how they work

Industrial water treatment systems meet a variety of purification and separation needs. They can range from relatively compact and straightforward to complex, multiunit processes that serve a variety of applications. If you're new to water treatment, you might be asking **"What is an industrial water treatment system and how does it work?"**

Since industrial water treatment is a complex family of technologies and systems, this section will focus on giving a high-level overview of the technologies that are typically used and summarize how they work, helping you to better understand the best possible solutions for your facility.

What is an industrial water treatment system?

An industrial water treatment system **treats water so it is more appropriate for a given use, whether for consumption, manufacturing, or even disposal**. That said, each system will vary depending on the facility's needs and many of the technologies that make up these systems can be similar. In general, some of the most-needed industrial water treatment systems typically include:

- Raw water treatment systems
- Boiler feed water treatment systems
- Cooling tower water treatment systems
- Wastewater treatment systems

The technologies selected and in what order they appear in each water treatment system will vary depending on the contaminants that need to be removed, but it is possible to narrow down what you might see in these four common industrial treatment systems. The following is a breakdown of what might be included in a typical water treatment system:

Raw water treatment systems

What they are

Raw water is any untreated water that occurs naturally in the environment, including sources such as rainwater, groundwater, wells, lakes, and rivers. In industrial settings, raw water may be used for cooling, rinsing, product formulation, or even human consumption if it is properly purified.

Raw water treatment systems are used for pretreatment and optimization of source water, usually with an eye toward improving production efficiency and process performance for a particular application. Examples include pretreating cooling tower/boiler feed water, process/production water, and/or water for drinking. Often, raw water treatment is focused on protecting downstream equipment from scaling, fouling, corrosion, and other forms of damage or premature wear due to contaminants present in the source water. Raw water treatment systems typically remove suspended/colloidal solids, silica/colloidal silica, iron, bacteria, and hardness.

How they work

Raw water treatment systems vary from one installation to the next. Nonetheless, the following steps demonstrate how a raw water treatment system will usually work:

- **Intake.** Raw water is drawn into a plant through gravity and/or pumps. The water is usually passed through a metal grate or mesh screen to prevent large objects from entering the system.
- **Clarification.** The water then continues for clarification, which is a multistep process used to remove suspended solids from a solution. Clarification begins with coagulation, where chemical and/or pH adjustments cause particles to begin clumping together, followed by flocculation, which involves physical agitation to encourage the formation of larger particles. Then comes a sedimentation step, where the stream flows to a gravity settler that allows solids to settle to the bottom in what is known as a sludge blanket. Finally, the stream is filtered through a gravity sand filter to trap any small particles that did not settle out.
- **Disinfection.** If biological contamination and/or water potability is a concern, the water may then be disinfected to remove any pathogens. Disinfection may be accomplished through the application of chemical disinfectants (e.g. chlorine), physical disinfectants (e.g. UV or heat), as well as some forms of membrane filtration.

- **Lime softening.** In some cases, a lime softening step may be added to reduce hardness in streams with high mineral or sulfate content. The process involves the application of lime or lime soda to raise the pH of the stream, which in turn encourages mineral constituents to precipitate out of the solution.
- **Ion exchange (IX).** In some cases, the raw water treatment system may include an IX unit for hardness removal, or other specialized treatment needs. In IX softening, a stream is directed through a strong acid cation resin that is "charged" with sodium; as the water flows through, the resin captures the hardness-causing calcium or magnesium ions while releasing the sodium ions into the stream.
- **Distribution.** Following treatment, the water is pumped or otherwise routed for use elsewhere in the facility.
- **Membrane filtration.** As microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF) systems have become more affordable in the last few decades, they are increasingly being used in place of conventional technologies such as clarification and lime softening.

Boiler feed water treatment systems

What they are

Boiler feed water treatment systems are used to protect boiler unit components and piping from damage due to certain contaminants present in the boiler and/or makeup feeds. These contaminants may include dissolved solids, suspended solids, and organic material, such as iron, copper, silica, calcium, magnesium, aluminum, hardness, and dissolved gases. Without proper treatment, boiler feed water can cause scaling, corrosion, and fouling of the boiler and downstream equipment, which can result in costly plant downtime, expensive maintenance fees, increased fuel consumption and boiler failure.

How they work

An effective boiler feed water treatment system works by both removing harmful impurities prior to entering the boiler as well as controlling the acidity and conductivity of the water. While treatment trains vary, a typical system will consist of primary treatment and possibly polishing depending on the boiler pressure, steam use, and chemistry of the boiler feed and makeup water. A boiler feed water treatment system will typically include some or all of the following steps:

- **Makeup water intake.** As boilers are used, they lose water to steam consumption, loss of condensate return, and leaks. This water must be replaced with what is known as makeup water. Makeup water may be drawn from a treated city supply or a raw water treatment system.
- **Filtration.** The stream is typically filtered through one or more filtration units for removal of sediment, turbidity, and organic material. When used for pretreatment ahead of IX and other equipment, membrane filtration units can be a cost-effective means of preventing fouling and excess maintenance of downstream equipment.

- **Softening.** IX is often used for removing hardness from boiler feed water, including bicarbonates, sulfates, chlorides, and nitrates. This is accomplished by using a softening resin, which is typically a strong acid cation resin that allows it to effectively capture hardness ions from the stream.
- **Dealkalization.** Alkalinity can cause foaming and carryover in boilers, as well as corrosion in piping; therefore, boiler feed streams are often treated with strong anion IX, or weak acid IX followed by degasification, which serve to remove bicarbonate, sulfate, and nitrate ions, reducing pH.
- **Reverse osmosis (RO) and nanofiltration (NF).** RO and NF are not always used for boiler feed water treatment; however, they can be useful for removal of bacteria, salts, organics, silica and hardness. RO and NF are both types of membrane filtration, meaning that they employ a semi-permeable membrane to capture any contaminants too large to fit through their pores, while allowing water molecules to flow through.
- **Primary ion exchange (IX).** For large volumes of water or high-pressure boilers, deionizers may be used instead of membrane filtration. IX typically produces water of comparatively higher quality and resistivity, and better yields.
- **Deaeration or degasification.** Following all other treatment steps, the makeup water and condensate from the boiler system are combined and degasified. Deaeration/degasification is the removal of dissolved oxygen and carbon dioxide from the liquid stream, which is important for preventing corrosion.

- **Polishing.** Depending on the boiler requirements, polishing technologies may be required. This step can follow RO or primary IX. Typical polishing technologies include mixed bed deionization (DI), electrodeionization (EDI), or offsite regenerable DI.
- **Distribution.** Following all treatment steps, the boiler feed water is piped to the boiler, where it is heated to form steam. The condensate can then be combined with treated makeup water, and the cycle begins again.

Although these steps represent common boiler feed water system trains, it is important to understand that **an individual boiler's unique makeup/chemistry is an extremely complex calculation** that will dictate the technologies needed. We recommend consulting the boiler manufacturer for their water purification specifications. You should also consult a water treatment specialist to conduct a thorough treatability study, which can help determine which combination of these technologies would best suit your boiler.

Cooling tower water treatment systems

What they are

Cooling tower water treatment systems are used to protect cooling tower components from damage due to contaminants present in feed water, circulation water, and/or blowdown water. These contaminants may include chlorides, hardness, iron, biological materials, silica, sulfates, total dissolved solids (TDS), and/or total suspended solids (TSS). Untreated cooling tower feed water can cause scaling, corrosion, biological growth, and fouling of cooling tower equipment, which can result in costly plant downtime, reduced productivity, and excessive maintenance or equipment replacement costs over time.

How they work

An effective cooling tower water treatment system works by removing harmful impurities in line with the manufacturer recommendations for water quality requirements for the type of cooling tower used. While treatment trains vary depending on the requirements of the cooling tower equipment and chemistry of the feed, makeup, and blowdown water, a typical cooling tower water treatment system will usually include the following steps:

- **Makeup water intake.** As water circulates through a cooling tower system, a portion is lost to evaporation, bleed to drain, and leaks. This water must be replaced with what is known as makeup water. Like boiler makeup water, cooling tower makeup water may be drawn from a variety of sources, whether raw water, municipal water supplies, wells, or recycled plant wastewater. In some cases, the source water must also be treated for hardness or silica removal and/or pH adjustment.
- **Filtration.** Upon intake, the stream is typically filtered through one or more filtration units for removal of sediment, turbidity, and organic material. As previously mentioned, when filtration is used for pretreatment ahead of IX and other equipment, it can be a cost-effective means of preventing fouling and excess maintenance of more sensitive downstream equipment.

- **Softening.** If there's high hardness in the source/makeup water, a softening resin or membrane softener can be used. These contaminants, if present, will otherwise cause scale deposits and rust. Depending on feed water quality, softening can improve the efficiency of cooling tower water use.
- **Chemical addition.** Next, the stream will usually undergo some form of chemical treatment, which can include the application of corrosion inhibitors to neutralize acidity; algaecides or biocides to reduce growth of biological contaminants; and/or scale inhibitors to prevent contaminants from forming scale on pipes and other components.
- **Side-stream filtration.** Many cooling towers are designed to recirculate water following use. If this is the case, a side-stream filtration unit will be helpful in removing any problematic contaminants that have entered through drift contamination, leaks, etc. About 10% of the circulating water will filter through what is usually a high-quality multimedia filtration unit or SAMCO tube filtration technology.
- **Post-treatment.** There are various types of post-treatment options that may be used depending upon plant conditions. If large quantities of water are required for cooling, or if water is scarce at the facility's location, plants may opt to treat the blowdown water with RO or IX and reuse it. For discharge of blowdown water and/or bleed water, other post-treatment systems may be leveraged to minimize disposal costs or bring the waste stream in line with discharge regulations.

Wastewater treatment systems

What they are

A wastewater treatment system is used to convert spent streams into an effluent that can either be reused or safely discharged to the environment or municipal treatment facility.

The most appropriate wastewater treatment system will help the facility avoid harming the environment, human health, and a facility's equipment, process or products (especially if the wastewater is being reused). It will also help the facility curb heavy fines and possible legal action if wastewater is being improperly discharged to either the environment or publicly owned treatment works. The relative complexity of a wastewater treatment system will depend heavily upon the compliance regulations impacting your plant and the composition of your waste stream.

While the contaminants present in a waste stream can vary greatly from one process to the next, wastewater treatment systems commonly treat for biochemical oxygen demand (BOD), nitrates, phosphates, pathogens, metals, TSS, TDS, and synthetic chemicals.

How they work

While a wastewater treatment train will vary considerably from one installation to the next depending upon discharge regulations, stream constituents, flow reuse strategies, and other factors, these steps represent some of the more common technologies you might expect to see:

- **Clarification.** The first step of wastewater treatment is often clarification, which is a multistep process used to precipitate out metals, silica, and suspended solids from the solution. Depending on the characterization of the waste water, clarification can be a series of reaction tanks with chemical addition, coagulation, flocculation, sedimentation, followed by filtration. These steps are usually necessary for removal of any fine particulates and/or by-products, some of which can be recovered if they are of value (such as silver).
- **Disinfection.** Pathogens—bacteria, viruses, fungi, or any other microorganisms that can be present in wastewater—can lead to all kinds of health issues, including acute sickness, severe digestive problems, or death. When industrial wastewater containing these harmful pathogens is released to the environment, it can spread illness and disease, making their removal or neutralization a key aspect of treatment.
- **Softening.** For streams with high hardness or sulfates, a lime softening step may be added to reduce mineral or sulfate content. The process involves the application of lime or lime soda to raise the pH of the stream, which in turn encourages mineral constituents to precipitate out of solution. In some cases, IX or membrane softening may also be used.
- **Special processes.** Since wastewater streams are typically complex and highly variable from one facility to the next, special processes are often required to fully meet wastewater treatment needs.

- **Distribution.** Following wastewater treatment, the water is routed for reuse within the facility or, complying with local regulations, discharged to the environment or local sewer.

Additionally, because wastewater treatment is almost always subject to fluctuations in composition, flow rate, or effluent requirements, a well-designed system should accommodate such fluctuations and offer options for scalability.

Chapter Two

DOES YOUR PLANT NEED AN INDUSTRIAL WATER TREATMENT SYSTEM?

DO YOU NEED AN INDUSTRIAL WATER TREATMENT SYSTEM?

How to know if it's necessary

While industrial water treatment systems are not always necessary, they can provide a dramatic return on investment for your facility. Well-designed water treatment systems can help trim energy costs, maintenance costs, lost dollars due to wasted products/byproducts, discharge fees, and even regulatory fines. If you're wondering how to add efficiency to your process, you may be asking **"How do I know if my plant needs an industrial water treatment system?"**

If so, it pays to have a basic understanding of how and why the major types of industrial water treatment systems are used. This section will help you to understand some of the key reasons for implementing an industrial water treatment system, so you can determine what technologies might be a good fit for your facility.

Does your plant draw from a raw water source?

Water drawn from a lake, river, ocean, groundwater supply, or other raw water source almost always needs some form of treatment before it can be used for a given process. You may need a raw water treatment system if:

- **You need to remove off tastes and/or colors.** Particularly important for the food and beverage industry, raw water treatment is often key for removal of tastes and colors that compromise product quality.
- **You need to remove pathogens or biological contaminants.** Raw source water frequently contains bacteria, viruses, algae, fungi, or other biological components that can cause disease when ingested by humans as well as fouling of downstream equipment.
- **You want to optimize or protect process equipment.** Raw water treatment can remove suspended solids, silica, hardness and other contaminants that can cause scaling or fouling of downstream equipment.

Does your plant use a boiler?

Boiler systems subject your water feed to high-heat and high-pressure conditions, which can exacerbate the damaging effects of certain contaminants. Treatment of feed water and makeup streams can ensure a more predictable stream for safe and efficient operation of your boiler system. You may need a boiler feed water treatment system if:

- **You want to maximize boiler service life.** Scaling, clogging, and corrosion can significantly shorten the functional life of your boiler equipment. A boiler feed water treatment system can help protect your investment by removing dissolved oxygen, carbon dioxide, calcium, magnesium, silica, and other problematic substances.

- **You use a high-pressure boiler unit.** Since tolerance for impurities decreases as system pressure increases, boiler feed water treatment is often necessary to ensure safe operation of high-pressure boilers.
- **You're looking to save on energy or maintenance costs.** Impurities in you water feeds can accumulate on pipes and equipment surfaces, which can inhibit heat transfer, and restrict flow. Treatment can remove contaminants in order to minimize energy costs for heating and circulating water through a boiler unit.

Does your plant use a cooling tower?

Cooling towers make use of multiple streams, including feed water, circulation water, and blowdown water. Each of these can contribute to problems such as fouling, scaling, and corrosion. You may need a cooling tower water treatment system if:

- **Your feed water is too acidic or alkaline.** In order to mitigate the risk of scale and corrosion on cooling tower components and pipes, your cooling tower feed water may need treatment so that it falls within a given pH range suitable for your equipment.
- **You need to decrease the concentration of total dissolved solids (TDS).** Hardness and TDS can deposit on surfaces, which can result in clogging, equipment damage, and excess downtime down the road.
- **You want to cut source or discharge costs.** Treating blowdown water for reuse can be a cost-effective strategy for reducing discharge volumes and/or cutting water consumption, especially in areas with strict discharge regulations or water scarcity challenges.

- **You need to remove microbiological contaminants.** Due to the warm conditions in cooling towers, biological fouling can easily get out of hand, potentially causing health risks or jeopardizing compliance with state mandates. Treatment of makeup or other water can help to remove or neutralize biological contaminants such as bacteria, fungi, and algae.

Does your plant produce wastewater?

Wastewater is almost always a byproduct of industrial production, forcing facilities to grapple with challenges that range from cutting disposal costs, to effective reuse and recycling of waste streams. You may need a wastewater treatment system if:

- **Your wastewater contains pollutants or toxic materials.** Oils, grease, suspended solids, metals, inorganic contaminants, high biochemical oxygen demand (BOD), and other contaminants must often be removed from waste streams prior to reuse and/or discharge.
- **You need to comply with regulatory requirements for discharge.** If you discharge to the environment, you'll likely need to bring your stream into compliance with a National Pollutant Discharge Elimination System (NPDES) permit. Alternatively, if you discharge to the local publicly owned treatment works (POTW), you may need to treat your effluent to meet the standards of your municipality. Either way, it pays to be proactive, as failure to meet compliance guidelines can result in hefty fines.

- **You want to reuse your waste streams for other processes.** Recycling your waste streams can be extremely efficient, as it can drastically reduce your discharge costs and water use. Still, you'll need to properly treat your waste streams to remove any contaminants that could damage process equipment or compromise product quality.

What now?

When it comes to deciding whether an industrial water treatment system is right for your plant, it is essential to consult a qualified water treatment specialist who can help you identify the right system to meet your goals and budget. While there are a wide variety of specialized water treatment applications, those mentioned here comprise some of the more common systems sought by industrial facilities. An expert can perform treatability studies to get a better handle on your needs and can also help you navigate the many water treatment technologies suitable for your unique process conditions and stream chemistry.

Chapter Three

COMMON INDUSTRIAL WATER TREATMENT SYSTEM ISSUES AND HOW TO FIX THEM

COMMON INDUSTRIAL WATER TREATMENT SYSTEM PROBLEMS

What are they? How do you fix them?

If your facility relies on some form of industrial water treatment, or if you are planning to install a new system, it makes sense to consider the problems that might affect your industrial water treatment system, as well as steps you can take to mitigate or prevent these issues.

While industrial water treatment can be simply defined as a process for converting a liquid stream to a form more appropriate for a given use, it is a broad group of technologies, equipment, and processes. This chapter will offer a high-level overview of **"Common industrial water treatment system issues and how to fix them,"** giving you a helpful jumping-off point for investigating the issues most relevant to your facility.

Raw water treatment systems

Raw water treatment systems are used to treat source water for a given application, such as heating, cooling, rinsing, processing, or even for consumption. Since it is drawn from sources such as rainwater, groundwater, wells, lakes, and rivers, **raw water**

characteristics can fluctuate significantly in response to various environmental factors. The most common problems facing raw water treatment systems often come down to the inability to adapt to changing treatment needs over time. These include:

- **Variable turbidity levels.** Seasonal fluctuations in the turbidity of raw water can result in contamination of process streams, failure to meet discharge compliance requirements, and system backups or downtime for sludge treatment equipment and clarifiers. To avoid these issues, consider raw water treatment system designs that will accommodate greater-than-expected turbidity levels, or consider implementing variable chemical feed controls for greater flexibility.
- **Variable flow rates.** Variations in flow rate can overwhelm a raw water treatment system, allowing contaminants to carry over into process streams or foul filters and other equipment. One way to avoid problems associated with variable flow rates is to implement holding tanks and/or add variable controls to chemical feed systems.
- **Changing feed chemistry.** Seasonal changes in water chemistry can result in contaminant concentrations that overwhelm a raw water treatment system, leading to poor process water quality, and fouling or damage to downstream equipment. To avoid these issues, consider implementing physical-chemical technologies that can be adjusted to efficiently remove contaminants at various concentrations.

- **Changing quality requirements.** The technologies, processes, and regulatory guidelines at your plant will almost certainly change over time, which can impact the level of water quality needed to support production at your facility. Periodic assessment of water quality needs can help to protect equipment, and ensure that your effluent continues to meet discharge regulations, among other benefits. This can mean needing to install ancillary equipment to augment your existing raw water treatment system, so it's always a good idea to consider scalability if you are implementing a new system.
- **Secondary waste.** Raw water treatment plants produce waste that will need to be disposed of in some way—whether by discharge to the environment, a municipal facility, or otherwise. Costs associated with compliance and disposal of waste can add up quickly, so it is important to consider this when designing a raw water treatment system.

Boiler feed water treatment systems

Boiler feed water treatment systems are used to remove certain contaminants from water used in boiler makeup and condensate return water. Since treatment strategies vary according to boiler unit specifications and composition of the source water to be treated, it is always advisable to seek expert help to address any boiler feed water treatment issues you may be experiencing at your facility. Some of the most common problems that impact boiler feed water treatment systems include:

- **Sludge buildup.** Boiler sludge is a comparatively softer buildup of solids or oil in low-flow areas of the boiler system. Sludge buildup can impede heat exchange, resulting higher energy costs, and can damage piping or cause unsafe pressure conditions. It may be possible to blow out existing sludge, but the best solution is prevention through either filtration, or application of chemical sludge conditioners.
- **Scale buildup.** Scale is an extremely hard deposit consisting of silica, iron, calcium, magnesium, or aluminum. In general, the level of water purity needed will depend upon the pressure that the boiler operates at. For low-pressure boilers, simple sodium softeners will likely be sufficient, but for high pressure boilers, reverse osmosis, electrodeionization, or deionization may be required to achieve adequate water purity.
- **Corrosion.** Corrosion is the breakdown of metal elements in a boiler unit, which can lead to cracks and eventual system failure, usually caused by dissolved oxygen and carbon dioxide in water and is exacerbated by heat and low pH levels. Common corrosion prevention methods include application of oxygen scavengers and deaerators, as well as managing overall water chemistry and pH.
- **Foaming and priming.** As boiler feed water is heated to form steam, dissolved solids can cause the water to foam or bubble up. As the water foams, the impurities can be carried away with the steam in a process known as priming, which can cause deposits to form on various parts of the boiler unit. Effective methods for preventing foaming and priming include removing dissolved solids and controlling alkalinity.

Cooling tower water treatment systems

Cooling tower water treatment systems are used to remove contaminants present in feed water, circulation water, and/or blowdown water in order to prevent damage to cooling tower components. While the issues you might expect to see vary depending upon the type of system you have, the most common problems with cooling tower water treatment systems have to do with inefficiency in energy or other resource use. These include:

- **Excess blowdown.** As water moves through a cooling tower, dissolved solids can get left behind, forming deposits that can cause scaling or corrosion. Buildup is typically flushed out through routine blowdown cycles, however, excess solids will demand more blowdown or makeup water. Common solutions include filtration of side-stream or feed water and treatment of makeup water feeds.
- **Low cycle of concentration.** The cycle of concentration is a ratio that indicates the loss of makeup water and blowdown over the cooling cycle. A low cycle of concentration often means greater cost due to greater water consumption and chemical usage. Common strategies for increasing cycles of concentration include removal or neutralization of various contaminants, such as hardness, iron, silica, and microbials, as well as controlling pH and alkalinity to limit scaling.

- **Secondary waste disposal.** Any treatment system will result in waste that will need to be discharged or disposed of in compliance with regulatory requirements. When it comes to designing a new cooling tower water treatment system, or upgrading an old one, it pays to carefully review any permits or discharge requirements to ensure that there are no surprise costs in dealing with waste.
- **Water scarcity.** Regulatory bodies are increasingly placing stringent limits on the amount of water that facilities can draw and/or discharge, making it increasingly cost-effective for facilities to invest in treatment strategies to make cooling towers function more efficiently. These include ion exchange and reverse osmosis for treatment of blowdown water, as well as demineralization. For areas requiring zero liquid discharge (ZLD), a more robust treatment strategy may be needed.

Wastewater treatment systems

Wastewater treatment systems are used to convert spent streams for reuse or safe discharge to the environment or a municipal facility. Since waste streams are so unique from one production line to the next, and discharge compliance standards vary across regions, wastewater treatment is a highly individualized process that should be customized to the conditions at your facility. Still, since most plants must comply with some form of effluent regulations, wastewater treatment systems often face a common set of issues, among them:

- **High biochemical oxygen demand (BOD).** BOD limitations are often included in regulatory requirements to protect waterways from harm due to oxygen depletion. BOD levels are typically kept in check by aerating the waste stream to encourage biological oxidation, which produces solids that may be removed through filtration or clarification.
- **High total suspended or dissolved solids.** Discharge regulations typically include some limitation for maximum total suspended solids (TSS) or total dissolved solids (TDS) permissible in effluent streams. Typical solutions include clarification and sand or carbon filtration for TSS reduction. TDS reduction is somewhat more complicated, usually requiring chemical treatment, demineralization, evaporation, or a combination of these.
- **High nitrate or phosphate levels.** Nitrates and phosphates can enter water through human and food waste, detergents, and pesticides. They have extremely detrimental effects on waterways, and their levels are therefore strictly regulated in effluent streams. Removal of nitrates is typically accomplished through IX, RO, or biological treatment, while phosphate levels are typically controlled through clarification or biological treatment.
- **Oil or grease in waste stream.** In addition to causing environmental damage, oils and greases can clog sewer and drainage pipes. In many cases, regulations will typically stipulate some limit for oils and greases in your effluent. Oil and grease removal is typically achieved through dissolved air flotation (DAF), ultrafiltration, or activated carbon filtration.

- **Discharge volume is too high.** In many regions, connection fees are based on water usage and discharge volumes. If your facility produces large volumes of effluent or if your face costly discharge fees, it may make sense to invest in technologies that allow you to treat your effluent for reuse, or even zero liquid discharge (ZLD).
- **Changing compliance regulations.** Effluent regulations can change over time, which can mean your facility may need to periodically update its wastewater treatment system in order to comply with new standards. Taking proactive steps to stay on top of changing discharge regulations can help to avoid costly consequences, such as permit revocation or fines and fees.

Chapter Four

HOW TO CHOOSE THE BEST INDUSTRIAL WATER TREATMENT SYSTEM FOR YOUR PLANT

WHICH INDUSTRIAL WATER TREATMENT SYSTEM IS BEST?

Here's how to tell

With new water treatment technologies emerging all the time, it can be difficult to identify the ideal solution for your needs. Well-designed industrial water treatment systems can help you meet your production objectives and gain efficiencies along the way. The key is simply taking the time to understand the major factors that determine the best solutions for common water treatment goals.

If you're wondering **"How do I choose the best industrial water treatment system for my plant?"** this chapter will outline the most important factors to consider for each major type of industrial water treatment system.

Choosing the best raw water treatment system

If your facility draws from a raw water source, you'll likely need to treat the water to promote operational efficiency and ensure consistent quality in your products. Selecting an ideal raw water treatment system to suit your needs can involve several factors, though some key considerations include:

- **Water quality.** You'll need to consider the quality of your source water as well as the level of quality needed to best support your processes, products, and equipment. Raw water treatment systems can treat source water for a variety of applications, but choosing the best treatment system for your facility is a matter of balancing a few factors, including intake water characteristics, the volume of water needed, and target water quality.
- **Testing and treatability study results.** Water treatability testing is the critical first step in identifying an appropriate raw water treatment system. The resulting lab report will help to determine whether your raw water can be treated for your process and tell you how it needs to be treated.
- **Plant lifespan.** In general, the longer you plan to use a system at your facility, the more rugged the build materials should be. While choosing stainless steel over PVC, for example, can mean higher up-front costs, you'll more than make up for it by saving on maintenance and replacement costs in the long term.

Choosing the best boiler feed water treatment system

If your facility uses a boiler system, it is critical to properly treat feed water to not only prevent damage to boiler components, but also to ensure safe operation under high heat and pressure conditions. Important factors to consider in finding the right boiler feed water treatment system include:

- **Feed water quality.** Boiler feed water consists of a blend of condensate return water and boiler makeup water. The right treatment strategy for your makeup water will depend upon which impurities are present, and the contaminant tolerance of your specific boiler model. Condensate return water often does not require treatment, though certain technologies can be applied to prevent corrosion due to the presence of dissolved gases.
- **Boiler specifications.** Whenever possible, you should use manufacturer specifications to determine what level of quality is needed for your boiler unit. In general, low-pressure boilers (<600 PSI) can safely accept water with some total dissolved solids, whereas high-pressure boilers (>600 PSI) demand reverse osmosis (RO), ion exchange (IX) or other technologies capable of delivering higher quality water.

Choosing the best cooling tower water treatment system

Cooling tower water treatment systems may be used to treat various streams involved in a cooling tower, including feed water, circulation water, and/or blowdown water. Choosing the best system for your needs may involve treating one or more of these streams, especially with regard to the following factors:

- **Cooling tower specifications.** The type of cooling tower (open circulating, once-through, or closed loop), as well as the water quality specifications of your specific equipment, will determine the technologies needed to optimally treat your streams.

- **Feed water characteristics.** If you're looking to protect cooling tower equipment from damage due to scale, corrosion, clogging and other issues, it pays to check the pH, hardness and TDS levels of your source water to ensure that they measure within an acceptable range for your cooling tower equipment.
- **Regulatory requirements.** Be sure to check relevant safety and discharge guidelines to be sure that makeup water and blowdown water are compliant. If not, your ideal treatment system may involve treating for biological or other contaminants. Additionally, if your plant struggles with source and/or discharge costs, it may be worthwhile to treat your blowdown water for reuse.

Choosing the best wastewater treatment system

Effective treatment of the waste streams generated by your processes will help to ensure that you minimize disposal costs and avoid consequences for failure to comply with discharge regulations. Finding the right wastewater treatment system involves balancing a few factors, including:

- **Wastewater characterization.** Thoroughly assessing the contents of your waste stream(s) will help to narrow your focus to the technologies and systems most capable of meeting your needs. If present in large quantities, contaminants such as grease, oil, suspended solids, metals, and BOD or COD can demand more specialized treatment strategies.

- **Regulatory requirements.** A good place to start in deciding how to best treat your wastewater is by consulting applicable discharge requirements set by regulatory agencies and/or your local municipality. The best wastewater treatment systems will not only bring you into compliance with existing discharge guidelines, but can also offer some scalability to ensure that you can adapt as regulations change over time.
- **Treatability study and/or pilot test results.** A treatability study is a critical first step in designing a treatment system to suit your needs, as it will give you an understanding of the exact character of your waste stream, and offer some strategies for meeting your objectives. A pilot study, while not strictly necessary, will allow you to test out a selected treatment solution to further optimize the design for your environment.

What now?

Choosing the best industrial water treatment system for your plant is often a complex and highly individualized process. No matter what your water treatment objectives are, it is essential to consult a qualified water treatment specialist who can provide guidance in selecting the right system to meet your goals and budget. An expert can perform treatability and pilot studies to get a better handle on your needs, and can also help you to navigate the many water treatment technologies suitable for your unique process conditions and stream chemistry.

Chapter Five

HOW MUCH DOES AN INDUSTRIAL WATER TREATMENT SYSTEM COST?

WHAT INDUSTRIAL WATER TREATMENT SYSTEMS COST

Pricing, factors, etc.

Industrial water treatment is **a complex family of technologies and systems, serving a wide range of industries and applications**. Whether your needs include water treatment, process purification and separation, wastewater treatment, or a combination of these, you're probably wondering **"How much does an industrial water treatment system cost?"**

As you've likely found, estimating the cost of a water treatment system is complicated, in part due to the many factors and variables that play a role in system design. This chapter helps to tease out some of these factors and show how they apply broadly across a variety of industrial water treatment systems.

What's included in an industrial water treatment system?

Industrial water treatment encompasses **a few main types, including water treatment, process purification and separation, and wastewater treatment**. The specific equipment used in your system will depend heavily upon which of these treatment types you need, as well as the unique conditions of your process and plant. The following is a list of equipment commonly deployed across a variety of industrial water treatment systems:

- **Clarifiers** for removal of suspended solids by sedimentation, flocculation, or coagulation.
- **Lime softeners** for reduction of total dissolved solids (TDS) in feed and wastewater.
- **Oil/water separators** and/or dissolved air flotation device for removal of oils.
- **Particle filtration** for removal of larger particulates and suspended solids.
- **Membrane filtration** for removal of dissolved particles, biological contaminants, and ionic substances.
- **Reverse osmosis or nanofiltration** for water purification.
- **Filter presses** for sludge dewatering.
- **IX columns** for softening and/or selective removal of ionic substances, including hardness, alkalinity, chloride, mercury, metals and organics, among other substances.
- **Reactors and chemical additives** for pH adjustment and/or precipitation of metals
- **Control panel** (depending upon desired level of automation).
- **Peripherals**, including pumps, tanks, piping, valves, and skids.

The actual components of your industrial water treatment system will depend upon your specific application. There is often flexibility in the use of these and other technologies in fulfilling a given treatment need, and familiarity with factors that drive costs up or down can help you to understand the best treatment system components to meet your needs and budget.

The main cost factors of an industrial water treatment system

There are **four main factors that determine the cost** of industrial water treatment systems:

- What are the flow-rate requirements of the system? In other words, how fast will you need to process a given volume of water?
- What is the chemistry and quality of your influent stream?
- What is the target level of quality for treated water?
- What construction materials are required?

Answering these questions can help you to pinpoint your needs, and better understand the costs associated with an industrial water treatment system that's right for your facility.

Flow rates

In general, when it comes to industrial water treatment systems, **lower flow rates translate to lower capital costs**. While this rule holds true across most systems, flow rate can make a larger difference for some technologies over others. Cost differences between large and small microfiltration (MF) units, for example, are relatively scalable based on flow once you cover the base cost of engineering, control panel, cleaning systems, while the cost of large capacity ion exchange (IX) systems can be slightly more. As an example, increasing the flow by 50% can increase cost by about 20%.

System flow rate is usually measured in gallons per minute (GPM) and/or gallons per day (GPD). When you budget for a new water treatment system, keep in mind that the higher the GPM or GPD capacity, the higher your investment will likely be. Flow rates are always factored into the system cost, so be sure you have an accurate measurement of your process needs when requesting a quote for a new water treatment system.

Water quality

A key factor in the cost of most industrial water treatment systems is the chemistry and content of the stream to be treated. It is important to thoroughly understand the types and concentrations of substances present, as well as any variability in stream makeup. In general, **the greater the number of contaminants present, the greater the number of steps in a water treatment train, and the greater the up-front cost**. This is particularly evident with IX systems, where a complex stream can increase the up-front cost several times over due to the need for greater numbers of resin varieties, chemicals, and IX beds or columns.

For some technologies, such as RO/NF units, complex streams can greatly inflate costs due to the need for pretreatment. While not always strictly necessary, investment in appropriate pretreatment equipment can help to drastically cut long-term costs by protecting downstream equipment, improving product yields, and reducing waste disposal costs.

Target purity

It is also important to understand the target output you wish to achieve from an industrial water treatment system. If you are investing in a pharmaceutical water treatment system, for example, you are likely aiming **to comply with regulatory standards**, which can range substantially depending upon your products manufactured. Fully understanding the contaminant thresholds that are acceptable for your production limits can help to ensure that you choose the right technology to meet your needs, without overspending for water quality that exceeds your target range.

Construction materials

The materials used to construct your water treatment system can have a huge impact on cost. While many industrial applications involve harsh conditions, such as high flow rates, extreme temperatures or pH levels, and/or damaging chemicals, others are less demanding. If this is the case at your facility, **you may be able save on up-front costs** by using more affordable materials such as PVC piping and FRP tanks, as opposed to more expensive components such as rubber-lined or stainless-steel vessels and/or piping. In many cases, you may also have the flexibility to choose between less-costly manual controls and comparatively more expensive automated PLC panels.

Other important factors to consider when pricing an industrial water treatment system

- **Up-front planning.** The critical first step in securing an industrial water treatment system is planning the concepts, designs, and regulatory requirements for your project. The cost of engineering can typically run 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.
- **Space requirements.** When planning for any water treatment system, the size of your system and your plant location will affect cost. If physical space is very expensive at your plant, for example, it may be more cost-effective to invest in technology with a compact footprint. Depending upon your specific water treatment goals and process conditions, you may not have much flexibility in system size, however it pays to take the system footprint into account if you are considering various treatment technologies.
- **Installation rates.** Labor costs can vary widely from one location to the next, so be sure to investigate the installation rates specific to your area when planning your project budget. In areas where installation costs are high, prepackaged modular systems may be more affordable than build-in-place facilities. Installation costs typically range between 15–40% of the project cost, depending on the degree of prepackaging and amount of site civil work needed.

- **Level of system automation needed.** There are two basic approaches to managing your water treatment system. The first is a higher level of automation that requires very little operator intervention. This approach can eliminate human error associated with running the equipment, and can also minimize ongoing labor costs. The downside is that greater automation means a costlier up-front investment in sophisticated PLC controls and instrumentation. The second approach involves a lower level of automation and a greater reliance on operators. While manual controls can save up-front capital costs, they can also mean a greater long-term investment in labor. Considering your staffing availability as well as long- and short-term costs can help you decide on the level of automation that's right for your water treatment system.
- **Turnkey and prepackaged systems.** Depending upon the scope and complexity of your water treatment needs, you may have the opportunity to choose between a prepackaged and a build-in-place solution. Prepackaged systems typically cost the same or less, and can save up to a few months of construction time. Another benefit to choosing a prepackaged water treatment system is that the production facilities and fabrication shops that offer turnkey systems generally have specialized knowledge and experience in manufacturing the types of equipment used in your solution. This translates to quick and efficient fabrication, as opposed to the delays and added costs that can arise from hiring and onboarding a field crew for a build-in-place system.

- **Shipping the system to your plant.** When having your water treatment system shipped to your plant, plant on 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.
- **Operation costs.** In water treatment, operational costs are often based on a complex and interconnected set of factors. In planning a water treatment system, you'll need to weigh the pros and cons of initial versus long-term cost investment, the cost ramifications of adding a pre- or post-treatment system, as well as the availability of staff and space at your plant. For IX resin technologies, you'll also need to consider whether contracting for off-site regeneration is the better choice. No matter which systems you rely on, commissioning an operating cost analysis can help you to accurately budget for all the chemicals, equipment, labor, and other costs involved in maintaining your system through its life cycle.
- **Regulatory costs.** It is important to fully understand regulatory requirements for your plant, especially in terms of the cost of compliance for waste disposal. As regulations are increasingly stringent and activity is often subject to oversight, be sure to thoroughly investigate whether you'll need permits to discharge, and that your facility is approved prior to releasing any waste, as failure to comply with local restrictions can result in heavy fines.

- **Waste disposal costs.** Also consider that there will be costs to treating the secondary waste produced by your water treatment system(s). 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.
- **Other possible costs and fees.** When purchasing a water treatment system, you'll also want to be sure not to overlook other hidden costs and fees. For example: Will there be any taxes on the system or additional purchasing fees? What effect will the proposed system have on utility costs? Will you need to pay for ongoing analytical, lab, and/or compliance testing?

With these factors in mind, it is often a good strategy to check with your system engineers and/or manufacturer about affordable alternatives. They might be able to shed some light on installation-friendly systems or provide suggestions to help keep your costs to a minimum.

The bottom line

Industrial water treatment systems cover a diverse range of applications, and are used across plants of varying size and process complexity. System costs can range significantly due to these variables, with **some simple, low-flow systems running as low as $45,000, to high-end, high-capacity systems with price tags exceeding tens of millions of dollars**. While an accurate estimate of system cost is virtually impossible without taking your specific process needs into account, we've compiled some ballpark estimates by system type:

Process water treatment

Pretreatment and process water treatment systems are generally used to optimize performance and service life by preventing scaling, fouling, or other damage to downstream equipment. The cost for design, engineering, equipment, installation, and startup for process water treatment systems can vary greatly from one application to the next:

- **Boiler feed water treatment systems.** Low-pressure boilers require less exacting feed water quality than high-pressure boilers, making their respective treatment systems comparatively less involved and less costly. That said, a 100 to 200 GPM system would likely range between **$50,000 and $250,000** for low-pressure applications, and **$500,000 to $1.5 million** for high-pressure applications.
- **Raw water treatment systems.** A standard 200 to 1000 GPM capacity raw water treatment system can range from **$975,000 to $3 million**, depending upon flow rate and water quality.
- **Cooling tower water treatment systems.** A standard 100 GPM system would run somewhere between **$50,000 and $250,000**, with more complex needs like desilication and softening pushing the cost toward the upper limit.

Process purification and separation

Process purification and separation systems are used for a variety of applications, such as protecting downstream equipment, treatment or recycling of brine streams, removal of contaminants, concentration of products, recovery of valuable by-products, product purification and potable water generation, among other uses. Estimated costs for various types of process separation units are as follows:

- **Microfiltration (MF) and ultrafiltration (UF) systems.** While MF/UF are often cited for their cost-effectiveness, their costs can range widely depending upon the materials used and the flow rate needed. A basic 10 to 20 GPM MF/UF system would likely **cost less than $100,000**, while a larger 100 to 200 GPM unit would run **between $150,000 and $450,000** depending upon the quality of materials used.
- **Nanofiltration (NF) and reverse osmosis (RO) systems.** Costs for RO/NF systems range significantly depending upon the flow rate and level of pretreatment needed. A simple RO/NF system of 5 to 10 GPM capacity might run **less than $60,000**, while a large 300 GPM system with a complex pretreatment system might run **as much as $2 to $4 million**.
- **Ion exchange (IX) resin systems.** IX systems represent a large family of separation strategies, with widely variant costs that are closely tied to stream chemistry, as well as flow rate and fabrication materials. At the low end, a simple 20 GPM IX system would likely cost **less than $100,000**, while a system of similar capacity but greater chemical complexity might double or even quadruple the cost. At the high end, a complex IX system with a capacity of 2000 GPM might cost **as much as $7 to $10 million**.

Wastewater treatment systems

For most industrial applications, a 150,000 GPD capacity WWTS would cost an estimated **$500,000 to $1.5 million** inclusive of all necessary design, engineering, equipment, installation, and startup. More complex streams, higher flow rates, and higher effluent quality standards will all drive the system cost upward.

Zero liquid discharge (ZLD) systems present a special case where waste treatment is concerned. Since they remove all water from the effluent stream, they include specialized evaporator/crystallizer units which can account for well over half the total system cost. All in all, a fully-installed 1 to 20 GPM ZLD system will run **between $250,000 and $2 million**, while a 1000 to 3000 GPM capacity ZLD system will cost **$25 to $50 million**.

HOW CAN SAMCO HELP?

SAMCO has over 40 years' experience helping design and engineer some of the most effective industrial water treatment systems available. 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 engineers.

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