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Sustainable Utility Operations: The Hidden Cost of Water

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ABSTRACT

Water usage in breweries plays a crucial role in determining their sustainability, with utilities such as steam generation, cooling processes, and wastewater treatment significantly impacting resource consumption and operational efficiency. This article explores the importance of implementing comprehensive water treatment programs that address operational, mechanical, and chemical factors to optimize water and energy consumption, reduce wastewater surcharges, and extend equipment lifespan. Improperly managed systems can lead to substantial water, energy, and maintenance costs due to issues like scale, corrosion, and microbiological fouling. The brewing process utilizes 2–5 gal of water or more per gallon of beer produced, highlighting the need for effective management of closed and open-loop systems, steam boilers, and wastewater systems. Key practices include maintaining chemical balances, preventing fouling, and implementing sustainable solutions, such as water reuse and energy-efficient technologies. For wastewater, meeting regulatory requirements for pH, solids, and organic loading is essential, with options ranging from biological treatments to advanced digestion systems. Adopting these practices ensures breweries will minimize their environmental impact, reduce costs, and enhance equipment longevity. By prioritizing sustainable water management, breweries can align operational success with environmental responsibility, contributing to a more sustainable future for the brewing industry and their surrounding communities.

Introduction

The amount of water used by breweries for utilities (steam generation, cooling processes, and wastewater) directly impacts a brewery's sustainability. A well-run water treatment program considers the operational, mechanical, and chemical aspects of a program and provides opportunities to optimize utilities (water and energy consumption) to reduce or reuse wastewater, while extending equipment life. When improperly operated, steam boilers, chillers, and cooling towers can waste thousands of gallons of water, resulting in increased water, gas, and energy costs. Using sustainable practices, such as minimizing water, energy, and natural gas consumption in process/utility water programs, can prevent unexpected surcharges and offers the potential for water reuse.

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Process/Utility Water

The process water lifecycle typically starts as municipal drinking water, becomes brewhouse utility water, and then returns to the city as wastewater. The quality of the water and types of equipment using it dictate how the water needs to be mechanically and chemically treated to reduce consumption and optimize utility costs and equipment life. The goal of any successful water treatment program is to optimize water, gas, and energy consumption and examine opportunities for reuse and reduction. Ingredient water is often the first thing that comes to mind when thinking about water in the production of beer. However, the actual amount of water used in process (i.e., process water) can be 2–5 gal, or more, for every gallon of beer produced (1). Effective management of boiler, cooling, and wastewater systems is essential for optimizing the equipment operational schedule, energy and gas consumption, and overall water usage.

Best Practices for Sustainable Water Use in Common Process Equipment

Common issues affecting sustainability in energy or water consumption are scale, corrosion, and microbiological growth. Both scale deposits and microbiological fouling are very insulating on heat exchange surfaces, requiring process pumps to run longer or at higher speeds or to use more water to achieve desired cooling and increasing overall costs (Fig. 1). Corrosion leads to equipment failure, and the root cause is often biological. The Association for Materials Protection and Performance estimates that 20% of corrosion is microbiologically influenced corrosion (2).

Small craft breweries may have process/utility water that consists only of a chilled glycol loop and wastewater that primarily consists of clean-in-place and rinse water that flows to their mu-

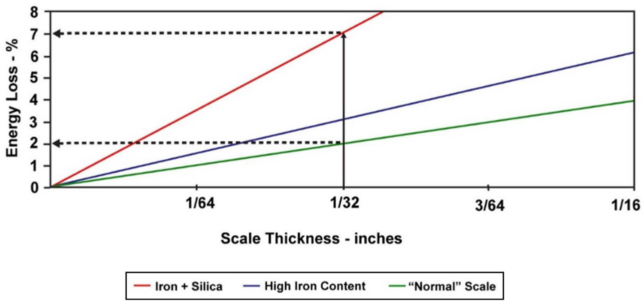

Figure 1. Energy loss from scale deposits.

nicipal sewer. As breweries grow, the complexity of their needs grows as well. Glycol loops may need to expand from air-cooled chillers to water-cooled chillers, requiring the installation of a cooling tower and/or a larger chilled loop. Boilers may be added to provide steam for vessel jacket heating or keg sanitation. Each of these changes will potentially add to the volume of process water used. As wastewater flow increases, pH may need to be neutralized and suspended solids and organic loading reduced before the publicly owned treatment work can accept discharge. Let's look at a few of these systems for examples of how they may change your requirements.

Closed Loops: Hot/Chilled Water and Glycol Systems

Closed loops, whether they are hot or chilled water or chilled glycol systems, need sufficient water treatment to prevent corrosion, mineral scale, and microbiological growth. Closed water systems should be checked for chemical inhibitor and mineral content monthly or at least quarterly. Glycol-water mixtures are used in chilled loops because glycol reduces the freezing point of water and allows for low-temperature cooling without freezing pipes. One hundred percent glycol can be very expensive, and it is seldom necessary for the amount of cooling required. Mixtures of 25–30% glycol and water plus corrosion inhibitors are the industry accepted standard best practices. Thirty percent glycol will inhibit microbial growth, but low levels (less than twenty-five percent) can contribute to microbial growth. Low glycol levels are generally the result of leaks or facility expansions where water, not additional glycol, was added to the expanded loop. Fouling, whether biological or mineral, will increase the amount of energy it takes to chill or heat the closed loop and for the loop to chill or heat the process. Proper treatment of closed loops keeps the heat exchange surfaces clean, which optimizes your process heating and cooling. As the heat exchange surface fouls, it takes more pumping energy to achieve the desired loop temperature.

Well-maintained loops can last for years with good performance. Maintaining corrosion inhibitor and microbiological control maintains asset lifetime, and preventing fouling optimizes process efficiency by keeping water and utilities consumption low.

Open Cooling Systems

Open cooling systems, such as evaporative condensers and fluid coolers, are used in the brewing industry to cool various stages of production by ejecting heat through evaporation. Water-based cooling is more efficient than air-based cooling, but it uses a large amount of water to operate. It is extremely important to operate a brewery's water-cooled systems as efficiently as possible. Water treatment programs are dictated by the specific mineral content of your local water source. You should always consult with an experienced professional to develop a water treatment program best suited for your specific needs.

Table 1. High cost of scale deposits in steam boilers

Boiler Load	Excess Annual Fuel Cost 1/64 in.	1/32 in.	1/16 in.
250 HP	$20,044	$40,923	$85,401
1,000 HP	$80,178	$163,693	$341,606
60,000 lb/h	$139,440	$284,684	$594,097

The goal should be to minimize the amount of water used in your cooling system, while simultaneously protecting your investment from corrosion, scale, and microbiological growth. Since corrosion is the act of destroying metal, a water treatment program that does not control or minimize corrosion rates can significantly reduce the operational lifespan of the cooling system.

A program that does not control system fouling (deposits) will significantly reduce system efficiency, resulting in increased water and electrical consumption and maintenance costs. Fouling includes soft biofilm and hard mineral scale. Scaled systems have the mineral content of the condenser water deposited onto the heat-exchange surfaces. While soft biofilm can be found on heat-exchange surfaces, it also can span across heat-exchanger tubes or plates or tower fill-media reducing flow (described in Appendix). Both hard and soft deposits are extremely insulating and result in loss in system efficiency and driving up water use and electrical costs.

Boiler Water Systems

A steam boiler is an expensive capital expenditure but when treated properly will last decades. All boiler feedwater should be chemically treated to prevent scale, corrosion, and oxygen pitting, both in the boiler itself and in the steam lines. The feedwater, boiler water, and any condensate return should at least be tested monthly to ensure correct chemical inhibitors and mineral content. Best practices for boiler maintenance go beyond maintaining quality boiler feed water and include inspection and preventative maintenance of the fuel or fire side (3). If you currently operate a steam boiler and don't have regular chemical treatment and mechanical service, stop reading and immediately call your local friendly boiler water treater! This article will be here when you return, your boiler may not be! There is a specific maintenance schedule that should be performed annually on your boiler by a knowledgeable professional, just like routine maintenance on your car. A rigorous maintenance schedule will ensure that the fire side and water side of your boiler are inspected, and any issues are identified early (3).

Corrosion in the boiler can cause leaks, leading to expensive repairs, a reduction in steam capacity, and increased maintenance costs. Mineral scale in the boiler is insulating and will increase the amount of gas or electricity needed to produce steam. Mineral scale is typically calcium carbonate, which is already insulating, but may include high amounts of iron from corrosion byproducts and potentially silica from poor pretreatment, which is even more insulating. Even small amounts of scale will lead to huge increases in the cost of producing steam. (Table 1)

Steam, steam line piping, and associated equipment also require proper protection. If the steam is not consumed in the process, it is often high-quality hot water, called condensate, which can be reused as boiler feedwater. This steam condensate should be protected by stream-line treatment; the treatment consists of adding a chemical inhibitor that prevents corrosion by neutralizing the pH of the steam as it condenses back into water. Steam lines can corrode prematurely without adequate neutralization, causing valuable steam and hot water to be lost. Steam traps are crucial for optimizing boiler utilities—a single failed steam trap can cost $263/year in excessive water and electricity or fuel costs! These automatic valves allow steam to flow but drain condensate for collection and reuse (4). Proper insulation of hot steam and condensate lines saves reheating costs by preventing over-cooling of the steam and/or condensate return.

Neglect of best practices in your boiler can lead to inefficiencies in both the fire and water sides of the boiler from corrosion and scale driving up water and electricity or fuel use.

Wastewater Systems

Brewery wastewater is a combination of brewhouse drains and the sanitary sewer of the facility. Water treatment authorities are increasingly requiring breweries to meet and maintain a certain level of wastewater quality before accepting the plant discharge. This means treating the wastewater onsite before discharge. Most sewer permits include effluent limits on pH, temperature, suspended solids and organic loading (Appendix). Organic loading is referred to as biological oxygen demand (BOD) or chemical oxygen demand (COD) (defined in note 1 in the Appendix). Rinses from cleaning and sanitizing agents may need to be collected and neutralized to meet pH requirements (5). Small breweries may be able to address organic loading (BOD and COD) by diverting yeast slurries or mash tun rinses from drains, perhaps to local farms, as is often done with spent grain. Breweries with relatively low amounts of flow may be able to utilize drain maintenance solutions, such as is done in the restaurant industry, where automatic dosing of specialized bacteria consumes the BOD and reduces COD (Appendix).

Larger breweries, or those with strict permits, may need additional specific steps to remove COD and BOD. Specialized digesters employ microorganisms through aerobic or anaerobic digestion to break down COD and BOD. The activated sludge process is historically the most common aerobic method used in wastewater; it requires a large footprint and many physically separated steps. Modern alternatives with excellent COD and BOD removal have drastically reduced the required footprint. Some examples include moving bed biofilm reactors (MBBR) and membrane bioreactors (MBR). Activated sludge, MBBR, and MBR are aerobic processes (note 2in the Appendix)—some breweries are using an alternative method called anaerobic digestion (note 3 in the Appendix) to convert their COD and BOD into consumable biogas (methane). Whether anerobic or aerobic, both solutions are capable of producing water suitable for reuse or discharge, and the specific equipment chosen will depend on the needs and goals of the brewery. These kinds of capital expenditure projects are usually justified through surcharge fee avoidance ($1,000–10,000/month or more in our experience) or water savings through reduction or recovery.

Conclusions

Optimizing water usage within breweries is a critical component of sustainability; it is not just a matter of operational efficiency. By implementing effective water treatment programs that address the operational, mechanical, and chemical aspects of water management, breweries can significantly reduce water consumption, energy costs, and wastewater production. The substantial water footprint of brewing (exceeding 2–5 gal for every gallon of beer produced) highlights the need for careful monitoring and management of all types of process water—from steam generation to sanitation.

Embracing sustainable practices not only minimizes the environmental impact, but also enhance financial performance by preventing unnecessary surcharges and extending the lifespan of equipment. As breweries increasingly prioritize sustainability, adopting best practices in water management will not only contribute to their operational success, but also promote a responsible approach to resource use within the industry. Ultimately, by investing in these strategies breweries can lead the way in creating a more sustainable future for both their operations and the broader community.

Appendix

1. COD measures all oxidizable organic matter, including both readily biodegradable and nonbiodegradable substances, while BOD only measures the portion of organic matter that can be broken down by microorganisms. COD is always higher than BOD, and BOD makes up a portion of COD.
2. Aerobic processes require an oxygen source.
3. Anerobic processes require the absence of oxygen.
4. Microbiological fouling has an impact four times greater than mineral scale.
5. Common Wastewater Discharge Permit, actual ranges vary by authority:

Example of a Wastewater Discharge Permit to a Local Water Authority[a]

Contaminant or Regulated Component	Min	Max
Flow, volume		Varies with daily and/or monthly max
Temperature		140°F
pH	5	9
Nitrogen, as NH_3-N		20–40 ppm
Phosphorous, as P		2–10 ppm
FOG (fats, oils, grease)		100 ppm
TSS (total suspended solids)		200–300 ppm
BOD (biological oxygen demand)		250–500 ppm
COD (chemical oxygen demand)		500 ppm
Heavy metals (e.g., Cu, Pb, etc.)		<1.0 ppm
Volatile organics (e.g., benzene, toluene, etc.)		<0.05 ppm

[a] Actual discharge allowances will vary by local authority.

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