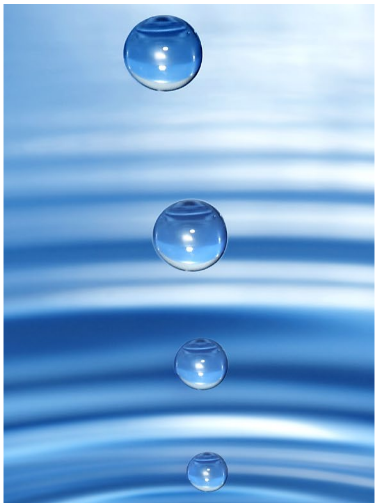
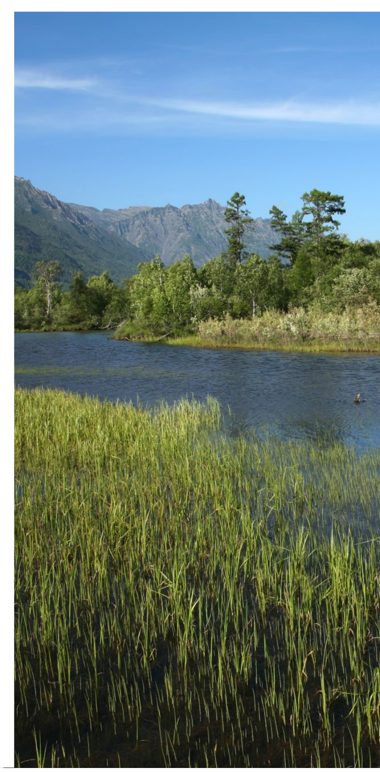


Brewers Association

Water and Wastewater: Treatment/Volume Reduction Manual



BREWERS ASSOCIATION

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acknowledgements

This project would not have been possible without the support of many Brewers Association members. The case studies they provided illustrate the creativity and application of sustainability best practices in the craft brewing sector.

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introduction

Craft brewers are innovative leaders in the beverage sector. The breweries take pride in developing new products and processes that give both brewery employees and customers options for sustainable living. Despite significant improvement over the last 20 years, water consumption and wastewater disposal remain environmental and economic hurdles that directly affect breweries and the brewing process. It is no surprise that many breweries have found innovative solutions for water and wastewater management. These solutions go beyond facility water conservation programs to find collaborative, sustainable solutions for the community and for the environment.

The abundance of clean, affordable water in the United States has created complacency among users and the public. Businesses, municipalities and academia all agree that the current usage rate with future population growth may create an unsustainable pattern.

I am convinced that, under present conditions and with the way water is being managed, we will run out of water long before we run out of fuel.

- Peter Brabeck-Letmathe, Chairman Nestlé Corporation

Given these pressing concerns, brewers need to be mindful of the future risks of cost and supply, which are key staples of a growing business. While the average water use ratio for a brewery is around seven barrels of water to one barrel of beer, many craft brewers are world leaders with ratios below three to one. Although the payback for reducing water usage is typically longer than recommended using standard financial calculators, the long-term sustainability and growth of a business may depend on the ability to efficiently use water resources. The best practices in this manual will help provide tools needed to work towards optimal efficiency, as well as to ease potential future risks and enhance community value.

This manual is a consolidated resource for effective water and wastewater management solutions in the craft brewer segment. Solutions outlined can apply to all breweries, regardless of location and operational size. It will provide guidance for small brewers that are just beginning to explore water and wastewater reduction programs, as well as provide new ideas for brewers that are looking to improve a well-established program or build improved efficiency into expansions or new facilities. Brewers will also find tools they can easily incorporate to integrate water use reduction and conservation measures into everyday operations and to identify on-site wastewater treatment opportunities.

In addition, there are checklists, resource lists, and other visual tools throughout the manual and in Appendix A to help breweries make informed decisions about water usage and wastewater reduction opportunities.

Disclaimer: the following information provided constitute suggestions that may or may not fit the need of each brewery specifically. Brewers should proceed with caution when implementing any new programs. It is not guaranteed that operating under the guidance of this manual will lead to any particular outcome or result.

The information presented is a pathway to effective and sustainable water and wastewater management from start to finish. This information is organized into five sections:

1. **Segment Profile:** A discussion of water usage and wastewater effluent trends, where to find information on regulatory drivers, examples of non-regulatory drivers, and risks and opportunities for cost savings.
2. **Data Management:** A guide to identifying the components of water and wastewater information, establishing key performance indicators and goals, managing water and wastewater data, and benchmarking progress toward goals.
3. **Best Practices:** Guidance on best practices to reduce water usage and wastewater generation focusing on opportunities in the brewing process, including packaging, warehousing, utilities, and food service/events.
4. **Onsite Wastewater Treatment:** An overview of drivers for onsite wastewater treatment and example technologies.
5. **Case Studies**: Selected brewery examples which provide more detail of water and wastewater reduction programs.

section one

Segment Profile – Water Usage & Wastewater Generated by Craft Brewers

Beer is about 95% water in composition; however, the amount of water used to produce a container of beer is far greater than the amount of water contained in the beer that is actually packaged and shipped out. Although water usage varies widely among breweries and is dependent upon specific processes and locations, the U.S. average is about seven barrels of water for every barrel of beer produced. Most craft brewers receive their water from municipal suppliers, while a few use well water as an alternative source.

In addition to the water used in production, wastewater generation and disposal presents another improvement opportunity for brewers. Most breweries discharge 70% of their incoming water as effluent. Effluent is defined as wastewater that is generated and flows to the sewer system. In most cases, brewery effluent disposal costs are much higher than water supply costs.

In many communities, breweries may be the largest consumer of water and the largest source of organic effluent that must be treated by the municipal treatment plant. This presents unique supply and cost concerns. In the U.S., the cost of incoming water from a municipal supplier (tap fee) is relatively inexpensive compared to other brewery utilities. When combining that cost with treatment (physical and chemical) and effluent disposal costs, brewers are presented with a reflection of the true or full cost of water. Establishing this concept of full cost of water is an important factor in cost/benefit analyses and will be discussed later in this document.

Water awareness and conservation practices provide an effective mechanism for brewers to reach out into communities. Outreach efforts have a number of benefits, including building brand image and being recognized as an important part of the community.

Community Benefits

Economic:

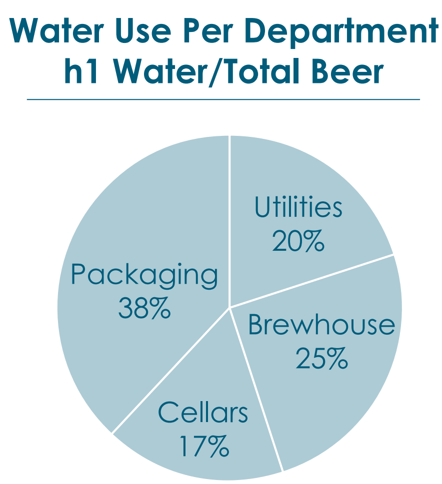
- *Helps sustain community growth and business investment.*
- *Results in better bond ratings that help communities in need of financing.*
- *Helps cities and communities showcase their waterfront areas and commitment to clean water, thereby supporting new development and encouraging related commerce.*

Environmental:

- *Helps decrease the pollution in waterways that harms wildlife and the ecosystem.*
- *Reduces water and energy usage, leading to a decrease in greenhouse gas emissions and less strain on natural resources.*
- *Ensures that community natural resources and wildlife will be protected.*

Within a brewery, there are four main areas where water is used: brewhouse, cellars, packaging and utilities. In addition, ancillary operations such as food service and restrooms contribute to water usage.

Typical Brewery Water Use Per Area

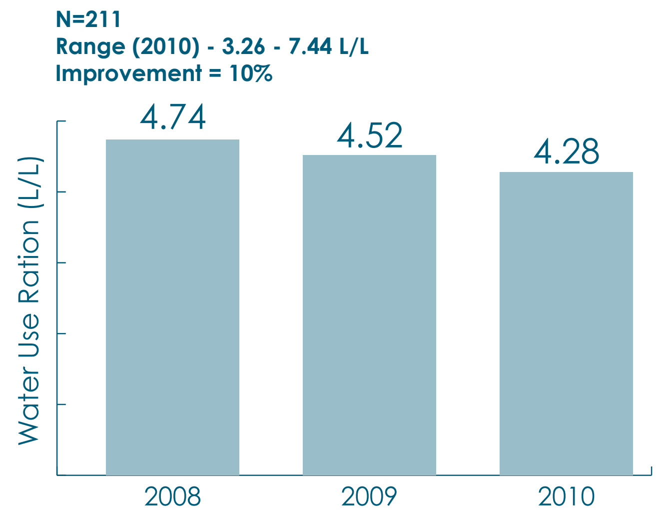


This section will identify the primary uses of water at craft breweries. It will show trends in water usage and discuss regulatory implications associated with water use. It will also cover non-regulatory drivers as well as risks and opportunities for cost savings.

1.1 Overview of Current Water Usage & Wastewater Performance Trends

In 2011, the Beverage Industry Environmental Roundtable (BIER) performed a study to benchmark water use in the beverage industry and identify trends. In the graph below, brewery data shows a consistent improvement in the industry-wide water use ratio. Although BIER members are usually larger brewers, this trend and the conclusions can be replicated as an example for craft brewers.

BIER Brewery Water Use Ratios[1]



This reduction over time seen in the brewing sector can be attributed to a number of factors, including: efficiency improvement, cost reduction, risk minimization, brand marketing and image enhancement. Several factors influence this ratio, such as packaging mix, pasteurization and volume brewed.

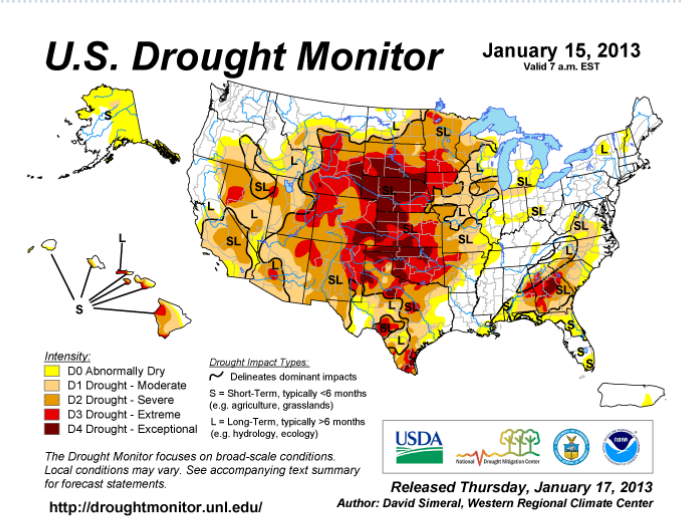
Conclusions Drawn From The Bier Study

- *The type of packaging used has a significant influence on water use ratios. Smaller packages (like 12 oz. bottles) tend to require more water use than larger packages (like kegs).*
- *The size of the facility has a major influence on a brewery's water efficiency. Facilities with larger production volumes tend to have lower water use ratios.*
- *Reducing water use reduces effluent load. Focusing on water conservation will positively affect both water and wastewater reduction in the brewery.*

While specific risks vary among facilities, common examples of water-related risks include water shortages and reliability, water quality issues that require additional water treatment, increasing water costs, and supply chain interruptions. In regions where water is scarce, it can be challenging to meet basic human needs for clean water and sanitation. Intense competition for scarce water resources can occur among public water supplies, agriculture, industry, and fisheries. In the United States, the aging infrastructures for water supply will likely drive costs higher in the future. Municipal water suppliers will soon be forced to find new sources of capital to fund these initiatives.

Climate change is predicted to magnify many of these water risks. Increasing global temperatures will likely lead to increases in water demand, water scarcity, more vulnerable ecosystems, and more frequent extreme weather events.

Map Of Water Short States[2]



Today, a small craft brewer may not be the focus of regulatory restrictions in drought-prone regions. With increasing population and demand for water, brewers can expect to experience increased scrutiny and water-related business risk in the near future.

When looking at wastewater and effluent discharges in craft breweries, there is also a trend towards a more regulated (from local authorities) and more controlled system. Craft brewers in different states and cities are increasingly questioned about wastewater or need to provide flow and chemical sampling data.

A recent survey of craft brewers was conducted to identify the current status of wastewater treatment or effluent discharges. The main questions focused on current costs and regulations around effluent and wastewater treatment.

Distribution Of 76 Breweries Included In Survey

Present in bar chart?

- *19 Breweries 0-1000 Bbls*
- *18 Breweries 1001-5000 Bbls*
- *9 Breweries 5001-15,000 Bbls*
- *10 Breweries 15,001-50,000 Bbls*
- *9 Breweries 50,001- 100,000 Bbls*
- *11 Breweries 100,001 + Bbls*

Relevant key results of this survey included:

- Not many breweries have a dedicated onsite wastewater treatment system. Most discharge their effluent to a municipal treatment center.
- Some operations have some special collection of high strength waste.
- About half did not have any pre-treatment installed at their facility to treat the effluent prior to the municipal discharge. Those who had some pre-treatment mainly adjusted the pH and settled and removed the solids.
- Wastewater costs are mainly determined based on the incoming water purchased - only a few brewers' costs were based on the real flow of effluent discharged (based on metering); the rest were based on a formula or sampling.
- Approximately one third paid an extra surcharge based on the effluent strength (BOD and TSS).

Survey Insight

- *From a cost perspective, it is important to reduce water usage, not only to purchase less water, but to reduce wastewater costs based on the amount of incoming water purchased.*
- *Onsite pre-treatment will reduce the strength of the effluent being discharged and may be required by local authorities through ordinance or permit. Discharge limits are being applied more often to brewers because of the high organic load untreated brewery effluent may contain.*

This manual focuses on reducing water and effluent first, and then reducing the strength of the effluent.

1.2 Regulatory Drivers

Demand for water in the U. S. more than tripled between 1950 and 2000. This increase in demand has put further stress on water supplies.

Experts believe that in 2013, more than 70% of the United States is experiencing or will experience some type of local, regional or statewide water shortage. By 2025, four billion people - about half of the world's population - will live in 'severe water stress' conditions.

Environmental Drivers

- *Stress on water supplies*
- *Risk of (local) water shortage*
- *Risk of (local) water pollution*

In addition to human needs, protection of endangered species and ecosystems will compete with available water supply. It is likely that the U. S. Environmental Protection Agency (U. S. EPA) will introduce new laws and regulations that keep water "in-stream" for species protection. The ongoing debate of water for human consumption, economic development, species protection, recreation, tourism and flood control will continue into the future.

Excessive water pollution can impact ecosystems. The high organic nature of brewery wastewater causes oxygen in a surface water to be depleted at a rapid rate, which negatively impacts living species and biodiversity. A number of water bodies in the United States remain above pollution levels considered safe for ecosystems. Additional regulatory restrictions are expected in the near future to address this problem.

An impaired waterway is a river, lake, stream, pond, bay, or estuary that does not meet the water quality standards of the Clean Water Act and the state. The graphic below illustrates the extent of impaired waterways in the United States.

As a result of shortages, water allocation issues are escalating between political subdivisions because of the various stakeholders involved. These are often extended legal proceedings around state and local water rights. In most cases, the craft brewer will not be directly involved or aware of these activities; however, these actions will drive decisions that will impact the availability and cost of water and wastewater services provided to the brewer. Due to increasing populations and technology, more resources are constantly needed to match lifestyle expectations. With so many different needs for this scarce resource, priorities must be established. How much water should be used to extract natural gas, produce electricity, irrigate agricultural crops, or used for human consumption in the form of packaged beverages?

Congress has passed legislation and the U.S. EPA has introduced rulemaking to protect surface water bodies from pollution. The Clean Water Act regulates the discharge of pollutants into U.S. waters and establishes quality standards for surface waters. Under the Clean Water Act, the following rules may directly or indirectly impact craft brewers operations.

Common legal drivers under the Clean Water Act

- Effluent Limitations Guidelines: national standards for industrial wastewater discharges to surface waters and publicly owned treatment works.
- Pre-treatment Streamlining Rule: pre-treatment programs for the control of industrial discharges into sewage collection systems.
- NPDES Permit Program: regulating point sources (single, identifiable sources of pollution such as pipes or man-made ditches) that discharge pollutants into U.S. waters.
- Sewage Sludge (Biosolids) Rule: requirements for the final use or disposal of sewage sludge.
- Total Maximum Daily Load (TMDL) and Impaired Waters Rules: states, territories, and authorized tribes are required to develop lists of impaired waters that are too polluted or degraded to meet set water quality standards.

In addition, the Safe Drinking Water Act (SDWA) sets legal limits on levels of certain contaminants in drinking water.

In addition to these regulatory guidelines, there are also regional compacts that can govern water use and wastewater effluent. There are groups (i.e., The Great Lakes Compact) working together to protect local watersheds. It requires all water-intensive businesses within the watershed to implement water conservation practices.

Great Lakes Compact

The Great Lakes—St. Lawrence River Basin Water Resources Compact is a legally binding interstate compact among the U.S. states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. The compact details how the states manage the use of the Great Lakes Basin's water supply and builds on the 1985 Great Lakes Charter and its 2001 Annex. The compact is the means by which the states implement the governors' commitments under the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement that also includes the premiers of Ontario and Quebec. The interstate compact seeks to ban the diversion of Great Lakes water, with some limited exceptions, and set responsible standards for water use and conservation within the basin.

There are also general prohibitions for discharge to publicly owned treatment works (POTW). For example, in most local ordinances, there is a prohibition on pass through or interference ("A User may not introduce into a POTW any pollutant(s) which cause Pass Through or Interference").

From a practical standpoint, this suggests that brewery wastewater must be screened for large particles (like bottle caps, broken glass, grains, etc.) and chemically pretreated for pH, temperature, and organic concentration.

1.3 Non-Regulatory Drivers: Image/Brand, Community Ties

In addition to regulatory drivers, brand image and positioning will drive many water and wastewater improvement programs at craft breweries. These efforts start with employees and can extend into the community.

Many breweries educate and engage employees in water-efficiency efforts at the facility and encourage them to adopt similar practices at home (e.g., check for leaks, use efficient appliances and faucets, turn off water when not in use, etc.). Changing the water use culture in a brewery can often be a challenge. Incentives, in the form of monetary or visual recognition, can play an important role in this effort.

Photo Of Community Clean Up[3]

Some breweries partner with community members and local organizations to conduct projects that improve water use, water quality, and/or water management resources. Consider using Lean methods—such as a wastewater walk (to identify leaks and unnecessary drainage), kaizen event, or even a Lean design event—to rapidly brainstorm and test improvement ideas for projects, and include community stakeholders in those efforts.

Key Efforts

World Water Day - Every year on March 22, the UN-Water Partnership, comprised of 28 different UN organizations, celebrates World Water Day. World Water Day focuses public attention on water-related issues and on sustainable management of freshwater resources. There are events held all around the world, providing great opportunities for brewers to communicate efforts to help conserve this precious resource.

The Clean Water Act 40th Anniversary - The Clean Water Act is one of the landmark environmental laws in the U. S. The year 2012 marked its 40th anniversary.

Along with the value of community engagement, these strategies can improve the impact the facility has on local water resources. Some leading global beverage companies have set goals to replenish the local water supply with at least the amount of water consumed.

TCCC Water Stewardship Campaign

The Coca-Cola Company set three water stewardship goals for its global operations. These goals are:

1. Reduce*: By 2012, improve water efficiency by 20% compared with a 2004 baseline. In essence, this is an efficiency target not unlike many other beverage companies have set. It is measured as water use ratio, the amount of all water needed to make one liter of beverage.*
2. Recycle*: By 2010, return to the environment – at a level that supports aquatic life –the water used in the system operations through comprehensive wastewater treatment. This is a water treatment standard, whereby the company strives to clean all wastewater from its operations to a very high standard of cleanliness, often exceeding local requirements. The goal is called recycle because the resultant discharge is clean enough to be recycled in nature's water cycles without harming aquatic life.*
3. Replenish*: By 2020, safely return to nature and to communities an amount of water equal to what is used in the finished beverages and their production. This goal depends on successful community water partnership programs and eco-systems projects to be reached. For each can of Coca-Cola beverage an equivalent can of water has to be given back, either to communities in the form of potable water (where this was not available before) or as clean water back to an eco-system. The latter can be achieved in a myriad of ways. For example, replanting with native vegetation can increase the retention of water in the basin. Increasing groundwater recharge through reforestation or artificial aquifer recharge could also be considered as a replenishment activity. Coca-Cola depends on external and independent validation of the amount of replenishment water they can claim for replenishment.*

Reducing water use and improving management processes can provide a competitive marketing advantage. Customers and employees alike see proactive efforts to improve the environment as an important and desirable attribute. This increases customer loyalty and improves a brewery's ability to attract and retain employees.

People around the world view water issues as a key sustainability challenge. For example, more than 90% of the 32,000 people polled for a GlobeScan and Circle of Blue survey in 2009 perceived "water pollution" and "freshwater shortage" to be serious problems (70% considered them very serious problems). Some companies can tap into significant market niches by offering cus¬tomers water-efficient choices and solutions.

Summary of Circle of Blue Survey

General concerns

- *96% agree that it is important for all people to have adequate, affordable drinking water.*
- *88% worry that fresh water shortages will become an increasingly severe problem worldwide.*

Particular concerns

- *57% is primarily concerned around water pollution*
- *56% is concerned about the lack of safe drinking water*
- *47% is concerned about the lack of water for agriculture*
- *35% is concerned about the cost of water*

Who should be held responsible ensuring clean water in communities?

- *44% water companies*
- *41% the government*
- *39% large companies (Note: 79% think that companies need to be a part of the solution)*
- *30% individual citizens*
- *Little responsibility is placed on farmers and NGOs*

Last, a majority (60%) of Americans believes that individuals have the ability to contribute to the solution when addressing water shortages, and 75% indicate they need more information before they would feel able to help protect water.

Community ties give breweries the opportunity to promote water conservation outside the four walls of the facility, further supporting the brand and image. Saving water and educating employees can be demonstrated through projects like rainwater harvesting.

5 Seasons Brewery Rainwater Harvesting

Not only were the folks behind this microbrew looking to save water, they want to educate people. According to Randy Kauk, President of RainHarvest Systems:

"We are extremely excited with our new partnership with 5 Seasons Brewery. We believe it uniquely demonstrates the broad array of applications where rainwater can be used instead of chemically treated drinking water; plus it is a great way to create public awareness of rainwater harvesting. "

Addressing water and wastewater issues should be critical elements on any brewery's agenda. Linking local efforts to larger national and global events is one effective approach to raising awareness among employees and in the community.

1.4 Risks and Opportunities: Water Use Reduction and Wastewater Management

Water supply and wastewater discharges present a number of risks and opportunities for craft brewers. As with any business investment, a cost benefit analysis should support any decision to expend resources in these areas.

Historically, capital to support water usage reductions has been difficult to justify due to the low tap fees associated with municipal water supplies in the United States. Even using the full cost of water accounting methods, water reduction and re-use projects often do not meet brewery hurdle rates for expenditures. Many craft brewers have justified these projects based on image and community drivers alone.

Water Cost Considerations

Common Costs Associated with Water Use (Box 7)

- *Raw Material Costs:*
  - *Water purchased from utilities; marginal costs of purchasing additional water versus costs of conservation*
  - *Cost of water treatment, filtering, and softening before use*
  - *Costs for chemicals needed to treat and manage water*
- *Energy Costs:*
  - *Cost of energy to heat water*
  - *Cost of energy to pump water from its source, or within the facility itself*
  - *Energy and labor costs for operating and maintaining water-using equipment*
- *Pollution Control Costs:*
  - *Wastewater and stormwater service rates, including surcharges*
  - *Total cost of treating wastewater for disposal, including labor, energy, chemicals, equipment, and residual disposal*
  - *Marginal costs of increasing effluent treatment capacity when water demand increases*
- *Regulatory Compliance Costs:*
  - *Labor costs for regulatory compliance activities such as completing permit applications, monitoring compliance, and reporting wastewater discharges to regulatory agencies*

It requires a lot of energy to move and use water, so water savings result in cost savings. Approximately 20% of all the energy used in the state of California is used to move, use, and treat water. Although water savings projects are often not cost effective due to the low price of water in the US, when the electricity savings are also included, it adds another layer of savings.

The largest driver to date has been wastewater compliance. In order to meet wastewater effluent regulatory requirements, many craft brewers have initiated reduction projects. Most breweries are charged for their wastewater based on the incoming water purchases as well on the strength of the effluent.

There are many incentives that focus on water use and wastewater reduction. Reducing the effluent load and decreasing water use will reduce bottom line costs. Brewers should recognize that reduced water usage will result in lower wastewater discharges; however, the concentrations of pollutants in this case may be higher. It is important to check this potential increase in concentration against regulatory limitations.

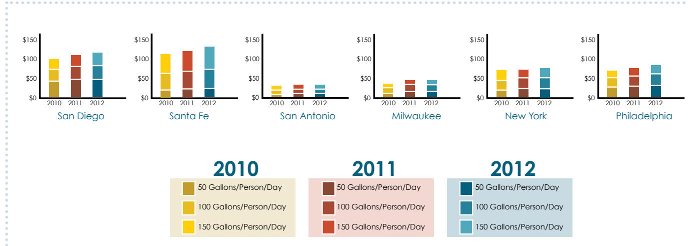
The following graphic illustrates typical annual wastewater surcharges for different sized breweries.

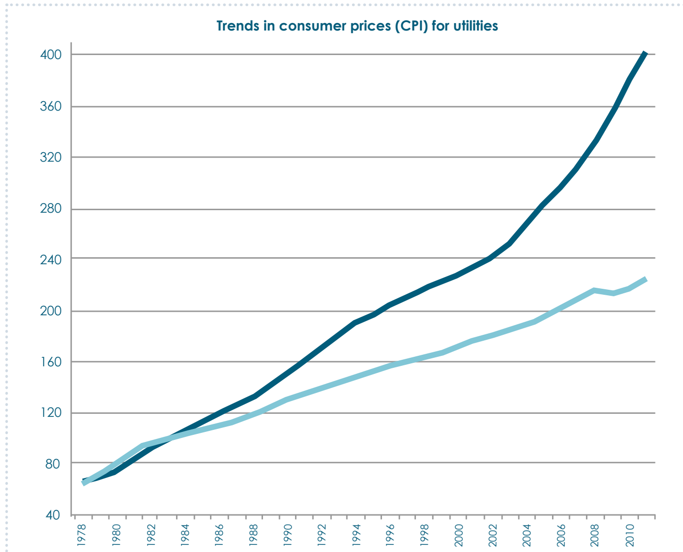
Example Of Typical Annual Wastewater Surcharges

Annual Beer Production (bbl)	2bbl ww/bbl beer	4bbl ww/bbl beer	10bbl ww/bbl beer
1,000 - 15,000	$550 - $8,200	$1,100 - $16,400	$2,800 - $41,000
15,000 - 100,000	$8,200 - $54,700	$16,400 - $110,000	$41,000 - $274,000
1000,000 - 600,000	$54,700 - $328,000	$110,000 - $656,000	$274,000 - $1,700,00
6,000,000 - 2,000,000	$328,000 - $1,100,000	$656,000 - $2,200,000	$1,700,000 - $5,500,000
>2,000,000	>$1,1,00,000	>$2,200,000	>$5,500,000

The price of water continues to increase. This increase has affected the cost of utilities in many municipalities.

Increase In Municipal Utility Costs





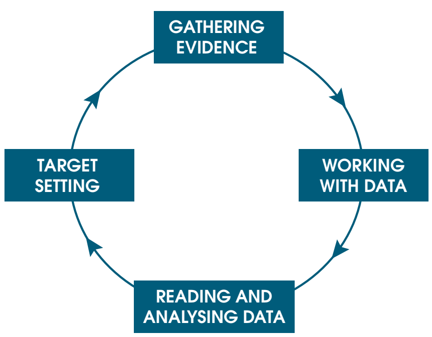
When considering the above items, it becomes clear that water management and wastewater minimization efforts make good business sense from both a cost savings and from a business continuity perspective.

section two

Data Management

Data management is more than just a component of a successful program – it is a necessity for a successful business strategy. As discussed previously, there are both risks and opportunities in water and wastewater management. Making informed business decisions to minimize risk and maximize opportunity requires effective data management.

Effective Data Management System



This section covers best practices in data management, from establishing a data collection routine and ensuring the data is accurate, to creating key performance indicators and setting goals.

2.1 Data Collection

Successful data management enables cost-effective decisions to be made. Data management often goes beyond collecting usage and cost data from a monthly utility invoice. It includes identifying process areas, support functions, and facility operations that have the greatest opportunities for improvement. Strategies include tracking water metrics as part of process improvement activi-ties, as well as installing water meters on processes that use large amounts of water and have a history of inconsistency. Understanding water use is critical to starting an effective conservation program.

Where to start?

1. Where is the water going?
2. How much water is used? What are typical values?
3. How much water is discharged?
4. What's in the water discharge? What are typical values?
5. How can water use and discharge be managed?

Brewery Size Versus Wastewater Generation

Annual Beer Production		ww @ 2bbl ww/bbl beer		ww @ 4bbl ww/bbl beer		ww @ 10bbl ww/bbl beer	
bbl	gallons	bbl/year	gallons/ day	bbl/year	gallons/ day	bbl/year	gallons/ day
5,000	155,000	10,000	850	20,000	1,700	50,000	4,200
1,500	465,000	30,000	2,550	60,000	5,100	150,000	12,700
300,000	9,300,000	800,000	51,000	1,200,000	102,000	3,000,000	255,000
1,000,000	31,000,000	2,000,000	170,000	4,000,000	340,000	10,000,000	850,000

The ability to collect or estimate water consumption data by process step can lead to more effective water conservation practices.

The previous section identified five main uses of water in a brewery or brewpub:

1. Brewhouse
2. Cellars
3. Packaging
4. Utilities
5. Ancillary

A third party utility bill will often provide usage and cost data for the main water meter only. Creating a formal mass balance of water and wastewater in the brewery is often costly and resource intensive; however, there are some data management steps that can be completed early in a water conservation program using a survey checklist.

Survey Checklist Example

1. *Map the brewery's water distribution network and mark the routes of major pipes and drains on the site plan. Are the drawings up to date?*
2. *Identify the major points at which water is used.*
3. *Identify the major of wastewater discharge.*
4. *Identify the content of the effluent (yeast, trub, etc.), if possible.*
5. *Estimate the amount of water used and discharged at each major point.*
6. *Identify the water quality and availability at each [major] point.*
7. *Include designations for hot, cold and drainage systems.*
8. *Check water use in different areas of the brewery when production has ceased. If liquid is flowing through pipes or drains, either there is a leak or equipment has been left switched on (potential energy savings).*
9. *Label pipework, valves and manholes for easy identification.*

This task and checklist is often helpful for a new employee to fully and quickly understand the brewery and its processes. These checklists are also a good opportunity to partner with interns from a local university or trade program.

Keep in mind that a detailed water balance can be difficult to do because of evaporation losses. Evaporation, particularly from refrigeration plants, can account for as much as 25% of incoming water usage. Wastewater treatment also has a high rate of evaporation.

Common Survey Findings

- *Unidentified and cross connections*
- *Broken and incorrectly set valves*
- *Leaks*
- *Excessive, unnecessary and unknown use*
- *Clean water discharges directly to effluent (e.g., cooling water)*
- *Unauthorized discharges to effluent*
- *Surface water drainage from potentially contaminated areas*

Installing sub-meters at key locations is the best way to quantify and segregate water usage. Pulse output mechanical meters allow for automatic data collection, reducing measuring errors, and eliminating manual reading of the meters.

Using Water Meters To Identify Opportunities

Revised procedures help brewery to reduce hot liquor waste

The Brewery operated by Hardys & Hansons had a single, cold liquor tank, situated outside the Brewery on the South side. A second tank, twice the size of the first, was subsequently installed to meet authority storage requirements. Flow into and out of the tanks is controlled from the brew-house using actuated valves.

During hot weather, the temperature of the cold liquor rose from 12°C to 20°C. This, combined with an outdated heat exchanger, produced an excess of low quality hot liquor which had to be diverted to drain. The wort also required further cooling in the fermenters before a brew could begin.

Installing water meters helped to identify these problems. Procedures have been revised to allow the brewer to bypass one of the cold liquor tanks, depending on demand and the ambient temperature. Cold liquor storage time is now minimized and temperature gain reduced. A further reduction in hot liquor waste has been achieved by automating flow through the heat exchanger and adding a chilled water section. In addition, the hot liquor retained is of a higher quality and processing has been speeded up.

A single meter isn't capable of providing enough details on water usage in different process steps, so installing additional meters is highly recommended. If installing sub-meters is not possible, there are several other ways of estimating water volume. In places where water is transported in a constant flow, read the pump capacity and multiply this flow by the operating hours. Be careful when using this method and don't assume that the equipment is actually doing what it says on the nameplate. Be sure to check the numbers against expected outputs.

Flow Measurement Considerations

- *How accurate does the data have to be?*
- *Does the data need to be trended or will a one-off measurement suffice?*
- *What is the size and material of the pipe?*
- *What is the operating pressure and temperature?*
- *What is the expected flow range (min to max)?*
- *Are there any existing meters that can be connected to a data logger or transmitter?*
- *When a tank is filled on demand, which is based on low-level/high-level switches, count the number of filling cycles. Determine the time it takes to fill one gallon in a bucket. This can help estimate the water flow.*

As described in the previous section, many utility companies estimate wastewater effluent volume based on a percentage of incoming water billings. There are allowances for domestic use and calculating the amount of water leaving the site in the product and through evaporation. This method requires assumptions on the amounts of water used in flush toilets, wash basins, canteens, etc. When using this method, inform the utility of any changes in staff numbers or modifications to staff facilities. These changes may affect water consumption and the allowance for domestic use.

Determine if rainwater is discharged to the same sewer system as process effluent. It may be beneficial to separate these flows, especially when there is an onsite pre-treatment facility.

Labeling Process And Storm Drains

A simple way to separate sewage water (effluent) and surface water (rain water) is to label or color-code all drains. This will allow easy identification of the different pipes.

Installing a wastewater meter or demonstrating a different ratio may be beneficial for a craft brewer; however, flow measurement becomes quite inaccurate when solids are present in the effluent, as is the case with brewing effluent. The most accurate flow measurements can be obtained using a flume, although it is usually not easy to find the right conditions for installation.

Wastewater Flume

A flume is an open artificial water channel, in the form of a gravity chute that leads water from a diversion dam or weir completely aside a natural flow. A flume can be used to measure the rate of flow. Specific designs include the Venturi, Parshall, Palmer-Bowlus, trapezoidal, and H-Flume.

Unlike incoming water, it is important to sample other parameters besides volume on a regular basis, since most utilities have a surcharge cost for brewers based on organic and solids sent to the municipal treatment system. A surcharge is established to recover the cost of transporting and processing wastewater that exceeds levels normally associated with typical household (domestic) wastewater levels.

Typical Domestic Wastewater Levels

Biochemical Oxygen Demand – less than 400 ppm
Total Suspended Solids – less than 400 ppm
Oil & Grease – less than 100 ppm

A surcharge by a municipality is typically determined by using laboratory test results from wastewater samples taken from the discharge of the brewery where it enters the municipal system. The current water consumption and established municipal surcharge rates are used to calculate additional fees beyond those required of domestic wastewater discharges.

Before contacting your municipal water agency, an effective first step for a responsible brewer involves contacting a private laboratory to analyze a composite wastewater sample. This knowledge can help to establish the most effective strategy for approaching the water agency.

Samples can be taken either by the brewery or by the utility and can be either spot samples or 24-hour composite samples. The choice will depend on the utility requirements.

Composite Wastewater Sampling

A 24-hour sample will generally give a more reliable measurement, since any peaks due to the variations in the brewery process are leveled. A flow-weighted composite sample can be taken, which is the most accurate measurement, as it compensates for the flow variations of the effluent during the day.

Be aware that brewery effluent is highly degradable and thus samples need to be stored properly. Samples must be kept at the proper temperature and measurements should be performed as soon as possible. Any pH measurements should be performed immediately, since the result will vary after a few hours.

Each brewery will have different wastewater concentrations; however, there are typical values and ranges of key components that have been associated with untreated brewery effluent.

Typical Ranges Of Brewery Untreated “End-Of-Pipe” Wastewater Effluent

PARAMETER	TYPICAL RANGE
Water to beer ratio	4 - 10 liter/liter
Wastewater to beer ratio	1. 3 - 2 liter/liter lower than water to beer ratio
Biochemical Oxygen Demand (BOD)	600 - 5,000 ppm
Chemical Oxygen Demand (COD)	1,800 – 5,500 ppm
Nitrogen	30 - 100 ppm
Phosphorus	30 - 100 ppm
pH	3 - 12
Total Suspended Solids (TSS)	200 – 1,500 ppm

Typical Ranges Of Brewery Pre-Treated “End-Of-Pipe” Wastewater Effluent

PARAMETER	TYPICAL RANGES
BOD	100 - 400 ppm
pH	6-9
TSS	50-500 ppm

Although each brewery is different, breweries can generally achieve an effluent discharge of 3 to 5 liter/liter (considered an industry best practice goal) of sold beer (exclusive of cooling waters).

Effluent from individual process steps is variable. For example, washing bottles produces a large volume of effluent that contains only a minor amount of the discharged organics from the brewery. Effluent from fermentation and filtering are high in BOD and low in volume, accounting for about 3% of total wastewater volume but 97% of BOD. The average pH of combined effluent is around 7. But this can fluctuate from 3 to 12 depending on the use of acid and alkaline cleaning agents. The pH of waste beer usually ranges between 4 and 5. CIP effluent temperatures average about 86°F.

Most brewers discharge over 70% of their incoming water as effluent.

Main Areas Of Wastewater Generation

SOURCE	OPERATION	CHARACTERISTICS
Mash Tun	Rinsing	Cellulose, sugars, amino acids. ~3,000 ppm BOD
Lauter Tun	Rinsing	Cellulose, sugars, spent grain. SS ~3,000 ppm, BOD ~10,000 ppm
Spent Grain	Last running and washing	Cellulose, nitrogenous material. Very high in SS (~30,000 ppm). Up to 100,000 ppm BOD
Boil Kettle	Dewatering	Nitrogenous residue. BOD ~2,000 ppm
Whirlpool	Rinsing spent hops and hot trub	Proteins, sludge and wort. High in SS (~35,000 ppm). BOD ~85,000 ppm
Fermenters	Rinsing	Yeast SS ~6,000 ppm, BOD up to 100,000 ppm
Storage tanks	Rinsing	Beer, yeast, protein. High SS (~4,000 ppm). BOD ~80,000 ppm
Filtration	Cleaning, start up, end of filtration, leaks during filtration	Excessive SS (up to 60,000 ppm). Beer, yeast, proteins. BOD up to 135,000 ppm
Beer spills	Waste, flushing etc	1,000 ppm BOD
Bottle washer	Discharges from bottle washer operation	High pH due to chemical used. Also high SS and BOD, especially thru load of paper pulp.
Keg washer	Discharges from keg washing operations	Low in SS (~400 ppm). Higher BOD.
Miscellaneous	Discharged cleaning and sanitation materials. Floor washing, flushing water, boiler blow-down etc.	Relatively low on SS and BOD. Problem is pH due to chemicals being used.

2.2 Ensuring Accuracy

After data measures for water usage and wastewater are identified and quantified, the information should be reviewed for accuracy. Without reliable data, especially as the starting point, it will be difficult to track progress. Having accurate initial data is also important to monitor for new water usage and wastewater generation, identify mid-point goal milestones, and cost savings. To verify the data, three key questions are:

- Does the volume of water used and wastewater generated appear reasonable based on the amount of beer produced?
- Is the volume of water used and wastewater discharged consistent with historical volumes (e.g., last month and the same time last year)?
- Is there any missing data that should be included (e.g., new wastewater stream, or one-time beer dump due to quality issues)?

After the data is verified and approved, the information should be shared with team members, such as brewery employees and management. Breweries that have collected information for several years can report progress toward water reduction goals and overall cost savings. It is always important to openly communicate both the starting point and the ultimate goals and targets that the brewery is aiming to achieve.

2.3 Benchmarking: Key Performance Indicators (KPIs)

Key Performance Indicators (KPIs) are defined by breweries to measure the effectiveness of a reduction program over time. Defined KPIs are standard points of reference that provide valuable insight into a program's performance. KPIs are usually defined as a rate or ratio (e.g., total water use ratio) instead of a quantitative total, such as total water used.

Typical KPIs for Water

Facility-Wide Metrics

- *Volume of water used each month or other appropriate time period (e.g., gallons/month or gallons/shift)*
- *Volume of wastewater (e.g., gallons/month or gallons/shift)*
- *Water used for specific end uses (e.g., gallons/ per month for outdoor irrigation, cooling water evaporation, heated process water, bathrooms and kitchens, etc.)**

Metrics Normalized to Production

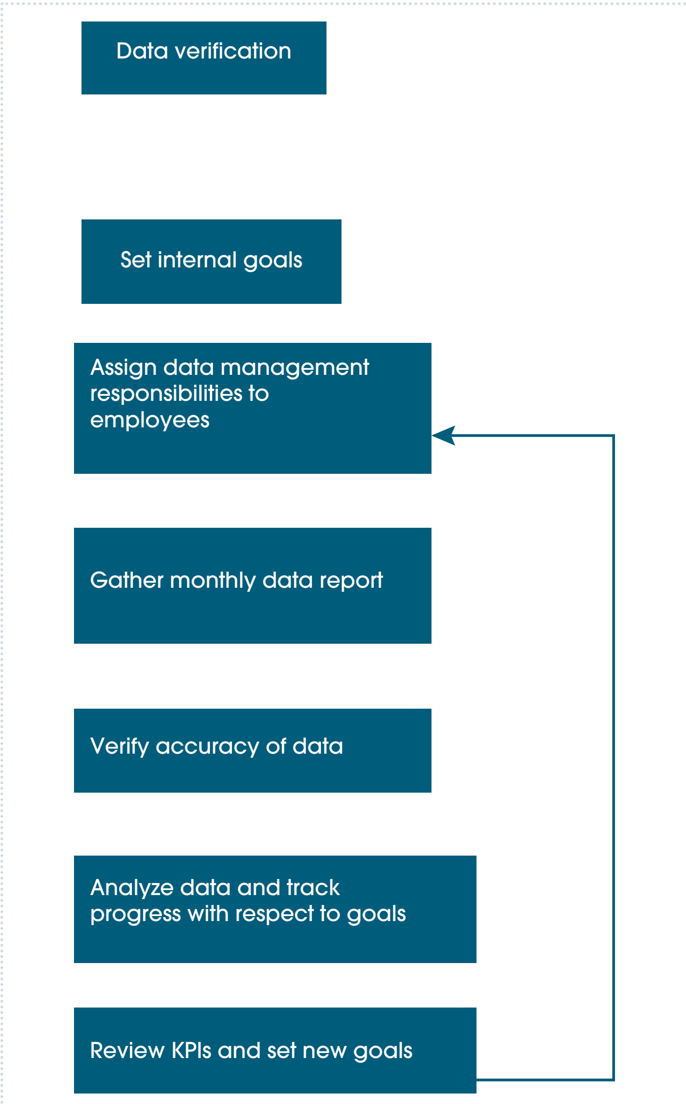
- *Volume of water used per product (e.g., gallons/ pound of product, gallons/product)*
- *Volume of wastewater discharged per product (e.g., gallons/pound of product or gallons/product)*

KPIs are often used internally to manage a water reduction program by encouraging comparison over time. Initially, there may only be one or two KPIs that focus on basic water streams. As the water management program matures, KPIs may change or new KPIs may be created to encourage continuous improvement, especially in areas that may be lagging behind.

Once KPIs have been defined, breweries should establish an annual internal benchmarking plan. Assign data management roles to brewery personnel so that the data set can be built up throughout the year. Repeat the benchmarking exercise each year and report progress on goals.

When there is confidence in the accuracy and performance of the brewery water data set, consider sharing benchmarking results with external stakeholders, customers, and peers. Sharing this information could be as simple as including statistics on a brewery tour, including performance information on the brewery website or social media outlets, such as blogs or Twitter feeds, or producing a basic sustainability report document. As facility benchmarking continues to mature, the brewery may also consider reporting performance to external stakeholders.

Data Flow Progression



Once the water management program is established and KPIs have been calculated for several periods, benchmarking the brewery to peer companies and sector averages will help gauge the effectiveness of the program.

2.4 Guidelines for Setting Measureable Goals and Objectives

Establishing goals and objectives to reach a desired future state will drive continuous improvement in the water reduction program. Several important things to consider when defining objectives and setting goals:

Considerations For Goal Setting

- *Prioritize opportunities: What is most important for the brewery in the short term? What opportunities are good for the brewery, but could wait a few years for implementation?*
- *Set meaningful targets and align goals with a philosophy: Make sure goals are meaningful and realistic – building the brewery's philosophy into water reduction goals will boost interest and enthusiasm for the program. Set attainable performance targets to ensure the brewery is effectively working toward goals.*
- *Establish a benchmarking plan: A benchmarking plan will ensure continuous improvement over time. Plans will vary based on brewery size and program maturity.*
- *Look at the big picture: Think beyond primary goals to larger objectives (e.g., employee engagement in water reduction, expanding the understanding of water across the entire brewery lifecycle, from supplier to consumer).*

Targets are designed to be more stringent and specific than goals. Often, targets are set in response to goals. For example, the brewery may set a goal of 6 liters of water per liter of beer produced by 2020, and set targets for a continuous improvement of 20% water reduction every two years. While goals should align with the brewery's philosophies and may be more aspirational, targets should be more realistic and attainable.

What are good targets?
- Have a set deadline
- Are ambitious, yet attainable
- Are quantifiable
- Are relevant to program improvement
- Can be reassessed and enhanced after original target is met

New Belgium Brewing Company Water Target

New Belgium Brewing Company has defined water stewardship as responsible consumption through minimizing waste and protecting watersheds. They have set a water use target of 3.5:1.0 ratio by 2015.

section three

Usage & Reduction Best Practices

Increasing yield and reducing beer loss should always be the first priority in any resource efficiency program. Reducing the amount of beer being spilled and wasted saves water, energy and ultimately, provides an immediate cost return.

Water reduction programs usually follow beer loss programs. There are usually some quick fixes for brewers just starting water reduction programs. The costs of even minor leakage is often overlooked or underestimated.

As previously discussed, water reduction projects have been difficult to justify based on the cost of water; however, if the full cost of water is calculated, some projects may become more attractive, especially if future price increases are taken into account and value is put on business continuity and water reliability.

Full Cost of Water

Costs Associated with water use = $\underbrace{\text{Price of incoming water} + \text{Sewer Service Charge}}_{\text{The “price on the water bill”}}$ + Cost of energy and chemicals needed to process water + Labor and other costs associated with water processing and treatment

The cost of water use at a facility can be much greater than the amount on the water bill.

Cost of Water Leaks

Leak detection is cost-effective. The Eagle Brewery operated by Charles Well Ltd has a comprehensive utility monitoring system that covers the water supply to the main process areas. Since it was installed, the system has paid for itself many times through rapid identification of leaks. Continuous metering allows the brewery to identify changes in normal water use due to leakage from a single component, like a valve, as well as identifying major leaks. Example faults and the estimated potential hourly costs are listed below

FAULT	ESTIMATED POTENTIAL COSTS (U.S.$/HOUR)
Hose left on	14.00
Bottle pasteurizer rinse jets left switched on	14.00
Bottle rinser left switched on	6.10
Leaking float valve on the cooling tower	4.10
Leaking ball valve on the bottle pasteurizer	2.00
Leaking ball valve in the keg plant	1.90
Pasteurizer header tank top-up valve jammed	1.65

When calculating the potential savings from a particular measure, there may be savings in the cost of:

- Water use
- Onsite water pumping and associated maintenance
- Water treatment (chemicals, filter backwash, etc.)
- Water heating or cooling
- Effluent pumping
- Effluent treatment
- Effluent discharge

Example Of Total Unit Costs

Table 3: Costs Associated with Water Used in an Industrial Process	
Activity	**Unit Cost ($/1000 Gallons)**
City Water Purchase	**$3.55**
Sewer Rate	**$3.99**
Deionized using reverse osmosis	
Equipment	$0.57
Energy	$1.20
Labor	$1.43
Total Deionized water	$2.31
Deionized water (flexible cost)*	40% x $2.31 = **$0.92**
Wastewater treatment	
Sludge disposal	$3.46
Treatment chemicals	$2.44
Energy	$0.32
Labor	$6.25
Total wastewater treatment	$12.47
Wastewater treatment (flexible cost)*	40% x $12.47/gallon = **$4.98**
Total cost of water	**$13.44**
* Flexible cost savings of conserved water is estimated to be 40 percent of total investment cost	

Besides these total costs, some additional cost savings may be calculated from:

- Increased beer production
- Greater recovery of materials suitable for sale as animal feedstock
- A delayed requirement of additional water storage capacity
- Increased production without having to upgrade the water supply system
- Lower capital expenditures on a planned or future effluent treatment system

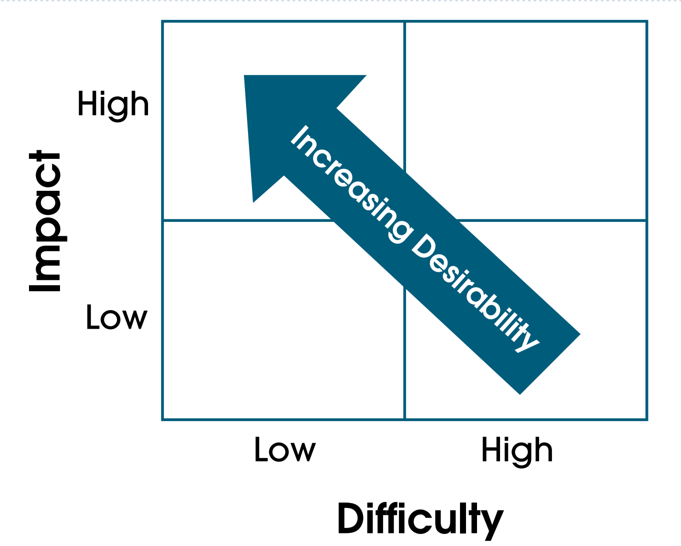
It is important to challenge the status quo ("this is the way it has always been done") when looking for water and wastewater reductions. The following questions can be useful when starting a water reduction initiative or when reviewing a mature program on a regular basis:

Is the process or activity necessary?

- Is it necessary to use water?
- Why does the process use so much water?
- Can the amount of water be reduced?
- Can lower quality water be used?
- Can water be recovered elsewhere?
- Is the process authorized and legal?
- Is it necessary to produce wastewater or effluent?
- Is clean water going down the drain?
- Is the discharge authorized and legal?
- Would it be cost effective to treat wastewater or effluent onsite for re-use?

Ways to reduce water use range from simple strategies, such as adjusting flow or install¬ing water-conserving equipment, to more involved options, such as reusing water or switching to a low-water or waterless process.

Impact – Difficulty Matrix



There are five general types of water-saving strategies, ranging from easy to more difficult implementation, but also moving to a bigger impact. Consider these strategies when brainstorming ideas in cross-functional team meetings and other improvement efforts.

Moving From Simple To More Complex Actions

- ✓ Adjust water flow
- ✓ Modify existing equipment or install water-saving devices
- ✓ Change to more water-efficient equipment
- ✓ Reuse or recycle water (treat if needed)
- ✓ Shift to a low-water or waterless process

Key things to consider when starting water minimization efforts

- Prioritize opportunities: What is most important for the brewery in the short term? What opportunities are good for the brewery?
- Consider water efficiency improvements in the context of other process improvements and lean performance goals to get the best results.
- Evaluate how process changes might affect wastewater volume or quality, or have other environmental impacts. (For example, switching from a water-based lubricant to an oil-based lubricant or solvent could have implications for worker health and the environment.)
- Consider which water-efficiency best management practices and technologies make sense for the facility.
- Adopt visual controls or "mistake proof" devices on equipment (e.g., automatic shutoffs), and/or procedures to help ensure that process changes are effective and can be easily maintained.
- After testing potential solutions, make changes and evaluate actual performance and/or procedures to help ensure that process changes are effective and can be easily maintained.
- After testing potential solutions, making changes, and evaluating actual performance, be sure to develop or update the standard work for the activity so that employees can easily identify the current, best way to perform an activity.

When evaluating water reuse opportunities, it is important to consider both quality and quantity. Not all processes need the cleanest, highest quality water. Many processes can reuse the "waste" water from one process as an input to another process or use (e.g., air-handling condensate, reverse osmosis reject water, etc.), provided the quality of water needed for its intended use is matched. Testing and additional treatment may be necessary to ensure it is acceptable for future uses. When evaluating the feasibility of using process water for irrigation or other outdoor uses, check with the local utility or water pollution control agency about restrictions on water reuse applications. The water may require testing to ensure it meets pollutant limits.

Bell's Brewery Focus On Water Reduction

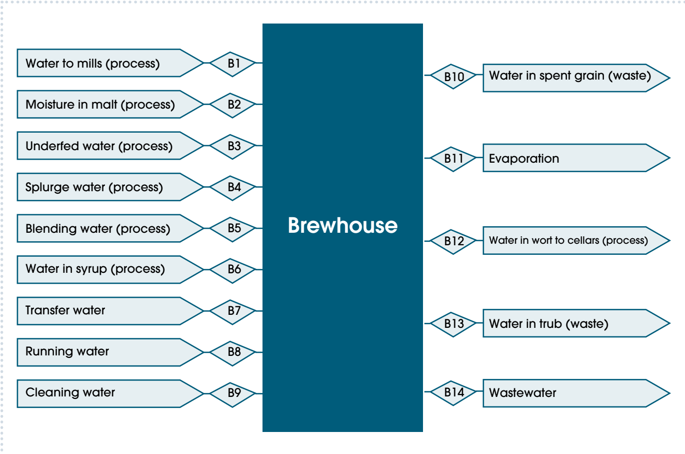
- *The brewery consistently monitors water use with the goal of decreasing water intensity. Sub-meters track water use in the brewhouse, cellar and on both the bottling and kegging lines. Engineering and procedural changes have also helped reduce water usage.*
- *The cellar CIP (Clean-in-Place) system has reduced the amount of water to clean the brewery's tanks by about 65% over the previous procedure.*
- *A new filler vacuum pump design reduced water that goes to drain from 57 liters per minute to 8 liters per minute, saving about 20 million pints of water annually on their filling operation*

Best practices can be found throughout the craft brewing sector. These practices are presented according to the different water-using areas in a brewery or brewpub. Within each area, best practices are organized according to the five strategies: adjust flow, adjust current equipment, change to new equipment, reuse or recycle water and, last, shift to a low-water or waterless process.

3.1 Brewing

In Section 2.0, a water survey helped to identify the main users of water in the brewery. This survey can work as a starting point for further identification of possible water minimization measures.

Brewing Water And Wastewater Sources



By using recent water and sewer billings together with any sub-metering data, a water balance can be developed.

A water balance helps to:
- Understand and manage water and effluent efficiently
- Identify areas with greatest cost saving potential
- Detect leaks

Based on the water balance, a leak-detection checklist can be used on a regular basis to determine possible 'hot spots' or areas where leaks can occur. A water balance should be reviewed on at least a 12-month basis to ensure all changes and adjustments to the process and equipment are covered and the balance is up-to-date.

Leak Detection Checklist

A systematic program of leak detection and repair can prevent future water waste. On a regular basis, thoroughly check the following areas:
- *restrooms and shower facilities (in-tank-type toilets, conduct dye tests to locate hidden leaks)*
- *kitchens, dishwashing facilities and food-preparation areas*
- *wash-down areas and janitor closets*
- *water fountains*
- *water lines and water delivery devices*
- *process plumbing, including tank overflow valves*
- *landscape irrigation systems*

Increasing employee awareness will ensure that measures taken to minimize the water use are understood and accepted by the operators and other staff. It will enhance the generation of ideas and it will make people proud when they can contribute to a more efficient brewery.

Some items that can be used for an employee awareness program include:
- A water ambassador or champion. He or she is the main contact for all water-saving projects, measures and metering. All employees know this person and know where to go to in case of questions or ideas. This water ambassador will also be responsible for the regular leak surveys.
- An incentive program. Employees are challenged to bring in ideas for water- or effluent-saving measures. For example, every three months the employee with the best idea (e.g., highest water saving potential, or most simple idea) is rewarded.
- Employee education. Set up a toolbox meeting on a regular basis to explain, discuss and educate with the employees new findings, data and ideas on water savings. This will enhance the involvement and acceptance of any process adjustments, work procedures or equipment changes.
- Alignment with home usage. This will help the employee understand the importance of water minimization, as well as helping to put things in perspective.

It is difficult to estimate the water savings possible with the introduction of best practices, since each brewery may be different from the next; however, there are some generally accepted ranges of reductions as shown in the table below:

Typical Reductions In Water Use

Water saving measure	Possible application	Typical reduction in process use (%)
Closed loop recycle	Fermentor cooling	>90
Cleaning-in-place (CIP)	New CIP set	60
Re-use of wash water	Cask washer	50
Countercurrent rinsing	CIP set	40
Good housekeeping	Hose pipes	30
Cleaning-in-place	Optimisation of CIP set	30
Spray/jet upgrades	Cask Washer	20
Brushes/squeegees	Fermentor cleaining	20
Automatic shut-off	Pump cooling water	15

Best Practices - Mash Cooker, Lauter Tun, Boiling Kettle And Whirlpool

The following best practices can minimize water use, effluent flow and effluent strength.
- Do not fill the mash or lauter tun too full. Train staff to add the correct amount of liquor and investigate the costs and possibilities of installing a meter to measure the volume of liquor being added.

- If new batches are frequently brewed, store surplus of wort and add it to the next brew.
- Store residual wort with trub for possible sale to farmers as animal feed supplement.
- Do not mix residual wort with surplus yeast – the mixture will start fermenting and the value of both waste streams will be reduced. Fermentable matter needs to be kept separate to maintain its value as an animal feed and yeast needs to be kept separate to maintain its value for food manufacturers.
- Separated grains and discharges to sewer will have a high BOD concentration. Excess settleable solids to sewer can cause blockage of pipes and accumulate at manholes. Where possible, use dry methods (brush or rake) to remove grains from the mash tun. There is no need to use water jets and subsequently discharge large amounts of effluent to the drain. Fit fine mesh baskets in the floor drains to collect and prevent grains from entering the drainage system.

Float Operated Valves

New valve pays back in less than five months

Fitting a float-operated valve at a low level in the hot liquor tank at J W Lees & Co's Manchester brewery minimised both the overflow of hot liquor to drain and the quality of cold top-up liquor required. The one-off cost of the alterations was £2000 for the valve, plus minor modifications to the tank and pipework. The savings in water, evergy and trade effluent charges are worth £5000/year.

Best Practices - Heat Exchangers

Compact heat exchangers are used in almost all breweries to recover heat from hot wort. The recovered energy can be used to pre-heat subsequent mash water or for washing purposes.

Since fermentation temperatures and cold liquor temperatures may vary among the different brews, automatic temperature control will allow for flow optimization of wort and cold liquor and will minimize water use.

Heat Exchanger[4]

Make sure the heat exchangers are well maintained and regularly check the meter readings of the water flow. Pollution of the heat exchanger will negatively affect the heat transfer and cause an excess of water flow.

Check to ensure cold liquor is not excessively warmed by ambient conditions.

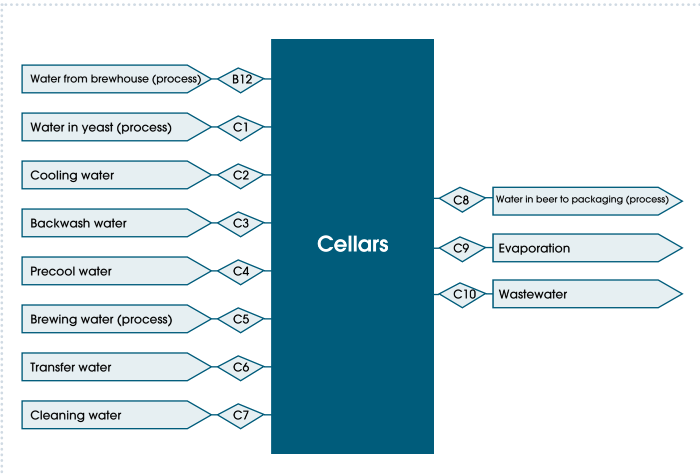
It is important to check the heat exchanger capacities and the settings of the top-up valves, to prevent hot liquor tank overflows.

Best Practices – Fermentation Vessels

Single pass cooling of fermenters uses vast amounts of water. It is generally found at sites with inexpensive and readily available water (borehole or river extraction) and permission to discharge the cooling water to another location other than the sewer.

Closed loop systems will have pumps and control systems in place to regulate the cooling water flow through the fermenters cooling system. Make sure the pump size is adequate to cope with the maximum flow of cooling water when all fermenters are in use. Also, prevent overflow by setting the top-up level in the chilled water tank so that it is not topped-up until the reception tank is full. Install frequency controllers on the pump to fine-tune the water flow based on cooling needs. This will help to minimize the water flow as well as reduce energy use. Ensure procedures are in place to stop the cooling water supply when the fermentation process comes to an end.

Fermentation Water and Wastewater



Since open fermenters typically require manual cleaning, some measures can be taken to optimize the cleaning of the vessels and minimize the water use, as well as lower the effluent strength (fermenters can be the source of almost half of the BOD content and almost 70% of the suspended soils content of a typical brewery).

Yeast and tannins tend to stick on the wall of the fermenters, resulting in high water use for removal. Products are available to make the manual cleaning of the fermenters easier, thereby reducing cleaning times and water use.

Detergent sprays are available for more effective removal of deposits. The foam is used to soften the deposits (after an initial rinse) with a minimum of water. Only a small amount of water is needed afterwards to remove the foam. Foam canisters can be obtained through many detergent suppliers.

Use of scrapers and brushes will reduce the time needed to clean the vessel with a hose. Avoid disposing of large amounts of peracetic acid (for tool sterilization) to the drain and try to eliminate the need for rinsing by storing the sterilized tools in dilute propionic acid. This will reduce the effluent strength.

Best Practices - Yeast Disposal

When the beer is drawn off, a yeast slurry remains for removal. Avoid disposing this slurry to the drain, as it has a high BOD value and high suspended solids content. Also, large quantities of yeast lead to organic acids formation, affecting the pH (making the effluent more acidic).

Removing Sources of High BOD Demand

Farmers save brewery money by taking away surplus yeast and other wastes

Ringwood Brewery stores surplus yeast in a former fermenter vessel. Weak wort, trub, ullage and spoilt beer are stored together in another vessel. The 4900-litre (30 barrel) tanks cost £400 each and another £500 to install them both on steel supports. The tanks are emptied free of charge by local farmers. The savings in trade effluent charges to the Brewery are worth approximately £3000/year, giving a payback period of just over five months.

An alternative may be to pass the slurry through a filter press or centrifuge to recover residual beer that may be reuse in the process. The remains may be disposed separately or sold as animal feed additives. Yeast contains over 40% protein and can be suitable as an animal feed supplement. If no filtration is possible or the residual beer cannot be reuse, the complete slurry may be sold as well as animal feed and the liquid waste can be disposed to the drain.

Best Practices - Filtration

Diatomaceous earth, plate and frame, or rotary filters have traditionally been used to filter the beer prior to packaging; however, water consumption is high with these technologies. Alternatives include cross-flow or membrane filtration. Cross-flow filtration involves circulating the beer though a microfiltration cartridge containing a ceramic membrane. Yeast, bacteria, and other solids are retained on the membrane. This produces a thick yeast slurry that can be disposed as described above. Since all bacteria are removed, no further pasteurization is needed.

Best Practices - CIP system

Using a CIP system is generally more efficient than manual cleaning. The advantages include:

- Increased vessel cleanliness due to chemicals and high temperatures employed
- High level of automation possible
- Reduced water and chemical consumption

CIP is not a novel technology, yet it is often considered as such. There is significant opportunity to improve CIP, which offers water, cost and environmental savings.

Steps to Reducing CIP Water

- *Eliminate a CIP Program Step*
- *Reduce intermediate and final rinse times*
- *Reuse cleaning and rinsing water*

If CIP is not possible, a high-pressure hose will use much less water than a standard hose.

Definition of CIP

The Society of Dairy Technology defines CIP as: "The cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of the surfaces or circulation of cleaning solutions under conditions of increased turbulence and flow velocity".

The table shows a comparison of water and detergent use by various cleaning methods for a 3,000-liter vessel with identical cleaning parameters for each method. The figures demonstrate the increased resource efficiency from full re-use automated CIP.

Advantage of a CIP system

SYSTEM	WATER (LITERS)	DETERGENT (LITERS)
Boil out system	6,500	45
Total loss	3,000	30
Single use	1,200	3
Partial reuse	1,100	2
Full reuse	600	2

Simple CIP systems can be retrofitted into an existing plant, though this can be more costly and difficult than consideration at the plant design stage.

Simple systems use the vessel to be cleaned as a detergent reservoir. The most complex systems are multi-channel with tanks for detergent, pre and post rinses and sometimes disinfectant.

With complexity comes ease of operation, repeatability and reduced running costs at the expense of higher installation charges and reduced flexibility in terms of the ability to adapt to plant or product changes.

It may be possible to reuse the water and detergents from different washing operations to clean the mash tun. For example, detergents used to clean the fermenter could be stored and subsequently transferred to the mash tun. After cleaning the mash tun, the same detergent could be reused to clean the copper.

A water tank can be installed so that the final rinse water can be recycled to the pre-rinse stage. To prevent overflows from the recovered water tank, make sure the volume of the water used in the final rinse and the pre-rinse roughly balances.

Recover and reuse detergents or caustic several times. pH measurements can be used to determine the strength of the chemical solution. In automated controlled CIP sets, the amount and types of usage can be determined automatically. When recovering water, consider the volume in the pipework when determining the switch-over time between CIP tanks. Incorrect settings can allow first rinse water to enter the final rinse water tank.

Since an automated controlled CIP set often only has a limited number of programs, take into account the vessel size and shape when adjusting the CIP programs. The potential content of the vessels and the distance of the vessels from the CIP set (volume in pipework) are also relevant.

CIP Tanks[5]

Best Practices - Vacuum Pumps

Many vacuum pumps use water for cooling and for forming 'the seal' (a liquid ring). Instead of using water on a once-through basis, it can be recovered for reuse, by recirculating the seal water via chillers or cooling tower.

If a closed-loop system is not possible, consider using the water as rinse water in the cask or bottle washer.

Best Practices - Good Process Design

It is good practice to design equipment with fewer parts and no points where fluid accumulates and that detergent cannot reach. This will reduce cleaning time as well as save water, chemicals and energy. Also, the design of pipes and drains can influence the accumulation of solids, making them more difficult to clean. The graphics shows examples of good and poor designs.

Best Practices - Chase Water

When beer is transferred in pipes, the pipes have to be cleaned and rinsed often. The operator needs to decide, in the case where pipes are rinsed with water, when the cleaning is ready and when the pipes can be filled with beer again. This process relies heavily on the judgment of the operator, which can lead to more water use than necessary. Automated interface detection systems may help, but tend to be unreliable. Purging with CO2 is an option, but not often done because of the pressure involved and leaking of CO^2.

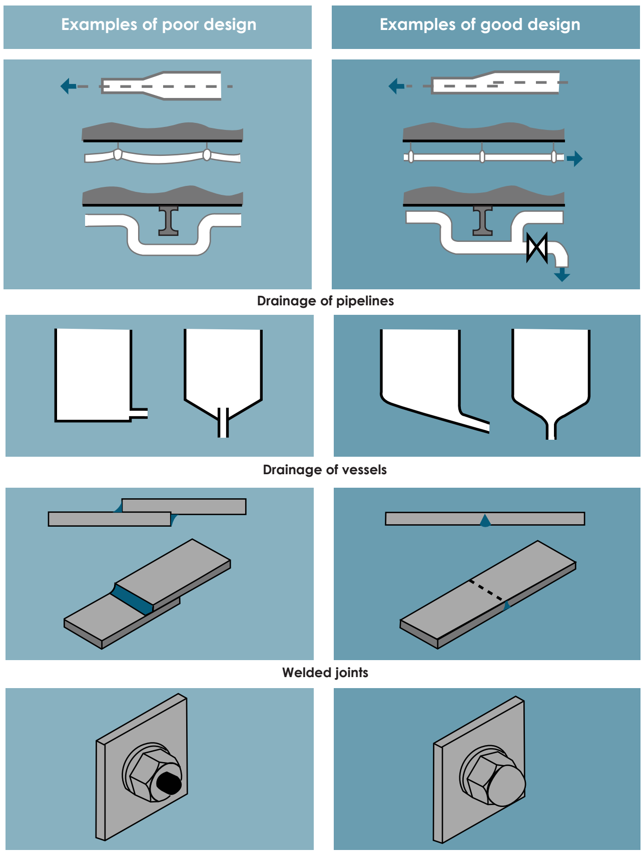
Another method is using a 'pigging' system. This is an engineered plug or ball which fits inside the pipe and is pushed through the pipe either mechanically or hydraulically to clear material ahead of the 'pig'. This can only be used where bends have a long radius and valves have bore openings.

3.2 Packaging

Traditionally, canning and bottling lines have used water as a lubricant to reduce friction on conveyer belts and reduce static between cans or bottles, with water sprayed directly onto the lines through jets. Opportunities to save water include:

- Good maintenance of the conveyer belt system can reduce water consumption of a water-based lubrication system by up to 45%.
- Change from water spray lubrication to a dry-lube system.
- Deploy plastic belts instead of standard steel belts.
- Large amounts of water are also lost if the water continues to spray when the conveyor belts stop. Fitting a solenoid valve to isolate the flow when the conveyor is switched off is a low-cost measure that can produce large savings in water use and effluent costs.
- Optimize conveyor rinse jet pressures. Replace nozzles to increase the pressure and nozzle diameter.

Poor and Good Design Examples



Solenoid valves

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Multiple solenoid valves can be placed together on a manifold.

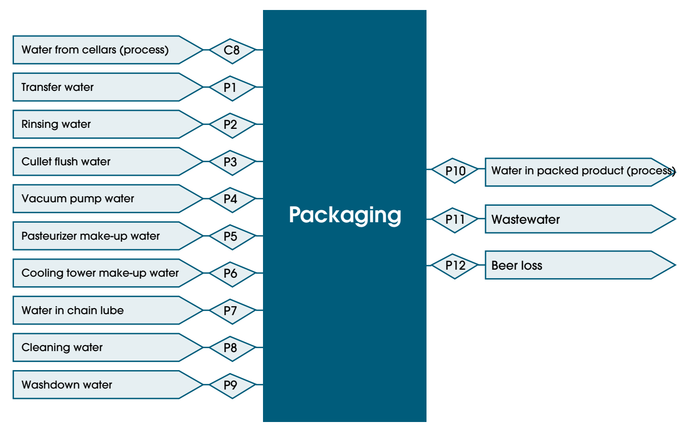
Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

Solenoid Valve Case Study

A soft drink producer installed solenoid valves on a conveyor system and adjusted the spraying nozzles (from 2 mm to 0. 2-0. 3 mm). Implementation of these measures allowed water savings of:

- *26,697 kl per year for the installation of solenoid valves*
- *29,160 kl per year for the optimization of nozzles and jet pressures*

Packaging Water And Wastewater



Best Practices - Cask and Keg Washing

Disposal of spent beer remaining in returned packages should be conducted before cask and keg washing. This spent beer represents a high BOD source to sewer. The removal and storage of spent beer with other high strength liquids should be considered.

A second, more general measure for cask and keg washers is the effective design of the spray nozzles. High-efficiency spray nozzles use water at a lower pressure and the improved spraying action ensures better water contact with the cask. To reduce the risk of nozzle damage for moving beam washers, make the cask position as reliable as possible. For manually handled cask movers, simplify the procedures and make employees aware of the risk. Check the nozzles regularly and repair or replace them immediately to avoid inadequate cleaning.

Improved Cask Washing Process

Major savings with improved cask washing process

Bass Brewers knew that the cask washing plant at its Burton C Brewery used water inefficiently. A quality improvement team formed to evaluate the washing process identified three areas where major savings could be achieved, i.e.:

- *redesign the spray nozzles to give more effective water contact with the cask;*
- *ullage collection and sieving;*
- *recovery of final rinsewater and re-use for the external rinse, oil cooking and conveyor washing stages.*

These and other modifications produced cost savings of £86 900/year and reduced water consumption by about 43 000 m3/year. Total project costs were £95 350, giving a payback period of only 13 months.

Full details of this project are given in Good Practice Case Study (GC21) Improved Cask Washing Plant Makes Large Savings, *available free of charge through the Environmental Helpline on freephone 0800 585794.*

A third consideration is the recovery of final rinse water. This water can be re-used for the external rinse or for the pre-rinse of the cask. If that is not possible, the final rinse water may be used for cooling applications or for conveyor belt washing.

The use of detergents can cause an extended final rinse. It can be evaluated (water versus energy use) to minimize the detergent concentration and perhaps increase the temperatures or make the hot rinse longer.

Another effective method for water reduction is to adjust working procedures to optimize cask cleaning relative to the cask size. For automated cask washers, the automation needs to be adjusted.

For small, manual cask washers, the timing between the rinse stages in valve settings can be adjusted to take into account the volume of water remaining in the pipes.

Best Practices - Cask and Keg Filling

Beer lost at the filling stage is expensive in terms of lost product, wasted labor, energy, water and raw ingredient inputs and effluent charges. Meter the volume of beer used to fill the casks, rather than trust capacity fills. This reduces the need to rely on the internal return system. This backflow system avoids the loss of beer due to foaming or over-filling of the casks.

Bottle Rinser[6]

Best Practices - Glass Bottle Washing and Pasteurizing

Much of the waste from bottle washers and pasteurizers is due to the overfilling of the feed tanks at the base of the units. This can be caused by leaks or by faulty valves or simply by an excessive top-up rate. In many washers or pasteurizers, the overflow points cannot be seen by the operators and overfilling of the feed tanks goes without notice. Ensure overflow points are visible for operators by extending the pipe to a position where operators can see it. Water metering will also allow identification of water use during periods the machines are not operating.

Consider the re-use of the final rinse water of the washers for the pre-rinse stage (or any other stage or application). For single-use bottles, the rinse water used before the filling can be reused for many applications; however, as it may contain glass fragments, it should not be reused if there is a risk of contaminating the product.

Optimize the caustic dosing to the minimum quality standards to allow minimum water use during rinsing. Finally, it is a good idea to inspect the valves and the pipes of the washers and the pasteurizers regularly to detect leaks.

Bottle Washer Case Study

Water recycling was implemented on a bottle washer for a system with a pre-rinse followed by three caustic and three water sections. The solution in the first caustic section of this system is filtered and recycled to this first section. In the third caustic (spray) section, an air fan was installed, to minimize the carryover of caustic to the warm water sections.

In the last rinsing section, rinsing was previously performed with three nozzles for the inside and one for the outside of the bottle. The rinsing at this line was modified to two inside spray nozzles operating with 7 kl/h fresh water. This rinse water is then collected, treated and used for one inside rinse and one outside rinse nozzle (overall, 7 kl/h). This rinse water is again collected and reused:

- *first for a cold water bath*
- *second for a cold water rinse*
- *third for a warm water rinse*
- *finally for the pre-rinsing of the bottles*

The treatment of the rinse water consists of a buffer tank, two parallel membrane filters of 5 µm and disinfection by UV lamps.

The fresh rinse water flow is adjusted according to the running of the bottle washer, presence of bottles, bottle speed, water level and temperature.

These measures resulted in a decrease of the specific water consumption (bottles of 1 and 1. 5 l) from 0. 6 to 0. 4- 0. 5 l/bottle. The total fresh water consumption decreased from 39,590 to 23,960 kl/year and is equal to a water reduction of 39%.

3.3 Warehousing

Not much water is used in the warehouse, with most being used only for cleaning purposes. Consider using water from final rinses or other clean streams from the brewery process for this application.

Make people aware of water wasting, as described earlier, and optimize the hoses used. In many cases, high pressure hoses, which use less water, can be used effectively in warehouse areas.

3.4 Support Systems (Utilities)

Support systems include all utility and powerhouse operations. Often, water used for sanitary needs and outdoor landscaping is included in this category.

Best Practices - Cooling Towers

Evaporative cooling is a common and efficient way of dissipating thermal loads. Cooling towers and evaporative condensers require significant quantities of 'make-up' water to compensate for losses associated with evaporation, drift (or mist) and blowdown (or purge).

A key parameter used to evaluate cooling tower operation is "cycles of concentration" (sometimes referred to as cycles or concentration ratio). This is calculated as the ratio of the concentration of dissolved solids (or conductivity) in the blowdown water compared to the make-up water.

Cooling Towers[7]

Water use can be minimized by:

- Maximizing the cycles of concentration. Many systems operate at two to four cycles of concentration, while six cycles or more may be possible. Increasing the cycles from three to six will reduce cooling tower make-up water by 20%, and cooling tower blowdown by 50%
- Undertaking routine surveys of cooling towers and evaporative condensers for leaks and losses, and taking remedial action as soon as possible
- Repairing or replacing poorly operating blowdown valves promptly
- Checking overflows (e.g., make-up water tank) and ensuring they are not overflowing

Best Practices – Steam Generation

Boilers and steam generators consume varying amounts of water depending on the size of the system, the amount of steam used, and the amount of condensate returned.

Boilers[9]

The key to operating an efficient steam boiler is to maximize steam generation and minimize losses to sewer by:

- Inspecting the boiler, condensate system and steam traps to find and promptly repair leaks.
- Properly insulating steam and condensate pipes and hot well to decrease steam requirements and heat loss.
- Minimizing blowdown volumes by ensuring water treatment is optimized and blowdown automated.
- Ensuring condensate return is maximized and the system is working effectively. Recovering condensate for re-use will reduce water use, chemical use and energy consumption.

Best Practices - Compressors

Refrigeration compressors often need cooling water. Since they produce excessive noise, these compressors tend to be isolated and only inspected when needed.

Compressor[8]

If possible, consider changing to a closed-loop system with a cooling tower, or otherwise, integrate the compressor cooling with another chilled water loop, like fermenting cooling. This chilled water loop is particularly effective when the brewery has several water cooled units. A small bleed will be needed for hygiene reasons.

If a closed-loop system is not possible, there may be a potential to reuse the water for various washing operations described earlier, like a cask washer or the CIP system. In this case, connect a solenoid valve to the cooling water supply to automatically cut off the supply when the compressor stops. Also install a frequency control to the pump of the cooling water supply to prevent manual tampering of the flow.

Air-Cooled Compressors

When replacing a water-cooled compressor, consider the use of an air-cooled unit to save water and during *cool ambient conditions, it may save energy as well.*

Some (tank) radiators tend to accumulate ice due to humidity in the area. Do not use water to remove this ice. It will need an excessive amount of water and will increase the humidity even more. It is more efficient to use excessive heat or hot water or, in low peak hours, use electrical heating.

3.5 Food Service

Many craft breweries include a brewpub within their operational footprint. In these instances, water and wastewater issues associated with food and drink services must be addressed. There have been a number of best practices identified for saving water in food service establishments. The National Restaurant Association has developed the Conserve Sustainability Education Program. It is an excellent online resource to help restaurants reduce operating expenses and leave a lighter footprint on the environment. Many of the ideas presented in this section are from the Conserve program.

Also check with your local water supplier for free water audits or rebates and incentives for restaurant water savings.

Top Water-Saving Opportunities For Restaurants/ Brewpub

- *Metering (control and predict your water use)*
- *Retrofit*
- *Use low-flow pre-rinse spray valves, faucets, toilets and urinals*
- *Add aerators*
- *Add insulation*

Water is a significant part of restaurant operations. It is used for cooking, cleaning, food production, customer consumption, and sometimes for landscaping. Conserving hot water is always a smart idea, because it trims two bills: water and the electricity or natural gas used to heat it.

A brewpub can be split into the kitchen area, the dining and restroom area and the outside of the brewpub (landscaping). Similar as with the brewing process, it all starts with some generic measures, like employee awareness and understanding water use.

Training employees on water usage and how they can contribute will help the understanding and acceptance of measures.

Sierra Nevada Brewing Company Taproom Water Saving Projects

- *Replace Bathroom Faucet Aerators - 789,983 liters/year (immediate payback)*
- *Retrofit flush valve toilets w/ dual flush handles – 288,811 liters/year (0. 7-year payback)*
- *Install Air-Cooled Ice Machine – 3,159,930 liters/ year (1. 5-year payback)*
- *Replace Pre-Rinse Spray Valves – 988,186 liters/ year (immediate payback)*

Best Practices - Dishwashing

When cleaning dishes and plates, avoid using running water to thaw or rinse food. Instead, gradually thaw frozen food in a refrigerator. Wash vegetables in ponded water; do not let water run in preparation sink. Train employees to immediately scrape & wipe plates.

Use squeegee scrapers and avoid rags which soak water. Soak dirty pots and pans instead of rinsing them in running water. Pre-soak with sustainable cleansers, using baking soda to pre-soak pots and vinegar to cut grease.

Dishwasher Tips

- *Run fully loaded dish racks*
- *Pay attention to the pressure gauge – only 20 psi needed*
- *If conveyor-style dishwasher, make sure it's in auto mode*
- *Turn off at night and when idle for long periods of time*
- *Add or maintain wash curtains*
- *Repair leaks*
- *Replace worn spray heads*
- *Soak heavily soiled dishes*
- *Use heat exchangers (usually called an indirect exchanger – it's a plate heat exchanger so that the wastewater doesn't come in contact with incoming water)*
- *Check that water temperatures are between 120 to 130 degrees and the booster heater is used to reach 180 degrees if the dishwasher is high-temperature.*

Check with the manufacturer to see if dishwasher spray heads can be replaced with more efficient heads or if flow regulators can be installed without voiding manufacturer sanitation warranty. Replace existing spray valves with efficient, high-velocity models.

Reduce the water volume in the dishwasher by use of a pressure regulator. A good practice includes installing manual triggers on all sink spray hoses so that water is used on demand only.

When manually washing dishes, use the three compartment sink for dipping dishes and equipment, instead of using running water.

In conveyer type washers, ensure that water flow stops when there are no dishes in the washer. Install a sensing arm or ware gate that will detect the presence of dishes and shut off water when there are no dishes on the conveyor. Some machines are designed to dispense water if the conveyor moves, whether it is carrying dishes or not. If this is a problem, install an "electronic eye" sensor system, which will turn on water only when dishes are moving on the conveyor belt.

Install spray valves that uses less than 6. 1 liters per minute. Efficient pre-rinse spray valves do as good of a job as older, less efficient models, but use a fraction of the water. Savings depend on the flow rating of the existing unit, the water pressure at your facility, and the flow rating of a new efficient model. This may be the most cost effective energy and water saving initiative for the brewpub.

Best Practices – Refrigeration

Refrigeration in the kitchen includes coolers, chillers and ice machines. Water-cooled ice machines and refrigeration equipment should be replaced with air-cooled units or units that are cooled with a closed loop of water.

Icemakers use water in two ways: for cooling the machine and for freezing water into ice. Water-cooled ice machines producing 363 kilograms of ice per day and running at 75% capacity will consume about 3,400 liters of water a day just for cooling. That amounts to over one million liters a year. As for the ice-making process itself, there is a wide range of water consumption depending on the manufacturer and type of machine.

Ice cube makers use the most water, typically 76-95 liters to produce 45 kilograms of ice cubes. Some machines use considerably more, up to 341 liters of water per 45 kilograms of ice. Machines that make ice flakes, on the other hand, consume far less, about 57-76 liters of water to produce 45 kilograms of ice.

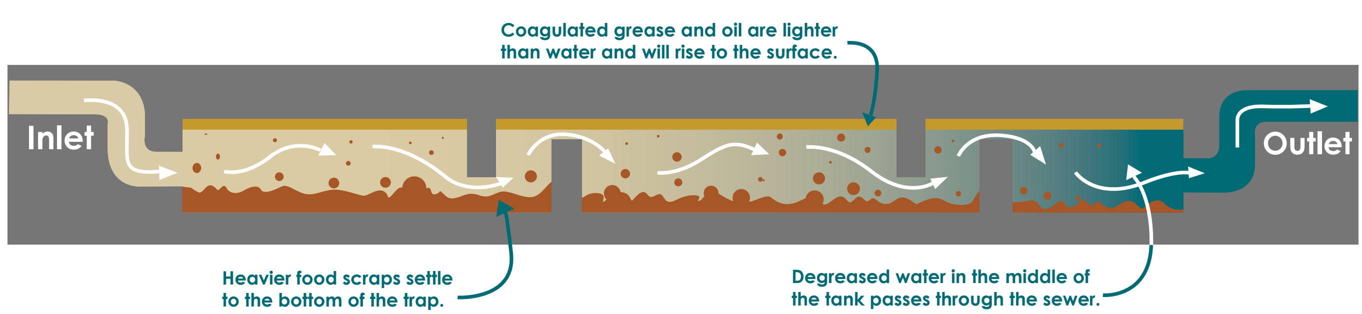
Best Practices - Grease Traps

The installation of grease traps will help to minimize grease and other contamination going to the sewer. In addition to often being required by city ordinance, it will also help to reduce effluent strength. If a surcharge is being paid to the sewer authority for BOD, the removal of grease can help to lower these fees.

Best Practices – Dining Area

Implement a water conservation policy for food servers. Serve water in bars and restaurants only upon request to reduce wash and ice loads. Provide information at each table regarding the reasons for such measures. Automatic

Grease Trap Operation



water service is a practice of the past. Not every guest wants or will drink the glass of water. Changing this practice is as simple as asking, "Would you like a glass of water?" When you reduce the number of glasses of water served, you'll not only reduce the amount of water that would have filled the glass, but you'll also conserve ice, water used to wash the water glasses, straws, lemons (if you garnish water in your establishment), beverage napkins, and/or coasters.

Let sales volume determine batch sizes needed for beverages. If you brew coffee or tea or make specialty beverages, such as flavored teas or lemonade, determining whether a full or half batch is required will help you save water and product.

Determine whether a glass tender or the triple sink method for washing bar glasses best suits your establishment. If using a glass tender:

- Make sure it is not running continuously
- Wash glasses only when you have enough for a complete cycle (except at closing when all glasses need to be cleaned)

Use ice properly. Reduce the amount of standing ice in your bin throughout the day so that very little remains at close. This way, you will use very little hot water to melt what remains. One technique used in the industry is to scoop the ice out of the bin into a bus tub. The ice from the bus tub is then emptied onto the landscaping. Very little water is then needed to clean and sanitize ice bins.

Best Practices - Restrooms

Many restroom faucets use 9.5 to 19 liters per minute. Low-flow faucets are affordable and can reduce the flow to less than 5.7 liters per minute.

Post signs in restrooms/lavatories to remind customers and staff to not dispose any non-flushable items in toilet. Any material other than toilet paper will force the septic tank to use more water to flush the material down the drain.

Replace existing toilets and urinals with plumbing-code-conforming high-efficiency toilet (HET) or ultra-low flush (ULF) models. Provide additional urinals in men's restrooms and reduce the number of toilets.

High-Efficiency Toilets (HET)

- *High-efficiency toilets flush at 20% below the 6.1 liters-per-flush (lpf) U. S. maximum or less, equating to a maximum of 4.85-lpf. (The HET category includes dual-flush toilets.) The average water savings for HETs is estimated to be 144 liters per day (lpd) when replacing a non-ULFT and 26 lpd when replacing a ULFT.*
- *High-efficiency urinals (HEU) operate at 1.9 lpf or less. (The HEU category includes non-water urinals) Based on data from actual usage, these urinals save 75,708 liters of water per year with an estimated 20-year life. In addition to saving water and sewer costs, non-water urinals are an improvement over traditional urinals in both maintenance and hygiene.*
- *Ultra-low-flush toilets (ULF) use no more than 6.1 lpf, rather than 13.2 to 26.5 liters of water used by older designs. The required minimum was set to 6.1 lpf in 1997 for commercial use.*
- *Waterless/No-Flush Urinals work completely without water or flush valves. They save up to 170,343 liters of water per year per urinal.*

Use low-flow aerators. Aerators should use 1.9 - 3.8 liters per minute. Hand-washing sinks that are used infrequently will have a longer wait time for hot water as a result. Low-flow models should never be used where containers are filled. The time it takes to fill containers is increased, thus increasing labor costs, and there is no significant energy or water savings. Nationally, there is no specific pressure for hand-washing sinks, but the flow of hot water for the sanitizing rinse in a dishwasher must not be less than 7 kilograms per square inch. However, there may be city/county/building plumbing codes that have different minimum water pressure requirements.

Best Practices – Parking Lot/Landscape

Use of water for outdoor activities, such as cleanup or landscaping can have a significant impact on costs. Most breweries pay sewer charges based on a percentage of incoming water usage. Excessive use of water for outdoor activities will result in higher water and sewer charges. This can be alleviated by negotiating the percentage with the authority or by installing a separate meter on water used for outdoor purposes.

Landscaping should be planned with drought-resistant and native plants where possible. Native plants require less water, and are better adapted to existing soil, climate, and wildlife. Cluster plants by similar irrigation needs.

Turf Grass

Minimize the use of lawn or turf grasses. These choices require significant watering to maintain their appearance, regular mowing and topical amendments, such as fertilizer and herbicides, which can cause harmful runoff. Use ground cover or mulch around landscape plants to prevent evaporation. Mulch helps keep soil moist and retards the growth of weeds.

Develop a rain water catchment system (i.e., rain barrel) and reuse this water for landscaping or for instance for truck washing as well. Watering should be conducted early in the morning or in the evening when wind and evaporation are lowest. Apply water, fertilizer, or pesticides to landscape only when needed rather than on an automatic schedule. Be sure all hoses have shutoff nozzles.

Often sidewalks and decks are overcleaned. Therefore, scrub and/or power wash these surfaces only when needed. Also, use a broom to sweep away debris before washing. Hoses use large amounts of water, so reducing the use greatly reduces the amount of water.

Xeriscaping

Xeriscape can be defined as "water-efficient landscaping appropriate to the natural environment." The goal of a xeriscape is to create a visually attractive landscape that uses plants selected for their water efficiency. Properly designed and maintained, a xeriscape can use less than one half the water of a traditional turf-dominated landscape.

3.6 Concerts/Events

The concert venue and the selected caterer/concessionaire may be able to offer and highlight its commitment to using water responsibly. Reducing or eliminating the need for bottled water is a key to not just reducing waste from plastic bottles, but to also reduce the water footprint needed for the manufacturing process of the bottles. Check with the local water utility if they support concerts and events through a potable water truck. For example, in the Denver area, the local utility has a water truck for use for community events and concerts.

Select venues and concert promoters that are responsible with their water footprint and wastewater discharge. Planet Bluegrass, a festival and concert producer in Colorado, performed several eco-audits and examined their energy and water usage. As a result, they now use low-flow faucets and are investigating dual-flush toilets in many of their venues.

Case Study—Gillette Stadium, Foxborough, MA.

The stadium that serves as the home of the New England Patriots, as well as numerous soccer matches, concerts and other public events has the distinction of having one of the largest recreational water reuse systems. When the Town of Foxborough advised the private developers that constructed the stadium that they could not furnish enough water or treat the wastewater from the planned 68,000-seat stadium, it became apparent that the reuse of reclaimed water was the only answer.

section four

Onsite Wastewater Treatment

In the previous section, best practices that lower water use and thus incoming water costs are outlined. A reduction in water usage will help lower wastewater costs when charges are based on the amount of incoming water.

Best practice reduction measures were discussed as well as ways to lower the strength of effluent. Since surcharges are applied based on this effluent strength, these measures make sense to implement.

The remaining effluent volume and strength is typically discharged by most craft brewers through a public sewer system to a municipal or private treatment system. Some brewers have installed onsite pre-treatment systems before discharge to a municipal treatment system. This decision is typically based on regulatory compliance or economics. It is also highly dependent upon land space available at the brewery site. Most pre-treatment units require a large footprint that may not be available to space limited sites.

When Should You Consider Advanced Treatment?

Some smaller brewers have been forced to install advanced pre-treatment units to meet local regulatory requirements. In general, advanced systems do not have an economic payback until there are some economies of scale associated with larger volumes of wastewater. As a rule of thumb, consider advanced wastewater pre-treatment when annual sewer discharge costs approach, or are greater than, $250,000. This cost equates to a brewery size of 150,000 – 300,000 bbl/year based on flows of 2-4 bbl wastewater/bbl beer. This assumes sewer surcharge rates of $0.30/lb BOD, TSS.

Onsite pre-treatment can reduce the amount of solids and organics sent offsite for treatment. It usually does not treat any sanitary waste, since that may be discharged through a separate sewer system.

Effluent pre-treatment systems reduce effluent loads using either aerobic or anaerobic methods. Both require large holding tanks, de-sludge operations, and sensitive controls and/or operating conditions. In the dynamic field of wastewater pre-treatment, increasing numbers of new systems are being trialed at food and beverage facilities.

There are three primary pre-treatment processes utilized at breweries:

- pH neutralization
- Solids removal
- biological treatment

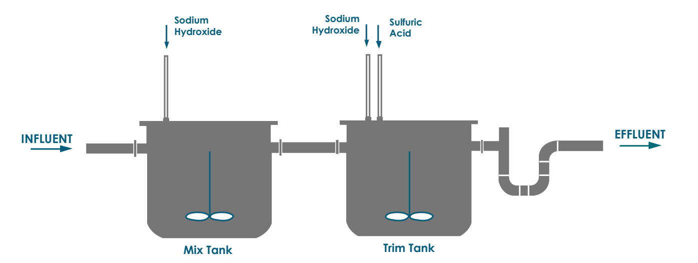
Regulatory limits usually dictate the need to install pH neutralization. Solids removal is typically driven by regulatory or cost savings requirements. Biological treatment normally is driven by cost savings; however there are situations where a municipality requires some form of organic pre-treatment.

4.1 pH Neutralization

Adjusting the pH in a waste stream can be one of the most difficult processes in wastewater treatment. Good pH neutralization and adjustment includes proper mixing, tank configuration, and instrument control.

Brewery wastewater can contain slugs of materials that can be very low in pH or very high, depending upon the timing of acid or caustic usage. Over a longer period of time, brewery pH may be closer to neutral. However, municipal treatment ordinances typically regulate pH to protect workers that may be doing maintenance on sewer lines, the integrity of the sewer lines, and to protect aerobic bacteria in their biological treatment systems.

Typical pH Neutralization



Two key components of these systems include the following:

- Flow equalization is a technique used to consolidate wastewater effluent in holding tanks for "equalizing" temperature or pH before introducing wastewater into downstream treatment processes.
- Chemical adjustment of brewery pH and flocculation of solids are the most common pre-treatment techniques used at breweries. The acidity or alkalinity of wastewater affects both wastewater treatment and the environment. Brewery wastewater tends to gravitate towards a higher pH due to the amount of caustic used for cleaning. Low pH indicates increasing acidity while a high pH indicates increasing alkalinity (a pH of 7 is neutral).

Small Brewer pH Neutralization Example

The Lone Tree Brewing Company in Colorado installed a simple 500-gallon plastic tank for pH equalization. This allows the discharge to the municipal plant to be more consistent by leveling high and low pH swings from cleaning operations.

4.2 Solids Removal

Brewers that install pH pre-treatment facilities or those that cannot meet regulatory restrictions for solids may install onsite solids removal systems. These systems can be categorized as follows:

- Physical treatment is for removing coarse solids and other large materials, rather than dissolved pollutants. This may be a passive process, such as sedimentation to allow suspended pollutants to settle out or float to the top naturally.
- Screening is typically a first step to remove glass, labels, and bottle caps, floating plastic items and spent grains.
- After the wastewater has been screened, it may flow into a grit chamber where sand, grit, and small stones settle to the bottom.
- With the screening completed and the grit removed, wastewater still contains dissolved organic and inorganic constituents along with suspended solids. The suspended solids consist of minute particles of matter that can be removed from the wastewater with further treatment, such as sedimentation or chemical flocculation. Flocculation is the stirring or agitation of chemically-treated water to induce coagulation. Flocculation enhances sedimentation performance by increasing particle size, resulting in increased settling rates.

4.3 Biological Treatment

After the brewery wastewater has undergone physical and chemical treatment, it can be biologically treated. Biological treatment of wastewater can be either aerobic (with air/oxygen supply) or anaerobic (without oxygen). Generally, municipalities have relied upon aerobic systems for the treatment of brewery wastewater. Recently, anaerobic systems have become a more attractive option since biogas can be generated for energy use.

Anaerobic wastewater treatment is the biological treatment of wastewater without the use of air or elemental oxygen. Anaerobic treatment is characterized by biological conversion of organic compounds by anaerobic microorganisms into biogas. Biogas is mainly methane (55-75 vol%) and carbon dioxide (25-40 vol%) with traces of hydrogen sulfide.

Anaerobic Treatment in the Brewing Industry

- Suited for brewery wastewater
- Generally soluble organics and medium to high strength
- Produces low amounts of sludge
- Requires small amounts of chemicals
- Produces valuable biogas and sludge
- It is a 'tried & true' technology

Smallest entry-level anaerobic system

- The smallest is a 50 kl UASB system
- Equivalent to a brewery size of between 118,000 – 236,000 bbl per year production
- Installed cost: $700,000 - $1,200,000 U.S.

Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end products.

Aerobic treatment utilizes biological treatment processes, in which microorganisms convert non-settleable solids to settleable solids. Sedimentation typically follows, allowing the settleable solids to settle out.

Aerobic Treatment System[10]

Smallest entry- level aerobic system

- There are packaged systems available that can treat as little as 3,785 lpd or less
- Practically speaking, the smallest aerobic system will be sized to treat 37,854 lpd
- Equivalent to a brewery size of between 17,000 - 33,000 bbl per year production
- Installed cost: $400,000 - $900,000 U.S.

Pre-treatment of brewery wastewater will reduce the effluent strength as an end-of-pipe solution. Both aerobic and anaerobic treatment options are available. There are differences, advantages and disadvantages of these two systems.

Comparison Of Two Pre-Treatment Options

	AEROBIC TREATMENT	ANAEROBIC TREATMENT
CONS	Higher energy use	80+% COD reduction
	Generates biomass (sludge) requiring disposal	
	High operating costs	
	Larger Footprint	
PROS	99+% BOD reduction	Provides renewable energy (biogas) and low biomass
		Low operating costs
		Smaller Footprint
		Capital equal or slightly lower than aerobic

A common problem with effluent pre-treatment systems is the long retention time required. Brewery effluent is highly biodegradable and contains active micro-organisms. If the effluent remains for an extended period in the balancing tank, microbial action consumes all the available dissolved oxygen and the effluent becomes anaerobic leading to increasing acidity. Acidic conditions cause damage to concrete structures and inhibit subsequent biological treatment processes. This can result in discharge limit violations and odor problems.

Small Brewer Organic Treatment Example

CB's Brewing Company installed an organic pre-treatment system at their brewery in Honeoye Falls, New York. The system reduced BOD levels by 90%. The project was built in partnership with the village of Honeoye, a small community that has the capability to treat mainly residential wastewater. CB's brews about 7,500 BBLs annually. Installation of an organic pre-treatment system was driven as a condition of village approvals, not from an economic return perspective.

Optimizing Wastewater Pre-Treatment Operations

Reducing the retention time in the balancing tank reduces trade effluent charges

The effluent treatment plant at George Bateman & Son's Brewery consists of a large effluent pumping station, an unmixed balancing tank, a biotower and a settlement tank. The Brewery had experienced problems with a low pH in the final effluent and poor COD removal.

Measurements of pH at the inlet and outlet of the balancing tank revealed that the pH was falling from 7.0 to less than 5.0 during balancing. Although degradation of organic acids in the biofilter allowed the pH to rise slightly, the brewery was not reliably achieving compliance with the consent minimum of pH 6.0.

The Brewery plans to overcome these problems by using low-cost methods to reduce the retention time in the balancing tank. As well as improved compliance with consent limits, savings in trade effluent charges of around £3 000/year are anticipated.

Other Biological Treatment Options

The number and variety of biological treatment solutions scaled for craft brewers is increasing rapidly. Advantages to such smaller systems can include relative affordability, smaller footprint, engineering support and lower operating (power, water, reagent and maintenance) costs.

Notable features of treatment solutions provided by two vendors during the compilation of this manual include:

- Integrated aerobic and anaerobic media technologies (Baswood "AIMS" system)
- Multiple integrated treatment processes for various effluent types (Contech "Magellan" system).

A directory of waste and effluent treatment system suppliers can be found in the Supplier Directory on BrewersAssociation.org.

section five

Brewery Case Studies

5.1 Water Reduction

Bell's Brewery – Kalamazoo, Michigan

At Bell's Brewery, employees are consistently monitoring their water use with the goal in mind to decrease the brewery's water intensity. They use sub-meters to track water use in their brewhouse, cellar and on both the bottling and kegging lines. Their CIP system has reduced the amount of water to clean brewery tanks by about 65% over their previous procedure. In addition, they have installed a new filler vacuum pump design, which reduced water that goes through the drain from 56. 8 liters per minute to 7. 6 liters per minute. Annually this will save Bell's over 9 million liters of water associated with their filling operation.

Long Trail Brewing Company – Bridgewater Corners, Vermont

Long Trail has an in-house Heat Recovery System that condenses the steam back into water and, in doing so, doing recovers 3. 7 million BTUs per day in the form of heat energy that is promptly used for the preparation of the next brew, thereby significantly reducing propane use.

New Belgium Brewing Company – Fort Collins, Colorado

New Belgium's packaging hall has some great water-saving features: The water used to first rinse the inside of the bottles is recovered and reused on the final exterior rinse. Also, the CIP system is designed with a hot water recovery tank to recover heat and water from their hot water sanitizations to use on the subsequent cleaning cycle. At the brewery, there is a xeriscaped approach to landscaping that is crucial in arid climates like Colorado. Xeriscape practices include native plants that require little, if any, additional watering as well as proper soil amendments to help retain moisture. The approach also calls for watering practices that reduce run-off and evaporation.

Sierra Nevada – Chico, California

Sierra Nevada is doing many great things when it comes to water conservation. In order to know where to go, they first determined where they were at. Sierra Nevada currently has five different audits to manage their water use: plantwide CIP, plant sanitation, fuel cell energy solar, east and west house brewhouse, and cooling tower audits.

To conserve their water use, the brewery has installed several new technologies. They replaced bathroom faucet aerators, which saved close to 800,000 liters of water a year - providing an immediate payback. They retrofitted flush valve toilers with dual flush handles, which saved them almost 300,000 liters a year for a 0.7-year payback. They installed Air-Cooled Ice Machine, which saves them over 3 million liters a year for a 1.5-year payback. In addition, they replaced their pre-rinse spray valves, which saved almost 1 million liters a year for an immediate payback.

Standing Stone Brewery – Ashland, Oregon

At the Standing Stone Brewery restaurant in Ashland, Oregon, resource conservation is a key message that they want to convey to the customer. Their kitchen has a high-temperature dishwasher that reduces the amount of water and chemicals needed for rinsing and sanitation. This technology minimizes the use of water as well as reduces the amount of energy needed for wastewater management by using fewer chemicals.

5.2 Wastewater Pre-treatment

Bluetongue Brewery – Warnervale, Australia

Bluetongue Brewery is a new plant in Warnervale on the Central Coast of New South Wales, Australia. The brewery is owned by Pacific Beverages, a joint venture between Coca-Cola Amatil (CCA) and SABMiller.

Onsite at the brewery, a wastewater pre-treatment facility filters out waste from the brewing process, which eases the strain that would otherwise be put on the water treatment center in town.

CST Wastewater Solutions is partnering with Global Water Engineering (GWE) to deliver and install a treatment system with best-practice water reuse standards, while at the same time providing renewable energy for the brewery, reducing its dependence on fossil fuels. The $120 million state-of-the-art brewery now being built on NSW's Central Coast will eventually have an annual capacity of 150 million liters, making it the Australian state's second largest. The new brewery's wastewater will pass several pre-treatment steps before entering a GWE ANUBIX-B anaerobic methane reactor, in which the wastewater's organic content (COD) is digested by bacteria in a closed reactor, degrading the compounds and converting them into valuable biogas and cleaned effluent. This anaerobic treatment will significantly reduce the brewery's carbon footprint by avoiding the release of carbon dioxide into the atmosphere.

Biogas from the process will be collected and reused as renewable energy to power the brewery's boiler.

Treated effluent will then continue to an aerobic post-treatment stage in which organic content is further reduced by GWE's proprietary MEMBROX Membrane Biological Reactor (MBR) system.

In the water polishing step, the water from the MBR unit is sent through a reverse osmosis (RO) installation.

Finally, the effluent is led to a disinfection and storage unit, where the recycled water will be kept for reuse applications.

City Brewing Company, La Crosse, Wisconsin

Gundersen Lutheran Health System, based in La Crosse, Wisconsin, has entered into a unique renewable energy partnership with a local brewing company, City Brewery. In 2009, the two organizations powered up a combined heat and power project that is expected to generate 8 to 10% of the electricity used on Gundersen Lutheran's campuses in La Crosse and Onalaska, WI.

The renewable energy project uses waste biogas discharged from City Brewery's waste treatment process and turns it into electricity. Currently, it is generating three million kilowatt (kW) hours per year; this is equivalent to planting 490 acres of forest or removing 395 cars from the road and is enough electricity to power 299 homes.

Here's how it works. The brewing process creates waste that must be pretreated by City Brewery before it is sent to La Crosse's municipal wastewater treatment facility. Biogas, including methane, is created during that pre-treatment process. (Previously, City Brewery flared the gas to dispose of it.) The combined heat and power project allows the waste biogas to be captured, cleaned and sent through an engine Gundersen Lutheran installed at the City Brewery site. The engine generates electricity that is then transferred to the power grid. In addition, heat generated from the engine is captured and recycled back to City Brewery's wastewater treatment process to make it more efficient.

This renewable energy partnership between Gundersen Lutheran and City Brewery, and this type of gas-cleaning system, are both the first of their kind. The project is supported, in part, by Focus on Energy.

Long Trail Brewing Company - Bridgewater Corners, Vermont

The Long Trail Brewery sits directly on top of a water source that has been named Vermont's Best Tasting Drinking Water. The artesian well supplies the brewery with up to 76,000 liters a day of crystal clear quality water. In order to maintain the pristine natural environment, however, Long Trail developed a proprietary process for removing nearly all the impurities from the brewery's wastewater. They are licensed by the state of Vermont to return this high quality effluent to the ground via underground injection into onsite leach fields.

Sierra Nevada – Chico, California

Sierra Nevada focuses on minimizing the brewery's usage of its water resources and continually audits the process to minimize wasteful practices. They have been able to reduce their water usage to almost half of the historical value typically used by breweries in the United States.

Sierra Nevada made the commitment several years ago to treat all of the brewery's production wastewater to remove this burden from the local municipality. They installed a

European-designed, two-step anaerobic and aerobic treatment plant that reprocesses and purifies all of the water produced from their brewing operations.

The methane generated from the anaerobic digestion of the wastewater is captured and used to fuel their boilers. This uses 100% of an energy byproduct as fuel for another process, instead of releasing it into the atmosphere. Additionally, water used for truck washing is collected and purified through their own facility.

Stone Brewing Company – Escondido, California

Stone Brew Co. in Escondido, California, built a brand new brewing facility with a simple wastewater treatment system adjacent to a restaurant and 1-acre beer garden in 2005. After some significant production growth, the city threatened to significantly increase the brewery's water rate to be able to accommodate the higher organic strength and solids content in the water. This resulted in Stone Brew's installation of an aeration tank to meet biochemical oxygen demand (BOD) limits and a dissolved air flotation (DAF) unit to meet total suspended solids (TSS) limits in 2008. By doing this, the brewery was able to negotiate with the City to leave the water rate at the existing value. Typical influent water quality to the WWTP was 12,000 mg COD/L, 7300 mg TSS/L at a pH of 5.4. The issues with running an industrial WWTP with a rudimentary design, however, quickly became apparent.

Due to the degree of difficulty in treating the brewery wastewater, which consists mostly of sugars, proteins, carbohydrates and yeast, the DAF was not able to achieve sufficient solids removal or facilitate consistent BOD removal required to meet the local limitations. Issues included excessive process control problems, such as the need to haul away sludge that could not be separated by the DAF unit, foaming events and overflows, high chemical consumption, multiple mechanical failures and trouble with sludge dewatering. These factors caused breaches in water quality restrictions, costly repairs and time consuming labor.

Since the WWTP was onsite next to a restaurant and outdoor beer garden, there were also concerns with the unpleasant odors created from poor biological performance and sludge handling becoming visible to customers. After a little over a year of operation with the problem-riddled system, the plant decided it would be advantageous to change the treatment scheme to something better suited for their particular wastewater.

The decision to replace the DAF with a membrane bioreactor (MBR) system was mainly motivated by the guarantee in TSS removal via membrane filtration. Other reasons included enhanced BOD removal and the possibility to reuse the effluent water within the plant. The MBR system was commissioned in January 2010 and was designed to process 227,124 liters per day. It utilized two HYDRAsub®-MBR HSM500 modules, each containing 500 m^2 of surface area. Upon stabilization of the system, various benefits of the MBR were soon realized. First of all, TSS in the effluent was drastically reduced and COD removal was greatly improved. Process control was enhanced so that all activated sludge could be treated and recycled back to the aeration tank, not hauled away. The simplistic and almost fully automatic operation of the system resulted in low maintenance and labor time compared to the DAF. The chemical usage and cost for separating solids and sludge dewatering decreased significantly. Finally, as soon as the MBR system was stabilized, an RO system was commissioned to further treat the effluent for reuse purposes.

5.3 Community Outreach

Founders Brewing Company – Grand Rapids, Michigan

Founders Brewing Company and Grand Rapids Whitewater have partnered together in an initiative to restore the Grand River to its original splendor by putting the Rapids back in the Grand. Their collective vision is to create a safe, beautiful, more natural and healthy resource for the community.

The improved river landscape will encourage canoeing and kayaking while providing an enhanced environment for fishermen and other recreationalists. Rapids will promote a cleaner, healthier aquatic ecosystem, strengthening marine life habitats.

To help bring this vision to life, they ask customers to donate $1 to Grand Rapids Whitewater each time they refill a Whitewater growler in the brewery taproom; they are also raising awareness for the cause with a specialty water bottle. Their motto is to: share a beer or two, and share in the vision for changing the face of Grand Rapids.

New Belgium Brewing Company – Fort Collins, Colorado

In 2010, New Belgium Launched SaveTheColorado.org, a campaign to fund water stewardship efforts on the Colorado River (which supplies almost half the water coming to Fort Collins). New Belgium committed $300,000 over three years to nonprofit organizations working to study and repair the Colorado River. They are also joined by several other companies and individuals in this effort (www.savethecolorado.org).

appendix a

Tool Box

Guidance and Checklists

- Guidance – Sanitary Water Usage
- Guidance – Water losses from Leaks
- Checklist – Water Efficiency Opportunity (USEPA)
- Checklist – Water Audit Data Collection Sheet

On-Line Excel-Based Tools

- Calculating the full cost of water
- Calculating the costs and returns of pre-treatment

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