EAST BAY MUNICIPAL UTILITY DISTRICT

Commercial Water Efficiency Guidebook

2nd Edition

EBMUD

East Bay Municipal Utility District

375 11th Street, Oakland CA 94607

Phone: 1-866-403-2683

E-mail: waterconservation@ebmud.com

TABLE OF CONTENTS

CHAPTERS

= For all industries (chapters 1–4)

= For specific industries (chapters 5–15)

ACKNOWLEDGMENTS

The completion of the 2nd edition of this Guidebook by East Bay Municipal Utility District (EBMUD) represents a collaborative effort involving the dedication and support of numerous individuals and workgroups within EBMUD.

Special recognition is due to the members of the Water Conservation Division team who contributed their expertise, insights, and dedication to this project. Their tireless efforts and dedication to excellence have been instrumental in shaping the content and ensuring its relevance to our stakeholders – our customers.

Anya Kamenskaya – *Water Conservation Representative*

Charles Bohlig – *Manager of Water Conservation*

David Wallenstein – *Associate Civil Engineer*

Geneva Gondak – *Supervisor of Water Conservation*

Jolene Bertetto – *Water Conservation Representative*

Nicolle Patterson – *Water Conservation Representative*

Luke Sires – *Info Systems Support Analyst II*

Rolando Gonzales – *Community Affairs Rep II*

Eric Fiebig – *Graphic Designer II*

We are also grateful to the external experts and stakeholders who generously shared their knowledge and experiences. Their valuable contributions have enriched the guidebook and enhanced its utility for practitioners in our field.

Maddaus Water Management

HW (Bill) Hoffman & Associates, LLC

Lee Norton – ***CEO Mark VII Equipment Inc.***

Hal McConnellogue – ***Drake's Brewing Company***

Taylor Nokhoudian – ***SFPUC***

Mike Eurkus – ***Cordia Energy***

Robbie Pickering – ***ERG***

Todd Bell – ***Frontier Energy***

Finally, we extend our appreciation to the readers who will benefit from this guidebook. It is our sincere hope that this resource will serve as a valuable tool in advancing the objectives of water use efficiency and promoting best practices within our commercial business community.


RAIN MASTER™ EAGLE PLUS
ALARM
IRRIGATION
TH 09:51:05A WK1
WATER OFF
[MAIN] -ALARMS(5)-
PRESS
ENTER
PROGRAM
SETUP
HOME
ECP8
321000193
MANUAL
WATER OFF
Irritrol
Master Valve Off
Pump Off
Location
Irritrol
by Hardie

INTRODUCTION

This guidebook was developed to help Commercial, Industrial and Institutional (CII) water users be more water efficient. It provides information on water-saving technologies and best management practices applicable to these sectors and will include an appendix section which provides seasonal water use benchmarks for numerous business types. These benchmarks provide readers with a comparison to their own water usage patterns and consumption levels. The guidebook is intended for use as a resource by:

- Existing and new businesses
- Developers, consultants, and designers
- Planning agencies, for benchmarking purposes
- Water providers, for reviewing and estimating water use at existing businesses

In this guide, readers will find eight broad categories of water-using or monitoring technologies:

- Data Collectors
- Metering of Individual Units
- Indoor Plumbing
- Restrooms
- Water Treatment
- Process Water
- Alternate On-site Water Sources
- Landscapes

Readers can also explore six business categories commonly represented in the CII sectors:

- Food Service
- Laundries & Dry Cleaning
- Medical Facilities & Laboratories
- Pools & Spas
- Vehicle Washes
- Cannabis Operations

Many of the technologies discussed in this guidebook can also be applied to other business types not specifically addressed herein. For example, restroom fixtures, process water and landscape technologies can also apply to many business types, and some of this information can also be applied to the residential sector. Each chapter has an introduction that includes a discussion of the end uses of water, as well as references on where to find technical data for such information as the estimated life-cycle water savings, costs, and payback (cost-effectiveness) of the technology where applicable.

For Water Providers and Utilities

Though this water efficiency guidebook was written to assist EBMUD customers, it also includes additional resource savings recommendations where applicable. Note that some of the recommendations may be specific to Northern California, but as a whole, many of the technologies can be applied to improved water efficiency world-wide. While it is left to each agency to decide what water-saving technologies might be appropriate for their service area, this guidebook includes examples of proven water conservation practices.

The business community can capture the benefits of reduced costs for water, energy, chemicals, wastewater, and onsite water- and wastewater- treatment facilities. For example, system-capacity charges imposed by water providers (i.e., water-provider connection fees) may be reduced due to either smaller meter sizes or reduced water use resulting from the water-saving technology. Thus, planning for and incorporating water- (and energy-) efficient technology during the design and construction phase of a project can represent a win-win scenario for all stakeholders, including the environment. Lastly, using this guidebook for new projects adopting water-efficiency standards can be considerably more cost-effective for both water utilities and businesses than retrofitting businesses with water-efficient technology after construction.

How to Use This Guide

The chapters "The True Cost of Water," "Data-logging Devices," "Plumbing," and "Restrooms" are broadly applicable to most business and facility types. They lay a foundation for understanding the interplay of water and energy costs, the utility of tracking and analyzing water use data, the basics of plumbing, and the considerations for restrooms, respectively.

In addition to these chapters, business and facility types will also want to focus on chapters directly relevant to their industry.

Example 1: Car Wash

This type of business will benefit from the following chapters, covering important aspects of water usage involved in washing cars, as well as the filtration, disposal, and potential reuse of wash water.

- → Vehicle Washes
- → Water Treatment
- → Process Water
- → Alternate On-Site Water Sources

Example 2: Hospital

Hospitals and medical facilities will want to focus both on the chapters concerning public-facing water fixtures, in addition to the specific specialized facilities often present on a medical campus.

- → Metering of Individual Units
- → Water Treatment
- → Process Water
- → Alternate On-Site Water Sources
- → Landscape Water Use Efficiency
- → Food Service Operations
- → Laundries & Dry-Cleaning Operations
- → Medical Facilities & Laboratories

Example 3: Restaurant

Restaurant operators will want to choose sections that reflect the building type that they are housed in. Stand-alone restaurant buildings with surrounding landscaping will have a few more considerations than restaurants operating in a mixed-use development setting.

- → Metering of Individual Units
- → Food Service Operations
- → Landscape Water Use Efficiency

Since technology changes over time, this guidebook will be reviewed every 5 years and updated accordingly.

Reader feedback is appreciated from those who gain experience with the use of this guidebook. Please provide comments to waterconservation@ebmud.com or write to:

EBMUD
CII Guidebook
375 11th St. MS 314
Oakland, CA 94607

Chapter 1
THE TRUE COST OF WATER

The full, true cost of water used in a commercial or industrial establishment is more than just the money paid to the local water utility. Wastewater, water treatment, pretreatment and energy costs to heat water for a commercial facility are important factors in calculating the cost of water for a property. Presenting these costs to the average worker in units they can understand is also important so that all staff can appreciate the interrelated impacts of water and energy use. This chapter examines these cost relationships.

Water Rates in East Bay Municipal Utility District

Water rates for EBMUD are expressed in dollars per 100 cubic feet (CCF). One CCF is equal to 748 gallons.

Commercial and industrial rates include non-potable water and multifamily customers. Multifamily is included since these are businesses whose function is housing people. In addition to these water rates, the utility charges a fixed monthly fee based on the size of the water meter and pressure zone.

Check with your local water service provider for information on water rates and other billing information.

Wastewater Rates in East Bay Municipal Utility District

Wastewater rates can vary significantly by the wastewater utility in the area. Although EBMUD provides treatment facilities, each wastewater utility has specific rates by type of commercial or institutional user.

Much of the variation in volume charge is based on waste strength (Chemical Oxygen Demand – COD, and Total Suspended Solis – TSS) and other factors. EBMUD requires that users whose wastewater exceeds the assigned strengths obtain wastewater discharge permits under EBMUD's permit program. Each utility handles these charges in a different manner.

Putting Water and Wastewater Charges Together

Some account types such as irrigation-only are not assigned wastewater charges since wastewater is not generated from their consumption. In a similar fashion, commercial customers that do not discharge a significant amount of their incoming water to the sewer can apply for a permit that estimates the wastewater volume, which would otherwise be based on the incoming water volume and calculates the treatment charge. This "Estimation of Wastewater Charges" permit can result in significant savings for the customer. Buildings with cooling towers, for example, can be given evaporation credits by many utilities for the water that is evaporated and not returned to the sanitary sewer. However, almost all commercial and institutional indoor uses are not separable. Therefore, the cost to use water should include both water and wastewater volumetric charges.

Energy for Heating Water

The associated energy necessary to heat water is an often-overlooked water cost. Hot water use in restaurants is primarily in the kitchen for dishwashing and other activities. High temperature dishwashers must have 180°F water while other operations can use water in the 130°F to 140°F range. Hot water is used in lavatories, sinks, and for showers and on-site laundry. Hotels and hospitals have significant water costs for showering and medical equipment. Many other uses of hot water can be found in the commercial and institutional sectors.

The cost to heat water can add significantly to the cost of the water that is being used. The amount of energy needed depends on the tap water temperature; the colder the incoming water, the more energy needed to raise the water to the desired temperature.

Electricity and natural gas are the two main ways of heating water in commercial and institutional operations . This is also generally true in industrial operations, although other fuels are sometimes used.

Electricity rates can vary by time of use. The price of natural gas and propane also generally increases annually and can adjust seasonally or even daily.

Businesses should be aware of their current electric and natural gas rates. Pacific gas and Electric (PG&E) is the main energy provider to EBMUD. Rates vary by total use and season.

Cost to heat one gallon of water:

- The cost of natural gas or electricity
- The temperature of the water supplying the water heater
- The final temperature of the hot water
- The efficiency of the water heating system

The energy cost of heating water per gallon can be higher than the combined water and wastewater cost of that water per gallon. **Tables 1-1 and 1-2** show how much it costs to heat water at 100 percent water heater efficiency. Currently, electric water heaters operate in the range of 98% to 99% efficiency, and as of October 2015, commercial gas water heaters are required to achieve 80% efficiency[1]. Older water heaters were generally 70% to 75% energy efficient when brand new. New natural gas condensing heaters have efficiencies in the 90% to 95% range. However, the efficiency of hot water delivered to the point of use includes heat loss in the pipes. As water heaters age, their efficiency also tends to decline.

When energy costs are added, the cost of water increases dramatically.

The following examples illustrate how to use the sample tables.

Example 1: A new electric water heater operating at 80 percent efficiency heats water from 60°F to 140°F, an increase of 80°F. If the cost of electricity is 30 cents per kWh, the cost at 100% efficiency is 5.86 cents per gallon. At 80 percent efficiency, the actual cost is 5.86/0.80 = 7.33 cents per gallon. When added to the total water and wastewater cost, the hot water costs are 8.58 cents per gallon = $85.80 per thousand gallons ($64.18 per CCF).

Example 2: The 140°F hot water is then used to feed a high temperature dishwasher operating at 180°F using an electric booster heater. The water must be heated an additional 40°F with electricity at 30 cents per kWh. The rise in temperature from 140°F to 180°F cost would be 2.93 cents a gallon. Adding the water and wastewater cost of 1.26 cents and the gas heater cost to raise the water to 140°F 3.56 cents, the total cost = 4.78 cents per gallon = $47.80 per thousand gallons.

Typical Percentages of Hot Water Use for Commercial and Institutional Users

The cost of water used will depend on what percent of the water used in the application is heated.

For example, the percentage of water used in a shower depends on the temperature of the cold water and the preference of the person taking the shower. Cold water (water and wastewater combined) may cost 1.25 cents a gallon and hot water may cost approximately 2.60 cents a gallon. Therefore, if 60% percent of the water used in the shower is heated water, the cost of water would be calculated as follows: (1.25 X 0.40) + (2.6 X 0.60) = 2.06 cents per gallon. **Table 1-3** shows the range of hot water use for various types of hot water use in commercial and institutional establishments.

Treatment Costs

While many industries, such as restaurants, will generally not need to further treat their municipal water, certain commercial and industrial operations such as refineries require a specific chemical composition of water. In these cases, further treating municipal water could be necessary, adding to the cost. The two most common commercial treatment options are softening and reverse osmosis.

Softening is done with a softener that uses either sodium or lithium chloride to recharge the softener. Commonly, commercial heating and cooling applications, such as in cooling towers, require "softer" water that removes naturally occurring minerals. Water from the East Bay Municipal Utility District has an average hardness of 140 ppm as calcium carbonate. This is equal to 7.9 grains of hardness. The State of California requires residential

1 https://appliance-standards.org/product/commercial-water-heaters

softeners remove at least 4,000 grains of hardness per pound of salt. Commercial systems can generally operate at this efficiency or even higher.

If the softener is operating at 4,000 grains per pound of salt and the hardness is 7.9 grains per gallon, one pound of salt will treat 506 gallons of water. The average cost of softening salt is in the range of 4.5 cents to 5.5 cents per pound. In this example, salt cost for softening to treat 500 gallons is 10 cents per thousand gallons - a relatively small amount.

Reverse Osmosis systems remove dissolved solids (salts and minerals) from water with a molecular level filtration type system. "Industries like mechanical, chemical, pharmaceutical, and lumber/pulp industries, utilize reverse osmosis systems for pre-boiling water treatment/conditioning."[2] Feed water to reverse osmosis (RO) systems is also often softened before RO is used. In some commercial operations such as car washes and in medical and laboratory systems, feed water to the RO unit is pressurized with a pump. For small RO applications in kitchens and point of use treatment, line pressure is used. Although, energy costs for systems using a pump are real, for most RO systems, they are small if only fresh water is the source. The main factor is how much water is discharged to waste for every gallon produced. Some older inefficient systems dumped five gallons of water into the sewer for each gallon provided for use. For car washes and kidney dialysis systems, typically, one gallon is dumped for every gallon produced. These two examples are used because for car washes with recirculation systems, dumped water is not wasted. It is caught and used for the first wash cycles. For the kidney dialysis systems, that water is lost. Modern under the sink RO systems typically dump two gallons per gallon produced, while much larger systems for laboratories can dump as little as a quarter of a gallon per gallon produced.

The following are examples of calculations.

Example 1: A small under the counter RO unit that discharges four gallons for each gallon produced by the RO system. In this case, for every one gallon produced, five gallons are used. The cost for water and wastewater is 1.246 cents per gallon. Therefore the total cost = 5 x 1.246 cents per gallon = 6.23 cents per gallon which equals $46.60 per CCF!

Example 2: A kidney dialysis clinic with an RO system that produces one gallon and discharges one gallon. In this case, two gallons are used for each usable gallon produced. At 1.246 cents a gallon, each usable gallon cost 2.49 cents a gallon ($18.64 per CCF).

The Impact of Inflation on Future Water Costs

Since 2000, water and wastewater rates have had an inflation rate between 5.5% and 5.6%[3]. Using historical rates means that rates for water and wastewater in 2021 were some 2.96 times more than in 2001. If this inflation rate prevails, current water and wastewater rates will double in 14 years. Table 1-4 shows this impact on the cost to flush a toilet.

Energy rates, such as for natural, also continue to increase. Figure 1-1 shows average natural gas prices for commercial establishments in California since 2010.

2 Intec America *https://www.intec-america.com/blog/reverse-osmosis-ro-industrial-applications*

3 Black & Veatch. (2021). 2021 50 Largest Cities Water and Wastewater Report. *https://bv.com/resources/2021-50-largest-cities-water-and-wastewater-report*

TABLE 1-1: The Cost of Heating Water with Natural Gas at 100% Efficiency

DOLLARS PER MCF	DEGREES F° OF INCREASE IN TEMPERATURE										
	40°	50°	60°	70°	80°	90°	100°	120°	130°	140°	150°
$6	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.65	0.70	0.75
$8	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.80	0.87	0.93	1.00
$10	0.33	0.42	0.50	0.58	0.67	0.75	0.83	1.00	1.08	1.17	1.25
$12	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.20	1.30	1.40	1.50
$14	0.47	0.58	0.70	0.82	0.93	1.05	1.17	1.40	1.52	1.63	1.75
$16	0.53	0.67	0.80	0.93	1.07	1.20	1.33	1.60	1.73	1.87	2.00
$18	0.60	0.75	0.90	1.05	1.20	1.35	1.50	1.80	1.95	2.10	2.25
$20	0.67	0.83	1.00	1.17	1.33	1.50	1.67	2.00	2.17	2.34	2.50

TABLE 1-2: The Cost of Heating Water with Electricity at 100% Efficiency

CENTS PER KWH	DEGREES F° OF INCREASE IN TEMPERATURE										
	40°	50°	60°	70°	80°	90°	100°	120°	130°	140°	150°
8	0.78	0.98	1.17	1.37	1.56	1.78	1.96	2.35	2.54	2.74	2.93
10	0.98	1.22	1.47	1.71	1.96	2.22	2.44	2.93	3.18	3.42	3.67
12	1.17	1.47	1.76	2.05	2.35	2.67	2.93	3.52	3.81	4.11	4.40
14	1.37	1.71	2.05	2.40	2.74	3.11	3.42	4.11	4.45	4.79	5.13
16	1.56	1.96	2.35	2.74	3.13	3.56	3.91	4.69	5.08	5.48	5.87
18	1.76	2.20	2.64	3.08	3.52	4.00	4.40	5.28	5.72	6.16	6.60
20	1.96	2.44	2.93	3.42	3.91	4.45	4.89	5.87	6.36	6.84	7.33
22	2.15	2.69	3.23	3.76	4.30	4.89	5.38	6.45	6.99	7.53	8.07
24	2.35	2.93	3.52	4.11	4.69	5.34	5.87	7.04	7.63	8.21	8.80
26	2.54	3.18	3.81	4.45	5.08	5.78	6.36	7.63	8.26	8.90	9.53
28	2.74	3.42	4.11	4.79	5.48	6.23	6.84	8.21	8.90	9.58	10.27
30	2.93	3.67	4.40	5.13	5.87	6.67	7.33	8.80	9.53	10.27	11.00
32	3.13	3.91	4.69	5.48	6.26	7.12	7.82	9.39	10.17	10.95	11.73

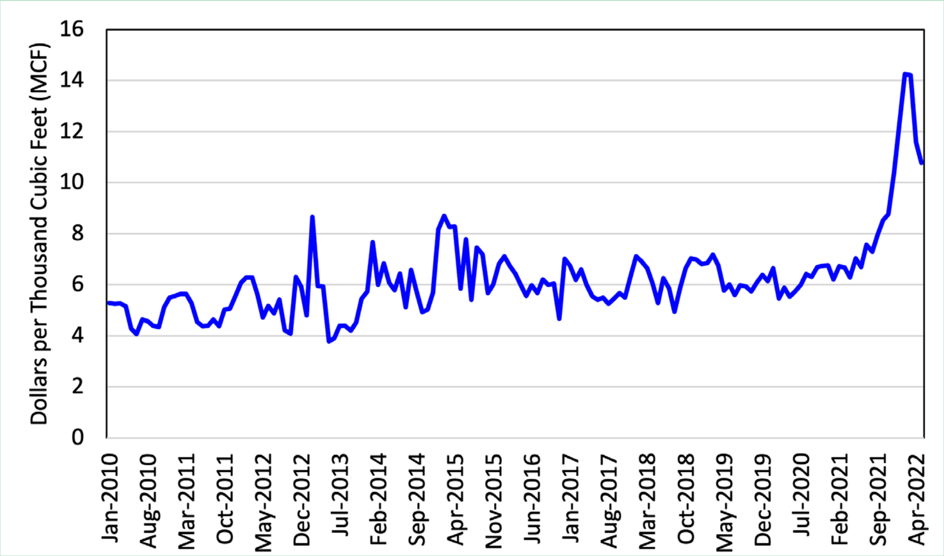
TABLE 1-3: Typical Percentages of Hot Water Use for CII Users

TYPE OF USE	PERCENT RANGE OF TYPICAL HOT WATER USE
Lavatory Faucets	10% to 30%
Showers	40% to 80%
Hotel Laundry Operations	5% to 35%
Coin Laundry Operations	20% to 35%
Commercial Dishwashers	100%
Pre-Rinse Spray Valves	0% to 100%

TABLE 1-4: Cost to Flush a Toilet Now and in 10 and 20 Years

GALLONS PER FLUSH	CENTS PER FLUSH		
	2022	10 YEARS	20 YEARS
5.0	6.2	10.1	16.7
3.5	4.4	7.1	11.7
1.6	2.0	3.2	5.4
1.28	1.6	2.6	4.3
1.0	1.2	2.0	3.3
0.8	1.0	1.6	2.7

FIGURE 1-1: California Commercial Gas Prices Since 2010



Source: Energy Information Administration

Resources

1. Alliance for Water Efficiency. (2019). Water Audit Guidance for Commercial Buildings
   www.allianceforwaterefficiency.org/sites/www.allianceforwaterefficiency.org/files/assets/City_Energy_Project_Water_Audit_Guidance_For_Commercial_Buildings.pdf
2. Black & Veatch. (2021). 2021 50 Largest Cities Water and Wastewater Report
   https://bv.com/resources/2021-50-largest-cities-water-and-wastewater-report

Chapter 2
TECHNOLOGIES FOR REAL-TIME WATER USE: AMI, FLOWMETERS AND DATA LOGGERS

Thanks to advances in data monitoring technology, water use data is now frequently available at high volumetric resolutions and measurement frequencies that can be readily used to identify and implement water saving opportunities.

There are several technological options for capturing high-resolution water use data, including Advanced Metering Infrastructure (AMI) meters installed by utilities as well as flowmeters and data loggers installed by water users, or plumbers acting on the water users' behalf. This section provides a brief overview of each technology, followed by general recommendations and a table listing the efficiency, benefits, and drawbacks for the different technologies.

Advanced Metering Infrastructure (AMI)

AMI is a combination of utility-installed meters and associated devices or systems used to capture, transmit, and store high resolution water use data. Traditional metering systems record water use at monthly, bi-monthly, or quarterly intervals whereas AMI metering systems record data at daily, hourly, or sub-hourly intervals. In addition to more frequent measurements, AMI meters may capture, and report water use at gallon or even fractional gallon (or cubic foot) volumes, compared to traditional systems which often report in thousand-gallon (kgal) or hundred cubic foot (hcf) volumes.

While the systems are owned and operated by the utility, AMI systems also frequently include a customer-facing data portal and are sometimes integrated alongside utility billing systems. This gives the user access to nearly real-time water use data.

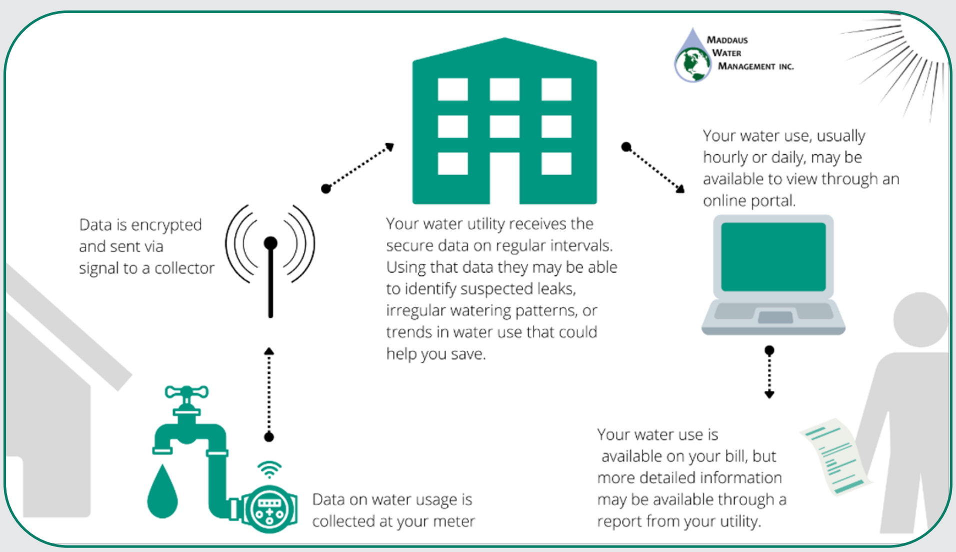
AMI technology represents a substantial improvement over many aspects of traditional metering systems but also requires a substantial capital investment by the utility. Not all utilities have made the switch to AMI, and those that have switched sometimes target specific customers, areas, or meter types for systematic replacement over time. As of 2023, EBMUD has not yet made the transition to AMI meters for the majority of its service area.

Opportunities to save include:

- Leak identification (including verification of leak repair)
- Increased operational efficiencies through benchmarking and other means
- Identification and replacement of inefficient equipment and fixtures

Although the data captured by AMI systems can seem overwhelming, tools are available to assist both water users and utilities in extracting meaningful and actionable information. Data collected by AMI systems can be processed in various ways, including automated methods implemented by utility staff or through processing handled by AMI data portals.

AMI components



Source: US EPA, https://www.epa.gov/system/files/documents/2022-09/ws-commercial-ami-guide-facilitymanagers.pdf

TABLE 2-1: METHOD/TECHNOLOGY TABLE

METHOD/ TECHNOLOGY	BENEFITS	DRAWBACKS
AMI Customer Portals	• With access to data in near-real-time, portals inherently encourage water use efficiency as you can actively monitor use to keep use/bills low • The Portal can identify some end uses such as irrigation or potential leaks and bursts.	• Customers must actively use and engage with the portal
AMI Leak Notification Programs	• Alerts customers of leaks quickly, preventing high bills and associated water damage. • Can automatically enroll customers so they are notified even if they have not proactively engaged with the customer portal.	• Requires advanced algorithms to detect CII leaks • False positives or multiple small leaks can be viewed as nuisances
AMI Threshold-Based Notifications (incl. water budgets)	• Allows customers to identify and address potential issues before a high bill is received. • Helps customers to reduce water to meet budget by showing actual versus desired usage • Can support operational efficiency by displaying accurate real-time water usage information	• Thresholds vary greatly across use types and individual users, so can be difficult to establish
Flowmeter / Data Logger Equipment	• Add bullet before this one: Allows customers to see real-time usage even without utility-installed AMI • Allows precise water use monitoring for specific equipment/systems and associated benefits (leak detection, efficiency improvements, etc.) • Customer can often easily self-install externally attached models • May help meet green building certifications and other sustainability goals	• Initial install as well as calibration, testing, or repair may require system drain-down and plumbing expertise • Isolation of individual uses may not be possible for all customers • Equipment replacement and upgrades can be costly • Not all models offer real-time notifications via app • Some models require Wi-Fi, cellular subscriptions, and/or external power sources

Meaningful Utilization of AMI Data:

- Setting threshold-based notifications (e.g., notifying the utility and/or customer if water usage is greater than the user-specified number of gallons per hour/ day/week)
- Projected bill amounts based on current usage to date
- Continuous usage (also known as suspected leak) notifications
- Advanced systems may also identify distinct large water usages such as irrigation or potential bursts possibly indicative of pipe breaks

Notifications regarding high usage, suspected leaks, or frequent irrigation are often part of a customer portal service, used by utilities, that can help water users address their own high usage and suspected leak issues before they escalate.

In addition to notification-driven savings, Commercial, Industrial & Institutional (CII) users can achieve even greater savings using AMI by actively monitoring their water use during operational events (E.g.: equipment that runs overnight).

This data can be used to form a baseline operational assessment. This assessment includes conducting a comprehensive review of typical water use and documenting water use for specific equipment and processes, or for the entire facility over various time periods. By comparing the actual water consumption for a piece of equipment or process to the manufacturer's description of expected use, it becomes easier to identify inefficiencies or potentially failing equipment. This information can be used to target efficiency projects and upgrades.

Flowmeters & Data Loggers

Flowmeters and dataloggers offer even higher resolution data than AMI meters and can provide data at fractions of a gallon every second. Sometimes, this more granular data makes identifying the cause of leaks and high usage easier than with AMI alone. Flowmeters are often in-line equipment that require system drain-down or wet tap and plumbing expertise to install, although clamp on models are also available. There are many types of flowmeters with varying suitability considerations, including pipe diameter, water properties, and desired accuracy. For additional information about flowmeter and data loggers, see the EPA's publication, [WaterSense at Work: Metering and Sub Metering].

Data loggers on two water meter dials

Image source: HW (Bill) Hoffman & Associates, LLC

Flowmeters can be connected upstream of specific equipment, such as cooling towers or irrigation systems, to provide high resolution data associated with specific equipment and end uses. Some flowmeters can also measure additional water parameters, such as pressure and temperature.

Dataloggers collect similarly high-resolution data but must be attached externally to existing metering equipment. Dataloggers can be attached to city-owned meters in some situations or can be attached to user-owned submeters or flowmeters.

Note that flowmeters and dataloggers are often referred to interchangeably. Both flowmeters and dataloggers require calibration and testing during initial setup and at recommended intervals, which vary by device. Both devices can either store data locally for manual retrieval or transmit data through a network method such as Wi-Fi or cellular. Platforms for accessing water use data are specific to each manufacturer, but most offer the ability to export data to a common platform like Microsoft Excel.

Recommendations

- Leverage capabilities of AMI system and data portals, if available
- Set up contact details and other parameters (ex: thresholds) for AMI notifications
- Familiarize key staff with AMI data access, monitoring, and other system features
- Install flowmeters or dataloggers upstream of high usage equipment and systems
- Actively monitor water usage during specific time periods and operational phases using AMI and/or flowmeters/dataloggers; compare over time or to available expected usage data (e.g., benchmarking studies) to identify opportunities for efficiency improvements.

Resources

1. City of Santa Rosa. (2022 June 15). Santa Rosa Water Combines AMI, WaterSmart Portal and Audits to Uncover Leaks. ACWA.com
   https://www.acwa.com/innovation/santa-rosa-water-combines-ami-watersmart-portal-and-audits-to-uncover-leaks
2. Brueck, T; Williams, C; Varner, J; Brink, Penny. (2022, September) AMI-Meter Data Analytics Water Research Foundation
   https://www.waterrf.org/research/projects/ami-meter-data-analytics
3. Advanced Metering Infrastructure: A Guidance Manual for Water Utilities – prepared by the Alliance for Water Efficiency
   https://www.allianceforwaterefficiency.org/resources/topic/advanced-metering-infrastructure-guidance-manual-water-utilities
4. American Water Works Association. (2018). M33 Flowmeters in Water Supply, Third Edition. AWWA.org
   https://engage.awwa.org/PersonifyEbusiness/Store/Product-Details/productId/69279701
5. (2022, February). Increasing consumer benefits & engagement in AMI-based conservation programs: Guidebook for Practitioners AWWA.org
   https://www.awwa.org/Portals/0/AWWA/ETS/Resources/Technical%20Reports/ami_guidebook_feb_2022.pdf
6. Akesson, J; Hahn, R; Kacha, O; Leavell, V; Ong, J. (2022, February). Increasing consumer benefits & engagement in AMI-based conservation programs. AWWA.org
   https://www.awwa.org/Portals/0/AWWA/ETS/Resources/Technical%20Reports/ami_report_feb_2022.pdf
7. Environmental Protection Agency (2017, February). WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities EPA.gov
   https://www.epa.gov/sites/default/files/2017-02/documents/watersense-at-work_final_508c3.pdf
8. (2022, September). Improving Water Management Using Advanced Metering Infrastructure Data for Facility Managers EPA.gov
   https://www.epa.gov/system/files/documents/2022-09/ws-commercial-ami-guide-facility-managers.pdf

Chapter 3
PLUMBING FIXTURES

Plumbing fixtures are a ubiquitous part of our daily lives, and every building with a water supply uses plumbing to convey and control the water. Because of the large variety of plumbing fixtures and the enormous amounts of water they collectively use, federal and California statues set water-use standards for some fixtures and appliances.

Backflow preventers and vacuum breakers are required by state or local code so water supplies will not be contaminated by sources at the point of use.

Manufacturers and water utilities have continued to examine opportunities for water efficiency and associated energy efficiency. Ongoing plumbing fixture performance testing results in updated water flow specifications. Plumbing fixtures are also prime targets for replacement or retrofit with high-efficiency technologies. This chapter highlights ways that fixture leaks and inefficiencies can be mitigated in:

- Backflow Preventers
- Fire Protection Systems
- Floor Drain Trap Primers
- Janitorial Mop Sinks
- Outdoor Faucets
- Pumps
- Surge Tanks & Other Forms of Potable Water Storage
- Valves & Other Devices

Backflow Preventers

Backflow preventers stop water from flowing in the wrong direction through cross connections. Backflow preventers and vacuum breakers are required by state or local code so water supplies are not contaminated by sources at the point of use.

If one end of a hose, pipe, drain-trap primer, submersible pump, or other device is in non-potable water, and if the back pressure of the non-potable water exceeds the supply pressure, without a backflow preventer this potentially bacteria-laden or contaminated water could be sucked back into the potable-water supply line. Such cases are possible if a potable water system is connected to a boiler, cooling tower, booster or recirculating pump, or encounters any substance that could cause a health hazard or affect the aesthetic quality of the water supply. If any of these conditions exist at your site, you will be required to install an appropriate backflow preventer.

By health regulation, backflow devices between public-water supplies and private facilities should be inspected and tested on a regular schedule. For example, the California Code of Regulations, Title 17, mandates water purveyors such as EBMUD[1], which helps to keep potable water from contaminant and pollution exposure. Check with your local water supplier for details specific to your service area.

Brass Backflow Preventer

1 *https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/dw_regulations_2019_03_28.pdf*

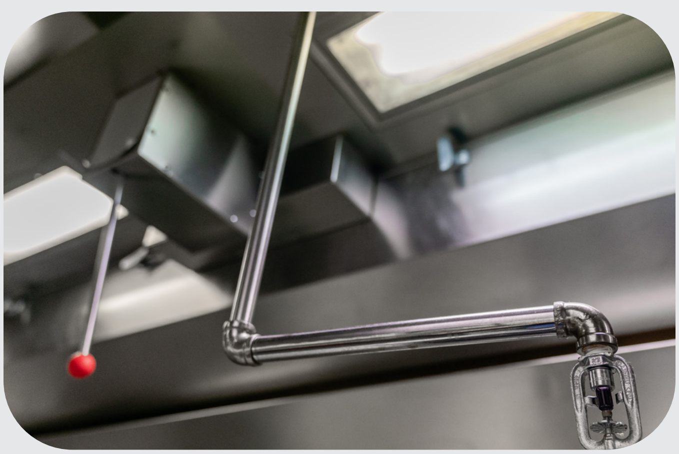
To avoid any cross connections between fire-protection and water supply plumbing, **mark fire-protection plumbing conspicuously**.

Recommendations

- Install backflow preventers and vacuum breakers as required by code and utilities
- Regularly test and maintain all backflow prevention devices installed at the service connection per local regulations
- Locate devices in easy-to-observe locations, and provide easy access for inspection and testing
- In non-freezing climates, mount exterior backflow preventers above ground so any leaks may be easily observed
- For interior devices, place small wells to collect any leak water where it may be observed

Fire Protection Systems

Fire Sprinkler in a Commercial Kitchen Facility



On the customer premises, a fire protection system is typically served by a dedicated plumbing system. No flow should occur except in the case of a fire emergency or testing. Connections to such a system by the customer for other purposes are prohibited.

Utilities meter and bill fire protection water supply lines separately from potable water supplies. Flow detection meters should be installed on fire service flows to indicate cross connections and improper use of fire water. To have an effective program, these meters need to be read when other meter readings are taken.

Install flow indicators to show the presence of leaks. Utilities may also require flow check meters capable of detecting small flows (less than 1 gallons per minute) on the fire supply line.

All fire meters require periodic pressure testing which can use 20 to 50 gallons per check. Most public utilities charge in units of water (1 unit = 1 CCF = 748 gallons). However, by the time one unit of water registers from normal use a year or longer could have elapsed. Thus, if the fire meter registers water use on consecutive billing periods, that is a sign that a leak may be occurring on the system.

Recommendations

- Allow no connections to fire-protection system except for fire protection
- Install flow-detection meters on fire services
- Conspicuously mark fire-protection-system plumbing
- Check billing for water usage to ensure there are no consecutive billing periods with water usage; this is a sign of water leak in the system.

Floor Drain Trap Primer

Floor drains often exist in spaces where regular water use may spill or where floors may be washed frequently. Plumbing codes require traps to prevent gases and odors from seeping from sanitary sewers into the room through the drains. Gas is blocked by water trapped below the drain in an “S” shaped pipe called a “P trap.” In some rooms the trapped water evaporates when the floor is seldom washed, damp-mop floor-cleaning methods are used, or little water reaches the drain. This condition may allow the sewer gasses, other odors, and/or vermin to enter the room.

To sustain water in the trap, additional water must be added with a device called a trap primer. A trap primer is a valve or other connection from a water source that allows a small amount of water to flow through pipes to recharge traps of one or more drains.

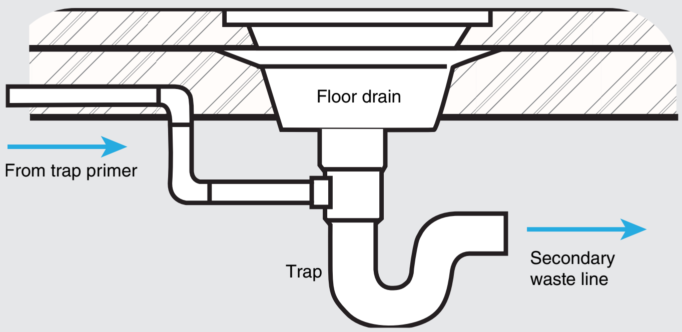
TABLE 3-1: Sample Water Use of Trap Primers

PRIMER TYPE	NUMBER OF ACTUATIONS PER DAY	DAILY WATER USE PER DRAIN SERVED	ANNUAL WATER USE IN GALLONS
Continuous	Continuous	0.25 gallons per minute (gpm), 360 gallons per day (gpd)	360 gpd X 365 = 131,400
Flush-activated	Depends upon flush valve use	For 10 flushes: 0 X 1 oz = 0.08 gallons	28
Pressure-sensitive	Depends upon fixture use	For 10 flushes: 0 X 1 oz = 0.08 gallons	28
Electronic	1 (one)	0.08 gallons	28
Waterless	0 (zero)	0 (zero)	0 (zero)

The common types of trap primers include:

- Continuous flow
- Pressure-drop activated
- Flush-valve activated
- Electronically timed

Schematic of a Floor Drain



Water sources for trap primers include cold-water pipes, the discharge side of flush valves, or washbasin drainpipes, depending upon the distance to the drain and the frequency that the supply device provides water. A seldom-used valve might provide inadequate water to maintain the trap function. The most efficient floor-trap primer will have a connection size and discharge frequency that provides a volume of water only slightly greater than the evaporation from the trap. Most pressure-sensitive, flush-activated or electronic trap primers discharge only a few ounces of water for each outlet during each operating cycle. Comparatively, a continuous flow trap primer can use over 300 gallons per day. Primers connected to sink drains use wastewater. However, the debris screens to these inlets need to be cleaned periodically. Where drains are used as sanitary sewers, such as in animal pens, additional water may be applied to the drain rim to flush debris from the surface of the drain.

Waterless floor drain trap primers, or barrier-type seal protection devices, can aid in saving water because they don't use water to maintain a seal. Waterless trap primers feature a one-way membrane that acts in the same way a check valve does.

Recommendations

- Ensure that selected trap primer(s) meet current state and/or national plumbing codes
- Select pressure-activated or electronic trap primers, each serving several drains
- For the largest water savings, select waterless trap primers
- Avoid continuous-flow trap primers
- Physically inspect traps at least once a year

Janitorial Mop Sinks

Mop sinks, also known as service sinks, are large wash basins or set tubs used for janitorial purposes in commercial settings. Mandatory in many jurisdictions, their installation and use are required to support proper sanitation and are thus regulated by building and health codes.[2]

Janitorial Mop Sink

Recommendations

- Install check valves overhead on the mop sink faucet supply lines to help prevent back feed between hot or cold water supply lines
- Do not let the faucet run, especially if a hose is attached, to clean dirty items

Outdoor Faucets

Outdoor faucets, often known as hose bibs, water spigots, sill cocks, or hose hydrants, are valves which are often threaded to allow easy connection to hoses, pressure washers, and other equipment. Not generally subject to specific flow limitation, flows through hose bibs are determined by the equipment being used.

For hose bibs where vandalism and unauthorized use is a concern, use a “loose key” or attach a hose bib lock. Instead of an attached handle, there is a slot for a removable square key to be used to operate the hose bib. Alternatively, provide a locked box over the hose bib or eliminate hose bibs.

Hose Bib Outside of a Commercial Business

Recommendations

- Faucet flow should not exceed 5 gallons per minute
- Install self-closing nozzles and valves on equipment connected to hose bibs
- Install a hose bib lock or “loose key” where water theft or vandalism may be an issue
- Prevent water waste in freezing conditions:
  - Install outdoor pipes and fixtures so they can be drained before freezing weather
  - Use freeze-proof bibs that extend through the wall into a warm environment
  - Insulate pipes and plumbing attachments and add heat tape for seasonal use

Pumps

Pumps can be present in a variety of commercial and institutional processes. Our focus is leakage that may occur from pumps used to move water and to increase water pressure. Pumps with packing glands have a reputation for leaks and frequent need for replacing the packing. Mechanical seals are superior to packing glands in that they are far less likely to fail and leak.

2 CA Retail Food Code, Page 124, Article 3. Janitorial Facilities, 114279. Curbed cleaning facility. *https://ochealthinfo.com/sites/healthcare/files/2024-01/CalCode%20effective%20January%202024%20Digital.pdf*

Recommendations

- Choose pumps with mechanical seals rather than packing to reduce chance of seal failure
- Choose newer vacuum pumps that do not use water seals
- Choose pumps that are air-cooled
- Carefully test pumps upon installation to ensure leak-free operation

Surge Tanks and Other Forms of Potable-water Storage

A surge tank is a water storage device used as a pressure neutralizer in a hydropower water conveyance system to resist excess pressure rise and pressure drop conditions.

Surge tanks absorb the pressure transients, also known as water hammers, of fast-acting valves to reduce plumbing system damage. A water hammer is a pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly[3]. Expansion tanks and pressure-relief tanks are safety devices to store expanded heated water and relieve pressure on the plumbing system. A water hammer can occur in a building when the overall pressure of the water main entering a building is too high. A normal water pressure at the municipal water meter is 40 to 60 pounds per square inch (PSI) and when the pressure gets above this range it can increase the changes of a water hammer. Water pressure more than 100 psi can damage pipes and water using fixtures. Storage tanks may be placed atop high-rise buildings to maintain pressure in the building.

Tanks and their fittings sometimes leak only intermittently when water pressure is higher. An observation well or collection basin can collect the leakage and provide visible evidence of the leak so that repairs can be taken.

Altitude-control valves are supposed to sense the level of water in the tank and stop inflow if the storage level exceeds a specified elevation. If the altitude-control valve fails, the tank may overflow with great loss of water and sometimes property damage. The overflow is usually channeled through a pipe to a drain. Install a signal device to show that overflow has occurred.

Recommendations

- Provide visible and audible monitoring signals for tank overflow
- Provide monitoring wells to capture and make visible any leakage
- Inspect and verify all tanks every 12 months
- Inspect tanks and verify operability in accordance with the manufacturer's instruction, and/or any municipality having jurisdiction

Valves and Other Devices

Devices listed in this section are used to limit water losses during pipe ruptures, equipment failures, and other emergencies. Unlike much of the other equipment and processes described in this guide, these devices do not readily lend themselves to cost effectiveness analysis. These controls may be inactive for many months or even years, when suddenly their function becomes immediate. In the meantime, small leaks or overflows may occur. Install these devices in easily visible locations, so leaks may be noted, and corrective repairs performed.

Emergency Shutoff Valves and Isolation Valves

Emergency shutoff valves can be used to stop water flow when pipes rupture, connections leak, or equipment fails. During repairs, isolation valves can stop flows to individual pieces of equipment, while avoiding shutting down water to major portions of a building. Shutoff valves are relatively cheap compared with the potential damage they can minimize. Their usefulness relates to how well they are marked and their accessibility. Never block access to shutoff valves, and plainly mark the location of emergency shutoff valves near the valve site and in the area where the water is used.

Recommendations

- Add isolation valves to all pieces of water-using equipment, if not provided by the manufacturer
- Place additional emergency shutoff valves near critical water-use areas
- Plainly mark the location of emergency shut-off valves
- Attach information on the valve, stating which portions of the facility are supplied by the valve
- Meet plumbing codes for your state and county
- Consult the American Society for Mechanical Engineers and the National Board Inspection Code for more details relevant to your specific valves

3 *https://en.wikipedia.org/wiki/Water_hammer*

Water Heater Temperature Pressure Relief Valves (TPRVs) and Relief Valves

Located on the upper portion of a tank-style water heater, this valve prevents the build-up of hazardous pressure by releasing water to an overflow pipe. Water-supply pressure should be within the range recommended by appliance and equipment manufacturers — usually 40 to 60 psi. Flows from the valve discharge pipe should be easy to observe. Place visible indictors to show when the valves are actuated, and operations need to be corrected.

Recommendations

- Insert visible indicators that will show if the valve has activated
- Test valves roughly every six months
- Meet plumbing codes for your state and county
- Make the outlets to valve-discharge pipes easy to inspect for flow
- If no date is specified, a pressure relief valve shall be replaced no later than five years following the date of its manufacture

References/Resources

1. Allied Valve Inc., Pressure Relief Valves: Guidelines for Installation and Operation, *https://alliedvalveinc.com/the-valve-expert/pressure-relief-valves-guidelines-for-installation-and-operation*
2. American Backflow Prevention Association, Backflow Prevention - What Does it Mean to You? *https://www.abpa.org/page/BackflowPrevention?&hhsearchterms=%22commercial%22*
3. California Plumbing Code Chapter 4 *https://up.codes/viewer/california/ca-plumbing-code-2016/chapter/4/plumbing-fixtures-and-fixture-fittings#418.0*
4. Dialectic Engineering, Is Sewer Gas Giving Your Customers the Wrong Impression? *https://dialecticeng.com/wp-content/uploads/2019/06/Dialectic_Plumbing-Trap-Paper_October-2018.pdf*
5. East Bay Municipal Utility District, Backflow Prevention *https://www.ebmud.com/water/about-your-water/water-quality/backflow-prevention/*
6. Jay R. Smith Mfg. Co., Inc., Trap Primers *https://www.jrsmith.com/search.aspx?q=Floor%20Drain%20Trap%20Primer*
7. Whole Building Design Guide, Water Conservation *https://www.wbdg.org/resources/water-conservation*

Chapter 4
RESTROOMS

Since restrooms often account for a majority of the water used in commercial buildings, they are an important area of focus for commercial water efficiency. Because of the large numbers of plumbing fixtures and the volume of water they some restroom fixtures and appliances.[1] In addition, performance testing has resulted in targets pecifications, such as the EPA WaterSense specifications for high-efficiency toilets (HETs)[2], showerheads and faucets. Restroom fixtures are prime targets for new design or retrofit with high-efficiency technologies.

Two Flush Valve Toilets

The State of California requires all public and privately owned buildings have a bathroom.[3] Bathrooms must be equipped with enough toilets, sinks and drinking fountains to meet the needs of the public at peak hours.

Starting in 2019, the conservation standards that applied to single-family homes were extended to commercial and multifamily buildings. While previous regulations had applied specifically to new construction and renovation, provisions are unique in that they apply to any existing plumbing fixtures in buildings built before 1994.

Water efficient models are now the norm in the state of California and are getting more traction across the country. Legislation at both the state and federal level mandating efficient toilet fixtures has helped save trillions[4] of gallons of water annually.

The choice of plumbing fixtures for new structures should be driven not by the minimum standards, but rather by the lifecycle cost for the building operator.

In addition to fixtures that are more water-efficient, non-potable water supplies are being used to flush toilets. These water supplies include treated municipal wastewater and lavatory wash water. Using non-potable water may require more maintenance checks to ensure the mechanism is not clogged. Check with local and state codes for acceptance. See Chapter 7, Alternate Onsite Water Sources, for more information on non-potable water use.

Water-use standards for plumbing fixtures used in restrooms are set by both federal and California statute and are now included in the Uniform Building Codes. Codes have been noted in the table where applicable and are accurate as of 2023.[5] The California Energy Commission 2015 Title 20 standards apply to most restroom fixtures, if they are sold in California. Senate Bill 407 required that properties built prior to 1994 be fully retrofitted with water conserving fixtures by the year 2019 for commercial properties

Water Efficiency Measures for Restrooms Fixtures

Table 4-1, below, consolidates efficiency recommendations and California Plumbing Code requirements for a variety of restroom fixtures. Each efficiency intervention and/or code requirement has additional notes regarding either the relative impact of the intervention, or the designated fixture volumetric requirements.

1 California Plumbing Code Chapter 4 *https://up.codes/viewer/california/ca-plumbing-code-2016/chapter/4/plumbing-fixtures-and-fixture-fittings#4*
2 *https://19january2017snapshot.epa.gov/www3/watersense/products/toilets.html*
3 California Plumbing Code title 24, Part 5 Section 2901. *https://codes.iccsafe.org/content/CBC2019P4/chapter-29-plumbing-systems*
4 *https://www.allianceforwaterefficiency.org/news/20-years-energy-policy-act-18-trillion-gallons-saved-through-more-efficient-toilets*
5 *https://codes.iccsafe.org/content/CAGBC2022P1/chapter-5-nonresidential-mandatory-measures#CAGBC2022P1_Ch05_SubCh5.3_Sec5.303*

TABLE 4-1: Water Efficiency Measures for Restroom Fixtures

METHOD/ TECHNOLOGY	RECOMMENDATION/CODE	EFFICIENCY
TOILETS (AKA WATER CLOSETS) & URINALS	CODE: maximum 1.28 gallons per flush (gpf) (4.8 L)	Medium
	Use non-potable water (rain capture or recycled water) for flushing, where available and codes and health departments permit	High
	Flush should not exceed 3 to 7 seconds for flush valves fixtures.	
	Prohibit continuous water-flushing systems in urinals and toilets	Medium to high
	Prohibit automatic optical or motion-sensing flushing systems for toilets and urinals	Medium
URINALS	Install urinals using 0.5 gpf or less	High
	CODE: maximum 0.125 gallons/flush (0.47 L) for wall-mounted type and 0.5 gallons/flush (1.89 L) for floor-mounted or other type	High
SHOWERS & BATHS	CODE: 1.8 gallons per minute measured at 80 psi and must comply with Division 4.3 of the California Green Building Standards Code (CALGreen)(required by code). In showers with multiple heads, the combined rate of all showerheads controlled by a single valve may not exceed 1.8 gpm in total.	7 gallons per shower for a 10-minute shower and going from a 2.5 gpm to a 1.8 gpm showerhead
	Install only one shower head per personal shower stall (ensure that a properly selected mixing valve is used to reduce scalding hazards).	7 gallons per shower for a 10-minute shower and going from a 2.5 gpm to a 1.8 gpm showerhead
	For group showers, such as in school gyms and prisons, require individual valves for each shower head.	Medium & dependent on behavior
	Install metering showers valves and systems for public showers, detention facilities, or any shower where water usage needs to be controlled	High
	Specify recirculating hot-water systems for large buildings	High
	Select point-of-use hot-water heaters for small applications	Medium
	Substitute showers for bathtubs whenever possible	20 to 30 gallons/shower.
FAUCETS (AKA HAND WASHING LAVATORIES)	CODE: maximum 0.5 gallons (1.89 L) per minute at 60 psi for public lavatory faucets, self-closing faucets, and lavatory faucets installed in common and public use areas (outside of dwellings or sleeping units) in residential buildings	High
	CODE: maximum 0.20 gallons per cycle for metering faucets	Medium
	Businesses with high hand-washing demand should use self-closing faucets with foot-pedal actuators not to exceed 0.5 gpm	Medium to high
	CODE: maximum 1.2 gallons (4.54 L) per minute at 60 psi.	Medium
	Combine a self-closing faucet with low-flow aerator or laminar-flow restrictor	Medium
	CODE: maximum 1.28 gallons per flush (gpf) (4.8 L)	Medium

Toilets

California's AB 715 law requires that 100% of toilets and urinals (other than blow-out urinals) sold or installed in California be high efficiency.[6]

The consumer should be aware that **not all 1.28 gpf toilets are created equal**. A toilet must be able to remove solid waste in a single flush. Different models are designed and engineered to remove solid waste with a certain volume of water. **The most efficient toilets completely remove 600 to 1,000 grams of waste in a single flush**. Acceptable minimums are in the 250-to-350-gram range.

In addition, the law requires that waterless urinals be approved for sale and installation in California. The law also requires that any state agency adopting or proposing building standards for plumbing systems to consider developing building standards that would govern the use of waterless urinals for submission to the California Building Standards Commission. This law imposes a state-mandated local program, and violation of the State Housing Law is punishable as a misdemeanor. This law exclusively applies to toilets and urinals, and no other residential or commercial plumbing fixtures, fittings, appliances, or equipment.

When efficient toilets were first mandated in 1994, many manufacturers released models that had not been adequately engineered or tested for the proper water volume needed to achieve effective performance. Continued improvements are subjected to improved testing standards for endorsement by water utilities and government agencies. Efficienct models were proven to perform better than older high-flush-volume toilets in 2006 by Veritec and Koeller through its MaP Toilet Testing program[7] which continues today. Some Ultra High Efficiency Toilets (UHETs) use as little as 0.8 gallons per flush (gpf), though the 1.28 gpf is now most common. The technology has proven so successful that California, Colorado, the District of Columbia, Georgia, Massachusetts, New York, Texas, Washington, and New York City have adopted toilet efficiency standards that require products to use no more than 1.28 gpf. One of the benefits in installing HETs, aside from the water saved, is less water going down the waste stream and therefore a savings on wastewater costs.

Flush Valve Toilet in a Commercial Bathroom

A toilet flush can be actuated by manual mechanical levers, push buttons, or electronic sensors. The hands-free sensors eliminate the need for human contact with the valve, but sometimes flush needlessly multiple times while the toilet is still in use.

Although the primary purpose of toilets is to remove human waste and initiate transportation to a wastewater treatment facility, toilets in public places are often used to dispose of other materials. Toilets for public locations should have a glazed trap of at least two inches diameter — the bigger the diameter, the better to prevent clogging.

Major requirements for minimizing water use in toilet operations include:

- Flush the toilet bowl clear
- Transport waste through pipelines to the sanitary sewer; operate reliably
- Have a leak-proof discharge valve

6 https://www.buildinggreen.com/newsbrief/california-law-raises-efficiency-toilets-and-urinals
7 https://map-testing.com/wp-content/uploads/2022/09/MaP-Testing-Specification-Version-7-revised-April-19-2018.pdf

Today's high-efficiency and ultra-high efficiency toilets (UHETs) offer a powerful flush without wasting water.

Gravity-Assist Toilets: these toilets work by moving water down into the bowl from the tank to easily move waste down the drain. They are popular because they are inexpensive and easy for plumbers and handy homeowners to fix. These toilets use rubber seals at the bottom of the tank called "flappers" that need to be replaced once every few years as water softens down the material and a proper seal cannot be maintained. Flapper leaks can be very quiet and very expensive if not detected. It is recommended that these toilets be checked 3 to 4 times a year for leaks by doing a toilet dye tab test. Also, water levels should be periodically checked, and the water level should be ½ to 1 inch below the top of the overflow tube.

Dual-Flush Toilets: these models offer users a choice based on whether you need to flush solid or liquid waste. For instance, a liquid waste 1st stageflush will only use about 0.8 to 1.1 gpf, while a "full-power" 2nd stage flush will use 1.28-1.6 gpf, depending on the toilet model's efficiency rating.

Image source: The Bathroom Blueprint

Pressure-Assisted Toilets: these toilets have a plastic tank within the ceramic porcelain tank. The inner tank is sealed and works by using mechanical air-pressure as the tank refills with water. When it is flushed, that pressurized air pushes out water with force and flushes it down bowl and the pipes. Some drawbacks are that these models are more expensive and harder to fix when they break. The PA toilet also tends to make some noise. When these toilets leak, they create a hissing noise which should be checked immediately.

Image source: Sloan

Commercial flush valve toilets: These toilets do not have a tank and use pressure to force water down the bowl. These toilets should flush between 3-7 seconds. If they flush for longer than that, it could indicate that the flushing mechanism called a "diaphragm" may need to be replaced. These toilets are the preferred model for businesses as they don't have a tank that needs to be checked. The flush time should be 7 seconds or less.

Urinals

Urinals are made to accept liquid waste, but not solid waste. They come in several configurations and combinations of features:

- Wall-mounted urinals for single-person use. These are flushed after each use, either manually by the user or by automatic actuator
- Wall-mounted troughs for simultaneous multiple-person use. Intended for high use areas such as sports venues, they are flushed continuously during the high use period and are controlled with a valve and timer, but not by the user
- Wall-mounted waterless urinals for single-person use that require neither flushing nor water supply plumbing

The potential for water savings depends upon the number of users at a given site. Urinals are used more often than toilets in buildings when both fixtures available. Based upon U.S. Green Building Council numbers, urinals are

Wall-Mounted Urinals

used two to three times a day. Addition energy savings can result from the reduced need to pump water to higher elevations in high rise buildings for water-efficient urinals.

Showers and Baths

The average bathtub is 60 inches long, 30 inches wide and 14 to 16 inches high. The capacity, in gallons, of an average bathtub is about 40 to 50 gallons when full and most people only fill it with 20 to 30 gallons as their mass will displace the water. 10-to-15-minute shower with a 2 gallon per minute showerhead. Where plumbing code and health officials allow, the wastewater from showers and baths may be captured, treated, and redirected for toilet flushing or other non-potable, non-contact uses.

The hospitality sector touts the relaxation and luxury of infinity and whirlpool baths (approximately 90 gallons per fill or equivalent to a 45-minute shower using a 2-gpm showerhead). In the hospitality sector, hot water is often circulated from a water heater, through a pipeline loop, to the guest rooms. Unused water returns to the water heater. This provides hot water quickly to the guest showers/baths and reduces the water wasted while waiting for warm water. The circulated hot water should be placed on a timer, as this may increase energy usage.

Installing a Water Efficient Showerhead

Manually Operated Faucet with a Water Efficient Aerator in Action

Tubs come in various sizes. Select shallower bathtubs that have smaller water capacity. The water level will cover the bather when immersed.

Shower heads are available with a variety of spray patterns, water-droplet sizes, and pulsations. Both shower and bathtub water are used and typically discharged to sanitary wastewater. In locker rooms and similar situations, several people may wash in a communal shower room with multiple shower heads. Showerhead shut-off valves can be added to maximize water savings. Installing a shower shut-off valve works by allowing the user to "turn-off" water while shampooing or lathering up and then turning the water back on to rise. Showerhead shut-off valves allow for a small amount of water to trickle through when fully in the "off" position in order to prevent hot water from accumulating at the front of the showerhead and scalding when turned back on. Installation of point-of-use hot water heaters will reduce the wait time, water and energy usage. However, do not use point-of-use hot water heaters on recirculating lines or at the far end of the water line.

Excluded from this discussion are shower heads required for emergency cleaning of personnel due to chemical and other contamination.

Faucets

A faucet is a device for delivering water from a plumbing system. It can consist of the following components: spout, handle(s), lift rod, cartridge, aerator, mixing chamber, and water inlets. When the handle is turned on, the valve opens and controls the water flow adjustment under any water or temperature condition. Outdoor hand-operated valves are known as hose bibs.

Hand-Washing Lavatories

Several types of faucets offer different flow durations and flow rates:

- Manually operated faucets require someone to open the valve and to close the valve
- Self-closing faucets run as long as the user holds the handle in the open position. Once released, the spring-loaded faucet closes itself
- Metering faucets are actuated manually or automatically. They deliver a preset amount of water (some models deliver 0.25 gallons during a 5- to 10-second cycle; other models have cycles that can be set to 45 seconds) before shutting off. Operating conditions, such as water pressure, temperature, and flow rate, may affect the timing cycle. Some manufacturers provide a 5-year warranty
- Automatic faucets sense the proximity of the user and start the flow of water, which is maintained while the user is within sensor range. Then the faucet shuts itself off
- Drinking-water bubblers operate with self-closing faucets

Aerators may be added to faucets to entrain air, reduce splash, and reduce the water flow. An aerator is a circular screen disk attached to the end of the faucet. Common aerator flow rates are:

- 0.5 gpm (for bathrooms)
- 1.0 gpm (for multi-purpose sinks)
- 1.5 gpm (for breakrooms)
- 2.0 gpm (for commercial kitchens)
- 2.2 gpm (for dish wash fill sinks)

Vandal- and tamper-proof aerators should be installed in non-residential buildings. Aerators with manual flow adjustment are available for kitchen faucets but the proper flow should be installed at each sink. We do not recommend aerators with manual flow adjustment. They require behavior modification which often is not followed, with the aerator often set at its maximum rate of flow.

An aerator separates a single flow of water into many tiny streams which introduces the air into the water flow. Because aerators entrain air which may contain pathogens into the water stream, and the pathogens may reside on the internal aerator screens, aerators should not be used in medical facilities. California regulations prohibit aerator use in hospitals, but laminar flow restrictors may be used to prevent splash and reduce flow without air entrainment. Other aerators should be replaced or at least cleaned every few years.

In high traffic areas (more than 100 uses per day) it is recommended aerators be replaced every 2 years.

Recommendations

Toilets and urinals

- Check flush diaphragms annually and replace flush diaphragms every 3-5 years, depending on traffic

Faucets

- Units with sensors should stop immediately after hands are removed from sensor area
- Units that use push valve activation should be calibrated to stop after 10 to 12 seconds run time
- For public faucets, anti-tampering or unremovable aerators are recommended. A special key is needed to install and remove them
- Medical facilities: Use laminar-flow faucets that use no more than 1.5 gpm

Bathtubs

- If there is a bathtub spigot present to regulate water temperature, once the shower is turned on there should be no water coming from the spigot. If water comes out, the diverter valve needs to be replaced
- Use low-volume tubs where possible

Resources

1. Appliance Standards Awareness Project 2021
   https://appliance-standards.org/product/faucets#:~:text=In%202015%2C%20the%20California%20Energy,maximum%20flow%20rate%20for%20private
2. California Building Standards Commission
   https://www.dgs.ca.gov/BSC/Codes
3. California Energy Commission, California Code of Regulations Title 20, Sections 1601 Through 1608, Toilets, Urinals, and Faucets Regulations Effective January 1, 2016.
4. California Energy Commission, Appliance Efficiency Regulations - Title 20
   https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20
5. California Green Building Standards Code—Part 11, Title 24, California Code of Regulations—known as CALGreen
   https://www.dgs.ca.gov/BSC/CALGreen
6. California Green Building Standards Code Chapter 5, Division 5.3
   https://codes.iccsafe.org/content/CAGBC2022P1/chapter-5-nonresidential-mandatory-measures#CAGBC2022P1_Ch05_SubCh5.3_Sec5.303
7. CalGreen Plumbing Fixture Requirements
   https://calgreenenergyservices.com/2019/11/30/calgreen-plumbing-fixture-requirements/
8. California Plumbing Code 2019
   https://up.codes/viewer/california/ca-plumbing-code-2019/chapter/4/plumbing-fixtures-and-fixture-fittings#411.0
9. John Koeller, P.E., Koeller & Company, Bill Gauley, P.Eng., Gauley Associates, Ltd., MaP Testing, Commercial Flushometers Toilet & Urinal List Downloads - May 4, 2021
   https://www.map-testing.com/downloads.html
10. National Conference of State Legislatures, Water-Efficient Plumbing Fixtures
    https://www.ncsl.org/research/environment-and-natural-resources/water-efficient-plumbing-fixtures635433474.aspx
11. Plumbing Supply.com, Showeroff® Metering Shower Systems
    https://www.plumbingsupply.com/metering-shower-systems.html
12. US EPA, WaterSense Commercial Toilets Specifications
    https://www.epa.gov/watersense/commercial-toilets#:~:text=WaterSense%20labeled%20flushometer%2Dvalve%20toilets,adequate%20flow%20to%20function%20effectively
13. US EPA, WaterSense, Case Studies for Commercial Buildings
    https://www.epa.gov/watersense/case-studies
14. US Department of Energy, Energy Cost Calculator for Urinals
    https://www.energy.gov/eere/femp/energy-cost-calculator-urinals#output

Chapter 5
METERING OF INDIVIDUAL UNITS

From a water management perspective, it makes sense to meter a facility's total water use and as many end uses of water as practical. This discussion focuses on the metering of individual dwelling units at commercial, mixed use, and multi-family properties. Submetering of individual end-uses such as tenant spaces allows businesses to evaluate their usage, address leaks, and make data-informed decisions about behavioral, equipment, or operational changes that could result in lower utility costs and water and energy usage. Business owners also often need to address changing regulations and business priorities and are increasingly focused on engaging in sustainable business practices that lower their environmental impact and support meeting sustainability certification requirements.

Submetering individual multi-family residences, commercial units, or water-intensive fixtures is beneficial to property managers and tenants for a variety of reasons:

- Commercial water damage is one of the most common and costly claims for businesses, yet it is a regular exception in insurance policies. Beyond the cost of the water itself, water damage can affect floors, walls, ceilings, equipment, and even foundations. Facility flooding can also damage electrical equipment or lead to environmental or safety hazards related to gray or black water damage and mold, which can result in operational downtime, repair costs, and lost revenue.
- Submeter and meter data can be integrated into a building management system, enabling the operator to track usage and quickly identify where there are water-related problems that need to be repaired. In some cases, leaks may occur under the building foundation or in non-obvious or observable locations.
- Submeters can be useful tools by allowing staff to isolate sections of mainline for further investigation by a leak detection company.
- Submetering also allows the property manager to benchmark water use across multiple properties and report savings to executive management to get buy-in for efficiency projects such as retrofitting shared water-using fixtures and targeting water-consuming buildings to incorporate best management practices. In many cases, energy use is directly tied to water usage, such as with hot water devices, and water waste may also cause energy waste. See Chapter 1, The True Cost of Water, for more information.
- Submetering individual units/spaces at business parks can result in better regulation of wastewater discharges that may not otherwise be detected. A lack of submetering may lead to unmonitored and unregulated wastewater discharges and lost discharge fees. Submetering individual occupants could eliminate or reduce these issues, especially if there is communication between the water provider and the wastewater authority.

Submetering Basics

A primary meter (also known as a "master meter") measures the total amount of water consumed by an entire property and is generally the meter a utility will use to bill water customers. While primary meters show total water use, they cannot indicate how much water is consumed by each building, unit, or water-using fixture that may be on one property, unless there is one primary meter for each unit or water-using fixture.

A "submeter" is a secondary meter, often a non-billing, third-party device purchased by an owner or site manager, that is installed downstream of a primary meter.

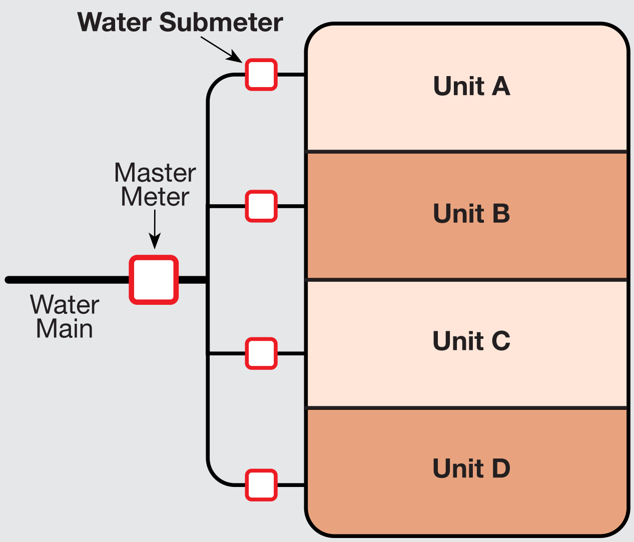
A submeter can provide more targeted water consumption information such as for:

- An individual unit within a multi-family residential structure
- An individual unit in a mixed-use residential or commercial structure
- A water-intensive fixture such as a pool, boiler, or cooling system

After installing a submeter, users may see a 10% - 20% reduction in water use due to easier identification and elimination of leaks that may otherwise go unchecked for extended periods of time.[1] EBMUD recommends using "smart" submeters that can log water use history, send alerts, or provide a remote dashboard. This water

1 Santa Clara Valley Water District (2007, April 13) ValleyWater.org
https://www.valleywater.org/sites/default/files/Water-Submeter-Results-for-manufactured-housing_SCVWD_2007.pdf

Figure 5-1: Water Submeter



The building illustrated has a primary meter ("master meter") that measures the total volume of water consumed by all units. Then, submeters measure the water consumed by each unit.

consumption information can be provided to end users in multiple ways. While utility-managed metering data is generally provided by the utility via bills or an online dashboard, users installing submeters will need to manage the submeter data in a way that best suits their specific needs..

Submetering Multifamily Tenants

There is a wide scope of residential developments that may want to submeter tenant water use. The list includes duplexes, condominiums, townhouses, mobile-home parks, and multi-unit apartments. Submetering, with billing based upon actual water use, is much more equitable for customers where water usage can vary significantly among tenants. Billing water use volumetrically can promote accountability in tenant water use, as well as accountability for managing shared water use such as landscapes, pools, and common spaces. Billing practices are regulated and certified by local authorities and state law; be sure to check with the local water utility prior to moving to volumetric billing.

A national study on submetering and allocation programs conducted in 2004 found 15% water savings[2] and 21% indoor energy savings associated with submetering by third-party billing entities (non-water providers) at existing multi-family buildings. At sites where the occupants also had some landscaping, such as condominiums, townhouses, and mobile-home parks, the water savings is estimated at 20%.[3]

For new developments submetering may be required by law. In California, SB-7 has required multi-family developments seeking water service to submeter tenants since January 1, 2018.[4] For those required to submeter tenants, we recommend installing systems that provide the end users convenient access to hourly or real-time water use information in their space, as well as the option to receive leak alerts.

Vendor-installed and managed submeter systems are increasingly common for multi-family and high-rise residential buildings. These systems are often offered as packages that include installing meters, maintaining meters, and billing customers. Some systems offer leak alert notifications and water consumption read outs installed in residential units. Submetering is often more cost effective, in terms of water savings, when unit occupants are also responsible for outdoor irrigation. If a central boiler is used, individual hot water meters may be required to measure hot water.

For existing buildings that are not submetered, the decision to submeter is typically determined by feasibility and the expense of installing submeters within the development's existing plumbing layout as well as applicable regulations. While retrofitting existing buildings can be expensive, the long-term costs associated with finding and repairing leaks and mismanaged water use can make a compelling case for investing in the upgrade. It is possible that some buildings may be relatively inexpensive to submeter, and some buildings may have been intentionally designed with submeter retrofits in mind.

In submetered developments there may be some water use that is considered 'common' use that typically benefits all users – such as landscapes, pools, laundry, or cooling systems. These water uses may or may not have their own direct submeter and are frequently accounted for by taking the total primary meter water use, and subtracting all metered tenant uses.

We recommend directly submetering the common use water sources, so that it is easier to understand how efficiently the common water use is being managed.

2 *https://calwep.org/wp-content/uploads/2021/03/Submetering-of-Multi-Family-Residential-Properties-PBMP-2005.pdf*
3 *https://www.ebmud.com/download_file/force/1310/809?submeter_report.pdf*
4 *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB7*

Submeter Selection

Developments experiencing difficulties dividing the water bill among tenants, frequent leaks, or other challenges controlling water (and wastewater) costs **are great candidates for submetering.**

It is very important to select the appropriate type and size of submeter for the uses occurring at the desired submetering location. Undersized water meters can cause excessive pressure loss, reduced flow, and noise. Oversized meters are not economical and do not accurately measure minimal flow rates.

> ***Work with the meter manufacturer to select an appropriately sized submeter.***

It is critical to understand both the buildings and individual units' size, function, fixture types, usage occupancy, and peak use to select an appropriately sized meter. These statistics determine the minimum and maximum flow rates and will assist in the selection of a properly sized water meter for each unit. A brief overview of different meter types is listed in Table 5-1 on the following pages.

For additional resources on meter selection, sizing, maintenance, and installation, see the References and Resource section below.

Recommendations

- → Meter individual units in new apartments, condominiums, townhouses, mobile-home parks, and mixed-use buildings of less than four stories
- → Submeter all tenant units/spaces individually, particularly those where any of the following applies:
- → When designing the plumbing system for a multi-family building, supply each unit with a single pipe source for the water to facilitate individual unit submetering.
    - Water consumption could exceed 500 gal/d (0.021 L/s) for that unit/tenant
    - Tenant space is occupied by a commercial laundry, cleaning operation, restaurant, food service, medical office, dental office, laboratory, beauty salon, or barbershop
    - Total building area exceeds 50,000 square feet (4,645 square meters)

TABLE 5-1. OVERVIEW OF DIFFERENT METER TYPES

METER TYPE	PROS	CONS	BEST USES
POSITIVE DISPLACE-MENT	• Usually lower cost • Have been in production many years • Less sensitive to upstream and downstream flow conditions	• Can be sensitive to orientation • Accuracy can diminish over time • Sensitive to water quality	• For small commercial or institutional applications
TURBINE	• High speed accuracy • Less pressure loss than PD meters • Easier function to explain to customers • Have been in production many years • Less sensitive to water quality	• Low speed inaccuracy • Sensitive to upstream and downstream flow conditions • Requires regular calibration	• Most appropriate for continuous, high-flow applications • Not usually recommended for commercial, institutional, or residential buildings because water flows are in constant fluctuation, with very low minimum flow rates such as from leaks
COMPOUND	• Accurate at both high and low range • Have been in production many years	• Low speed inaccuracy • Sensitive to upstream and downstream flow conditions • Sensitive to orientation Usually higher cost • Potential problems with crossover range between PD and Turbine elements • Often has two dials instead of one • Heavy and bulky size • Requires regular calibration	• Good choice for large commercial or institutional facilities

TABLE 5-1. OVERVIEW OF DIFFERENT METER TYPES (continued)

METER TYPE	PROS	CONS	BEST USES
STATIC	• Less frequent calibration requirements, if any • Higher range of accurate flowrates • Less head loss and less noise • Sometimes provide Pressure and Temperature • Compact design	• Limited by battery life if not replaceable battery • Past history of water intrusion in pit settings • May be more expensive than mechanical meters • “Black box,” difficult to explain function to some customers	
SINGLE/ MULTI-JET	• Easier function to explain to customers • Low flow accuracy • Compact design • Can be lower cost than PD and static • Multi-jet can work better with impurities in water • Some can be installed vertically	• Single jet can be sensitive to upstream and downstream flow conditions • Accuracy can diminish over time • Potential for overspin and startup error reducing accuracy with frequent starts and stops	

Resources

1. Aquacraft. (2004). National Multiple Family Submetering and Allocation Program Study, *https://aquacraft.com/downloads/study-of-impacts-of-sub-metering-on-multi-family-water-use/*
2. City of Austin, Texas. (1999, December 16(adopted)). "Installation of Water Meters," Section 2.3.3. Water and Wastewater Criteria Manual.
3. City of Austin, Texas. (2007, May 3). Water Conservation Task Force Water Conservation Strategies Policy Document, Recommendation IN-2, p. 10.
4. East Bay Municipal Utility District. (2006, September). Metering Program for New Non-Single Family Dwelling Units: Findings, Conclusions, and Recommendations.
5. Miami-Dade County Consumer Services Department. (1996). Miami-Dade County Water Remetering Ordinance, 96-137.
6. Texas Commission on Environmental Quality. (2005, April 13(adopted)). "Utility Submetering and Allocation," Utility Regulations, Chapter 291, Subchapter H.
7. Environmental Protection Agency. (2012, October). WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities. EPA.gov *https://www.epa.gov/sites/default/files/2017-02/documents/watersense-at-work_final_508c3.pdf*
8. Ibid. (2017, January 19). Resource Manual for Building WaterSense® Labeled New Homes. *https://19january2017snapshot.epa.gov/www3/watersense/docs/home_builder_resource_manual_v1.1_508.pdf*
9. Ibid. (2022, September). Improving Water Management Using Advanced Metering Infrastructure Data: A Guide for Facility Managers. EPA.gov, *https://www.epa.gov/watersense/advanced-metering-infrastructure*
10. Texas Water Development Board. (2018, May). Best Management Practices for Commercial and Institutional Water Users. twdb.texas.gov, *https://www.twdb.texas.gov/conservation/BMPs/CI/doc/Commercial%20&%20Institutional%20BMP%20Guidebook.pdf*
11. Greenest City Scholar Program, Chloe Sher. (2016, August 12). Water Submetering Promote Water Efficiency-A Survey of Existing Literature and Local Case Studies. UBC.com, *https://sustain.ubc.ca/about/resources/water-sub-metering-promote-water-efficiency*
12. Santa Clara Valley Water District. (2007, August 13). Water Submetering in Mobile Home Parks. ValleyWater.org, *https://www.valleywater.org/sites/default/files/Water-Submeter-Results-for-manufactured-housing_SCVWD_2007.pdf*

EBMUD Resources

13. New Meter Installation
https://www.ebmud.com/customers/new-meter-installation/
14. Multi-Family Study
https://www.ebmud.com/water/conservation-and-rebates/water-conservation-publications/multi-family-submetering-billing-allocation-study/
15. Indoor and Outdoor Requirements for new and expanded service
Water Efficiency Review - Indoor Water Use Requirements
Water Efficiency Review - Outdoor Water Use Requirements
16. Regulations Governing Water Service
https://www.ebmud.com/customers/new-meter-installation/regulations/regulations-governing-water-service/

Meter and Submeter Certification for Billing Purposes

17. National Certification
    https://www.ncwm.com/ntep-certificates
18. National Sanitation Foundation
    http://info.nsf.org/Certified/PwsComponents/Listings.asp?TradeName=meters&

California Resources

19. SB-7 2007 – 2016
    https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB7
20. Division Of Measurement Standards: California Type Evaluation Program
    https://www.cdfa.ca.gov/dms/programs/ctep/ctep.html
21. California Type Evaluation Program (CTEP) Certificates of Approval (COA) Database Search
    https://www.cdfa.ca.gov/dms/ctep.html

Bay Area Resources

22. Alameda County Weights and Measures
    https://www.acgov.org/cda/awm/
23. Contra Costa Weights and Measures
    https://www.contracosta.ca.gov/2205/Weights-Measures
24. City of Oakland
    https://www.oaklandca.gov/topics/state-regulations-for-water-metering-per-senate-bill-sb-7-for-multi-unit-structures

Meter Selection, Installation, Maintenance Resources

25. American Water Works Association, M6 Water Meters - Selection, Installation, Testing, And Maintenance, Fifth Edition
    https://engage.awwa.org/PersonifyEbusiness/Store/Product-Details/productid/39311822
26. American Water Works Association, M22 Sizing Water Service Lines and Meters, Third Edition
    https://engage.awwa.org/PersonifyEbusiness/Store/Product-Details/productId/47430593
27. 2021 International Green Construction Code® (IgCC®)
    https://shop.iccsafe.org/international-codes/2021-international-green-construction-coder-igccr.html
28. LEED Guide to Water Metering (2020)
    https://www.usgbc.org/resources/leed-guide-water-metering
29. U.S. Department of Energy, Water Metering Best Practices (2022)
    https://www.osti.gov/biblio/1866391/
30. Resource Manual for Building WaterSense® Labeled New Homes (2014)
    https://www.epa.gov/sites/default/files/2017-01/documents/ws-homes-builder-resource-manual.pdf

Chapter 6
PROCESS WATER

Water used in commercial or industrial operations to manufacture a product is known as "process water." Much of the information in this chapter is specific to certain products or industries. However, on the whole, increasing water conservation in industrial processes can range from simply adjusting equipment or behaviors to use less water, to adopting entirely new practices or processes that use little to no water at all.

Beverage bottling plant conveyor belt in action

This section discusses the following industries and their uses of process water:

- Food and beverages, page 41
- Auto repair and service, page 47
- Paper manufacturing, page 48
- Metal finishing, page 50

This chapter will not cover opportunities to save water by using efficient plumbing fixtures [link to chapter] and irrigation systems [link to chapter], since these are covered elsewhere.

General Discussion

All industrial operations use water in a wide variety of ways. However, the opportunities to reduce water use in any operation can be analyzed by using the following ranking of possible measures. All will result in water savings, but savings are increased as one moves down the list.

Ranking of Possible Measures

Good

1. Adjust equipment
2. Modify equipment or install water saving devices
3. Replace with more efficient equipment
4. Water reuse/recycle
5. Change to waterless process

Best

Site Assessment

There are seven basic questions to ask about how water is used in any industrial operation. The purpose of these questions is to stimulate the water reduction thought process:

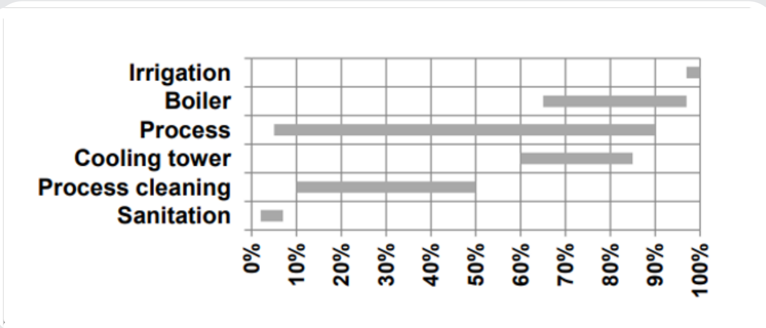
1. **How much?** Water needs to be measured to be properly managed
2. **Where is it being used?** What processes are using water
3. **When is it being used?** Pay attention to "off-hours" flows
4. **Why is it being used?** What is the purpose of the water usage
5. **Who is in charge?** Who is responsible for the design and control of water use
6. **Is there another way?** Can any process needs be met with less or no water

It is also important to distinguish between water use, water consumption, and return flow:

- **Use** means the total water purchased or withdrawn from a fresh or saline body of water or from a well
- **Consumption** refers to water that is included in the product, evaporated, or otherwise not returned as an effluent from the facility
- **Return flow** refers to water that is returned to either a wastewater facility or made available for additional reuse by another entity such as a farm for crop irrigation.

The following figure shows that the amount of water consumed in various types of industrial and commercial operations can vary considerably:

Figure 6-1: Range of Consumptive Use in Industrial Operations



Source: HW (Bill) Hoffman & Associates, LLC – independent research.

Industrial uses of water in manufacturing or building maintenance processes can vary significantly, but generally fall into the following categories:

1. Manufacturing process
   a. Inclusion in product
   b. Equipment cleaning
   c. Process cooling
2. Refrigeration cooling
3. Employee sanitation
4. Air pollution/dust control
5. Area wash-down
6. Miscellaneous uses

Figure 6-2: Typical Industrial Water Use Breakdown

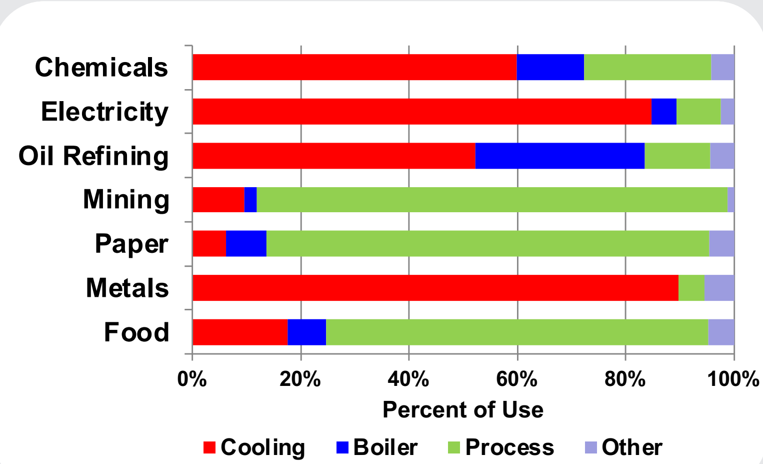


Figure 6-2 shows how water has historically been used in industrial settings. Cooling water, boiler water and process water are the major uses.

Water savings considerations for the industrial operations listed above will be discussed in detail. Two case studies are described here; in many cases, implementing measures like these can have almost instantaneous payback.

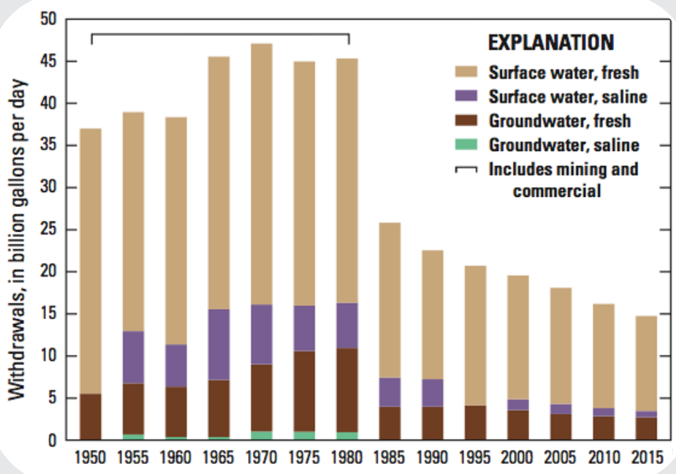
- A simple example is from a factory manufacturing windshield wiper blades. One of the manufacturing steps included running the rubber through a strong chorine solution. This process involved a makeup water flow of eight gallons per minute to the process tank. To remove chlorine fumes generated from this process tank, a flow of approximately eight additional gallons per minute was needed. By using the scrubber water from chlorine fume removal as the makeup water for the process tank, the facility cut water use in half at almost zero cost to implement.
- Another major water user is single pass cooling water for pumps. A brewing operation in EBMUD's service area, Drakes Brewing Company, previously used a vacuum pump on their bottling line that required water for cooling. After hearing about the EBMUD rebate for engineered water reduction solutions, Drake's created a closed loop cooling system. The new system reduced water for that particular process by 99% and reduced overall usage in that department by 38%. *Info provided by Hal McConnellogue of Drake's.*

Beginning with the US Environmental Protection Agency Clean Water Act in 1970's, industrial water use has been dropping steadily despite manufacturing increasing or remaining constant.[1] The first major decrease in water use was due to the new requirements for industry to treat wastewater to acceptable limits. Further reductions have been the result of higher water costs and other factors encouraging more efficient water use.

The cost of water has also been increasing faster that the consumer price index and the cost of energy. These cost increases have also been a driving factor in the reduction in industrial water use.

1 *https://www.macrotrends.net/2583/industrial-production-historical-chart*

Figure 6-3: Self-Supplied Industrial



Source: *https://www.usgs.gov/media/images/self-supplied-industrial-withdrawals-1950-2015*

Technological Advances

There have been many recent technological advances allowing CII users to decrease their process water use. Three of these advances are internal recirculation and reuse, zero liquid discharge processes, and process control and monitoring

- **Internal recirculation and reuse** – One of the most cost-effective ways to reduce water and wastewater costs. For more details, please see [link to Alternative On-Site chapter]. Some examples of on-site sources of water for reuse include:
  - Air conditioner condensate
  - Air pollution scrubber water
    Cooling tower blowdown
  - Equipment wash water
  - Foundation drain water
  - Graywater
  - On-site treated wastewater systems
  - Process water
  - Rainwater harvesting
  - Reverse osmosis (RO) and Nanofiltration (NF) reject water
  - Stormwater harvesting
  - Swimming pool filter backwash water
- **Process control & monitoring** – Improved process control and monitoring has allowed significant reduction in water that once was wasted due to lack monitoring data. One example is in the operation of cooling towers. Conductivity and pH controllers, as well as flowmeters on the make-up and blowdown lines, allow for fine control of water chemistry and usage. Wifi-enabled models and a data aggregation platform are recommended in tandem for ease of monitoring, setting up alerts, and more. Prior to the wide usage of these technologies, water quality testing and water use tracking was less frequent. This resulted in cooling tower chemistry being programmed for a "worst case scenario" setting of the cycles of concentration, or in the case of an equipment malfunction such as a stuck float valve.
- **Zero Liquid Discharge** – Most commonly used in wastewater processing, this practice recovers all wastewater and concentrates dissolved minerals and chemicals to be recovered in a solid form. This method offers significant reduction in other wastes since much of the solids recovered have a marketable value. However, these systems can be energy intensive and come with a hefty price tag.[2]

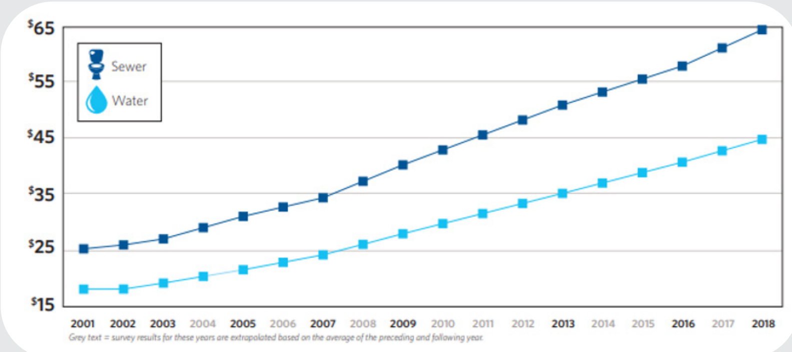
Food and Beverage Processing

Before beginning this discussion of water conservation in food processing, one should remember that health and sanitation are overriding concerns. All actions to reduce water use must be measured against this primary consideration. The food and beverage processing industry includes a wide range of products and manufacturing processes:

- Bakery/pastry shops
- Breweries
- Canneries
- Dairy food processors
- Frozen food producers
- Grocery stores and restaurants that produce food products for sale
- Industrial bakeries
- Meat, fish, and poultry processing
- Snack food manufacturers
- Soft drink and juice manufacturers
- Wineries

2 *https://pubs.acs.org/doi/10.1021/acs.est.6b01000*

Figure 6-4: Average Industrial Water and Sewer Costs per Month (10 Million Gallons)



Source: *https://webassets.bv.com/2019-10/50_Largest_Cities_Rate_Survey_2018_2019_Report.pdf*

For each manufacturing process, it is important to consider all instances of water use throughout to identify savings opportunities. The quality and purity of the water is of primary concern since it is used to make products that will be consumed. In addition to being a key production ingredient, water is also used to clean and sanitize floors, processing equipment, containers, vessels, and raw food products prior to their processing. Hot water, steam, cooling, and refrigeration also require source water.

Designing and building a food and beverage processing facility that has a reduced requirement for water includes:

1. Designing the facility for ease of cleaning
2. Providing adequate metering, submetering, and process control
3. Taking advantage of dry methods for cleanup and transport
4. Using product- and byproduct-recovery systems
5. Incorporating water reuse and recycling
6. Designing for minimal or no water use

End-Use Example: Soft Drink Manufacturing

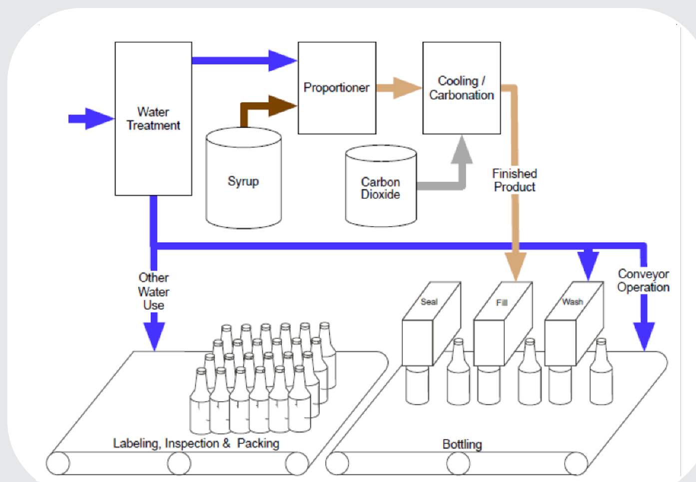
Because of the complicated and highly varied nature of the food and beverage manufacturing industry, providing a simple guide to water efficiency that covers all types of facilities is not possible. This section will instead use soft drink manufacturing as a general example; much of the advice herein can also be applied to other types of processes.

The following example illustrates ways water can be used in the soft drink industry. Potable water is first treated to soften it and, if needed, to remove additional minerals. It is chilled and blended with flavorings and sweeteners, then carbonated. Cans or bottles are filled and sealed, then rinsed and sent through a warming bath to avoid creating condensate in the open air and ensure they are dry before packing.

The major water using processes in soft drink creation are:

- Water softening, which requires periodic filter backwash
- Water included in the product
- Water to clean and rinse cans
- Water to warm cans after processing
- Water sprayed on the conveyor line as a lubricant
- Water to operate cooling towers for refrigeration equipment and boilers for heat
- Water to sanitize and clean the plant and vessels
- Water for employee sanitation, irrigation, etc.

Figure 6-5: Carbonated Soft Drink Manufacturing



Source: *https://www.usgs.gov/media/images/self-supplied-industrial-withdrawals-1950-2015*

Major Water Using Activities

Top water intensive processes in the food and beverage manufacturing sector are described below, along with examples from specific industries where appropriate.

Cleaning and Sanitation

Information on floor cleaning and the cleaning of outdoor areas is found in all sectors [link "Food Service" chapter]. Dry cleanup, preventing spills by controlling processing equipment and leaks, and proper storage and handling of ingredients all reduce water needed for cleaning

For example, breweries are one type of beverage manufacturing that use a large percentage of their total water for various cleaning processes. The Brewers Association, which publishes benchmarking data from craft breweries of all sizes, shows that breweries use, at best, 25% of their total water usage for the product.[3] A brewing company in EBMUD's service area, Drake's Brewing, uses 20% and even smaller breweries only use 6-13%, with the lion's share of water use dedicated instead to cleaning and related processes.

Brewery tanks

Two solutions for water use reduction in brewery cleaning is burst rinsing, a type of Clean In Place (CIP) methodology, and metered rinsing.[4] Burst rinsing includes an initial water rinse, followed by a series of caustic and acid washes, an intermediate water rinse, and a final hot water or sanitizer disinfection rinse. If multiple tanks are present, the acid and caustic washes can also be reused.[5] Metered rinsing involves using mechanical or electric timers to start and stop rinsing procedures to eliminate behavioral bad practices.

Thermodynamic Processes

Another common use of water is in the production of steam and hot water. Steam sterilization and pasteurization are most common examples of these thermodynamic processes. Metering and submetering [See Chapter 5] are important in understanding how much water is used in each process or type of equipment. Proper process controls are essential to managing water and energy use.

Transportation and Cleaning of Food Products

Some food processing facilities will use flumes (open channels or chutes carrying a stream of water) to transport and clean produce. Water is also used in the cleaning and processing of meat, poultry, and fish. Common water conservation techniques begin with reducing water use by:

- Recycling transport water
- Adjusting design of flumes to minimize water use
- Using flumes with parabolic cross sections
- Providing surge tanks to avoid water loss
- Including float control valves on makeup lines
- Installing solenoid valves to shut off water when equipment stops
- Using vibration and air to help clear fruit and vegetables of debris and dirt before fluming or washing
- Can cooling water for first flush
- Installing electronic monitoring equipment to manage the process
- Installing systems to treat and reuse water

All these techniques can reduce the need for water, but changing the process has even more potential:

- Replace fluming with conveyor belts, pneumatic systems, or other dry techniques to move food products
- Install sprays to wash food
- Use mechanical disks and brushes
- Install counter-flow washing systems
- Control sprays on belts
- Control process equipment to reduce waste

3 https://www.brewersassociation.org/the-new-brewer/jan-feb-2020/
4 https://www.brewersassociation.org/seminars/clean-up-your-act-safe-cip-practices/
5 https://brewerycleaners.com/wp-content/uploads/2019/02/CleaningSystemForBreweries.pdf

Larger equipment that cannot be disassembled easily must be cleaned in place. A clean-in-place (CIP) system allows such large equipment to be sanitized while also carefully controlling the facility's water and chemical use.

Grocery stores and smaller bakeries should follow good food service sector washing practices for meats, fruits, vegetables, and other food products before final packaging. Further, ensure that all water using process equipment has proper level and flow controls.[6]

As an example, a Minnesota vegetable-processing firm reduced water use for conveying corn by 20 percent, or 1,000 gpd, just by employing proper controls and recycling 20 percent of the water in the flumes.[7]

Equipment Cleaning

Equipment to be cleaned ranges from large process facilities and equipment to the hand-held equipment and cooking utensils found in smaller bakeries and grocery stores. Smaller utensils should be washed following the ware-washing considerations found in Chapter 9, Food Service Operations.

Choices of procedures for cleaning equipment can yield multiple advantages include:

- Product recovery
- Reduced wastewater loading
- Reduced water use
- Reduced chemical use
- Reduced energy use

Good design and layout of equipment are essential to easy cleaning:

- Design equipment that minimizes spills, leaks, and residual product that must be removed before cleaning
- For closed systems such as tanks and piping, eliminate "low spots" so equipment can easily and completely drain
- Provide easy access to all areas of the equipment that must be cleaned
- Select materials and surfaces that are easily cleaned
- Change procedures to reduce the need for cleaning

CIP methods range from flooding the equipment with hot water, detergent, and chemicals, to dry cleaning. Dry cleaning as a first step is essential for saving water, since it reduces the water needed in the wet cleaning phase, sometimes eliminating it completely. Dry cleaning includes:

- Removing and storing as much otherwise-wasted product as possible
- Scraping equipment and vessels to remove as much waste as possible
- Using dry brushes, cloths, and paper towels to remove waste
- Using wet towels

Dry cleaning can be labor intensive, but the labor costs are offset by the potential to recover product, reduce pollution loading, and potentially clean equipment more thoroughly. It also allows employees to closely examine equipment and discover possible mechanical problems at an early stage.

For open equipment such as mixers, extrusion and molding equipment, or conveyor belts, cleaning should start with the physical removal of residual materials and then be followed by wet washing. Install and locate drains and sumps so water and wastes enter quickly to prevent the use of a hose as a broom. Four water efficient principles of wet cleaning are:

- Use targeted small volumes of water, instead of one large volume at once
- Use high pressure, low volume sprays
- Install shutoffs on all cleaning equipment
- Use detergents and sanitizing chemicals that are easily removed with minimal water use

For closed vessels like pipes and delivery tubs, cleaning

---

6 Costello, Jim. Spring 2001. "Brewing Up Prevention Ideas." Newsletter. University of Minnesota Technical Assistance Program.

7 North Carolina Department of Environment and Natural Resources, Division of Pollution Prevention. August 1998. Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.

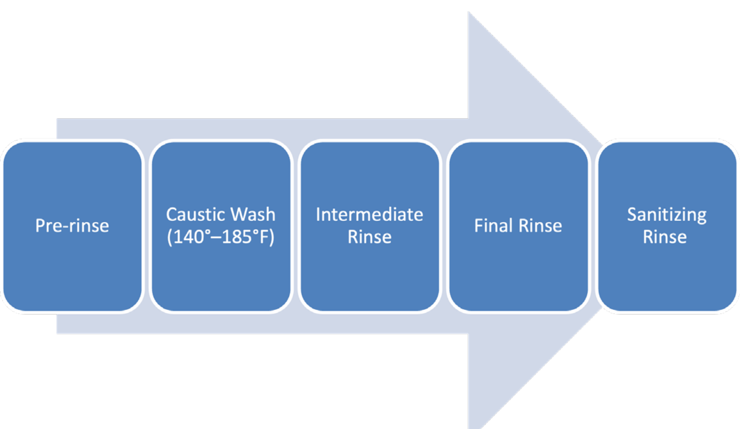
techniques are very different. They require "Clean in Place" (CIP) and "Sanitize in Place" (SIP) methods. Before cleaning a process piping system, it is essential to remove as much of the product as possible. At its simplest, this involves draining the tank or piping system. Designing the piping to eliminate low spots that can trap product is a major aid in this process. Following this, several methods can be employed to remove extra product and clean the vessel and piping. For piping, three methods find common use, including:

- Slug rinsing
- Air blowing
- Pigging

A medium sized bakery in Minnesota used 65 to 100 buckets a day for storing icing. Washing these buckets required approximately three hours of labor each day, and icing that stuck to the bottom and sides was wasted. **The bakery replaced the one-bucket-at-a-time preparation method with a large vat.** This reduced the number of containers that had to be washed to three large vats which in turn **reduced washing time from three hours a day to a few minutes,** thus saving water.[8]

***Pigging* is a process in which a flexible rubber or plastic projectile is forced through a pipe to push the product out. In Europe a technique using "ice pigging" has recently been developed that uses ice slurry. The pig is forced through the pipe with air, water, or cleaning fluids. CIP systems can also be designed to reuse water and chemicals, if product safety allows.**

Clean-in-place (CIP) systems are found throughout the food and beverage industry. As an example, dairy processing facilities typically use a five-step process as outlined below:



CIP Equipment at a Dairy Processing Facility

Image source: HW (Bill) Hoffman & Associates, LLC

Water is cascaded from one type of wash or rinse to the next phase. For example, caustic wash water which also contains detergents is used for pre-rinse water, the intermediate rinse water is used to make up the caustic wash water, the final rinse water can be used for the intermediate rinse, etc. Final rinse water is always very clean water, potable water or in some cases water that has been treated with reverse osmosis. As this shows, CIP water is used many times in the process, thus conserving water.

For vessels, a ball that sprays water in all directions has historically been employed for washing. Replacing that with a high-pressure, low volume rotating spray that washes product down the sides can reduce the amount of water needed. In many cases, this dilute first rinse can be captured and product recovered. In the dairy industry, pasteurization tanks must be filled with hot water after cleaning to pre-pasteurize the vessels. This water is often captured and reused as wash water for other CIP needs, thus saving both water and energy, since the water is already hot.

8 http://www.mntap.umn.edu/wp-content/uploads/simple-file-list/Water/Water-Conservation-Tips.pdf

Vessel, barrel, and cask-cleaning water can also be used for irrigation in the wine industry and, to some extent, in the brewing and vegetable and fruit processing industries. The use of this water for irrigation also removes solids and biological oxygen demand from the waste stream and places it where it can be an asset to growing plant material.

Container (Bottles, Cans, Cartons, etc.) Cleaning

Cleaning bottles, cans, and containers prior to filling is common throughout the food and beverage industry. For returnable bottles, the use of air bursts to remove lose debris and materials and the reuse of water from can warming and other operations are common ways to reduce water use. Other methods include use of pressure sprays and steam instead of high volumes of hot water to clean containers.

One brewery recovered the bottle wash water and used it for washing the crates in which the bottles are placed. This saved more than 4,500 gallons of water a day (Hagler).

Cleaning cans, bottles, and containers after they have been filled offers other opportunities. Some spillage and overfilling are inevitable, but with proper equipment control this can be minimized. Reducing water use to a minimum and passing the wash water through nanofiltration can recover both the sugars and product for use as animal feed or for growing yeast, while the water is cleaned and made available for additional reuse.

Additional water savings techniques:

- Reuse pump seal wastewater or other available sources for washing crates and pallets
- Use self-closing valves and automatic sensors to only allow sprays when items are passing spray nozzle
- Use ozone as a sanitizing agent instead of steam or hot water

Lubricating Can and Bottle Conveyor Belts

One of the most unusual uses of water in the food and beverage industry is as a lubricant for conveyor belts that move cans and bottles, so they can “slip” easily on the high-speed conveyor belts and not tip over. This water is softened and mixed with biocides and soaps before it is sprayed onto the conveyors. Many attempts have been made to use dry lubrication systems or find other ways to move the cans and bottles at the high speeds needed in modern operations, but the use of water as a lubricant remains the standard for the industry. Many have been able to reduce water use or even capture and recover belt lubricant water. In Australia, eight Cadbury Schweppes plants tested dry lubricant conveyor systems[9]. For now, ensuring that the spray nozzles are properly sized, well aligned, and equipped with automatic shutoffs is the best that can be done.

Beverage Bottling Plant Conveyor Belt in Action

Can and Bottle Warming and Cooling

Water is often used in cooling or heating cans as a heat-transfer agent. This water remains relatively clean and is an excellent source of water for reuse. Water is used to cool cans after they have been removed from pressure cookers in the canning process. In most cases this water is cooled in a cooling tower or a refrigeration unit that employs a cooling tower in the process.

In the warming process, cans and bottles that have been filled with cold liquids are heated so condensate does not form on them, and they dry more quickly before packing. These operations offer significant opportunities for reuse for almost all the other water needs in the operation, except where potable quality is required by regulation. Please see [Alternate On-Site Water chapter] for more details.

9 https://water360.com.au/wp-content/uploads/2022/10/1132-installation-of-waterless-conveyer-technology-final-report.pdf

Recommendations

- Require that new facilities provide a list of possible areas of water recovery and reuse
- Require that all major water-using areas be separately metered
- Consider using telemetry to track real-time usage
- Require automatic shutoff and solenoid valves on all hoses and water-using equipment, where applicable
- Incorporate routine inspection for leaks, identification of leaks and leak repair in normal operation
- Monitor daily water use to track unexplained increases in use.
- Use low volume high pressure cleaning
- Develop a procedure for facilities to self-audit
- Use pigging (using mechanical devices to perform pipeline or tubing maintenance operations), air blowing, or slug washing as part of CIP systems for process pipes
- Use floor cleaning and vacuum machines where possible
- Minimize the use of water-lubricated conveyor belts
- Minimize the need to use a hose as a broom by installing drains close to areas where liquid discharges are expected
- Provide pressure-washing equipment in place of washdown hoses
- Utilize reverse osmosis and nanofiltration to increase water reuse
- Engage employees in water conservation efforts and audits
- Use vibration and air to help remove dirt and debris prior to washing

Design principles

- Design the facility for ease of cleaning
- Provide adequate metering, submetering, and process control
- Take advantage of dry methods for cleanup and transport
- Use product and byproduct recovery systems
- Incorporate water reuse and recycling
- Design for minimal or no water use

Automotive Services

The automotive service and repair industry is one of the most ubiquitous types of commercial enterprises in any city. Establishments include:

- Service stations
- Oil change/lubrication
- Body repair
- Tune-up shops
- Full-service repair shops
- Fleet maintenance
- Tire service

The design of a water efficient shop depends to some extent upon the type of service offered. New air quality regulations[10] have also meant that shops have switched from solvent based parts and brake cleaning systems to aqueous based systems. Floor cleaning with dry methods, preventing spills and leaks from entering the wastewater discharge system, and the proper design of oil separators have as much to do with pollution prevention as they do with water conservation.

Three areas of operation offer both reduced water use and pollution loading possibilities:

- Proper design of aqueous parts and brake cleaning
- Pollution prevention and water use reduction in shop floor cleaning
- Proper handling of spent fluids and oils

Aqueous Cleaning Equipment

The development of aqueous parts and brake cleaning equipment has been driven by air quality requirements. Such systems can employ filtration for sludge removal and oil skimming. By filter cleaning water used during this cleaning process, it can be recycled, thus saving on total water use.

Floor Cleaning

Keeping floors clean in the first place reduces the need for frequent washing.

- Install secondary containers under fluids-storage containers to catch leaks and using drip plans under vehicles being worked on
- Use dry cleanup with hydrophobic mops for oil and using absorbent materials (kitty litter, rice hulls,

10 *https://ww2.arb.ca.gov/sites/default/files/classic/technology-clearinghouse/rules/RuleID276.pdf*
https://www.baaqmd.gov/~/media/files/compliance-and-enforcement/tips-and-faq/compliancetips_reg8_16_102104.pdf

Table 6-1: Virgin Fiber vs Recycled Copy Paper

	1 Ton Virgin Fiber Paper	1 Ton 100% Recycled Paper	Environmental Savings from Recycled Content
Trees	24 trees	0 trees	100%
Energy	33 million BTUs	22 million BTUs	33%
GHG released - CO2 equivalent	5,601 lbs	3,533 lbs	37%
Wastewater	22,853 gal	11635 gal	49%
Solid waste	1,922 lbs	1,171 lbs	39%

Source: Pulp and paper mills have significant recycling of process water opportunities, https://samcotech.com/reduce-water-usage-in-pulp-and-paper-industry/

pads, rags, pillows, and mats) to clean up spills

- Seal floors with an epoxy material, which significantly aids in cleanup and prevents oils and liquids from penetrating concrete floors
- Provide floor cleaning equipment that scrubs and vacuums up its own water
- Eliminate the use of open hoses for cleanup and using pressure-washing equipment infrequently and for major cleanup events only
- Mark drains clearly to ensure that floor drains are clearly differentiated from storm drains and all floor drains are connected to an oil separator

Handling of Spent Fluids

Recovery and recycling of radiator flush water both saves water and reduces pollution loading. Using storage vessels designed to hold spent antifreeze and other fluids, such as oil and transmission fluid, both eliminates the need to clean and flush these fluids down a drain and is required as part of modern pollution control methods. Water use in facilities that recycle radiator flush water has been shown to be less than 10 percent of water use in non-recycling facilities (San Antonio Water System).

Recommendations

- Require new facilities to provide secondary containers to catch drips, leaks, and spills from stored liquids and solvents
- Require shop floors to be sealed to ensure easy cleanup
- Require automatic shutoff and solenoid valves on all hoses and water-using equipment, where applicable
- Require aqueous parts- and brake-cleaning equipment to employ recirculating filtration to minimize the need to dump water
- Require all drains to be properly identified
- Have proper facilities for the capture, storage, and recycling of spent fluids, oils, and fuels, including antifreeze and radiator flush-water
- Have pressure-washing equipment available
- Have drip pans available at workstations to place under vehicles

Paper Manufacturing

Paper manufacturing ranges from making paper from trees to manufacturing converted paper products, such as paper containers, cups, boxes, bags, coated paper, envelopes, and stationery products. The focus of this discussion is the creation of paper products.

Producing paper from pulpwood or other fiber sources is the first step in the process. It is also the most water and energy intensive stage in the life of a paper product.

An average of six gallons of water are used to make one pound of paper.[11]

11 https://www.sierraclub.org/sierra/2015-1-january-february/ask-mr-green/hey-mr-green-what-about-all-water-it-takes-make-paper

Paper and Pulp Mill

Recycling paper and cardboard products cuts this energy and water use in half.[12] According to Conservatree, an organization that promotes paper recycling, most repulping for recycled paper is done at pulp and paper mills, or in special facilities that manufacture products such as cellulose insulation or pulp products such as egg cartons.

Pulp and paper mills use mixture of virgin and recycled pulp, the latter of which is rapidly becoming the most common source of paper and cardboard stock for commercial converted products. Most paper pulp is destined for the printing industry (California EPA). Examples of finished products include cardboard tubes, roofing paper, corrugated boxes, paper bags, tissue and toweling, folded boxes, cellulose padding, stationery and envelopes, and paper cups and liquid containers.

During the initial manufacturing process, wood pulp is suspended in water. Depending on the end use of the pulp, bleaching and further refining processes can occur. These processes produce a wastewater that must be treated. The pulp is then washed several times to remove lignin and other products from the wood as well as pulping chemicals. Many water recovery processes are available to the pulp and paper industry, from conventional physical and chemical treatment to membrane biological reactors and reverse osmosis systems

Sourcing recycled paper eliminates the water and energy intensive raw material pulping stage of the production process. During paper recycling, scrap paper is shredded and put into a hydro-pulper. The pulp is washed to remove ink and dirt and then remade into new paper products. A 2012 publication, Paperwork: Comparing Recycled to Virgin Paper, provides a detailed comparison of resources used to produce virgin and recycled paper.

The manufacture of products from recycled paper, cardboard stock, or dry pulp represents the types of paper manufacturing operations found in most urban areas, which most commonly involve:

- Cutting and folding
- Gluing
- Coating
- Printing

Cutting and folding, along with the handling of paper stock and products, is principally a dry process. Floor cleaning should follow principles outlined in the section on Cleaning and Sanitation. The last three of these operations involve wet or solvent cleaning of some type. The advent of water-soluble paints and inks has reduced volatile-organic-compound (VOC) emissions, but the use of water as a cleaning agent is more prevalent. The same principles used in cleaning equipment in the food and beverage processing industry apply here, with the addition of solvent cleaning, which is still used in many non-aqueous printing processes.

Recommendations

Manufacturing of Recycled-paper Products

- Properly remove as much waste product as possible by pouring and storing for future use
- Scrape equipment and vessels to remove as much waste as possible
- Use dry brushes, cloths, and paper towels to remove waste
- Use wet towels or solvent-soaked towels
- Apply water or solvent only to areas to be cleaned

12 *https://www.stopwaste.org/sites/default/files/Documents/1030136122004paperfactsheet.pdf*

Printing Operations (including flexography, gravure, screen-printing, lithography, and digital processing)

- Design the layout of equipment for easy access
- Ensure that ink containers are easily sealed
- Provide non-drying aerosol sprays to keep ink fountains from drying overnight
- Ensure that presses have proper controls, such as automatic ink levelers

Metal Finishing

The metal finishing industry offers many opportunities to reduce both water use and pollution abatement costs. The plating and anodizing processes involve a multi tank, multi-step process. Water saving practices include:

- Drag-out control
- Good tank design
- Efficient rinse practices
- Process controls and meters
- Chemical recovery
- Good exhaust-hood design

As with all industrial and commercial operations, efficient cleaning methods are key practices that will result in reduced water use.

Description of End Use

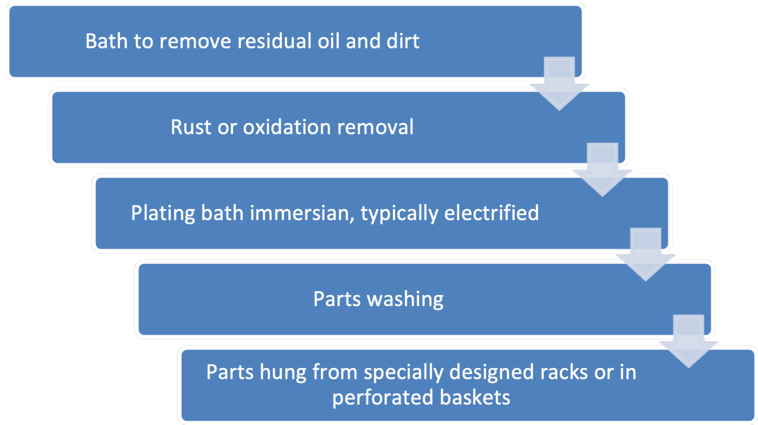
The classic example for the metal-finishing industry was once the plating of car bumpers (when chrome car bumpers were still manufactured). In the present-day, chrome, zinc, copper, tin, nickel, gold, and silver are among the more common metals plated onto objects. In some processes objects are plated with two layers of metals, such as an under layer of copper followed by chrome.

In one common process, parts to be plated are moved sequentially from a treatment tank to a rinse or wash tank to another treatment tank to another rinse tank, until the desired number of plating steps have been accomplished.

Water is used for the following process purposes:

- Chemical and plating solution make-up
- Rinsing
- Fume-hood scrubbing
- Equipment cleaning

Typical Metal Plating Sequence



As chemicals from one step build up in the following rinsing tanks or contaminate the process chemicals, water must be replaced. Fumes produced from all the tanks, and the acid (pickling) and plating processes in particular, must be safely removed with fume hoods which then pass this contaminated air to scrubber systems to prevent air pollution.

Recommendations

Drag-out control (Tank-to-tank liquid recovery)

- Design racks, baskets, and barrels so parts drain and do not retain liquids
- Use sprays in place of dipping parts
- Use turning, tilting, and "bumping" to remove excess liquid
- Using air knifes, fogs or misting to remove solution
- Use drip or drain boards to collect and drain liquids back into the source tank
- Install drip guards between tanks
- Allow parts to remain over the tank for a few seconds (dwell time)
- Vibrate parts to knock liquid off
- Ensure parts are pointed down for efficient drainage
- Wash or blow contaminants back into process or dead tanks using fogs, sprays, or air knives
- Use wetting agents
    - Using chemicals or heat to reduce plating-solution viscosity
- Operate the solutions at minimum possible concentration

Tank Design Methods
(Good design reduces water use or allows for better reuse and recovery of metals)

- Use air or mechanical agitation to promote mixing and good contact
- Hard plumb all piping so hoses cannot be left on inadvertently
- Prevent short-circuiting of fluids
- Size tanks to the minimum for the pieces to be plated
- Segregate waste streams so both metals and water can be recovered more easily

Rinsing Methods
(Efficient rinsing saves water and chemicals, and reduces associated wastewater costs)

- Use sprays on flat pieces of metal
- Employ counter-current rinsing, where the piece is rinsed in successively less concentrated tanks, with the water from the first tank being used as feed for the second, and so on
- Employ reactive rinsing, where the rinse water from the final tank is used for the pickle-rinse tank and the pickle-rinse tank water is used as feed to make up the alkaline-rinse tank (see figure following)
- Use air agitation in the tanks

Flow and Process Control

- Install conductivity controllers to discharge water only if the chemicals have become too concentrated
- Meter makeup water for good process control and to identify problems
- Use flow restrictors to limit the amount of water being added

Chemical and Water Recovery

- Filter plating fluid to remove suspended matter
- Use membrane technology to recover metals and water
- Use reverse osmosis (RO) or deionization for the feed water for both rinse and process-fluid tanks to reduce interference from other ions
- Regenerate spent acids
- Use RO-reject water for cleanup around, but not in, the tanks

Exhaust Hood Design

- Recirculate scrubber liquid
- Use scrubber water above plating tanks as make-up water for that process
- Use RO-reject water or similar reject streams as make-up water for scrubbers for which scrubber effluent will not be reused

Resources

Food and Beverage Processing

1. A&B Processing Systems (201 South Wisconsin Ave, Stratford, Wisconsin). A Guide to Clean In Place (CIP), *https://www.jbtc.com/foodtech/wp-content/uploads/sites/2/2021/09/Product-Recovery-Systems.pdf*
2. Aquacraft, Inc. for the California Department of Water Resources and U.S. Bureau of Reclamation. 2003. Demonstration of Water Conservation Opportunities in Urban Supermarkets.
3. Carawan, Roy E. Liquid Assets for Your Bakery. March 1966. North Carolina Cooperative Extension Service Publication No. CD-41.
4. Commonwealth of Pennsylvania. Department of Environmental Protection. Water Conservation Ideas for the Beverage Industry.
5. Costello, Jim. Spring 2001. "Brewing Up Prevention Ideas." Newsletter. University of Minnesota Technical Assistance Program.
6. Encyclopedia Britannica. "Carbonated Soft-Drink Manufacturing", *https://www.britannica.com/topic/soft-drink#ref66703*
7. Environmental Technology Best Practices Program. Reducing the Cost of Cleaning in the Food and Drink Industry. Report No. GG 157. *https://p2infohouse.org/ref/23/22916.pdf*
8. GDS Associates, Chris Brown Consulting, Axiom-Blair Engineering, Inc., Tony Gregg, PE. 2004. Water Conservation Best Management Practices Guide. Texas Water Development Board. Austin, Texas.
9. Galitsky, Christian. 2004. Best Winery: An Integrated Benchmarking and Energy and Water Management Tool. Lawrence Berkeley National Laboratory.
10. Hagler Bailey Consulting. 1997. Pollution Prevention Diagnostic Assessment — Brewery. United States Office for International Development. Office of Environmental and Natural Resources.
11. Hoffman, H. W. (Bill). March 2006. Building Reduced Water and Wastewater Cost into the Design. Austin Water Utility. Austin, Texas.
12. Kentish, Graeme, and Morgan, Peter. October 2006. Conversion of Product Conveyors from Wet Lubrication to Dry Lubrication. Cadbury Schweppes, Tullamarie, Victoria, Australia.
13. Maryland Department of the Environment. Water Saving Tips for Food Processing Facilities, *https://mde.maryland.gov/programs/water/waterconservation/pages/beverage.aspx*
14. Massachusetts Water Resources Authority. "Beverage/Food Processing Industries." Water Conservation Bulletin No. 3.
15. Minnesota Technical Assistance Program. October 2004. Best Management Practices — Bakery. University of Minnesota.
16. North Carolina Department of Environment and Natural Resources, Division of Pollution Prevention. August 1998. Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.
17. Ogunbameru, Gus, Ph.C., Ch.E. 2004. Best Management Practices for Selected Industries and Additional Resources. Massachusetts Office of Technical Assistance.
18. Platts Research and Consulting. 2002. Management of Energy Cost in Grocery Stores. McGraw Hill Companies, Inc.
19. Rausch, Kent D, and Powell, Morgan G. 1997. Dairy Processing Methods to Reduce Water Use and Liquid Waste Load. Cooperative Extension Service. Kansas State University. Manhattan, Kansas.
20. North Carolina Department of Environment, Health, and Natural Resources. August 1995. A Soft Drink Bottling Company — North Carolina.
21. Smart Water Fund of Australia. 2006. "Installation of waterless conveyer technology", *https://water360.com.au/wp-content/uploads/2022/10/1132-installation-of-waterless-conveyer-technology-final-report.pdf*

22. Water Use Efficiency Report for California League of Food Processors (Parts 1, 2, and 3 of 3), 2015, *https://clfp.com/wp-content/uploads/CLFP_Water-Use-Efficiency-Study_02-11-15_PARTS 1.pdf, Kennedy/Jenks Consultants and Brown and Caldwell, 2015*
23. California Department of Water Resources. Commercial, Industrial, and Institutional Task Force Water Use Best Management Practices, Report to the Legislature, 2013.

Automotive Services

24. California Department of Toxic Substance Control. P2 Opportunities Checklist for Vehicle Maintenance Activities.
25. San Antonio Water System. June 1998. Water Saver Awards.
26. U.S. Environmental Protection Agency. Region 9. Auto Repair and Fleet Maintenance Pollution Prevention, *https://archive.epa.gov/region9/waste/archive/web/html/factauto.html*
27. U.S. Navy. Navy Water Conservation Guide for Shore Facilities. https://apps.dtic.mil/sti/tr/pdf/ADB219530.pdf

Printing and Paper Manufacturing

28. Alameda County Waste Management Authority and Recycling Board. www.stopwaste.org
29. Environmental Protection Agency. Pulp, Paper and Paperboard Effluent Guidelines - Documents Related to 1998 Rule, *https://www.epa.gov/eg/pulp-paper-and-paperboard-effluent-guidelines-documents-related-1998-rule*
30. City of San Jose, California. Environmental Services Department. Best Management Practices to Reduce Pollution for Printing and Photo processing Operations.
31. Conservatree. Recycled and Environmental Paper Information. San Francisco, California, *www.conservatree.com*
32. *https://environmentalpaper.org/wp-content/uploads/2017/08/Paperwork.pdf*
33. Eco-Efficiency Centre, The. Dalhousie University. 2006. Fact Sheet: Eco-Efficiency in the Printing Industry. Dartmouth, Nova Scotia
34. Kinsella, Susan. Fact Sheet: Buy Recycled Paper! Buy Recycled Business Alliance of the National Recycling Coalition, *https://www.stopwaste.org/sites/default/files/Documents/1030136122004paperfactsheet.pdf*
35. *https://www.sierraclub.org/sierra/2015-1-january-february/ask-mr-green/hey-mr-green-what-about-all-water-it-takes-make-paper*

Metal Finishing

36. Brown, Jerry. 2000. Pollution Prevention Case Study – Conductivity Controller Technology. TN -72. Chicago, Illinois.
37. CH2MHill. May 2002. Air Force Water Conservation Guidebook.
38. De Deitrich. Electroplating Rinse Practices and Evaporator Sizing. www.ddpsinc.com.
39. Department of Planning and Environmental Protection. Broward County, Florida. October 2003. Pollution Prevention and Best Management Practices for Metal Finishing Facilities. Fort Lauderdale, Florida.
40. Donovan, Robert P., Morrison, Dennis J., and Timon, Robert P. November 1998. Design of Recycling Systems for Spent Rinse Water in Sandia's Microelectronics Development Laboratory. International SEMATECH TT# 98113599A-ENG.
41. Environmental Protection Agency of Victoria, Australia. 1993. Waste Minimization—Assessment and Opportunities for Industry. Southbank, Victoria. ISBN 07306-2888-4.
42. Minnesota Technical Assistance Program. 2010, *http://www.mntap.umn.edu/wp-content/uploads/simple-file-list/Water/Water-Conservation-Tips.pdf*

43. Narragansett Bay Commission, The. P2 Facts: Industrial Rinse Water Reduction. Providence, Rhode Island.
44. National Center for Manufacturing Science. 2007. Printed Wire Board. Printed Wire Board Resource Center. Ann Arbor, Michigan. Metal Products and Machinery (MP&M) PWB Subcategory
45. New Mexico. Office of State Engineer. July 1999. A Water Conservation Guide for Commercial, Institutional and Industrial Water Users.
46. North Carolina. Department of Environment and Natural Resources. Division of Pollution Prevention. August 1998. Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.
47. Ogunbameru, Gus, Ph.C., Ch.E. 2004. Best Management Practices for Selected Industries and Additional Resources. Massachusetts Office of Technical Assistance.
48. Rosemont Analytical Inc. 2003. Water Conservation in Metal Finishing. Emerson Process Management. Irvine, California.
49. Thompson, Chris, and Lickteig, Edward. October 2008. Recycling High Purity Rinsewater at Samsung Austin Semiconductor. Samsung Austin Semiconductor. Ultrapure Water. Austin, Texas.

Chapter 7
ALTERNATE ONSITE WATER SOURCES

Many commercial and industrial facilities have the potential to reuse onsite wastewater streams in non-potable applications within their operations and production processes. Such end uses can include toilet flushing, irrigation, cooling tower makeup water, and more. This chapter provides definitions for different categories of reusable wastewater, a summary of relevant regulations, and examples of possible sources.

This chapter does not cover the onsite treatment of blackwater, or treated municipal wastewater reuse, including direct potable reuse. To learn more about the onsite treatment of blackwater, consult the San Francisco Public Utility Commission's excellent resource, Onsite Water Reuse Program Guidebook. To learn about EBMUD's recycled water programs for commercial and industrial customers, visit the recycled water information portal. For information on California's Direct Potable Reuse regulations, in effect as of October 1st, 2024, visit the California State Water Board's website.

Potential Sources of Alternate Onsite Water Sources

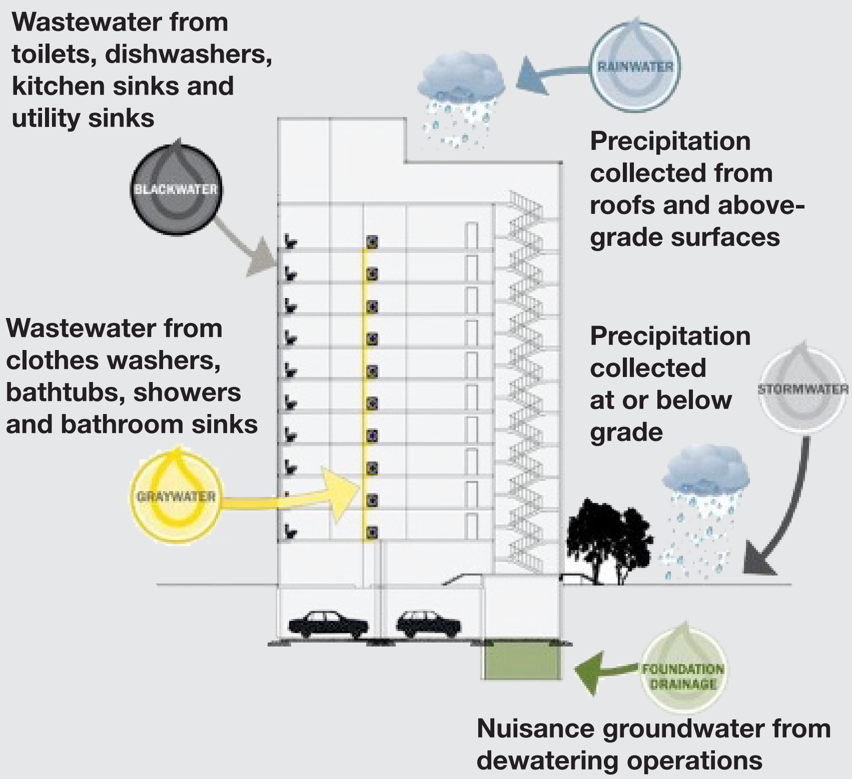


Image source: San Francisco Public Utility Commission

Alternative sources of water covered in this guide:

- **Graywater –** untreated wastewater not contaminated by high levels of biological solids, or toilet discharge or infection
- **Rainwater –** typically collected from roofs
- **Stormwater –** rainwater that has come into contact with the ground
- **Foundation drain water –** groundwater interacting with the built environment
- **Cooling tower blowdown**
- **Air conditioner condensate**

Other sources not covered can include:

- **Blackwater –** untreated wastewater from toilets, kitchen sinks, dishwashers, and utility sinks
- **Swimming pool drain water**
- **Chemical mixing water**
- **Defrosting of refrigeration coils**
- **Equipment cleaning water such as:**
  - Shipment containers and crates flush-out
  - Gutter and sewer flushing
  - Fluming, washing of fruits and vegetables
  - Makeup water for conveyor lubrication systems

Overview

The initial step in determining the reuse potential for an alternate water source is to identify the requirements, such as water quality regulations, that the alternate water source will need to meet for the desired end use. Where an end use requires a very high-quality source water, the reused wastewater will require additional treatment

Table 7-1: Treatment types per end us water quality needs

Source	Filtration	Sedimentation	Disinfection	Biological Treatment	Other Considerations
Rainwater	D	D	D		May be used for irrigation w/out additional treatment
Stormwater	T	D	D	D	For non-potable use only
Air conditioner condensate			T		Segregate coil cleaning water
Pool filter backwash	T	D			May have high TDS and chlorine levels
Cooling tower blowdown	D	D	T		Consider TDS monitoring
RO & NF reject water					Consider TDS monitoring
Graywater	T	D	T	D	Per CA regs, cannot be stored >24 hrs without treatment. Subsurface drip requires the least treatment
On-site wastewater treatment	T	T	T	T	Biologically unstable for long periods of storage unless treated
Foundation drain water	D		D		May be hard if in alakaline soils

T = treatment likely needed
D = treatment depends on use

Source: HW (Bill) Hoffman & Associates, LLC

to remove contaminants or constituents. Removing contaminants for specialized end use is standard procedure; even potable water needs to be treated for certain industrial processes. The next step is to verify that the desired volume of end-use water demand can be consistently and reliably met by the identified alternative onsite source.

General water quality and treatment considerations for use of alternate sources are summarized in Tables 7-1 and 7-2.

Each section below provides criteria for evaluating a potential onsite water supply and includes basic considerations for system design. However, due to the site-specific nature of both non-potable water demand and potential supply, these are necessarily broad. A latter section discusses some general design considerations for the coordinated use of surface water and groundwater.

Onsite reuse design and evaluation considerations include:

- Identifying possible uses for wastewater streams
- Matching water quality of source water to type of end use
- Choosing water treatment type, if needed
- Determining reliability/regularity of the non-potable source

Due to the widely varied circumstances of each site in regard to the proposed end use versus the source water, cost effectiveness evaluations are unique to each project. As a result, a feasibility study at the proposed site is recommended to determine cost implications and payback period.

Table 7-2: Water Quality Considerations for Alternative On-Site Sources of Water

Source	Sediment	TDS	Hardness	Organic (BOD)	Pathogens (A)	Other Considerations
Rainwater	1-2	1	1	1	1	None
Stormwater	3	?	1	2	2	Pesticides & fertilizers
Air conditioner condensate	1	1	1	1	2	May contain copper when coil cleaned
Pool filter backwash	3	2	2	1	2	Pool treatment chemicals
Cooling tower blowdown	2	3+	3	2	2	Cooling tower treatment chemicals
RO & NF reject water	1	3+	3	1	1	High salt content
Graywater	3	2	2	3	3	Detergents and bleach
On-site wastewater treatment	3	2	2	3+	3+	Human waste
Foundation drain water	1	?	?	2	2	Similar to stormwater

1 - Low level of concern
2 - Medium level; may need additional treatment depending on end use
3 - High concentrations are possible and additional treatment likely
? - Dependent on local conditions
(A) All water used indoors (e.g., toilet flushing) should be disinfected

**The use of pass-through cooling water is also a posssible source of on-site water, but should be discouraged because of its huge potential to waste water, despite providing a relatively pure source of water. For that reason, it is not included in this list.*

Source: HW (Bill) Hoffman & Associates, LLC

Regulations

In California, onsite non-potable reuse is regulated by the State Water Resources Control Board (SWRCB), the Clean Water Act (CWA) (33 U.S.C. §§ 1251 et seq.), the California Plumbing Code (CPC) (Cal. Code Regs. tit. 24, § 5) and, in the absence of local treatment requirements, the NSF/ANSI Standard 3501. For information on regulations in other states, visit the EPA's Regulations and End-Use Specifications Explorer (REUSExplorer).

In 2018, California Senate Bill 966 was passed, requiring the California State Water Resources Control Board (SWRCB) to develop uniform water quality standards for onsite treatment and reuse of water. The bill also required that municipalities establish local programs to comply with the state's new standards. The bill "prohibits an onsite treated non-potable water system from being installed except under a program established by a local jurisdiction in compliance with the bill's provisions.[1]"

1 https://pacinst.org/wp-content/uploads/2021/01/Role-of-Onsite-Water-in-Silicon-Valley-Jan-2021.pdf

Table 7-3: NSF/ANSI 350 and 350-1 On-Site Water Reuse Systems

	NSF/ANSI 350 for Above Ground And Sub-Surface Use	NSF/ANSI 350-1 for Sub-Surface Discharge Only
Building Types	Single family residential up to 1,500 gallons per day / Commercial all above 1,500 plus all commercial laundry water	Single family residential up to 1,500 gallons per day / Commercial all above 1,500 plus all commercial laundry water
Influent Types	Black water, graywater, bathing water only, and laundry water	Black water, graywater, bathing water only, and laundry water
End Uses	Non-potable application such as irrigation and toilet and urinal flushing	Subsurface irrigation only

Table 7-4: Nonpotable Water System Water Quality Requirements

Recycled Water Class/Category	Source Water Type	Water Quality Parameter	Specification	Sampling/ Monitoring Requirements
Onsite treated non-potable graywater systems (toilet & urinal flushing, above/below ground irrigation, trap primers)	Graywater	The minimum water quality for onsite treated non-potable graywater systems shall meet the applicable water quality requirements for the intended applications as determined by the public health authority having jurisdiction. In the absence of local water quality requirements, the requirements of ANSI/NSF 350 shall apply.		
Harvested Rainwater	E. coli	<100 CFU/100mL	Water quality should be tested every 12 months or after system renovation or repair	
	Turbidity	<10 NTU		

This development resulted in updated CPC regulations. Table 7-3 summarizes the results.

Please note the following exceptions to the summarized water quality guidelines, excerpted from the CPC:

- Untreated graywater systems that are used exclusively for subsurface irrigation that are regulated by Chapter 15 (commencing with Section 1501.0) of the California Plumbing Code (Part 5 of Title 24 of the California Code of Regulations).
- Untreated rainwater systems that are used exclusively for surface, subsurface, or drip irrigation that are regulated by Chapter 16 (commencing with Section 1601.0) of the California Plumbing Code (Part 5 of Title 24 of the California Code of Regulations)."

Rainwater catchment system components

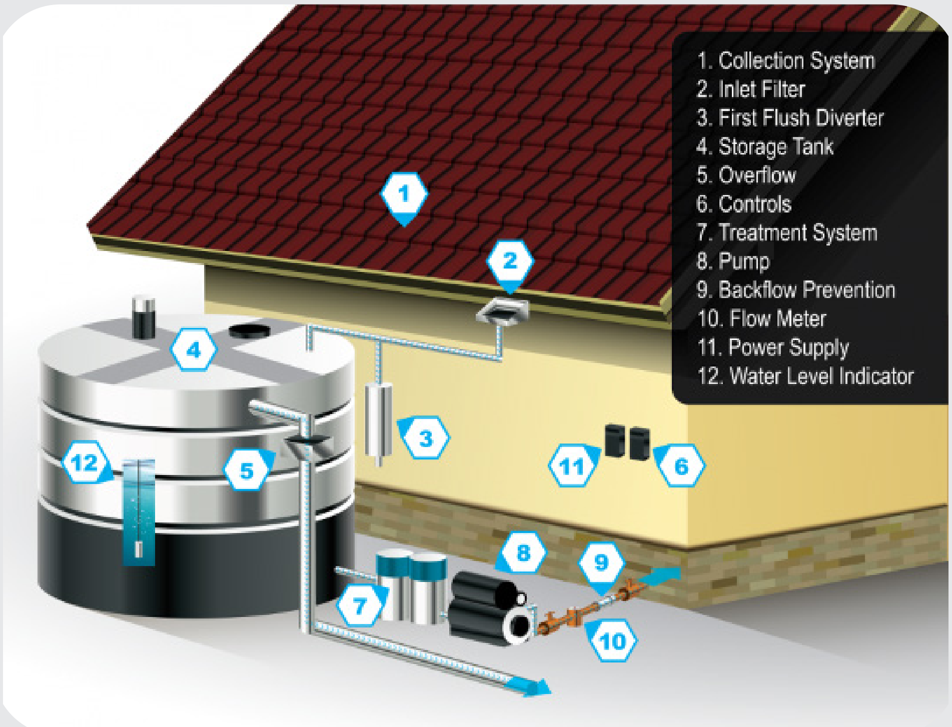


Image source: www.energy.gov - Federal Energy Management Program

The type of roof surface impacts the quality of the rainwater runoff.

For the highest quality rainwater, especially if the water is to be used for in-building uses such as flushing toilets and urinals, harvesting should ideally employ smooth metal roofs and non-toxic, non-leaching surface finishes.

Gutter design should employ at least a 1 percent slope and route water to a central collection point for transfer to a cistern or storage tank. The system will need a "first-flush diverter" to minimize the debris and waste or debris of any kind from the roof surface that enters the cistern.

Rainwater Harvesting

Rainwater harvesting captures, diverts, and stores rainwater from rooftops for later use[2]. The California regulations Cal. Code Regs. tit. 24, § 5, also known as the California Plumbing Code, defines the following approved onsite non-potable reuse applications for the use of harvested rainwater:

- Toilet and urinal flushing
- Clothes washing
- Ornamental fountains and other water features
- Cooling tower make-up water
- Car washing
- Surface, subsurface, and drip irrigation
- Spray irrigation

Facilities with large areas of impervious roof cover can capture runoff and use the water for various non-potable purposes with little treatment. This section deals with methods available to facilities that capture water from their roofs. Harvested rainwater can also be combined with air-conditioner condensate, the next option.

For rainwater destined for landscape watering, additional consideration should be given to diverting water directly into landscaped areas, with swales and berms to capture and direct the flow.

Care must be taken in designing such landscape rainwater harvesting to avoid long-term pooling of water and creation of potential insect vectors.

The following illustration shows the basic components of most commercial-scale rainwater catchment systems:

Costs are considerably lower for systems which do not include tanks or cisterns, such as rain gardens and bio swales. These designs slow the water down to allow it to percolate into the landscape and provide additional stormwater runoff reduction benefits as well.

Approximately 0.62 gallons of water can be collected per square foot of collection surface per inch of rainfall. In practice, however, most installers assume an efficiency of 80% (percent). Some rainwater will always be lost to the first flush, evaporation from the roof surface, or splash-out from the gutters. Rough collection surfaces are also less efficient at conveying water, and water captured in pore spaces is lost to evaporation.

2 *https://www.energy.gov/femp/rainwater-harvesting-systems-technology-review*

In California, onsite treatment of stormwater for reuse is only permitted for outdoor irrigation.

The inability of the system to capture all water during heavy storms also affects practicable efficiency. For instance, spillage may occur if the flow-through capacity of a filter-type first flush is exceeded, and overflow rainwater can be lost after storage tanks are full if a raingarden or bioswale is not designed downstream of the overflow. Therefore, special consideration should be given to the size of storage tanks, how often they will be used, and where overflow will be directed to.

The use of rainwater collection systems, also referred to as cisterns, is most practical in regions with periodic precipitation throughout a plant's growing season. However, in regions such as California where rainfall is restricted to a few months out of the year, cistern storage is still possible with careful planning and system design. If capturing enough water to last the dry season is the goal, sites and budgets that can accommodate large storage capacities are ideal. This storage capacity will also need some space within the building that is protected, therefore, a large cistern may not be feasible. However, if the rainwater harvesting system is included as part a wholistic portfolio of water sources for a given industrial process or irrigation end point, it can still make up a valuable portion of the water conservation portfolio even without meeting an entire dry season's water use needs.

The American Rainwater Collection Systems Association (ARCSA) is a source of much useful information on rainwater harvesting. Visit arcsa.org.

Calculations

Annual production potential:

Gallons = roof area (sq. ft.) x annual precipitation (in.) × (0.62 x 0.8)

Required annual storage capacity for the planned landscape should be determined as follows:

- Calculate the monthly water budget for the planned landscape using the water budget calculations in the section, "Landscape Irrigation Efficiency."
- Estimate the monthly average rainfall quantities that could be harvested, based upon roof area and rainfall for the location.
- Estimate the amount of rainwater storage that would be cost-effective to construct, based upon monthly inflows from rainfall and outflows based upon the landscape water budget.
- This calculation assumes that 20% of rainwater will be lost to evaporation, roof washing and other losses.

Rainwater Harvesting Regulations Map

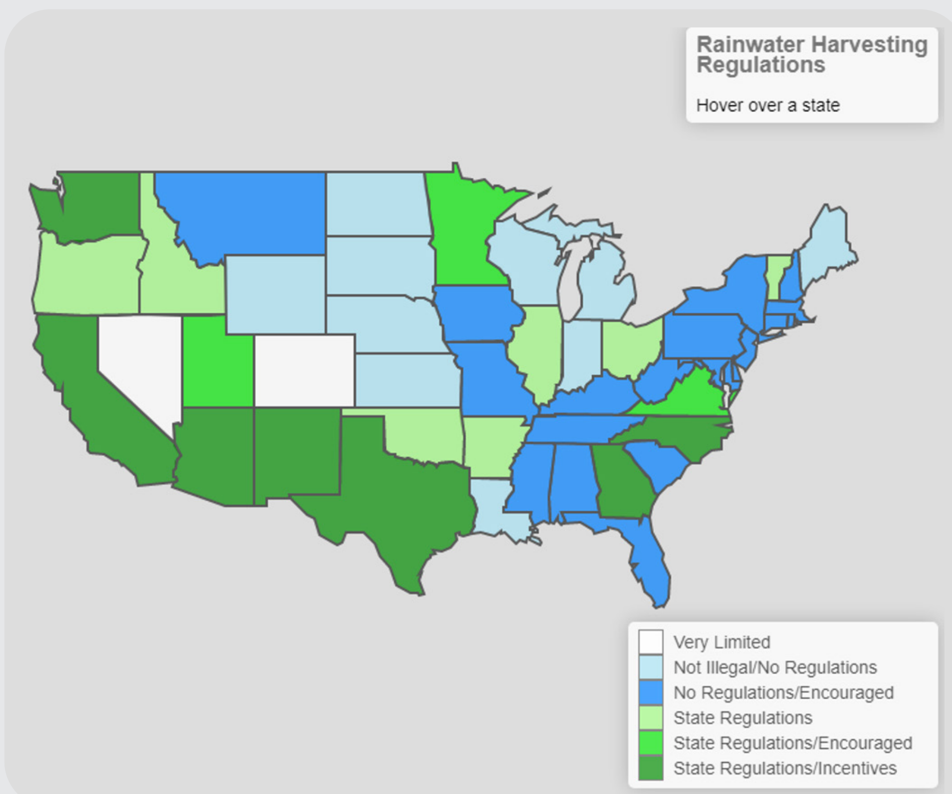


Image source: www.energy.gov - Federal Energy Management Program

Recommendations

- Examine the statutes in your area. In California, see the California Plumbing Code, Chapter 16: Non-Potable Rainwater Catchment Systems and Cal. Code Regs. tit. 24, § 5
- Use the American Rainwater Catchment Systems (ARCSA) technical materials as a quide
- Examine the International Association of Plumbing and Mechanical Officials (IAPMO) Uniform Plumbing Code section on alternate sources of water
- New commercial developments with more than 20,000 square feet of roof area to provide a preliminary feasibility study, including cost analysis, to determine whether rainwater harvesting is viable at the site.

Stormwater

Stormwater is commonly differentiated from rainwater as being precipitation that reaches the ground and drains to a low point or storm drain. Because of the contact with surfaces such as roadways and pavement, which present greater likelihood of contamination, stormwater tends to require greater treatment than rainwater.[3] According to the California State Water Resources Control Board (State Water Board), "capturing and using urban stormwater as a resource provides multiple benefits such as offsetting drought related impacts through additional groundwater recharge and aquifer storage, mitigating pollution of stormwater, creating green and open spaces, enhancing fish and wildlife habitat, supporting watershed processes, and improving water use efficiency while mitigating the adverse effects of flood flows.[4]" Other benefits can include reducing strain on sewer systems during large rain events, especially in areas with combined sewer systems.

As of the time of publication, in California, onsite treatment of stormwater for reuse is only permitted for outdoor irrigation. The State Water Board is still in the process of drafting and adopting regulations for risk-based water quality standards for onsite treatment and reuse of non-potable water for non-potable end uses in multifamily residential, commercial, and mixed-use buildings.[5] Tentatively slated for acceptance in 2025, these regulations will likely increase the opportunities for CII-scale onsite stormwater capture and reuse.

Stormwater capture and landscape irrigation reuse opportunities can be examined during the planning stages of new construction, when stormwater systems are being

Multi-Benefits of Stormwater Capture and Use

Image source: Federal Environmental Protection Agency - Link here

3 https://watereuse.org/educate/types-of-reuse/stormwater-reuse/

4 https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2023/PRD/RMS/Draft-Urban-Stormwater-Runoff-Capture-and-Management-RMS.pdf

5 https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/onsite_nonpotable_reuse_regulations.html

designed[6], or during a retrofit project process. The overall concept is to keep the rain on the site where it falls to the maximum extent possible. The water captured and held can displace part or all of the potable water otherwise used for irrigation and can optimize groundwater infiltration, water quality, and slow-release augmentation of local streams

Stormwater capture and reuse can look like:

- Storage in the soil profile
- Capture in onsite features, such as berms, swales, rain gardens, or terraces
- Capture in a detention structure, such as a pond, from which it can be pumped back to the landscape
- Green infrastructure, such as rain gardens, planter boxes, permeable landscape

Recommendations

- Include capture in on-site features, such as berms, swales, rain gardens, or terraces, and the use of soil as a water-storage medium jointly in the design of landscape and stormwater facilities
- Create and build green infrastructure where possible
- Examine the statutes in your area. In California, see the Cal. Code Regs. tit. 24, § 5
- Examine the potential of captured and stored stormwater along with other on-site water sources
- Additional resources:
  - SFPUC On-site Reuse Handbook
  - SFPUC On-Site Reuse webpage
  - EPA Water Reuse resource webpage
    - Water reuse case studies/success stories
  - CA Waterboards Stormwater Storymap

US Dept of Energy's Condensate Capture Potential Map

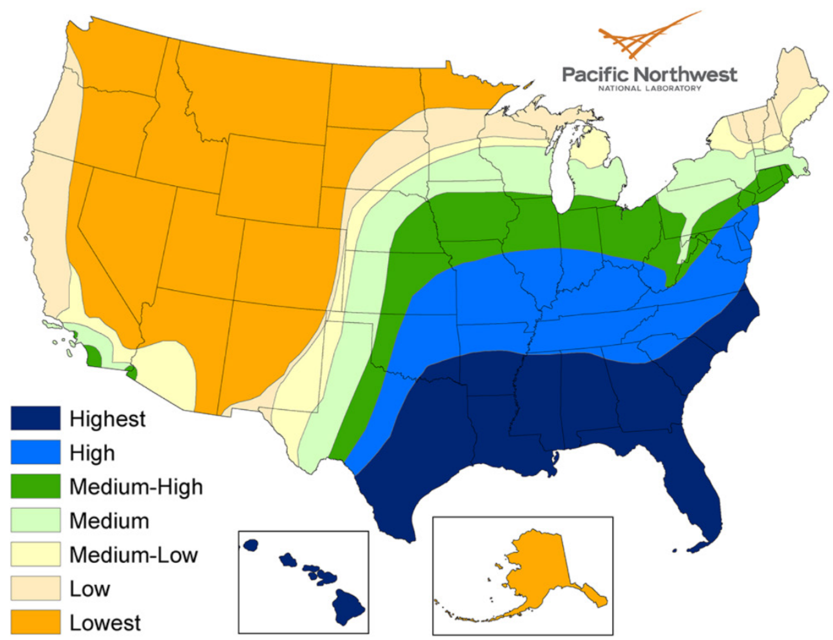


Image source: www.energy.gov/femp/condensate-capture-potential-map

Air Conditioner Condensate

Water condenses on air-handling units (AHUs) and cooling coils when humid air contacts these cool surfaces. A large amount of condensate can form on cooling equipment in areas with hot, humid summers such as the southeastern United States. Water that collects on the AHUs and cooling coils must be drained to prevent damage to the equipment or the building from water buildup. Typically, the condensate is collected in a central location and discharged to a sewer drain. In a condensate capturing system, the condensate is directed to a central storage tank or basin and then distributed for reuse6.

Captured condensate recovery water can be used as make-up water for cooling towers. Due to its relatively good water quality, it will generally not decrease cycles of concentration achievable in cooling towers.[7] Condensate can also be used for irrigation and other non-potable uses. `If it is used for landscape irrigation, provisions may have to be made to divert water collected during coil cleaning to the sewer, if copper concentrations would be of concern.

Readers interested in estimating the recovery potential of HVAC condensate at their site can consult Building Green's Revised Air Conditioner Condensate Calculator.

6 *https://www.epa.gov/npdes/stormwater-planning*
7 *https://www.energy.gov/femp/condensate-capture-potential-map*

The potential volume of condensate recovery varies by region and is based on local climate conditions of a given city. The condensate capture potential illustrated below may also vary due to local annual weather patterns. Additional factors to consider when assessing the potential for condensate capture can include:

- Size of cooling system: Larger systems can potentially produce more condensate (depending on cooling system operation).
- Cooling system operation: Hours of operation and temperature set points will influence total hours of operation and condensate production.

Recommendations

- Download the free condensate estimator from Building Green.
- Commercial sites with more than 100-tons of air-conditioning must examine the feasibility of diverting all condensate drain water to a common point where it could easily be captured.
- If necessary in your jurisdiction, help change regulations that require condensate to be discharged into a sewer to allow for other alternative uses.

Foundation Drain Water

Foundation drain water, another potential source on large commercial campuses, can be captured to preserve foundation integrity. End uses can range from non-potable irrigation systems, to leach field distribution, to other creative solutions that vary with the water needs of adjacent structures and landscapes.

Foundation Drain Water Storage and Treatment Infrastructure Mid-Installation

Image source: San Francisco Public Utilities Commission

Drain water can originate from a variety of sources, including subsurface waterways, or groundwater. Following is a case study of a creative solution to recover over 30 million gallons of groundwater intruding each year into a local subway system. The groundwater was able to be redirected into a steam plant that serves a large portion of San Francisco's downtown commercial buildings.

Subway Groundwater Intrusion Solution

This water reclamation project required collaboration between the City of San Francisco Public Utilities Commission (SFPUC), the local subway operator SFMTA, and Cordia, an energy solutions company that manages a large, centralized steam plant in downtown San Francisco. This steam plant serves approximately 180 customers for space heating, domestic hot water, air conditioning, and industrial process use.

The project included constructing a system that transported groundwater from the Powell Street Station to the Cordia plant via a newly installed underground pipeline, then treated to boiler-grade levels of purity — a much higher standard than regular drinking water. For the new system to be successful, it needed multiple steps of purification to remove trash, dirt, biologicals, minerals, and chemicals. It also required the use of an advanced front-end filtration plant, which integrates with the existing water softening equipment at the steam plant, and a new and innovative reverse osmosis (RO) treatment system. This project reduced the steam plant's domestic water use by 30%.

Recommendations

- Sites that require the use of a foundation drain should provide a feasibility summary study of how the sources might be used.

Cooling Tower Blowdown

Evaluate the feasibility of reusing cooling-tower blowdown water for another purpose, such as diversion for compressors, vacuum pumps, and other equipment with water-cooled air-condenser units. A detailed analysis is beyond the scope of this section, but any such project should be closely coordinated with local stormwater and water-quality officials, since the type of cooling-tower water treatment will determine the quality of the blowdown water. Using blowdown water may offer a classic example of tradeoffs. Often, achieving the maximum numbers of cycles of concentration is a primary goal of cooling tower management. In some cases, however, if the need for irrigation water (or other desired end-use) exceeds blowdown volumes at the site, the designer may wish to consider reducing the cycles of concentration and, instead, choose treatment that will produce blowdown suited for irrigation purposes. This also avoids water-quality problems for streams receiving runoff from the property. The net benefits of using blowdown are that it makes use of all the water entering the tower, displaces potable water use for irrigation, and eliminates wastewater discharge from the tower. One benefit of diverting cooling-tower blowdown for reuse in other areas is the possibility of reducing wastewater costs, such as [EBMUD's Estimation of Wastewater Volume Permit Application](). Check with your local water agency or municipality for more details.

Layout of the New Groundwater Transport System

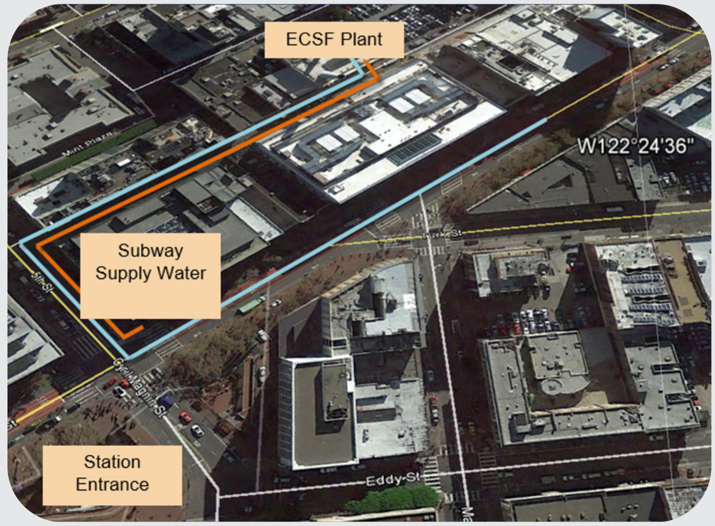


Image source: Cordia

Pipeline Components of the New Groundwater Transport System

Image source: San Francisco Public Utilities Commission

ECSF Projected Water Cost Improvement with Ground and Well Water 2018-2024

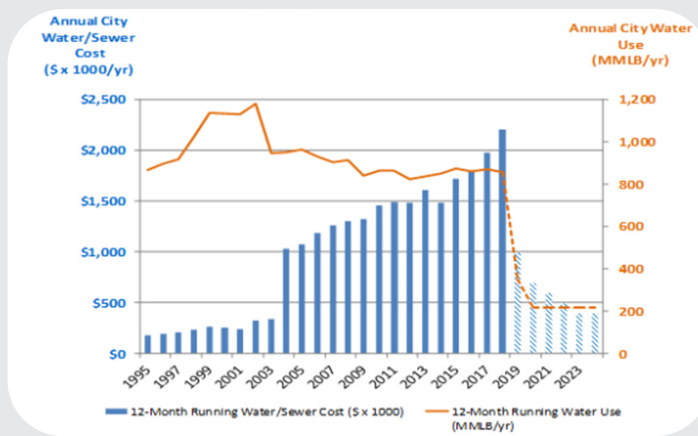


Image source: Cordia

Schematic of the Groundwater Treatment Process

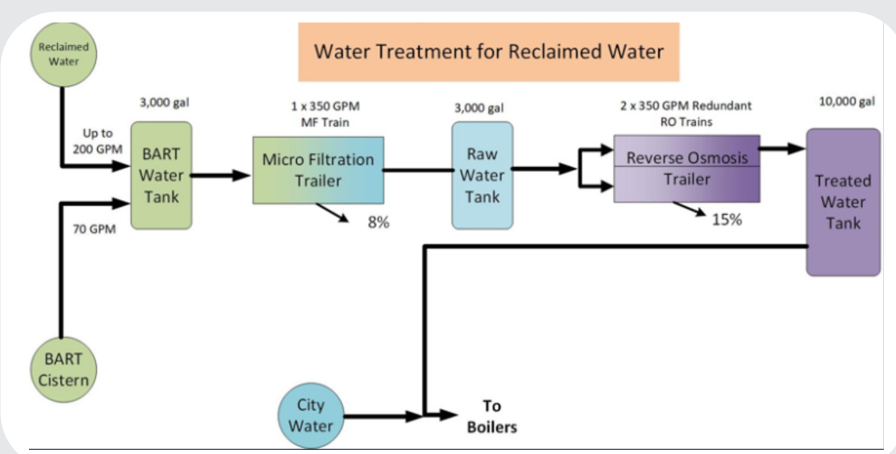


Image source: Cordia

Another option is to use nanofiltration or reverse osmosis to treat tower make-up water so that extremely high cycles of concentration can be achieved. Reject water can then be used for irrigation.

Figure 7-1 shows how indoor and outdoor water use varies for facilities in Texas. This breakdown will be different for every area in the United States. What the figure shows is that outdoor uses can be significant.

Recommendations

- New projects that employ filtration and membrane processes should provide a feasibility summary study of how these sources might be used.

Onsite Treatment of Graywater and Wastewater

Graywater is defined in California law as "untreated wastewater which has not come into contact with toilet waste. Graywater includes wastewater from bathtubs, showers, bathroom wash basins, clothes-washing machines, and laundry tubs, or an equivalent discharge as approved by the Administrative Authority. It also does not include wastewater from kitchen sinks, photo-lab sinks, dishwashers, or laundry water from soiled diapers," in Title 24 section 5 of the Code. The use of gray water or on-site treatment of wastewater for onsite reuse requires a project-by-project analysis and is beyond the scope of this document. However, many commercial projects have employed technologies ranging from simply using septic tanks and near-surface dosing of the effluent for subsurface irrigation to the installation of full-capacity wastewater-treatment plants, followed by conventional landscape irrigation. Another example is treating effluent to a quality sufficient for toilet and urinal flushing.

As an example, the 250-unit Solaire Apartments in Battery Park was a private-public partnership and is the first "green" residential high-rise building that incorporates advanced materials, energy conservation, and water reuse in an urban setting. The Solaire Apartments selected the ZENON Membrane Solutions proprietary ZeeWeed MBR (membrane bioreactor) process to treat, store, and reuse wastewater for toilet flushing, irrigation, and cooling towers. This approach reduces the fresh water taken from the city's water supply by more than 75 percent and significantly decreases energy costs, since less drinking water is pumped from the city's treatment plant and wastewater is not transferred to the city's wastewater treatment system. The system is the first on-site water-recycling system in the U.S. built inside a multi-family, residential building.

Gray water from wash basins, bathing and showers, and laundry operations has also been considered. Graywater generally does not contain fecal matter and, thus, can more easily be treated and reused on-site. Gray water requires simple filtration to remove suspended particles and, when stored, requires only treatments such as chlorination for odor or aeration for nutrients in the water.

A primary concern is to involve health department, code enforcement, and stormwater quality officials in the design and development of any project to ensure that all applicable environmental concerns are taken into account, that appropriate technologies are employed, and that regulations are met.

Recommendations

- Consult local regulations for design considerations. In California, that is the California Plumbing Code, Chapter: Alternate Water Sources for Non-Potable Applications

Figure 7-1: How Water is Used in Texas Facilities with Cooling Towers

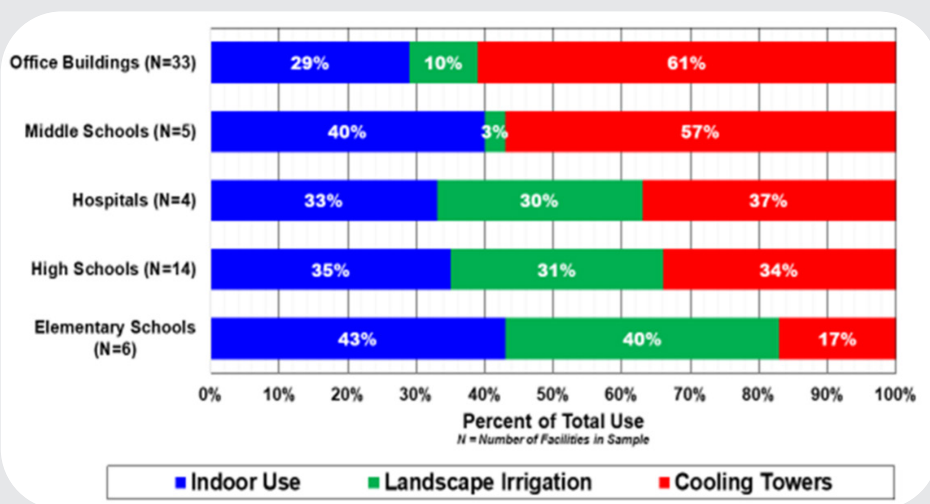


Image source: HW (Bill) Hoffman & Associates, LLC

Combining Multiple Alternative Sources

Plumbing of rainwater, gray water, drain water, and blowdown from various sources to common end uses, like landscape irrigation, or non-potable indoor uses, such as toilet flushing, is not common, but is recommended. Cost effectiveness of such "hybrid" systems is improved by diversifying the sources of water and improving the consistency of water availability, since rainfall episodes, often the largest and most significant single source of water, are sometimes separated by long dry periods.

Recommendations

- Clarify in local ordinances the specific plumbing uses of alternative sources of water and their relationships to the potable water system.
- Consult the EPA's Water Reuse Resource Hub by End-Use Application for more information

Resources

1. US EPA, Onsite Collected Waters for Potable Water Reuse
   https://www.epa.gov/waterreuse/california-onsite-collected-waters-potable-water-reuse
2. US EPA, Onsite Non-Potable Water Reuse Research
   https://www.epa.gov/water-research/onsite-non-potable-water-reuse-research
3. US EPA, Stormwater Management Practices at EPA Facilities
   https://www.epa.gov/greeningepa/stormwater-management-practices-epa-facilities
4. US EPA, Basic Information about Water Reuse
   https://www.epa.gov/waterreuse/basic-information-about-water-reuse
5. AW_onsitereuse@austintexas.gov. "INTRODUCTION TO ONSITE WATER REUSE SYSTEMS." ONSITE WATER REUSE PROGRAM GUIDEBOOK, 2020
   https://www.austintexas.gov/sites/default/files/files/Water/AlternativeWater/AW_OnsiteWaterReuse_Guidebook.pdf
6. Farahani, Mohammad Hossein Davood Abadi, et al. "Recovery of Cooling Tower Blowdown Water for Reuse: The Investigation of Different Types of Pretreatment Prior Nanofiltration and Reverse Osmosis." Journal of Water Process Engineering, vol. 10, Mar. 2016, pp. 188–99
   https://doi.org/10.1016/j.jwpe.2016.01.011
7. City Farming, Water Harvesting: Can I use air conditioning condensate to water my garden,
   https://cityfarmingbook.com/water-harvesting/
8. Pacific Institute, Heather Cooley, Anne Thebo, Cora Kammeyer, and Darcy Bostic, The Role of Onsite Water Systems in Advancing Water Resilience in Silicon Valley
   https://pacinst.org/wp-content/uploads/2021/01/Role-of-Onsite-Water-in-Silicon-Valley-Jan-2021.pdf
9. Sciencing, How to Recycle Air Conditioning Water Condensation
   https://sciencing.com/recycle-air-conditioning-water-condensation-23439.html
10. WATERCORE, Cooling tower water reuse with reverse osmosis
    https://watercore.com.au/posts/recycling-cooling-tower-blowdown-with-ro/
11. Buildinggreen, Free condensate estimator
    https://www.buildinggreen.com/blog/revised-air-conditioner-condensate-calculator-available-buildinggreenco
12. US Environmental Protection Agency, A Case for Stormwater Capture and Reuse
    https://www.epa.gov/system/files/documents/2022-03/wrap-pure-potential-report.pdf
13. US Department of Energy Sstatus of rainwater harvesting regulations and incentives in the United States
    https://www.energy.gov/eere/femp/rainwater-harvesting-regulations-map
14. Greywater Action- for a Sustainable Water Culture, Map of States where Graywater is Allowed
    https://greywateraction.org/greywater-codes-and-policy/
15. HW (Bill) Hoffman & Associates, LLC, Water Quality Consideration for Alternate On-site Sources of Water
16. HW (Bill) Hoffman & Associates, LLC, Types of Treatment That May Be Employed Depending on Intended End Use Quality Needs
17. Water Research Foundation Report 4619, Rebecca Fedak, Derek Hannon, Zach Taylor, and Amy Volckens Brendle Group Developing Water Use Metrics for the Commercial and Institutional Sectors, Developing Water Use Metrics for the Commercial and Institutional Sectors, 2019
    https://www.waterrf.org/research/projects/developing-water-use-metrics-commercial-and-institutional-sectors
18. SBDDW-22-001 Regulations for Onsite Treatment and Reuse of Nonpotable Water
    https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/onsite_nonpotable_reuse_regulations.html

Chapter 8
ON-SITE WATER TREATMENT AND REUSE

On-site water treatment is used in many commercial operations, including food services, laundries, laboratories, pharmacies, and car washes. The type of treatment depends upon the application and the required water purity. Where applicable, water treatment and subsequent reuse can also be a useful tool in the water conservation arsenal, keeping the same volume of water on-site for multiple uses.

Water treatment in the CII sector ranges from simple cartridge filtration to sophisticated systems that produce extremely pure water. For example, ice machines often have cartridge sediment and carbon filters installed on the make-up water, so the ice is free of particles and chlorine taste. Some laboratories and the pharmaceutical and electronics industries also require "ultrapure water." This type of ultra-purified water has had all but a few parts per billion of minerals, organics, and other substances removed through a train of treatment, including membrane filtration, carbon filtration, softening, reverse osmosis, and strong acid/base ion exchange, followed by microfiltration and ultraviolet-light disinfection.

Water-Savings Potential

The most accessible water treatment conservation opportunity is questioning the need for additional treatment in the first place.

If treatment is deemed necessary and can be performed in a cost-effective manner, choose methods that need the least amount of cleaning and backwash or that have reject streams.

All membrane processes, for example, produce a reject stream, which in the case of nanofiltration and reverse osmosis might be reusable. Table 8-1 compares various treatments found in commercial operations.

Different CII end uses require different water purity levels. As an example, the following lists the eight grades of water used in the manufacture of drug products[2]:

- Non-potable
- Potable (drinkable) water
- USP* purified water
- USP water for injection (WFI)
- USP sterile water for injection
- LUSP sterile water for inhalation
- USP bacteriostatic water for injection
- USP sterile water for irrigation

*The USP designation means that the water is the subject of an official monograph in the current US PHARMACOPEIA with various specifications for each type

Water Chemistry and Quality Relationships

There are some basic water quality considerations common to most commercial, institutional and industrial operations.

There are many reasons why water treatment may be needed. These include:

- Dissolved Salts
- Alkalinity, pH, Bicarbonate, etc.
- Hardness
- Iron and Manganese
- Organics
- Particulates
- Silica
- Biological Species

The cosmetics company L'Oreal provides an example of on-site water treatment and reuse.

Over 50% of L'Oréal's factories have on-site wastewater treatment plants, which are essential for recycling. At L'Oréal's manufacturing sites, recycled water is used for cleaning cosmetics production equipment. Depending on the site, up to 50% of the treated wastewater is linked back to the utilities. All incoming and used water is treated on site prior to being used for other purposes.[1]

1 https://www.wbcsd.org/Programs/Food-and-Nature/Water/Resources/Case-studies/Recycling-and-reuse-of-treated-industrial-wastewater-in-cosmetics-operations

2 https://www.fda.gov/inspections-compliance-enforcement-and-criminal-investigations/inspection-technical-guides/water-pharmaceutical-use

Common water quality terms:

> **Mesh size:** The number of holes per square inch in a membrane
>
> **Micron:** A thousandth of a millimeter (the size of the holes in a filter that will pass a particle that is a micron or larger)
>
> **pH scale:** The measurement of how acidic or basic water is (water is acidic if the pH is lower than 7.0 and basic above 7.0)
>
> **Hardness:** The amount of dissolved calcium and magnesium in water[3]

The remainder of this section describes common treatment processes to achieve the quality of water needed for the intended end use. Specialized industrial treatment processes are beyond the scope of this chapter.

Description of End Use

Each treatment technology offers unique opportunities for water conservation, as described below:

Sediment filtration is one of the most common treatment techniques. Swimming pools, water feeds to commercial ice machines, cooling tower side-streams, drinking water, and water-using medical equipment are examples where sediment filters are found. They remove particles down to a few microns in size. The two basic designs use disposable cartridges or granular filter media, but many other types of filters can be used.

Types of sediment filters include:

- Strainers
- Particulate Filtration
- Micro and Ultra Filtration

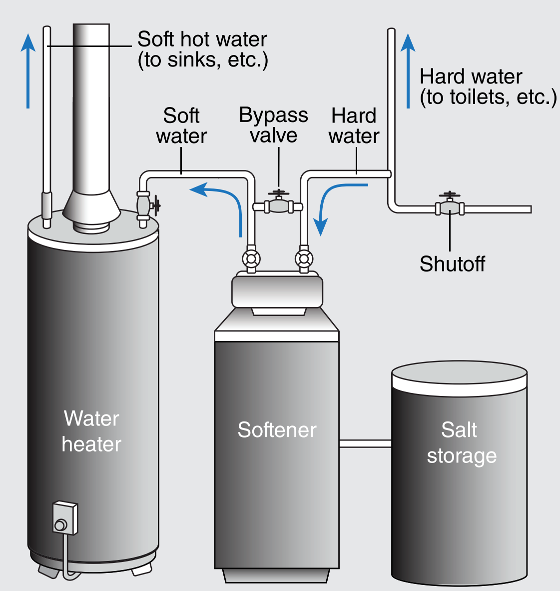
By their nature, cartridge filters are usually not designed for very large flows. Sample uses include pre-filters for ice machines, smaller medical equipment, and smaller swimming pools and spas. A filter's main objective is to remove debris, small particles and sediment from the water it is filtering. Other types of filters can filter out chlorine or other contaminants. Filter material varies from tightly wound fibers to ceramics, fused powdered-metals, or other materials. Such filters are left in place until the sediment buildup causes a predetermined increased pressure drop across the filter, at which time the filter is replaced, backwashed, or removed and cleaned for reuse.

The second type of sediment filter is often found where larger volumes of water must be processed or higher levels of sediment must be removed. These include granular media such as sand, coated media (DE, cellulose, and perlite), and mixed-bed filters. All of these must be backwashed. The backwash water is generally discharged to the sanitary sewer. In some larger applications, however, the sediment can be allowed to settle out and the clarified water can be reintroduced at the head of the filtration process. Common applications include swimming pools, industrial water treatment, and side-stream filtration for cooling towers.

Carbon filtration removes chlorine, taste, odor, and a variety of organic and heavy metal compounds from water by adsorption. Activated carbon, which has an enormous surface area per unit volume, attaches to the unwanted materials and holds them on its surfaces. Restaurants and food service providers for hospitals and other institutional operations often use activated carbon for drinking water and ice machine feed water. It is also used in the beverage industry for taste and odor control.

Activated carbon is also used to remove pollutants in the metal-finishing industry and other operations where pretreatment to remove metals or organics is needed. These systems can employ either disposable cartridges or packed columns, where the activated carbon can be removed and sent for recharge. With both cartridge and packed column systems, water simply passes through the carbon medium until its adsorptive capacity is used up.

Water Softening System



3 https://www.usgs.gov/special-topics/water-science-school/science/hardness-water

TABLE 8-1: Commercial Water Treatment Examples

	SEDIMENT FILTRATION	CARBON FILTRATION	SOFTENING & ION EXCHANGE	MEMBRANE PROCESS	DISTILLATION	DISINFECTION	OTHER
All Food Service	X	X	X	X			X
All Laundry & Dry Cleaning	X		X				
Hospital & Laboratory	X	X	X	X	X	X	X
Car Wash	X		X	X			
Beverage Manufacturing	X	X	X	X		X	
Metal Plating	X	X	X	X			X
Cooling Tower & Boiler	X		X	X		X	X
Pool, Spa, & Water Feature	X					X	
Office & Non-process	X	X	X			X	X

Water softening employs zeolites or ion exchange resins, where calcium and magnesium ions are exchanged for sodium or potassium ions. Softening removes hardness to control scale, improves water for washing, and prevents “hard water” spots. Recharge is done with a salt solution containing sodium or potassium cations, the most common being sodium chloride (table salt). Water is used in the recharging process to make up the brine solutions and to purge the softener of brine prior to being returned to service. All softener systems should be equipped with controllers that are activated based upon the volume treated, not on timers. They should either be adjusted for the hardness of the water supply or be equipped with a hardness controller that actually measures the hardness and volume treated, if the hardness of the feed water varies.

Softeners are commonly found where hardness interferes with water use or where scale formed by hard water could be detrimental. Laundries, car washes, boiler feed water, laboratory water, hot water systems for restaurants and food service establishments, and metal plating operations commonly employ softening. It is used occasionally for cooling tower feed water or in a process called side stream softening, which helps extend the usefulness of cooling tower water.

General Water Softening System Design Principles

There are certain design principles that are common to the previously mentioned technologies. First, the configuration of these devices is simply a vessel in which an ion exchange resin is located. It can be configured so that the water flows from the top down or the bottom up. The bottom-up flow pattern is reported to be more efficient, but excess sediment in the feed water will tend to clog the softener head unless a sediment filter is used before entering the softener.

Up flow configuration | **Down flow configuration**

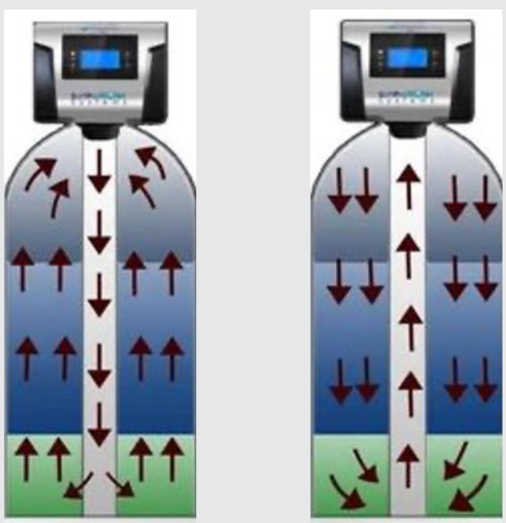


Image source: https://www.softenerparts.com/Upflow-vs-Downflow-Regeneration_c_389.html

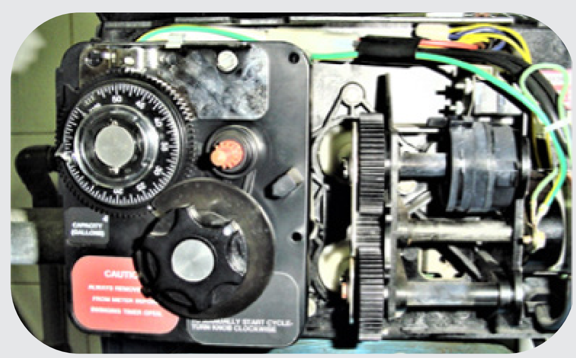
Methods used to know when to recharge the ion exchange resin:

1. **Timer control:** This is the oldest and most wasteful option. The system recharges the resin even when it does not need it. This wastes both water and chemicals.
2. **Flow meter:** The refill volume is pre-determined based on the water chemistry. When the resin has been exhausted based on the average volume of water that correlates to a specific water hardness, the recharge cycle will be triggered.
3. **Sensor-based control:** The most efficient method. The sensor measures the hardness, cation, or anion concentration and only recharges when the resin has been exhausted.

Deionization, a type of water softening, also employs exchange resins, but it is different from softening. Strong acid/base ion exchange resins, known as deionization resins, are used to produce extremely pure water for laboratory analysis, kidney dialysis, and feed water for a number of industrial processes. Water use is similar to that of recharging softening systems, but the ion removal systems operate similarly to ion exchange systems and have similar water use patterns. Ion exchange resins can also remove a variety of ionic contaminants, such as arsenic or fluoride.

Timer Control

Flow Volume Control



Images source: HW (Bill) Hoffman & Associates, LLC

According to the U.S. Environmental Protection Agency, "Up to 10 percent of a laboratory's water consumption can be related to the multi-step process of generating deionized (DI) purified water through reverse osmosis (RO). Water savings can be achieved by carefully regulating purified water generation rates to meet laboratory demand and making sure that systems are sized accordingly. EPA's Environmental Science Center in Fort Meade, Maryland, saves approximately 1.5 million gallons of water and more than $5,000 in annual water costs by reducing DI/RO system operation from 24 hours per day to 12 hours per day."[4]

4 https://www.epa.gov/greeningepa/water-management-plans-and-best-practices-epa

Best Management Practices

- Do not use timers to regenerate systems
- Base recharge on either cumulative flow through the exchanger or on probes in the media that detect when to recharge
- For cation and anion exchange resins, follow the manufacturer's recommendations
- Do not over size the system
- The National Sanitation Federation provides the following additional advice:[5]

  "Actuation of regeneration of water softeners shall be by demand initiation. Water softeners shall be listed to NSF/ANSI Standard 44. Water softeners should have a rated salt efficiency exceeding 3,400 grains of total hardness exchange per pound of salt, based on sodium chloride equivalency, and shall not generate more than 5 gallons of water per 1,000 grains of hardness removed during the service cycle."

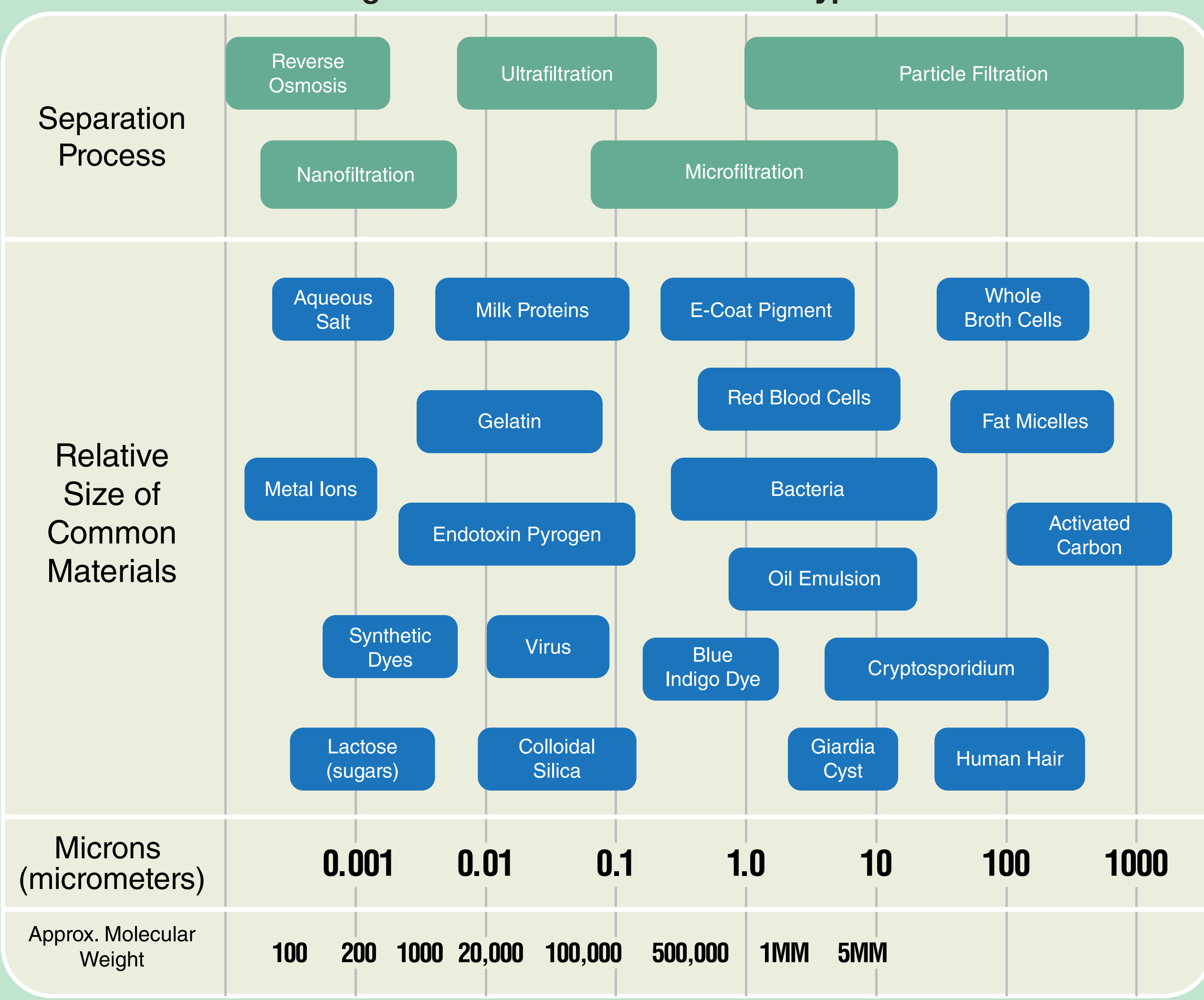
Membrane processes include several water treatment methods. A membrane, usually composed of a polymer material, is used to remove contaminates.

All membrane processes have three things in common:

1. A feed stream
2. A retentate or waste stream
3. A product called permeate

The type of membrane process used depends upon the size or type of contaminant one wishes to remove, as illustrated by Figure 8-1.

Figure 8-1: Membrane Process Types



Note: 1 micron (micrometer) = 4×10^{-5} inches = 10^4 Angstrom units

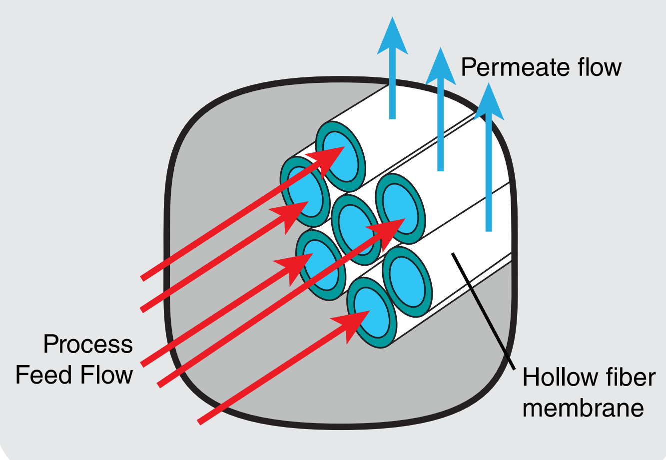
5 *https://savetexaswater.org/bmp/commercial/doc/CI_BMP_Guide030413.docx*

Microfiltration employs membranes that remove particles of 0.1 to 10 microns in size or larger. It is used in municipal water treatment to remove bacterial and Giardia lamblia cysts, and Cryptosporidium oocysts. Water is forced through the membrane until the pressure drop reaches a set point. The filter is then backwashed. The membranes also require periodic chemical cleaning. Both the backwash and cleaning processes use water. Retentate (what is retained, for example by a filter or porous membrane) or waste volumes are usually a small percentage of the total feed volume. The retentate is often recirculated and only a small stream of "bleed water" is discharged as wastewater. Some ceramic filters can also filter in this range.

Ultrafiltration operates at higher pressures than microfiltration and removes materials that are much smaller, including viruses and proteins. It is often used to separate milk and whey. These filters must be backwashed and cleaned in a manner similar to microfiltration membranes.

The following diagram represents an ultrafiltration membrane, but could represent any of the four membrane processes.

Permeate/Feed-Stream/ Retentant Diagram



Nanofiltration membranes have pore sizes midway between those of ultrafiltration and reverse osmosis. Nanofilters are often referred to as "softening" filters, since they are effective in removing multivalent cations such as calcium and magnesium.

Reverse osmosis (RO) removes salts from a water stream. It finds use wherever very pure water is needed, such as laboratories, medical uses including kidney dialysis, metal plating, boiler feed water, and other related applications. Typically, RO will reject 90 to 95 percent of the salts. RO is also used before strong acid/base deionization for the production of ultrapure water for laboratory, pharmaceutical, and microelectronics manufacturing operations.

Acoustic nanotube technology employs acoustics instead of pressure to direct water through small-diameter carbon nanotubes. The technology is based on an acoustically driven molecular screen integrated with carbon nanotubes that allow the passage of water molecules while blocking any larger molecules and contaminants. It consumes less power than traditional filtration systems and drives water away from contaminants instead of removing pollutants from water. The process also eliminates the need for flushing the filter system.

The primary applications of acoustic nanotube technology are municipal water plants, medical facilities, laboratories, distilleries, desalination plants, industrial facilities, wastewater treatment plants, and the consumer segment. The innovation is scalable with the integration of multiple filters, according to the filtration needs of users[6].

Photocatalytic water purification technology uses photocatalysts and ultraviolet (UV) rays to remove toxic substances from water. Photocatalysis can break down a range of organic materials, estrogens, pesticides, dyes, crude oil, and microbes such as viruses and chlorine-resistant pathogens, as well as inorganic compounds such as nitrous oxides. Photocatalytic water treatment systems are suitable for use in water and wastewater treatment facilities and can treat industrial wastewater polluted with high loads of organic substances or metals. This technology was developed by Panasonic[6].

Automatic Variable Filtration (AVF) technology is a simple process by where upward flow of influent is cleaned by downward flow of filter media. It eliminates the need for any additional process or freshwater for filter media cleaning. AVF systems are suitable for municipal drinking water and wastewater treatment, wastewater recycling and reuse, pre-filtration for membrane processes and desalination applications[7].

6, 6, 7 *https://www.water-technology.net/features/latest-water-purification-technologies-top-five/*

Best Management Practices for RO and Nanofiltration Systems

- Size equipment to meet the need
- Choose systems that maximize the percent of water that is recovered as product water
- Require that new systems achieve at least 75% product recovery
- RO and nanofiltration reject water should be captured and reused for irrigation, cooling tower makeup, and other appropriate uses wherever possible

Distillation is a process once common to make water for laboratory applications and is still found in many laboratories. Electric or gas stills are the most common still types. Production quantity depends upon the size of the still. Smaller stills often use once-through condenser water and can waste huge volumes of water to produce a single gallon of distillate. Small and medium size stills use air to cool the coils and have no discharge. These are the most water efficient stills. Some larger stills have reject streams to prevent scale buildup. These typically dump 15-25% of the water entering the still.

Best Management Practices for Distillation Systems

- Do not use systems that rely on once-through cooling
- Air cooled systems and systems that use the feed water for cooling should be used

Disinfection and related technologies can consume small amounts of water if chemicals are fed in a liquid or slurry form. Chemical disinfection technologies include use of chlorine compounds, ozone, and hydrogen peroxide, as well as pH control with acids and bases and the addition of antiscalants and sequestrates such as sodium hexametaphosphate. Ultraviolet light, heat, and extreme mechanical sheer are among other technologies in use.

The potential for water savings by choosing among disinfection technologies is not great; however, the potential to waste water in cleaning the equipment and storage vessels is a concern which can be abated by the use of waterless cleaning methods

Recommendations

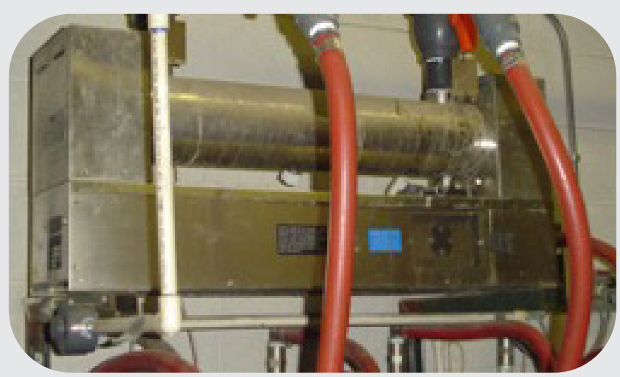
- For all filtration processes, require pressure gauges to determine when to backwash or change cartridges
- For all filtration processes, base backwash upon pressure differential
- For all ion exchange and softening processes, require recharge cycles to be set by volume of water treated or based upon conductivity controllers
- Use water treatment only when necessary
- Choose a reverse-osmosis or nanofiltration system with the lowest reject rate for its size
- Choose distillation equipment that recovers at least 85 percent of the feed water
- Evaluate opportunities to reuse backwash waste streams

Examples of Actual CII Water Treatment Systems

The following images provide examples of actual water treatment insulations in CII establishments.

"Bench-top" Ultra Pure Systems Commonly found in Laboratories

Ultra Violet Water Disinfection System



Images source: HW (Bill) Hoffman & Associates, LLC

Examples of Actual CII Water Treatment Systems (continued)

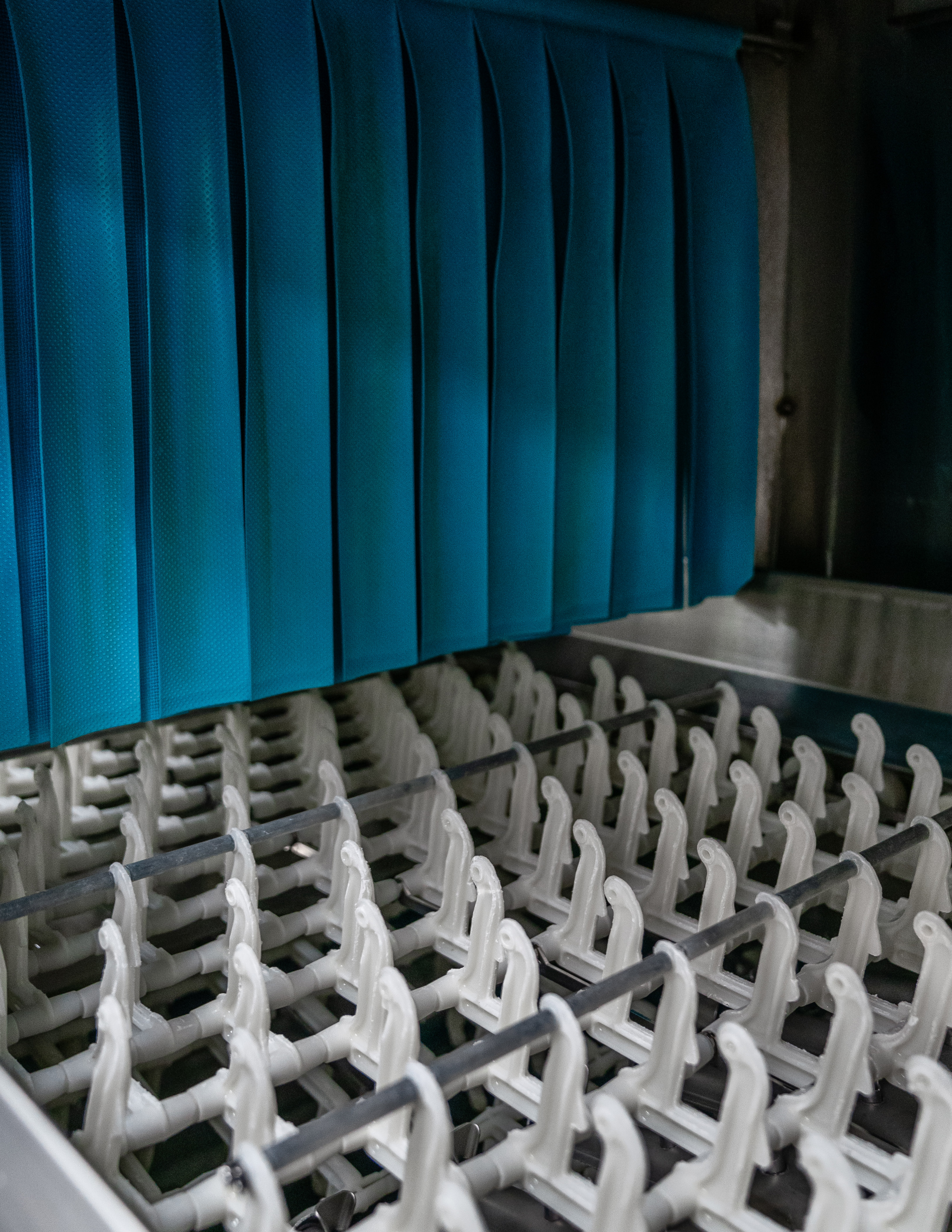
RO Filters at a Car Wash

Sand Filter for Olympic Size Swimming pool

Images sources: HW (Bill) Hoffman & Associates, LLC

Resources

1. Appliance Standards Awareness Project 2021
   https://appliance-standards.org/product/faucets#:~:text=In%202015%2C%20the%20California%20Energy,maximum%20flow%20rate%20for%20private
2. California Building Standards Commission
   https://www.dgs.ca.gov/BSC/Codes
3. California Energy Commission, California Code of Regulations Title 20, Sections 1601 Through 1608, Toilets, Urinals, and Faucets Regulations Effective January 1, 2016.
4. California Energy Commission, Appliance Efficiency Regulations - Title 20
   https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20
5. California Green Building Standards Code—Part 11, Title 24, California Code of Regulations—known as CALGreen
   https://www.dgs.ca.gov/BSC/CALGreen
6. California Green Building Standards Code Chapter 5, Division 5.3
   https://codes.iccsafe.org/content/CAGBC2022P1/chapter-5-nonresidential-mandatory-measures#CAGBC2022P1_Ch05_SubCh5.3_Sec5.303
7. CalGreen Plumbing Fixture Requirements
   https://calgreenenergyservices.com/2019/11/30/calgreen-plumbing-fixture-requirements/
8. California Plumbing Code 2019
   https://up.codes/viewer/california/ca-plumbing-code-2019/chapter/4/plumbing-fixtures-and-fixture-fittings#411.0
9. John Koeller, P.E., Koeller & Company, Bill Gauley, P.Eng., Gauley Associates, Ltd., MaP Testing, Commercial Flushometers Toilet & Urinal List Downloads - May 4, 2021
   https://www.map-testing.com/downloads.html
10. National Conference of State Legislatures, Water-Efficient Plumbing Fixtures
    https://www.ncsl.org/research/environment-and-natural-resources/water-efficient-plumbing-fixtures635433474.aspx
11. Plumbing Supply.com, Showeroff® Metering Shower Systems
    https://www.plumbingsupply.com/metering-shower-systems.html
12. US EPA, WaterSense Commercial Toilets Specifications
    https://www.epa.gov/watersense/commercial-toilets#:~:text=WaterSense%20labeled%20flushometer%2Dvalve%20toilets,adequate%20flow%20to%20function%20effectively
13. US EPA, WaterSense, Case Studies for Commercial Buildings
    https://www.epa.gov/watersense/case-studies
14. US Department of Energy, Energy Cost Calculator for Urinals
    https://www.energy.gov/eere/femp/energy-cost-calculator-urinals#output



Chapter 9
FOOD SERVICE OPERATIONS

The food service operations sector includes technologies and equipment found in commercial kitchens, which are establishments that prepare food for public consumption or where food can be prepared for many people. Restaurants and bakeries are obvious members of this category, but commercial kitchens exist in a wide range of facilities. Most schools, hospitals, hotels, service stations with stores, and convenience stores have food service operations. Larger office buildings, factories, and institutional facilities provide food service of some type to their employees and occupants. Because food-service facilities are characterized by many kinds of water uses and high energy and water consumption, they are a good focus group for incentives or requirements for water-efficient equipment, both for new construction and retrofit of existing facilities.

Water is an essential component in a commercial kitchen; it is used for everything from food preparation to cooking, cleaning, refrigeration, and sanitation. Based on a 2019 study by The Water Research Foundation, eating and drinking places have the most intensive water use per square foot of any commercial and institutional facility (Table 9-1). This conclusion is based on data from six water utilities across the nation. Additionally, a 2015 California Energy Commission report shows that over 75 percent of hot water in the commercial and institutional sectors, from grocery stores to schools to prisons, is used by food service operations[1]. Thus, more efficient hot water use and energy efficient appliances will contribute to improved water efficiency and cost savings in this sector.

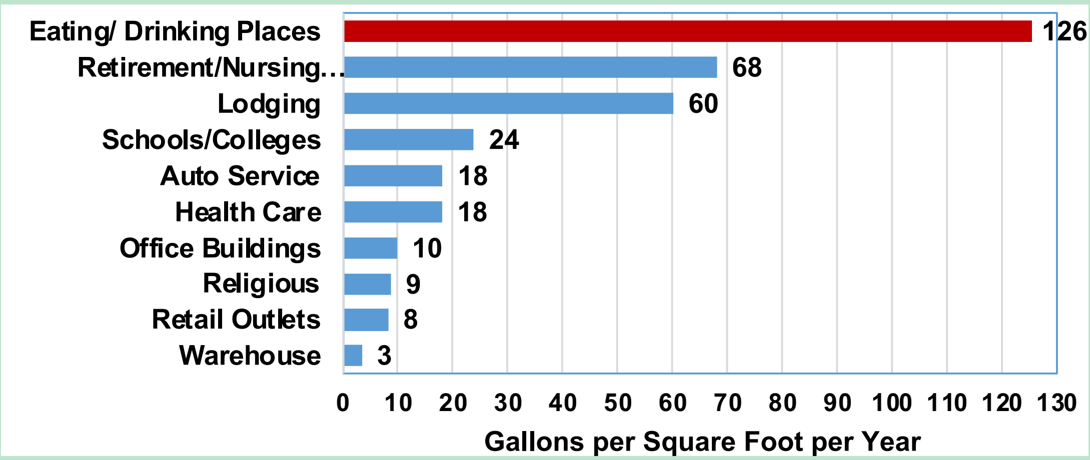
The US Environmental Protection Agency (EPA) WaterSense at Work Program estimates that 52 percent of a restaurant's water use is for kitchen use with the rest being for restrooms, landscape, and other uses (Table 9-2). The latter uses are covered in other chapters in this document. The focus of this section will be on the techniques and technologies applicable to operations in the kitchen and any other food service area.

See the References section at the end of this chapter for a list of resources.

This chapter will examine the operational areas of water efficiency in the food service sector, including:

1. Selection of food service equipment
2. The potential cost savings with each technology and method of operation
3. Best management practices for each technology and method of operation

TABLE 9-1: Comparison of Water Use per Square Foot per Year for Various Commercial Establishments Across the USA



1 Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment in Foodservice Facilities
https://babel.hathitrust.org/cgi/pt?id=uc1.31822039658588&view=1up&seq=1

General Considerations to Reduce Water Use

The transition to water efficient practices and procedures relies on the successful implementation of processes that achieve and monitor the following:

- Training staff on the proper use of equipment and selecting efficient equipment
- Prompt reporting of malfunctions and leaks and systems to ensure these problems are addressed swiftly
- Tracking water use and water, wastewater, pretreatment, and energy costs associated with water

Selection of Food Service Equipment

The selection of water and energy efficient equipment is a cornerstone of minimizing water and energy costs. There are many water efficient equipment options available on the market. In this section, the following types of equipment will be discussed:

- Refrigeration and Freezer Equipment
- Ice Makers
- Water Using Cooking, Preparing, Serving, and Holding Equipment
  - a. Food Steamers and Combination Ovens
  - b. Steam Kettles
  - c. Pasta Cookers
  - d. Woks
  - e. Steam Tables
  - f. Food Prep Sinks
  - g. Reverse Osmosis Filtration System
- Scullary Operations
  - a. Three Compartment Sinks
  - b. Pre-rinse Spray Valves and Sluice Troughs
  - c. Food Waste Disposal Methods
  - d. Pot Soakers
  - e. Commercial Dishwashers
  - f. Dipper Wells
- Washing and Sanitation
  - a. Floor Washing
  - b. Hood Washing
  - c. Washing Outdoor Areas
  - d. Hand Washing Sinks

Refrigeration and Freezer Equipment

Commercial Refrigerator

Air-cooled refrigeration equipment is the most common type of equipment found in food service facilities. In some cases, this equipment can be connected to the chilled water system.

In cases where facilities have cooling towers as part of their air conditioning system, it is important to choose the most efficient equipment to reduce the heat load on the cooling tower.

Ice cream, gelato, and frozen beverage equipment and similar equipment should always be air-cooled. Refrigeration equipment can also play a significant role in reducing the use of water to thaw food (see previous section on water efficient practices). Ensuring proper capacity to thaw food in a refrigerator is a water conservation method.

Once-through cooling systems, sometimes called single-pass cooling, are prohibited in California and in all modern plumbing codes.

Ice Makers

Commercial Ice Maker

Ice making equipment can be either air or water cooled. Neither the EPA or the California Energy Wise program list water-cooled equipment and once-through cooling is prohibited in California and all modern green plumbing codes. However, the Federal Energy Management Program does allow water-cooled ice makers if the water is hooked to a chilled water or cooling tower water circuit.[2] Ice making equipment is rated on how many pounds of ice the machine makes in one day. One hundred pounds of ice is equivalent to 12 gallons of water.

There are two types of ice makers: batch type and continuous.

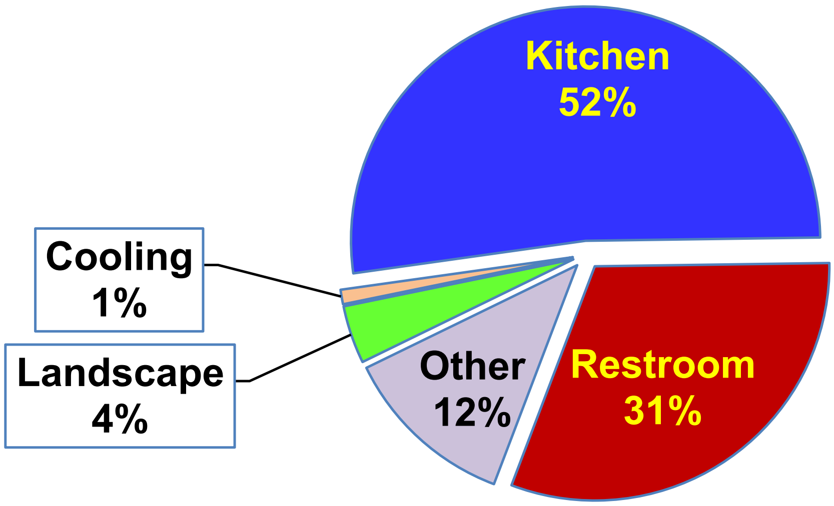
- **Batch type (cube)** ice makers produce a hard cube that has been rinsed to remove minerals that may precipitate out in the freezing process. Water is frozen in small ice trays and rinsed in the last phase of the process. The ice trays are dumped into the ice bin when finished.
- **Continuous type** ice makers have a rotating drum. Water freezes on the inside of the drum where it is scraped off with an auger in the form of flakes of ice. This equipment operates continuously. Flake ice is often used in operations such as salad bars. The flake ice can be formed into shapes for use in drinks.

Methods of cooling ice makers:

- **Water-cooled** ice makers can be cooled by simply passing tap water through a heat exchanger and dumping it into the sanitary sewer. This is called pass-through or once-through cooling. The heat exchanger can also be connected to a chilled water loop or cooling tower loop.
- **Air-cooled** ice makers can reject the waste heat generated into the room where it is located. These are called “ice making heads” (IMH). The compressor part of refrigeration equipment can also be located outside, similar to home air conditioning units. These are called “remote condensing units” (RCU). This type of ice maker rejects compressor heat to the outside. Another type of air-cooled ice maker is the self-contained, smaller, under the counter ice maker (SCU).

The Air Conditioning Heating and Refrigeration Institute (AHRI) lists both air- and water-cooled ice makers and information about water use for different ice makers is available through their website.

TABLE 9-2: Typical Water Use in Restaurants



2 https://www.energy.gov/eere/femp/purchasing-energy-efficient-water-cooled-ice-machines

Recommendations

- Purchase only air-cooled EPA certified ice makers meeting US Environmental Protection Agency – Energy Star criteria. Energy Star program criteria for ice makers can be [found here](#)
- Consider remote head equipment to reduce heat buildup in the building
- Use continuous ice makers that use less energy and water than batch/cube machines

Water Using Cooking, Preparing, Serving, and Holding Equipment

This section describes water conservation best management practices for the following equipment:

- Food Steamers and Combination Ovens
- Steam Kettles
- Pasta Cookers
- Woks
- Steam Tables
- Food Prep Sinks

Food Steamers and Combination Ovens

Combination oven

These two types of equipment are used to cook food using steam. Food steamers can only use steam to cook food while combination ("combi") ovens can cook either in steam mode or dry mode like conventional ovens. Combination ovens also have a feature where moisture can be injected into the cooking cavity during baking to keep the food from drying out. For both types of equipment, there are boiler and boilerless options. There are also pressure and vacuum options available for total pressure and temperature control.

Boiler type steamers and combi ovens use a separate boiler that produces steam. This boiler often requires that water feeding it is softened or otherwise treated to make it usable with the appliance. Because the boiler type steamers and combi ovens must be connected to both a water supply and sewer line, setting one up is costly and location options for installation in the kitchen are limited. They also require that makeup water be treated to remove minerals that can be deposited on the boiler surfaces and require regular descaling to remove deposits. When gas is used, the combustion gases must be vented. Boiler type steamers and combi ovens also require that water be purged from the boiler at the end of each run time and produce condensate that must be sent to the sanitary sewer. Plumbing codes[3] require that water discharged to the sewer be below 140°F.

To accomplish this, most steamers and combination ovens operating in steam mode run potable cold water continuously down the drain to ensure that the discharge is below 140°F.

Depending on the design and size, boilers can hold from three to over fifteen gallons of water which is dumped every time the equipment is turned off. During the cooking process, steam condensate is constantly discharged. Many steamers automatically open a valve to run water down the drain continuously while in operation to ensure that adequate cold water is flowing to achieve 140°F or less. Water tempering devices are available that only allow tempering water to flow when hot water is present. Costs for the tempering kits are in the range of $1,000 to $2,500.

Boiler type steamers are typically only used where a variety of items must be cooked on-demand since they have a faster recovery time, but if a set menu or quantity of food is produced or a feasible plan is created for facilities where food is cooked on-demand, boilerless steamers and combi ovens are a great alternative.

3 *https://forms.iapmo.org/email_marketing/codespotlight/2018/Nov15.htm*

Boilerless steamers use significantly less energy and water and do not require tempering water at all.

The Federal Energy Management Program, based on Food Service Technology Center data, reports that **boiler type steamers typically use 30 times more water than boilerless type steamers.**[4]

Boilerless steamers only require a power source and that a reservoir be filled manually. Since they use a closed system, steam condensate is re-boiled for multiple uses.

Benefits of boilerless steamers and combi ovens include:

- 30 times less water used than boiler-type steamers
- No tempering water needed
- Much less energy use in the steam mode for combi ovens – some report up to 75 percent savings
- No need for expensive water pretreatment
- No need for water and sewer connections
- Fewer moving parts to break
- Ease of cleaning

Recommendations

- Prioritize boilerless steamers and combination overns wherever possible
- Only use boiler type equiment where absolutely necessary
- Look for the EnergyStar label when purchasing equipment
- Consider installing water tempering devices on boiler type discharges
- Do not turn on the steamer until ready to cook. Only use the steam compartments that are needed
- Keep in mind that steamers require 15 minutes or less to preheat
- Cut down idle time on boiler steamers
- Maintain the equipment with regular maintenance checks:
- Inspect door gaskets. A badly aligned door hinge can let steam escape, increasing business costs on water and energy, and increasing cooking times.
- Cool full loads of food in the combi oven whenever possible

Steam Kettles

Steam kettles are used to cook large volumes of food. There are two types of steam kettles:

1. Steam can be either provided by remote boiler or
2. By a self-contained boiler, where food and water are loaded into the kettle and the jacket around the kettle is heated with steam.

When a remote boiler is used, steam condensate should be returned to the boiler. For self-contained boilers, condensate is automatically returned to the boiler in most cases. Softened and often demineralized water is used to feed self-contained boilers. Remote boilers also require specially treated water.

Recommendations:

- Purchase steam kettles with self-contained boilers when possible
- Where a central boiler is used to provide steam, ensure that steam condensate is returned to the boiler
- Ensure that the drain valve does not leak which can easly happen if food lodges in the valve
- Train staff to properly clean the kettle with water savings in mind

Pasta Cookers

Pasta cookers are designed to boil water and cook pasta. The principal is straightforward: water is boiled and pasta is placed in the boiling water to cook. Water needs to be dumped and replaced only when the starch content of the water is too high and causes excessive foaming.

When buying a pasta cooker, it is important to consider the volume of water needed for pasta at the food service operation. In a small venue not focused on pasta service, a smaller pasta cooker that holds about 2 to 3 gallons should be considered. Larger venues where pasta is a major component of what is served should consider a

4 https://www.energy.gov/eere/femp/water-efficient-technology-opportunity-connectionless-food-steamer

larger floor model that can hold up to 12 gallons. Pasta cookers can also hold more than one vat for cooking. Since the cooker water can reach over 140°F, it must be cooled prior to discharge. Allowing water to sit and cool at the end of the day prior to discharge will save water, rather than using tempering water.

Recommendations

- Adjust the equipment temperature to just high enough to cook pasta to save water and energy (simmer or slow boil)
- Only refill when starch content limit is reached
- Select equipment with overflow controls
- Allow water to cool before dumping so tempering water is not needed
- Train staff on the proper ways to operate a pasta cooker

Woks

Woks are used to cook items in oil at high temperature. Using conventional woks requires a continuous water flow over the stove surface where woks are being used to keep temperatures low enough for cooks. This water is typically discharged to the sewer once it flows over the stove top.

Waterless woks are available. In this type of wok, the top of the stove is insulated so cooling water is not needed. Waterless woks also require less maintenance and corrosion damage is reduced, according to an Australian study.[5]

Recommendations

- If possible, use waterless woks
- If conventional woks are used, a "knee bump" valve can be installed so water is only used when someone is at the stove cooking
- Adjust flows to the minimum amount needed if using a conventional wok

Steam Tables

Steam tables have been a common piece of equipment on food serving lines for decades. These are used to keep food above 140°F so it is safe to eat. Health codes require this temperature for hot foods on serving lines.

Steam Tables

These tables have three working parts:

- They can hold significant volumes of very hot water
- The water is kept hot with either electric or gas heat.
- Trays of hot food are placed in the open "wells" to keep the food hot.

At the end of each meal cycle, the water is dumped. Both open-well and sealed-well tables are available. The difference is that sealed-well tables have built-in tray containers to hold the food trays without coming into contact with the hot water. Large steam tables can hold over 100 gallons of water.

The discharge of hot water at the end of a serving cycle must be controlled so as not to exceed 140°F when being drained into the sewer.

Dry serving line equipment that does not use hot water to keep the food at adequate temperature is available.

Recommendations

- Use dry serving equipment wherever possible
- If steam tables are used, minimize the water level and reuse the hot water that is dumped for mopping and other cleaning uses

5 *https://p2infohouse.org/ref/50/49033.pdf*

Scullary Operations

This section describes water conservation best management practices for the following equipment:

- Three Compartment Sinks
- Pre-rinse Spray Valves and Sluice Troughs
- Food Waste Disposal Methods
- Pot (Power) Soakers
- Commercial Dishwashers
- Dipper Wells

TABLE 9-3: Spray Valve Comparison

Nozzle Rated Flow (Gallons per Minute)	1.6	1.28	1.2	1.0
Daily Usage (hrs.)	3 hours	3 hours	3 hours	3 hours
Gallons per Day	288	230	216	180
Gallons Annually	105,120	84,096	78,840	65,700

Three Compartment Sinks

Thee compartment sinks are the workhorse of the food service industry. These multi functional sinks are most commonly used to wash cooking utensils, pots and pans, and other kitchen ware. They come in several configurations but the classic dish washing configuration is to use the first compartment for soapy water, the second to rinse, and the third to hold a disinfectant solution. The most important water conservation technique for three compartment sinks is to train employees on proper ways of using the sink.

Three Compartment Sink

Recommendations

- Do not overfill the basins
- Turn water off when not needed
- Do not use three compartment sinks for washing hands
- Promptly report faucet leaks and other malfunctions

Pre-Rinse Spray Valves and Sluice Troughs

Pre-rinse spray valves are used to spray and remove food wastes prior to placing the plates, pots and other food service ware in the dishwasher. The food waste is either washed directly into a food waste grinder or into a sluice trough. A sluice trough washes food waste into the grinder where the food waste is ground up and washed into the sanitary sewer. The WaterSense threshold established by the Department of Energy limits the flow rate for pre-rinse spray valves to under 1.28 gallons per minute.[6] Hot water is often used for pre-rinse spray valves.

If hot water is used with a spray valve, the valve consumes both energy and water. In a large restaurant serving breakfast, lunch, and dinner, such a valve may have as many as four hours of continuous use. Table 9-3 that compares different flow rates of spray valves and their water use.

6 https://www.epa.gov/watersense/pre-rinse-spray-valves#:~:text=The%20U.S.%20Department%20of%20Energy,energy%20regulation%20covering%20these%20devices

Recommendations

- Eliminate or minimize the use of sluice troughs and reduce their flow to a minimum
- Install pre-rinse spray valves that use less than 1.28 gallons per minute
- Do not keep the valve on continuously
- Follow recommendations for food waste disposal in the next section
- Wait until the dishwashing rack is completely full before sending it through a mechanical dishwasher
- Presoak utensils and dishes instead of rinsing them under running water

Food Waste Disposal Methods

There are three methods to dispose of food waste, commonly referred to as food scraps, produced during food service preparation and dishwashing operations:

1. Via a commercial compost pickup service/facility
2. Via the solid waste stream
3. Into wastewater
4. Guidelines established by local jurisdictions should be referred to when planning to dispose of food waste in solid food waste containers (because of potential problems with insects and rodents) and in general when devising food waste disposal systems. ome common methods of disposing of food waste used by food service operations are:
   - Composting Options
   - Food Grinders (disposers)
   - Mechanical strainers
   - Pulpers
   - Strainer baskets

Composting

As of January 1, 2022, people and organizations throughout California are required to separate organic material (mainly food scraps and yard waste) from other garbage[7]. Composting is the natural process of breaking down biodegradable materials into a rich soil known as compost. Materials can include not only organic matter such as vegetables, but also biodegradable packaging such as food-soiled cardboard boxes or compostable-certified films and bags.

Composting Options

Under SB1383, commercial properties in California must:[8,9]

- Get Service – sign up for organics recycling
- Set Up Indoor Bins – complete with color-coded bins and labeling
- Sort Correctly – materials must be placed in proper bins
- Donate Surplus Food – some businesses, such as large restaurants, must recover and donate surplus food

Commercial food service establishments must therefore structure their food preparation and disposal workflows to prioritize composting. For readers in areas without mandatory composting requirements, such voluntary practices may still confer water savings.

Food Grinders (Disposers)

The operation of food waste grinders in food service operations is the same as home disposer operation. Food

7 https://www.californiacompostlaw.com/
8 https://www.stopwaste.org/rules/overview
9 https://www.cccrecycle.org/224/SB1383-Organic-Waste-and-Edible-Food-Rec

waste enters the grinder and mixes it with water which is then discharged to the sanitary sewer. Grinders of different horsepower and water flow rates are available.

Mechanical strainers

Mechanical strainers have large strainer baskets that catch food waste for disposal. Water is drained into the sanitary sewer or can be recirculated for rinsing plates and other items before placing them in the dishwasher. This eliminates the need for a pre-rinse spray valve in many cases. Since food solids are strained from the waste stream, they require less water per minute than garbage grinders and use less electricity. The food solids can be disposed of along with other solid waste from the facility or diverted to a composting operation.

Pulpers

Pulpers use an extruder screw to squeeze water out of food wastes. Like the mechanical strainers, this equipment can include a recirculation feature that recirculates water to wash food waste from plated and other items. Water removed from the food is either sent to the sanitary sewer or a limited part of the water is recirculated. These systems have the advantage of removing solid waste, fats, oils, grease, and other components from the wastewater. According to manufacturers' literature, they can also recirculate up to 75 percent of the water to the head of a sluice-trough system. The food solids can be disposed of along with other solid waste from the facility or diverted to a composting operation.

Strainer Baskets

Strainer baskets are one of the least energy and water intensive technologies for capturing and diverting food waste from the sanitary sewer, as they require no water use. They can replace mechanical operations such as garbage disposals, and thus eliminate the water use associated with those technologies[10]. Strainer baskets can be installed in sink drains and in tandem with pulper systems.

Comparison of Disposal Methods

When comparing food waste disposal techniques, three considerations need to be made:

- Water and Energy Use
- Overall Resource Use
- Ease of Staff Use

Table 9-4 shows the basic considerations when choosing a method of food waste management. The pre-rinse spray valve and grinder combination is the most common method used by food service facilities, however, it tends to have the most energy and water use, especially if sluice troughs are used. Both mechanical strainers and pulpers produce a wet concentrated waste stream and use energy and water, although less than a food grinder trough system. Strainer baskets require the least amount of energy and water inputs. Mechanical strainers and pulpers use less water and energy than grinders. From a staff standpoint, a disposer – trough – pre-rinse spray valve system may require less work, while the other three systems require about the same amount of human effort.

Understanding that each application has unique needs, the table is intended to be a decision-making matrix, with each facility choosing the least energy and water intensive options that continue to meet their specific requirements.

Recommendations

- The most efficient food disposal method is to compost food waste directly rather than relying on a food disposal device. If in California, refer to your local city or other jurisdiction's specific compliance process with the Compost Law
- Use strainer baskets for the lowest water and energy use and the potential to compost
- If food grinders, pulpers, mechanical strainers, and/or food waste disposers are used, ensure they have a time out system with push button to reactivate. The maximum allowable run time cycle shall be 10 minutes[11]
- Sluice troughs should have automatic shutoffs

Pot (Power) Soakers

Pot or power soakers are often use in food service establishments where many pots, pans and casserole dishes must be washed. These systems are comprised of large stainless steel vessels filled with hot soapy water. This combination of hot water and soap softens and helps remove baked on food materials. It also reduces the time employees must scrub such items and how long pre-rinse spray valves may be needed. After soaking, the items can be hand washed in a three compartment sink or placed in a dishwasher. The water used in this system is maintained at a temperate of 115°F to 120°F and the water is vigorously recirculated.

10 https://www.epa.gov/system/files/documents/2023-05/ws-commercial-watersense-at-work_Section_4.9_Food_Disposals.pdf
11 https://epubs.iapmo.org/NSPC/2021/

TABLE 9-4: Food Waste Disposal Technologies

Impact of Technology	Grinder	Mechanical Strainers	Pulper	Strainer Basket
Solids to Sewer	Yes	No	No	No
Recirculate	No	Yes	Yes	No
Strain Solids Recovered	No	Yes	Yes	Yes
Compost Possible	No	Yes	Yes	Yes
Flow Restrictor	Yes	No	No	N/A
Horse Power	1-10	0.75-7.5	3-10	0
GALLONS PER MINUTE (Potable only)	3-8	1-2	1-2	0
Sluice Trough GALLONS PER MINUTE	2-15	2-15	2-15	0
Water Recirculation	No	Yes	Yes	N/A

The main function of a pot or power soaker is to save employee cleaning time. Typical dimensions vary. Some systems are configured with a rinse and sanitizer sink following the power soaker. Water use depends on the depth to which the soaker is filled and the number of times it is dumped and refilled.

Recommendations

- Keep water levels as low as possible
- Only dump and refill when water becomes laden with food particles

Dipper Wells

Dipper wells have been used for decades to rinse and hold ice cream scoops and other serving utensils between uses. Traditional dipper wells operate by having a constant stream of potable water flow over the utensils and down the drain. In a 2017 study by Frontier Energy,[12] dipper wells in ice cream shops, juice shops and restaurants used over 500 gallons of water a day. A potential problem with traditional dipper wells is that the valve can be left on when the well is not in use.

The dipper well is a tool of convenience and can easily be replaced with a number of available alternative technologies. Options include cleaning procedures such as shower rinse for the scoop, or a heat utensil holder that maintains a minimum water temperature of 135°F. The above-referenced Frontier Energy report describes some of these alternatives.

The California Energy Commission is currently considering updated appliance efficiency regulations for dipper wells. The California Investor-Owned Utilities (CA IOUs) advocate for establishing a maximum flow rate of 0.2 gallons per minute at a supply pressure of 60 pounds per square inch[13]. This recommendation “aligns with both the 2023 International Association of Plumbing and Mechanical

12 *https://www.bewaterwise.com/assets/2015icp-dipperwellfrontierenergy.pdf*
13 *https://efiling.energy.ca.gov/GetDocument.aspx?tn=260581&DocumentContentId=96883*

Officials (IAPMO) Water Efficiency and Sanitation Standard (WE-STAND)[14] and 2024 IAPMO Uniform Plumbing Codes."[15]

Recommendations

- Use one of the alternatives to dipper wells now available
- Consider rinsing scoops under a faucet with a 0.5 gallons per minute aerator
- If dipper wells are used, install a flow restrictor to adjust the flow to a maximum of 0.2 gallons per minute
- Ensure staff knows that dipper well faucets should be shut off at the end of the work day
- Store ice cream scoops that require a dipping well in hot water (140°F or above) or in the ice cream itself with the handle out (each flavor must have its own individual scoop)

Dishwashers

Dishwashers can be assessed by machine type and method of sanitation they use. Operational considerations are discussed below.

Method of Sanitation

There are high temperature and low temperature dishwashers (also known as chemical sanitizing machines). High temperature systems use hot water to sanitize dishes while chemical types use chlorine compounds.[16] Chemical sanitizing systems tend to use more water per rack than high temperature systems. The EPA Energy Star program classifies dishwashers into high temperature and low temperature type categories.

Energy Star requirements for energy and water use are shown in Table 9-5. Note that a "rack" is a 20 inch by 20 inch rack where dishes and ware are placed to be inserted into the washer.

Machine Type

As the table above shows, there are many machine types:

- Under the counter machines
- Door-type dishwashers that allow a rack of dishes to be placed in the washer
  - Wash cycles typically last from one to three minutes
- Conveyor systems that pull the racks through the machine
- Flight type washers that operate by continuously pulling pegged racks of ware to be washed through the machine. Washing is complete in one to three minutes.
  - These systems are designed for very high volume operations; typically found in large institutional facilities such as hospitals and large hotels with banquet facilities

TABLE 9-5: Energy Star Requirements for Energy and Water Use

Machine Type	High Temp Efficiency Requirements		Low Temp Efficiency Requirements	
	Idle Energy Rate*	Water Consumption**	Idle Energy Rate*	Water Consumption**
Under Counter	≤ 0.30 kW	≤ 0.86 GPR	≤ 0.25 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.55 kW	≤ 0.89 GPR	≤ 0.30 kW	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 0.90 kW	≤ 0.58 GPSF	n/a	n/a
Single Tank Conveyor	≤ 1.20 kW	≤ 0.70 GPR	≤ 0.85 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 1.85 kW	≤ 0.54 GPR	≤ 1.00 kW	≤ 0.54 GPR
Single Tank Flight Type	Reported	GPH ≤ 2.975x + 55.00	n/a	n/a
Multiple Tank Flight Type	Reported	GPH ≤ 4.96x + 17.00	n/a	n/a

14 https://iapmo.org/newsroom/press-releases/2023-iapmo-water-efficiency-and-sanitation-standard-now-available
15 https://epubs.iapmo.org/2024/UPC/
16 https://www.anfponline.org/docs/default-source/legacy-docs/docs/ce-articles/fpc112017.pdf

Dump and Fill vs. Recirculation

Most door type dishwashers are dump and fill type machines. Conveyor and flight types can recirculate water form the rinse cycle for the first wash if they are multi tank types. Multi tank washers are more water efficient.

Operational Considerations

- In busy food service operations where large amounts of racks are washed small differences in gallons used per rack becomes important
- Employees failing to fill dish racks completely is a practice that wastes water
- The restaurant industry makes extensive use of refurbished dishwashers. Many of these older refurbished models are far from water efficient

Recommendations

- When leasing or purchasing equipment, always specify that the dishwasher meets Energy Star criteria
- Do not allow leasing entities to install old, non-qualified equipment, and instruct them to set the equipment for energy and water efficient operations
- Train staff in how to properly operate the equipment
- High temperature machines are more water efficient in general
- Use multi-tank washers where possible
- “Fill and dump” style machines are not recommended

Washing and Sanitation

- Floor Washing
- Hood Washing
- Washing Outdoor Areas
- Handwash Sinks
- Clean in Place Systems

Mop Sink

Floor Washing

Cleaning floors in kitchen, dining, and restroom areas is a reccuring operation. A customary practice is to mop the kitchen floor with soapy water and use a high-pressure hose with hot water to rinse the soapy water into the floor drain. Squeegees are an alternative for the removal of excess soapy water without the need for additional clean water. Where the floor is full of tables and chairs or food preparation equipment, mopping is often the only choice for cleaning. When cleaning items such as meat processing equipment or floors with a lot of grease and oils, pressure washing may be necessary. In these cases, high pressure equipment that sprays both cleaning chemicals and high-pressure water can be used. Pressure washers with hoods that contain the spray and minimize water use can be used, and some have a vacuum adaptation that will vacuum up the wash water.

Where floor space is more open and permits, floor cleaning machines that both clean and squeegee used water are available and are one of the most water efficient ways to wash floors.

Recommendations

- Ensure that all spray type equipment is equipped with self-closing nozzles
- Avoid using garden hoses without a nozzle
- Choose water efficient floor cleaners that both wash and squeegee the floor
- Choose pressure-washing equipment for floor and floor-mat washing
    - If hot water pressure washers are used, ensure that they use 2.5 gallons per minute or less
- Use floor-cleaning machines on smooth surfaces
- Arrange equipment so squeegeeing can be done easily

Hood Washing

Hoods over cooking equipment are found in most food service establishments. The hoods collect grease and other fire hazard material. Hand cleaning of hoods is time-consuming, whereas hood washer systems offer a convenient way to clean a variety of hoods.[17] The hood washer sprays soapy hot water over the grease-extractor systems after the hood is turned off. Timing can be pre-set depending upon the amount of grease that collects.

Hood washers may or may not use less water than conventional manual cleaning methods, depending upon the frequency of washing and how the water use with the hood system compares to water use of manual cleaning, usually done with a pressure washer. Hood systems may save water when properly operated.

Washing Outdoor Areas

Outdoor areas including outdoor eating areas, areas around dumpsters, food delivery truck areas, and other hard surface areas around a facility can often only be cleaned by washing. In general, sweeping is encouraged, but if water is needed a comparison of water broom flow rates to other equipment flow rates (such as hose nozzles or industrial wash down sprayers) should be made to decide on the best equipment to use.

Recommendations

- Sweep or use a leaf blower where possible
- In some jurisdictions, allowing wash water with detergents and/or chemicals is prohibited. In these cases, use cleaning techniques that also vacuum up the wash water.
- Use water brooms where runoff is not an issue.
- Water use should be limited to 3.0 gallons per minute or less.
- Limit low volume pressure washer use
- Do not use a garden hose without a shutoff nozzle

Handwash Sinks

Upgrading to 0.5 gallons per minute aerators in all kitchen handwash sinks can save significant water saving impact since hand washing is constant in food service establishments. Installing automated features for kitchen faucets can also help conserve water, such as motion sensor or hands free (foot or knee activated) faucets.

Upgrading the Aerator for a Handwash Sink

17 https://hvac-blog.acca.org/understanding-commercial-kitchen-exhaust-hoods/

Resources

1. Alliance for Water Efficiency, Commercial Kitchens Water Use Efficiency and Best Practices Guide, March 2017, *https://www.allianceforwaterefficiency.org/impact/our-work/commercial-kitchens-guide*
2. Alto-Shaam, Inc., *https://www.alto-shaam.com/en*
3. American Hospital Association, Optimize ice machine water use, *http://www.sustainabilityroadmap.org/pims/49#.YRV5zYhKjD5*
4. Arizona Municipal Water Users Association, Facility Manager's Guide to Water Management, August 2008, *https://www.amwua.org/resource_documents/facility_managers_guide.pdf*
5. California Energy Codes & Standards, CALGreen Commercial Kitchens, *https://title24stakeholders.com/measures/cycle-2016/calgreen-commercial-kitchens/*
6. California Energy Wise, *https://caenergywise.com/instant-rebates/*
7. California Legislative Information, AB-831 California Retail Food Code, *https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB831*
8. California Retail Food Code, *http://www.publichealth.lacounty.gov/eh/docs/specialized/cacode.pdf*
9. California Water Efficiency Partnership, BMP Cost and Savings Study Update, June 2016, *https://calwep.org/wp-content/uploads/2022/11/Cost-and-Savings-Study-Update-2016.pdf*
10. City Energy Project, Water Audit Guidance for Commercial Buildings, May 2019, *https://www.cityenergyproject.org/resources/water-audit-guidance-for-commercial-buildings/*
11. Consortium for Energy Efficiency, Inc., Commercial Kitchens Initiative Description, *http://www.cee1.org/content/cee-program-resources*
12. Consortium for Energy Efficiency, Inc., High Efficiency Specifications for Commercial Ice Machines, *https://library.cee1.org/content/cee-high-efficiency-specifications-commercial-ice-machines/*
13. Energy Star Program, Commercial Food Service Equipment, *https://www.energystar.gov/products/commercial_food_service_equipment*
14. Energy Star Program, Commercial Kitchen Equipment Tools, Materials and Resources, *https://www.energystar.gov/partner_resources/energy_star_training_center/commercial_food_service*
15. Energy Star Program, Commercial Buildings, *https://www.energystar.gov/buildings?s=mega*
16. Energy Star Program, Guide for Cafés, Restaurants, and Commercial Kitchens, *https://www.energystar.gov/sites/default/files/asset/document/ES%20Restaurant%20Guide%202017-2018%20v16.pdf?8f42-0607*
17. Foodservice Equipment & Supplies, Guide to Commercial Steamers, *https://fesmag.com/products/guide/cooking-equipment/13403-product-knowledge-guide-steamers*
18. Foodservice Equipment Reports, Inc., Building a Better Waste Management System, *https://www.fermag.com/articles/9966-building-a-better-waste-management-system/*
19. Frontier Energy, Dipper Well Replacement Field Evaluation Report, *https://www.bewaterwise.com/assets/2015icp-dipperwellfrontierenergy.pdf*
20. Frontier Energy, Flight-Type Dish machine Replacement—Field Evaluation Report, *https://www.meiko.us/fileadmin/editor_upload/meiko.us/Images/FEM_2019/SR_Marriott_Dishmachine_Replacement_1-29-2019.pdf*
21. Frontier Energy, *https://frontierenergy.com/commercial-foodservice/*

22. Grainger, Inc., *https://www.grainger.com/know-how/industry/food-and-beverage/kh-five-ways-to-conserve-water-and-save-money-in-the-food-and-beverage-industry*
23. KaTom Restaurant Supply, Calculating the Cost of Ownership of Commercial Refrigeration, *https://www.katom.com/learning-center/commercial-refrigeration-cost-ownership.html*
24. KaTom Restaurant Supply, Commercial Ice Maker Standards for Energy Efficiency, *https://www.katom.com/learning-center/new-efficiency-standards-ice-makers.html*
25. Natural Resources Defense Council 2021, New Efficiency Standards for Automatic Commercial Ice Makers Will Save $942 Million, *https://www.nrdc.org/experts/meg-waltner/new-efficiency-standards-automatic-commercial-ice-makers-will-save-942-million*
26. NYC Environmental Protection, Restaurant Managers Guide to Water Efficiency, *https://www1.nyc.gov/assets/dep/downloads/pdf/water/drinking-water/restaurant-managers-guide-to-water-efficiency.pdf*
27. SoCal Water$mart, Air-Cooled Ice Machines, *https://socalwatersmart.com/en/commercial/rebates/available-rebates/commercial-devices/air-cooled-ice-machines/*
28. South Florida Water Management District, Water Audits at Commercial and Institutional Facilities- A Guide for Facility Managers, July 2013, *https://www.sfwmd.gov/sites/default/files/documents/water_efficiency_improvement_self_assess_guide.pdf*
29. Sydney Water, The waterless wok stove, *https://p2infohouse.org/ref/50/49033.pdf*
30. The Public Health and Safety Organization, NSF/ANSI 3 Commercial Ware Washing Equipment Racks per Hour / Dishes per Hour / Water Consumption Calculations, *http://info.nsf.org/Certified/food/Listings.asp?Standard=003&Company=08850&*
31. The US Environmental Protection Agency Energy Star, *https://www.energystar.gov/productfinder/*
32. US Department of Energy, Water-Cooled Ice Machines, *https://www.energy.gov/sites/prod/files/2013/10/f3/spec_watercooledicemachines.pdf*
33. US EPA, *https://www.epa.gov/greenerproducts/identifying-greener-foodservice-and-foodservice-ware*
34. US EPA, *Pre-Rinse Spray Valves, https://www.epa.gov/watersense/pre-rinse-spray-valves*
35. US EPA, WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities, *https://www.epa.gov/sites/default/files/2017-02/documents/watersense-at-work_final_508c3.pdf*
36. USDA Food Safety and Inspection Service, The Big Thaw — Safe Defrosting Methods, *https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/big-thaw-safe-defrosting-methods*
37. Vulcan, An Introduction to Food Steamers – Commercial, Industrial, and Restaurant Steamers, *https://www.vulcanequipment.com/blog/introduction-food-steamers-commercial-industrial-and-restaurant-steamers*

Chapter 10
LAUNDRIES AND DRY CLEANING OPERATIONS

This chapter will provide an overview of the standards and water use characteristics of laundry equipment, including water saving technologies such as water reuse, recycling, and ozone.

A Typical Laundromat

Photo by Ryan McGuire from Pixabay

Commercial laundry operations cover a range of applications from laundromats and common laundry-rooms in apartment buildings, to on-premises laundries for institutions and commercial operations, such as hotels, nursing homes, hospitals, athletic facilities, and prisons. Industrial laundries offer services for the same set of on-premises users, as well as uniform, diaper, and linen services. Dry-cleaning establishments often have on-premises laundry equipment as well. The U.S. laundry facilities and dry-cleaning services market size is expected to reach USD 14.4 billion by 2028. It is estimated to grow at a compound annual growth rate (CAGR) of 4% from 2021 to 2028.[1]

The first equipment standards were enacted at the state level in California with the Warren-Alquist Act in 1974.[2] At the national level, the Energy Policy and Conservation Act (EPCA) was enacted in 1975, and established a federal program consisting of test procedures, labeling, and energy targets for consumer products. EPCA was amended in 1979 and the Department of Energy (DOE) was directed to establish energy conservation standards for consumer products.[3] Federal energy efficiency requirements established for covered products under EPCA generally supersede State laws and regulations concerning energy conservation testing, labeling, and standards.[4]

Table 10-1[5] summarizes the size of various types of entities that have commercial or industrial laundries or use industrial laundries for cleaning their fabrics.

TABLE 10-1: US and California Laundry and Dry-Cleaning Market

	NUMBER OF ENTITIES	
	USA	California
HOTELS AND MOTELS	132,228	5,596
LAUNDROMATS	18,304	2,275
INDUSTRIAL LAUNDRIES	2,538	468
DRY CLEANERS	30,723	1,910

1 https://www.businesswire.com/news/home/20210630005665/en/US-Laundry-Facilities-Dry-Cleaning-Services-Market-2021-2028-Coin-operated-Retail-LaundryDry-Clean-Services-CorporateIndustrial-Laundry-Services

2 https://database.aceee.org/state/appliance-standards-summary

3 https://www.energy.gov/eere/buildings/history-and-impacts#:~:text=At%20the%20national%20level%2C%20the,energy%20targets%20for%20consumer%20products.

4 https://www.federalregister.gov/documents/2021/12/20/2021-27461/energy-conservation-program-energy-conservation-standards-for-commercial-clothes-washers#citation-3-p71842

5 https://www.dreambigtravelfarblog.com/blog/hotel-industry-statistics, https://www.ibisworld.com/industry-statistics/number-of-businesses/laundromats-united-states, https://www.ibisworld.com/industry-statistics/number-of-businesses/industrial-laundry-linen-supply-unitedstates, https://www.ibisworld.com/us/industry/california/dry-cleaners/14979

Clothes-washing equipment used at commercial and industrial laundry operations include:

- Top-loading washers
- Front-loading washers
- Tunnel washers
- Washer extractors

Common Terminology

- **Coin/card operated** – A clothes washer used in laundromats, hotels, dormitories and other self-help laundry services. The washer and dryer use coins or a card for payment
- **Hard mount** – A clothes washer bolted to the floor to overcome centrifugal force during the spin cycle.
- **Soft mount** – A clothes washer that is stabilized by weight to overcome centrifugal force during the spin cycle and not bolted to the floor
- **Industrial Laundries** – Very large laundry facilities taking in volumes of laundry ranging from company uniforms to hospital and institutional laundry to heavily soiled wipe rags and fabrics.
- **Integrated Water Factor (IWF)** - The gallons of water used per cubic foot of volume (volumetric capacity of the clothes washer container) for one load. Common units in gallons per cubic foot per cycle (load).
- **Modified Energy Factor (MEF)** – The quotient of the volumetric capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle (load), including energy used to run the equipment, energy used to heat the water, and the energy used to dry the clothes. Common units in cubic feet per total kilowatt hours to wash and dry the clothes.
- **Multi load washer** – A clothes washer found in laundromats and similar facilities. Standard washers have drum capacity of 2.0 to 4.0 cubic feet while multi-load washer have capacities up to, and possibly exceeding, 9.0 cubic feet.[6]
- **On-premises system** – Laundry equipment for over 40 and up to 700 pounds of laundry per load used by hotels and other larger commercial and institutional operations. Unlike residential equipment, these washers have a wide range of settings for wash time, volume of water and types of chemicals that are fed. Route operators typically help program this equipment.
- **Route operator** – A representative, often of the chemical company, that supplies the laundry with detergent and other chemicals and is the one who sets the clothes washer for each type of fabric washes (chemicals fed, and the time, water use and chemical use for each type of fabric washed). Route operators are an integral component in effective water conservation programs.

Equipment Standards

Manufacturers have been required to comply with the DOE energy conservation standards for clothes washers since 1988.

However, it wasn't until 2005 with the passage of the Energy Policy Act (EPAct), which amended the EPCA, that commercial clothes washer (CCW) soft-mount machines with a horizontal axis and 3.5 cubic feet of volume and top-loading machines with 4.0 cubic feet of volume were regulated for the first time.

Manufacturers have been required to comply with the DOE energy conservation standards for CCWs since 2007.

EPAct established standards for CCWs and directed DOE to conduct two rulemakings to determine whether the established standards should be amended. DOE completed the first of these rulemakings by publishing a final rule on January 8, 2010 that amended energy conservation standards for CCWs manufactured on or after January 8, 2013.

DOE's most recent energy and water conservation standards for CCWs were published in the February 2024 Final Rule, which applied to CCWs manufactured on or after January 1, 2018.[7]

The standards listed in Table 10-2 are applicable as of June 13, 2024.

"Relative to the prior standards, which took effect in 2013, the new standards represent energy savings of 15% and 18% for top-loading and front-loading washers, respectively. The standards also reduce the water consumption of front-loaders by 20%, while the maximum water use of top-loaders remained essentially unchanged. MEF is expressed in terms of cubic feet of

6 For example, the Maytag Rigid Mount MYR65Pd has a capacity of 9.25 cubic feet: *https://www.whirlpool.com/content/dam/global/maytag/commercial-laundry/commercial-washer/spec-sheets/Maytag_MultiLoadWasher_Vended_1Page_Rigid_SpecSheet.pdf*

7 *https://www.federalregister.gov/documents/2021/12/20/2021-27461/energy-conservation-program-energy-conservation-standards-for-commercial-clothes-washers#citation-3-p71842*

TABLE 10-2: Federal Energy Conservation Standards for Commercial Clothes Washers Manufactured On or After January 1, 2018

EQUIPMENT CLASS	MINIMUM MODIFIED ENERGY FACTOR ("MEF") - CUBIC FEET ("FT 3")/KILOWATT-HOUR ("KWH")/CYCLE	MAXIMUM INTEGRATED WATER FACTOR ("IWF") - GALLONS ("GAL")/FT 3/ CYCLE)
TOP-LOADING	1.35	8.8
FRONT-LOADING	2.00	4.1

TABLE 10-3: EPA Energy Star Integrated Water Factor for Clothes Washers

PRODUCT TYPE	CURRENT CRITERIA LEVELS (AS OF APRIL 22, 2021)
ENERGY STAR Residential Clothes Washers, Front-loading (> 2.5 cu-ft)	**IMEF ≥ 2.76** **IWF ≤ 3.2**
ENERGY STAR Residential Clothes Washers, Top-loading (> 2.5 cu-ft)	**IMEF ≥ 2.06** **IWF ≤ 4.3**
ENERGY STAR Residential Clothes Washers (≤ 2.5 cu-ft)	**IMEF ≥ 2.07** **IWF ≤ 4.2**
ENERGY STAR COMMERCIAL Clothes Washers	**MEFJ2 ≥ 2.20** **IWF ≤ 4.0**
ENERGY STAR Combination All-in-One Washer-Dryer	**Meets IMEF, IWF and the current ENERGY STAR requirements for clothes dryers (except the time requirements) for the closest product type**

washer capacity per kWh of energy consumed per cycle. MEF incorporates machine electrical energy consumption, hot water energy consumption, and the energy required to remove the remaining moisture in the clothes. IWF is expressed in terms of gallons of water consumed per cubic foot of washer capacity. A higher MEF indicates better energy efficiency, while a lower IWF indicates better water efficiency" (Appliance Standards Awareness Project).

The US Environmental Protection Agency Energy Star Program also has energy and water use standards for residential and commercial clothes washers. The maximum integrated water factor to be Energy Star certified for a commercial clothes washer is 4.0 and the EPA only certifies washers up to 8.0 cubic feet of capacity.[8] The Energy Star Program does not certify top loading clothes washers because they are both energy and water inefficient. As demonstrated in Table 10-3, the Federal DOE standards for commercial clothes washers are much less stringent than the US EPA Energy Star standards.

The Energy Star database[9] lists all certified clothes washers meeting their commercial washer standards.

Commercial Laundries

An Array of Front-Loading Machines at a Commercial Laundry Facility

Commercial clothes washers are defined as soft-mounted (not bolted to the floor) front-loading or top-loading clothes washers that are no more than 3.5 cubic feet for front loaders, no more than 4.0 cubic feet for top loaders, and used in applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas, coin laundries, or other commercial applications. According to the Alliance for Water Efficiency (AWE), while in-home machines average only 6 to 8 loads per week, common area machines often wash 20 to 50 loads per week per clothes washer. Single load washer capacity is under 20 pounds but multi load washers can wash up to more than 50 pounds.[10] The volume capacity of laundromat equipment ranges from 1.7 to over 12 cubic feet.

According to the Alliance for Water Efficiency, most coin-op washers are vertical-axis and have a Water Factor (WF) rating of 9.5 to 12; using 32 to 38 gallons per load (132.5 L to 170.29 L) (lower WF rating equates to less water use). Newer water efficient models have a WF rating of 4 to 8; using as little as 15 gallons per load (56.8 L).[11]

Top-load, soft-mount washers previously dominated the market; however, commercial front load washers are starting to be used more frequently in laundromats. Front loading machines are more efficient than top loading machines because the horizonal configuration allows for more room to put clothes in and less water is required to cover the clothes. Instead of using an agitator or impeller, a front-load washer cycles the clothes through a minimal amount of water and detergent by rotating the drum in different directions. Gravity drops the clothing in the water repeatedly throughout the cleaning process. A host of specialty cycles ensure effective and energy-efficient washing, according to Energy Star.

Significantly greater energy and water savings could be achieved if all commercial clothes washers met the efficiency levels of front-loading machines. Under the current CCW equipment standards, a top-loading washer can consume almost 50% more energy and more than twice as much water as a front-loading washer with the same cubic feet capacity (US Department of Energy).

Commercial multi-load washers can exceed capacities of 80 pounds per load as compared with less than 20 for conventional equipment. Standards for multi-load equipment and single-load hard-mount equipment were not included in the EPCA. Multi-load equipment

8 *https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%208.1%20Clothes%20Washer%20Final%20Specificaiton%20-%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf*

9 *https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results*

10, 11 *https://www.allianceforwaterefficiency.org/resources/topic/laundromats-and-common-area-laundry-facilities* is essentially the same as the equipment used by commercial on-premises and industrial laundries. Multi-load equipment is designed with many possible settings and cycles to accommodate a range of washing requirements with large variations in water use. The manufacturer or equipment provider must preset the controls for the washing requirement prior to installation to avoid excessive water use.

As water and wastewater rates increase throughout the country, it is to the benefit of laundromat owners to rent or buy machines that are efficient to minimize utility costs. Water efficiency also helps increase energy savings as the need for hot water is reduced.

Many laundromats lease their machines and, to achieve water savings, the laundromat owner must work with the clothes washer leasing agent to rent and maintain higher efficiency equipment.

Example of an On-Premises Laundry Facility

On-Premises Laundries

On-premises laundries (OPL) use washer-extractors are identical to the multi-load equipment used in laundromats, except they have no coin boxes and can be much larger. Load capacities range from 25 to as much as 1,000 pounds. Washer-extractors are designed to wash everything from relatively clean hotel towels and bedding to heavily soiled items from nursing homes and commercial kitchens. All equipment in this category uses a horizontal configuration and is, therefore, relatively efficient. Examples of OPL applications include prisons, jails, hotels, hospitals, athletic facilities, food and beverage manufacturers, and uniform washing for businesses and military.

TABLE 10-4: On-Premises Laundry Production in Common Operations

TYPE OF OPERATION	POUNDS/PERSON/DAY	POUNDS/ROOM/DAY
HOSPITALS		25
NURSING HOMES		25
MOTELS		23
HOTELS		36
UNIVERSITY DORMS	20	
JAILS	10	
PRISONS	12	

Source: (Riesenberger and Koeller)

A typical washer extractor uses 3-4 gallons of water per pound of fabric, and in the most efficient of the machines, only 2.5 gallons of water is needed per pound of fabric.[12] Some washer extractors have recycling features built in that allow the water to be reused.[13] Because the items being washed vary greatly, the equipment needs to be adjustable. A study for the California Water Efficiency Partnership[14] illustrates these points.

Table 10-4 shows the amount of laundry produced by each of the most common OPL operations and laundry characteristics based upon degree of soiling.

The level of soiling strongly influences the amount of water required, because of the number of cycles needed to wash the items and the corresponding water levels needed for each cycle. Unlike residential and coin/card type laundry equipment, OPL equipment has the possibility of many settings including time of wash, temperature, volume of water in the washer, and the types of fabric. This makes the volume of water used susceptible to how the equipment is set up to operate, but also gives the benefit of being able to use the minimal amount of water, energy, and chemicals. Sorting laundry items and using the correct setting can save significant amounts of water.

Industrial Laundries

A Commercial Dry-Cleaning Facility

Industrial laundries comprise a special subset of commercial laundries. These are very large operations that typically offer services to institutional users such as hospitals and prisons and commercial enterprises such as hotels and restaurants. They often offer uniform and linen leasing, cleaning, and related functions. Industrial laundries use horizontal washer extractors identical to those used by OPL operations and large volume equipment called tunnel washers. Tunnel washers are commonly found in operations processing over 1,500 pounds of laundry an hour.

G. A. Braun Inc. in Syracuse, N.Y., states that tunnel washers have achieved water usage rates as low as 0.3-0.4 gallons per pound. This is opposed to 2.0 to 3.5 gallons per pound of laundry for other on-premises systems.[15] A tunnel washer works just like a front-loading machine but can wash loads 30 times larger than an average laundry machine. Tunnel washers are very expensive and typically not justified unless the laundry is washing 800 pounds of laundry an hour or more.[16]

Dry Cleaning

The dry-cleaning process uses a chemical agent to clean clothing instead of water (unless the operation uses a "wet cleaning" method). Typically, clothes are added into a drum machine with a chemical agent and sometimes other detergents, spun to remove the agent, then tumbled with hot air. Dry cleaning operations are phasing out the use of perchloroethylene (perc) as a dry-cleaning agent due to air-quality and carcinogenic concerns.

In the 2008 EBMUD Guidebook, there were three technologies that were considered to replace perc dry-cleaning operations:

- Supercritical or liquid carbon-dioxide (CO2) technologies
- Silicon-based compounds
- Wet-cleaning methods, similar to front-loading washers

Carbon dioxide and silicon based technologies nearly eliminate water use so long as air cooling is used in the process-fluid operations. Silicon based technology can be used in some existing dry-cleaning equipment that currently uses perchloroethylene. Pressurized (liquid) CO2 and detergent can be circulated through specialized equipment to remove dirt from clothes with no water.

12 https://www.milnor.com/technical-knowledge-base/washer-extractors/general-information-4/water-usage/
13 https://unimac.com/products/unimac-washer-extractors/
14 https://calwep.org/wp-content/uploads/2021/03/On-Premise-Laundries-PBMP-2005.pdf
15 American Laundry News, December 2018, https://americanlaundrynews.com/articles/efficient-flexible-tunnel-washers
16 https://www.milnor.com/technical-knowledge-base/

Detail from a Commercial Dry Cleaning Facility

Photo by Waldemar on Unsplash

The wet cleaning method uses washer equipment almost identical to normal horizontal washers and uses water in the process. Volumes per cubic foot are lower than those for conventional washer operations.

More technologies[17] have been developed to replace perchloroethylene. Although some of these technologies are less toxic than perc and promoted as a "safe, green or environmentally friendly" alternative, some of these solvents are still flammable, volatile, and hazardous:

- n-Propyl bromide (nPB)
- Cyclic volatile methyl siloxane decamethylcyclopentasiloxane (D5)
- Propylene glycol ethers
- High-flash hydrocarbons
- Acetals (butane (butylal))

Water Reuse, Recycling and Ozone Systems

Water reuse, recycling, ozone, and low water laundry systems using developing technologies such as reusable polymer spheres, can reduce water use and wastewater volumes. These technologies can also reduce pretreatment costs and energy use.

A simple recycle and reuse laundry system recovers the discharge from the final rinse in a multi-cycle operation for use in the first flush or first rinse of the next cycle. More complex systems can recover more than 85% of the water for reuse. Simple laundry systems rarely incorporate any type of treatment, since the final rinse water tends to be very clean. These systems are limited to a 10 to 35% savings (Laundry Today, 2005).

However, to achieve consistently higher recovery rates, used wash water must be treated to some extent before reuse.

Ecolab's Aquamiser and the Aqua 360 systems are examples that have been around for more than a decade. Water is filtered to remove lint and dirt, then reheated and sent for reuse. Still other systems process wash water to the point that it can be recycled for use in all cycles of the washing process. These systems can recycle up to 90% of wastewater.

Other laundry companies have included water saving technologies such wastewater recycling, water storage, water softeners, and reverse osmosis with the goal of reducing water consumption and wastewater costs. These technologies are more likely to be used in industrial laundry operations than in a local commercial laundromat.

A Commercial Dry-Cleaning Facility

17 *https://www.ftc.gov/sites/default/files/documents/public_comments/16-cfr-part-423-trade-regulation-rule-care-labeling-textile-wearing-apparel-and-certain-piece-goods-.r511915-00054%C2%A0/00054-85206.pdf*

While using ozone in the laundry process is providing to be an environmentally friendly way to reduce energy usage in the commercial laundry washing process, potential water savings as a result of the technology are inconsistent. One US Department of Energy report found a 60%reduction in hot water energy requirements. However, the same report notes that water usage can vary from site to site, and that unlike energy savings, water savings are not ensured by the installation of an ozone system.[18]

Recommendations

General

- Choose the most water efficient equipment available
  - Look for the EPA Energy Star rating
  - Choose machines with a high Integrated Modified Energy Factor (IMEF) and a low Integrated Water Factor (IWF)
  - Consider systems with water reuse, water recycle, and/or ozone capabilities
- Retrofit laundromats with multi-load units
- Install sub- or flowmeters [include link to/page for metering chapter] on the cold-water line, including a meter for the feed to the facility boiler (water heater).
  - Monitoring means faster identification of issues, as well as volumetric tracking
  - Sub- or flowmeters should be read daily or connected to the facility dashboard
  - Schedule routine equipment leak checks and maintenance/upgrades
  - Ensure that steam and hot water systems are insulated and operating properly

Operational

- Choose tunnel washers where laundry volume is large enough (tunnel washers are the most water and energy efficient systems)
  - Choose tunnel systems using less than 0.6 gallons per pound of laundry
  - Perform regular review of the tunnel washer computer control system to minimize water, energy, and chemical use
- Choose equipment with a broad range of possible wash settings
  - Work with a route operator to formulate settings for the types of items to be washed so that the setting use will minimize energy, chemical, and water use
  - Wash clothes in cold water using cold-water detergents whenever possible
- Ensure that staff are trained and that there is proper signage to separate laundry by the washing setting needed.
- Post energy and water use data for employees to see and award increased water and energy efficiency

Laundromats

- Single-load hard-mount laundromat or other coin- and card-operated machines should have a WF of 8.0 or less.
- Multi-load coin and card operated machines must have an IWF of 8.8 or less and be installed with proper settings to achieve the required IWF
- Post signage encouraging customers to wash and dry full loads
- For small loads, encourage customers to use the appropriate water-level setting
- Purchase single-load soft-mount washers with a WF of 3.8 or less
- Encourage the use of non-wet dry-cleaning
- Use dry lint collection systems with appropriate fire suppression systems that only activate when there is an actual fire risk

18 https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Ozone_Tech_Demo_Flyer_508.pdf

Resources

1. EPA, Best Management Practices
   https://www.epa.gov/watersense/best-management-practices
2. Consortium for Energy Efficiency (CEE)
   https://cee1.org/content/about
3. Energy Star, Commercial Clothes Washers
   https://www.energystar.gov/products/commercial_clothes_washers
4. US Department of Energy, Appliances and Equipment Standards Rulemakings and Notices
   https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=68&action=viewlive
5. Riesenberger, James, and Koeller, John. November 2005. Evaluation of Potential Best Management Practices - On-Premise Laundries
   https://calwep.org/wp-content/uploads/2021/03/On-Premise-Laundries-PBMP-2005.pdf
6. San Diego Water Authority, Water Management, Inc., Western Policy Research, and Koeller and Company. 2006 Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program.
7. 2021 Appliance Standards Awareness Project, Commercial Clothes Washers
   https://appliance-standards.org/product/commercial-clothes-washers
8. Alliance Laundry Systems LLC, UniMac, High-Performance Industrial Washer Extractors
   https://unimac.com/products/unimac-washer-extractors/
9. Alliance for Water Efficiency, Laundromats and Common Area Laundry Facilities
   https://www.allianceforwaterefficiency.org/resources/topic/laundromats-and-common-area-laundry-facilities
10. Next Generation Standards: How the National Energy Efficiency Standards Program Can Continue to Drive Energy, Economic, and Environmental Benefits 2016
    https://appliance-standards.org/sites/default/files/Next%20Gen%20Report%20Final_1.pdf
11. Danamark, Optimize Water And Energy Usage In Hotel Laundry Machines
    https://danamark.com/resources/improving-water-footprint-laundry-machines/
12. Pellerin Milnor Corporation, Technical Knowledge Base
    https://www.milnor.com/technical-knowledge-base/
13. SAHF – Stewards of Affordable Housing for the Future, Efficiency Opportunities in Multi-Family Common Area Laundry Facilities
    https://assets.ctfassets.net/ntcn17ss1ow9/3wb7I1yXahjWP8boavk13q/af77171dbe757aaa377230ae6ecdb932/efficiency-common-laundry-areas-sahf-20170327.pdf
14. T&L Equipment Company, Common Commercial Washing Equipment, http://www.washcycle.com/four-generic-types-washing-equipment/
15. Coin-Operated Clothes Washers in Laundromats and Multifamily Buildings: Assessment of Water Conservation Potential
    https://calwep.org/wp-content/uploads/2021/03/Coin_Operated-Clothes-Washers-PBMP-2012.pdf
16. Code of Federal Regulations Title 10, Chaoter II, Subpart D, Part 431, § 431.156 Energy and water conservation standards and effective dates
    https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-I
17. Pacific Gas and Energy, Support for Small and Medium Businesses
    https://www.pge.com/en_US/small-medium-business/save-energy-and-money/rebates-and-incentives/product-rebates.page
18. American Laundry News. May 21, 2020. Maximizing Pounds Per Operator Hour: 7 suggested steps to help improve laundry operation's PPOH
    https://americanlaundrynews.com/articles/maximizing-pounds-operator-hour

Chapter 11
MEDICAL FACILITIES AND LABORATORIES

Hospitals as well as medical, veterinary, and dental clinics along with medical laboratories use water in similar ways. Many factors can increase or decrease the amount of water that is being used in a medical facility such as on site laundry, food preparation, and landscape practices, just to name a few. There is a significant opportunity in this industry to design more water efficient facilities.

The US EPA estimates that "**implementing water-efficient practices in institutional facilities can decrease operating costs by approximately 11 percent and energy and water use by 10 and 15 percent**, respectively." Additionally, the US EPA shows that just 28 percent of water is used directly in the lab, while the rest is accounted for in cooling, sanitation, and outdoor irrigation.[1]

Hospitals and laboratories also often have high rates of fresh air intake compared to other types of facilities, which means that their air conditioning systems often produce higher volumes of air conditioning condensate, especially in humid areas. This points to the substantial potential to capture and reuse condensate for non-potable uses. The chapter Alternate Onsite Water Sources covers options for recovery and reuse of this water source.

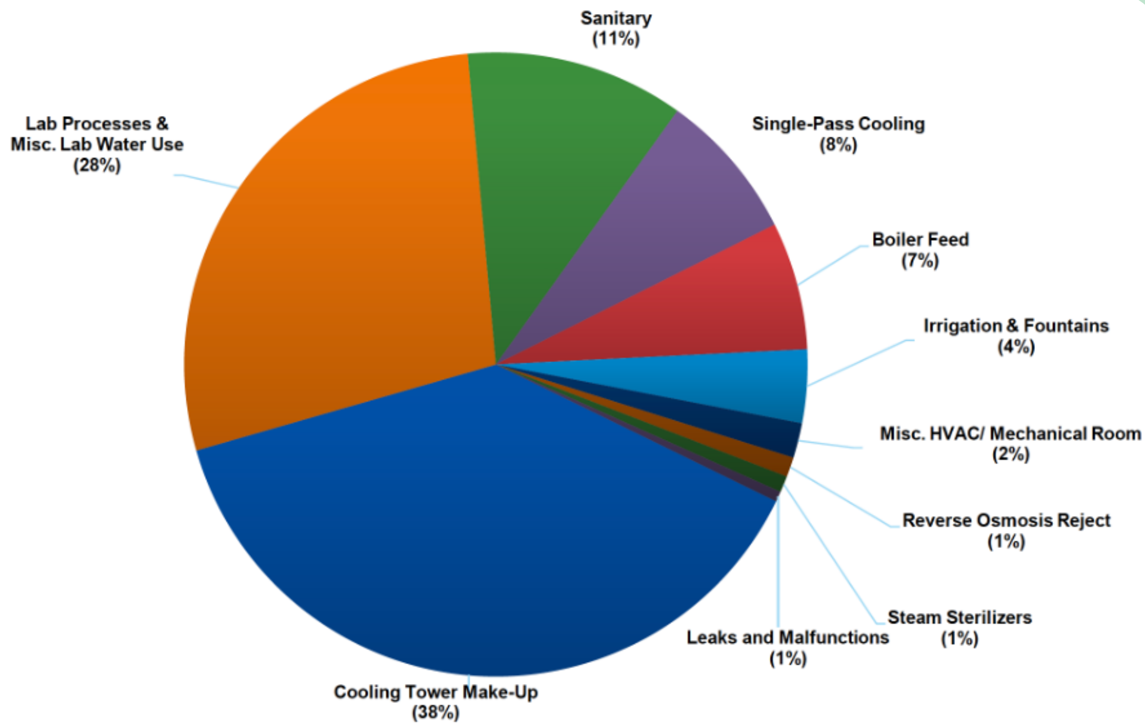
Equipment and Operations within Medical and Laboratory Facilities

1. **Medical instruments, glassware, cages, racks, and bottles washers**
   - Pre-sterilization washers
   - Glassware and equipment washers
   - Cage and bottle washers
2. **Sterilizers**
3. **Vacuum and compressor systems**
   - Whole building systems
   - Point-of-use systems
   - Ultra-high vacuum systems
   - Compressor systems
4. **Instrument and equipment cooling**
   - List of potential equipment using cooling
   - Water and energy efficient cooling methods
5. **Medical air and compressor systems**
   - Compressor types
6. **Laboratory fume hoods**
   - Perchlorate hoods
   - Scrubber hoods
7. **Vivarium and aquarium operations**
   - Vivariums
   - Aquariums
8. **Kidney dialysis and specialty laboratory or medical water treatment**
   - Kidney dialysis water treatment
   - Medical water treatment
   - Ultra-pure lab water treatment
9. **Humidification**
   - Types of equipment
   - Types of water use
10. **Medical therapeutic equipment**
    - Pools, whirlpools, whirlpool spas, hot tubs, and physiotherapy tanks
11. **Miscellaneous equipment**

Water Quality Testing Laboratory

1 https://www.epa.gov/system/files/documents/2022-08/ws-webinars-Laboratory-Water-Efficiency.pdf

Figure 11-1: Water Use Profiles of a Laboratory



Typical EPA laboratory building water use, based on data collected during water assessments conducted at EPA's laboratories between 2011 and 2019.

Graph source: I2SL, https://www.epa.gov/system/files/documents/2022-08/ws-webinars-Laboratory-Water-Efficiency.pdf

Medical Instrument, glassware, and cages, racks, and bottles washers

This section describes cleaning and washing methods including:

1. Pre-sterilization Washers
2. Glassware and Equipment Washers
3. Cage Washers and Bottle Cleaning
4. Types of Wash Water

Pre-sterilization washers:

Although not accounting for the most significant water use in hospitals and medical facilities, pre-sterilization washers are a critical part of cleaning instruments and equipment prior to sterilization. During pre-sterilization, the instruments and equipment are placed in an enzymatic detergent hand wash where heavy contamination is removed. This can be followed by both an ultrasonic cleaning and then washing in an instrument washer. The cleaned instruments are then sent to sterilization.

Instruments and equipment with many plastic parts require hand cleaning. Recommended manual cleaning procedure involves hand washing the instruments in a three compartment sink operation. Although tap water can be used in the first part of the washing sequence, distilled water and water treated by reverse osmosis (RO) is often required. The first sink is used to pre-rinse with cold water to remove any pretreatment product or biological contaminants. The second sink is used to pre-soak and physically wash instruments with an enzymatic or neutral detergent solution. The third sink is the final rinse sink and often uses distilled or RO water

Water conservation techniques for hand washing include making the most use of the water in sink and having efficient water treatment processes in place as discussed in the section on Water Treatment.

After manual cleaning, instrument cleaning is followed by either mechanical or automatic cleaning via ultrasonic cleaners, washer decontaminators, washer-disinfectors, or washer-sterilizers.

Tray of Surgical Instruments Ready for Sterilization

Image source: HW (Bill) Hoffman & Associates, LLC

Ultrasonic cleaning is used to penetrate hard to reach crevices, hinges, and lumens. The ultrasonic system produces extremely fine bubbles and ultrasonic waves to clean the instruments. For more information on softened or RO water used in this process, see Water Treatment section. Since these systems are a fill and dump type system, the water efficient approach is to only dump and refill when needed.

Washer-Disinfectors, often compared to high efficiency dish washers, are the typical next step in the process. These washers use high pressure sprays along with cleaning and disinfecting solutions to provide a more though cleaning. If enzymatic cleaners are used, the water temperature should be around 140°F and if surfactant cleaners are used, temperatures should be around 180°F. Wash cycle times and pressure setting can impact water use. The final rinse is typically done with RO water. The instruments are then ready for sterilization.

Recommendations:

1. When hand washing, only use the amount of water needed
2. Use softened or RO rinse water sparingly while following all proper cleaning methods
3. When using ultrasonic washers, only dump and refill when necessary
4. Operate instrument washer equipment only when needed
5. Wash full loads as a matter of practice
6. Follow recommended settings that minimize water use, such as wash time and pressure

Glassware and Instrument Washers

Laboratory Ware Washers:

The use of laboratory ware washers is reported to significantly reduce water use. The Labconco study[2] showed that hand washing used from 16 to 66 gallons per load while the automated ware washer used only 10 gallons and 27 minutes of labor. The mean water use by hand washing was a little over 34 gallons. By contrast, the automated ware washer only used 10 gallons and 19 minutes of labor. This is a water savings of 15 gallons per load. If two thousand loads are washed annually, this equals 30,000 gallons of water saved, and this is hot water that has been softened and of which some.

Most washers offer a five-step washing process, including pre-wash using softened water, a main wash cycle(s) using either softened hot water or deionized water, and two rinses, but special needs of the laboratory can require up to Five additional cycles. Water is used in several ways:

- Pre-rinse water which is typically softened water or water recycled from the final rinse cycles
- Wash water which can be either softened water or deionized water
- Rinse water
- Tempering water to cool discharge to below 140°F to meet plumbing codes
- Steam if steam heating is used
- Tempering water if the steam condensate is discharged to the sewer and not returned to the boiler

Ultrasonic Surgical Instrument Washer

Image source: HW (Bill) Hoffman & Associates, LLC

2 https://www.labconco.com/download/hand-washing-case-study/1836

Tunnel Surgical Instrument Washer and Thermal Disinfector Washer

Image sources: HW (Bill) Hoffman & Associates, LLC

Since water must be heated, up to as high as 203°F depending on the laboratory requirements, the reduction in water use is also the best way to reduce energy use.

Modern glassware washers are significantly more energy and water efficient than models even a decade ago. All modern glassware washing equipment can be set for different wash cycles depending on the laboratory's needs. Flask and beaker washer, pipet washers, and miscellaneous glass and plastic ware are the most common types of material washed, but specialty equipment such as bioreactors require special racks and cleaning procedures. High level analytical and many life science operations require extra levels of washing, thus higher water use settings.

Another major factor impacting water use is the size of the washing equipment. The equipment ranges from under-the-counter washers to large cabinet washers. Large cabinet washers require more water for each full washing cycle than small under the counter models do, but the cabinet washers can wash significantly more glassware at a time so total water use per item washed remains about the same for full loads.

A special consideration are pipette washers. The old fill and siphoned systems can use significant volumes of water by continuously filling and draining water. Most glassware washers can wash pipette. Some manufacturers offer systems that reduce water use by using compressed air and other ways of reducing water use compared to the old fill and siphon systems.

Rinsing equipment with a counter-current rinsing setup reduces water by using cleanest water only for the last rinse, and then used that water in a cascading manner for dirtier items. The basic premise is to use the cleanest water only for the final or last stages of a rinse operation; water for early rinsing tasks, when the quality of the rinse water is not as important, is obtained later in the process.

Lab Glass Water Washer and Pipette Washer

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations:

- Avoid hand washing where possible
- Ware washers are more water efficient when used appropriately:
  - Only run glassware washers when they are full; fill each glassware washer rack to maximum capacity
  - Operate the glassware washer near or at the minimum flow rate recommended by the manufacturer
  - Choose settings that minimize energy and water use while still cleaning the glassware to the desired level
  - If deionized water necessary, use only in final rise cycles where possible
  - Clean glassware as soon as possible so deposits do not dry on, thus requiring special cleaning
  - Choose water and energy efficient models; look for the WaterSense and EnergyStar labels
  - Select washer size that fits the needs of the laboratory; do not oversize
  - Choose models that have computer-controlled capability to minimize energy and water use.
  - Choose models that monitor the load and use only the fill water needed
  - Choose models that recycle the final rinse water for the first wash cycle
  - Most manufacturers offer “cool-down” tanks that cool the water prior to discharge thus eliminating the tempering water
  - Consider heat recovery systems available from many manufacturers that both conserve energy and eliminate the need for tempering water.
    - Tempering water uses potable tap water to mix with the discharge from the washer to reduce in-sewer temperatures to below 140°F
- If steam is used: install heat recovery systems to prevent the need for tempering water and return condensate to the boiler

Cage Washers and Bottle Washers

Vivariums and other research animal facilities must wash the cages and bottle and feeding containers used to nourish and hydrate the animals.

Labware Drying Rack

For vivarium operations (laboratory rats and mice), special “rack and bottle washers” are the most efficient way to clean rat cages and water bottles in large operations. These washers are large roll in systems that hold whole racks of rat cages and with special holders, watering bottles.

Cage, rack, and bottle washers, and cart and utensil washers are batch-type washers with racks.

A Lab Rat Cage Washer and the Inside of that Washer with a Rack of Cages Ready to Wash

Image source: HW (Bill) Hoffman & Associates, LLC

Choose modern washers using roughly 12 gallons to 50 gallons per wash cycle,[3] or no more than 50 to 100 gallons per load.

Traditional cage-and-rack washers are programmed with a pre-rinse, wash with detergents and chemicals, and a final rinse cycle. Softened water can be used in the pre-rinse and wash cycles, but deionized water is often uses in the final rinse. Rinse and often wash cycle washes typically use hot water heated to 180°F or more. Optional cycles using hydrogen peroxide, acid washes and special disinfection washes are available, each increasing water use.

Tunnel washers are conveyor-type washers that accommodate cages, racks, and other laboratory accessories at once.

Large Monkey Cage Tunnel Washer and Lab Rat Tunnel Cage Washer

Images source: HW (Bill) Hoffman & Associates, LLC

Some researchers note that, "cage and rack washers, while not the industry standard for large-scale animal cage washing, are more efficient and cost-effective to operate than tunnel washers.[4]"

Since many tunnel washers vent into the workspace, more air-conditioning may be required, thus potentially also increasing energy costs. Tunnel washers are typically found only in laboratories with a very large number of cages and other equipment to wash. There are typically four main cycles in the tunnel washer: pre-rinse, wash, first rinse, and final rinse. The final rinse uses only fresh water, while the other cycles can use water recycled from the wash, first rinse, or final rinse. Starting with the final rinse cycle, water moves countercurrent within the tunnel washer and is disposed of after the pre-rinse cycle.

Types of water used in all types of these washers varies with the laboratory needs, but can include:

- Tap water
- Softened water
- Water heated to 180°F or more
- Deionized water
- Steam if used, and
- Drain tempering water to reduce wastewater discharge to below 140°F

Recommendations

- Avoid washing partial loads
- Where possible, install modern washers with water-efficient cycles
- If needed, retrofit existing cage and rack washers to make use of counter-current flow systems to reuse final rinse water from one cage-washing cycle in earlier rinses in the next washing cycle
- With tunnel washers, use fresh water only for the final rinse; other cycles can use water recycled from the wash
- Install heat recovery features where possible
- Install water tempering kits, and if an energy recovery feature cannot be used that only flow cold tap water with water over 140°F is being discharged.

3 *https://www.tecniplast.it/*
4 *https://www.tradelineinc.com/reports/2013-6/recommended-shift-away-tunnel-cage-washers*

Figure 11-2: Aspirator in Lab and Venturi Vacuum on Sterilizer

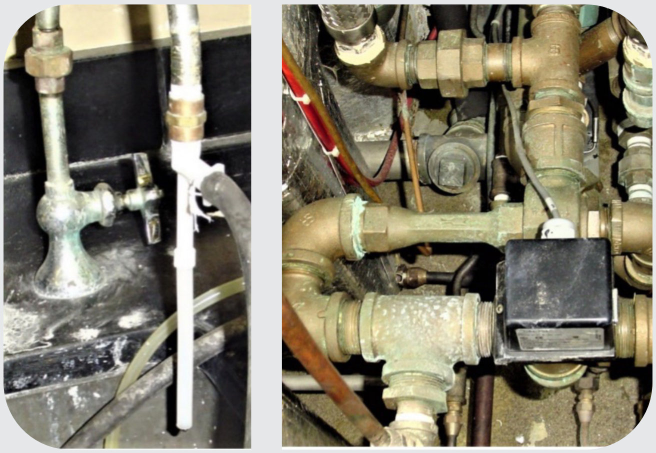


Image source: HW (Bill) Hoffman & Associates, LLC

Vacuum Systems

Vacuum systems are a common element of both medical and laboratory work. Because of the wide variety of vacuum system needs, this section is broken down into:

- Medical and dental systems
- Low-vacuum laboratory use
- High-vacuum laboratory use

Venturi aspirators should be replaced with dry vacuum systems wherever possible. These systems are found in many teaching chemistry labs and were previously used to create a vacuum to evacuate air from vacuum steam sterilizers. Sterilizer venturi systems can use 6.5 to 10 gallons per minute, with the vacuum phase lasting up to 30 minutes. Water use is in the range of 350 to 400 gallons per cycle.

As an alternative to laboratory aspirators, some labs use air aspirators like the one shown in Figure 11-2. Venturi aspirator vacuum systems in teaching laboratories where they are used only a few hours a year would be costly to convert to a dry system. If the system is run only a few hours a year, they do not use huge amounts of water.

Recirculating venturi aspirator vacuum systems are available that recirculate water to produce the vacuum such as the system in Figure 11-3. These are useful in settings such as biological laboratories where the gas being evaluated is not corrosive or otherwise a waste that should be sent to the sewer. Another option is to use a compressed air venturi system such as Figure 11-4, located in a university teaching laboratory.

Liquid-ring vacuum pumps were the mainstay of medical and dental vacuum systems until recently. They use a closed impeller that is sealed with water to form the vacuum. The water acts as both a seal and a once-through cooling system. Water requirements are typically in the range of 0.5 to 1.0 gallons per minute (gpm) per horsepower (hp). Dental clinics have historically used liquid ring vacuum pumps in the one to four horsepower range. The amount of water that may be saved varies with the type and size of equipment. According to product literature for several types of liquid ring dental pumps, these pumps use approximately a half gallon per minute per horsepower, so a two-horsepower pump would use approximately 1.0 to 1.5 gpm. An office that is open for eight hours would use 300 to 800 gallons a day. Medical facility central vacuum systems can be 5.0 to 20.0 hp. Therefore, medical facilities can use as much as 20 gpm of water.

Figure 11-3: Recirculating Venturi Vacuum System

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-4: Compressed Air Venturi System

Image source: HW (Bill) Hoffman & Associates, LLC

Many cities do not allow liquid ring dental pumps. Dry vacuum pumps eliminate the need for water to create a vacuum. A small amount of water is needed at the end of each day to flush the “knock-out drum” that collects the waste.

Dry Vacuum Pump at a Dental Clinic

Image source: HW (Bill) Hoffman & Associates, LLC

Liquid Ring Vacuum Pump in a Large Hospital

Image source: HW (Bill) Hoffman & Associates, LLC

Dry Claw Vacuum Pump in a Hospital

Image source: HW (Bill) Hoffman & Associates, LLC

Central vacuum systems on hospitals are much larger than dental vacuum systems. One hospital had seven liquid ring vacuum pumps, five of which ran continuously. Each pump discharged 7.5 gpm, which is equal to each pump using 10,800 gallons a day. With five pumps running continuously, these liquid ring pumps were using over 19 million gallons of water a year.

Dry vacuum pumps offer real savings, both on water and energy. There are a number of dry vacuum systems that use from 20% to 40% less energy and no water to generate the vacuum. Using the above example with the five continuously running liquid vacuum pumps, at an assumed water rate of $10.18 per thousand gallons, the annual water savings that could be achieved by replacing the liquid ring system with a dry vacuum pump would be on the order of $193,000, not inclusive of energy savings.

The following is a list of the variety of dry vacuum pumps available. Each type of pump has its advantages and appropriate applications:

- Liquid-ring pumps
- Vane pumps
- Claw pumps
- Rotary pumps
- Scroll pumps
- Piston pumps

In the hospital example above, installing dry vacuum pumps to replace the seven liquid ring pumps would significantly cut yearly water, wastewater, and electricity costs. While the new vacuum systems are costly, the payback in water and other utility savings would be swift, with an estimate ROI of under two years.

Laboratory Vacuum Systems

There are many different vacuum needs in laboratories, but they fall into three basic categories. The first are lab bench type systems. These vacuum systems vary significantly, ranging from the aspirators discussed above to tabletop vacuum pumps which for the most part, do not use water. Examples of tabletop and laboratory hood vacuum systems are shown in Figures 12-5 and 12-6.

Figure 11-5: Dry Vacuum System in Water Quality Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-6: Dry Laboratory Vacuum Pump for Chemical and Biological Work

Image source: HW (Bill) Hoffman & Associates, LLC

Large laboratory facilities use vacuum systems for the whole building. The vacuum pump shown in Figure 11-7 is a lubricated vane dry vacuum pump. This type of pump find use in both laboratory and medical applications.

Figure 11-7: Lubricated Rotary Vane Dry Vacuum Pump

Image source: HW (Bill) Hoffman & Associates, LLC

Again, one can find water and energy-inefficient liquid ring pumps. The liquid ring vacuum system shown in Figure 11-8 was installed in a university biological laboratory building.

Figure 11-8: Lubricated Rotary Vane Dry Vacuum Pump

Image source: HW (Bill) Hoffman & Associates, LLC

Many laboratory applications require higher vacuum levels. The two pumps shown in Figure 11-9 are for evacuating vessels and other uses in laboratories. Again, these pumps do not use water.

Figure 11-9: Laboratory Higher Dry Vacuum Type Pumps

Images source: HW (Bill) Hoffman & Associates, LLC

Laboratories can sometimes require extremely high vacuums like diffusion pumps. These are found in industrial vacuum processing such as the production of microelectronics and in laboratories where mass spectrometry, analytical instrumentation, research and development for ion implantation, and nanotechnology.

Unfortunately, some of these pumps must be water cooled. However, a chilled water loop for the building's air conditioning system is often used in large systems such as universities. Again, all once-through cooling should be avoided.

Diffusion Pump

Images source: HW (Bill) Hoffman & Associates, LLC

Dry systems do not use water for the pump seal but can use water for cooling the pump. Water use rates for a liquid-ring pump range from 0.5 to 1.0 gallons per minute per horsepower. Even this will be totally eliminated if no cooling water is used. Pumps should never be cooled with a once-through system. If a water using system must be used, it should be connected to a closed-loop or radiator-type system. The typical dental unit with a 1.5 hp liquid-ring pump can use 360 to 720 gpd (Sable Industries). For a large medical facility with a 12 hp pump, the water used per day can range from 8,640 to 17,280 gallons. Newer liquid-ring pumps try to minimize water use, so their consumption would most likely be in the range of 8,600 to 10,000 gpd. Using a dry vacuum pump will save significant volumes of water or eliminate water use (Tuthill).

Recommendations

- Avoid the use of non-recirculating venturi aspirators
- Chose systems that are sized to the need and capable of handeling the types of gases being evacuated
- Where possible, use dry vacuum systems
- If a liquid ring vacuum pump must be used because of corrosive conditions, use a non-potable source of water or water recirculation system if possible
- Where water cooling is needed, connect the vacuum system to the chilled water system for recirculation

Medical Air and Compressor Systems

Medical air and compressor equipment is used for a multitude of purposes in most dental and medical facilities. The only water use associated with this type of equipment is for cooling, done with once-through cooling, a radiator type system, or a closed loop system, such as a cooling tower or chilled water loop. Many air compressors today are air-cooled. For water efficiency, use air-cooled or closed loop systems.

Compressed air has a wide variety of applications in both medical and laboratory operations. There are four main types of air compressors:

- Rotary screw compressors
- Reciprocating air compressors
- Axial compressors
- Centrifugal compressors

Axial and centrifugal compressors are called dynamic systems. Rotary and reciprocating pumps work on the principle of positive displacement. The three main components of any compressed air system used by medical and laboratory systems are:

1. The compressor
2. The cooling system
3. The compressed air storage tank.

Reciprocating Piston Air-cooled Laboratory Compressor

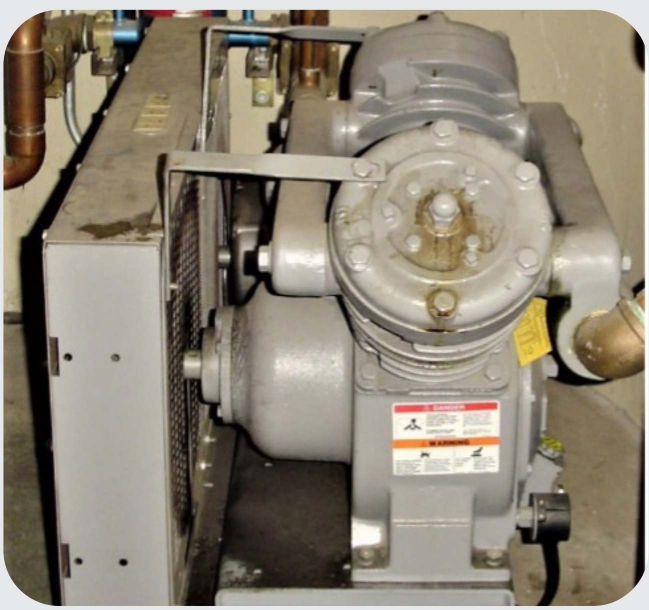


Image source: HW (Bill) Hoffman & Associates, LLC

When air is compressed, heat is generated in accordance with the following equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This waste heat can be removed either by air or water. Air is the most common method of cooling compressed air systems. Where water is used, it should always be used in conjunction with chilled water or cooling tower cooling loop.

Hospital compressed air must be free of any oils, so oil-less systems are used. The air is filtered and dried. Air humidity control is important. All hospital and clinical applications must meet the National Fire and Protection NFPA -99 Code Standards since compressor operation produces heat. The uses of compressed air in medical application include:

- Driving incubators and ventilators and for controlled air flow with certain oxygen gas systems for patients
- As a carrier gas for anesthesia
- To operated certain physical therapy equipment
- As a power source for pneumatic surgical tools
- Dental compressed air systems are used to drive dental tools.

Laboratory compressor types will depend on the specific use for the air. However, the methods of cooling the compressor are the same as for medical applications.

Recommendations

- Use air-cooled systems wherever possible
- If a water-cooled compressor must be used, ensure it is connected to chilled water or cooling tower cooling loop
- Never use once-through cooling

Medical and Laboratory Equipment Cooling

Water cooled laboratory and therapeutic equipment have historically used once-through cooling. Connecting this equipment to a closed-loop system such as a cooling tower or chilled water loop is often impractical, but air-cooled chiller units are available. Cooling medical and laboratory equipment offers significant opportunities to save water.

A common practice in organic chemistry laboratories is to dry used solvents for recovery and reuse. Many labs use reflux condensers to dry the spent solvents. Labs using reflux condensers to dry solvents typically cooled the condensers with a continuous flow of tap water like the petroleum engineering example in Figure 11-10. The reflux column is used to strip oils out of a test block at a petroleum engineering teaching laboratory at a university. This system ran some 5,000 hours a year and the flow rate of the tap water cooling part of the apparatus was 1.5 gpm, which totaled 450,000 gallons of water a year.

Figure 11-10: Reflux Column Used to Strip Oils Out of a Test Block in Petroleum Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

These solve drying systems operate year around, have flow rates in the range of one to three gallons per minute and also present a fire hazard. For both water conservation and fire safety many laboratories have converted to desiccant systems such as the one pictured in Figure 11-11. Such systems use metal tubes filled with desiccant material that is regenerated by heating elements. This eliminates all water use and recovers valuable organic solvents while reducing fire hazards.

Additional examples of laboratory equipment that may require cooling are listed in Table 11-1:

Figure 11-11: Desiccant Drying System for Solvent Recovery

Images source: HW (Bill) Hoffman & Associates, LLC

There are three options to eliminate once-through cooling. The first is a recirculating chiller that chills the water circulating through the instrument such as a rotary evaporators, reflux condensers and similar laboratory devices and for the devices listed in Table 11-1.

Table 11-1: Examples Of Recommended Lab Equipment That May Need Cooling

Diffusion Pumps	Rotary Evaporator/Concentrators	Stills
Electron Microscopes	Extractors	Turbo Molecular Pumps
Spectrometers	Vacuum Systems	Air Compressors
Gas Chromatography	Mass Spectrometers	Centrifuges
Optics and Laser Equipment	Ion Implantation Equipment	Metallurgical Lab Equipment

This device mechanically cools the recirculating water and pumps it through system or equipment to be cooled. These systems have very wide application. The reduce water use to zero and are energy efficient.

These chillers are available for from $4,000 to $20,000 depending on capacity and special features. The following shows a laboratory hood with equipment using dry vacuum pumps and a recirculation chiller. Chillers also have the advantage of allowing researchers to precisely control temperatures.

Recirculating Chiller

Image source: HW (Bill) Hoffman & Associates, LLC

Example of a Laboratory Equipped with a Chilled Water Source and Return

Image source: HW (Bill) Hoffman & Associates, LLC

Many modern laboratory facilities are now equipped with chilled water loops to cool laboratory equipment. This totally eliminates the waste of water.

Some laboratory equipment requires that the cooling water be deionized water such as the mass spectrometer shown in Figure 11-12. To accommodate this, the deionized water loop is connected to a chilled water loop.

Laboratory Hood with Equipment Using Both a Dry Vacuum Pump and Recirculating Chiller

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-12: Mass Spectrometer Requiring Deionized Water for its Cooling Loop and Connection to Building System Chilled Water Loop

Images source: HW (Bill) Hoffman & Associates, LLC

Another cooling method for laboratory reflux condensers, rotovaps, and distillation columns is to use compressed air.[5]

As an alternative, once-through cooling water from laboratory equipment can be collected directly for reuse. The University of Texas has a campus-wide system that collects air conditioning condensate, foundation drain water and chillers are not used, once-through cooling water for use in the campus cooling towers.

Cooling Water Collection System Chemistry Laboratory on the University of Texas Campus

Image source: HW (Bill) Hoffman & Associates, LLC

All these techniques can satisfy the requirements in areas that prohibit once-through cooling. Air-cooled condensers also reduce the risk of laboratory flooding, which can have costly consequences for the facility and research team.[6] They can also be easier to set up, as they do not require tubing or connectors for water cooling. This leaves more time and lab space for other research activities (Radleys).

Recommendations

- Eliminate all once-through cooling as soon as possible, In many areas it is prohibited by code.
- Use desiccant systems to dry organic solvents.
- Use stand alone chiller units for lab bench equipment.
- Connect to a chilled water system where possible.
- If once-through systems are the only option, capture and reuse the water.
  - Description
  - Compressor types - Rotary screw, vane and reciprocating
  - Recommendations

Autoclaves & Sterilizers

Autoclaves and central sterile operations are found in all medical facilities. Autoclaves are used to kill pathogens on instruments, equipment, and waste generated during routine lab operations, or, in a hospital setting, during medical procedures and surgery. Both steam and chemical sterilizers are used, depending upon the materials being sterilized. Chemical sterilization is used for instruments that are sensitive to heat, such as plastic and rubber products, and for instruments such as endoscopes. Steam is used for everything else.

Chemical sterilization has seen dramatic changes in recent years as ethylene oxide (EO) or glutaraldehyde (GA) systems, that are known carcinogens, are being replaced with non-polluting venturi vacuum systems. These systems can be found across a variety of systems including x-ray, laboratory, and pharmacy. Hydrogen peroxide has emerged as one of the most commonly used sterilization materials. Unlike the EO and GA systems, peroxide systems can use mechanical vacuum pumps that use no water. It is important to ensure that mechanical vacuum systems are used.[7]

Autoclaves kill harmful pathogens with live steam that is fed into a central pressure chamber in which instruments and equipment have been placed. There are three major classes of autoclaves:

- Table-top and stand mounted
- Gravity
- Vacuum

Table-top and stand mounted units use a small reservoir of water and electric heat to produce steam. They tend to be both water and energy efficient but are not large enough for the high rate of production needed in major lab or medical facilities.

Large labs and medical facilities must use large steam autoclaves fed by the facilities' boiler systems. The live steam injected into the pressure chamber is held for a period of time to ensure sterilization. The steam is then allowed to condense and exit through a steam trap. In busy facilities, fifteen to twenty loads can be sterilized per day. The process of sterilizing a load is called a cycle. In busy facilities, the jacket around the inner chamber is kept hot with live steam even when the chamber is empty, so instruments can be processed on an emergency basis as needed. As the steam in the jacket condenses, the water is released through a steam trap. Usually only a pint or

5 *https://cen.acs.org/articles/91/web/2013/09/New-Condensers-Cool-Solvent-Without.html*
6 *https://www.science.org/content/blog-post/no-water-no-problem*
7 *https://www.sterrad.com/products_&_services/sterrad/index.asp*

two of condensate is released and then only intermittently. This condensate must be cooled to below 140°F before it can be discharged to the sewer system. In older units, a stream of tap water was continuously run through a valve into the sewer connection to mix with the condensate. Most autoclaves are allowed to cool naturally, and the condensate drains from the chamber by gravity.

An Array of Autoclaves

Where volume is high or equipment needs to be sterilized quickly, a vacuum can be used to draw on the chamber and dry the instruments and evacuate moisture quickly. Historically, venturi aspirator equipment has been used to produce this vacuum. It works by passing water through a tube that tapers.

Typical flow rates are in the range of 5 to 10 gallons per minute, and the vacuum phase can last up to 30 minutes. Water use per cycle is in the range of 350 to 400 gallons per cycle.

Description of Medical Sterilizer Types - Sterilization of surgical instruments, fluids, pharmaceuticals, equipment, and bandages is an integral part of modern medical and laboratory practice. Over the years, different sterilization techniques have been used:

1. Chemical (ethylene oxide, peroxides, ozone, etc.)
2. Radiation
3. Dry heat
4. Steam sterilization

The first three techniques do not use water and are included as alternatives to steam sterilizers, but since they generally do not use water, they are not the topic of this discussion. However, they should be considered as alternatives to steam sterilizers. The following shows pictures of various types of steam sterilizers.

Small Sterilizer in Biological Laboratory

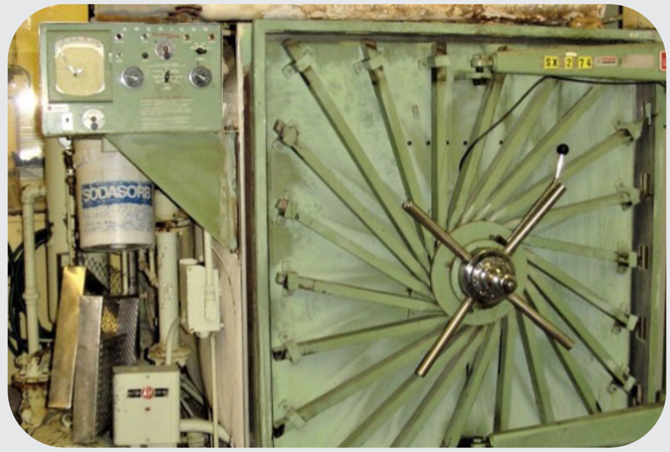


Image source: HW (Bill) Hoffman & Associates, LLC

Large Steam Sterilizer at a Laboratory to Sterilize Primate Cages

Image source: HW (Bill) Hoffman & Associates, LLC

Hospital Sterilizer and Cart with Items to Load Into Sterilizer

Image source: HW (Bill) Hoffman & Associates, LLC

Large Materials Autoclave at University Engineering Laboratory and Auto Clave for Polymer Work at Chemical Engineering Lab

Image source: HW (Bill) Hoffman & Associates, LLC

For medical and dental use, there are three major categories of steam sterilizers:

- Tabletop
- Gravity
- Vacuum

The two major configurations for steam sterilizers are tabletop and freestanding.

> ***Tabletop-type sterilizers have a water reservoir that is heated by a heating element to make steam.***

They use little water and are not considered further in this discussion.

Freestanding sterilizers include gravity displacement autoclaves and the high speed pre-vacuum sterilizer. For both freestanding gravity and vacuum type sterilizers, steam is injected into a closed sterilization chamber housing the instruments or equipment to be sterilized. Steam is also injected into the hollow jacket surrounding the sterilization chamber. Steam used for these purposes must be "clean steam" meaning that the water used to make the steam has been demineralized. Steam sterilizers are commonly found in medical, dental, pharmaceutical, medical laboratories, and in science and engineering laboratories.

In the gravity type, steam pushes air out of the chamber filling the top of the chamber with steam. The air is heavier than steam and can be “drained” by gravity out the bottom of the sterilizer with the vacuum type, a vacuum pump draws the air out. The vacuum type dries the sterilized materials more quickly than the gravity type.

In both cases, the sterilizer chamber is surrounded by an outer chamber that is also filled with steam to help keep the whole cavity hot. In many hospitals, a central boiler provides steam for the whole hospital for space heating, and for steam sterilizer use and other purposes. As the steam in the outer chamber condenses, it is often discharged through a steam trap to the sanitary drain. In years past, a constant flow of water was plumbed into the sanitary drain to dilute the quart of hot water discharged to keep temperatures in the sewer below 140°F. For older sterilizers, water tempering systems can be retrofitted to the sterilizer that only flows water when hot water is being discharged. For the last 20 years freestanding sterilizers have come equipped with a water tempering device.

Condensate Discharge to the Drain

Image source: HW (Bill) Hoffman & Associates, LLC

A study conducted in the 1990’s showed that water tempering kits significantly reduced water use (See Table 11-2). New sterilizers with built in tempering systems achieve similar savings.

Self-contained boiler systems are also available. With a self-contained system, a boiler is located at the sterilizer. The condensate is recirculated into the boiler directly. With these systems, there is no need for condensate tempering and the energy in the condensate is conserved. In other words, no water is needed for condensate tempering since the condensate is reused.

Vacuum sterilizers can also use significant volumes of water in the creation of the vacuum.

Table 11-2: Comparison of Condensate Retrofit Savings

Retrofit Equipment	Sterilizer Type	Before Retrofit (GPD)	After Retrofit (GPD)	Reduction %
Steris Corp	AMSCO 3021 Gravity	4,326	1,354	68%
	AMSCO 3023 Vac.	3,187	525	84%
Omega Medical	AMSCO 3021 Gravity	3870	305	92%
	AMSCO 3023 Vac.	3419	64	98%
Continental Equipment	AMSCO 3021 Gravity	1519	117	92%
	AMSCO 3023 Vac.	2510	267	89%

Water Tempering Retrofit Kit for a Steam Sterilizer

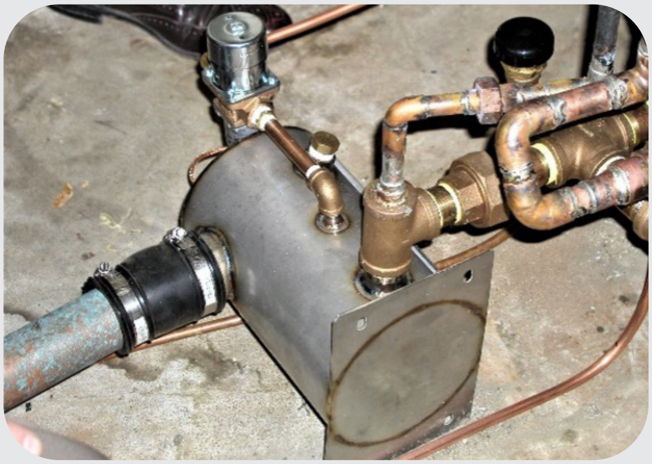


Image source: HW (Bill) Hoffman & Associates, LLC

For non-medical purposes, dry vacuum systems should always be used.

Where allowed by Federal Drug Administrator 510(K) regulations, dry vacuum systems should be used on medical vacuum sterilizers.[8] These savings are summarized in Table 11-3.

Recommendations

- Where feasible, choose something other than a free-standing steam sterilizer, such as a chemical, radiation, or dry heat sterilizer
- Where feasible, use small tabletop sterilizers
- Choose sterilizers with self-contained boiler systems that recycle all condensate
- Ensure that free standing steam sterilizers are equipped with water tempering devices, that the steam is returned to the boiler, or that it is condensed using a chilled water condenser
- Consider stand alone boilers on each autoclave
- Do not use venturi vacuum systems on vacuum sterilizers
- Use dry vacuum systems where FDA 510K regulations are not applied such as laboratory sterilizers

The US Green Building Council's LEED (Leadership in energy and environmental design) Version 4.0 draft contains the following additional requirement for steam sterilizers:

- For 60-inch sterilizers, water use cannot exceed 6.3 gal/U.S. tray.
- For 48-inch sterilizers, water use cannot exceed 7.5 gal/U.S. tray.

The guide can be found at the US Green Building Certification website.

8 https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-premarket-notification-510k-sterilizers-intended-use-health-care-facilities

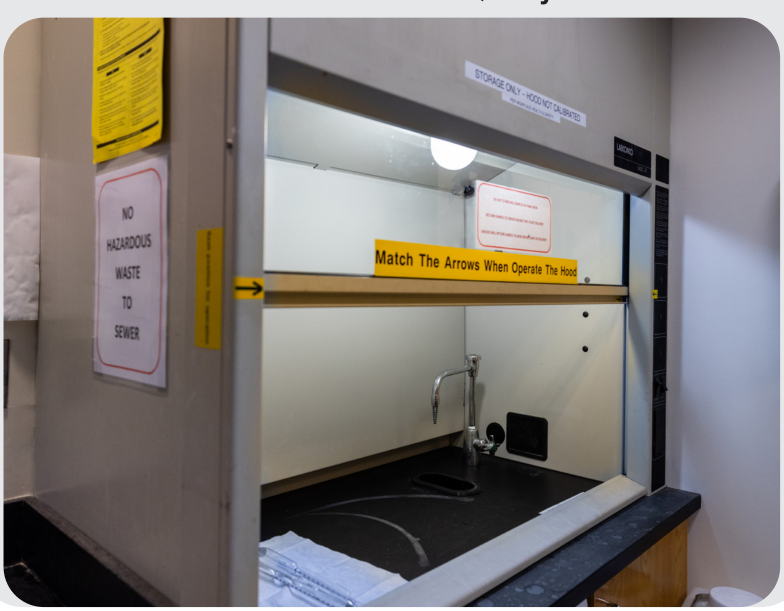
Table 11-3: Comparison of Vacuum System Water Use for Steam Sterilizers*
Based on 10 uses a day, and 250 days per year

Venturi Ejector Water Use (gpm)	Gallons Used per Cycle	Venturi Vacuum Pump Gallons per Year	Liquid Ring Gallons per Year	Dry Vacuum Pump Gallons per Year
6	189	495,000	123,750	0
11	363	907,500	226,875	0
18	594	1,485,000	371,250	0
*Source: California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment				

Laboratory Fume Hoods

Fume hoods are found in most laboratories. Their primary purpose is to remove harmful fumes from the workspace. Many laboratory operations (e.g., those involving acid fumes, organic vapors, toxic materials, biological substances, and perchlorate) require hoods that remove contaminants through special treatment prior to the air being exhausted to the atmosphere. There are a variety of technologies that can provide this function, including some that do not require the use of water. For example, some filtration systems utilize inert adsorbents (e.g., activated carbon, activated alumina) or chemically active adsorbents (e.g., potassium permanganate). These dry filtration systems are effective for low concentrations of contaminants. Laboratories must make sure to check and maintain the adsorbent levels regularly.

Fume Hood in a Water Quality Lab



Systems that do require water include wet scrubbers or special wash-down equipment to remove potentially combustible products are the most common type of hood scrubbers. Within these scrubbers, contaminated air from the fume hood passes through a spray or wet packed column, where it is mixed with water, which dissolves water soluble gases, vapors, aerosols, and particulates.

The scrubbing liquid in the hood scrubber should always be recirculated back though the scrubber.

A small amount of the liquid will eventually need to be discharged, or blown down, to control total dissolved solids and other contaminants, and make-up water is added to maintain scrubber circulating water quality along with scrubber reagents. Mist and drift eliminators installed in the discharge from the scrubber both prevent the release of the scrubber fluid and save water.

Recommendations

- Turn off water flow when systems are not in use
- Always use water (scrubber fluid) recirculating systems
- Use non-potable water sources when possible
- Make sure liquid level controllers and water make-up valves are functioning properly
- Blowdown based on scrubber fluid chemistry, rather than allowing continuous blowdown or based on a timer
- Minimize air flow through the wet scrubbers. Reducing the amount of air passing through the scrubbers will reduce evaporation
- Size equipment to the task and install mist and drift eliminators

Perchlorate or perchloric acid wash-down systems are a specialty type of fume hood used for unstable or combustible compounds that tend to deposit on hood and ductwork surfaces. Wash-down systems are used to periodically wash these substances from the surface of the fume hood and associated ducts. Water is sprayed onto the hood and ductwork surfaces and discharged to the sewer. Fume hood systems and ducts should be designed to minimize surface area and thus the amount of water needed. Ductwork should be designed to take the shortest path to the outside. This specialized ductwork should also remain separate from other building ductwork. This both reduces the surface area that needs to be washed (thus saving water) and avoids perchlorate from coming into contact with organic fumes and other combustible substances. Applicable regulatory guidance can be found in ANSI/AIHA/ASSP Z9.5 –Laboratory Ventilation, and NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.

Recommendations

- Continuous washers should never be used and should be retrofitted to include automatic shutoff valves when the hoods are not in use
- Establish operating procedures to schedule wash downs only when necessary to ensure health and safety. Reducing the runtimes of this equipment will save water
- Work with the provider of the equipment to design the most efficient system and operating procedures
- Energy considerations should also be considered for all ventilation systems that exhaust air from the room to the outside. In addition to reducing water used in wet scrubbers, minimizing air flow while still complying with air volume requirements should be considered to reduce the amount of conditioned air that is required in the laboratory

Vivarium and Aquarium Operations

The first consideration of any vivarium watering system is to provide an adequate volume of clean for the water for the desired purpose. During this delivery process, the prevention of transmission of pathogens requires careful consideration. One of the uses of water that must be considered is its pretreatment before its use by the animals. Choosing water efficient pretreatment processes should be part of the water efficiency consideration for all laboratory operations.

Although the majority of laboratory animal system are for rodents, primates, rabbits, and other animals are used in some circumstances. All of this will influence the type of watering system used. If pretreatment of the water is required, the water used by the treatment equipment such as softeners, reverse osmosis units require additional water use.

Both bottle and automated watering systems are in common use. Bottles must be washed and refilled on a routine basis. Washing involves the use of bottle washers, or cage and bottle washing equipment. Modern equipment uses much less energy and water. Consider new equipment that is more efficient.

Automated systems are typically found in larger operations. Automated systems can either flushing or recirculating systems or a hybrid of the two types.

For all automated vivarium system types, the distribution manifold needs to be flushed with adequate pressure to remove contamination and buildup in the system.

Recommendations

- Consider utilizing recirculating systems, which use less water during the proper treatment and recirculation process
  - For recirculating and hybrid systems, monitor water that is used or discharged in the recirculating treatment operations
- Continuous flushing systems should be replaced with automated systems

- Closely monitor flushing systems which can result in large volumes of water sent to the sewer

- Hybrid systems reduce flushing, thus saving water, while maintaining water quality
- Where bottle washing is used, choosing newer, energy and water efficient bottle and/or cage and bottle washing equipment (see the bottle and laboratory glassware washing sections [include section info here]
- Flushing systems should be automated to reduce flushing cycles that flush only when water quality considerations dictate
- Use air purge (instead of water) to help clean manifold lines where appropriate
- Consider collecting and reusing wastewater from animal watering systems for irrigation and other purposes. Precautions against zoonotic diseases must be considered with such systems.

Aquariums are found in many research facilities and laboratories. Filtration systems such as cartridge filters can significantly reduce water use as smaller facilities. For larger aquariums, large sand filters like swimming pool filters are often used. As with all filtration systems, the Recommendations included in this document for water treatment should be followed.

Filtration System for Ichthyology Lab Aquariums

Image source: HW (Bill) Hoffman & Associates, LLC

Aquarium Sand Filters

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations

- Best practices include the proper use of filtration equipment, using water treatment systems to remove specific contaminants that may be unique to the situation, and proper care and cleaning of aquarium surfaces.
- The control of ammonia buildup in aquariums is beyond the discussion for this document.

Kidney Dialysis and Specialty Laboratory and Medical Water Treatment

Examples of a Total Treatment System of Laboratories

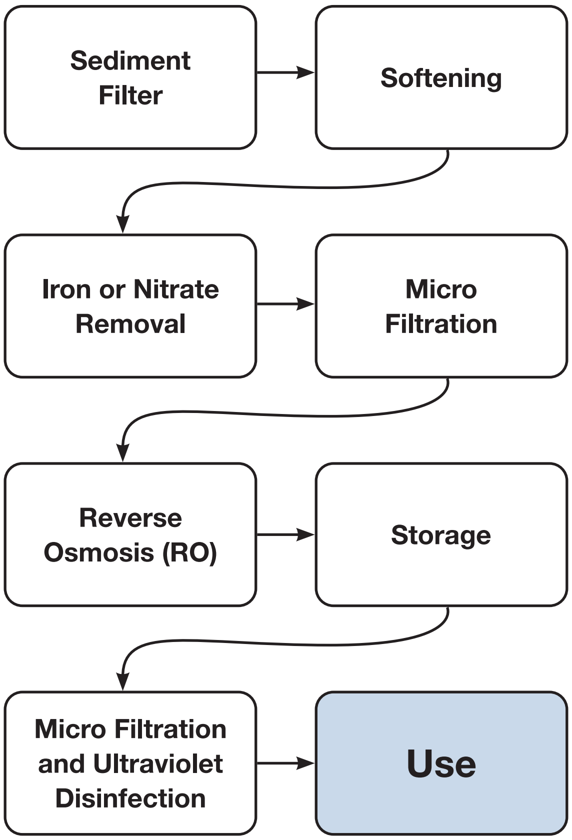
The level of treatment for laboratory water supply varies significantly depending on the end use of that water. Figure 11-13 shows the treatment for a water quality laboratory. It includes filtration, softening, reverse osmosis, and cation and anion exchange to produce water of extremely high quality.

Water used for all types of laboratory and medical operations must also be treated to levels required for that operation.

Examples of a Total Treatment System for Kidney Dialysis

Kidney Dialysis systems must produce ultra-pure, sterile water for the protection of the patient. To accomplish this, they use a combination of treatment systems.

The following shows a typical treatment train for this purpose:



The purity of water used for dialysis must be carefully controlled to protect the health of the patient. For most dialysis systems, the amount of product water produced is just about equal to the water rejected by the RO unit.

Figure 11-13: Treatment for a Water Quality Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations

- The Recommendations found in the section on total water treatment should be followed.

Treated Water Piped to Labs

Image source: HW (Bill) Hoffman & Associates, LLC

Point of Use Treatment System

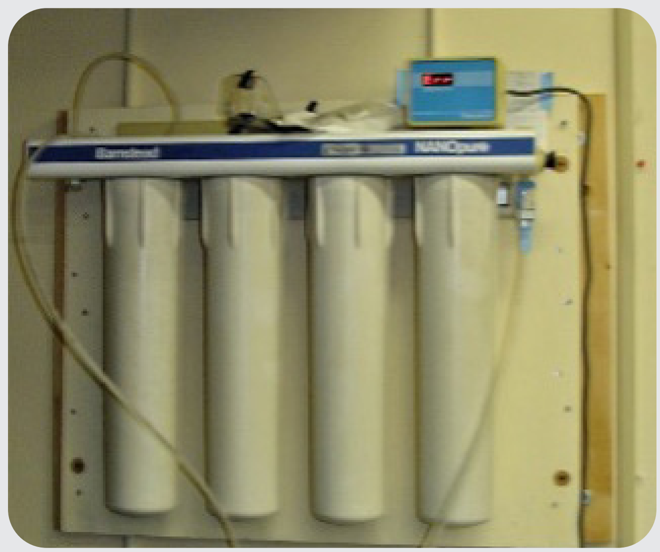


Image source: HW (Bill) Hoffman & Associates, LLC

Dialysis Equipment and Treatment System

Image source: HW (Bill) Hoffman & Associates, LLC

Humidifiers

Humidification of the laboratory working space is necessary, especially in the colder months, to maintain proper humidity both for creature comfort and to control the growth of harmful organisms such as mold, viruses, bacteria, and mites. Most laboratories try to keep relative humidity between 40 percent and 60 percent for the above reasons. Since many laboratories require significant fresh air turnover rates, proper humidification is required. Two basic types of humidification processes are available:

- Isothermal systems use an external heat source to boil water which is injection as steam or water vapor directly into the circulating air.
- Adiabatic systems which either spray water into the air space (atomizers) or those that cause the air in the room to evaporate water with the aid of wetted medial or mechanical energy.

By design, humidifiers consume water to add moisture to conditioned air. However, additional water use can occur from either 1) blowdown or discharge to prevent a buildup of minerals in the system; or 2) treatment of the incoming water supply. Like with cooling towers and boilers, blowdown is required in humidifiers to periodically control the levels of TDS and minerals in the system. The only exception to the need for blowdown is atomizer systems that spray treated water directly into the room. Direct steam injection from a central boiler system does not require additional treatment or blowdown at the point of use, but blowdown and treatment are required at the central boiler. Very pure water produced by reverse osmosis or deionization is recommended for many types of humidifiers, and even then, some water must be blown down or flushed out. Atomizers typically require purified water many laboratories since tap water contains minerals and other contaminants that would be sprayed into the indoor air. Also, wet media, ultrasonic, centrifugal, and hybrid spray systems need the water in them to be controlled for bacteriological growth through the addition of biocides, even when high purity water is used. When operating humidifiers or selecting new equipment, laboratories should examine the water that is required for blowdown, as well as waste generated through generation of reverse osmosis and deionized water.

Energy is also a consideration when selecting or operating humidifiers. Isothermal humidification requires the generation of steam or hot water, which can be energy intensive. Since centralized boiler systems are usually operated more efficiently than stand-alone steam boiler humidification systems, direct steam injection tends to be both more energy and water efficient. Adiabatic systems require the evaporation of water which has a cooling effect on the air in the space being humidified. This is beneficial in warm, dry climates where cooling is needed in addition to humidification. In colder climates, or in winter more energy will be required for space heating, however energy savings may still be achieved by not having to generate steam or hot water, as is required for isothermal humidifiers.

Table 11-4: ASHRAE (Chapter 22, 2016 ASHRAE Handbook—HVAC Systems And Equipment) List of Humidifiers

Isothermal	Adiabatic
Steam heat exchanger	Ultrasonic atomizer
Hot-water heat exchanger	Centrifugal atomizer
Direct-injection steam	Pressurized-water atomizer
Electrode steam	Compressed air atomizer
Electric resistance steam	Wetted media
Gas-fired steam	Hybrid spray/media
Electric infrared steam	

Recommendations

- All humidification operations should be properly controlled with instrumentation to measure relative humidity and keep the levels typically between 40 and 60 percent. This ensures that only the water and energy needed to control humidity is used and comfortable, safe conditions are maintained.
- All humidifier equipment and operating conditions should be carefully chosen and sized for type of laboratory in which it is being installed. Work with a qualified vendor to select equipment and controls designed for energy and water efficiency.

Medical Therapeutic Water Using Equipment

Hydrotherapy and related treatment methods are used for a multitude of purposes ranging from recovery from muscular skeleton injuries and illnesses to therapy for burn victims. Equipment ranges from small vessels for hand and foot injuries to hole body whirlpools and swimming pools.

Therapy pools operate like swimming pools and the Recommendations for pools apply. For special baths, strict medical procedures are used to prevent transmission of infections. The Center for Disease Control (CDC) has strict protocols for the cleaning, disinfection and maintenance of this equipment. Among other things special baths and treatment tanks must be drained and disinfected after each use. The only recommendation is that institutions should follow the CDC guidelines.

Alternative Water Sources

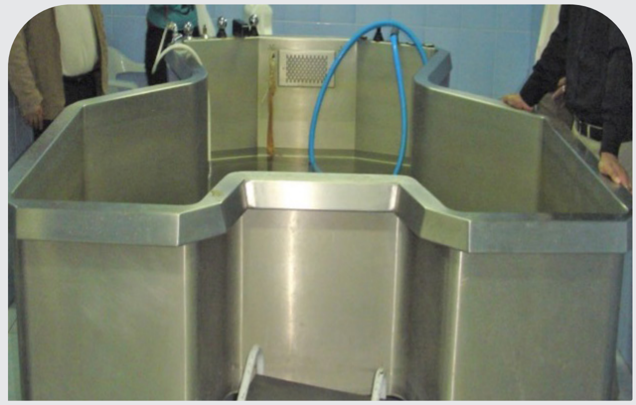
Before beginning a discussion of the water savings potential of the technologies described above, it is important to remember that the potential to collect and reuse clean but non-potable water is significant in larger medical and laboratory facilities. This approach is promoted by "Labs for the 21st Century," a joint program of the US EPA and the Department of Energy.

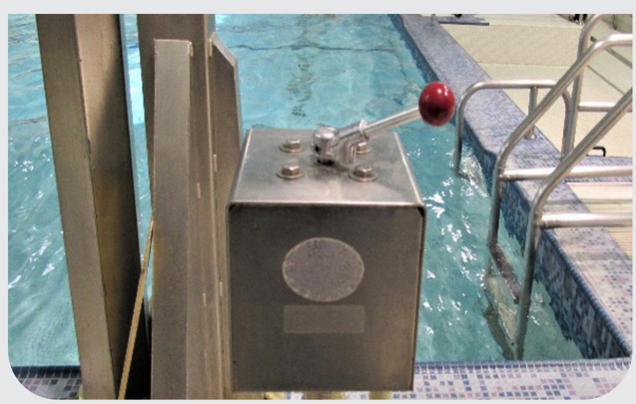
Possible sources of water include, but are not limited to:

- Once-through cooling water discharge
- Water from reverse osmosis units
- Foundation drain water
- Rainwater

Using reclaimed water from municipal sources is also possible for irrigation and cooling tower makeup, as well as toilet and urinal flushing.

Examples of Therapeutic Equipment (Top to Bottom): Physiotherapy Tank, Whirlpool Bath, Whirlpool, Pool





Images source: HW (Bill) Hoffman & Associates, LLC

Figure 11-4 is for illustrative purposes only. Such a system must be equipped with proper backflow prevention and pumps where pressurized output is needed. Learn more in the Alternate Onsite Water Sources chapter.

Water Savings Potential

For the equipment described in the section above, the following water savings are possible:

Vacuum Systems

Dry systems do not use water for the pump seal but can use water for cooling the pump. Water use rates for a liquid-ring pump range from 0.5 to 1.0 gallons per minute (gpm) per horsepower (hp). Water use can be eliminated entirely if no cooling water is used. Pumps should never be cooled with a once-through system. If a water-using system must be used, it should be hooked to a closed-loop or radiator-type system. The typical dental unit with a 1.5 hp liquid-ring pump can use 360 to 720 gpd.[9] For a large medical facility with a 12 hp pump, the water used per day can range from 8,640 to 17,280 gallons. Newer liquid-ring pumps try to minimize water use, so their consumption would most likely be in range of 8,600 to 10,000 gpd. Using a dry vacuum pump will save significant volumes of water or eliminate water use (Tuthill).

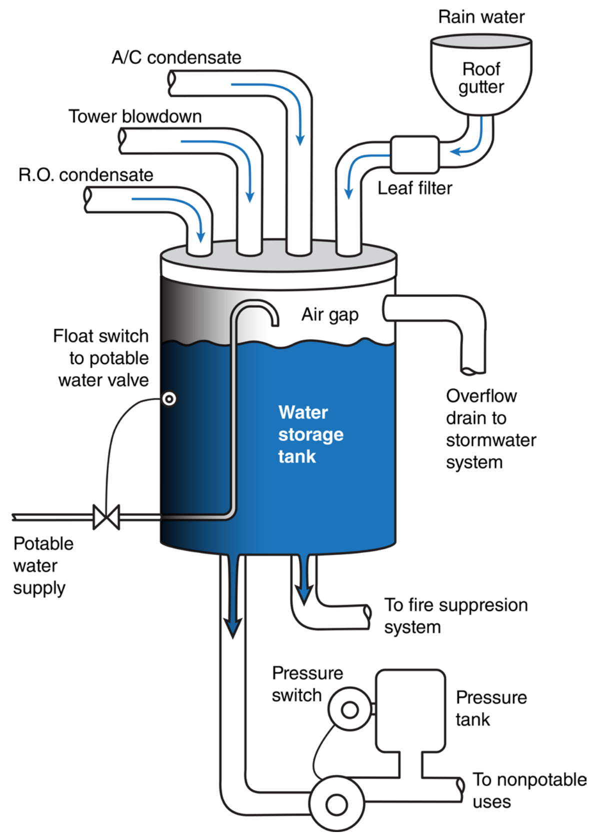
Medical Air and Compressor Equipment

Compressors generate significant heat as they compress the air. Smaller units, such as those used in dental and smaller medical facilities, can easily be air-cooled. Compressors larger than 10 or 15 hp (Tuthill), however, often require water cooling. Ten hp equals 7.5 kW, and a once-through-cooled compressor that size would require a constant stream of 5 to 6 gpm to cool it when in operation. When water cooling is necessary, the compressor cooling system must be hooked to a looped cooling system. If not, water demands for this example could exceed 8,000 gpd.

Sterilizer Operations

Water use per cycle for large vacuum steam sterilizers ranges from 350 to 400 gallons per cycle (TDK Consulting). Now new equipment often comes equipped with condensate-tempering systems (CTS). Mechanical vacuum pumps and other equipment can be retrofitted with after purchase equipment (Continental Equipment). To reduce water use per cycle to less than 80 gallons.

Figure 11-4: Reclaimed Water Reuse Example



The use of CTS on gravity and vacuum sterilizers also reduces water use significantly. Since the typical flow rate for tempering is 0.3 to 1.0 gpm, water use can be in the range of 450 to 1,500 gpd. The installation of a CTS can reduce this water use by 85 percent to 65 to 200 gpd.

Water-cooled Laboratory and Therapeutic Equipment

Daily water use depends upon the type of equipment being cooled and the length of time the equipment is used daily. Flow rates of 0.5 to 5.0 gpm are possible for each piece of equipment. Connecting larger stationary equipment to a closed-loop system is the first logical step in reducing water use to near zero. Recirculating water systems also minimize water use.

Laboratory Hood Scrubbers

Flow rates in scrubbers can be high. Recirculating systems reduce this use to a few gallons per minute when operating.

9 www.sableindustriesinc.com

Cost-Effectiveness Analysis

Vacuum Systems

Because liquid-ring vacuum systems must move both air and water, they are inherently less energy efficient and use significant amounts of water. However, they also tend to be the least expensive vacuum systems, based upon size and capacity (from a search of web sites for such equipment), so there is a true trade off between initial cost and operating cost.

Several dry vacuum systems are available for dental applications. The cost for a new dry vacuum pump in the one to two hp size is $5,000 to $10,000. By comparison, a liquid ring pump of the same hp costs $2,000 to $7,000. However, because dry systems are more efficient, a one hp dry system can often replace a 1.5 to 2.0 hp liquid ring system. This partially offsets this cost difference. On an annual basis, dry systems use one-third to one-half less electricity than a liquid-ring pump and have zero water use (Tuthill). As an example, compare a system that requires a 1.5 hp liquid ring pump with a 1.0 hp dry pump. In an eight-hour day, the liquid ring pump will use 540 gallons of water and 9 kWh of energy. The dry pump will use no water and only 6 kWh. Depending on where the facility is, the business will not only save on water costs but wastewater costs as well.

If the liquid ring system of a large medical center requires a 23 hp pump, a comparable dry system (piston, vane, or non-lubricated) would require only 12 to 15 hp. Liquid-ring pumps require as much as twice the horsepower of equivalent dry vacuum pumps because both water and air must be pumped. Liquid ring pumps in continuous operation use water at a rate of 16,000 to 30,000 gpd.

In one example from a firm that sells all four kinds of pump systems, a 23 horsepower pump will use about 2.9 million gallons of water per year and 152,000 kWh of power (Tuthill). In contrast, the same tasks could be accomplished by a 12 hp vane pump, which would use no water and only 80,000 kWh of power (Tuthill). The costs for operating these systems will be dramatically different. The liquid-ring system cost would be about $8,000 to $20,000, while vane and piston pumps would cost twice that. Liquid ring and dry vane pumps have about the same life span of 10 years or fewer, while piston pumps can last several decades (Tuthill). As an example, one medical facility replaced a liquid ring pump with a dry 10 hp vacuum system. The savings in energy and water were over $60,000 per year (Deckkler).

Another major cost savings with dry systems is that they do not have to be plumbed for water or have a backflow system. These costs can be from $200 to over $5,000, depending upon how much plumbing must be done. Dry systems also eliminate the costs of annual inspections of backflow equipment, which typically cost from $50 to $300 depending on who the water utility is.

Medical Air and Compressor Equipment

Air-cooled systems do not use water, while once-through systems will use half a gallon to one gallon per horsepower-hour. Hooking up to a closed loop system can be relatively inexpensive if the water line is readily available or expensive if long runs must be made. Typical costs of a few hundred to one to five thousand dollars can be expected.

Sterilizers and Central Sterile Operations

Most new sterilizers are equipped with water tempering equipment at the factory, and medium and large vacuum systems come equipped with mechanical vacuum pumps, according to Steris's information on their web site (www.steris.com/).

Water cooled Laboratory and Therapeutic Equipment

Cooling any piece of equipment with air is always the least expensive method. Where water must be used, hooking to a closed loop system is the next best option. The cost for doing this is dependent upon the location and availability of chilled water for cooling tower loop piping.

Laboratory Hood Scrubbers

Equipment and operating costs for scrubbers vary with application, and case-by-case analyses are necessary. Remember that dry hoods are always less expensive than systems that require scrubbers, because they require no water or sewer hookups and backflow preventers, consume less electricity, and use no water. Typical costs of a few hundred to one to three thousand dollars can be expected.

Recirculating chillers are also available. This equipment has the advantage of very precise temperature control and the ability to achieve low water temperatures if needed. Equipment is rated in watts of energy removed and can vary in size from 1,000 to 10,000 watts. The cost for this equipment ranges from $2,000 to more than $15,000, depending upon capacity and brand. The price per watt will vary depending on the region and fluctuate with the time of the day and year but the overall price is 20.06 cents per kilowatt hour, compared with an average 16.06 cents statewide and 10.48 cents nationally. There is also an electricity cost based upon the electrical-rating wattage of the equipment. For example, a 5,000-watt machine will consume 6.4 kWh in continuous operation, including the heat input from the motor of 3.5 watts removed per watt of motor energy input. Most units will not run continuously and will operate only when there is a heat load from the laboratory or therapeutic equipment being used.

The water savings are also based upon the amount of heat removed. Using the example above, a 5,000-watt machine with once-through cooling and a temperature rise of 10 degrees will use about 6.33 gpd in continuous operation.

Recommendations

Proven Best Practices for Superior Performance

- Use dry vacuum systems in medical, dental, and laboratory facilities
- Air cool or use a radiator cooler or a chilled-loop or cooling tower system with all vacuum and compressor systems. Once-through cooling with potable water should be prohibited
- Equip all stand-alone steam sterilizers with condensate tempering systems
- Equip all vacuum sterilizers with mechanical vacuum systems
- Cool laboratory equipment with a closed-loop system, such as a chilled water or cooling tower system, or with a recirculating chiller unit
- Equip all hood scrubbers with recirculating systems
- Perchlorate hoods on fume hood washdown systems should have self-closing valves
- Consolidate loads. Don't run an autoclave to sterilize a small amount of equipment
- Right-size your autoclave. If you don't need a large autoclave, use a smaller one instead
- Consider a water and energy efficient “Green” autoclave when purchasing autoclaves
- Install water saving devices on existing autoclaves whenever possible

Additional Practices That Achieve Significant Savings

- Use dry hood-exhaust systems wherever possible
- Promote the use of digital X-ray equipment
- Recover and reuse water from sources such as RO reject water, air conditioner condensate, rainwater, foundation drain water, and any other applicable source for use as irrigation water, scrubber water makeup, and cooling tower makeup
- Use dry cooling for all equipment where possible
- Promote use of condensate return systems for sterilizers

Resources

1. ANSI/AIHA/ASSP Z9.5 –Laboratory Ventilation, and NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.
2. ASHRAE (Chapter 22 - 2016 ASHRAE Handbook – HVAC Systems and Equipment) lists the following types of humidifiers.
3. Arizona Municipal Water Users Association, Black and Veatch. March 2003. Facility Managers Guide to Water Management. Version 2.3.
4. Beckinghausen, David. October 1, 2006. "Energy-Efficient Washing Systems." ALN Magazine. *www.alnmag.com/article/energy-efficient-washing-systems.*
5. The California Urban Water Conservation Council, "Evaluation of Potential Best Management Practices - Steam Sterilizer Retrofits" *https://calwep.org/wp-content/uploads/2021/03/Steam-Sterilizer-Retrofit-PBMP-2004.pdf*
6. CH2MHill. May 2002. Air Force Water Conservation Guidebook. *https://www.wbdg.org/FFC/AF/AFDG/af_waterconservationgb.pdf*
7. Center for Maximum Potential Building Systems, Hospitals for a Healthy Environment, Merk Family Fund, New York State Energy Research and Development Authority, et. al. 2014. Green Guide for Health Care 2.2. *https://www.yumpu.com/en/document/view/27300369/gghc-v22-02-checklistpdf-green-guide-for-health-care*
8. Communication with Andrew Arvanites, October 20, 2021, Business Manager -Washing, Automation), Material Handling *https://www.tecniplast.it/*
9. Consolidated Sterilizer Systems, Green Technology for Reducing Sterilizer Water Consumption *https://consteril.com/products/smart-options/water-saving-systems/*
10. Consolidated Sterilizer Systems, Sterilization for Beginners: The Inner Workings of a Laboratory Autoclave, *https://consteril.com/how-does-a-laboratory-autoclave-work/*
11. Continental Equipment Company. Tonganoxie, Kansas. *www.sterilizer.net/contact.* 800-710-9674
12. Corporate Wellness Magazine, Redefining Healthcare with Design of the Green Hospital, *https://www.corporatewellnessmagazine.com/article/redefining-healthcare-design-green-hospital*
13. Deckker Vacuum Technologies, Medical Vacuum Solutions. *https://www.dekkervacuum.com/en/resources/principles-of-operation*
14. Donovan, Robert P., Morrison, Dennis J., and Timon, Robert P. November 1998. Design of Recycling Systems for Spent Rinse Water in Sandia's Microelectronics Development Laboratory. International SEMATECH TT# 98113599A-ENG. *https://www.osti.gov/servlets/purl/767884*
15. GlobalVac, Vacuum Pump Applications in the Medical Industry, *http://globalvac.com/vacuum-pump-applications-in-the-medical-industry/blog.html*
16. Hursh, Debbie. March 2005. Hazardous and Medical Waste Program, Fact Sheet on Information Papers – Ethylene Oxide (EtO) Sterilizers. U.S. Army Aberdeen Proving Ground.
17. International Institute for Sustainable: Laboratories/ US Environmental Protection Agency, Best Practices Guide – Water Efficiency in Laboratories, *https://www.i2sl.org/documents/I2SLBestPractices_WaterEfficiencyinLaboratories_June2022_v2.pdf.*
18. Johnson, Greg, Glitsis, Don, Beckwith, Clois, Huff, Winston, and Scoccia, Vince. March 2007. How to Achieve Water Efficiency Credits. GGHC/2E Green Building Teleconference Series.
19. Labconco.com, 2017, *www.labconco.com/download/hand-washing-case-study/1SR5LugetfoPx9lw9HiznD*
20. Lessick, Dale. November 2002. Converting X-Ray Machines from Water Pass-Through to Re-Circulating. Irvine Ranch Water District. Irvine, California.

21. Muratore, Tom, and Lorange, Bob. April 2006. Water Water Everywhere: Water Supply and Usage. GGHC/H2E Green Building Teleconference Series.
22. National Library of Medicine - *https://www.ncbi.nlm.nih.gov/books/NBK569311/table/ch3.tab42*
23. New Mexico. Office of State Engineer. July 1999. A Water Conservation Guide for Commercial, Institutional and Industrial Water Users.
24. North Carolina Department of Environment and Natural Resources, Division of Pollution Prevention. August 1998. Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.
25. Payette architects Jeffrey Zynda and Michael Hinchcliffe A Recommended Shift Away From Tunnel Cage Washers | Tradeline, Inc. *tradelineinc.com*
26. The Phoenix Medical Facility Study - Project Number: 0742-004-01 *https://static.sustainability.asu.edu/docs/dcdc/website/documents/24_WILCUT_PhoenixMedicalSector.pdf*
27. Sable Industries. *www.sableindustriesinc.com*
28. Safety Emporium, Aerator for WaterSaver Laboratory Faucets, *https://www.safetyemporium.com/bo055*
29. Steris Healthcare, Guide to Steam Sterilization Cycles - Steam Flush Pressure Pulse, *https://www.steris.com/healthcare/knowledge-center/sterile-processing/guide-to-steam-sterilization-cycles-steam-flush-pressure-pulse*
30. Sterrad. *www.sterrad.com/products_&_services/sterrad/index.asp*
31. Sustainable Chemistry: Chemists modify glassware to save water while running common reactions, by Leigh Krietsch Boerner, September 26, 2013, *https://cen.acs.org/articles/91/web/2013/09/New-Condensers-Cool-Solvent-Without.html*
32. TDK Consulting Services, The Reduction in Water Consumption of Sterilizer Equipment Resulting from the Installation of Water-Mizer Systems. Parkville, Missouri. *https://www.sterilizer.net/wp-content/uploads/2018/07/TKD-2005-Sterilizer-Water-Savings.pdf*
33. Texas State University. Cleaning Laboratory Glassware. *https://www.txst.edu/chemistry/student-resources/Stockroom/cleaning-laboratory-glassware.html*
34. Torke, Ted. September 1994. Recommendations for Hospitals and Medical Facilities. Palo Alto Regional Water Quality Control Plant.
35. Tschudi, William, and Rumsey, Peter. Using Benchmarking to Identify Energy Efficiency Opportunities in Clean Rooms, The Labs 21 Approach. Laboratories for the 21 Century (Labs 21) U.S. Environmental Protection Agency. *http://www.Labs21century.gov/toolkit/bp_guide.htm*
36. Tuthill Vacuum and Blower Systems, Vacuum Solutions. Springfield, Missouri.
37. UC Riverside, Autoclave study, Delphine Faugeroux Office of Sustainability, *https://chesc.org/wp-content/uploads/UCR-Autoclave-study-2016-PROCUREMENT-DF.pdf*
38. US CDC, Guidelines for Environmental Infection Control in Health-Care Facilities, *https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf*
39. US Department of Energy, Best Management Practice Case Study #12 — Laboratory/Medical Equipment, *https://www.nrel.gov/docs/fy11osti/48950.pdf*
40. U.S. Environmental Protection Agency, Region 9. 2002. Replacing Ethylene Oxide and Glutaraldehyde. *https://19january2017snapshot.epa.gov/www3/region9/waste/archive/p2/projects/hospital/glutareth.pdf*
41. US EPA “Saving Water in Hospitals”, *http://www.pacepartners.com/wp-content/uploads/2018/06/hospital_fact_sheet.pdf*
42. US Green Building Council's LEED (Leadership in energy and environmental design) Version 4.0, *http://www.usgbc.org/node/2611746?return=/credits/healthcare/v4*

43. US Green Building Council Indoor water use reduction *http://www.usgbc.org/node/2611746?return=/credits/healthcare/v4*
44. U.S. Navy. Navy Water Conservation Guide for Shore Facilities. *https://apps.dtic.mil/sti/citations/ADB219530*
45. Vacuum Science World, Vacuum Technology in Medical Applications, *https://www.vacuumscienceworld.com/blog/vacuum-technology-medical-applications*
46. Water Conservation at Tufts New England Medical Center (NEMC). *www.h2e-online.org/pubs/tuftsh2o.doc*

Chapter 12
POOLS AND SPAS

Pools, spas and hot tubs can waste large volumes of water if not properly designed, equipped, and maintained for efficient operation. Recommended practices for suitable design, equipment, and maintenance of these water features can be summarized into five principles:

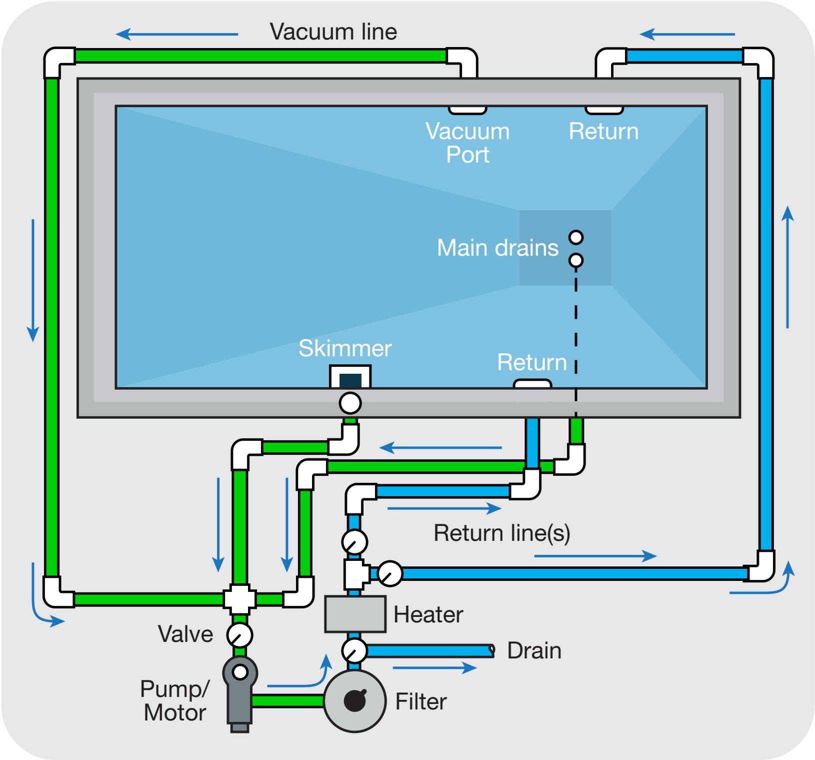
1. Install water features only where they provide tangible benefits.
2. Choose alternative types and sizes that use less water.
3. Design the mechanical equipment to filter, clean, and operate efficiently.
4. Design the water feature and ambient surrounding area to minimize water loss.
5. Promptly inspect, repair, and replace any components that are not working properly.

The primary uses of water in water features are for make-up (filling), splashing and drag-out (water removed when a person exits a pool or spa), backwashing the filter (cleaning the filter), and replacing water lost to leaks and evaporation. Practices and considerations that will result in more efficient water use include:

- Periodically checking for and repairing leaks.
- Installing a submeter for the pool or spa to track the feature's use and easily identify leaks.
- Tracking water use on a weekly or monthly basis.
- Choosing a filtration system that minimizes water use while accommodating cost considerations.
- Maintaining proper pool chemistry and keeping water features free of debris to limit cleaning and drainage events.
- Including splash troughs that drain back into the pool.
- Using a secure and durable pool cover anytime practicable, especially over an extended off-season period.
- Carefully monitoring backwashing to ensure that times are not excessive and reuse backwash water for irrigation where possible.
- Considering use of alternative water sources such as rainwater for fountains and other water features.

Draining and Refilling Pools and Spas

The following diagram shows how a pool works:



Water is used to refill a water feature to make up for water lost through evaporation, splash-out, or to replace water lost during filter backwash. Refilling also occurs when the water feature is drained, either for periods of non-use or when the total dissolved solids (TDS) content of the water has become too high. How often a pool or spa will require draining and refilling varies based on use, maintenance, temperature and more. Based on multiple sources, recommendations range from every three to seven years. The American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas recommends the following options to lower TDS levels as an alternative to draining and re-filling the water feature:

- Use reverse osmosis or nanofiltration.
- Use ozone and/or ultraviolet light (UV) to allow for lower chlorine demand which will help to reduce the buildup of TDS.[1]

1 Association of Pool & Spa Professionals. (2017). ANSI/APSP/ICC-13 2017 American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas. *https://issuu.com/thephta/docs/apsp-13_2017*

Drained water can be reused for irrigation if the dissolved solids are controlled, and chemical and chlorine levels are not too high

- Allow pool or spa drainage water to settle until the chlorine concentration is 1.0 milligrams per liter. This meets most municipal potable-water parameters, at which time it is safe to use for landscape irrigation.
- The pH level of public pool or spa water should be between 7.2 and 7.8.[2]
- The water should be clear with no algae present.
- Plants in the landscape where pool or spa water is being used for irrigation should have a salt tolerance. Some species do not tolerate water with salt, such as fruit trees, roses, and star jasmine.
- Lawns can be watered with pool or spa water if the chlorine content is low.

If using drained pool or spa water for irrigation is not an option, always check local ordinances regulating discharges to the sanitary sewer or storm drain system (if separate in the applicable jurisdiction). Many cities in California prohibit the discharge of pool or spa water to the street, gutter, or storm drain due to the possible presence of chlorine and copper. Copper is sometimes used in pool and spa treatment as an algicide, and both treatments are toxic to aquatic organisms.[3]

Operational Water Loss

Water loss in water features is primarily caused by evaporation, leaks, splashing, and/or "drag-out," the water that is removed when a person exits a pool or spa.

Evaporation

The rate of evaporation from a pool, spa, or other water feature is dependent on several variables, including temperature, humidity, wind speed, pH and chemical content of the water. The California Water Efficiency Partnership estimates that evaporation accounts for 56% of pool water use across all pools installed in California.[4] This water must be replaced to keep the water at the proper level.

To reduce evaporation, operators of pools, spas, fountains and other water features should observe the following practices when applicable:

- Cover pools and spas when not in use to reduce evaporation and keep water cleaner.

The Environmental Protection Agency (EPA) estimates that, depending on climate, an uncovered 500-square-foot swimming pool could lose between 12,000 and 31,000 gallons of water per year on average due to evaporation.[5]

  - Covers range from single sheets of plastic to insulated materials. Using a solid pool cover can reduce evaporation by over 90%.[6]
    - The EPA provides additional guidance on pool covers here.
  - In California, Title 24 requires that a heated pool be covered when not in use.[7]
- Reduce water temperature in pools and spas
  - The greater the temperature differential between ambient air temperature and water, the higher the rate of evaporation.
- Use low water, size appropriate plant material and fences as windbreaks to reduce water loss due to wind evaporation.
- Turn off the tile-spray device on automatic pool cleaners.

2 Centers for Disease Control and Prevention. (2022). Operating Public Swimming Pools. https://www.cdc.gov/healthywater/swimming/aquatics-professionals/operating-public-swimming-pools.html

3 Alameda County Clean Water Program. (2013). Proper Disposal of Wastewater. https://cleanwaterprogram.org/wp-content/uploads/2022/11/Pools-Spas-and-Fountains.pdf

4 U.S. Environmental Protection Agency. (2017). WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities. https://www.epa.gov/watersense/best-management-practices

5, 6 U.S. Environmental Protection Agency. (2022). Jump Into Pool Water Efficiency. https://www.epa.gov/system/files/documents/2022-09/ws-outdoor-pool-guide.pdf

7 Koeller, John & Hoffman, H.W. Bill. (2010). Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains. California Water Efficiency Partnership. https://calwep.org/wp-content/uploads/2021/03/Pools-Spas-and-Fountains-PBMP-2010.pdf

- Spray water often evaporates before it hits the tile, splashing invites evaporation losses, and over-spraying can send water out of the pool.

- Avoid using sprays and finely divided streams of water in fountains and waterfalls.
  - Aeration causes a significant amount of evaporation, especially on windy days

Leaks

Pools, spas, and other water features can leak with no obvious signs other than a high-water bill. Leaks can occur in several places in a pool, spa, or water feature, but the most common leaks are due to:

- Mechanical issues
- Structural damage, broken tiles
- Plumbing
- Broken pipes
- Loose or broken fittings

Automatically refilling a pool can make it challenging to detect leaks. It is recommended that commercial or public pool and spa operators check for leaks at least once a month by shutting down all filtration systems for 24 hours or the maximum time between closing the pool or spa and opening the next day.[8]

A submeter should be placed on the make-up (fill) water line used for keeping the pool, spa, or other water feature full to determine whether leaks are occurring. A submeter on the make-up line can quickly identify abnormal use and help monitor water use volumes for backwashing filters and other operations. A submeter with Wi-Fi signal that reads water use by the hour could help automate water leak detection. See additional EBMUD guides for more information on submeters here.

TABLE 12-1: Primary Water Uses in Pools and Spas

WATER USE	EFFICIENT PRACTICES
MAKE-UP (filling)	→ Install a submeter so you can monitor water use and identify and repair leaks → Track water use on a weekly or monthly basis (see "Submetering" chapter) → Maintain proper pool chemistry; keep water features free of debris to limit cleaning and drainage events → Consider use of alternative water sources such as rainwater for fountains and other water features
SPLASHING AND DRAG-OUT (water removed when a person exits a pool or spa)	→ Include splash troughs that drain back into the pool
BACKWASHING THE FILTER (cleaning the filter)	→ Choose a filtration system that minimizes water use while accommodating cost considerations → Carefully monitor backwashing to ensure that times are not excessive and reuse backwash water for irrigation where possible
REPLACING WATER LOST TO LEAKS AND EVAPORATION	→ Periodically check for and repair leaks → Use a secure and durable pool cover anytime practicable, especially over an extended off-season period

8 Association of Pool & Spa Professionals. (2017). ANSI/APSP/ICC-13 2017 American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas. https://issuu.com/thephta/docs/apsp-13_2017

Finally, installing a length of Plexiglas pipe on the backwash line of a pool or spa can help operators verify if backwash valves are completely closed and that water is not being lost through the backwash line during normal operation.

Splashing and Drag-Out

Water loss due to splashing and drag-out in pools and spas can be reduced through design and operational changes such as:

- Design pools to incorporate splash troughs along the edge to catch water that would normally be splashed out onto the deck. Troughs should drain back into the pool.
- Keep the water level at the lower operational level of the skimmer opening.
- Block the overflow line when the pool is in use or during periods of particularly heavy use.

Filtration and Disinfection

All water features should have properly sized equipment to filter and disinfect the water. The three main types of filters are:

- Sorptive media such as diatomaceous earth filters, perlite filters, and regenerative filters that reuse the filter media
- Sand
- Cartridge

Each type of filter has advantages and disadvantages. Depending upon the type of filtration used, a substantial amount of water may be discharged when the filter is backwashed. The amount of water used to backwash a filter depends upon the size of the pump, which in turn depends upon the size of the pool or spa. In California, the recirculation system needs to have the capacity to provide a complete turnover of pool water (pump it through the filter) per the following specifications:

- One-half hour or less for a spa pool
- One-half hour or less for a spray ground (splash pad)
- One hour or less for a wading pool
- Two hours or less for a medical pool
- Six hours or less for all other types of public pools[9]

Pool filters should be backwashed based on pressure and never on a timer or pre-set schedule.

Manufacturing specifications will direct when to backwash. Automatic backwash equipment will not backwash a filter until the proper pressure drop has occurred, minimizing the number of backwashes to only what is needed.

The American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas recommends that filters be backwashed, replaced, or re-coated when the following conditions occur for each filter type:

- Sand Filters – when the pressure gauge reading is 8-12 PSI higher than the starting pressure or when flow decreases below the required or desired rate.

Table 12-2: Pool Filtration Method/Technology

CHARACTERISTICS	SORPTIVE MEDIA	SAND	CARTRIDGE
Filtration Ability	5 microns	20-40 microns	10-20 microns
Water Usage	**Moderate**	**High**	**Low**
Filter Media Lifetime	2-3 years	3-6 years	2-4 years
Recommended For Use In Large Public Pools	Yes, with proper design	Yes	No, too labor intensive

9 California Association of Environmental Health Administrators. (2018). Public Swimming Pools and Spas. https://deh.acgov.org/operations-assets/docs/recreationalhealth/Pool_Code_Book_Title_22.pdf

- Cartridge Filters - when the pressure rises 8-12 PSI above the starting pressure or when flow decreases below the required or desired rate.
- DE Filters - when the pressure rises 8-12 PSI above the pressure reading upon re-coating after cleaning, or when flow decreases below the required or desired rate.
- Vacuum DE/Sand Filters – when the working vacuum reading is 10 in Hg (inches of mercury) above the starting vacuum or when flow decreases below the required or desired rate.[10]

Sorptive Media Filters

Sorptive media filters include conventional diatomaceous earth (DE) filters, perlite filters, and regenerative filters that reuse the filter media. These filters remove particles down to 3-5 microns in size, while silica sand and cartridge filters work in the 10- to 40-micron removal range.[11] Sorptive media filters contain hundreds to thousands of fabric-coated tubes inside a pressure container. The medium (DE or perlite) is made into a slurry and mixed with the water in the filter. The medium is then deposited on the tubes by the water being pumped through the filter. Conventional sorptive media filters must have the DE or perlite replaced after each backwash. With regenerative sorptive media filters, the medium is periodically "bumped" off of the filter tubes by backflow, air agitation, mechanical shaking, or a combination of the three, and then recoated onto the filter cloth. No water is lost in the recoating process. This makes regenerative sorptive media filters very water efficient.

Sand Filters

Sand filters are commonly used for residential pools and can be used for large commercial applications such as public pools and water parks. Sand filters use silica sand, glass, or zeolite to capture particles between 20-40 microns. Sand may last for several years before needing to be completely replaced; however, sand may need to be added periodically to replace any lost during backwash. Backwashing a sand filter is a water intensive process, making these filters the least water efficient.

Cartridge Filters

Cartridge filters are not designed for larger size pools like municipal pools because of the waste of materials and labor-intensive cleaning process. A superior option is to use a reusable filter cartridge that lasts two to five years; however, this requires two sets of filters. When one set is removed for cleaning, it must be soaked in a cleaning solution and then brushed and rinsed off. A significant advantage is that no backwash water is used, making cartridge filters the most water efficient filter option.

Alternatives to Pools

Water-saving alternatives to pools include playscapes that use sprays and other water features activated only when someone is going to use them. Although fine spray and mist can increase evaporation, efficiency is possible if the water is captured and treated after each use. Water can be stored in a tank with a filtration and disinfection system. Tank storage also reduces evaporation and chemical use over an open wading pool, where water is dumped and refilled.

Recommendations

- Consider use of alternatives to wading pools, such as spray-scapes.
- Use pool and spa covers, especially during periods when a pool or spa is not in regular use.
- Require make-up submeters to be installed on all pools, spas, and other water features.
- Require all water features be equipped with recirculating filtration equipment.
- Require in-ground pools to be built with splash troughs around the perimeter.
- Maintain proper water quality levels for key indicators like pH, alkalinity, and hardness to avoid the need to drain the pool or spa.[12]
- Use sorptive media filters where possible for pools.
- Use cartridge filters for smaller spas, where the costs of filters and cleaning make them economically feasible.
- Ensure filters are only backwashed when needed.
- Reuse backwash water for irrigation or consider retreatment and reuse in the pool.
- Use low water, size-appropriate plant material or fences to shade pools and spas and block winds that increase evaporation.

---

10 Association of Pool & Spa Professionals. (2017). ANSI/APSP/ICC-13 2017 American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas. *https://issuu.com/thephta/docs/apsp-13_2017*

11 Leslie's Pool Care. Pool Filter Comparison. *https://lesliespool.com/blog/pool-filter-media-types-a-comparison-guide.html*

12 U.S. Environmental Protection Agency. (2017). WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities. *https://www.epa.gov/watersense/best-management-practices*

References and Additional Resources

1. Alameda County Clean Water Program. "Proper Disposal of Wastewater." 2022
   https://cleanwaterprogram.org/wp-content/uploads/2022/11/Pools-Spas-and-Fountains.pdf
2. Association of Pool & Spa Professionals. ANSI/APSP/ICC-13 2017 American National Standard for Water Conservation Efficiency in Residential and Public Pools, Spas, Portable Spas and Swim Spas, 2017
   https://issuu.com/thephta/docs/apsp-13_2017
3. Ibid. ANSI/APSP/ICC-1 2014 American National Standard for Public Swimming Pools, 2014
   https://issuu.com/thephta/docs/apsp-1_2014
4. California Department of Public Health. California Swimming Pool Requirements, 2019
   https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/RecreationalHealth/California-Swimming-Pool-Requirements.aspx#
5. California Association of Environmental Health Administrators. Public Swimming Pools and Spas, 2018
   https://deh.acgov.org/operations-assets/docs/recreationalhealth/Pool_Code_Book_Title_22.pdf
6. Centers for Disease Control and Prevention. Operating Public Swimming Pools, 2018
   https://www.cdc.gov/healthywater/swimming/aquatics-professionals/operating-public-swimming-pools.html
7. De Haan, William. "Michigan Swimming Pool Pest Management - Category 5A." Michigan State University, 2015
   https://www.canr.msu.edu/resources/swimming_pool_pest_management_category_5a_e2621
8. Harris, Tom. "How Swimming Pools Work." HowStuffWorks.com, 2015
   https://home.howstuffworks.com/swimming-pool.htm
9. International Code Council. International Swimming Pool and Spa Code. 2021
   https://codes.iccsafe.org/content/ISPSC2021P2
10. Koeller & Hoffman. "Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains." California Water Efficiency Partnership, 2021
    https://calwep.org/wp-content/uploads/2021/03/Pools-Spas-and-Fountains-PBMP-2010.pdf
11. Leslie's Pool Care. Pool Filter Comparison
    https://lesliespool.com/blog/pool-filter-media-types-a-comparison-guide.html
12. Northeast Spa & Pool Association
    www.nespapool.org/
13. Pool and Hot Tub Alliance
    https://www.phta.org/
14. U.S. Department of Energy. "Energy Conservation Program: Energy Conservation Standards for Dedicated-Purpose Pool Pumps." Direct final rule. 2017
    https://www.regulations.gov/document/EERE-2015-BT-STD-0008-0109
15. U.S. Environmental Protection Agency. Cases in Water Conservation. 2002
    https://www.epa.gov/sites/default/files/2017-03/documents/ws-cases-in-water-conservation.pdf
16. Ibid. (2017). Best Management Practices for Commercial and Institutional Facilities
    https://www.epa.gov/sites/default/files/2017-02/documents/watersense-at-work_final_508c3.pdf
17. Ibid. "Jump Into Pool Water Efficiency." 2002
    https://www.epa.gov/system/files/documents/2022-09/ws-outdoor-pool-guide.pdf
18. Ibid. "WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities." 2017
    https://www.epa.gov/watersense/best-management-practices
19. Water – Use It Wisely. Saving Water Outdoors
    https://wateruseitwisely.com/saving-water-outdoors/swimming-pools/

Chapter 13
VEHICLE WASHES

Water efficiency in commercial vehicle washes derives from both proper equipment and operational measures. Car wash systems are primarily a variation of:

- Conveyorized tunnel
    - Brushless/touchless
    - Touchless
    - Exterior wash only
- In-bay touchless automatic
- In-bay friction automatic (brushes)
- Self-service
- Full-service
- Stand-alone arches or spray wands

These systems can be found at vehicle washes that are available for public use at stand-alone facilities, as well as those alongside convenience stores, lube shops, and fuel stations. They also can be found on private property as part of businesses that own, operate, or service a fleet of vehicles. These can include vehicle dealerships, fleet vehicle operators, car rental agencies, bus and transit companies, quarries, warehousing operations, and other industrial operations involving transportation.

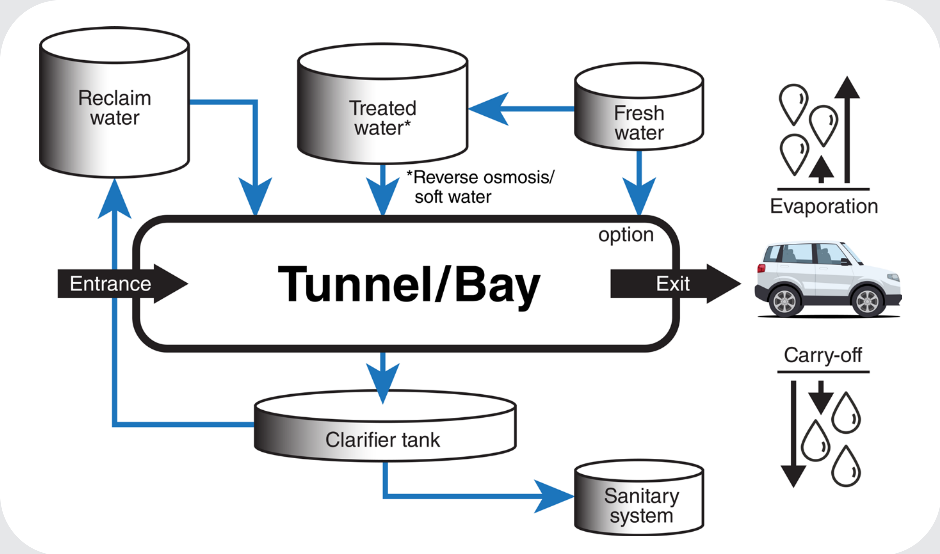
Example of a Conveyorized Vehicle Wash

Image source: Lee Norton, Mark VII Equipment, Inc

Carwash Water Reclamation

In addition to proper equipment and operational measures, water reclamation technology and evolving regulations for commercial car washes are changing the industry and further increasing water efficiency. California Water Code Section 10951 requires in-bay and conveyor car washes permitted and constructed after January 1, 2014, to install, use, and maintain a water recycling system that reuses at least 60 percent of the wash and rinse water. Alternatively, these types of facilities may use recycled water provided by a water supplier for at least 60 percent of their wash and rinse water.[1] Moreover, stormwater and wastewater discharge regulatory requirements have placed an additional emphasis on water reclamation.

Water Uses in Professional Car Washes



1 https://casetext.com/statute/california-codes/california-water-code/division-6-conservation-development-and-utilization-of-state-water-resources/part-212-recycled-water-usage-by-car-washes/section-10951-requirements-of-in-bay-car-wash-or-conveyor-car-wash

Conveyor, in-bay, self-service, and stand-alone/spray wand vehicle washes are described below, along with the water-savings opportunities related to use of water reclamation systems and equipment choices which improve efficiency.

Conveyorized Tunnel Systems

The conveyor vehicle wash, usually installed in a tunnel, includes a series of cloth brushes or curtains and arches from which water is sprayed while the car is pulled through the tunnel on a conveyor chain. In some "touch-free" vehicle washes, only spray nozzles are found. In full-service conveyor vehicle washes, hand drying usually follows the conveyor processes, and often hand-held wands like those found at self-service vehicle washes are used for the pre-soak.

Pre-soak sprays should be limited to 3 gallons per minute or less.

In a 2017 study for the industry by the International Car Wash Association, the facilities evaluated with conveyor systems used on average 30 gallons per vehicle and used an average amount of reclaimed water ranging from 1.9 to 4.9 gallons of reclaim per gallon of freshwater.[2]

Most **in-bay car washes** will use an average of **45 gallons per vehicle**.

In friction vehicle washes, the wash and/or pre-soak cycle is accomplished with brushes or soft cloth curtains known as mitters. Mitters is a generic term for car wash portals that are equipped with long textile strips that dry cars by rubbing. The mechanical action of the mitters on the car surface replace the use of high-pressure water spray that can be found on touchless equipment.

Mitters are available in different variants; side-to-side, front-to-back or as a carousel.

Conveyors with friction components use less water because the brushes or curtains pick up water and detergent from earlier vehicles and do not need to be rewetted throughout the day.[3]

Mitters can often be installed as curtains in the pre-soak area of the conveyor, and rotating brushes are often found in the wash cycle (although this is not universal).

Mitters in Action During a Pre-Wash Cycle in a Conveyorized System

Image source: Lee Norton, Mark VII Equipment, Inc

Timing is a critical component in vehicle wash-water efficiency.

In properly calibrated conveyors, nozzles are timed to turn on as the vehicle passes under an arch and to shut off as it exits each arch. Each arch is on for a matter of seconds since conveyors can process ninety or more cars

Mitters at Work During a Wash Cycle

Image source: Lee Norton, Mark VII Equipment, Inc

2, 3 *https://8374610.fs1.hubspotusercontent-na1.net/hubfs/8374610/Pulse%20and%20Research/Water+Use%2c+Evaporation+and+Carryout+in+Professional+Car+Washes.pdf* an hour. Efficiency is also maintained by proper nozzle configuration, alignment, and water pressure. A number of nozzle types can be found in conveyor vehicle washes. Nozzle tips which emit water in a fine, fan-shaped spray appear to use the least water. Nozzles referred to as “guns” or “gatling guns,” however, provide high-flow volumes and should be used only with reclaimed water.

Self-service vehicle washes use the least water on average per vehicle. A self-serve foaming brush car wash uses an average of **1 to 2 gallons per minute per vehicle** and self-service high-pressure wand car washes use an average of **15 gallons per vehicle per three-minute cycle.**

Blowers at the ends of tunnels should be oriented to push water back into the tunnel. Conveyors should have a longer stretch of tunnel after the final-rinse arch, so water that otherwise would be carried out of the tunnel can flow back into the sump and be reclaimed and reused in the vehicle-wash system.

Conveyor Wash Blowers in Action at Cycle’s End

Image source: Lee Norton, Mark VII Equipment, Inc

Towel drying is one of the services offered in a full-service conveyor or vehicle-detailing business. In many older car washes, towel-washing sinks were designed to have a constant flow-through of water. A float-ball valve that halts the water flow when it reaches an optimum level is one efficiency measure for such sinks.

New vehicle washes should not use flow-through sinks or top-loading washing machines and should install high-efficiency clothes washers from the Consortium for Energy Efficiency’s Tier 3 or 4.

A conveyor wash, referred to by the industry as “exterior-only,” does not offer drying or detailing services. A visual inspection is recommended to confirm whether a vehicle-wash system is a full-service or exterior-only conveyor.

In addition to the savings already mentioned for conveyor washes, a full-reclaim system can be installed. It is cost-effective to build conveyor and in-bay automatic carwashes with water-reclaim systems, which can reduce potable water use by as much as 90 percent, although average savings found in studies are more likely to fall in the range of 50 percent. These systems can provide additional filtration for rinse water. They can also be designed so the pit extends outside the edge of the tunnel, and the driveway and roof gutters direct rainwater into the pit, thus providing rainwater as an alternative water supply. These types of conveyors can be built in commercial settings, but safety considerations typically preclude their use except on private property. Because the pit would extend outside the area of the tunnel, safety should be improved by placing a steel grate above the pit to prevent workers from accidentally falling in.

In-Bay Automatic Vehicle Washes

With in-bay automatics, the customer stays in the car, while the car remains stationary within the carwash bay during the process. The carwash equipment is mounted on a gantry, which moves over or around the car. In-bay automatics can use either spray nozzles or brushes or a combination to wash the vehicle. In-bay automatics also have the greatest variety in basic design, with some machines comprising an entire movable arch and others having vertical and horizontal arms suspended from the gantry. Other designs include spinning arms that are attached to the gantry. In-bay automatics that use brushes typically have spinning bars with brush material attached that roll over and alongside the vehicle.

For in-bay touchless car washes, there is no physical touch applied to the vehicle (friction) and instead a combination of high-pressure wash and chemicals are used to clean the vehicle.

Example of an In-Bay Automatic Wash

The number, size, and alignment of nozzles, the water pressure, and the speed of the machinery all affect the water use of in-bay automatics. The number, size, and alignment of nozzles can be specified in design guidelines. Water pressure and speed are operational considerations. Most in-bay car washes will use an average of 45 gallons per vehicle.[4]

As with conveyor vehicle-washes, in-bay automatics that use foam brushes or cloth material that use less water than frictionless or “touch-free” washes. Some in-bay automatics also reduce water use by employing photo eye sensors[5] to precisely measure the length of the vehicle being washed, limiting the gantry movement and timing of the wash based upon the sensor signals.

In an in-bay automatic system, all water flows to one pit, and all chemicals mix together. Therefore, water reclaim systems can be more costly and a bigger challenge to maintain than in conveyor carwashes.

Self-Service Vehicle Washes

Self-service vehicle washes are typically credit card and/or coin-operated and have spray wands and brushes operated by the customer. This same equipment is often found in truck washes, and some dealerships or fleet operations also use spray-wand and brush technology. A typical commercial self-service facility with four-to-six wash bays will have an equipment room where water is mixed with cleaning chemicals and where pumps and treatment equipment are housed. The customer controls whether and for how long low-pressure or high-pressure settings are used. Thus, the vehicle wash owner/operator does not have direct control over water use at the facility. The owner/operator can, however, help reduce water waste by installing the most efficient nozzles. In addition to water used in the pre-soak and wash cycles, many self-service operations also offer a spot-free rinse using reverse osmosis (RO), deionized, or softened water. Reject water from a Reverse Osmosis (RO) unit can be used in landscape watering, where landscape exists. Ideally, deionization equipment should be used rather than water-softening or RO systems.

Self-service vehicle washes use the least water on average per vehicle. A self-serve foaming brush car wash uses an average of 1 to 2 gallons per minute per vehicle and self-service high-pressure wand car washes use an average of 15 gallons per vehicle per three-minute cycle.

This can be attributed to the direct relationship between water use and price in the self-service vehicle wash: the

Spray Wand in Action

4 *https://8374610.fs1.hubspotusercontent-na1.net/hubfs/8374610/Pulse%20and%20Research/Water+Use%2c+Evaporation+and+Carryout+in+Professional+Car+Washes.pdf*

5 *http://automation-and-controls.blogspot.com/2009/05/how-to-install-and-maintain-photoeye.html*

longer the customer runs the wash, the more expensive the service, since they are charged by the minute.

Self-service operators sometimes find evidence of oil dumping or larger debris, like yard waste, in the wash pits. This can occur because customers wash their own cars unattended. Due to the relatively low potential water savings and the potential for organic materials and debris to foul the filters, water-reclaim systems are seldom cost-effective in a self-service vehicle wash. Where zero discharge is required by regulations, self-service operators have installed reclaim systems, but have also hired on-site staff to monitor and clean the wash bays, thereby increasing the cost of doing business

Stand Alone Arches and Spray Wands

Some outdoor vehicle washes in industrial or commercial settings restrict public contact and use a single arch to rinse off the vehicle prior to returning it to the public right-of-way. These washes, built on private property, can use aerobic biotreatment in open pits which capture both the wash runoff and the rain that falls on the pit, the pad, and the paved area around the pad. Such "total" reclaim systems can also be designed or used for tire-washing, which reduces dust on vehicles leaving quarries and other industrial facilities. A bus wash water reclamation system in Seattle was able to achieve more than 80 percent efficiency and save more than 200 gallons per vehicle.[6]

Recommendations

All:

- Complete periodic visual inspections for leaks.
- Perform monthly meter checks.
    - Shut down all equipment & record meter readings at shutdown and prior to startup.
- Clean spray nozzles every couple of months.
- Replace spray nozzles every 6 to 12 months depending on the volume of cars going through the system.
- When present, towel washers should be front-loaded, high-efficiency machines with a Consortium for Clean Energy rating of Tier 3 or 4.
- If a planned commercial building project includes on-site vehicle washes, follow all local regulations for water efficiency and reclamation requirements.

Conveyorized tunnel:

- Use friction components, such as mitters or foam brushes, in every conveyor vehicle wash for pre-soak and/or wash cycles.
- Spray nozzles on arches should produce a fan-shaped spray, oriented parallel to the arch.
- Limit gun-type undercarriage nozzles to use of reclamation water.

Table 13-1: Average Water Usage by Vehicle Wash Type

Type	Water Usage
Conveyor	30-40 gal/vehicle
In-bay	45 gal/vehicle
Self-service: foaming brush	1-2 gpm
Self-service: high pressure wand	15 gal/vehicle/3 min cycle

6 https://calwep.org/wp-content/uploads/2021/03/Vehicle-Wash-Systems-PBMP-2006.pdf

In-bay touchless:

- In-bay automatics which include a spot-free rinse option should use deionization equipment, rather than water-softening or RO systems.

Self-service/Stand-alone:

- Optimum operating pressure nozzle flow rate should be three gallons per minute or less (based upon pump design).
- Use a low-pressure pass for pre-soak.
- Use stainless steel or hard ceramic nozzles to reduce corrosion, especially in areas with hard water.

Reclamation:

- Design wash pads, parking and staging areas, and tire-rinse systems at industrial sites to capture rainfall and wash water for reuse.
- Where RO is used, reject water should be sent to the recycling system (or otherwise reused in the washing process).
- At minimum, vehicle-wash-water reclaim systems should provide water to the pre-soak, undercarriage, and initial wash cycles.
- Equip vehicle washes for buses and other commercial vehicles with filtration systems sufficient to allow all wash and rinse cycles except the final rinse to use reclaimed water.

Resources

1. Water Code § 10951 – *https://casetext.com/statute/california-codes/california-water-code/division-6-conservation-development-and-utilization-of-state-water-resources/part-212-recycled-water-usage-by-car-washes/section-10951-requirements-of-in-bay-car-wash-or-conveyor-car-wash*
2. Barnes, Laura. Best Management Practices for Commercial Car Washes." Great Lakes Regional Pollution Prevention Roundtable, 2016 – *core.ac.uk/download/pdf/158322942.pdf*
3. Brown, Chris "Water in the car wash: Car wash operators information guide." International Carwash Association, 2002 – *p2infohouse.org/ref/22/21070.pdf.*
4. Brown, Chris. "Water Use, Evaporation and Carryout in Professional Car Washes." International Carwash Association, 2018 – *8374610.fs1.hubspotusercontent-na1.net/hubfs/8374610/Pulse%20and%20Research/Water+Use%2c+Evaporation+and+Carryout+in+Professional+Car+Washes.pdf.*
5. Car Wash Advisory "Types of Car Washes: Automatic, In-Bay, Express, Mini, Conveyor – Let's Decipher the Mess of Terms." – *www.carwashadvisory.com/learning/carwashtypes.html*
6. Clear Technologies, Inc. "Searching for the right water reclaim system." 2021 – *www.carwash.com/searching-right-water-reclaim-system/*
7. Earth 911 (2018) How New Car Wash Technology Saves Water – *earth911.com/eco-tech/water-conservation-and-car-washing/*
8. Ghaly, Abdel, et. al. Water Use, Wastewater Characteristics, Best Management Practices and Reclaimed Water Criteria in the Carwash Industry: A Review. 2021 – *researchgate.net/publication/351269422_Water_Use_Wastewater_Characteristics_Best_Management_Practices_and_Reclaimed_Water_Criteria_in_the_Carwash_Industry_A_Review.*
9. Koeller, et al. "Evaluation of Potential Best Management Practices – Vehicle Wash Systems." 2002 – *calwep.org/wp-content/uploads/2021/03/Vehicle-Wash-Systems-PBMP-2006.pdf.*
10. Kusek, Meagan. "Carwash Equipment 101."2017 – *www.carwash.com/carwash-equipment-101/.*
11. O'Donnell, Michael. "Navigating Water Conservation." 2022 – *www.carwash.com/navigating-water-conservation/*
12. Earth 911. How New Car Wash Technology Saves Water. 2018 – *earth911.com/eco-tech/water-conservation-and-car-washing/*
13. *www.carwash.org/resources*
14. United States Environmental Protection Agency. "Car Wash Chain Drives Down Water Use With Efficiency Upgrades." 2017 – *www.epa.gov/sites/default/files/2017-05/documents/ws-commercial-casestudy-heb-commercial-carwash-508.pdf*
15. United States Environmental Protection Agency. "Highlights of the Automotive Trends Report." 2022 – *www.epa.gov/automotive-trends/highlights-automotive-trends-report*
16. Western Carwash Association Do Professional Car Washes Really Save Water? – *www.wcwa.org/page/WaterConservation*
17. Market Scale. "Innovations Have Reduced Water Consumption in Car Washes." 2019 – *marketscale.com/industries/building-management/innovations-have-reduced-water-consumption-in-car-washes/*
18. Kleen-Rite Corporation, High Pressure Nozzle Selection and Sizing – *www.kleen-ritecorp.com/t-High%20Pressure%20Nozzle.aspx*
19. Spraying System Co., Car Wash Spray Product – *spray.com/-/media/dam/industrial/usa/sales-material/catalog/c25c_spray_products_car_wash.pdf*


EBMUD

Chapter 14
LANDSCAPE WATER USE EFFICIENCY

This section will provide information on EBMUD and California regulations regarding landscape irrigation and design, as well as cost-effective approaches to manage a water efficient landscape, including water management tools, irrigation, design, and maintenance.

In California, outdoor irrigation efficiency can be a significant contributor to a site's water use and should be considered in any water management plan.

The U.S. Environmental Protection Agency (EPA) indicates that, "As much as 50 percent of the water we use outdoors is lost due to wind, evaporation, and runoff caused by inefficient irrigation methods and systems.[1]" Therefore, focusing on increasing landscape water use efficiency is an integral part of a wider water conservation strategy at any landscaped commercial facility.

Irrigation Survey

If a customer suspects that a landscape is using more water than it should, a professional landscape survey can be a valuable primary intervention. Surveys can include:

- An evaluation of historic water use
- Inspection of irrigation equipment
- Review of irrigation scheduling
- Review of applicable utility rebates

EBMUD offers free commercial irrigation surveys to water customers and has also partnered with several non-profit organizations[2,3] to assist customers in hiring experienced and reputable landscape professionals.

Landscape with Climate-Appropriate Plants

Programming an Irrigation Controller

1 https://www.epa.gov/watersense/when-its-hot
2 https://qwel.net/
3 https://rescape.memberclicks.net/directory

Converting from spray to drip irrigation has been shown to reduce water use by **30-40%** compared to spray in residential settings.[4]

Irrigation System Review

There are many ways to reduce water use in the commercial landscape and still maintain healthy plant material:

- Check out EBMUD's irrigation tips to save water and resolve common irrigation problems such as:
  - Broken or misdirected sprinklers
  - Clogged or leaking drip irrigation
  - Leaking or stuck irrigation valves
  - Irrigation runoff from lawn or groundcover
- Review the watering schedule and adjust your irrigation controller for the weather and season.
- Consider investing in irrigation system improvements such as self-adjusting controllers, flow sensors, master valves, high efficiency nozzles, drip irrigation and pressure regulators to reduce inefficient water application – these upgrades may be eligible for rebates with your local water provider.

Landscape Design

If the property includes large sections of turf, consider replacing lawn with climate appropriate plants to reduce water use and support local ecosystems. Many property owners are saving water and money by removing non-functional turf. For example, an HOA in Alameda, California, converted turf on median strips and reduced water use by more than 70%.

For low water use landscape design ideas check out online gallery, design templates, and demonstration gardens. Seek out a resource such as Alameda County's Lawn to Garden water savings calculator to estimate savings for a lawn conversion project on your site.

Select plants appropriate to your local climate and check out your water utility's webpage for localized lists and resources. In the San Francisco Bay Area, residents can use EBMUD's list of Top 100 plants and EBMUD's WaterSmart Plants webpage. Remember to group plants together based on their watering needs (hydrozoning), and make sure to add 3" layer of mulch to retain moisture and protect plant health.

Pressure Regulator on an Irrigation Line

Whether you are trying to improve water management, fix broken irrigation, or create a new design, there may be times when site managers may need additional resources. Check out EBMUD's hiring a landscape professional page for how to select a professional. For a comprehensive CII guidebook for site managers, see the Pacific Institute's Sustainable Landscapes Guidebook.

Ordinances and Regulations

Local water conservation and water waste regulations

EBMUD, like most water utilities, requires an evergreen baseline of water efficient practices from its customers in order to "conserve the District's water supply for the greatest public benefit." 1 Proper water use is guided by Section 29 of the utility's Water Use Restrictions, which outline prohibited uses of potable (as opposed to recycled) water. Readers not located in EBMUD's service area should consult their local water utility's water use regulations for more information.

4 *https://www.waterrf.org/research/projects/residential-end-uses-water-version-2*

In October 2023, California Governor Gavin Newsom signed into law AB 1572, **prohibiting irrigation of non-functional* turf with potable water at Commercial, Industrial and Institutional (CII) sites**. This law, already in place as an extended Drought Emergency Regulation, will go into effect in tiered phases, **starting in 2027**.

*Non-functional turf is defined as "[Turf] that is solely ornamental and not regularly used for human recreational purposes or for civic or community events. Non-functional turf does not include sports fields and turf that is regularly used for human recreational purposes or for civic or community events.[5]

Prohibited potable water use for non-residential customers includes:

- Single pass cooling systems in new connections, and non-recirculating systems in all new conveyer car wash and commercial laundry systems.
- Applying potable water to sidewalks, driveways, or other hard surfaces or materials that results in excessive use and runoff.
- Non-recirculating ornamental fountain or other decorative water feature.
- Use of potable water for construction, street cleaning, soil compaction and dust control, if a feasible alternative source of water is available. EMBUD permit required for all potable water use for construction, soil compaction and dust control.

Additional water efficient guidelines for non-residential customers include:

- Use systems that recycle water where feasible.
- Measurable leaks with water flows onto adjacent property or hardscapes shall not be turned on or restored to service until repairs have been completed.
- Hotels and motels are required to prominently and clearly offer patrons the option of not having their towels and linens washed daily.

The Model Water Efficient Landscape Ordinance (MWELO)

MWELO is a statewide water conservation regulation in California for new and rehabilitated developments that promotes low water use landscapes. The implementation of and compliance with MWELO will help to secure EBMUD and statewide water supply for long-term planning and growth.

MWELO applies to single- and multi-family residential, commercial, public, and institutional projects that require a permit, plan check, a new water meter, change in water meter size, or business classification with:

- Construction of 500 square feet or more of new landscaping (E.g., building a new home on a lot) .OR
- Rehabilitation or remodeling of landscaping where the total existing landscape is over 2,500 square feet (e.g., constructing a pool and redoing landscaping.

Sprinkler Spray Bodies

An additional landscape regulation concerning Spray Sprinkler Bodies (SSB) went into effect on October 1, 2020. After this date, all newly manufactured SBB are required to be certified by the California Energy Commission's (CEC) appliance efficiency database known as the "Modernized Appliance Efficiency Database" before being offered for sale in California. Compliant SSB contain pressure regulating devices and adhere to a flow rate and pressure performance criteria including a minimum outlet pressure.

Non-Functional Turf Ban

In the fall of 2023, Assembly Bill 1572 was passed prohibiting the use of potable water to irrigate non-functional turf located on commercial, industrial, and institutional (CII) properties. The legislation will replace a temporary non-functional turf irrigation ban enacted in June 2022 by California's State Water Board and will be phased in beginning January 1, 2027.[6]

Non-functional turf is ornamental grass not used for recreation, civic and/or other community events. It includes turf irrigated for aesthetics such as street medians and parking lots

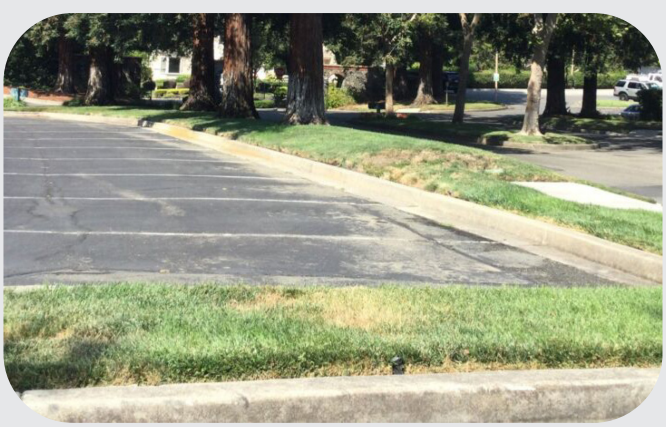
5 https://www.cvwd.org/597/Non-Functional-Turf-FAQs
6 https://calwep.org/california-lawmakers-approve-non-functional-turf-ban/

Example of Inefficient Overhead Spray Irrigation

The irrigation ban applies to CII properties including those below, but not limited to:

- City and county land
- Educational institutions
- Government, public agency buildings
- Grocery and retail stores
- Homeowner association owned properties and common interest developments
- Hospitals
- Office, warehouse, and industrial buildings
- Religious institutions
- Restaurants

Example of Non-Functional Turf in a Parking Lot.



Compliance will be phased in beginning January 1, 2027:

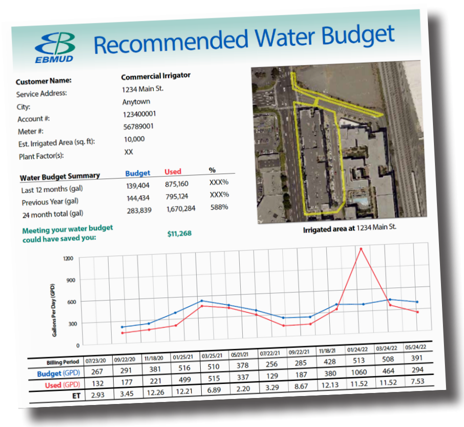
- State, local government, and public agency buildings beginning January 1, 2027.
- Institutional properties and all commercial and industrial properties, beginning January 1, 2028.
- All common areas of properties of homeowners' associations, and common interest developments, beginning January 1, 2029.
- All properties owned by local governments, local public agencies, and public water systems in a disadvantaged community, beginning January 1, 2031, or when funding is available.

Water Management Tools

As an EBMUD customer, consider using these four information-based water management tools to irrigate efficiently.

Water Budget Reports

EBMUD provides free water budget reports to commercial customers with dedicated irrigation meters. The water budget compares actual water consumption with target water consumption tailored to the site's landscape area, location, and plant type. The water budget provides a high-level overview of how effectively water is managed at the landscape.



EBMUD Recommended Water Budget

Customer Name:	Commercial Irrigator
Service Address:	1234 Main St.
City:	Anytown
Account #:	123400001
Meter #:	56789001
Est. Irrigated Area (sq. ft):	10,000
Plant Factor(s):	XX

Water Budget Summary	Budget	Used	%
Last 12 months (gal)	139,404	875,160	XXX%
Previous Year (gal)	144,434	795,124	XXX%
24 month total (gal)	283,839	1,670,284	588%

Meeting your water budget could have saved you: $11,268

Irrigated area at 1234 Main St.

Billing Period	07/23/20	09/22/20	11/18/20	01/25/21	03/25/21	05/21/21	07/22/21	09/22/21	11/18/21	01/24/22	03/24/22	05/24/22
Budget (GPD)	267	291	381	516	510	378	256	285	428	513	508	391
Used (GPD)	132	177	221	499	515	337	129	187	380	1060	464	294
ET	2.93	3.45	12.26	12.21	6.89	2.20	3.29	8.67	12.13	11.52	11.52	7.53

My Water Report Portal

EBMUD customers can also sign up online for the My Water Report program, which grants free access to historical water use history, billing information, leak detection tips, and more. Select water customers with "smart" meters can also edit their communication preferences to include leak alerts and high use notifications to address costly leaks in a timely manner. Water budgets and leak alerts helped a recent customer fix a 300 gallon per hour leak, saving nearly $1,250 per day.

Flowmeters

The majority of EBMUD meters are read every two months. Therefore, the Water Conservation Division recommends customers install a flowmeter to more closely monitor water use with up-to-the-minute water use data. Flowmeters measure and report water use down to a fraction of a gallon, with updates as frequent as every minute. They can alert customers to leaks, as well as be configured to send alerts through a web portal or mobile app. EBMUD provides rebates for this technology and also displays a list of approved devices.

Recommendations

Follow the principles of water-efficient landscaping, including:

- Plan and design based on your space (sun, shade, soil, slope, size etc.) and needs
- Conduct regular irrigation system maintenance (quarterly or bi-annually)
- Regularly check your irrigation system for leaks (monthly)
- Frequently review your irrigation schedule. Adjust the schedule seasonally, or install a smart irrigation controller for automatic daily adjustments
  - EBMUD rebate available
  - Sample irrigation schedule
- Upgrade to more efficient irrigation equipment like drip irrigation, high efficiency sprinkler nozzles, and smart irrigation controllers
  - EBMUD rebates available
- Choose water efficient and native plants
- Hydrozone: group plants in irrigation zones based on water needs
- Don’t leave any bare soil – maintain a healthy layer of mulch around plants
  - EBMUD coupons available
- Test and amend your soil for optimal plant health
- Consider turf alternatives, or use turf sparingly and appropriately

Resources

1. *https://calwep.org/wp-content/uploads/2021/03/Drip-Irrigation-PBMP-2014.pdf*
2. *https://calwep.org/wp-content/uploads/2021/03/Turf-Removal-PBMP-2013.pdf*
3. *https://www.epa.gov/sites/default/files/2017-09/documents/ws-products-spec-ssb.pdf*
4. *https://www.epa.gov/sites/default/files/2017-01/documents/ws-outdoor-water-efficient-landscaping.pdf*
5. *https://www.epa.gov/watersense/watersense-labeled-controllers*
6. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/hiring-landscape-professional*
7. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/lawn-garden-design-center*
8. *https://www.ebmud.com/water/conservation-and-rebates/water-efficiency-review*
9. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/magic-mulch*
10. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/sustainable-landscape-map*
11. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/watersmart-plants*
12. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/lawn-goodbye-landscape-gallery*
13. *https://www.ebmud.com/water/conservation-and-rebates/rebates/irrigation-equipment-rebate*
14. *www.ebmud.com/application/files/4915/6642/6964/Lawn__Landscape_Watering_Schedule.pdf*
15. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-irrigation-programs/commercial-irrigation-water-conservation-tips*
16. *https://www.ebmud.com/water/conservation-and-rebates/watersmart-gardener/plants-and-landscapes-summer-dry-climates*
17. *https://lawntogarden.org/water-savings-calculator*
18. *https://www.nrdc.org/bio/ed-osann/new-ca-lawn-sprinkler-standards-huge-water-energy-savings*
19. *https://plantmaster.com/presents/plants.php?id=5f736fa6604d7*
20. *https://pacinst.org/wp-content/uploads/2020/08/Sustainable-Landscapes-in-California-Pacific-Institute-2020.pdf*
21. *https://www.savingwaterpartnership.org/programs_list/landscape-design-templates/*
22. *https://water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance*

Chapter 15
CANNABIS PRODUCTION OPERATIONS

The medical and recreational cannabis market in the United States exceeds 20 billion dollars and is, "one of the fastest-growing industries, globally."[1] While cannabis is processed into multiple products, this section will focus on addressing equipment used in growing cannabis.

Additional areas that affect a cannabis business include cooling (HVAC), filtration systems, dehumidification, and cleaning. Be sure to check the chapters for those areas that affect your business.

Cannabis can be grown indoors, outdoors, and inside greenhouses. While outdoor operations have the lowest rates of water use per square foot,[2] indoor production tends to generate the highest yields per square foot due to a shorter growing cycle and higher planting density.[3] Indoor operations use significantly higher volumes of water per square foot of plant canopy, but less water per plant, as they are also able to produce more harvests per year.[4] The decision whether to cultivate indoors versus outdoors should take into account local regulations, facility rental or purchase costs, as well as water and energy costs.

Water sources used in the production of cannabis may include utility-supplied potable water, hauled (delivered) water, private well water, on-site reclaimed water, and natural sources such as rain or surface water.[5] Water is used for irrigation, humidification, cooling, cleaning, and to dissolve nutrients for application. The volume of water used in cannabis, as compared to other crops, is still an area ripe for research with conflicting studies frequently reporting that it is equal to, or less than, many major crops.[6]

More important than comparisons to the water use of other crops, however, is a focus on relative water efficiency of different production methods within the cannabis industry itself. Prior to irrigation, water should be tested to determine its suitability for the crop. Some water sources require additional filtration, and some water may be used for fertigation (combination of fertilizers and water prior to application).

Indoor Commercial Cannabis Operation

1 Lipson, Ross. Forbes. (2022, February 18). Where Is the Cannabis Industry Headed In 2022? Forbes. *https://www.forbes.com/sites/forbesbusinesscouncil/2022/02/18/where-is-the-cannabis-industry-headed-in-2022/?sh=49d5ffec72e2*

2 Long, Andrew. (2021, March 2) Marijuana cultivators should rethink how they measure water use, new report says. MJBizDaily. *https://mjbizdaily.com/rethinking-water-use-measurements-in-marijuana-cultivation/*

3 Wilson H, Bodwitch H, Carah J, Daane K, Getz C, Grantham T, Butsic V. (2019, September 12). First known survey of cannabis production practices in California. Calif Agr 73(3):119-127. *https://doi.org/10.3733/ca.2019a0015.*

4 Dillis, C., Grantham, T., Butsic, V., Carah, J., Parker-Shames, P. (2020) Water Use in Cannabis Agriculture. Cannabis Research Center. *https://crc.berkeley.edu/wp-content/uploads/2020/12/CRC_Brief_WaterUse_2020_1205.pdf*

5 New Frontier Data. (2021). Cannabis H2O: Water Use & Sustainability in Cultivation. *https://newfrontierdata.com/product/cannabis-h2o-water-use-and-sustainability-in-cultivation/*

6 Comprehensive Cannabis Consulting. (2018, January 12). Cannabis Cultivation: Water Efficiency and Regulations. *https://www.3ccannabis.com/2018/01/cannabis-cultivation-water-efficiency-regulations*

Table 15-1: Irrigation Methods for Indoor Cannabis Cultivation

IRRIGATION METHOD	BENEFITS	DRAWBACKS
HAND WATERING	• Eyes on all plants during watering • Gives grower "hands on" feel • No high-tech equipment required	• Inconsistency of volume per pot • Inconsistency between employees responsible for task • Labor-intensive
DRIP IRRIGATION	• Usually automated • Precise volume of water • Allows cultivator to water many plants at once	• Potential clogging of emitter • Manual inserting/removal of dripper when moving plants • Additional cost to install and maintain • More technical, with high learning curve
FLOOD TABLES	• Automated • Less chance of under-watering plants • Easy and inexpensive to build	• Large amounts of water used at once • Increased humidity if reservoirs do not have lids • Manual labor to clean and refill reservoirs

Table 15-1 includes the efficiency, benefits, and drawbacks for the most commonly used methods of indoor irrigation.[7]

Recommendations

Standard areas where the cannabis industry may benefit from best management practices for water efficiency include:

Leaks

→ All plumbing systems are susceptible to leaks. Leaks not only waste water but may result in lost nutrients, health and safety violations (wet floors and surfaces) and create an environment for harmful algae growth. Perform the following checks:

- Ensure pipes are correctly sized.
- Ensure pressure is appropriate for the type of irrigation application used.
- Regularly check fittings and emitters on irrigation systems and repair all leaks immediately.
- Consider investing in a sub- or flow meter to better understand irrigation use and quickly detect costly leaks[8] (and take advantage of any available utility rebates).

Automation

→ Automated irrigation systems can improve accuracy and efficiency of water application.

- Smart controllers and associated online software can manage irrigation remotely and save money on water use, adjusting based on local weather and site conditions.

7 City of Denver, Public Health and Environment. (2021, October). Cannabis Environmental BMP Guide. *https://www.denvergov.org/files/assets/public/climate-action/documents/2021_cannabis-bmp-guide_rev-11-23.pdf*

8 East Bay Municipal Utility District. Best Management Practices for Cannabis Facilities. *https://www.ebmud.com/download_file/force/7615/668?bmps_for_cannabis_facilities.pdf=*

- Smart controllers automatically shut off irrigation prior to or during rain events (for outdoor cultivators).
- Automated irrigation and flow metering systems can measure irrigation applied during each phase of growth and establish a baseline for runoff.
- Some software systems integrate additional data including fertigation.
- Take advantage of any available utility rebates for smart controllers and/or flow sensors.

Irrigation schedules

→ The frequency and duration of irrigation greatly depends on the growing medium, environment, and season.

- When programmed correctly, automatic irrigation systems can streamline operations, saving water and money.
- Thoroughly research the desired production approach and take the plant's growth phase into consideration to determine the ideal schedule.
- Watch for signs of an over-watered plant, especially in indoor environments where the humidity can remain high.[9]

Filtration

→ "Water can be purified using several different methods including carbon filtration, UV sterilization, and reverse osmosis. When considering environmental inputs, water treatment using carbon filtration has emerged as the most efficient method to reduce contaminants and minimize water loss."

Reverse osmosis for wastewater purification is expensive, creates significant waste, and is not recommended.

→ "For example, a typical point-of-use RO system will generate five gallons or more of reject water for every gallon of permeate produced."[10]

- Additionally, in water utility service areas such as EBMUD with low Total Dissolved Solids (TDS), additional purification is often not necessary. Check with your local water utility for more information.

Onsite water reuse (runoff, condensate)

→ Water in an agricultural setting is frequently wasted through missed opportunities in water use efficiency. In cannabis growing operations this can include the ability to capture, filter, and reuse water that would otherwise be lost to runoff, evaporation, disposal of unused irrigation, or ventilation water.

→ For outdoor applications, consider using mulch and raised beds to minimize or eliminate this waste.

→ For indoor applications, installation of HVAC systems designed to collect and treat condensate can be reused to minimize waste.[11] For more information on condensate reuse, see Chapter 7, Alternate Onsite Water Sources.

Green cleaning products and practices

→ Growing media is a contributing factor to the frequency and level of cleaning necessary in the work environment.

→ Soil may require more frequent cleaning of an indoor grow area than rockwool due to the likelihood of getting soil on the floor.

→ Be sure to properly dilute all cleaning solvents as higher concentrations do not necessarily work better and make it harder to process the water.

→ Use environmentally friendly cleaners such as those rated by Green Seal, Eco Logo or Safer Choice.[12]

Maintenance

→ Performing regular and routine maintenance can reduce leaks and equipment failure that result in water waste.

→ By choosing lower maintenance systems, you can minimize your water use and maintenance costs.

→ Regular HVAC system maintenance is crucial to system sustainability.

Water savings will vary with each business dependent on the size and type of the operation, the environment, and the need for water filtration.

9 Cannabis Training University. Overwatered Marijuana Plants: Comprehensive Guide to Spotting and Avoid Overwatering Cannabis Plants. *https://cannabistraininguniversity.com/growing/overwatered-marijuana-plants-how-to-spot-and-avoid-overwatering-cannabis-plants/*

10 Environmental Protection Agency. Point-of-Use Reverse Osmosis Systems. EPA.gov. *https://www.epa.gov/watersense/point-use-reverse-osmosis-systems*

11 *https://growersnetwork.org/cultivation/condensate-reclamation-practical-concerns/*

12 City of Denver, Public Health and Environment. (2021, October). Cannabis Environmental BMP Guide. *https://www.denvergov.org/files/assets/public/climate-action/documents/2021_cannabis-bmp-guide_rev-11-23.pdf*

Resources

1. Cannabis Research Center, University of California Berkeley
   https://crc.berkeley.edu/
2. Cannabis Training University. Overwatered Marijuana Plants: Comprehensive Guide to Spotting and Avoid Overwatering Cannabis Plants
   https://cannabistraininguniversity.com/growing/overwatered-marijuana-plants-how-to-spot-and-avoid-overwatering-cannabis-plants/
3. Cannagistics LLC. (2019, February 25). Best Practices Guide: Cannabis Environmental Management
   https://cannagistics.org/2019/02/25/best-practices-for-cannabis-environmental-management/
4. City of Denver, Public Health and Environment. (2019, October). Cannabis Environmental Best Management Practices Guide: Water
   https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/MJ%20Sustainability/3_Cannabis_BestPracticesManagementGuide_Water.pdf
5. City of Denver, Public Health and Environment. (2021, October). Cannabis Environmental BMP Guide.
   https://www.denvergov.org/files/assets/public/climate-action/documents/2021_cannabis-bmp-guide_rev-11-23.pdf
6. Commonwealth of Massachusetts, Cannabis Control Commission. (2024, January 29). Guidance on Best Management Practices for Water Use.
   https://masscannabiscontrol.com/wp-content/uploads/2024/01/Guidance-on-Best-Management-Practices-for-Water-Use.pdf
7. County of Sonoma, Agricultural Division. Best Management Practices Cannabis Cultivation
   https://sonomacounty.ca.gov/natural-resources/agricultural-weights-and-measures/divisions/agricultural-division/ordinances/best-management-practices-cannabis-cultivation
8. East Bay Municipal Utility District. Best Management Practices for Cannabis Facilities
   https://www.ebmud.com/download_file/force/7615/668?bmps_for_cannabis_facilities.pdf=
9. State Water Resources Control Board. Cannabis Cultivation Best Management Practices
   https://www.waterboards.ca.gov/water_issues/programs/enforcement/docs/cannabis_enfrcmnt/bmp_cc_flyer.pdf
10. National Cannabis Industry Association. (2020, October 17). Environmental Sustainability in the Cannabis Industry: Impacts, Best Management Practices, And Policy Considerations
    https://thecannabisindustry.org/wp-content/uploads/2020/11/NCIA-Environmental-Policy-BMP-October-17-final.pdf
11. New Frontier Data. (2021). Cannabis H2O: Water Use & Sustainability in Cultivation
    https://newfrontierdata.com/product/cannabis-h2o-water-use-and-sustainability-in-cultivation/
12. The Cannabis Conservancy. (2018). Energy Use in the Colorado Cannabis Industry
    https://resourceinnovation.org/wp-content/uploads/2019/12/18-CEO-MJ32-Energy-Cannabis-Report_FINALWEB.pdf

EAST BAY
MUNICIPAL UTILITY DISTRICT

375 Eleventh Street, Oakland, CA, 94607 • 1-866-403-2683 • www.ebmud.com