Table of Contents

Laboratory and Medical Equipment

EPA WaterSense

7.1 Introduction to Laboratory and Medical Equipment

EPA WaterSense

From dental and doctor's offices to large general hospitals, veterinary clinics, and research laboratories, medical and laboratory facilities have special operations and equipment. These systems can consume a significant amount of water through water purification, sterilization, photographic and X-ray processes, and vacuum systems. As shown in Figure 7-1, equipment such as steam sterilizers and reverse osmosis systems can account for 5 percent of a laboratory's total water use.[1] Hospitals can attribute more than 15 percent of their total water use to laboratory and medical equipment, including steam sterilizers and X-ray processing equipment, as shown in Figure 7-2.[2]

Figure 7-1. Laboratory Water Consumption

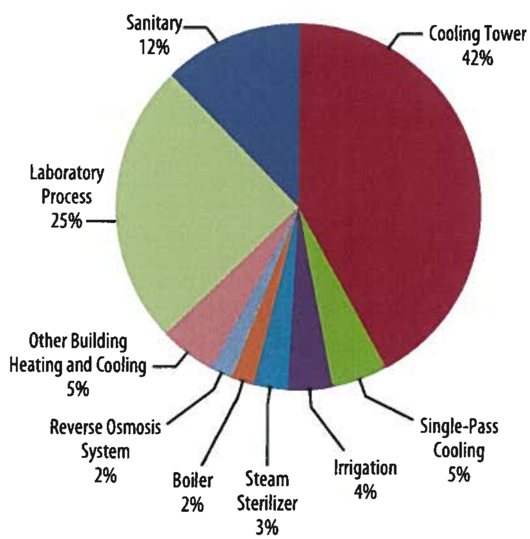
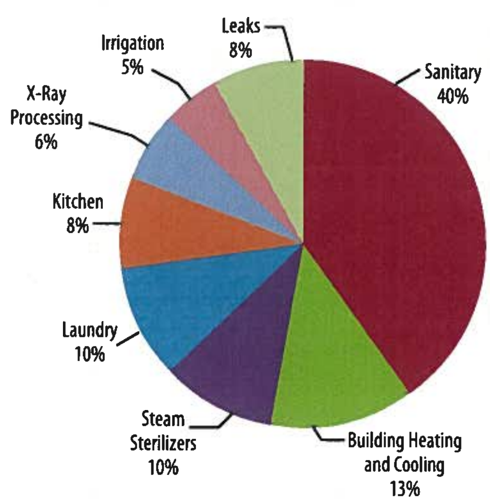


Figure 7-2. Hospital Water Consumption



[1] U.S. Environmental Protection Agency. Laboratory Water Use vs. Office Water Use. www.epa.gov/oaintrnt/water/lab_vs_office.htm.
[2] East Bay Municipal Utility District (EBMUD). June 25, 2003. "EBMUD Hospital Water Efficiency: Water Conservation Division." Page 5. www.cuwcc.org/WorkArea/downloadasset.aspx?id=2230.

7.1 Introduction to Laboratory and Medical Equipment

Many older pieces of medical and laboratory equipment use single-pass cooling continuously for the purpose of keeping equipment cool or for tempering hot water before it is discharged to the sewer. Newer technologies and better practices are available that can significantly reduce this water use. For example, retrofitting a steam sterilizer with a thermostatically actuated valve can reduce tempering water needed to cool hot steam condensate before discharge by up to 90 percent. Vacuum pump recirculation systems can save 50 to 80 percent of the water used to cool the vacuum. For traditional photographic and X-ray equipment, recycling and reusing the final rinse effluent as make-up for the developer or fixer solution can save 50 percent or more of the water required to process film. Converting to digital equipment can eliminate this water use entirely.

One consideration to note is that laboratories and medical facilities might face unique challenges because of the high quality of the water required for their equipment. Most of these facilities require the use of potable water at a minimum and more highly treated water in many cases. Water is frequently used to disinfect parts of these facilities as well. The need to maintain high-quality standards can preclude the use of certain technologies and alternative sources of water, as described in other sections within this document. For example, laboratories often require purified or deionized water to perform tests and experiments. Medical facilities also must maintain high standards for health and safety. These standards can limit the types of technologies that can be utilized in these types of facilities. Water efficiency alone will not be a driver in the choice of technologies or processes in these facilities. Rather, it should be a consideration after other requirements have been met.

Section 7: Laboratory and Medical Equipment of *WaterSense at Work* provides an overview of and guidance for effectively reducing the water use of:

- Water purification
- Vacuum pumps
- Steam sterilizers
- Glassware washers
- Fume hood filtration and wash-down systems
- Vivarium washing and watering systems
- Photographic and X-ray equipment

Laboratory and Medical Equipment Case Study

To learn how Providence St. Peter Hospital in Olympia, Washington, saved 31 million gallons of water by installing water-efficient laboratory and medical equipment and implementing many additional best management practices described in *WaterSense at Work*, read the case study in Appendix A.

7.2 Water Purification

Overview

Water purification systems are used in laboratory and medical applications requiring high-quality water that is free of minerals and organic contaminants. Generally, these systems purify water through physical or chemical means. Many water purification systems use additional water during a backwash phase to remove particle buildup on the purification media, or discharge a reject stream containing concentrated contaminants. Typically, as finer particles are removed, the purification process becomes more water- and energy-intensive. Therefore, it is important to evaluate the level of water quality required to ensure that the system does not deliver a higher level of purification than is needed. Systems that deliver a higher water quality than the facility needs will often be more expensive to operate than a more appropriate system and can result in wasted water and energy.


Water purification system in a laboratory

There are several technical standards for water quality that facilities can use to evaluate the appropriate water purification method, including ASTM International *ASTM D1193 Standard Specification for Reagent Water* and the International Organization for Standardization (ISO) *ISO 3696 Water for Analytical Laboratory Use—Specification and Test Methods.* These standards generally classify water quality into specific types based on the quality required.[3]

When determining the level of treatment needed to supply water of a specific quality, there are a number of water purification technologies used in lab and medical facilities that can be considered. These include: microporous filtration, carbon filtration, deionization, distillation, membrane processes, and water softening. Because no single water purification system is able to remove 100 percent of all contaminants, it is common for multiple water purification technologies to be installed in sequence where only a low level of contaminants can be tolerated.

Microporous Filtration

Microporous filtration physically removes solid contaminants by capturing them on the surface of the media. Microporous filtration typically occurs at low pressures and does not remove any dissolved solids.[4] After a period of use, filters will require backwashing with water to remove contaminants trapped on the media surface.

Carbon Filtration

Carbon filtration uses adsorption to attract particles as water passes through the filter. The adsorption process depends upon the physical characteristics of the activated carbon; the chemical compositions of the carbon and the contaminants;

[3] Millipore. Overview of Lab Water Grades. www.millipore.com/lab_water/clw4/tutorial&tabno=4.
[4] Messinger, Stephen. September 2006. "What Makes Water Taste Best?" *Water Conditioning & Purification Magazine.* www.wcponline.com/TOC.cfm?ISN=110.

the temperature and pH of the water; and the amount of time the contaminant is exposed to the activated carbon.[5] Carbon filters can use either disposable cartridges or packed columns. Disposable cartridges are disposed of once the adsorptive capacity is exhausted. Alternatively, packed columns can be removed and regenerated off site.[6] Water use is required to regenerate the columns; however, since regeneration is typically done off site, no water is used at the facility level.

Deionization

Deionization is a physical process similar to water softening that exchanges cations and anions present in the untreated water with hydrogen and hydroxide ions. Deionization is not effective at removing particulates, but because the process is relatively fast, it is commonly used in laboratory applications requiring a low level of water purification. Regeneration of deionization resins often occurs off site.[7] Water use is required to regenerate the resin; however, since the regeneration is done off site, no water is used at the facility level.

Distillation

Distillation functions by boiling water to form steam condensate using either an electric or gas still. Solid contaminants are left behind as the steam is generated, then the steam is condensed into a purified water stream. Distillers can use large volumes of water if once-through cooling water is used in the condenser, or if a reject stream is discharged from the boiler to prevent scale buildup. These systems typically reject 15 to 25 percent of water entering the system.[8]

Membrane Processes (Including Reverse Osmosis)

Membrane processes use a semi-permeable membrane layer to separate purified water from contaminants. Several types of membranes are used for water purification, including (from largest to smallest size of particles removed) microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Because reverse osmosis is capable of removing the smallest particles, it is used most often by laboratory and medical facilities requiring very pure water.

Reverse osmosis system

Reverse osmosis units use pressure to reverse osmotic pressure and force water with a high solute concentration through a membrane filter to create purified (i.e., low solute) water. Reverse osmosis is

[5] University of Minnesota | Extension. 1992. Treatment Systems for Household Water Supplies: Activated Carbon Filtration (Clean Water Series). www.extension.umn.edu/distribution/naturalresources/DD5939.html.
[6] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* Pages TREAT1-6. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.
[7] Water Online. Deionization. www.wateronline.com/product.mvc/Deionization-0001.
[8] EBMUD, *op. cit.*

able to remove a large portion of contaminants but recovers only a portion of the incoming water. The recovery rate, defined as the ratio of the purified water (i.e., permeate) to feed (i.e., incoming) water, is used to depict the efficiency of a reverse osmosis system. For commercial and institutional applications, reverse osmosis units typically have recovery rates of 50 to 75 percent.[9] Thus, the systems reject 25 to 50 percent of water entering the system.

Water Softening

Water softening is used to remove hardness minerals, such as calcium and magnesium, from water. Cation exchange water softeners are the most common type of water softening system, although other water purification technologies, such as reverse osmosis and distillation systems, can also soften water.

In a cation exchange water softener, hard water with positively charged calcium and magnesium ions passes through a mineral tank consisting of positively charged sodium ions attached to a bed of negatively charged resin beads. The calcium and magnesium ions are exchanged for the sodium ions on the resin beads, which causes the gradual depletion of available ion exchange sites. Eventually, the water softener must be regenerated to replenish the softening capacity. The regeneration process uses water to purge and rinse the system and replenish the sodium ion supply on the resin beads. As a result, the system generates sodium-rich wastewater that must be disposed.

The frequency of regeneration and the amount of water used by the water softening process is dictated by the hardness of the incoming water, the rate of water consumption, and the hardness removal capacity of the cation exchange water softener. The most efficient cation exchange water softeners are demand-initiated, which base the frequency of regeneration on the incoming water's hardness or the demand for softened water rather than a set regeneration schedule.

Other Technologies

Several less common technologies are also used to purify water. Chlorine compounds, ozone, or hydrogen peroxide can be used to chemically disinfect water. Ultraviolet light, heat, and extreme mechanical sheer can also be used to treat water with contaminants. These technologies might not require the backwash phase used by other water purification technologies, but they can require regular cleaning, which can be water-intensive.[10] Chemical disinfection can use additional water if chemicals are added in liquid or slurry form.

[9] U.S. Environmental Protection Agency (EPA) and U.S. Energy Department (DOE), Energy Efficiency & Renewable Energy (EERE), Federal Energy Management Program (FEMP). May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 5. www1.eere.energy.gov/femp/program/labs21_bmp.html.

[10] EBMUD, *op. cit.*

Operation, Maintenance, and User Education

For optimal water purification system efficiency, consider the following operation, maintenance, and user education techniques:

- Use water purification only when necessary and match the process to the actual quality of water required.
- For filtration processes, base backwash phases upon the pressure differential across the filtration media. A pressure drop will indicate that the filter requires backwashing.
- For carbon filtration and deionization processes where regeneration occurs off site, work with maintenance professionals to determine an optimal schedule for removing and regenerating units. This can be determined based on incoming water characteristics and the amount and quality of purified water required daily. Deionization systems should require regeneration based on the volume of water treated or conductivity.
- For distillation systems, periodically clean the boiling chamber to remove accumulated minerals. This will ensure efficient operation of the system.
- For water softeners, work with a plumbing professional or the product manufacturer to account for and program regeneration based upon the incoming water hardness and/or flow through the system. Monitor and adjust settings periodically.

Retrofit Options

Facilities might choose to install multiple water purification systems in sequence to increase the effectiveness and efficiency of the water purification process. When one of the later phases of treatment uses a membrane, at a minimum, it might be necessary to install a pretreatment step to remove larger particles.

For filtration processes, consider installing pressure gauges, if not already installed. Pressure gauges can be used to determine when to initiate a backwash phase.

Consider reusing water purification system reject water as an alternative onsite water source where appropriate and feasible. See *Section 8: Onsite Alternative Water Sources* for more information.

Replacement Options

Prior to purchasing a new water purification system or replacing an old one, evaluate the incoming water supply and assess the quality and quantity requirements of the intended use for a period of time. This will help to determine the level of water purification needed and the sizing of the system. Choose the least intensive treatment needed to achieve the desired quality level and size the system correctly for the intended use. Oversized systems can waste water and energy and lead to degraded quality due to of long, inoperable periods.

7.2 Water Purification

Consider water purification systems that require the least amount of backwashing or regeneration. For membrane processes such as reverse osmosis, consider a system with a high recovery rate for its size. For deionization systems, consider systems that regenerate based on the volume of water treated or conductivity. For distillation systems, consider units that use air-cooled coils, rather than water-cooled coils and recover at least 85 percent of the feed water.[11] For water softeners, consider demand-initiated systems instead of systems with manual or auto-initiated regeneration. In addition, consider installing multiple smaller, more efficient cation exchange water softeners that can be alternated to minimize the frequency of regeneration and allow for a constant, uninterrupted supply of soft water.

Savings Potential

The water use of a water purification system is dependent upon the level of purification required, incoming water quality, volume of use, and purified water demand. Water use is also specific to the type of water purification system used.

Carbon filtration and deionization systems are typically regenerated off site. If regenerated off site, the water use of these systems will not directly affect the water use of the facility. However, minimizing the frequency of removal and regeneration will help to reduce the water use of these systems.

The water use of distillers is dependent upon the method of cooling and the amount of reject water used to clear the boiler of scale buildup. Water savings can be maximized if air-cooled coils are used rather than water-cooled coils. Additionally, systems that produce less reject water will consume less water overall.

For filtration processes, water use is determined by the water quality requirements and frequency of the backwash phase. Optimizing the frequency of the backwash phase by initiating backwash only when a pressure drop occurs across the filter media will ensure less water is used overall.

The water efficiency of a reverse osmosis process can be determined by the recovery rate, which is defined as the ratio of permeate to feed. Systems with higher recovery rates are considered more efficient, because they are able to produce more purified water from the same amount of feed.

Recovery rates can vary widely depending upon the type of membrane and quality of incoming water. Some less efficient reverse osmosis systems, for example, have a recovery rate of 33 to 50 percent.[12] The recovery rate can be maximized by increasing the number of stages of membrane pressure vessels, which allows for higher pressures to be achieved in order to more effectively overcome natural osmosis. A one-stage system can achieve a recovery rate of 50 percent, while two- and three-stage systems can achieve recovery rates of 75 percent and 90 percent, respectively.[13] For example, the Sandia National Laboratories in Albuquerque, New Mexico, installed a high-efficiency reverse osmosis system with pretreatment before the membranes.

[11] *Ibid.*
[12] Pagliaro, Tony. 1995. "Commercial/Industrial Reverse Osmosis Systems: General Design Considerations." *WaterReview*. Page 3. www.wqa.org/pdf/Technical/cirodes.pdf.
[13] *Ibid.* Page 2.

The facility was able to achieve a 95 percent recovery rate, rejecting only 5 percent of the water entering the system.[14]

Additional Resources

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages TREAT1-6. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 5. www1.eere.energy.gov/femp/program/labs21_bmp.html.

Schultz Communications. July 1999. *A Water Conservation Guide for Commercial, Institutional and Industrial Users*. Prepared for the New Mexico Office of the State Engineer. www.ose.state.nm.us/wucp_ici.html.

[14] EPA and DOE, EERE, FEMP. August 2009. *Microelectronics Plant Water Efficiency Improvements at Sandia National Laboratories*. Page 2. www1.eere.energy.gov/femp/program/waterefficiency_csstudies.html.

7.3 Vacuum Pumps

Overview

Laboratories, medical facilities, and dental offices use vacuum pumps to collect waste gases, liquids, or debris from a vessel or enclosure. These vacuum pump systems range in size, depending upon whether they are used to supply a vacuum to several rooms or for point of use. Dental offices' pumps range from 1.0 to 4.0 horsepower (hp), while a central vacuum pump in a medical facility can be 5.0 to 20.0 hp.[15] Vacuum pumps can use water in two ways: to cool the pump or to create the vacuum seal in the rotating equipment, which generates the vacuum.

Vacuum pumps at the Kansas City Science and Technology Center

An aspirator is a type of vacuum system that can consume water in the process of creating the vacuum. In an aspirator, fluid (e.g., liquid, gaseous) flows through a narrowing tube. As the tube narrows, the velocity of the fluid increases and the static pressure within the system decreases due to the Venturi effect, which creates a vacuum. The simplest type of aspirator uses water as the fluid medium, which is used once and discharged to the drain, making the process very water-intensive. Because of their simplicity, water aspirators might commonly be found in many high school and college laboratories, but their use can be limited to just a few hours each semester. Although water aspirators are available, they are not the focus of this section. Instead, this section focuses on vacuum pump systems, which are more commonly found in commercial and institutional facilities. If a facility has a water aspirator that is used frequently, it should consider the replacement options discussed in this section.

Generating the Vacuum

Vacuum pumps can either be "dry" or "wet"—based upon how the vacuum seal is generated within the pump. Dry pumps do not use water to generate the seal for the vacuum. Instead, they create vacuums with turbines (i.e., fans) or use positive displacement (e.g., vane pumps, claw pumps, piston pumps). Wet pumps use a closed impeller that is sealed with water or other lubricants such as oil to generate the vacuum.

The most common type of wet vacuum pump is a liquid-ring vacuum pump, which uses water to form a moving cylindrical ring inside the pump casing. In these pumps, the vacuum is created by the changing geometry inside the pump casing as the impeller and liquid ring rotate. As the vacuum seal water rotates with the pump, it gains heat and gathers impurities from gases collected by the vacuum system.

In the most simple liquid-ring vacuum pump systems, the seal and cooling water are continuously discharged and replenished with fresh water to dissipate heat and

[15] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Page MED2. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

remove impurities. Water requirements for both creating the vacuum and cooling the equipment range from 0.5 to 1.0 gallons per minute (gpm) per hp.[16] To save water, these pumps can be equipped with a partial or full recovery and recirculation system. In the full recovery system, all the seal water is recovered from the discharge side of the pump, passed through a heat exchanger (if the system configuration allows for heat removal), and reused for sealing and cooling. A small amount of recycled water is discharged to remove impurities, and the system is replenished with make-up water. This full configuration recirculation system is estimated to reduce water use by 80 percent.[17]

Partial recovery and recirculation systems recirculate part of the sealing water. Make-up water is added to ensure that impurity concentration is not too high. In these systems, consideration should be made to avoid heat buildup in the pump. Partial recovery systems can reduce water use by about 50 percent.

Cooling the Vacuum Pump

Vacuum pumps can be water-cooled or air-cooled. Water-cooled vacuum pumps use single-pass cooling or recirculated cooling. Either wet or dry vacuum pumps can use water to cool the system. In single-pass cooling, water passes through the pump only once for cooling, then is discharged directly to the drain. A recirculated cooling system, on the other hand, passes the majority of cooling water through a heat exchanger, and the cooling water is reused. If the cooling water does not come in contact with the vacuumed gases or other impurities, it can be recirculated by connecting the pump to a larger building system chilled water loop or cooling tower water loop to remove the heat load. Air-cooled vacuum pumps use ambient air, rather than water, to remove the heat load from the vacuum pump.

Operation, Maintenance, and User Education

For optimal liquid-ring vacuum pump efficiency, consider the following tips:

- Turn off the pump when it is not in use or needed.
- Ensure that the vacuum pump is set at manufacturer specifications to discharge only the amount of water necessary to remove impurities and cool the vacuum pump.
- Periodically check the vacuum pump's operational control schemes, if available, to ensure optimum efficiency (e.g., timers, float-operated switches, total dissolved solids controllers that initiate discharge and make-up water).

Retrofit Options

If the facility is using a liquid-ring vacuum pump that continuously discharges water, the facility can consider equipping the pump with a full recovery and recirculation

[16] *Ibid.*
[17] U.S. Air Force Medical Service. *Dental Vacuum Systems*. Page 5. airforcemedicine.afms.mil/idc/groups/public/documents/afms/ctb_108329.pdf.

system, to reduce total water use by an estimated 80 percent.[18] The facility should consider the impurities gathered within the pump and other characteristics of the waste being removed when evaluating whether a full recovery and recirculation system is appropriate. A partial recovery and recirculation system could also be considered, and the facility could reduce water use by an estimated 50 percent with its installation. If either recovery and recirculation system option is installed, ensure that it is properly maintained per manufacturer instructions so that impurities are removed and hard water deposits do not remain in the system.

If the facility has any other type of vacuum pump that is cooled with single-pass, non-contact cooling water, a heat exchanger can be added, or it can be connected to a larger building system chilled water loop or cooling tower water loop. See *Section 6.2: Single-Pass Cooling* for more information.

Replacement Options

When purchasing a new vacuum pump or replacing older equipment, a non-lubricated, dry vacuum pump that is air-cooled can eliminate the pump's water use altogether. When choosing a vacuum pump, it is important to consider all factors, including energy and water use. Although they might be more expensive, dry, air-cooled vacuum pumps can be as much as 25 to 50 percent more energy-efficient than water-cooled or liquid-ring vacuum pumps.[19]

Facilities should note that, in some cases, liquid-ring vacuum pump discharge can pose a biohazard risk. Therefore, a non-lubricated, dry vacuum pump that is air-cooled could be the best option. However, if explosive or corrosive gases are being removed with the vacuum system, the facility might only be able to consider a liquid-ring vacuum pump. Dental facilities should note that new vacuum systems—wet or dry, and regardless of the type of cooling system—often need to add amalgam separators to prevent mercury contamination in water bodies.[20]

Savings Potential

Retrofitting existing liquid-ring vacuum pumps with full or partial recovery and recirculation systems can result in significant water savings, while replacing existing water-cooled and/or liquid-ring vacuum pumps with air-cooled, dry vacuum pumps can entirely eliminate water use.

To estimate facility-specific water savings and payback, use the following information.

Vacuum Pump Retrofit

Liquid-ring pumps that utilize water to create a vacuum can be retrofitted to recirculate sealing and cooling water rather than discharging to the drain.

[18] *Ibid.*
[19] EBMUD, *op. cit.*
[20] U.S. Air Force Medical Service, *op. cit.*, Page 1.

Current Water Use

To estimate the current water use of an existing vacuum pump, identify the following and use Equation 7-1:

- Flow rate of the discharged water from the existing vacuum pump.
- Average daily use time.
- Days of operation per year.

Equation 7-1. Water Use of Vacuum Pump (gallons per year)

= **Vacuum Pump Discharge Flow Rate x Daily Use Time x Days of Operation**

Where:

- Vacuum Pump Discharge Flow Rate (gallons per minute)
- Daily Use Time (minutes per day)
- Days of Operation (days per year)

Water Savings

Full water recovery and recirculation systems can reduce water use by approximately 80 percent,[21] while partial systems can reduce water use by approximately 50 percent.[22] To calculate the water savings that can be achieved from retrofitting an existing vacuum pump, identify the current water use of the vacuum pump as calculated using Equation 7-1 and use Equation 7-2, using 80 percent savings for a full system and 50 percent for a partial system.

Equation 7-2. Water Savings From Vacuum Pump Recovery and Recirculation System Retrofit (gallons per year)

= **Current Water Use of Vacuum Pump x Savings (0.80 or 0.50)**

Where:

- Current Water Use of Vacuum Pump (gallons per year)
- Savings (percent)

Payback

To calculate the simple payback from the water savings associated with retrofitting an existing vacuum pump, consider the equipment and installation cost of the retrofit recovery and recirculation system, the water savings as calculated using Equation 7-2, and the facility-specific cost of water and wastewater.

[21] *Ibid*. Page 5.
[22] Estimate based on manufacturer literature.

7.3 Vacuum Pumps

The facility should also consider the energy impact of the vacuum pump retrofit. The recovery systems might use energy, which can affect the payback period and cost-effectiveness.

Vacuum Pump Replacement

Existing liquid-ring vacuum pumps can be replaced with dry vacuum pumps that are air-cooled rather than water-cooled. This replacement entirely eliminates the water used to create a vacuum, as well as the water used to cool the vacuum pump.

Current Water Use

To estimate the current water use of an existing vacuum pump, use Equation 7-1.

Water Savings

Because air-cooled, dry vacuum pumps consume no water to create a vacuum, water savings will be equal to the current water use. To calculate the water savings that can be achieved from replacing an existing vacuum pump, identify the current water use of the vacuum pump as calculated using Equation 7-1 and use Equation 7-3.

Equation 7-3. Water Savings From Vacuum Pump Replacement (gallons per year)

= Current Water Use of Vacuum Pump

Where:

- Current Water Use of Vacuum Pump (gallons per year)

Payback

To calculate the simple payback from the water savings associated with replacing an existing liquid-ring vacuum pump with an air-cooled, dry vacuum pump, consider the equipment and installation cost, the water savings as calculated using Equation 7-3, and the facility-specific cost of water and wastewater.

By replacing a water-cooled or liquid-ring vacuum pump with an air-cooled, dry pump, facilities should also consider the potential increase or decrease in energy use. Some dry vacuum pumps can save energy over the existing water-cooled or liquid-ring pump. The energy use will also affect the payback time and replacement cost-effectiveness.

Additional Resources

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages MED1-2. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

Sydney Water. October 2004. *The Liquid Ring Vacuum Pump*. www.sydneywater.com.au/Water4Life/InYourBusiness/FactSheets.cfm.

U.S. Air Force Medical Service. *Dental Vacuum Systems*. airforcemedicine.afms.mil/idc/groups/public/documents/afms/ctb_108329.pdf.

7.4 Steam Sterilizers

EPA WaterSense

Overview

Disinfection/sterilization is common in hospitals and research institutions where it is necessary to destroy microorganisms that can cause infection or disease. A steam sterilizer (a subcategory of autoclaves) is the most common type of system used to disinfect and sterilize laboratory equipment, surgical instruments, medical waste, and other materials requiring sterilization.[23] Steam sterilizers can use water in three ways: to generate steam (i.e., the disinfecting/sterilizing agent); to cool steam condensate to appropriate temperatures before it is discharged down the drain; and to draw a vacuum through the sterilization chamber to expedite the drying process.

Steam sterilizer exterior

Several other types of autoclaves use different modes of sterilization, including dry heat, ethylene oxide, and radiation.[24] However, these modes of sterilization are not typically recommended unless the material being sterilized has special requirements that make it adverse to steam or high temperatures. This section focuses on steam sterilizers, the type of sterilization equipment that uses water.

The water-efficiency options discussed in this section do not address the water used to generate the steam that is used in the disinfection process and, therefore, do not impact the steam sterilizer's ability to disinfect and sterilize equipment. For information on optimizing a central boiler and steam system which may supply steam to steam sterilizers, refer to *Section 6.5 Boiler and Steam Systems*.

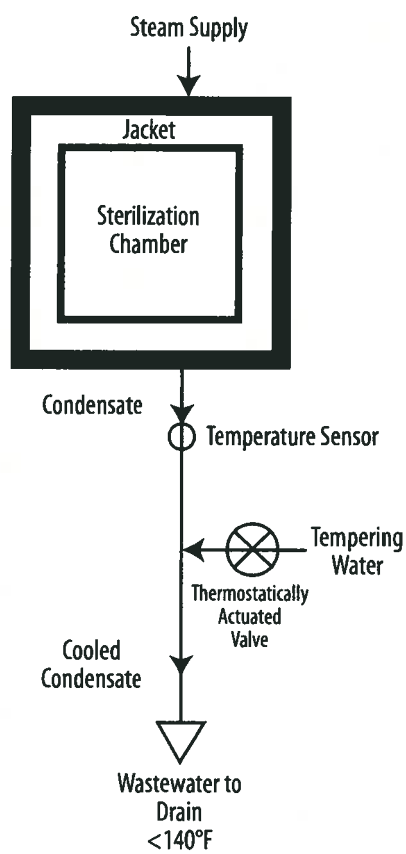
Steam sterilizer interior

Steam sterilizers are usually operated 24 hours per day in order for the equipment to remain sterile and ready to use at any time. Most systems are only actively sterilizing for eight hours per day or less and are idle for the remaining time.[25] During idle mode, low-pressure steam is passed into the chamber. During both idle mode and active sterilization, as the steam in the chamber condenses, the generated condensate discharges to a floor drain, where it is tempered with cool water to a temperature less than 140°F before it is discharged to the sanitary sewer. Most steam sterilizers use tempering water at a flow rate of 1.0 to 3.0 gallons per minute (gpm).[26] Older steam sterilizers can waste a significant amount of water if they allow tempering water to flow continuously.[27] Even at a flow rate of 1.0 gpm, the resulting tempering water use can range from 400,000 to 500,000 gallons per year.

[23] Alliance for Water Efficiency (AWE). Steam Sterilizer & Autoclaves Introduction. www.allianceforwaterefficiency.org/1Column.aspx?id=680.
[24] *Ibid.*
[25] U.S. Environmental Protection Agency (EPA) and U.S. Energy Department (DOE), Energy Efficiency & Renewable Energy (EERE), Federal Energy Management Program (FEMP). May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Pages 5-6. www1.eere.energy.gov/femp/program/labs21_bmp.html.
[26] *Ibid.*
[27] AWE, *op. cit.*

Newer steam sterilizers can be designed—or older systems retrofitted—with a thermostatically actuated valve (see Figure 7-3) and/or an uninsulated heat exchange tank to significantly reduce the amount of tempering water use. The heat exchange tank transfers heat from the condensate to the cooler, ambient atmosphere before it is discharged to the sanitary sewer. The tempering valve allows tempering water to flow only when the condensate reaches a certain temperature. Major steam sterilizer manufacturers in the United States began including water tempering kits on their systems in the late 1990s.

Figure 7-3. Steam Sterilizer Cooling Water Retrofit



Steam sterilizers can also be retrofitted or designed to reduce the amount of water necessary to draw a vacuum through the sterilization chamber. In a conventional steam sterilizer, the vacuum is generated by passing water at a high velocity through an ejector at a flow rate of 5.0 to 15.0 gpm and discharging it directly to the sanitary sewer.[28] To reduce this water use, a second pump and water reservoir can be added to capture and reuse a portion of the water. New steam sterilizers can also offer an electric liquid-ring vacuum pump that reduces water use by about 75 percent compared to the water used through the vacuum generation on a conventional steam sterilizer.[29]

[28] Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices*. Prepared for the California Urban Water Conservation Council. Pages 26. www.cuwcc.org/products/pbmp-reports.aspx.
[29] *Ibid*. Page 31.

While steam sterilizers with dry vacuum pumps are available in Europe, they are still not available in the United States at this time.

Operation, Maintenance, and User Education

To optimize the water efficiency of a steam sterilizer, consider the following operation, maintenance, and user education techniques:

- Adjust the tempering water needle valve flow rate to the minimum manufacturer recommendations and periodically review and readjust to ensure no unnecessary water is discharged to the drain.
- Change out the needle valve annually, because they can wear quickly. Worn valves can discharge excess water.
- If the steam sterilizer is already equipped with a thermostatically actuated valve to control tempering water flow, periodically check the valve to ensure it is opening and closing properly, so tempering water is not continuously discharged.
- Shut off the steam sterilizer unit when not in use.
- Use high-quality water to generate steam to improve the efficiency of the steam sterilizer.

Retrofit Options

There are two retrofit approaches to reduce the water use associated with steam sterilizers. One approach addresses the use of tempering water, and the other addresses the water used to create the vacuum in the sterilization chamber. Depending upon the operational settings, frequency, and timing of sterilizer use and whether the tempering water flows continuously, retrofitting a conventional steam sterilizer to reduce its water use can be cost-effective.

Tempering Water Retrofit

To reduce the amount of tempering water necessary to cool the steam condensate that is discharged, replace the standard needle valve with a thermostatically actuated valve. This type of valve can monitor the temperature of the condensate and will adjust and minimize the flow of cooling water necessary to maintain a discharge temperature below 140°F. In addition, consider diverting the steam condensate into a small, uninsulated tank prior to discharge. This tank will allow the condensate to cool through heat exchange with the ambient air to the point where little to no additional cooling water is required to meet the 140° F temperature discharge requirement.[30]

Vacuum Retrofit

Vacuum units contain an ejector that creates the vacuum in the sterilization chamber. Water is typically passed through the ejector at a very high flow rate before it is dis-

[30] *Ibid.* Pages 23-34.

charged down the drain. To capture and reuse a portion of the water passing through the ejector, a second, additional ejector with a pump and a water reservoir can be added. This modification channels 50 to 75 percent of the water flowing through the ejector into an uninsulated tank, where it is allowed to cool below 120°F before being reused through the pump and ejector. If the captured water does not cool fast enough, a thermostatic valve allows cold water to flow into the tank, and any overflow is sent to the drain. One limitation to this type of system is that it cannot be used on sterilizers with a sealing flange or any sterilizer that processes biohazardous material.[31]

Replacement Options

When looking to purchase a new steam sterilizer or to replace older equipment, look for models that only use tempering water when needed and that have the capability to cool the steam condensate prior to discharge. Look for models that have a vacuum unit with a second ejector and a reservoir to capture and reuse a portion of the water passing through the ejector or models with an electric liquid-ring vacuum pump.

In addition, look for models with features that can further reduce water use and improve efficiency, such as an automatic shut-off, or a programmable control system that shuts down the sterilizer during periods of non-use (e.g., non-business hours) and restarts the unit so it is ready for use when needed. Models are also available with improved chamber jacket cladding (i.e., insulation) to reduce sterilizer heat loss and ambient heat gain.

Savings Potential

Water savings can be achieved through steam sterilizer retrofit or replacement in two ways: reducing the amount of water required to temper the condensate, or reducing the water used to create the vacuum.

To estimate facility-specific water savings and payback, use the following information.

Steam Sterilizer Retrofit or Replacement to Reduce Tempering Water Use

Existing steam sterilizers can be retrofitted or new steam sterilizers can be purchased with a thermostatically actuated valve and a heat exchanger to reduce the amount of tempering water used to cool the steam condensate.

Current Water Use

To estimate the current tempering water use of an existing steam sterilizer, identify the following information and use Equation 7-4:

- Flow rate of the sterilizer's tempering water. Most steam sterilizers use tempering water with a flow rate of 1.0 to 3.0 gpm.[32]

[31] *Ibid.*
[32] EPA and DOE, EERE, FEMP, *op. cit.*

- Average daily idle period of the steam sterilizer. Note that some older models have tempering water that flows constantly, even if the unit is turned off and not in idle mode. In this case, the average daily use of 24 hours should be used instead of the daily idle period to calculate daily water use.
- Days of sterilizer operation per year. If the tempering water is flowing constantly, even when the sterilizer is not in use and the facility is closed, 365 days per year should be used.

Equation 7-4. Steam Sterilizer Tempering Water Use (gallons per year)

= Tempering Water Flow Rate x Daily Idle Period x Days of Operation

Where:

- Tempering Water Flow Rate (gallons per minute)
- Daily Idle Period (minutes per day)
- Days of Operation (days of sterilizer operation per year)

Water Savings

A study conducted at the University of Washington showed that a tempering water retrofit or installing new equipment that addresses tempering water can reduce tempering water use by up to 90 percent, depending upon how long the sterilizer is in idle mode.[33] To calculate the tempering water savings that can be achieved from retrofitting or replacing an existing steam sterilizer, identify the current water use of the equipment, as calculated using Equation 7-4, and use Equation 7-5.

Equation 7-5. Water Savings From Steam Sterilizer Tempering Water Retrofit or Replacement (gallons per year)

= Current Steam Sterilizer Tempering Water Use x Savings (0.9)

Where:

- Current Steam Sterilizer Tempering Water Use (gallons per year)
- Savings (percent)

Payback

To calculate the simple payback from the water savings associated with the tempering water retrofit or replacement, consider the equipment and installation cost of the retrofit or replacement, the water savings as calculated using Equation 7-5, and the

[33] van Gelder, Roger E. and Leaden, John. University of Washington. 2003. *Field Evaluation of Three Models of Water Conservation Kits for Sterilizer Trap Cooling at University of Washington*. Page 9. www.p2pays.org/ref/50/49036.pdf.

facility-specific cost of water and wastewater. A tempering water retrofit typically costs $2,900.[34] If the steam sterilizer was replaced, use the cost of the new steam sterilizer.

Steam Sterilizer Retrofit or Replacement With Additional Ejector (Vacuum Water Use)

Sterilizers can consume water to produce a vacuum. To reduce this water use, existing steam sterilizer equipment can be retrofitted or new units purchased with an additional ejector with a pump and water reservoir to capture and reuse a portion of the water passing through the ejector. Purchasing a new steam sterilizer with this vacuum configuration would require a longer payback period.

Current Water Use

To estimate the current water use of an existing steam sterilizer's vacuum, identify the following information and use Equation 7-6:

- Flow rate of water needed to pull the required vacuum. This will be dependent upon the size of the unit.
- Number of sterilization cycles run each day.
- Duration of the conditioning phase. The average conditioning phase lasts three minutes.[35]
- Duration of the exhaust phase. The average exhaust phase lasts 30 minutes.[36]
- Days of sterilizer operation per year.

Equation 7-6. Steam Sterilizer Vacuum Water Use (gallons per year)

= [Vacuum Flow Rate x (Duration of Exhaust Phase + Duration of Conditioning Phase)] x Sterilization Cycles x Days of Operation

Where:

- Vacuum Flow Rate (gallons per minute)
- Duration of Exhaust Phase (minutes per cycle)
- Duration of Conditioning Phase (minutes per cycle)
- Sterilization Cycles (sterilization cycles per day)
- Days of Operation (days of sterilizer operation per year)

[34] Escalated from 2004 dollars to 2010 dollars; 2004 dollars from: Koeller, John, et al., *op. cit.*, Page 32.
[35] Koeller, John, et al., *op. cit.* Pages 26-32.
[36] *Ibid.* Page 26.

Water Savings

On average, a vacuum retrofit or replacement that modifies the ejector can reduce vacuum water use by at least 50 percent.[37] To calculate the water savings that can be achieved from this type of modification, identify the current water use of the equipment as calculated using Equation 7-6 and use Equation 7-7.

Equation 7-7. Water Savings From Steam Sterilizer Vacuum Retrofit or Replacement With Additional Ejector (gallons per year)

= Current Steam Sterilizer Vacuum Water Use x Savings (0.5)

Where:

- Current Steam Sterilizer Vacuum Water Use (gallons per year)
- Savings (percent)

Payback

To calculate the simple payback from the water savings associated with retrofitting or replacing an existing steam sterilizer vacuum, consider the equipment and installation cost of the retrofit or replacement, the water savings as calculated using Equation 7-7, and the facility-specific cost of water and wastewater. An ejector modification vacuum retrofit typically could cost approximately $17,200.[38]

By retrofitting an existing steam sterilizer vacuum with an additional ejector, facilities should also consider the potential energy impact. The pump and other equipment included with the retrofit or replacement can use additional energy. The energy use can affect the payback time and cost-effectiveness.

Steam Sterilizer Replacement With Liquid-Ring Vacuum Pump (Vacuum Water Use)

When replacing a steam sterilizer, facilities can also select models that have an electric liquid-ring vacuum pump instead of a high-velocity ejector. Liquid-ring vacuum pumps can reduce vacuum water use by 75 percent compared to the water used through the vacuum generation on a conventional steam sterilizer.

Current Water Use

To estimate the water use of an existing steam sterilizer's vacuum, use Equation 7-6.

Water Savings

Purchasing a new steam sterilizer with an electric liquid-ring vacuum pump can reduce vacuum water use by approximately 75 percent.[39] To calculate the water savings

[37] *Ibid*. Page 27.
[38] *Ibid*.
[39] *Ibid*. Page 31

that can be achieved from replacing an existing steam sterilizer with one that has an electric liquid-ring vacuum pump, identify the current water use of the equipment, as calculated using Equation 7-6, and use Equation 7-8.

Equation 7-8. Water Savings From Steam Sterilizer Retrofit With Liquid-Ring Vacuum Pump (gallons per year)

= Current Steam Sterilizer Vacuum Water Use x Savings (0.75)

Where:

- Current Steam Sterilizer Vacuum Water Use (gallons per year)
- Savings (percent)

Payback

To calculate the simple payback from the water savings associated with replacing a steam sterilizer with one with a liquid-ring vacuum pump, consider the equipment and installation cost of the replacement, the water savings as calculated using Equation 7-8, and the facility-specific cost of water and wastewater.

By replacing a steam sterilizer with one with a liquid-ring vacuum pump, facilities should also consider the potential increase or decrease in energy use. The energy use will also affect the payback period and replacement cost-effectiveness.

Additional Resources

Alliance for Water Efficiency. Steam Sterilizer & Autoclaves Introduction. www.allianceforwaterefficiency.org/1Column.aspx?id=680.

EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program (FEMP). May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Pages 5-6. www1.eere.energy.gov/femp/program/labs21_bmp.html.

DOE, Energy Efficiency & Renewable Energy, FEMP. *Water Efficiency Improvements at Various Environmental Protection Agency Sites*. www1.eere.energy.gov/femp/program/waterefficiency_csstudies.html.

Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices*. Prepared for the California Urban Water Conservation Council. Pages 23-34. www.cuwcc.org/products/pbmp-reports.aspx.

van Gelder, Roger E. and Leaden, John. University of Washington. 2003. *Field Evaluation of Three Models of Water Conservation Kits for Sterilizer Trap Cooling at University of Washington*. www.p2pays.org/ref/50/49036.pdf.

7.5 Glassware Washers

EPA WaterSense

Overview

Glassware washers are automated washing devices that remove chemical or other particle buildup on laboratory glassware, such as pipettes, flasks, and graduated cylinders. Glassware washers are often supplied with both potable and purified water. Purified water is typically used in the final rinse stages to ensure that no contaminants are left on glassware surfaces. Potable water used during other wash or rinse stages might be treated with a water softener to remove hard water, which can cause scale buildup.

Newer, more efficient glassware washers use precise flow control to reduce water use for each wash and rinse cycle. Some also offer flexible programming, allowing the user to adjust the incoming water fill according to load size. Glassware washers that allow users to choose the number of rinse cycles or otherwise customize the washing and rinsing program can help reduce water use.

Glassware washers are almost always a more water-efficient method of washing when compared to hand washing and rinsing of lab glassware.

Operation, Maintenance, and User Education

For optimum glassware washer efficiency, consider the following operation, maintenance, and user education tips:

- 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.
- If the number of rinse cycles can be chosen, select as few rinse cycles as possible, considering the cleanliness requirements of the glassware.

Retrofit Options

If appropriate given the intended use of the glassware, consider installing a water recycling system that reuses rinse cycle wastewater as wash water in the next load. Some systems are capable of treating rinse cycle wastewater before reusing it. Consider the level of water quality needed before choosing a recycling option.

Replacement Options

When purchasing a new glassware washer or replacing an existing one, choose models with the following features:

- Cycle selection that allows users to optimize rinse cycles for both effective and efficient cleaning.
- Reuse of final rinse water as wash water for the next load, if appropriate.
- Water intake monitoring to adjust the amount of water used based on load size.

Savings Potential

Water savings can be achieved by replacing an existing glassware washer with a more efficient one. A glassware washer's water use is dependent upon the amount of water used during wash and rinse cycles, as well as the total number of cycles. A replacement glassware washer can use less water per cycle through flow control and allow users to select fewer cycles.

To estimate facility-specific water savings and payback, use the following information.

Current Water Use

To estimate the current water use of a glassware washer, identify the following information and use Equation 7-9:

- Average volume of water used during a full wash process. This might be provided by the product manufacturer through product literature or the manufacturer's website. The water efficiency will be dependent upon the flow rate of each rinse or wash cycle, duration of each cycle, and number of cycles. If the water use from the full wash process is not available from the manufacturer, add up the water use from each cycle to determine the water use from the full wash process.
- Average number of wash processes per day.
- Days of operation per year.

Equation 7-9. Water Use of Glassware Washer (gallons per year)

= Wash Water Use x Wash Processes per Day x Days of Operation

Where:

- Wash Water Use (gallons per wash)
- Wash Processes per Day (washes per day)
- Days of Operation (days of washer operation per year)

Water Use After Replacement

To estimate the water use of a more efficient replacement glassware washer, use Equation 7-9, substituting the average volume of water used during a full wash process of the replacement glassware washer. Efficient models can use less than 15 gallons during the full wash process. If the number of rinse cycles can be chosen, calculate the maximum potential water savings using the water use corresponding to the fewest average number of rinse cycles needed at the facility.

Water Savings

To calculate the water savings that can be achieved from the replacement of an existing glassware washer, identify the following information and use Equation 7-10:

- Current water use as calculated using Equation 7-9.
- Water use after replacement as calculated using Equation 7-9.

Equation 7-10. Water Savings From Glassware Washer Replacement (gallons per year)

= Current Glassware Washer Water Use – Water Use After Glassware Washer Replacement

Where:

- Current Glassware Washer Water Use (gallons per year)
- Water Use After Glassware Washer Replacement (gallons per year)

Payback

To calculate the simple payback from the water savings associated with replacing an existing glassware washer, consider the equipment and installation cost of the replacement glassware washer, the water savings as calculated using Equation 7-10, and the facility-specific cost of water and wastewater.

By reducing water use in a glassware washer, facilities can also save a significant amount of energy, since most of the water used during the rinse cycles is hot water. This energy savings will further reduce the payback period and increase replacement cost-effectiveness.

Additional Resources

EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Pages 6-7.
www1.eere.energy.gov/femp/program/labs21_bmp.html.

7.6 Fume Hood Filtration and Wash-Down Systems

EPA WaterSense

Overview

A fume hood is a ventilated enclosure where hazardous materials can be handled safely to limit exposure. Fume hoods draw contaminants within the work area away from the user to minimize contact and exhaust fumes through a ventilation system to remove contaminants from the building.

As a first step, a facility should determine if treatment is needed prior to exhausting fumes through the building ventilation system. Dry exhaust fume hoods use a fan to draw in air containing hazardous contaminants before expelling it without providing contaminant treatment. These systems might be appropriate depending upon the hazard level associated with the exhaust being ventilated. If minor treatment of exhausting fumes is necessary, a facility should consider using condensers, cold traps, or adsorbents such as activated charcoal, or neutralizing or converting toxic substances into other less hazardous species.[40]

When dealing with certain hazardous substances requiring more intensive treatment, a fume hood with a filtration system might be needed. There are two types of fume hood filtration systems typically used to handle hazardous substances: gas-phase filtration (includes wet scrubbers) and particulate filtration.[41] Wet scrubbers require the consumption of water to remove hazardous substances. Other gas-phase filtration or particulate filtration systems might be suitable alternatives to wet scrubbers in certain circumstances, as discussed below. In all cases, laboratories should follow manufacturer instructions and facility health and safety guidelines in order to ensure safe operation of fume hoods.

This section focuses on fume hood filtration systems, including those that use water (e.g., wet scrubbers) and fume hood wash-down systems. It also describes systems that do not use water that could be considered as an alternative to wet scrubbers.

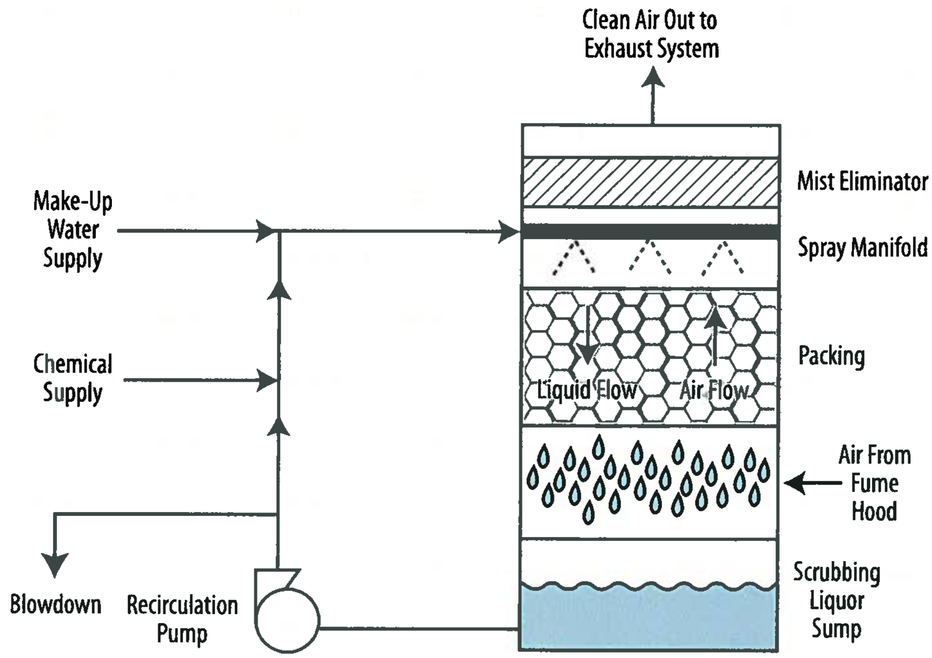
Fume Hood Filtration Systems

Wet Scrubbers

Fume hoods with wet scrubbers that use water to capture and trap hazardous substances are also known as liquid fume hood scrubbers. Contaminated air enters the scrubber system from below and passes through a packed bed. The packed bed is wetted from above with a liquid spray. As the contaminated air comes into contact with the water, water-soluble gases, vapors, aerosols, and particulates become dissolved. The trapped contaminants fall with the water and are discharged into a scrubbing liquor sump. The "scrubbing liquor" is recirculated, with make-up water added as needed to replace water that has evaporated. The scrubbing liquor is removed periodically through a blowdown valve to control total dissolved solids. The treated air is released through an exhaust system. See Figure 7-4 for a schematic of this process.

[40] Hitchings, Dale T. September 1993-January 1994. "Fume Hood Scrubbers—Parts I, II, and III." *Laboratory Building Design Update*. Page 1. www.safelab.com/resources.htm.
[41] *Ibid.* Pages 6-8.

Figure 7-4. Fume Hood Wet Scrubber



Other Gas-Phase Filtration

Besides wet scrubbers, there are two other basic types of gas-phase filtration systems for fume hoods: inert adsorbents and chemically active adsorbents, which do not require water use. Inert adsorbents include activated carbon, activated alumina, and molecular sieves. Chemically active adsorbents are simply inert adsorbents impregnated with a strong oxidizer, such as potassium permanganate, that react with and destroy the organic vapors.[42]

Because contaminants build up in the adsorbent and can be desorbed if the concentration is too high or if the adsorbent has a higher affinity for another contaminant, the adsorbent must be changed or regenerated regularly. Adsorbent systems are not effective in removing high concentrations of contaminants (i.e., spills inside the hood). Since these systems require a consistent check on contaminant concentrations and maintenance of the adsorbent, these factors should be taken into account when evaluating alternatives to fume hood wet scrubber systems, keeping in mind the contaminant and concentration that needs to be removed to ensure that the hazard is fully abated.[43,44]

[42] *Ibid.* Page 6.
[43] National Research Council, et al. 1995. *Prudent Practices in the Laboratory—Handling and Disposal of Chemicals.* Washington, DC: National Academy Press. Page 188. www.nap.edu/openbook.php?record_id=4911&page=188.
[44] Hitchings, Dale T., *op. cit.*, Pages 6-7.

Particulate Filtration

If radioactive or biologically active materials or other hazardous particulates are present, a particulate filter might be necessary. HEPA filters are often used for this purpose. Proper procedures for changing filters should be taken into account to ensure the safety of workers.[45] If considering a particulate filtration system instead of a wet scrubber system, it's important to evaluate the contaminant and concentration that need to be removed to ensure that the hazard is fully abated. HEPA filters are often only recommended for highly toxic particulates.[46]

The fume hood filtration systems discussed above are summarized in Table 7-2.

Table 7-2. Fume Hood Filtration Systems

Filtering Mechanism	How Does It Work?	How Is Contaminant Removed?	Does It Use Water?	What Are the Special Considerations?
Wet Scrubber	Packed bed system that is wetted with recirculated scrubbing liquor captures contaminants from air and releases cleaned air.	Scrubbing liquor with dissolved contaminants is blown down and the liquor is periodically replenished with fresh water.	Yes	None
Inert Adsorbents	Inert adsorbents such as activated carbon, activated alumina, and molecular sieves, adsorb contaminants.	Spent adsorbent must be changed or regenerated regularly.	No	Adsorbent systems are not effective in removing high concentrations of contaminants (i.e., spills inside the hood). These systems require a consistent check on contaminant concentrations and maintenance of the adsorbent.
Chemically Active Adsorbents	Inert adsorbents impregnated with a strong oxidizer such as potassium permanganate react with and destroy organic vapors.	Spent adsorbent must be changed or regenerated regularly.	No	Adsorbent systems are not effective in removing high concentrations of contaminants (i.e., spills inside the hood). These systems require a consistent check on contaminant concentrations and maintenance of the adsorbent.
Particulate Filtration	HEPA or other filters remove contaminants.	Filter must be changed regularly.	No	This is useful for radioactive or biologically active materials or other hazardous particulates. HEPA filters are often only recommended for highly toxic particulates.

[45] *Ibid.* Page 7.
[46] National Research Council, *op. cit.*

7.6 Fume Hood Filtration and Wash-Down Systems

Fume Hood Wash-Down Systems

Perchloric Acid Wash-Down Systems

Perchloric acid wash-down systems are a specialty fume hood used to remove perchloric acid. A laboratory using perchloric acid, a highly corrosive inorganic compound, requires a specialized fume hood. To prevent corrosion and reduce explosive perchlorate buildup, perchloric acid fume hoods use a system of nozzles to wash down the fume hood and exhaust system surfaces after each period of use.[47] Laboratories should follow instructions for washdown provided by the manufacturer of the fume hood or facility health and safety guidelines, but might be able to minimize perchloric acid wash-down system water use if shut-off valves are used to control the flow of water.

Operation, Maintenance, and User Education

For optimum fume hood wet scrubber efficiency, consider the following:

- Turn off water flow when systems are not in use.
- Ensure water flow rate does not exceed manufacturer specifications.
- In recirculating systems, make sure the liquid level controller and water supply valve are functioning properly to avoid excess water overflow from the recirculation sump.
- In recirculating systems, calibrate the blowdown process so that it is sufficient to remove entrained contaminants, without being overly excessive. In general, constant overflows or continuous blowdown wastewater.
- Consider using onsite alternative water sources to supply water for use in the fume hood. See *Section 8: Onsite Alternative Water Sources* for more information.

For optimum perchloric acid wash-down system efficiency, use systems only when necessary for perchloric acid handling.

Retrofit Options

There are currently no retrofit options available on the market to increase the efficiency of fume hood filtration systems.

For facilities requiring a perchloric acid wash-down system, it might be feasible to retrofit the system with shut-off valves to control the flow of water. However, facilities should be sure to follow manufacturer-provided instructions for perchloric acid wash-down systems and facility health and safety guidelines to ensure that any changes will not affect health and safety or the performance of the system.

[47] University of Louisville. 2012. *Laboratory Chemical Hood User's Guide*. louisville.edu/dehs/ohs/fumehoods/users_guide.html.

Replacement Options

When purchasing a new fume hood filtration system or perchloric acid wash-down system or replacing older equipment, consider the replacement options outlined below.

Fume Hood Filtration System Replacement

For facilities that need a fume hood filtration system, consider installing a gas-phase filtration system, such as activated carbon, that does not require water consumption. Replacing an existing fume hood wet scrubber system with an adsorbent dry filter system will eliminate water used to trap and contain hazardous substances. Because these systems require a consistent check on contaminant concentrations and maintenance of the adsorbent, these factors should be taken into account as an alternative to fume hood wet scrubber systems. Particulate filtration might also be considered, depending upon the type of contaminants present. Keep in mind the contaminant and concentration that needs to be removed to ensure that the hazard is fully abated.[48,49]

Keep in mind that a wet scrubber is sometimes necessary for the handling of highly toxic contaminants. Adsorbent dry filters should not be used if safety will be compromised as a result.

Perchloric Acid Wash-Down Retrofit or Replacement

For facilities requiring a perchloric acid wash-down system, consider a system with automatic shut-off valves, which limit the amount of water used during the wash-down process by controlling the duration of the wash-down cycle. Water savings will be dependent upon the reduction in wash-down cycle length and the flow rate of the wash-down sprayers.

Savings Potential

Sufficient information is not available to estimate the savings potential associated with these products.

Additional Resources

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Page MED4. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

Hitchings, Dale T. September 1993-January 1994. "Fume Hood Scrubbers—Parts I, II, and III." *Laboratory Building Design Update*. www.safelab.com/resources.htm.

Lab Manager Magazine. Fume Hood Homepage. www.labmanager.com/?articles.list/categoryNo/2042/category/Fume-Hoods.

[48] National Research Council, *op. cit.*
[49] Hitchings, Dale T., *op. cit.*, Page 6.

National Research Council, et al. 1995. *Prudent Practices in the Laboratory—Handling and Disposal of Chemicals*. Washington, DC: National Academy Press. Page 188. www.nap.edu/openbook.php?record_id=4911&page=188.

University of Louisville. 2012. *Laboratory Chemical Hood User's Guide*. louisville.edu/dehs/ohs/fumehoods/users_guide.html.

7.7 Vivarium Washing and Watering Systems

EPA WaterSense

Overview

Vivariums, or animal research laboratories, utilize water-using equipment for cleaning and animal watering purposes. This equipment includes cage, rack, bottle, and tunnel washers and automatic animal watering systems. Washers can use large volumes of water based on the number of rinse cycles and water used during each cycle. Animal watering systems can use large volumes of water if constant flows or frequent flushing is required.

Cage, Rack, Bottle, and Tunnel Washers

Cage, rack, and bottle washers are batch-type washers that are front-loaded with washer racks. Traditional cage-and-rack washers are programmed with a pre-rinse, wash, and final rinse cycle. During each cycle, the unit can use between 40 and 60 gallons of hot water. In addition, many washers have optional cold-water tempering systems that cool the wastewater from each cycle to ensure that the discharge water temperature does not exceed sanitary sewer requirements. Accounting for water use in all cycles, traditional cage-and-rack washers can use as much as 320 to 480 gallons of water per load.[50] More recent models of cage-and-rack washers use less water per cycle and allow users to choose the number of rinse cycles to minimize total water use. Some units also allow water from the final rinse cycle to be reused in the next cycle. More recent units can use less than 50 gallons per cycle, and some use as little as 12 gallons per cycle.[51]

Tunnel washers are conveyor-type washers that are capable of cleaning a number of cages, racks, and other laboratory accessories at once. Tunnel washers are typically found only in very high throughput vivarium operations. There are 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. Because tunnel washers are designed for high throughput, they are not necessarily more efficient than batch-type washers for smaller operations.

Animal Watering Systems

Automatic animal watering systems provide drinking water to laboratory animals. These systems are used instead of manually filling bottles. There are two types of animal watering equipment, which differ in their method of bacterial buildup prevention: flushing animal watering systems and recirculating animal watering systems. Flushing animal watering systems use a periodic, high-pressure flow to "flush" and remove bacteria from piping. Residual chlorination is typically used to further control bacterial growth. To control bacteria, recirculating animal watering systems use a constant flow of water treated with ultraviolet disinfection or other methods before distribution for

[50] Beckinghausen, David. October 1, 2006. "Energy-Efficient Washing Systems." *ALN Magazine*. www.alnmag.com/article/energy-efficient-washing-systems.
[51] *Ibid.*

animal watering. Flushing systems use more water than recirculating systems because water is discharged to the drain after the flushing cycle is complete.[52]

Automatic water systems require regular observation of the systems and the animals. If not maintained properly, they pose the risk of flooding cages or clogging valves. They do not allow for monitoring of animal water intake. Before choosing an automatic watering system, these issues should be taken into account.[53]

Operation, Maintenance, and User Education

To ensure that cage, rack, bottle, tunnel washers, and animal watering systems are using water most efficiently, consider the following operation, maintenance, and user education tips for each.

Cage, Rack, Bottle, and Tunnel Washers

- Only run cage, rack, and bottle washers when they are full. For tunnel washers, schedule wash runs to maximize the equipment washed during each run, thereby reducing the amount of tunnel wash runs required per day.
- Operate the cage, rack, bottle, and tunnel washers near or at the minimum flow rate recommended by the manufacturer.
- If the number of rinse cycles can be chosen, use the fewest number of rinse cycles necessary to effectively clean equipment.
- Fix and repair any leaks. Inspect valves and rinse nozzles for proper operation, and repair worn nozzles.

Animal Watering Systems

- For animal watering systems that use flushing, minimize the number of flushing cycles while ensuring sufficient control of bacterial growth.
- Consider collecting and reusing wastewater from animal watering systems for other purposes within the facility, matching the end use with the level of water quality that exists or that can be achieved through water treatment.

Retrofit Options

For animal watering systems, consider adding a recirculation system; however, it should be noted that for this purpose, piping and a water purification system will be required to treat and return the unused water.

[52] Schultz, Carl C. March 1, 2006. "Re-circulating vs. Flushing: Animal Watering System Alternatives." *ALN Magazine*. www.alnmag.com/article/re-circulating-vs-flushing-animal-watering-system-alternatives.
[53] Cosgrove, Chris, et al. July 1, 2003. "Vivarium Automation Part 1." *ALN Magazine*. www.alnmag.com/article/vivarium-automation-part-1?page=0,0.

Replacement Options

When purchasing a new cage, rack, bottle, or tunnel washer or replacing existing equipment, look for models that use less water per load with the following features:

- Cycle selection that allows users to choose fewer rinse cycles
- Reuse of final rinse water as wash water for the next load
- Water intake monitoring to adjust the amount of water used based on load size
- Use of high-quality water only during the final rinse cycle

As an alternative to automatic animal watering systems, manual bottle fillers use only as much water as the animals need for drinking purposes. Where automatic animal watering systems are used, consider systems that recirculate treated water when purchasing new equipment.

Savings Potential

Cage, rack, bottle, or tunnel washers can be replaced with more efficient equipment to save water. Retrofitting or replacing existing animal watering equipment will also achieve water savings.

To estimate facility-specific water savings and payback, use the following information.

Cage, Rack, Bottle, or Tunnel Washer Replacement

Washers can be replaced with new, more water-efficient technologies that reduce the amount of water used during rinse and wash cycles and reuse rinse water in the next wash cycle. These more efficient models can use up to 90 percent less water per load than older, conventional models.[54]

Current Water Use

To estimate the current water use of an existing cage, rack, bottle, or tunnel washer, identify the following information and use Equation 7-11:

- The washer's water efficiency in gallons per load. This is typically provided by the manufacturer through product literature or a website. The water efficiency will be dependent upon the flow rate of each rinse or wash cycle, duration of each cycle, and number of cycles.

- Average number of loads per day.

- Days of operation per year.

[54] Beckinghausen, David, *op. cit.*

Equation 7-11. Water Use of Cage, Rack, Bottle, or Tunnel Washer (gallons per year)

= Water Efficiency x Number of Loads x Days of Operation

Where:

- Water Efficiency (gallons per load)
- Number of Loads (number of loads per day)
- Days of Operation (days of cage, rack, bottle, or tunnel washer operation per year)

Water Use After Replacement

To estimate the water use after replacing an existing cage, rack, bottle, or tunnel washer, use Equation 7-11, substituting the water efficiency of the replacement washer. The water efficiency of the replacement washer should be provided by the product manufacturer. More recent models of washers can use up to 90 percent less water per load when compared to older, less efficient units by reusing rinse water and having shorter rinse and wash cycles. If the number of rinse cycles can be selected, base the water use on the water efficiency associated with the average fewest number of rinse cycles needed for effective washing operations.

Water Savings

To calculate the water savings that can be achieved from replacing an existing cage, rack, bottle, or tunnel washer, identify the following information and use Equation 7-12:

- Current water use as calculated using Equation 7-11.
- Water use after replacement as calculated using Equation 7-11.

Equation 7-12. Water Savings From Cage, Rack, Bottle, or Tunnel Washer Replacement (gallons per year)

= Current Water Use of Cage, Rack, Bottle, or Tunnel Washer – Water Use After Cage, Rack, Bottle, or Tunnel Washer Replacement

Where:

- Current Water Use of Cage, Rack, Bottle, or Tunnel Washer (gallons per year)
- Water Use After Cage, Rack, Bottle, or Tunnel Washer Replacement (gallons per year)

Payback

To calculate the simple payback from the water savings associated with the cage, rack, bottle, or tunnel washer replacement, consider the equipment and installation cost of the replacement washer, water savings as calculated in Equation 7-12, and the facility-specific cost of water and wastewater.

Because cage, rack, bottle, and tunnel washers use hot water, a reduction in water use will also result in energy savings, further reducing the payback period and increasing replacement cost-effectiveness.

Animal Watering System Retrofit or Replacement

Water savings from retrofitting or replacing a flushing automatic animal watering system with a recirculating automatic animal watering system will vary based on how much water can be recirculated. Facility managers should use their judgment when deciding whether potential water savings merit the equipment and installation cost of the retrofit or replacement.

Additional Resources

Beckinghausen, David. October 1, 2006. "Energy-Efficient Washing Systems." *ALN Magazine*. www.alnmag.com/article/energy-efficient-washing-systems.

Cosgrove, Chris, et al. July 1, 2003. "Vivarium Automation Part 1." *ALN Magazine*. www.alnmag.com/article/vivarium-automation-part-1?page=0,0.

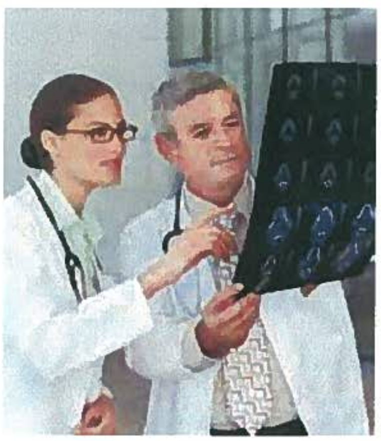
EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Pages 6-7. www1.eere.energy.gov/femp/program/labs21_bmp.html.

7.8 Photographic and X-Ray Equipment

EPA WaterSense

Overview

The traditional process of developing film can be quite water-intensive. Water is used during both the image development and printing processes. In X-ray equipment, water is sometimes also used for equipment cooling. Some X-ray film processing machines require a constant stream of cooling water flowing at a rate from 0.5 to 2.5 gallons per minute (gpm)[55] to as much as 3.0 to 4.0 gpm[56] to ensure acceptable image quality. Cooling water with a flow rate as low as 0.5 gpm can discharge more than 250,000 gallons of water annually. A number of advancements in X-ray technology, including digital imaging, however, are reducing the need for this water-intensive process.



For more traditional film processing, developing and printing can occur in a self-contained "mini-lab" with very little water use.[57] These changes also reduce or eliminate the need to use chemicals in film processing. Dry printing processes similar to laser printing are also available that do not use water.

Because of recent advances in imaging technology, many facilities have moved to digital photographic or X-ray film processing and computerized viewing and printing. Digital imaging has changed the means by which images are recorded and printed and eliminated the use of water entirely. X-ray equipment found at dental offices and other places where small pictures are taken use very little water for development. A typical dental office "wet" film processor uses under 1.0 gallon of water per day.

If converting to digital imaging is not feasible, retrofitting existing equipment to recycle the final rinse effluent as make-up for the developer/fixer solution can be a cost-effective option to significantly reduce photographic or X-ray film processing water use.

Operation, Maintenance, and User Education

For optimum traditional photographic and X-ray equipment efficiency, consider the following tips:[58]

- Adjust the water flow to the film processor to flow at the minimum acceptable flow rate specified by the equipment manufacturer. Post minimum flow rates near the processor and educate users on how to adjust and operate the equipment.
- Check the solenoid valve on the X-ray equipment cooling water to ensure it is working properly and stop flow when the equipment is in standby mode. If necessary, install a flow meter in the supply line to monitor flow from the equipment.

[55] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages PHOTO1-8. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

[56] U.S. Environmental Protection Agency (EPA) and U.S. Energy Department (DOE), Energy Efficiency & Renewable Energy (EERE), Federal Energy Management Program (FEMP). May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 6. www1.eere.energy.gov/femp/program/labs21_bmp.html.

[57] EBMUD, *op. cit.*

[58] EPA and DOE, EERE, FEMP, *op. cit.*

- For X-ray equipment in particular, turn off the cooling water flow when the unit is not in use.

Retrofit Options

To reduce the water use associated with traditional photographic or X-ray equipment, the primary retrofit option is to install a recycling system, which recycles the final rinse effluent as make-up for the developer/fixer solution.[59] An automatic shut-off valve can also be installed to turn off the flow of water when the unit is not in use. For these retrofits, it is essential to follow prescribed maintenance schedules in order to maintain water savings.

Replacement Options

When looking to purchase new photographic or X-ray equipment or to replace older equipment, consider digital X-ray and photography equipment and computerized laser or ink-jet printing options.

If transitioning to digital equipment is not feasible, look for equipment with a squeegee that removes excess chemicals from the film. The squeegee can reduce chemical carryover and the amount of water needed for the wash cycle.[60] If replacing a traditional wet printing, high-rinse flow system, consider a mini-lab system. Mini-labs provide a "washless" or "plumbingless" film development process. In these systems, wet chemical solutions are added only as needed for the amount of film being processed. A reservoir captures spent chemical solutions, which can be recovered and recycled.[61] It should be noted that mini-labs do not work for large frame X-ray film. They are for small camera picture prints only.

Savings Potential

Replacing traditional X-ray film processing equipment with digital imaging equipment will eliminate water use entirely, but it might not be cost-effective for every facility due to the high cost of the new equipment. Digital equipment, however, provides other advantages in addition to water savings, such as ease of use and image transfer and storage.[62] If converting to digital imaging is not feasible, retrofitting existing equipment to recycle the final rinse effluent as make-up for the developer/fixer solution can be a cost-effective option.

Retrofitting traditional X-ray equipment with a recycling system has been shown to save 500,000 to 1,600,000 gallons of water per year per X-ray film processor,[63] based on studies conducted by several water utilities in California.

[59] *Ibid.*
[60] *Ibid.*
[61] EBMUD, *op. cit.*
[62] Alliance for Water Efficiency. X-ray Film Processors Introduction. www.allianceforwaterefficiency.org/X-ray_Film_Processors.aspx.
[63] Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices.* Prepared for the California Urban Water Conservation Council. Pages 16-22. www.cuwcc.org/products/pbmp-reports.aspx.

Additional Resources

Alliance for Water Efficiency. X-ray Film Processors Introduction. www.allianceforwaterefficiency.org/X-ray_Film_Processors.aspx.

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages PHOTO1-8. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.

Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices*. Prepared for the California Urban Water Conservation Council. Pages 16-22. www.cuwcc.org/products/pbmp-reports.aspx.

EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 6. www1.eere.energy.gov/femp/program/labs21_bmp.html.