Reclaiming Resources: Reducing Water Consumption through Reuse

Although water reuse can be energy-intensive, its use is increasing across numerous industries

By: Al Goodman

***Al Goodman** is a principal with 42 years of experience serving clients in water reuse projects at the Louisville, Ky., office of CDM Smith (Boston).*

Communities and industries around the world are turning to water reuse. The drivers are varied: the need to augment strained water supplies, reduce nutrients in treated effluent, maintain ecological balance, use the most energy-efficient water sources, and reduce cost of purchased and treated water. The major driver is water scarcity in arid and semi-arid regions, though some regions of the world that are not considered to be water-scarce are implementing water reuse.

Ecological drivers are becoming more important in evaluating reuse as part of a response to rigorous and costly requirements to reduce or remove nutrients (mainly nitrogen and phosphorus) from discharges to surface waters. Though water reuse can be energy-intensive, depending on the level of treatment required, only a full life-cycle analysis can reveal whether overall resource costs are greater than or less than alternative water supplies.

Municipalities are implementing various types of urban water reuse and turning to industry and agriculture as potential customers of reclaimed water. Categories of water reuse applications are presented in the table. This article focuses on considerations relevant for municipal and industrial reuse. For more information on the full range of categories of reuse, refer to the U.S. Environmental Protection Agency's *Guidelines for Water Reuse* (2012; http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf).

Table. Categories of water reuse applications (adapted from the U.S. Environmental Protection Agency *Guidelines for Water Reuse*, 2012)

Category of reuse		Description
Industrial		Industrial applications and facilities (including food production and high-tech industries), power production, and extraction of fossil fuels
Urban		Nonpotable applications in municipal settings
Agricultural		Irrigation of food crops that may or may not be intended for human consumption
Environmental		Creating, enhancing, sustaining, or augmenting waterbodies, including wetlands, aquatic habitats, or stream flow
Groundwater recharge — Nonpotable		Recharge of aquifers that are not used as a potable water source
Potable	Indirect potable reuse (IPR)	Augmentation of a drinking water source (surface or groundwater) with reclaimed water, followed by an environmental buffer that precedes normal drinking water treatment
	Direct potable reuse (DPR)	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either co-located or remote from the advanced wastewater treatment system

There is great potential to expand water reuse in the United States and globally over the coming decades. Because the United States currently reclaims only about 7% to 8% of municipal wastewater, there is tremendous potential to expand reclaimed water use, particularly where demand is geographically close to the generation of municipal wastewater, such as in some types of power generation, industrial, and urban uses. In addition, there are significant efforts in the industry to evaluate onsite water reuse for various production processes.

Reclaimed water usage in various industries

Water can be reused in several ways for numerous applications, including cooling towers, boilers, high-tech, and prepared food manufacturing.

Cooling towers. Reclaimed water can be used for cooling tower makeup water. Evaporative cooling systems require significant volumes of makeup water to replace water lost through evaporation. Additionally, some water must be periodically discharged, referred to as "blow-down water," so that dissolved solids that are concentrated during evaporation do not build up in the cooling water and damage equipment. The main issues in using reclaimed water for cooling towers are controlling biological regrowth (i.e., when nutrients are present and a disinfectant residual is not maintained) and scaling (i.e., due to the presence of minerals, particularly calcium, magnesium, sulfate, alkalinity, phosphate, silica, and fluoride).

Boiler water make-up. Water for boiler make-up requires extensive pretreatment to control scaling and oxygen within the boiler, whether the source is reclaimed water or conventional potable water. Boilers are even more susceptible to corrosion due to scale build-up than cooling towers, because they operate at higher pressures and temperatures.

High-tech water reuse. Reclaimed water is used in high-tech manufacturing, such as the semiconductor industry for microchip manufacturing and the manufacture of circuit boards. Water quality for circuit board manufacturing is similar to that of boiler make-up water, requiring extensive treatment. Reclaimed water is also used at the associated facilities for cooling water and site irrigation. Intel Corporation (Santa Clara, Calif.) internally recycles approximately 2 billion gal (7.6 million m^3) of water per year, equivalent to 25% of its total water withdrawals. A large portion of this comes from using internally generated water. After ultra-pure water is used to clean silicon wafers during fabrication, the water is reused for industrial purposes, irrigation, cooling towers, scrubbers, and other facility uses through special dedicated plumbing networks.

Prepared food manufacturing. Prepared food manufacturing is most often a water-use intensive process, especially if irrigation used in the food chain supply is included. (In many areas of the country, 70% of water usage is for crop irrigation.) Though the food and beverage manufacturing industry was initially reluctant to use reclaimed water because of public perception concerns, the use of highly treated, drinking-water-quality reclaimed process water has been growing. With increasing knowledge of water reuse principles and treatment technology, comes the motivation to use reclaimed water at manufacturing sites, which helps minimize the total volume of water used. Companies such as Coca-Cola and PepsiCo/Frito-Lay are implementing water reuse as part of holistic approaches to reduce resource use.

Wastewater treatment for reuse

Because each opportunity for reuse presents site-specific and process-specific factors, water reuse consideration requires thorough data collection and careful analysis of the many options available. The primary factors affecting the decision to implement water reuse and required treatment processes include the following:

1. **What water quality is needed for reuse?** Potential water reuse options include land application/disposal, landscape irrigation, cooling, industrial reuse, and many other options. These uses vary in required water quality and treatment cost.

2. **What are the water flows at the facility?** Facilities should start with a water survey that considers daily and seasonal use variations, assesses current and future water use (both quality and quantity), and determines potential combined uses of recoverable water. Reuse for cooling and irrigation, for example, will vary considerably depending on the season and weather conditions.

3. **What are future water demands?** Reuse considerations should include a water-needs study to predict future demands and determine opportunities on a communitywide basis. This will help predict total treatment needs and capacities for design purposes and help determine the return-on-investment.

4. **What is the public perception and acceptance of the type of reuse?** The reuse of treated water will rely on acceptance of the end-user of the quality and reliability of the treatment technology, plant operations, and continuity of "guaranteed quality," including removal of unknown constituents that may be harmful. This is a critically important consideration and needs a business-based approach as well as public education and programmatic methods to confirm acceptance — before implementation or construction of reuse technologies.

5. **What is in the wastewater?** Sampling and analytical testing are needed during various process conditions to determine minimum, maximum, and average loadings on the treatment system. These may include nontraditional analytical parameters, salinity, hardness, alkalinity, silica, cations, and anions, especially if membrane treatment systems are considered. These process streams can vary considerably in biochemical oxygen demand; chemical oxygen demand; fats, oils, and grease; total suspended solids; pH; temperature; and salt concentrations.

6. **What waste disposal options are available?** Water reuse must be compared to traditional discharge options. In reuse scenarios that use reverse osmosis (RO) and other membrane-based processes, the concentrated stream must be carefully managed and disposed. If this stream cannot be discharged into the publicly owned treatment works or surface water, then onsite evaporation or further concentration of the reject may be required, significantly increasing costs and the space required.

What are the potential costs and savings? Reuse scenarios should be considered from a life-cycle cost perspective. Costs can include those for capital and operating and maintenance (with labor, electric/energy, chemicals, and residuals disposal being the primary ongoing operational costs). Water reuse treatment costs depend on the water quality required. As the quality increases, the costs increase somewhat exponentially, and the level of technical competence required of facility operators increases likewise.

Treatment technologies are available to achieve any desired level of water quality, and the level of treatment required depends on the reuse application. For most land application uses of reclaimed water, conventional processes involving secondary treatment, filtration, and disinfection steps are sufficient to achieve necessary water quality. In applications where the chance of human contact increases, or root crops are harvested, advanced treatment may be required. It is important to note that not all constituents have negative impacts for all uses. For example, nutrients (nitrogen and phosphorus) may be beneficial in reclaimed water when used for landscape irrigation to offset the need for fertilizers.

The highest water quality (i.e., drinking water quality) may require activated carbon or RO membranes. RO can remove salts and specific ions, while granular activated carbon (GAC) can adsorb potential fouling compounds prior to RO membranes. RO systems are often tubular or spiral-wound flat plate systems and are already used in desalination and many food industries.

An alternative treatment option for reuse is natural treatment using filtration into groundwater (rapid infiltration basins) providing indirect potable reuse, (IPR) followed by traditional treatment of groundwater.

As technologies have advanced to reduce facility water and energy use, industries and municipalities have increasingly embraced the use of reclaimed water for a wide-ranging suite of purposes: preventing salt water intrusion (as Orange County in California is doing) or using it as industrial process water, boiler feed water, cooling tower water, as well as using it for flushing toilets and site irrigation. Current technologies produce reclaimed water without degrading the performance of the intended uses when compared to more expensive potable water. As water resources become increasingly valued around the world, water reuse is anticipated to expand.

References

Kenny, Joan F.; N.L. Barber; S.S. Hutson; K.S. Linsey; J.K. Lovelace, and M.A. Maupin (2009). *Estimated Use of Water in the United States in 2005*. United States Geological Survey.

U.S. Environmental Protection Agency (2012). *Guidelines for Water Reuse*. EPA/600/R-12/618, Washington, D.C..