Water from Water: Closing the Cycle

by Prof. Takashi Asano

Providing a dependable system of water supply and wastewater disposal is becoming increasingly difficult all over the world. Reclaimed water is a resource available right at the doorstep of the urban environmental world, where water resources are needed the most and priced the highest.

Using treated effluent to augment existing water supplies is an option that is becoming increasingly attractive. The advantages of wastewater reuse can be identified as follows:

- Water pollution abatement (not discharging into receiving waters)
- Reliability of water supply
- Water demand and drought management
- Encouragement for conserving resources
- Availability of highly treated effluent for various beneficial uses

A common misconception is that reclaimed wastewater represents a low-cost new water supply. This assumption is true only when wastewater reclamation facilities are conveniently located near large agricultural or industrial users. Also it is true when no additional treatment is required beyond the facilities from which reclaimed water is delivered. The conveyance and distribution systems for reclaimed water represent the principal cost of most proposed water reuse projects.

Public health is one of the most important considerations in wastewater reclamation and reuse. The planning of infrastructure and facilities has to be examined closely, keeping economics in mind. Domestic water supply and reclaimed wastewater distribution have to be effectively integrated. Today, technically proven wastewater treatment processes exist to provide water of almost any quality desired.

Despite the fact that reclaimed water can be treated to potable water standards, there is a psychological barrier associated with drinking water reclaimed from sewage. Another consideration is that many chemicals that may enter wastewater are not listed in drinking water standards. The effects of ingesting these chemicals, however small in quantity, are still not known. Due to these uncertainties and also negative public perceptions, reclaimed water has not yet found acceptance for direct potable use.

Wastewater treatment technologies for water reuse

In evaluating wastewater reclamation technologies, the overriding considerations are the reliability of each treatment system and its capability to provide reclaimed water that meets specified standards.

In conventional wastewater treatment, the terms used to describe different degrees of treatment are preliminary, primary, secondary and tertiary/advanced treatment. A disinfection step is often the final treatment prior to storage and distribution for reuse. Because of cost considerations, preliminary and primary treatments in developing countries and secondary treatments in industrialized countries are generally considered as water pollution control requirements. The additional treatment required for water reuse is normally designated as tertiary or advanced wastewater treatment.

Based on water quality requirements, any effluent stream can be used as reclaimed water for various beneficial uses. The range of applicable technologies may include:

- Septic tanks, lagoons, wetland and natural treatment systems
- Secondary wastewater treatment systems
- Advanced physical-chemical treatment
- Advanced biological treatment, including biological nutrient removal (BNR)
- Advanced oxidation processes
- Membrane separation and membrane bioreactors
- Disinfection technologies
- Innovative reactor designs such as sequencing batches reactors and advanced mixing devices

Advanced treatment plays a critical role in the effective treatment of municipal and industrial wastewater to meet higher water quality objectives for water reuse and to protect public health. Wastewater treatment consists of a combination of physical, chemical and biological processes to remove settable, suspended and dissolved solids, organic matter, nutrients and pathogens from wastewater. Most of the current wastewater

reclamation and reuse technologies are essentially derived from those used in water and wastewater treatment. However, opportunities for technological innovations are greater for water reuse applications, because reclaimed water will have an economic value as an alternative water supply. Water reclamation and reuse also allow more flexibility in water quality management.

At present, the dominant applications of reclaimed wastewater are irrigation for agricultural land, parks and golf course. Applications are also increasing in other areas, such as toilet flushing, cooling, fire-fighting and stream flow augmentation. Future use of reclaimed water may involve a completely controlled "pipe-to-pipe" system, with an intermittent storage step. It may also include blending of reclaimed water with freshwater; either directly in an engineered system or indirectly through a surface water reservoir or a groundwater recharge system.

Tertiary and advanced wastewater treatment

After conventional biological treatment processes (such as activated sludge process), tertiary or advanced treatment can be applied to remove additional dissolved and suspended contaminants, nutrients, specific metals and other harmful constituents.

Filtration: Filtration is a solid-liquid separation process that effectively removes suspended solids larger than about 3 mm. When wastewater passes through a column of granular media, particles are removed by impaction, interception and physical straining. As head loss through the filter increases, the filter is cleaned by backwashing using a combination of air and water scour. Filtration can be used downstream of primary sedimentation (primary effluent filtration) or secondary sedimentation (tertiary filtration).

As pathogens are associated with particles, filtration is an effective process for reducing pathogen concentration in wastewater streams, and provides an excellent pre-treatment for disinfection. If water is to be treated by activated carbon, ion exchange or reverse osmosis, filtration is used to reduce solids loading on these processes and improve their overall effectiveness.

Adsorption: Activated carbon adsorption is effective in removing hydrophobic organic compounds from surface and groundwater sources. Compounds such as organic solvents and chlorinated organic solvents are adsorbable because of their low water solubilities. Water-soluble compounds and larger compounds are better removed by oxidation or ultrafiltration. In most cases, testing is necessary (isotherm evaluation, dynamic adsorption testing) to determine the applicability of activated carbon treatment.

Membrane Processes: Among advanced treatment processes, membrane applications have clearly emerged as a promising alternative to conventional advanced physical-chemical treatment, which usually includes chemical coagulation, flocculation and granular-medium filtration. Membrane processes ranging from microfiltration to reverse osmosis are finding their way to cost-comparable applications for removal of microorganisms, trace organic substances, ions and dissolved solids.

Membrane processes include microfiltration, nanofiltration, reverse osmosis and electrodialysis. While membranes have multiple applications, the useful life of a membrane depends on conditions that can cause fouling, scaling or chemical interactions. The success of membrane processes is highly dependent on pre-treatment.

Disinfection: Disinfection is an essential component of many wastewater reclamation and reuse treatment systems. The objective of disinfection is to inactivate or destroy pathogenic organisms and it is usually the final step in a treatment process. Chemical disinfection practices are based on the addition of a strong oxidizing chemical such as chlorine, ozone, hydrogen peroxide or bromine.

Chlorine is the most commonly used disinfectant at dosages ranging from 5 to 15 mg/l, with a recommended contact time of 30 minutes to 2 hours. For water reuse it is important to remove residual chlorine to prevent complications in downstream beneficial uses. Dechlorination is often carried out as a final step by using sulfur dioxide or other reducing agents.

Ultraviolet disinfection has been demon-

Wastewater reuse categories	Potential constraints
Agricultural irrigation: Crop irrigation Commercial nurseries	• Effect of water quality, particularly salts, on soils and crops • Marketability of crops and public acceptance • Public health concerns, especially for unprocessed food crops
Landscape irrigation: Park School yard Freeway median Golf course Cemetery Greenbelt Residential	• Surface and groundwater pollution if not properly managed • Public health concerns related to pathogens • Effect of water quality, particularly salts, on soils and plants
Industrial reuse: Cooling Boiler feed Process water Heavy Construction	• Reclaimed wastewater constituents related to scaling, corrosion, biological growth and fouling • Public health concerns, particularly aerosol transmission of organics and pathogens in cooling water and pathogens in various process waters
Groundwater recharge: Groundwater replenishment Saltwater intrusion Subsidence control	• Trace organics in reclaimed wastewater and their toxicological effects • Total dissolved solids, metals and pathogens in reclaimed wastewater
Recreational and environmental uses: Lakes and ponds Marsh enhancements Streamflow augmentation Fisheries	• Health concerns of bacteria and viruses • Eutrophication due to nutrients • Aesthetics, including odor
Non-potable urban uses: Fire protection Air conditioning Toilet flushing	• Public health concerns about pathogen transmission by aerosols • Effects of water quality on scaling, corrosion, biological growth and fouling • Potential cross-connections with potable water systems
Potable reuse (repurified water): Bleeding in water supply Pipe-to-pipe water supply	• Trace organics in reclaimed wastewater and their long-term toxicological effects • Aesthetics and public acceptance • Public health concerns on pathogen transmission, including viruses

Table 1: Categories of municipal wastewater reuse and potential constraints