

Wastewater Reuse/Reclamation

Karen Bodach

ABSTRACT

Wastewater reuse has been in development for over 100 years to meet worldwide water shortages. In the early stages of wastewater reclamation, wastewater was land applied. Today, wastewater is treated and reused to irrigate fields, recharge aquifers, flush toilets, and drinking water. Wastewater reuse is of concern with respect protecting human health and the general public sometimes opposes wastewater reuse. Environmental authorities, such as the US EPA and state agencies such as the Department of Natural Resources (DNR) carefully monitor the treatment of wastewater for reuse, with attention on pathogen removal. Wastewater reuse treatment technologies include microfiltration (MF) and ultrafiltration (UF) as pretreatment to a reverse osmosis (RO) unit, natural systems such as wetlands, soil aquifer treatment and coagulation-adsorption systems. Disinfection is very important to ensuring public safety to reclaimed wastewater, with UV disinfection becoming an emerging technology. Overall, wastewater reclamation has found worldwide success in increasing community water supplies.

KEYWORDS

Wastewater reuse, wastewater reclamation, microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO), ultraviolet (UV) disinfection

INTRODUCTION

Wastewater reclamation/reuse has been in development for over 100 years to meet worldwide water shortages, as shown in Figure 1. Early reuse technologies land applied the wastewater as a disposal option. In 1900, sewer systems became popular widely used in the United States and Europe to collect domestic wastewater and send it to a local sewage farm. While these sewage farms were used primarily for waste disposal, incidental use was made of the water for crop production or other beneficial uses (Veatch, 1938). In 1995, the use of reclaimed water was 1018 mgd, which was a 36% increase in 5 years (Solley et al, 1998). Table 1 provides a breakdown of sectors using reclaimed wastewater in the United States in 1995.

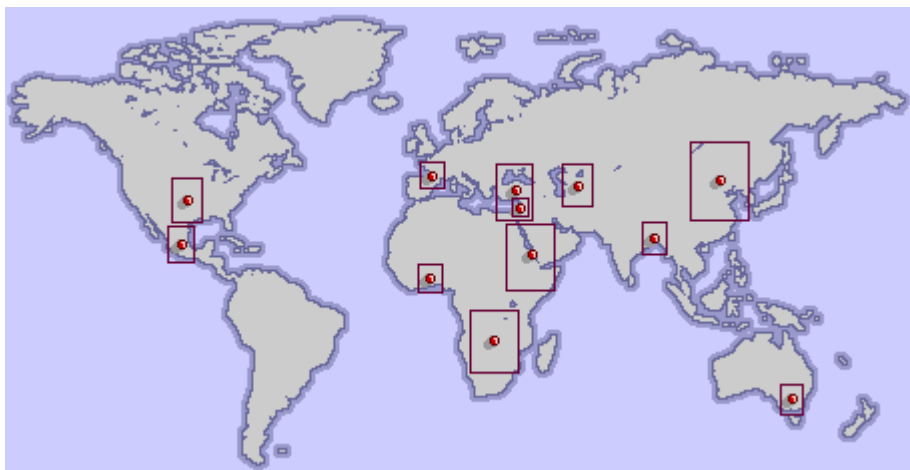


Figure 1: World map with pinpointed areas with water shortages (BBC News, 2000)

Table 1: Estimates of water reclamation in the United States in 1995 (Metcalf and Eddy, 2003)

Category	Quantity (mgd)
Public supply	57
Commercial	19
Industrial	110
Thermoelectric	100
Mining	14
Irrigation	718

Wastewater reclamation is an excellent water resource when properly treated to ensure protection of public health. Wastewater reuse applications determine the degree of treatment needed to ensure public health. The seven principal categories of municipal wastewater reuse are listed below in descending order of projected volume of use along with potential constraints for their application (Metcalf and Eddy, 2003).

1. Agricultural irrigation
 - California is leading state with 22 billion gallons per day which is 22% of national total for reclaimed wastewater
2. Landscape irrigation
 - Examples include irrigation of parks, playgrounds, golf courses, freeway medians, landscaped areas around commercial office and industrial developments
3. Industry
 - Used mainly in cooling towers or ponds and process needs
4. Groundwater recharge
 - Recharge groundwater aquifers
5. Recreational/environmental uses
 - Examples include man-made lakes and golf course storage ponds
6. Nonpotable urban uses
 - Examples include fire protection, air conditioning, toilet flushing, construction water and flushing of sanitary sewers
7. Potable reuse

This paper will discuss perception issues with wastewater reuse, treatment technologies and costs, disinfection of the wastewater and case studies on wastewater reclamation.

PERCEPTION ISSUES WITH REUSE OF WASTEWATER

Wastewater reuse is of concern with respect protecting human health. Environmental authorities carefully monitor the treatment of wastewater for reuse, but the public is still weary of treatment technologies in removal of pathogens and new emerging chemically active compounds.

The United States Environmental Protection Agency (EPA) has wastewater reclamation treatment guidelines to ensure public safety and therefore eliminate the public's stigma of reusing wastewater. The EPA has minimum reclaimed wastewater treatment requirements of disinfected secondary wastewater treatment plant (WWTP) effluent and disinfected tertiary (filtered secondary) effluent. Wastewater reuse regulations are then adopted by individual states and guidelines can vary from state to state (Metcalf and Eddy, 2003). For most developing countries, the greatest concern with reusing wastewater is the large amount of nematode eggs and bacterial pathogens present. The World Health Organization (WHO) recommends that irrigated crops likely to be eaten uncooked, sports fields, and public parks should be irrigated with wastewater treated by a series of stabilization ponds to achieve microbiological quality of less than 1 nematode egg per liter and fecal coliforms less than 1000 per 100 mL (Metcalf and Eddy, 2003).

Newly emerging chemicals of concern for wastewater treatment is N-nitrosodimethylamine (NDMA) which is a probable human carcinogen, *Giardia* and *Cryptosporidium* which are protozoan parasites and pharmaceutically active compounds such as endocrine disrupters, antibiotics, analgesics. These newly recognized chemicals present a risk to the public because not much research has been found on the impact of these chemicals in the world's waterways.

The best way wastewater reclamation facilities can reduce the public stigma about wastewater reuse is to conduct studies on their treatment plants and prove the wastewater meets the state's treatment regulations. The San Gabriel Valley Groundwater Recharge Project and Dublin San Ramon Services District are two examples of treatment plants that faced public opposition to reusing wastewater.

The San Gabriel Valley Groundwater Recharge Project located in Southern California was designed to introduce 20,000 AFY of reclaimed wastewater into a groundwater aquifer as to eliminate seawater intrusion. The project faced public opposition in 1993 because of the possibility that the will wastewater degrade the groundwater aquifer's water quality. A water quality study was conducted on the wastewater and found that the groundwater aquifer's water quality would not be degraded by the reclaimed wastewater. The study also conducted research to determine if NDMA, *Cryptosporidium* and *Giardia* and endocrine disrupting compounds were present in the wastewater. The study found that NDMA is produced from the manufacturing of solid rocket fuel and rubber products and is a chlorination disinfection byproduct. The current NDMA action level is 2 parts per trillion (ppt) which is below current detection level and is not regulated in drinking water. *Cryptosporidium* and *Giardia* testing was completed to ensure pathogen removal. It was found that 3 log removal of *Giardia* was accomplished for the tertiary treatment effluent and no *Cryptosporidium* oocysts were detected during the testing period (Hartling and Nellor, 2000). Endocrine disrupters are chemicals that produce hormone-effects in humans or fish that consume the water. The disrupters of concern are 17 β -estradiol which is natural estrogen excreted by women and ethinyl estradiol which is estrogen supplied in birth control pills. Preliminary research estimates that the estrogen-containing compounds are removed to one part per trillion in the wastewater treatment plant, but further research needs to be conducted on the effects of discharge into aquifers. In the end, the groundwater recharge project was approved, but was scaled back to 10,000 AFY.

The Dublin San Ramon Services District (DSRSD) located by the San Francisco Bay has constructed a 2.5 mgd tertiary treatment facility to recharge a groundwater aquifer. The treatment facility is using a microfiltration, reverse osmosis and ultraviolet disinfection to achieve potable water quality standards. Public concern surfaced about injecting wastewater into the groundwater aquifer and sixteen-week comprehensive testing was completed on a wide variety of organic and inorganic compounds, endocrine disrupting compounds, disinfection by-products, seeding for virus challenge studies, toxicity tests, and testing for radioactive components. The testing period found that the tertiary effluent achieved an overall 12.8 log virus reduction, no viruses and total coliforms were found in the effluent, the total organic carbon concentration was less than 1 mg/L, and the total dissolved solids concentration was approximately 16 mg/L (Salveson et al., 2000).

WASTEWATER REUSE TECHNOLOGIES

Membranes are the most popular treatment technology for reclaimed wastewater, with reverse osmosis (RO) being the most common treatment process. Microfiltration (MF) and ultrafiltration (UF) membranes act as pretreatment steps to the RO unit in order to reduce RO fouling. Pretreatment is essential to increasing the RO membrane lifespan and reduce the amount of fouling. The RO unit is capable of producing reclaimed wastewater with the highest water quality that can be used for potable water. Natural systems, soil aquifer treatment and coagulation-adsorption can also be used to treat wastewater, but are not as extensively used as the MF, UF and RO processes.

The treatment technologies are focused on removing organic material, viruses, pathogens, and turbidity. The treatment technologies also want to reduce the silt density index (SDI) which is equated to the amount of fine particles in the wastewater which fouls membranes. The lower the SDI value, the less suspended particles are present in the wastewater. In general, reclaimed wastewater should have SDI values less than 3.

The following section will explain the different treatment and pretreatment technologies available for reclaiming wastewater. Case studies will also be provided to showcase the different locations currently reclaiming wastewater.

Microfiltration (MF) Membrane

Microfiltration (MF) membranes, which are 0.2 micron pore size, are used to remove organic material from wastewater. In general, an MF unit alone cannot produce the water quality standards to meet potable drinking water standards and should be followed by a nanofiltration (NF) or RO unit. MF is a good pretreatment option for RO units to remove the larger particles and create less fouling for the NF/RO units. MF was selected to increase the capacity of the Charlotte-Mecklenburg McDowell Creek WWTP in North Carolina to meet new water reclamation uses (Lackey et al, 2002).

Ultrafiltration (UF) Membrane

Ultrafiltration (UF) membranes have a 0.01 micron pore size and serve as an excellent pretreatment technology for a NF/RO unit. A UF unit can reduce the silt density index (SDI) to approximately 3 and remove suspended solids and microorganisms.

The Middle East is very dry and arid location and experiences water shortages year round. The demand for irrigation water only increases in the Middle East and wastewater reclamation is becoming a viable alternative to alleviate the region's water shortages. Pilot studies were conducted to determine the effectiveness of using UF membranes for wastewater reclamation.

The first WWTP tested industrial wastewater using an Astrasand continuous sand filter followed by a 70m² UF and RO units. The sand filter reduced the high solids concentrations of 20-60 mg/L, normal operation, and 100-200 mg/L, if washout occurred. Ideally, the UF should have a maximum of 20 mg/L suspended solids to reduce UF membrane fouling. The UF was able to reduce the SDI to 1.8 with an operating flux of 70-80 L/m²-hr. The RO unit operated at a flux of 22-25 L/m²-hr instead of the recommended 15 L/m²-hr and achieved an effluent SDI less than 3.

The second location received municipal WWTP effluent that was fed to a 50µm microstrainer followed by a 15 m² UF membrane (van Hoof and Kordes, 1999). The UF unit operated at a flux of 75 L/m²-hr with flocculent dosages to decrease cleaning frequency. The UF unit was able to produce high quality effluent water. Overall, costs are combined with excellent properties for use as RO feed, make UF a very attractive WWTP reuse applications.

Reverse Osmosis (RO) Membrane

RO is currently the leading technology for wastewater reuse. It is able to remove organics, trace metals, total dissolved solids and has the potential for removal of all classes of pathogens (Gagliardo et al., 2000).

The City of San Diego conducted an experiment on municipal wastewater to determine the best pretreatment option for an RO wastewater reclamation plant. Four pretreatment options were investigated: (1) lime clarification, (2) membrane bioreactor MBR, (3) MF and (4) UF. All of the pilot membranes operated at 20 L/m²-hr.

The pilot studies found that that lime clarified effluent water quality varied throughout the testing period, with turbidity increasing from 0.2 NTU to 0.4 NTU with an SDI greater than 5. The RO averaged 99% salt rejection, with pH values ranging from 6.5 to 9.4. It was observed that higher pH values decreased the RO salt rejection, but the membranes were able to withstand lower pH values. Also, the RO unit required frequent cleaning. It was concluded that lime clarification was an expensive alternative due to the operational costs of lime dosing and frequent RO cleaning.

The MBR produced consistently high quality effluent with an average turbidity of 0.01 NTU and SDI less than 2. The RO membrane achieved greater than 98% salt rejection throughout the study. The MBR did not require frequent cleaning, but had shorter run times between cleaning than the MF and UF units. Despite the more frequent cleaning runs, the MBR has the advantage of combining secondary and tertiary membrane filtration in one unit operation, which could provide an overall more economical alternative to MF and UF units.

The UF also produced high quality effluent majority of the time with a turbidity value less than 0.1 NTU. The MF unit produced high quality effluent with an SDI less than 1 and turbidity less than 0.1 NTU. Overall, the MF and UF units had the longest run time (Gagliardo et al., 2000).

Cases where RO membranes may not be advisable to use are with wastewaters that contain boron, methanol, formic acid, formaldehyde and urea due to the low removal experienced. To remove these contaminants, several physico-chemical and biological processes can be used to pretreat the waters instead of an RO unit (del Pino and Durham, 1999).

Natural Systems

Constructed wetlands in Orlando, Florida have successfully produced 35 mgd of reclaimed wastewater for 14 years. The wetlands have meet Florida's stringent nutrient limits while providing a wildlife habitat and recreational opportunities for the community. The wetlands have lower total nitrogen concentrations from 2.5 to 0.8 mg/L and total phosphorus concentrations from 0.29 to 0.07 mg/L (Jackson et al, 2002).

Soil Aquifer Treatment

Research has shown that secondary effluent from a WWTP can be treated by soil infiltration to an aquifer. One particular study allowed secondary effluent to flow down 100 feet of unconsolidated sediments to a groundwater aquifer and resulted in greater than 95% reduction in residual estrogenic activity (Quanrud et al, 2002).

Coagulation-Adsorption

Coagulation-adsorption provides a viable pretreatment alternative to membrane processes by removing organic colloidal material prior to the membranes, ensuring less membrane fouling.

Research in Staouli, Algeria was conducted on a pilot coagulation-adsorption unit using iron chloride (FeCl_3) as the coagulant and powder activated carbon (PAC) as the adsorbent to remove organic material from a secondary effluent of a WWTP. The coagulant and adsorbent coupled together pretreated the wastewater prior to a UF membrane. The results showed COD dropped from 77 mg/L to 10.4 mg/L at a pH of 5.5 with a PAC dose of 20 mg/L and the FeCl_3 dose of 40 mg/L (Abdessemed et al., 2000).

In the state of Washington, satellite water reclamation plants "scalp" wastewater from adjacent trunk sewer lines to reduce local water demands (Geselbracht, 2003). The wastewater must be treated to a secondary or tertiary level before use, so pilot testing was conducted on primary treatment/biological aerated filter/filtration/membrane bioreactor. Results showed that all treatment alternatives would meet Washington's Class A water quality requirements (Wallis-Lage et al, 2002). Coagulation was also investigated as a pretreatment alternative in the wastewater

reclamation process. Fenton's reagent (Fe^{2+} , H_2O_2) was found to be an effective coagulant while disinfecting the wastewater and lowering sludge production (Duran-Moreno et al, 2002). Fenton's reagent was also found to remove *Salmonella*, a highly resistant bacteria, due to the highly acid conditions produced by the adding the hydrogen peroxide to the water (Ramirez-Zamora et al, 2002).

Costs

Cost is a very important factor when deciding which treatment technology to use. In 1999, a pilot investigating UF as a pretreatment alternative to RO estimated that operational costs would be \$0.34 to \$0.83/1000 gal of wastewater treated, depending on WWTP effluent quality (van Hoof and Kordes, 1999). In 2002, San Diego's wastewater reclamation program proposed \$1.05/1000 gal, which is just over half of the community's potable water rate of \$1.97/1000 gal (Geselbracht, 2003). In 2002, the O&M costs ranged from \$0.07 to \$0.13/1000 gal for effluent clarified and clarified plus filtered effluent from a wastewater reclamation facility (Liberti et al., 2002).

DISINFECTION OF WASTEWATER FOR REUSE

Disinfection is a crucial step in eliminating pathogens in the wastewater and ensuring the public's health. In Japan, wastewater reclamation has become very important to decrease the country's water shortages. There have been many problems with eliminating the amount of pathogens discharged in Japan's reclaimed wastewater. In Fukushima City, Japan the Abukuma River is the drinking water source for the city and is downstream from the city's wastewater treatment plant. Two wastewater reclamation scenarios were evaluated to determine the city's risk of ingesting poliovirus 1 from the reclaimed wastewater. The first scenario was reclaiming the wastewater from the undisinfected secondary effluent as a partial drinking water source or flushing toilets, whereas the second scenario investigated completely replacing the city's drinking water source with undisinfected secondary effluent. The study found that the infectious health risk increased exponentially when the wastewater was undisinfected for both scenarios of drinking water/flushing toilets and completely replacing the drinking water with reclaimed wastewater. The study found a greater exponential increase in health risk if the city's drinking water was completely replaced. The city then investigated the effect of chlorine disinfection on health risks and found that chlorine can inactivate 99.9% of poliovirus 1 in the wastewater effluent (Watanabe et al., 2003). It was determined that disinfection is a great way to increase wastewater reclamation without compromising public health of poliovirus 1 infections.

Ultraviolet (UV) disinfection is an emerging technology with proven success in inactivating viruses and pathogens in water and wastewater treatment. Chlorine disinfection is a common disinfectant in the United States, but has the disadvantage of using chlorine gas, a toxic chemical. UV disinfection was the only disinfectant found in the case studies, this does not mean that UV is the only disinfectant used in full-scale applications, but it is the newly emerging technology and therefore extensive research is being conducted.

UV Disinfection

UV Disinfection is an emerging disinfection technology in the United States. UV is widely used in Europe, but the United States primarily uses on chlorine gas for disinfection. UV offers a safe working environment by eliminating the use and storage of chlorine gas on-site, the price of UV systems is decreasing and UV does not create disinfection by-products. The disadvantage to UV is there is no residual disinfection, unlike chlorine which produces chloramines.

UV has proven to inactivate pathogens, but it is hard to determine the correct UV dose to remove fecal coliforms and resistant pathogens present in the wastewater. Factors that influence UV doses are particle UV transmittance, size and structure. It was been proposed that pathogens in wastewaters are either dispersed individually or bound within the wastewater particles. The two

most resistant pathogens in wastewater are the rotavirus and adenovirus, which require UV doses of 36 and 121 mJ/cm² to achieve a 4-log pathogen removal, compared to the fecal coliform UV dose of 12 mJ/cm². California Title 22 unrestricted wastewater reuse applications require 4-log virus inactivation and 2.2MPN/100 mL total coliform as a 7-day median (Wright et al., 2002). Florida wastewater reuse standards require non-detectable fecal coliform in 75% of all samples. A recommended UV dose after MF or UF is 80 mJ/cm², which obtains a 5-log poliovirus inactivation and a UV dose of 50 mJ/cm² is recommended following RO membranes. The World Health Organization (WHO) recommends a UV dose of 220 mJ/cm² for secondary effluent and 80 mJ/cm² for tertiary effluent (Santa'Ana et al, 2002). Overall, the wastewater treatment methods will determine the UV dose required and studies must then be conducted to ensure sufficient pathogen removal.

Along with the UV dose, it is important to decide which UV pressure system to use. A 35 mgd reclamation facility in Henderson, North Carolina decided to use a low-pressure/high intensity UV system (Smith and Brown, 2002). The reclamation facility in Livermore, California compared sodium hypochlorite and UV for disinfection. The sodium hypochlorite was the cheaper option, but the UV ensured that NDMA would not form. Livermore decided to use the low-pressure/low intensity UV system (Gittens et al, 2002).

The Stewart Creek Regional WWTP in North Texas sends their treated effluent to a creek outfall or a nearby golf course for irrigation. In 2002, the plant upgraded to a UV disinfection system and needed to validate the effectiveness of UV for inactivating *Cryptosporidium*. The study treated 1.74 mgd and achieved a 10-log removal of fecal coliforms at the design UV dose of 45 mJ/cm². The study concluded that *Cryptosporidium* can be inactivated at much lower UV doses than required to inactivate fecal coliforms (Hunter et al., 2003).

WASTEWATER REUSE CASE STUDIES

An advanced wastewater reclamation plant in Orange County, California has been running since 1994 and produces an annual 0.718 mgd of water. The WWTP effluent replenishes a groundwater aquifer adjacent to the Pacific Coast in order to stop seawater intrusion. The wastewater treatment plant uses MF, RO and UV disinfection to treat secondary effluent from an Orange County wastewater treatment plant (del Pino and Durham, 1999).

West Basin Water District in El Segundo, California created a water injection project to control saltwater intrusion into a fresh water aquifer. A U.S. Filter/Memcor continuous microfiltration (CMF) membrane is used to pretreat the reclaimed wastewater prior the RO unit. The effluent is then injected in the fresh water aquifer (del Pino and Durham, 1999).

The Tias wastewater treatment plant in Lanzarote, Canary Islands uses a U.S. Filter/Memcor MF unit to produce 0.26 mgd effluent with suspended solids below 1.0 mg/L, turbidity below 1 NTU and total and fecal coliforms are undetectable. The effluent SDI is below 3, total dissolved solids is 1100 mg/L and operates at 85% recovery. Approximately 0.16mgd is further treated in an RO unit which then produces 0.11 mgd which contains total dissolved solids concentration of 20 mg/L. The RO effluent and 0.10 mgd CMF effluent are then blended together and used for irrigation (Durham, 1999).

Two municipal wastewater treatment plants in Sao Paulo, Brazil produce 2.77 mgd of recycled water for industrial use (Valsecchi et al, 2002).

A wastewater reclamation project in Korea located next to the Incheon International Airport reclaims up to 60% of the plant's treated effluent for the airport's toilet flushing, hosing and cleaning, and landscape irrigation. The reclamation facility uses a continuous flow, modified SBR followed by sand and granular activated carbon (GAC) filtration and then chlorine disinfection (Wu and Timpany, 2002).

In Harare, Zimbabwe approximately half of the 74 mgd sewage produced is reclaimed and used for pasture irrigation. The remaining half the reclaimed effluent is discharged to Lake Chivero. The reclaimed effluent has high nutrient loadings into the lake and could help preserve the lake by the city reusing the reclaimed effluent instead of discharging to the lake (Nhapi et al, 2002).

A trickling filter and horizontal subsurface flow wetland reuses wastewater in Sicily, Italy to irrigate 150 ha of olive orchards (Barbagallo et al, 2002b).

A wastewater reclamation system in Limassol, Cyprus has been in operation since 1995. The reclamation plant produces approximately 2.5 mgd which is used for groundwater recharge, restricted irrigation for golf courses and public amenity areas, but excluding vegetable and food irrigation (Papaïacovou, 2001).

CONCLUSIONS

Wastewater reclamation is an excellent source of water and can greatly reduce community water shortages. Reclaimed wastewater can be used to irrigate fields, recharge aquifers, flush toilets, or drinking water. Public resistance to wastewater reclamation does exist, but can be overcome with properly testing programs on wastewater reclamation sites to ensure public safety. Wastewater treatment technologies include MF and UF as pretreatment to a RO unit, natural systems such as wetlands, soil aquifer treatment and coagulation-adsorption systems. Disinfection is very important to ensuring public safety to reclaimed wastewater, with UV disinfection becoming an emerging technology. Overall, wastewater reclamation has found worldwide success in increasing community water supplies.

REFERENCES

- Abdessemed, D.; Nezzal, G.; Ben Aim, R. (2000) Coagulation-adsorption-ultrafiltration for wastewater treatment and reuse. *Desalination*. **131**, 307-314.
- Barbagallo, S.; Cireli, L.; Consoli, S.; Somma, F. (2002) Wastewater quality improvement through storage: a case study in Sicily. *Proc. Int. Water Association World Water Congress 2002*. [CD-ROM], Melbourne, Australia.
- BBC News (2000)
http://news.bbc.co.uk/1/hi/english/static/in_depth/world/2000/world_water_crisis/default.stm
- Del Pino, M. and Durham, B. (1999) Wastewater reuse through dual-membrane processes: opportunities for sustainable water resources. *Desalination*. **124**, 271-277.
- Duran-Moreno, A.; Razmierz-Zamora, R.M.; Gonzalez-Lorenzo, E.; Malpica-Dela-Torre, J.; Duran-De-Bazua, C. (2002) Fenton's reagent and coagulation- flocculation as pretreatments of combined wastewater for reuse. *Proc. Int. Water Association World Water Congress 2002*. [CD-ROM], Melbourne, Australia.
- Durham, B. (1999) Long-term operating experience of wastewater reuse industry. *Water Recycling Reuse Conference*. London.
- Gagliardo, P.; Merlo, R.P.; Adham, S.; Trussell, R.S.; Trussell, R. (2000) Application of reverse osmosis membranes for water reclamation with various pretreatment processes. *Proc. of Water Environment Federation 73rd Annual Conference*. [CD-ROM], Anaheim, CA..
- Geselbracht, J. (2003) Water Reclamation and Reuse. *Water Environment Federation Literature Review*, **75**, 6, 1-63.
- Gittens, P.; Olsen, R.; Putnam, L. (2002) Implementing a UV system meeting NWRI Guidelines. *Proc. Water Reuse Association Symp. XVII*, [CD-ROM], Orlando, FL..
- Hartling, E.C. and Nellor, M.H. (2000) Overcoming impediments to water recycling- The San Gabriel Valley groundwater recharge project. *Proc. of Water Environment Federation 73rd Annual Conference*. [CD-ROM], Anaheim, CA..
- Hunter, G.; Stratton, L.; Spitzer, P.; Malley, J.; McKnight, D. (2003) *Cryptosporidium* and wastewater reuse- The city of Frisco, TX experience. *Proc. of Water Environment Federation 76th Annual Conference*. [CD-ROM], Los Angeles, CA..
- Jackson, J.A.; Lothrop, T.; Sees, M. (2002) Orlando easterly wetlands- fourteen years of operational history. *Proc. Water Reuse Association Symp. XVII*, [CD-ROM], Orlando, FL..
- Lackey, K.A.; Gullet, B.; Goins, P.; Parker, D.; Reuss, B. (2002) Advanced wastewater treatment and water reclamation using membrane filtration in Charlotte, North Carolina. *Proc. of Water Environment Federation 75th Annual Conference*. [CD-ROM], Chicago, IL..
- Liberti, L.; Notarnicola, M.; Petruzzelli, D. (2002) Advanced treatment for municipal wastewater reuse in agriculture. UV Disinfection: parasite removal and by-product formation. *Desalination*. **152**, 315-324.
- Metcalf and Eddy (2003) Wastewater Engineering Treatment and Reuse. *4th Edition*. Pgs. 1345-1366.

- Nhapi, I.; Gijzen, H.J.; Siebel, M.A. (2002) A conceptual framework for the sustainable management of wastewater in Harare, Zimbabwe. *Proc. Int. Water Association World Water Congress 2002*. [CD-ROM], Melbourne, Australia.
- Papaiacovou, I. (2001) Case study- wastewater reuse in Limassol as an alternative water source. *Desalination*. **138**, 55-59.
- Ramirez-Zamora, R.M.; Orta de Velasquez, T.; Duran Moreno, A. (2002) Evaluation of Fenton's reagent for pathogens removal from wastewater treated for reuse. *Proc. Int. Water Association World Water Congress 2002*. [CD-ROM], Melbourne, Australia.
- Santa'Ana, T.D.; Olivieira, F.F.; Barbosa, E.B.; Souza, W.G.; Casini, S.T.; Fanci Goncalves, R. (2002) Combining UASB, BAFs and UV Disinfection to produce high quality effluents in developing countries. *Proc. Int. Water Association World Water Congress 2002*. [CD-ROM], Melbourne, Australia.
- Salveson, A.; Requa, D.A.; Whitley, R.D.; Tchobanoglous, G. (2000) Potable versus reclaimed: water quality, regulatory issues, emerging concerns. *Proc. of Water Environment Federation 73rd Annual Conference*. [CD-ROM], Anaheim, CA..
- Solley, W.B.; Pierce, R.R.; Perlman, H.A. (1998) Estimated use of water in the United States. *U.S. Geological Survey Circular, U.S. Department of Interior*, Denver, CO..
- Valsecchi, A.M.; dos Santos, G.J.; Paracampos, F.J.F.; Nobre, P.C.A.; Nucci, N.L.R. (2002) Water reuse from wastewater treatment plants in the metropolitan region of Sao Paulo (RMSP) Brazil. *Proc. Water Sources Conference 2002*. [CD-ROM], Las Vegas, NV..
- Van Hoof, S.C.J.M.; Hashim, A.; Kordes, A.J. (1999) The effect of ultrafiltration as pretreatment to reverse osmosis in wastewater reuse and seawater desalination applications. *Desalination*. **124**, 231-242.
- Veatch, N.T., Jr. (1938) Chapter XVI The use of sewage effluents in agriculture. *L. Pearse, ed., Modern Sewage Disposal*, Federation of Sewage Works Associations, New York.
- Wallis-Lage, C.; Bucher, B.; Smyth, J.; Neethling, J.B.; Norton, M.; Willey, B. (2002) Reuse strategies: beyond conventional technologies. *Proc. Water Sources Conference 2002*. [CD-ROM], Las Vegas, NV..
- Watanabe, T.; Hashimoto, K.; Abe, Y.; Omura, T. (2003) Risk evaluation of pathogens in wastewater reclamation as a drinking water source. *Proc. of Water Environment Federation 76th Annual Conference*. [CD-ROM], Los Angeles, CA..
- Wright, H.B.; Mackey, E.; Cushing, R.; Tekippe, T. (2002) A comparison of UV disinfection for drinking water, wastewater, and reclaimed wastewater. *Proc. of Water Environment Federation 75th Annual Conference*. [CD-ROM], Chicago, IL..
- Wu, W. and Timpany, P. (2002) Design and initial performance of a wastewater reclamation plant using a novel modified SBR process. *Proc. of Water Environment Federation 75th Annual Conference*. [CD-ROM], Chicago, IL..