Water Reclamation and Reuse System as an Alternative Wastewater Treatment Method

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ABSTRACT

With the growth in technology different methods of wastewater treatment has been sought out. Wastewater reclamation and reuse has been a treatment method, which has recently increased in popularity. The cost of this method is reasonably inexpensive compared to linear system treatment facilities. The reclaimed water is used for such things as irrigation, soil compaction and industrial processing. The use of reclaimed water decreases the amount of damage done to the environment. Although there are many benefits to using reclaimed water, if the water is not properly treated, environmental and health risks can become a concern. These risks include being exposed to enteric bacteria, viruses and pathogens. Sheaffer & Roland, Inc. has used reclamation and reuse as the treatment method for Mill Creek Subdivision. This subdivision as well as others has been quite successful treating their wastewater with this technique. The San Francisco Master Plan involves water reclamation and reuse at one of the largest scales put into use.

KEY WORDS

Reclaimed water, irrigation, pathogens, oxidation ponds, activated sludge, circular system treatment.

INTRODUCTION

Water reclamation and reuse is a growing technology. " 'Reclaimed water' is defined as effluent derived in any part from sewage that has been adequately and reliably treated to a high quality so that it is suitable for beneficial uses" (Access Washington, 2005). There are different methods of water reclamation and reuse currently being used by different facilities. "Municipal wastewater treatment systems are typically designed to meet water quality objects based on biochemical oxygen demand (BOD_5), total suspended solids (TSS), total or fecal coliform, nutrient levels (nitrogen and phosphorous), and chlorine residual" (Asano, 1998). The system being used in the Mill Creek neighborhood in Geneva, Illinois designed by Sheaffer & Roland, Inc. will be analyzed in detail. The San Francisco Master Plan involving a method of water reclamation and reuse was one of the first put into use for a city of such a large magnitude. The methods used in San Francisco will also be discussed.

CLASSIFICATION OF WASTEWATER

Wastewater can be classified into two main types. The first type is domestic wastewater. This type of wastewater is commonly known as sanitary wastewater. "Domestic wastewater includes discharges from residences from residences and commercial, institutional, and similar facilities" (Tchobanoglous and Burton, 1991). The second type of wastewater is industrial waste. Industrial wastewater contains different types of contaminants than domestic. These contaminants are generated during the production process. These types and strengths of contaminants vary with the products and or process of production being used by the companies. Below is a diagram of how sewage is broken down while being treated.

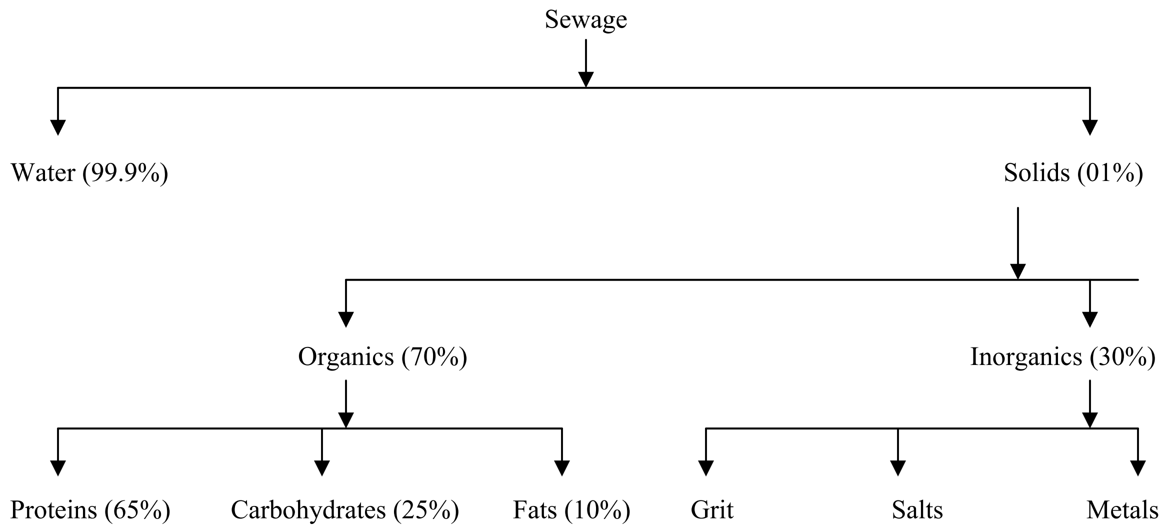

Figure 1 Composition of Sewage (Tchobanoglous and Burton, 1991)

USES OF RECLAMED WATER

Reclaimed water can be used in a variety of ways. Reclaimed water is not to be used for drinking water. It can be used for " landscape and crop irrigation, industrial processing, heating and cooling, dust suppressor and soil compaction, flushing of toilets in commercial buildings, wetland enhancement, stream flow augmentation, and groundwater recharge" (Access Washington, 2005).

Table 1: Uses of Reclaimed Water (Access Washington, 2005)

Category of Use	Specific Types of Use
Landscape irrigation	Parks, playgrounds, cemeteries, golf courses, roadway rights-of-way, school grounds, greenbelts, residential lawns
Agricultural irrigation	Food crops, fodder crops, fiber crops, seed crops, nurseries, sod farms, silviculture, frost protection
Nonpotable urban uses (other than irrigation)	Toilet and urinal flushing, fire protection, air conditioner chiller water, vehicle washing, street cleaning, decorative fountains and other water features
Industrial uses	Cooling, boiler feed, stack scrubbing, process water
Impoundments	Ornamental, recreational
Environmental uses	Stream augmentation, marshes, wetlands, fisheries
Groundwater recharge	Recharge aquifers, salt water intrusion control, ground subsidence control
Potable water supply augmentation	Groundwater recharge, surface water augmentation
Miscellaneous	Aquaculture, snow-making, soil compaction, dust control, equipment washdown, livestock watering

The science behind water reclamation and reuse systems is growing with the increase need of wastewater treatment. Water reclamation and reuse allows for water, which would typically be wasted, to be treated and used in the ways listed in Table 1. "The use of reclaimed water is nonpotable applications help to insure a long-term, reliable, local source of water even during times of drought" (Access Washington, 2005). The wastewater is treated and distributed to the areas needing irrigation typically during the months of April thru November. During the winter months, the water is treated and stored in the reservoirs. This time frame may be altered depending on the region and need of the community. In the mid-west, Figure 2 illustrates a general timeline for water storage and usage.

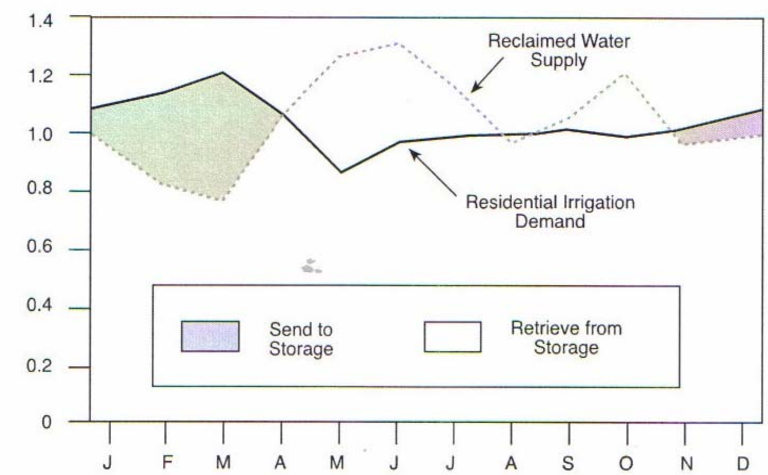

Figure 2 Reclaimed Water Supply vs. Irrigation Demand (EPA, 2005).

BENEFITS OF WATER RECLAMATION AND REUSE SYSTEMS

When using water reclamation and reuse as a method of treating wastewater there are many benefits to the environment, as well as communities, which are being served. With this method, which Mill Creek Water Reclamation District (MCWRD) uses, there is no discharge. "When the reclaimed wastewater is reused beneficially, no pollutants are discharged into our nation's navigable waters" (Sheaffer & Roland, Inc, 2005b). "The decomposition of organic matter provides for the reduction of more than 90 percent of the accumulated solids (sludge)" (Sheaffer & Roland, Inc, 2004). This results in the solids, which are not broken down settle to the bottom. Once the solids cumulate to a designated amount, the solids are disposed of.

Sewage being treated can also be used as raw materials. Materials such as plant fertilizer can be produced from sewage. The plant fertilizers have a combination of Nitrogen, Potassium and. "Irrigation with nutrient-rich reclaimed water has proven to greatly increase crop yields on certain utilization sites" (Sheaffer & Roland, Inc, 2004). This allows for farmers to increase their profit, while the environment benefits from the nutrients in the wastewater being reused. The reuse of wastewater also lowers the cost of sewer charges, which citizens pay typically on a monthly basis with their water bills. Using the wastewater treatment method of reclamation and reuseage lowers the need for fresh water. Fresh water will continue to be used for drinking, cooking and all of the current uses for it. However, the fresh water will be replaced by the treated wastewater for irrigation purposes as well as other uses listed in Table 1.

MILL CREEK NEIGHBORHOOD

The Mill Creek neighborhood has formed its own water districted MCWRD. The MCWRD treats the neighborhoods wastewater and uses it as irrigation for the community's two golf courses. The neighborhood has grown to 1700 homes as of summer 2005. "The existing MCWRD facilities have been designed and permitted for an annual average flow of 650,000 gpd or dwelling equivalency of 1857" (Sheaffer & Roland, Inc, 2005a). The MCWRD is looking to expand their facilities to handle a total annual average capacity of 1,310,000 gpd, within the next couple of years.

Mill Creek uses a method of water reclamation, which provides an odor free, and environmentally friendly wastewater treatment process. The system, which is in services at Mill Creek subdivision, is called a "circular." "It is based on the ecological principle that everything must be someplace and pollutants are merely resources out of place" (Sheaffer & Roland, Inc, 2004). The benefits of using a circular system are: (Sheaffer & Roland, Inc, 2004)

- Circular systems use reclaimed water as a resource to irrigate plants.
- Growing plants recycles valuable nutrients.
- Reclaimed water helps recharge groundwater supplies.
- No sludge handling on a regular basis.
- No odor produced.

The wastewater is first reclaimed in the deep aerated cells, and then followed by filtration and disinfection. MCWRD is unique with their aeration method. Owner of Sheaffer & Roland, Inc. John Sheaffer, III has designed an aeration system, MARS2000 which is used at Mill Creek as well as other ponds in the Chicago-land area.

The MCWRD uses the following process to treat their wastewater (Sheaffer & Roland, Inc, 2004):

- Communitor
- Aerated Treatment Cells
- Reclaimed (Treatment Area) water storage reservoir
- Intermittent Sand Filters
- Chlorination
- Irrigation Pump Station
- Distribution to Mill Creek Golf Course

The following is a description of how the treatment processes listed above are used in the MCWRD.

Communitor: Grinds up solids before the wastewater enters the aerated cells. This is kept covered to reduce the amount of odor being produced.

Aerated Treatment Cells: Two deep aerated treatment cells, which have a total retention time of two to five weeks. The wastewater enters the cells at the bottom to prevent odor from being released. The solids will settle to the bottom, which collect in the containment area where the final decomposition takes place. Once every 20-40 years the small volume of residual solids will be removed.

Storage Reservoirs: This is the storage place of the reclaimed water during precipitation, non-irrigation times, and cold weather.

Sand Filters: Filtration increases the efficiency of the disinfection process and minimizes clogging of irrigation equipment.

Chlorination: Chlorination is used for disinfection. Disinfection is necessary where there are high amounts of human activity in irrigation areas such as public parks, sports fields, picnic areas and golf courses.

Irrigation Pump Stations: These stations are used to pump the treated wastewater to the areas where irrigation is needed throughout the neighborhood.

An aerial photo of the Mill Creek water treatment facility can be seen in figure 3. The area located to the left of the storage reservoirs and sand filters is the proposed location for the facility expansion.

Figure 3: Aerial Photo of MCWRD (Sheaffer & Roland, Inc, 2005).

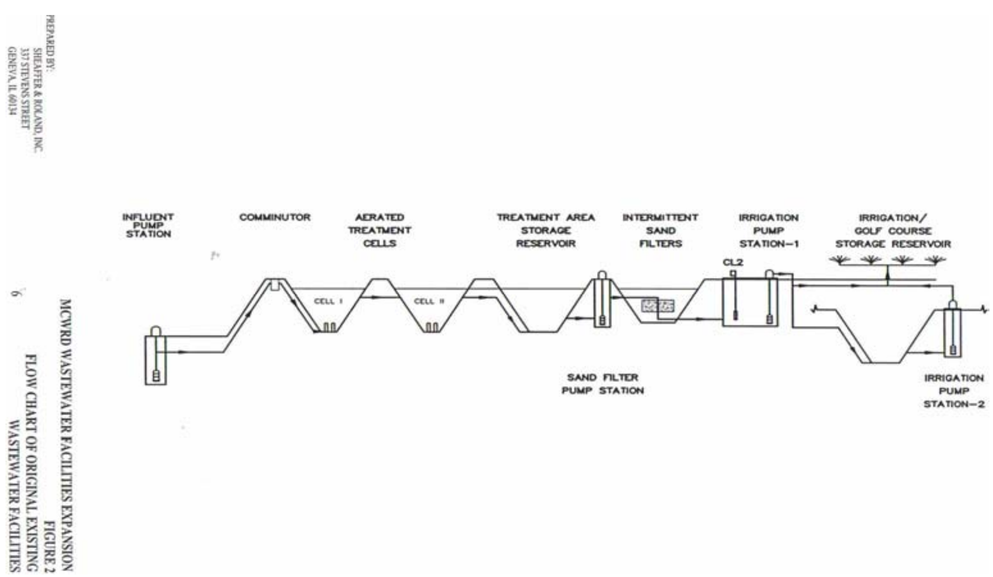

Figure 4: Treatment Process used by MCWRD (Sheaffer & Roland, Inc, 2004).

A general treatment process is described in Table 2. Each step is described as well as the process in detail. The methods of filtering out the sediments, solids and any infectious substances, which poses a threat to humans and the environment.

Table 2 Unit Processes in Water and Wastewater Treatment (Tchobanoglous and Burton, 1991)

	Water Treatment
Screening	Bars, mesh, or strainer for the removal of large coarse suspended and floating matter.
Flocculation	Mechanical mixing to favor agglomeration of solid particles
Coagulation	Addition of chemicals to coagulate suspended and colloidal solids
Sedimentation	Settling out of flocculated suspended substances under gravitational forces.
Flotation	Removal of particles with a mass density lower than that of the surrounding fluids.
Sand Filtration	Filtering out remaining suspended matter
Disinfection	Addition of disinfectant to kill harmful microorganisms
Sludge Treatment	Thickening by gravity and then disposing
Other units	Water softening, pH adjustment, fluoridation, etc.
	Wastewater Treatment
Preliminary Treatment	
Screening	As above
Grit Removal	Removing grit and inorganic materials (e.g. sand) but not organic matter
Storm Overflow	Diverting sewage in excess of capacity of treatment plant to storm water holding or storage tanks.
Primary Treatment	
Primary sedimentation	Settling of suspended solids (only 40 to 60% are removed), no chemicals are added.
	Sludge Treatment
Anaerobic digestion	Decomposing thickened sludge under anaerobic conditions
Gravity thickening	Thickening of primary and secondary sewage sludges
Mechanical dewatering	Removing water from sewage sludges by methods such as centrifuges, pressure or vacuum filters, etc.
Dry Beds:	Drying sewage sludge in open atmosphere.

MARS2000

The MARS2000 is an aeration device created by John Sheaffer, III of Sheaffer & Roland, Inc. The MARS2000 was designed to reduce the amount of mosquitoes by supply enough oxygen while treating wastewater. “The device combines a fine-bubble diffusion aerator with a large-bubble “pot” aerator, thus providing high air/water transfer efficiency with high volume air input. The increased aeration accelerates the breakdown of organic matter, eliminating foul odors typical of stagnant water bodies” (Sheaffer & Roland, Inc,. 2005b). The MARS2000 is a good example of an oxidation pond. The device produces oxygen, which allows for the biological breakdown of the fecal matter. Sheaffer & Roland, Inc. has been quite successful in using oxygen as the breakdown device of the solids in the wastewater being treated.

The MARS2000 is similar to other oxidation devices used in treatment processes. The aerators provide the water with enough oxygen to breakdown the solid matter. The MARS2000 is unique because John Sheaffer, who is the consulting engineer for the MCWRD where it is used, created it.

SAN FRANCISCO'S MASTER PLAN

San Francisco initially reviewed the idea of using the treated wastewater as irrigation during their severe droughts in the early 1990s. With the rapid increase in population during the 1990s and the severity of the droughts, the San Francisco Bay Area Regional Water Recycling Program (BARWRP) was formed. The Recycled Water Master Plan (RWMP) was completed in 1996. The San Francisco Public Utilities Commission (SFPUC) is now developing an updated Recycled Water Master Plan. The updated plan will use the recycled water for "landscape irrigation, commercial toilet flushing and industrial cooling" (SFPUC, 2005). Using the recycled water for the purposing previously described will:

- Help San Francisco increase its overall water supply reliability and meet its long-term drinking water supply needs;
- Free up potable water and groundwater for drinking;
- Better prepare San Francisco for drought and earthquake conditions; and
- Reduce wastewater discharge to the Bay and Ocean. (SFPUC, 2005)

The San Francisco Master Plan involves not only the City of San Francisco, but also the County of San Francisco. San Francisco has many treatment facilities. Each has similar treatment processes. "The City and County of San Francisco collection, treatment disposal system consists of a combined sewer system (which collects both sewer and storm water), three water pollution control plants (WPCP) and outfalls to San Francisco Bay and the Pacific Ocean" (SFPW, 2001).

The city of San Francisco currently uses the treated wastewater for "wastewater treatment plant process water, soil compaction, and dust control during construction, for some wash down operations" (SFPW, 2001). Although San Francisco does use the recycled wastewater, the city is trying to increase the community support. The methods used in San Francisco are similar to the wastewater treatment methods used in MCWRD, however it is at a much larger scale.

CONCERNS IN WATER RECLAMATION AND REUSE

Although there are many benefits of water reclamation and reuse, there are also aspects, which pose health concerns. "The contaminants of greatest concern when considering the reuse of treated wastewater are the enteric microorganisms" (Asano, 1998). Microorganisms pose a threat in a variety of ways, however they are quite dangerous as waterborne. " Microorganisms were responsible for 90% of the reported waterborne disease outbreaks in the United States between 1971 and 1994" (Asano, 1998). The microorganisms, which pose a threat, are generally viruses, fungi, bacteria, algal toxins and parasites. Fecal material is a major source of the microorganisms, which cause illness. Table 2 further explains the inorganic and organic concerns involved in water reclamation and reusage. "Biological reactions signify the biodegradation of organic matter and the utilization of certain inorganic substances by microorganisms which multiply selectively throughout the filter bed. The factors of concern include availability of nutrients, dissolved oxygen (DO) concentration, temperature variation, filtration time, and filter depth" (Rowe, 1995).

Table 3: Inorganic and Organic Constituents of Concern in Water Reclamation and Reuse (EPA, 2005).

Constituent	Measured Parameters	Reasons For Concern
Suspended Solids	Suspended solids (SS), including volatile and fixed solids	Organic contaminants, heavy metals, etc. are absorbed on particulates. Suspended matter can shield microorganisms from disinfectants. Excessive amounts of suspended solids cause plugging irrigation systems.
Biodegradable Organics	Biochemical oxygen demand, chemical oxygen demand, total organic carbon.	Aesthetic and nuisance problems. Organics provide food for microorganisms, adversely affect disinfection processes, make water unsuitable for some industrial or other uses, consume oxygen, and may result in acute or chronic effects if reclaimed water is used.
Dissolved Inorganic	Total dissolved solids, electrical conductivity, specific elements (e.g. Na, Ca, Mg, Cl, and B)	Excessive salinity may damage some crops. Specific in organics electrical conductivity ions such as chlorine, sodium, and boron are toxic to specific elements (e.g. in some crops, sodium may pose soil permeability Na,Ca, Mg, Cl, and B problems).
Residual Chlorine	Fee and combined chlorine	Excessive amounts of free available chlorine (> 0.05 Chlorine chlorine mg/l_ may cause leaf-tip burn and damage some sensitive crops. However, most chlorine in reclaimed water is in a combined form, which does not cause crop damage. Some concerns are experienced.

When dealing with waste of any kind, precautionary matters must be taken to ensure the safety of the public. The microorganisms found in wastewater can spread quickly. Although the bacteria, pathogens, and other organisms are dangerous, they are needed to breakdown the waste material.

The bacteria found in domestic wastewater are generally enteric bacteria. The bacteria are found in the fecal matter, which infects the gastrointestinal of humans. There are also enteric viruses. There have been more than 140 types of enteric viruses, which have been found to be in contaminated wastewater. "The results of infection caused by enteric viruses range widely-from inapparent, undetectable infections to a variety of diseases including gastroenteritis, respiratory illness, hepatitis, paralysis, encephalitis, and conjunctivitis" (Asano, 1998). Pathogens found in wastewater are also dangerous to humans. Protozoa and helminthes have been found in wastewater, which is not treated properly.

The severity of the threat of pathogens to humans is a big concern. Table 4 shows the level of pathogens throughout the treatment process.

Table 4: Pathogen Removal in Treated Wastewater (Asano, 1998).

	Enteric Viruses	*Salmonella*	*Giardia*	*Cryptosporidium*
Concentration in raw wastewater (no. L^{-1})	100,000–1,000,000	5,000–80,000	9,000–200,000	1–3960
Removal during:				
Primary treatment[a]				
% removal	50–98.3	95.5–99.8	27–64	0.7
No. remaining L^{-1}	1,700–500,000	160–3,360	72,000–146,000	
Secondary treatment[b]				
% removal	53–99.92	98.65–99.996	45–96.7	
No. remaining L^{-1}	80–470,000	3–1,075	6,480–109,500	
Tertiary treatment[c]				
% removal	99.983–99.9999998	99.99–99.9999995	98.5–99.99995	2–7[d]
No. remaining L^{-1}	0.007–170	0.000004–7	0.099–2,951	

[a]Primary sedimentation and disinfection.
[b]Primary sedimentation, trickling filter/activated sludge, and disinfection.
[c]Primary sedimentation, trickling filter/activated sludge, disinfection, coagulation, filtration, and disinfection.
[d]Filtration only.
Source: Yates, 1994; Robertson et al., 1994; Enriquez et al., 1995; Madore et al., 1987.

ALTERNATIVES FOR PATHOGEN REMOVAL

Other methods of removing pathogens include activated sludge and oxidation ponds. " Activated sludge typically removes 90% of the enteric bacteria and 80 to 90-99% of the enteroviruses and rotaviruses. Ninety percent of Giardia and Cryptosporidium can also be removed and are largely concentrated in the sludge" (Asano, 1998). The pathogen, Salmonella, is one of the most commonly found in municipal wastewater, as well as Vibrio, Leptospira, and Yersinia. Temperature is an important environmental factor, which affects the activity level of the pathogens in the wastewater. The bacteria which is found in the activated sludge is "responsible for the decomposition of the organic material in the influent" (Tchobanoglous and Burton, 1991). During the treatment process, biological floc typically forms. In the biological floc, the organisms are removed by absorption and or entrapment.

Oxidation ponds have been quite successful in removing pathogens in wastewater. "Given sufficient retention times, oxidation ponds can cause significant reductions in the concentrations of enteric pathogens, especially helminthes eggs. For this reason, they have been promoted widely in the developing world as a low cost method of pathogen reduction for wastewater reuse for irrigation" (Tchobanoglous and Burton, 1991). Because of the low cost, more facilities are looking into incorporating oxidation ponds into their treatment system. Although most results from oxidation ponds has been positive there are still some concerns. "The potential for short circuiting because of thermal gradient, even in multi-pond systems designed for long retention times" (Tchobanoglous and Burton, 1991) is one of the concerns.

The one downfall of oxidation ponds is if a facility is limited on space, oxidation ponds may not be able to be used. Oxidation ponds use a significant amount of land, however if the facility has sufficient space, oxidation ponds are a proven way of treating wastewater.

GOVERNMENTAL REGULATIONS

"There are no federal regulations governing water reclamation and reuse in the U.S.; hence, the regulatory burden rests with the individual states" (Sheaffer & Roland, Inc.. 2005b). With no regulations in place, states must oversee any wastewater using reclamation and reuse as the treatment method. If wastewater is not treated properly, health and environmental risks run high. Although the Environmental Protection Agency (EPA) has not published regulatory specifications, they have provided states with little regulations guidance. "The World Health Organization (WHO) has published recommended guidelines for wastewater use in agriculture and aquaculture, which are presented for comparative purposes" (Tchobanoglous and Burton, 1991). No regulations are in place, only guidelines are given from different organizations. Tests for total and fecal coliform are performed to determine if the organisms are in the treated water. If organisms are found, proper measures must be taken to treat the wastewater.

CONCLUSION

There are a variety of techniques to treating wastewater. Each technique has its benefits as well as its problems. Water reclamation and reuse has been quite successful in the cases, which it has been used. The cost is reasonable and the results have shown promise. With further studies, and experimental facilities, the effectiveness of the different methods of reclamation and the reuse of water will increase. The use of reclaimed water allows for the reduction in the use of cost for irrigation, industrial processing, dust settling on construction sites and many other uses. As technology grows in the wastewater treatment field, the effectiveness of the treatment processes will also increase.

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