11

Water Reuse and Sustainability

Rouzbeh Nazari[1], Saeid Eslamian[2] and Reza Khanbilvardi[1]
[1]City University of New York
[2]Isfahan University of Technology,
[1]USA
[2]Iran

1. Introduction

Water reuse simply is the use of reclaimed water for a direct beneficial purpose in various sectors from home to industry and agriculture. For a number of semi-arid regions and islands, water reuse provides a major portion of the irrigation water. In addition, the reuse of treated wastewater for irrigation and industrial purposes can be used as strategy to release freshwater for domestic use, and to improve the quality of river waters used for abstraction of drinking water. Specific water reuse applications meet the water quality objectives. Water quality standards and guidelines which are related to irrigation and industrial water reuse are described in this chapter. Other reuse consumptions such as urban, recreational and environmental are also discussed.

Water quality is the most important issue in water reuse systems in ensuring sustainable and successful wastewater reuse applications. The main water quality factors that determine the suitability of recycled water for irrigation are pathogen content, salinity, specific ion toxicity, trace elements, and nutrients. It will be introduced the important criteria for evaluation water quality and World Health Organization guidelines (WHO, 1989) and the United States Environmental Protection Agency guidelines (USEPA, 1992, 2004) which are the two main guidelines that frequently used in many countries around the world. Finally, it will be discussed briefly about different treatment method selections; the degree of treatment required and the extent of monitoring necessary which depend on the specific application. Wastewater reuse can be applied for various beneficial purposes such as agricultural irrigation, industrial processes, groundwater recharge, and even for potable water supply after extended treatment. Water reuse allows the communities to become less dependent on groundwater and surface water resources and can decrease the diversion of water from sensitive ecosystems. Additionally, water reuse may reduce the nutrient loads from wastewater discharges into waterways, thereby reducing and preventing pollution. This "new" water resource may also be used to replenish overdrawn water resources and rejuvenate or reestablish those previously destroyed. Most common types of wastewater reuses are summarized in Table 1.

2. Agriculture reuse

The reuse of wastewater has been successful for irrigation of a wide array of crops, and increases in crop yields from 10-30% have been reported (Asano, 1998, 2004). For a number of semi-arid regions and islands, water recycling provides a major portion of the irrigation water. In addition, the reuse of treated wastewater for irrigation and industrial purposes can be used as strategy to release freshwater for domestic use, and to improve the quality of river waters used for abstraction of drinking water by reducing disposal of effluent into rivers (USEPA, 2003). By knowing that water for agriculture is critical for food security and also by understanding that agriculture remains the largest water user, with about 70% of the world's freshwater consumption, it can be understood that how important it is to have new source of water available for this section. According to recent Food and Agriculture Organization data (FAO Website), only 30 to 40% of the world's food comes from irrigated land comprising 17% of the total cultivated land. One of the broad strategies to address this challenge for satisfying irrigation demand under conditions of increasing water scarcity in both developed and emerging countries is to conserve water and improve the efficiency of water use through better water management and policy reforms. In this context, water reuse becomes a vital alternative resource and key element of the integrated water resource management at the catchment scale (Asano and Levine, 1996; Lazarova, 2000, 2001).

However, despite widespread irrigation with reclaimed wastewater, water-reuse programs are still faced with a number of technical, economic, social, regulatory, and institutional challenges. Some of the water-quality concerns and evaluation of long-term environmental, agronomic, and health impacts remain unanswered. But water quality is the most important issue in water reuse systems so to ensure sustainable and successful wastewater reuse applications, the potential public health risk associated with wastewater reuse should be evaluated and also the specific water reuse applications should meet water quality objectives. Water quality of the effluent which is going to be used as reuse water, is the most important issue related to water reuse systems that determines the acceptability and safety of the use of recycled water for a given reuse application. The options for sustainable reuse projects are related to the quality of the effluent, and the environmental risk associated with land application for a variety of crops and activities and irrigation type and even the quality standard can vary during irrigation and non-irrigation period (Eslamian et al., 2010). It might be higher during interim periods when irrigation is not practiced to ensure a relatively safe discharge to receiving water bodies. The main water quality factors that determine the suitability of recycled water for irrigation are pathogen content, salinity, sodicity (levels of sodium that affect soil stability), specific ion toxicity, trace elements, and nutrients. All modes of irrigation may be applied depending on the specific situation. If applicable, drip irrigation provides the highest level of health protection, as well as water conservation potential (Valentina and Akica, 2005). The most important criteria for evaluation of the treated wastewater are as follows (Kretzschmar et al., 2002):

- Salinity (especially important in arid zones)
- Heavy metals and harmful organic substances
- Pathogenic germs

Table 1 presents the most important water quality parameters and their significance in the case of municipal wastewater reuse.

The goal of each water reuse project is to protect public health without necessarily discouraging wastewater reclamation and reuse. The guidelines or standards required removing health risks from the use of wastewater and the amount and type of wastewater treatment needed to meet the guidelines are both contentious issues. The cost of treating wastewater to high microbiological standards can be so prohibitive that the use of untreated wastewater is allowed to occur unregulated.

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances
Urban Reuse Landscape irrigation, vehicle washing, toilet flushing, fire protection, commercial air conditioners, and other uses with similar access or exposure to the water	Secondary[1] Filtration[2] Disinfection[3]	pH = 6–9 <10 mg/L biochemical oxygen demand (BOD) < 2 turbidity units (NTU)[5] No detectable fecal coliform/100 mL[4] 1 mg/L chlorine (Cl_2) residual (min.)	pH – weekly BOD – weekly Turbidity – continuous Coliform – daily Cl_2 residual – continuous	50 feet (15 m) to potable water supply wells
Agricultural Reuse For Non-Food Crops Pasture for milking animals; fodder, fiber and seed crops	Secondary Disinfection	pH = 6–9 < 30 mg/L BOD < 30 mg/L total suspended solids (TSS) < 200 fecal coliform/100 mL[5] 1 mg/L Cl_2 residual (min.)	pH – weekly BOD – weekly TSS – daily Coliform – daily Cl_2 residual – continuous	300 feet (90 m) to potable water supply wells
Indirect Potable Reuse Groundwater recharge by spreading into potable aquifers	Site specific Secondary and disinfection (min.) May also need filtration and/or advanced wastewater treatment	Site specific meet drinking water standards after percolation through vadose zone.	pH – daily Turbidity – continuous Coliform – daily Cl_2 residual – continuous Drinking water standards– quarterly Other – depends on Constituent	100 feet (30 m) to areas accessible to the public (if spray irrigation) site specific

[1] Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contactors, and many stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do no exceed 30 mg/L.
[2] Filtration means passing the effluent through natural undisturbed soil or filter media such as sand and anthracite.
[3] Disinfection means the destruction, inactivation or removal of pathogenic microorganisms. It may be accomplished by chlorination, or other chemical disinfectants, UV radiation or other processes.
[4] The number of fecal coliform organisms should not exceed 14/100 mL in any sample.
[5] The number of fecal coliform organisms should not exceed 800/100 mL in any sample.

Table 1. Reuse Chart (USEPA, 2004)

Parameter	Significance	Approximate Range in Treated Wastewater
Total Suspended solids (TSS)	TSS can lead to sludge deposits and anaerobic conditions. Excessive amounts caused clogging of irrigation systems. Measures of particles in wastewater can be related to microbial contamination, turbidity. Can interfere with disinfection effectiveness	< 1 to 30 mg/l
Organic indicators TOC Degradable Organics (COD, BOD)	Measure of organic carbon. Their biological decomposition can lead to depletion of oxygen. For irrigation only excessive amounts cause problems. Low to moderate concentrations are beneficial.	1 – 20 mg/l 10 – 30 mg/l
Nutrients N,P,K	When discharged into the aquatic environment they lead to eutrophication. In irrigation, they are beneficial, nutrient source. Nitrate in excessive amounts, however, may lead to groundwater contamination.	N: 10 to 30 mg/l P: 0.1 to 30 mg/l
Stable organics (e.g. phenols, pesticides, chlorinated hydrocarbons)	Some are toxic in the environment, accumulation processes in the soil.	
pH	Affects metal solubility and alkalinity and structure of soil, and plant growth.	
Heavy metals (Cd, Zn, Ni, etc.)	Accumulation processes in the soil, toxicity for plants	
Pathogenic organisms	Measure of microbial health risks due to enteric viruses, pathogenic bacteria and protozoa	Coliform organisms: < 1 to 104 /100 ml other pathogens: Controlled by treatment technology
Dissolved Inorganics (TDS, EC, SAR)	Excessive salinity may damage crops. Chloride, Sodium and Boron are toxic to some crops, extensive sodium may cause permeability problems	

Table 2. Water quality parameters for wastewater reuse and their significance (Asano, 1998)

Regulatory approaches stipulate water quality standards in conjunction with requirements for treatment, sampling and monitoring. These standards or guidelines are highly dependent on the kind of water use. Obviously, the landscape and forest irrigation has the lowest requirements concerning the treatment of effluent, compared to the potable reuse. But, the requirements of irrigation of limited crops (crops that need further processing) are not high and therefore it is applicable in economic terms.

The greatest health concern when using recycled water for irrigation is related to pathogens that could be present (Kretschmer et al., 2000). It is widely known that it is not practical to establish the presence or absence of all pathogenic organisms in wastewater or recycled water in a timely fashion. For this reason, the indicator organism, E-coli, was established many years ago to allow monitoring of a limited number of microbiological constituents.

Standards for wastewater reuse in many countries have been influenced by the WHO Health Guidelines (1989) (Table 3) and the USEPA Guidelines (2004) (Table 4). The Guidelines are set to minimize exposure to workers, crop handlers, field workers and consumers, and recommend treatment options to meet the guideline values. WHO's 1989 Guidelines which seems somehow old and there are no any newer WHO guidelines; for the safe use of wastewater in agriculture take into account all available epidemiological and microbiological data. The fecal coliform guideline (e.g. =1000 FC/100 ml for food crops eaten raw) was intended to protect against risks from bacterial infections, and the newly introduced intestinal nematode egg guideline was intended to protect against helminthes infections (and also serve as indicator organisms for all of the large settable pathogens, including amoebic cysts). The exposed group that each guideline was intended to protect and the wastewater treatment expected to achieve the required microbiological guideline was clearly stated. Waste stabilization ponds were advocated as being both effective at the removal of pathogens and the most cost-effective treatment technology in many circumstances.

Category	**Reuse Conditions**	**Exposed Group**	**Intestinal Nematode (arithmetic mean no. eggs per liter)**	**Fecal Coliforms (geometric mean no. per 100 ml)**	**Wastewater treatment expected to achieve the required microbiological guideline**
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, publics	≤ 1	≤ 1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Workers	≤ 1	No standard recommendation	Retention in stabilization pond for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by irrigation technology, but not less than primary sedimentation

Table 3. WHO (2001) guideline for use of treated wastewater in agriculture

Reuse Type	Treatment	Water Quality	Setbacks	Monitoring
……………………………………………… **Public Contact** ………………………………………………..				
Irrigation for public areas: * Parks * Cemetery * Golf Courses * Other landscapes **Agricultural irrigation for:** * Food crops that will not be commercially processed * Any crops eaten raw	Secondary Filtration and Disinfection	* pH 6-9 * ≤ 10 mg/L BOD * ≤ 2 NTU * No detectable fecal coliforms/100 mL * at least 1 mg/L residual chlorine	* 50 feet to potable water	* Weekly: pH, BOD * Monthly: Coliforms * Continuously: Turbidity, Chlorine Residue
………………………………………… **Limited or No Public Contact**……………………………………..				
Irrigation of restricted access areas: * Sod farms * Silvicultures * Other areas with limited or no public access **Agricultural irrigation for:** * Food crops that will be commercially processed * Non-food crops and pastures	Secondary Disinfection	* pH 6-9 * ≤ 30 mg/L BOD * ≤ 30 mg/L TSS * ≤ 200 fecal coliforms/100 mL * at least 1 mg/L residual chlorine	* 300 feet to potable water * 100 feet to areas accessible to public (if spray irrigation is used)	* Weekly: pH, BOD * Monthly: Coliforms and TSS * Continuously: Chlorine Residue

Table 4. USEPA (2004) guideline for agricultural reuse of wastewater

In contrast, USEPA (2004) has recommended the use of much stricter guidelines for wastewater use in the USA. The USEPA (2004) has established guidelines to encourage states to develop their own regulations. The primary purpose of federal guidelines and state regulations is to protect human health and water quality. To reduce disease risks to acceptable levels, reclaimed water must meet certain disinfection standards by either reducing the concentrations of constituents that may affect public health and/or limiting human contact with reclaimed water. The elements of the guidelines applicable to reuse in agriculture are summarized in Table 4. For irrigation of crops likely to be eaten uncooked, no detectable fecal coliform/100 ml are allowed (compared to 1000 FC/100ml for WHO), and for irrigation of commercially processed crops, fodder crops, etc, the guideline is 200 FC/100 ml.

Much wastewater reuse in agriculture is indirect and that is, the wastewater is predisposed into rivers and the contaminated river water is used later on for irrigation. However, international guidelines for the microbiological quality of irrigation water used on a particular crop do not exist (Ayers and Westcott, 1985). The United States Environmental Protection Agency (USEPA) recommended that the acceptable guideline for irrigation with natural surface water, including river water containing wastewater discharges, be set at 1000 FC/10 ml (USEPA, 1981). This standard has been adopted in some other countries as an irrigation water quality standard, for example, Chile, in 1978 (Ayers and Westcott, 1985). This standard is also consistent with guidelines for unrestricted irrigation. FAO has now recommended that the WHO (1989) Guidelines be used interim irrigation water standards, until more epidemiological information is available. Eslamian and Tarkesh-Isfahani (2010b) evaluate the most efficient irrigation systems in wastewater reuse.

3. Industrial reuse

Reuse of reclaimed water for industrial proposes is developed in many industries of United State of America, Europeans and other developed countries. Reclaimed water reuse is one of the strategies for sustainable management. Industrial reuse has increased substantially since the early 1990s for many of the same reasons urban reuse has gained popularity, including water shortages and increased populations, particularly in drought areas, and legislation regarding water conservation and environmental compliance. Utility power plants are ideal facilities for reuse due to their large water requirements for cooling, ash sluicing, rad-waste dilution, and flue gas scrubber requirements (Metcalf and Eddy, 2003, 2007). Petroleum refineries, chemical plants, and metal working facilities are among other industrial facilities benefiting from reclaimed water not only for cooling, but for processing needs as well. For the majority of industries, cooling water is the largest use of reclaimed water because advancements in water treatment technologies have allowed industries to successfully use lesser quality waters. These advancements have enabled better control of deposits, corrosion, and biological problems often associated with the use of reclaimed water in a concentrated cooling water system. The most frequent water quality problems in cooling water systems are corrosion, biological growth, and scaling. These problems arise from contaminants in potable water as well as in reclaimed water, but the concentrations of some contaminants in reclaimed water may be higher than in potable water (EPA, 1981).

Industrial reuse can be explained and defined for a number of industries in the world, but if the most industrial water consumption, cooling towers, is considered to this subject, the industrial reuse is defined for each industry and it can be defined as a quality standard for reclaimed water reuse. Eslamian and Tarkesh-Isfahani (2010a) evaluate the urban reclaimed water for industrial reuses in North Isfahan, Iran. Based on this and other research projects results on eight various industries, and case studies, articles and books, reclaimed water quality parameter limitation for use in cooling towers are defined and shown in Table 5.

Parameter	Measured Standard Method	Unit	Selected Range of Concentration for IOR Consumed
Electrical conductivity (EC)	Platinum Electrode, number 2510 B of Standard methods	µmhos/cm	500-600
Hardness (as $CaCo_3$)	EDTA Titrimetric, number 2340 C of standard methods	mg\L	150-250
Alkalinity	Titrimetric, number 2320 B of standard methods	mg\L	100-150
Chloride	Argentometric, number 4500-Cl^- B of standard methods	mg\L	175-250
Orthophosphate (PO4)	Vanadomolybdophosphoric Acid Colorimetric, number 4500-P C of	mg\L	0-1
polyphosphate	Vanadomolybdophosphoric Acid Colorimetric, number 4500-P C of standard methods	mg\L	Good
NO_2^-	Colorimetric, number 4500-NO_2^- B of standard methods	mg\L	<1
NO_3^-	Ultraviolet Spectrophotometric, number 4500-NO_3^- B of standard methods	mg\L	<5
NH_3	Nesslerization, number D1426 of ASTM	mg\L	<1
TSS	Gravimetric, number 2540 D of standard methods	mg\L	5-10

Turbidity	Nephelometric, number 2130 B of standard methods	NTU	<2
TDS	Platinum Electrode, number 2510 B of Standard methods	mg\L	250-500
Ca	EDTA Titrimetric, number 3500-Ca B of standard methods	mg\L	50-75
BOD_5	Respirometric, number 5210 D of standard methods	mg\L	0-5
COD	Closed Reflux-Titrimetric, number 5220 C of standard methods	mg\L	20-40
pH	Electrometric, number 4500-H^+ B of standard methods	-	6-8
SO_4^{2-}	Gravimetric, number 4500-SO_4^{2-} C of standard methods	mg\L	0-250
Na^+ (as NaCl)	Direct Air-Acetylene Flame Atomic Absorption Spectrometric, number 3111 B of standard methods	mg\L	150.200
Cr	number 3111 B of standard methods	mg\L	<0.5
Cu	number 3111 B of standard methods	mg\L	<0.05-1
Se	number 3111 B of standard methods	mg\L	<1
Mn	number 3111 B of standard methods	mg\L	<0.3-1
Pb	number 3111 B of standard methods	mg\L	<1
Zn	number 3111 B of standard methods	mg\L	<1
Mg	number 3111 B of standard methods	mg\L	<20-30
Co	number 3111 B of standard methods	mg\L	<1
Cd	number 3111 B of standard methods	mg\L	<0.1-1
Fe	number 3111 B of standard methods	mg\L	0.1-0.3
Sr	number 3111 B of standard methods	mg\L	<1
As	number 3111 B of standard methods	mg\L	<1
Hg	number 3111 B of standard methods	mg\L	<1
SiO_2	Molybdosilicate Colorimetric, number 4500-SiO_2 C of standard methods	mg\L	<10-20
Oil and Greece	Partition- Gravimetric, number 5520 B of standard methods	mg\L	<1
Total Chlorine Residual	DPD Colorimetric, number 4500-Cl G of standard methods	mg\L	<4
Total coliform (as log)	-	Log MPN/100ml	<2.2 MPN/100ml
Fecal coliform (as log)	-	Log MPN/100ml	<2.2 MPN/100ml
SRB (sulfate reducing bacteria)	-	MPN/100ml	nil
PAHs	Gas Chromatographic-Flame Ionization Detector	μg/L	nil
THMs	Gas Chromatographic-Mass Spectrometry	μg/L	nil
MTBE	Gas Chromatographic-Flame Ionization Detector	μg/L	nil
OCP-Pesticide	Gas Chromatographic-Electron Capture Detector	μg/L	nil
OPP-Pesticide	Gas Chromatographic-Nitrogen Phosphorous Detector	μg/L	nil
2,4-D	High Performance Liquid Chromatographic	μg/L	nil

Table 5. Range of water quality parameters for reuse of reclaimed water in cooling towers

4. Urban reuse

Urban reuse systems are a crucial part of water recycling since it can provide the reclaimed water for various non-drinking purposes such as Irrigation of public parks and recreation centers, athletic fields, school yards and playing fields, highway medians and shoulders, and landscaped areas surrounding public buildings and facilities, Irrigation of landscaped areas surrounding single-family and multi-family residences, general wash down, and other maintenance activities. Urban reuse can be expanded to cover commercial uses such as vehicle washing facilities, laundry facilities, window washing and mixing water for pesticides, herbicides, liquid fertilizers, toilet and urinal flushing in commercial and industrial buildings. Reclaimed water can also help with human health and safety in dust control and concrete production for construction projects and control the expansion of suspended particles in the air and provide water for fire hydrants. A 2-year field demonstration/research garden compared the impacts of irrigation with reclaimed versus potable water for landscape plants, soils, and irrigation components. The comparison showed few significant differences; however, landscape plants grew faster with reclaimed water (Lindsey et al., 1996). But such results are not a given. Elevated chlorides in the reclaimed water provided by the City of St. Petersburg have limited the foliage that can be irrigated (Johnson, 1998). Dual distribution systems could be used to deliver the reclaimed water to customers through a parallel network of distribution completely separated and marked to distinguish from the community's drinking water line. Design considerations for urban water reuse systems should include two major components: water reclamation facilities and reclaimed water distribution system, including storage and pumping facilities. The reclaimed water distribution system has the potential to become a third water utility, along with drinking water and wastewater. Reclaimed water systems are operated, maintained, and managed in a manner similar to the drinking water system. One of the oldest municipal dual distribution systems in the U.S., in St. Petersburg, Florida, has been in operation since 1977. The system provides reclaimed water for a mix of residential properties, commercial developments, industrial parks, a resource recovery power plant, a baseball stadium, and schools. The City of Pomona, California, first began distributing reclaimed water in 1973 to California Polytechnic University and has since added two paper mills, roadway landscaping, a regional park and a landfill with an energy recovery facility. As part of planning of an urban reuse system, communities have the option of choosing continuous or interruptible reclaimed water system. In general, an interruptible source of reclaimed water can be used as long as reclaimed water will not be used as the only source of fire protection. For example, the City of St. Petersburg, Florida, decided that an interruptible source of reclaimed water would be acceptable, and that reclaimed water would provide only backup for fire protection. If a community determines that a non-interruptible source of reclaimed water is needed, then reliability, equal to that of a potable water system, must be provided to ensure a continuous flow of reclaimed water. This reliability could be ensured through a municipality having more than one water reclamation plant to supply the reclaimed water system, as well as additional storage to provide reclaimed water in the case of a plant upset. However, providing the reliability to produce a non-interruptible supply of reclaimed water will have an associated cost increase. In some cases, such as the City of Burbank, California, reclaimed water storage tanks are the only source of water serving an isolated fire system that is kept separate from the potable fire service. Retrofitting a developed urban area with a reclaimed water distribution system can be expensive. In some cases, however, the benefits of conserving potable water may justify the cost.

5. Environmental and recreational reuses

Water reuse provides a dependable, locally-controlled water supply and tremendous environmental benefits. Environmental reuse includes creating artificial wetlands, enhancing natural wetlands and sustaining stream flows. Uses of reclaimed water for recreational purposes range from landscape impoundments, water hazards on golf courses, to full-scale development of water-based recreational impoundments, incidental contact (fishing and boating) and full body contact (swimming and wading). As with any form of reuse, the development of recreational and environmental water reuse projects will be a function of a water demand coupled with a cost-effective source of suitable quality reclaimed water. In California, approximately 10 percent (47.6 mgd) (2080 l/s) of the total reclaimed water use within the state was associated with recreational and environmental reuse in 2000 (Leverenz et al., 2002). In Florida, approximately 6 percent (35 mgd or 1530 l/s) of the reclaimed water currently produced is being used for environmental enhancements, all for wetland enhancement and restoration (Florida Department of Environmental Protection, 2002). In Florida, from 1986 to 2001, there was a 53 percent increase (18.5 mgd to 35 mgd or 810 l/s to 1530 l/s) in the reuse flow used for environmental enhancements (wetland enhancement and restoration). Two examples of large-scale environmental and recreational reuse projects are the City of West Palm Beach, Florida, wetlands-based water reclamation project and the Eastern Municipal Water District multipurpose constructed wetlands in Riverside County, California. Other applications of environmental and recreational water reuse include creation of natural and man-made wetlands, recreational and aesthetic impoundments and stream augmentation. The objectives of these reuse projects are typically to create an environment in which wildlife can thrive and develop an area of enhanced recreational or aesthetic value to the community through the use of reclaimed water. Other benefits of environmental reuse include decreasing wastewater discharges and reducing and preventing pollution. Recycled water can also be used to create or enhance wetlands and riparian habitats.

6. Economic considerations

One the major aspects of water reuse is the socio economic impacts assessment of implementation of such resources. Wastewater can decrease impacts of water shortage in arid and semi-arid regions of the world and promote means of sustainable development in the world. However, this will be highly dependent of environmentally sound implementation and management for reuse systems. Poor planning and management could leave significant damages on health and environment by contaminating valuable drinking water supplies and bring unwanted socio economic losses. Economic sustainability and public reception depend on the usage of reclaimed water. Most researches and surveys (Angelakis et al., 2001; Mantovani et al., 2001), have concluded that the best practices are those that substitute reclaimed water in lieu of potable water for use in irrigation, environmental restoration, cleaning, toilet flushing, and industrial uses. The main benefits of using reclaimed water in these situations are conservation of water resources and pollution reduction. Treating and reusing wastewater is economically reasonable in terms of increasing the water availability and the benefits of saving the environment from discharge of wastewater into other systems and controlling the spread of contamination into water and soil. Demand for municipal, industrial and agriculture is on the rise and are expected to reach 37, 23, and 340 bcm; respectively. Provided the low consumptive use of the municipal and industrial sectors, most of the appropriated water can be recovered (Kretschmer et al., 2003). In the agricultural sector, the large size of withdrawals encourages the collection and reuse of irrigation water. Wastewater is already in use around the world. In China, Chile and Mexico, extensive agriculture lands around are irrigated by wastewater (Sadik et al., 1994; Xie et al., 1993). Arab regions have also practicing wastewater reuse. About 7 bcm of wastewater was reused in 1996 out of 191 bcm the total withdrawal that year; this implies less than 4% recovery. Reused agriculture drainage was about 5 bcm out of 168 bcm withdrawn for that sector, less than 3% recovery and 2 bcm of municipal and industrial wastewater out of 23 bcm withdrawn, about 9% recovery (El-Ghamam, 1997). Wastewater is a source real economic activity involving local and federal government along with private industries. Various entities invest in getting rid of it or suffer the environmental damage. Either practice has a pervasive impact on public health and the sustainability of development. If wastewater is properly treated and reused, solves two major of saving local and regional environment and resolving water shortage. Over all the economic viability of water reuse has to be studied individually and the required treatment and cost efficiency, depend on type of pollutants, concentration and type of reuse.

7. Public health concerns and acceptance

The major emphasis of wastewater reclamation and reuse has been on non-drinking applications so far, such as agricultural and landscape irrigation, industrial cooling and in-building applications, such as toilet flushing, in large commercial buildings. Indirect or direct potable reuse raises more public concern because of real or perceived perception of aesthetics and long-term health concerns. Regardless, the value of water reuse is weighed within a context of larger public issues of necessity and opportunity and will not be implemented until two major problems of public health concerns and public acceptance is resolved. Each of these problems involves various issues from scientific concerns to human psychology. In the case of public health concerns, which are extremely viable concerns, presence of pathogenic organism and inorganic micro pollutants should be carefully examined for their short and long term impacts. Pathogens could impose serious threat to human health. They are found in water as bacteria, protozoa, helminthes and ruses which some of them can be easily detected and removed (Dishman et al., 1989). However, others are more difficult to detect and removed and there are not enough studies to assign a safe concentration limits to them. Furthermore, the risk of viral infections and waterborne diseases in general is still an unresolved issue. The inorganic pollutants of concerns in water reuse are nitrates, other nitrogen compounds and heavy metals which are easy to detect and remove. Organic micro pollutants also represent a large problem in direct potable reuse mainly because of lack of sufficient information on the health significance of many the known or suspected carcinogenic, mutagenic, allergenic, teratogenic organic compounds found in water (Crook, 1985). It is also necessary to mention that there are thousands of organic compounds in water that are awaiting discovery (Golden, 1984; Dishman et. al., 1989). The second problem that the potable use of reclaimed water has to facing is public acceptance. This a major obstacle to reuse and it roots in educational and psychological barriers which have to overcome in order to obtain public support. Numerous researches have highlighted the fact that public is not welcoming in this regard and most of the polls revealed major opposition to direct potable use (Gallup, 1973; Kasperson et al., 1974; Carley, 1985). The general feeling about use of wastewater for drinking purposes is negative, regardless of the degree of treatment and these feelings embody the psychological factors in the public's rejection of direct potable use of reclaimed water.

8. Conclusions

The world's population is on the rise and is expected to increase dramatically between now and the year 2020 (United Nations, 2006). This growth will put more pressure on our already scarce and damaged water resources. Communities around the world will be faced with an increased level of wastewater production with no use. Water reclamation and reuse can offer significant help for conserving and extending available water supplies. Water reuse may also present communities with an alternate wastewater disposal method as well as providing pollution abatement by diverting effluent discharge away from sensitive surface waters. However, water reuse has its own advantages and disadvantages which have been summarized in Table 6.

Advantages	Disadvantages
This technology reduces the demands on drinkable sources of freshwater.	If implemented on a large scale, revenues to water supply and wastewater utilities may fall as discharge of wastewaters is reduced.
It may reduce the need for large wastewater treatment systems, if significant portions of the waste stream are reused or recycled.	Reuse of wastewater may be seasonal in nature, resulting in the overloading of treatment and disposal facilities during the rainy season.
The technology may diminish the volume of wastewater discharged, resulting in a beneficial impact on the aquatic environment.	Application of untreated wastewater as irrigation water or as injected recharge water may result in groundwater contamination.
Capital costs are low to medium for most systems and are recoverable in a very short time; this excludes systems designed for direct reuse of sewage water.	Health problems, such as water-borne diseases and skin irritations, may occur in people coming into direct contact with reused wastewater
Operation and maintenance are relatively simple except in direct reuse systems where more extensive technology and quality control are required	In some cases, reuse of wastewater is not economically feasible because of the requirement for an additional distribution system.
Provision of nutrient-rich wastewaters can increase agricultural production in water-poor areas.	Gases, such as sulfuric acid, produced during the treatment process can result in chronic health problems.

Table 6. Advantages and disadvantages of water reuse

9. References

Angelakis, A., Thairs, T. and Lazarova, V., 2001, Water Reuse in EU Countries: Necessity of Establishing EU-Guidelines, State of the Art Review, Report of the EUREAU Water Reuse Group EU2-01-26, 52p.

Asano, T., and Levine, A.D., 1996, Wastewater reclamation, recycling and reuse: past, present, and future, Water Science and Technology, 33(10-11), 1-14.

Asano, T., 1998, Wastewater Reclamation and Reuse, Water Quality Management Library, Vol. 10, Technomic Publishing Company, Lancaster, Pennsylvania.

Asano, T., 2004, Water and Wastewater Reuse, An Environmentally Sound Approach for Sustainable Urban Water Management (http://www.unep.or.jp/)

Ayers, R.S., and Westcott, D.W., 1985, Water Quality for Agriculture, Food and Agricultural Organization of the United Nations, FAO Irrigation and Drainage, Paper 29, Rome, Italy.

Carley, R. L., 1985, Wastwater reuse and Public Opinion, Journal of the American Water Works Association, 77(7), 72.

Crook, J., 1985, Water Reuse in California, Journal of the American Water Works Association, 77(7), 61.

Dishman, M., Sherrard, J., and Rebhun, M., 1989, Gaining Support for Direct Potable Water Reuse, Journal of Professional Issues in Engineering, 115 (2), 154-161.

El-Ghamam, A. R. I. H., 1997, The Future of Agriculture and Food Production in Saudi Arabia: A Briefing, Country Report.

Eslamian, S., Tarkesh-Isfahani, S. and Malekpour, I., 2010, Investigating heavy metals concentration of a wastewater treatment plant for agricultural and landscape reuses, Dryland Hydrology: Global Challenges Local Solutions, September 1-4, Westin La Paloma,Tucson, AZ, USA.

Eslamian, S., and Tarkesh-Isfahani, S., 2010a, Evaluating the urban reclaimed water for industrial reuses in North Isfahan, Iran, The 4th International Symposium on Water Resources and Sustainable Development, Algiers, Algeria.

Eslamian, S. and Tarkesh-Isfahani, S., 2010b, Evaluating the most efficient irrigation systems in wastewater reuse, Pakistan Agriculture: Challenges and Opportunities, Kashmir, Pakistan.

Florida Department of Environmental Protection (2002), (dep.state.fl.us/water/ wetlands/).

Food and Agriculture Organization (http://www.fao.org/corp/statistics/en/).

Gallup, G.J. ,1973, Water Quality and Public Opinion, Journal of the American Water Works Association, 65(8), 513.

Johnson, W.D., 1998, Innovative Augmentation of a Community's Water Supply – The St. Petersburg, Florida Experience, Proceedings of the Water Environment Federation, 71st Annual Conference and Exposition, October 3-7, Orlando, Florida.

Kasperson, R. E. et al., 1974, Community adoption water reuse system in the United States, U. S. Office of Water Resources Research.

Kretzschmar, R., 2002, Best Management Practices for Florida Marinas, Florida Department of Environmental Quality, Florida.

Kretschmer, N., Ribbe, L., and Gaese, H., 2000, Wastewater Reuse for Agriculture, Technology Resource Management and Development, Scientific Contributions for Sustainable Development, Special Issue, Water Management, Vol. 2, Cologne.

Lazarova, V., 2000, Wastewater Disinfection: Assessment of the Available Technologies for Water Reclamation, in Water Conservation, Vol. 3: Water Management, Purification and Conservation in Arid Climates, Goosen, M.F.A. and Shayya, W.H., eds., Technomic Publishing Co. Inc., 171.

Lazarova, V., 2001, Role of Water Reuse in Enhancing Integrated Water Resource Management, Final Report of the EU Project CatchWater, EU Commission.

Leverenz, H., Tchobanoglous, G. and Darby, J. L., 2002, Review of Technologies for the Onsite Treatment of Wastewater in California, Report No. 02-2, Prepared for California State Water Resources Control Board, Center for Environmental and Water Resources Engineering, UC Davis, Davis, CA.

Lindsey, P.R., Waters, K., Fell, G. and Setka Harivandi, A., 1996, The Design and Construction of a Demonstration/Research Garden Comparing the Impact of Recycled vs. Potable Irrigation Water on Landscape Plants, Soils and Irrigation Components, Water Reuse Conference Proceeding, American Water Works Association, Denver, Colorado.

Mantovani, P., Asano, T., Chang, A. and Okun, D.A., 2001, Management Practices for Nonpotable Water Reuse, WERF, Project Report 97-IRM-6.

Metcalf and Eddy, 2003, Wastewater Engineering: Treatment and Reuse, 4rd ed., Mc-Graw Hill Inc., New York.

Metcalf and Eddy, 2007, Water Reuse: Issues, Technologies, and Applications, McGraw-Hill, New York.

Sadik, A., and Shawki B., 1994, The Water Problems of the Arab World: Management of Scarce Resources." In Rogers, Peter, and Peter Lydon (eds.), Water in the Arab World: Perspectives and Prognoses, Ch 1, 1-37, the American University in Cairo Press, Cairo, Egypt.

United Nations, 2006, World Population, the World at Six Billion and World Prospects: The 2006 Revision, Department of Social and Economic Affairs, Population Division, New York.

USEPA, 1981, Process Design Manual: Land Treatment of Municipal Wastewater, EPA Center for Environmental Research Information, EPA 625/1-81-013, Cincinnati, Ohio.

USEPA, 1992, Guidelines for Water Reuse, United States Environmental Protection Agency and & USAID (United States Agency for International Development), Cincinnati, OH.

USEPA, 2003, National Primary Drinking Water Standards, United States Environmental Protection Agency, EPA 816-F-03-016, Washington, D.C.

USEPA, 2004, Guidelines for Water Reuse, United States Environmental Protection Agency, EPA 645-R-04-108, Washington, D.C.

Valentina L. and Akica B., 2005, Water Reuse for Irrigation: Agriculture, Landscapes, and Turfgrass, CRC Press.

Virginia Cooperative Extension Materials (http://pubs.ext.vt.edu/452/452-014/452-014.html).

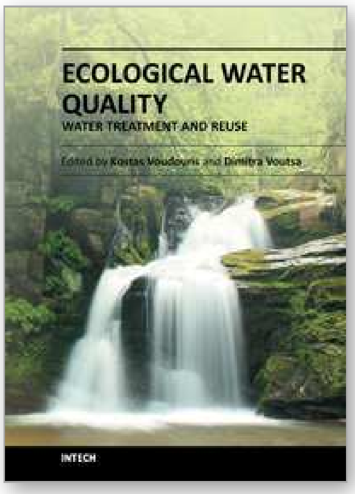
WHO Website (http://www.who.int/bulletin/archives/78%289%291104.pdf)

World Bank 1995, From Scarcity to Security: Averting a Water Crisis in the Middle East and North Africa, Washington D.C.

World Health Organization (WHO), 1989, Health Guideline for the Use of Wastewater in Agriculture and Aquaculture, WHO Technical Report Series, No. 778, Geneva, Switzerland.

World Health Organization (WHO), 2001, Water Quality: Guidelines, Standards and Health Assessment of Risk and Risk Management for Water-related Infectious Diseases, Available from http://www.who.int/water_sanitation_health/dwq/whoiwa/en/

Xie, M., Kuffner, U. and Le Moignee, G., 1993, Using Water Efficiently: Technological Options, World Bank Technical Paper No. 205., Washington D.C.



Ecological Water Quality - Water Treatment and Reuse

Edited by Dr. Voudouris

ISBN 978-953-51-0508-4
Hard cover, 496 pages
Publisher InTech
Published online 16, May, 2012
Published in print edition May, 2012

This book attempts to cover various issues of water quality in the fields of Hydroecology and Hydrobiology and present various Water Treatment Technologies. Sustainable choices of water use that prevent water quality problems aiming at the protection of available water resources and the enhancement of the aquatic ecosystems should be our main target.