Journal of Engineering and Applied Sciences 15 (6): 1522-1536, 2020
ISSN: 1816-949X
© Medwell Journals, 2020

Wastewater Reuse in the United States and Arabs Countries: A Survey of Current Practice, Issues and Needs

Nuralhuda Aladdin Jasim
Department of Civil, College of Engineering, University of Wasit, Kut, Iraq

Abstract: This literature review examines international survey of various countries in order to review current practices, needs and policies around the world. The objective of this literature review is to display in what manner wastewater reuse technologies are applied and to show the various approaches to reclaiming wastewater in light of various needs such as climate change water sacristy and population growth. In the first section, wastewater reuse in different countries including the United States and Arab Countries is presented. In the second section, an overview of current policies in the US and Arab Countries are presented to show different perceptions regarding wastewater reuse. In addition, public perceptions in the United States and Arab Countries are examined regarding wastewater reuse and reclamation. The existing regulations, legislation and guidelines of these countries are also studied. In the third section, various kinds of technologies are represented along with their advantages and disadvantages. For example, soil aquifer treatment technology is considered to be a natural system which has been used in some Arab Countries. Another technology examined is the double membrane which is the most advanced technology in use to remove organic and inorganic compounds. The idea of the double membrane is that a membrane bioreactor system is used as a pretreatment for reverse osmosis. In addition, the public has differing perspectives on wastewater reuse. In the US, public perceptions are positive while Arab Countries have a negative perspective. These differing views are due to the fact that in developed countries, wastewater reuse has been practiced and implemented for several years, using advanced technologies that have no negative effects on human health. However, the concept of wastewater reuse is considered a new option in developing countries (Arab Countries) and so, advanced facilities are required to protect human health. In developed countries which are the US, beneficial regulations and guidelines for reuse systems exist such as the USEPA guidelines and various water management approaches are implemented. In Arab Countries, though there has been some development of water reuse systems, some countries continue to face problems with poor facilities and equipment. Enforcement of regulations and further development are required in order to implement advanced reuse strategies. On the whole, planned and controlled water reuse should be considered as a part of practicable water resource management worldwide.

Key words: Wastewater, reuse, untied states, practices, needs and policies, worldwide

INTRODUCTION

In many communities, droughts, population growth and climate change impact water supply. To meet these demands, water reclamation from wastewater is considered for use. Wastewater can be a reliable alternative water source. Once treated, the characteristic or quality of wastewater is acceptable to the ecosystem. Therefore, directly conveying treated wastewater to a drinking water facility is considered an acceptable option. John says "that wastewater can be viewed as a resource, freshwater containing plant nutrients (nitrogen, phosphorous and potassium)".

The term wastewater reuse, wastewater recycling and wastewater reclamation are used synonymously. Most people in the general public do not comprehend these terms. In this case, some communities changed the term to water reuse which is more acceptable and presents a more positive image to the public. The wastewater reuse can be used for such purposes as landscape irrigation, industrial uses, agricultural irrigation, urban uses, groundwater recharge and fire protection.

Water reuse is practiced to preserve freshwater sources, to protect the environment and to use treated wastewater at higher water quality standards. In industrialized countries, wastewater reuse projects are used for municipal and industrial purposes. However, in some developing countries unplanned water reuse is necessity in order for local water supplies to meet basic sanitation needs.

Literature review: Literature review looks at water reuse projects in different countries that have caused negative effects on health and the environment in their efforts to provide a supply of water. It is important to underst and different forms, advantages, practices and controversial opinions about wastewater reuse around the world. Also, it is beneficial for wastewater reclamation to obtain maximum objectives from current polices such as laws, guidelines, regulations requirements in various countries. Moreover, it is important to consider different views or perspectives about wastewater reclamation and public attitudes towards wastewater reuse.

The first section looks at the survey conducted for wastewater reuse in the United States and Arab Countries. The history of wastewater reuse in the US and how it is practiced compared with examples of wastewater reclamation in these various Arab Countries is examined in this study. The water availability and treated wastewater quantities are presented for each country. The factors responsible for the US and Arab Countries leading the world in waste water reuse are also examined. Some agencies in these countries that have played an enforcement role in wastewater reuse management are also examined. Their various plans to meet the growing demands for safe public water supplies are also considered. For example, The Environmental Protection Agency (EPA) is in the US, an agency considered in this study. In the Arab Countries, a substantial expansion of wastewater reuse has been initiated as part of the Integrated Water Recourses Management (IWRM) approach. Moreover, the reasons for using wastewater recycling are presented in these Arab Countries such as water shortages and droughts.

The second section is an overview of current policies in the US and Arab Countries. The existing standards, guidelines, legislation and regulations are discussed in each country. The public attitudes towards wastewater reuse in different countries are also discussed. Furthermore, the factors affecting public perceptions in the general community are reviewed. Water treatment requirements are presented two. For instance, a typical treatment system would have at least secondary treatment and disinfection technology for any type of reuse in the United States.

Wastewater reuse requires modern and functioning technology in order to protect the environment. There are many technologies in use to treat wastewater reclamation and some of them are new technologies. This research also reviews these technologies in the field of waterreuse. The advantages and disadvantages of some technology also represented. For example, the Membrane Bioreactor (MBR) is an efficient approach for meeting water quality standards and in some countries it is used as a pretreatment prior to using Reverse Osmosis (RO) technology. Also, the double membrane is considered another option used in several countries.

MATERIALS AND METHODS

Overview of wastewater reuse in various countries

Wastewater reuse in the United States: Water availability is currently 10.135 m^3 per capita per year in the USA and the Water Intensity Use Index (WIUI) is 17.1%, up from 9.215 m per capita per year in 2007 (Binnie and Martin, 2008). “The water intensity index is derived by dividing the average regional consumptive use by the renewable water supply’’. The nearly 213 billion gallons per day (1 billion m^3/d) is measured as the total amount of water used, excluding thermoelectric power withdrawals. The 64% is used for agriculture, 20% for public water supplies, 9% for self-supplied industries and 6% for other purposes such as mining, domestic and livestock husbandry. At least 88 m^3/sec of treated wastewater are reused, mainly in Florida, Texas, New Mexico, Arizona, California, Colorado, Nevada and Hawaii. The most common form of reuse is agricultural irrigation, utilizing many schemes ranging from 0.012-2.2 m^3/sec (Binnie and Martin, 2008).

The environmental protection agency defines reclaimed wastewater as water that is transferred from one application to another, the most common type being the reuse of municipal wastewater (Mckenize and Metzgar, 2005).

The greatest amount of wastewater reclamation the USA takes place in Florida, California, Arizona and Texas. There are treatment requirements and guidelines including specific treatment processes and effluent quality criteria for reclamation treatment facilities. The guidelines also include standards concernin gtreatment plant reliability (Binnie and Martin, 2008).

History of WW (Wastewater) reuse: In the US, the principal wastewater reuse scheme was implemented in California in 1906. This project used septic tank effluent for irrigation and fertilizing crops. Industrial reuse first took place in Baltimore, Maryland in 1942 using chlorinated effluent for the steel processing industry. Since, the 1960’s urban reuse has been implemented inseveral regions including California, Colorado and Florida. The first worldwide standard for wastewater reuse was established in the state of California in 1918. This legislation became the very rigorous title 22 standards, implemented toprotect public health in that state. There are several projects in the US that have been found for reuse field (Binnie and Martin, 2008) (Table 1).

Motivating factors in the US: There are several factors motivating the development of wastewater recycling in the USA such as water scarcity which was the original one. Strict wastewater standards have been implemented and wastewater reuse schemes encouraged at both federal and local levels. “The Clean Water Act (CWA)’’lays out water quality standards for effluent to be used as reclaimed water or to be discharged into water bodies and wastewater treatment plants are constructed to meet those standards. Also, the application of CWA guidelines has upgraded the centralization of urban wastewater treatment

Table 1: Selected historical examples and milestones of water reuse in the US may be found by US EPA in 2004 and Florida DEP in 2007, Binnie and Martin (2008)

Years	Location	Type of prcject
1906	California	Reuse of water for irrigation (first reference in literature)
1912	Golden Gate Park, San Francisco, California	Watering of lawns and ornamental lake supply
1926	Grand Canyon National Park, Arizona	Toilet flushing, lawn sprinkling, cooling water and boiler feed water
1929	Pomona, California	Irrigation of lawns and gardens
1942	Baltimore, Maryland	Reuse of a chlorinated effluent in a metal cooling and steel processing plant at the Bethlehem Steel company
1960	Sacramento, California	California legislation encourages water reclamation and reuse in the State Water Code
1961	Irvine Ranch Water District, California	A project to reclaim water for irrigation, industrial and domestic uses beings. Later the project includes toilet flushing in high-rise buildings, distributing reclaimed water using a dual-distribution system
1962	County Sanitation District, California	The effluent of the Whittier narrows plant is used to recharge an aquifer through spreading basins at the Montebello Forebay
1965	San Diego County, California	The Santee recreation lakes, supplied with redaimed water, are opened for swimming and catch-and-release fishing
1976	Orange County Water District, California	Water factory 21 is the first project to study the feasibility of making sewage potable
1977	St. Petersburg, Florida	It is considered as the oldest municipal dual-distribution scheme and the biggest urban water redamation systems in the United States. Reclaimed water is provided for residential lawns, commercial developments, industrial parks, golf courses, a baseball stadium and schools. At 2007, highly treated recycled water is used for irrigation at 9,992 residential lawns, 61 schools, 111 parks and 6 golf courses
1976	Monterey, California	The first large system is designed to examine the risks and effects of irrigating with reclaimed water on food crops, including raw-eaten vegetables. The project happened in 1976 and results were published in 1987

plants, placing them near sites with a high demand for water. Recycled wastewater represents a substitute source for water as localized water demand increases due to population growth, especially, in the arid Western regions. These guidelines have also created publica wareness that recycled wastewater is safe and reliable. The institutional development of these regulations, legal frameworks and guidelines has been used topermit the institution of new recycling projects (Binnie and Martin, 2008).

Examples and methods of wastewater reuse in the US: Wastewater in the USA is used for several purposes suchas irrigation along with industrial, municipal and environmental uses with irrigation representing the largest share. For instance, 46% of California's reclaimed water is utilized for this purpose. Industries have begunreu sing wastewater in California, Nevada, Texas, Florida and Arizona, using it for boiler feed and cooling water processes. Municipal reuse consists mainly of landscape irrigation, along with toilet flushing and fire protection. Finally, groundwater recharge has been practiced in the US in many regions, making use of two methods; vadose zone injection which is the oldest one and direct injection. Direct injection is most common one that has advantage to create barriers to saline intrusion along the US coast (Binnie and Martin, 2008).

Examples of groundwater recharge

Mesa Northwest, Arizona: There are two water reuse plants in the city of Mesa. These plants use reclaimed water for different purposes such as crop irrigation, industrial uses, freeway landscape and golf course watering. The 'Northwest water' reuse plant is able to produce 68.000 m^3/d of tertiary effluent (US EPA., 2004). This plant also discharges effluent into two recharge sites and into the Salt River, so as to recharge the aquifers. Recharge methods have been developed in accordance with Mesa's 100 years supply plan. Moreover, this recycling plan represents a significant feature of Mesa's history (Binnie and Martin, 2008).

Orange Water District, California: The Orange County Water District Treatment Plant has practiced its advanced treatment, since, 1976. It recharges coastal aquifers with treated water (Binnie and Martin, 2008).

Gainesville, Florida: Around 32.277 m^3/d of reclaimed water is used to recharge the Floridian Aquifer through deep wells. The amount of recycled water used for irrigating the Botanical Gardens is about 1.400 m^3/d.

Fred hervey water reclamation plant, EI Paso, Texas: Recycled water is used to recharge the Hueco Bolson aquifer using a number of rejection wells. In addition, the effluent is treated to attain drinking water quality, though it is not used for drinking purposes but for industry. The Fred Hervey plant provides the EI Paso Electric Company with 4 million m^3/d of recycled water that is used for cooling towers (Binnie and Martin, 2008).

Examples of indirect potable reuse in the US (US EPA., 2004) (Binnie and Martin, 2008)

Upper Occoquan Sewage Authority (UOSA), Virginia: The UOSA project has been in use, since, 1978. It is able to discharge reclaimed water into the 40 million m^3 of the

Occoquan reservoir. It supplies more "than one million of people in Northern Virginia with water. This project produces up to 90% of its water from recycled supplies during droughts".

Los Angeles, County, California: The montebello forebay groundwater recharge is the name of the wastewater reclamation project in Los Angeles County. It has distributed reclaimed secondary treated and chlorinated water into the Whittier Narrows groundwater basin at montebello forebay. The reclaimed water is spread out to cover systems of spreading basins from which potable water is drawn. It is estimated that the amount of potable water derived from indirectly reclaimed water will reach 20-30% (US EPA., 2004).

Examples of water reuse for environmental and aesthetic purposes ((Binnie and Martin, 2008; US EPA., 2004)

Ironbridge STP, Orlando, Florida (wetland recharge): The areas used for hiking, jogging and biking including a 502 ha wetland, uses 23.185 m^3/d of reclaimed water.

Cochrage Memorial Park, Washington (wetland recharge): The Yelm, Washington scheme is intended tosubmerge wetlands designed for refined reclaimed water prior to groundwater recharge. This project includes a rainbow trout pond.

San Luis Obispo, California, (stream augmentation): Reclaimed water in the city of San Luis Obispo is used for numerous purposes including the enlargement of "in-stream habitats". The city has a river 24 km long which runs through the city. The flow of the river is made up entirely of treated water through out the dry season. Reuse programs for municipal and agricultural purposes have been initiated but the focus has shifted from conventional purposes to in-stream environmental enhancement due to the discovery of threatened and rare aquatic species (Binnie and Martin, 2008; US EPA., 2004).

Petaluma, California (wetland recharge): The Arcata Marsh and Wildlife Sanctuary is an important instance of wastewater reuse in wetland and wildlife environments. The city of Arcata reuses its wastewater at a secondary level and discharges it into Humboldt Bay, one of the main fish farming sites in California. Two wetlands have been designed to safeguard the Bay. One of them is a treatment wetland and the other isa reclaimed water-habitat marsh. In the first system, there s are three water surfaces which are parallel and capable of generating quality secondary effluent which is chlorinated. In the second system, the habitat marsh is used for recreational purposes (Binnie and Martin, 2008; US EPA., 2004).

Examples of water reuse for irrigation in the US

Irvine Ranch Water District, California: This project has been in use, since, 1961. It is used for many purposes such as irrigation along with domestic and industrial uses. Currently, it is also used for toilet flushing in multistory buildings (Binnie and Martin, 2008; US EPA., 2004).

Monterey County Water Recycling Project, California: The Monterey Wastewater Reclamation Project is located in the Salinas Valley. It comprises a local wastewater treatment plant, storage facilities, a pumping station, pipelines and other distribution systems for water reuse systems. About 68.000 m^3/d of disinfected tertiary treated water is used to irrigate 4.700 ha for food crops ((Binnie and Martin, 2008; US EPA., 2004).

Tallahassee, Florida: The Tallahassee agricultural reuse project has been in use, since, 1966. It operates under a contract between the city and a commercial enterprise to preserve the irrigation system and to run farming services. The project irrigates an area of 850 ha with a capacity of 111.400 m^3/d for crops such as corn and soybeans, among others (Binnie and Martin, 2008; US EPA., 2004).

Conserv 2 city of orlando and orange county, florida: The first scheme in Florida using reclaimed water to irrigate food crops has been in operation, since, 1979. In 1988, the city of Orlando and Orange County stopped discharging effluents into Shingle Greekto protect the aquatic life of Tohopekaliga Lake. Conserv 2 started operations in 1986, combining agricultural irrigation with rapid infiltration basins. The average flow produced by the two wastewater treatment plants (one in Orland and other in Orange) is about 189.000 m^3/d. The treated water is distributed to 76 agricultural and commercial customers, 40% of it for rapid infiltration basins. Citrus is the main crop irrigated (Binnie and Martin, 2008; US EPA., 2004).

Funding: Funding in the USA comes from those receiving the reclaimed wastewater service. Funds might also be provided by grants or by developers with the main funding sources being local governments, State Revolving Fund (SRF) and granting programs, capital contributions and supporters of the Clean Water Act (Binnie and Martin, 2008).

Wastewater reuse in Arab Countries: In the last three decades, Arab Countries have experienced increasing stress concerning water "in terms of water scarcity". This crisis has promoted these countries to "seek more efficient use of their water resources as well as ways of increasing water supplies to meet demand". Municipal wastewater reuse contributes to the development of strategies

Table 2: Total water withdrawal, amount of wastewater produced and volume of treated wastewater in various Arab Countries (Choukr-Allah, 2010)

Countries	Total water withdrawal (109 m^3/year)	Total wastewater produced (109 m^3/year)	Volume of treated wastewater (109 m^3/year)
Algeria	6.070 (2000)	0.8200 (2002)	-
Saudi Arabia	23.670 (2006)	0.7300 (2000)	0.5475 (2002)
Egypt	68.300 (2000)	3.7600 (2001)	2.9710 (2001)
United Arab Emirates	3.998 (2005)	0.5000 (1995)	0.2890 (2006)
Iraq	66.000 (2000)	-	-
Libya	4.326 (2000)	0.5460 (1999)	0.0400 (1999)
Jordan	0.941 (2005)	0.0820 (2000)	0.1074 (2005)
Kuwait	0.913 (2002)	0.2440 (2003)	0.2500 (2005)
Lebanon	1.310 (2005)	0.3100 (2001)	0.0040 (2006)
Morocco	12.600 (2000)	0.6500 (2002)	0.0400 (1999)
Oman	1.321 (2003)	0.0900 (2000)	0.0370 (2006)
Syria	16.700 (2003)	1.3640 (2002)	0.5500 (2002)
Tunisia	2.850 (2001)	0.1870 (2001)	0.2150(2006)
Yemen	3.400 (2000)	0.0740 (2000)	0.0460 (1999)

regarding non-conservational water resources. About 80% of the total amount of water supply is used for agriculture irrigation in Tunisia and it is up to 90% in Syria (Choukr-Allah, 2010).

The issues of both water sacristy and water stress can be eliminated by expanding the reuse of treated wastewater to be used for irrigation and other purposes. Aconsiderable expansion of wastewater reuse has been undertakenas part of the "Integrated Water Recourses Management (IWRM) approach". The reclaimed water in Arab Countries is used chiefly for agriculture in Syria, Jordan and Tunisia as a substitute for conventional ground and surface water sources. The IWRM approach attempts to promote the development and management of water. It is practical and makes use of implementation methods that ensure the health of the ecosystem, helping stakeholders make decisions concerning problems involving water resources and to set policy regarding the challenges of water resource management. The approach is designed to balance social and economic requirements (Choukr-Allah, 2010) (Table 2).

The Arab Countries Water Utility Association is a regional association that aims toutilize wastewater to expand its delivery service to its customers. Its aims are to promote the maintenance of water resources and standards of performance for the operation of wastewater reuse systems. Further, the organization supports "water legislation, policies and sector administration" and reform and focuses on applying best practices regarding wastewater reuse (Choukr-Allah, 2010).

Agricultural reuse is the most significant reuse option in Jordan, Egypt and Yemen. Tunisia, Morocco and the United Arab Emirates use "green space irrigation in urban centers". Groundwater recharge is used in Arab Countries to prevent sea water intrusion into fresh water aquifers. Gray water reuseisa method of collecting the run off from showers and sinks which is treated separately from sewage by secondary treatment and disinfection units. Most Arab Countries have instituted quality standards for reclaimed water. Not all, however have the capacity to meet them. For example, Jordan is represented as one of the more advanced countries regarding quality control and the safety of its reused water. Jordan has practical safety systems for agriculture while other countries such as Tunisia and Egypt have implemented strict standards limiting the use of recycled water for industrial crops and green spaces. Other Arab Countries fail to retain their wastewater because due to their long coastlines, much of it ends up in the sea. For instance, Morocco discharges 60% of itstreated and untreated wastewater into the sea, followed by Lebanon at about 80% and Dubai at 60%, (Choukr-Allah, 2010).

Yemen is less advanced than Jordan, Tunisia and Egypt. It has unsafecontrol systems, uncontrolled reuse patterns and its degenerated WWTP does not meet national quality standards. Moreover, it has limited sewer connections. In some Arab Countries, the most problem atictype of wastewater reuse is industrial, owing to its high concentrations of organic pollutants and its blending with domestic wastewater. Some countries impose additional standards on their WWTPs while others cannot reduce the high amount of heavy metals and persistent chemical compounds carried by their wastewater (ACWUA., 2010).

The Arab governments are working toincrease the quality of their water while lessening the environmental, economic and institutional impacts of wastewater reuse. Moreover, they get "support from regional and international organizations" to increase the volume of wastewater reused. Some Arab Countries have the potential for wastewater reuse. For most of them, the most pressing issue is to secure access to safe water and sanitation. Chouk-Alla reports that the ratio of "the volume of treated wastewater" to the total wastewater produced in Arab Countries is 54%, considered high as compared to Asia (35%), Latin American (14%) and Africa (1%) as based on an estimate made by the United Nation's Food and Agricultural Organization (ACWUA., 2010).

Examples and methods of wastewater reuse in various Arab Countries

Wastewater reuse in Baghdad, Iraq: The availability of wastewater reuse technology is necessary to Iraq. There are many factors influencing the development of sewage treatment facilities such as "a lack of funds, years of neglect and the recent war". Reconstruction and repair of wastewater treatment facilities is needed. Although, Iraq has two rivers, the Tigris and the Euphrates, water is scarce in some regions. In August 2004, a prefabricated cromaglass system was installed in Bagdad to treat 30,000 gallons of wastewater per day. The aims of this project are to treat wastewater to be used for irrigation and sanitation and to provide clean water for other purposes such as drinking. The system is effective in removing organic pollutants such as Total Dissolved oxygen (TDS) in limited sequences. The treatment method requires oxygen for the turbulent aeration of wastewater. The batch treatment of biomass is accomplished using separate aeration and quiet settling basins. The system is controlled by Programmable Logic Controls (PLCs). PLCs research by "receiving and responding to signals from level sensors in the tank". The treatment process is followed by a filtration system that removes residual suspended solids and other substances, combining pressure sand filtration with UV treatment to disinfect the effluent (Bogart, 2005).

Wastewater reuse in Jordan: Reclaimed water has been utilized for irrigation in this country for several decades. In accordance with the country's National Water Strategy, wastewater reuse has expanded, since, its inception in 1998. It also has high performance on the quality of water reuse. The volume of wastewater represents about 10% of Jordan's total water supply. While the remaining volume of treated wastewater is reused, this is about 85%. The "treated wastewater isutilized for unrestricted irrigation in the Jordan Valley after its mixture with freshwater". In 2009, the new National Water Strategy was established in order to aid wastewater reuse for irrigation (Choukr-Allah, 2010). It has established the following objectives for 2008-2020:

- To increase the efficiency of wastewater recycling for irrigation by setting suitable tariffs and incentives
- To regard wastewater reuse as an "essential part of the water budget"
- To makesure that recycled wastewater meets relevant national standards and regulations
- To designe ducational programs for the public and farmers promoting wastewater reuse for irrigation

In Jordan, there are about 21 wastewater treatment plants capable of reusing more than 100 million m^3/year. The volume of reclaimed water will reach 223 million m^3 by 2020. The effluent from WWTPs is used directly for irrigation. It can also storein reservoirs until it is utilized for other applications. Several projects have been implemented by the government of Jordan using direct water reuse for irrigation. Projects in Aqaba and Wadi Musa have showed that wastewater reuse can be safe, socially acceptable and reliable (Choukr-Allah, 2010).

The Wadi Musa pilot farm project makes use of the effluent of recycled water from the Petra Regional Wastewater Treatment Plant (WWPT) to irrigate various cropsincluding tree crops such as olives, dates and lemons, along with sunflowers, alfalfa, maize and various kinds of ornamental flowers (Choukr-Allah, 2010).

RESULTS AND DISCUSSION

Overview of existing papers on wastewater reuse policies

Public attitudes towards wastewater reuse/recycling

Public attitudes in the United States: The city of Corvallis, Oregon has considered wastewater reuse as an alternative resource rather than discharging treated water into the Willamette River. This change in attitude has been brought about by changing quality regulations concerning the Willamette River. BuBose, a graduate student in the water resources programs at the University of Oregon did a survey to evaluate public knowledge about and attitudes towards wastewater reclamation.

BuBose states that the factors influencing public acceptance include age, education, gender and ethnicity. The results showed that the public prefers a low level of contact with reclaimed water and that they are less likely to accept a high level of contact. The public involvement process is one method by which some wastewater programs have been opened to the public to provide information such as the design of a project and its implementation. BuBose also conducted interviews in which many respondents said that they preferred to receive information from the government or from scientists. Furthermore, BuBose found that 21% of the respondents chose public meetings as the best way to communicate with policymakers.

Public opinion in California favors using recycled wastewater for irrigation of "golf courses and parks, toilet flushing and firefighting". In addition, a poll taken in Clark County reveals that the respondents are optimistic about the use of recycled water. However, there is less public acceptance for the direct or indirect use of recycled water as drinking water. In their study on fifty wastewater operators and managers, Exall *et al*. (2008) reported that seventy percent of the participants accept the idea of wastewater reuse.

Public attitudes in Arab Countries: Abu-Madi *et al*. conducted a survey in Jordan and Tunisia. The results show that 30% of Jordanian farmers accept the use of recycled water for restricted irrigation and eighty percent of them accept the use of recycled water for unrestricted irrigation. In Tunisia, 67% accept the use of recycled water for restricted irrigation and 82% for unrestricted irrigation. On the other hand, 20 and 7% of the Jordanian farmers refuse to use reclaimed water for restricted and unrestricted irrigation, respectively as compared to approximately 10 and 8% in Tunisia. These results show that farmer's acceptance of these uses for recycled water have increased over the last 10 years. The main factors influencing the farmer's refusals and uncertainties in both countries include concerns regarding impacts on human health, religious prohibition, distrust of water quality, concerns about crop marketing and the availability of fresh water. Most of the farmers surveyed do not recognize the real health risks of wastewater reuse and claim that it has no effects. For instance, some farmers continue to use untreated wastewater for irrigation. Incentives are required in order to enforce restrictions on irrigation with fresh water, so that, reclaimed water can meet agricultural demand. In addition, some consumers do not know how crop marketing operates; therefore, they do not perceive the difference between crops irrigated with reclaimed water and those irrigated with fresh water. Thus, public understanding of crop marketing systems is important and contributes to high public acceptance of wastewater reuse. Religion is also an important factor affecting the farmer's rejection of the use of reclaimed water for restricted irrigation. In Jordan, 90 and 27% of farmers are unwilling to use reclaimed water for restricted and unrestricted irrigation, respectively; these figures are 20 and 11%, respectively, for Tunisian farmers. However, the use of wastewater is approved by the Organization of Eminent Scholars of Saudi Arabia for all purposes involving Islamic rituals. In short, religion is not an impediment to the acceptance of wastewater reuse for farmers and consumers (Abu-Madi *et al*., 2008).

Factors affecting public attitudes in the general community: The following factors can influence the general community's acceptance of a reuse scheme (Po *et al*., 2003).

Perceptions of risk associated with using recycled water: The perceived risk of using recycled water is an important factor as public health issues involving the use of reclaimed water affect public perception. Jeffrey and Jefferson in their conducted study in the United Kingdom showed that the majority of their respondents did not accept using reclaimed water unless the safety of the community could be guaranteed. In addition, Frewer, Howard and Shepherds pointed out that the public use "outage factors" to evaluate the circumstances surrounding wastewater reuse. Their respondents made use of social and moral values in arguing that recycled water is potentially risky because this source is not natural and might be harmful to the public as ordinary citizens would not be able to control the safety of reused wastewater and any choice made to use recycled water would be irreversible. According to Beckwith people use different strategies in making judgments governing their acceptance of risky decisions. Knowledge of judgment strategies used by the public is important in reuse research. People prefer already existing, familiar services to changing their attitudes towards wastewater reuse (Po *et al*., 2003).

Sources of water to be recycled: This factor plays a big role in the acceptability of recycled water. Po *et al*. (2003) "found that the reuse of gray water or treated wastewater from one's own household was more acceptable than that from other public or secondary sources" which is related to a reaction of disgust to using recycled water, however, some accept the use of gray water from their neighborhood rather than from their own households while others prefer treated wastewater coming from the whole city rather than their neighborhood (Po *et al*., 2003). In addition, studies found that the level of acceptability depends on the type of recycled water in question. For instance, rainwater garnered from one's own household roof is more tolerable than recycled wastewater or gray water. By, Po *et al*. (2003) using reclaimed water for aquifer recharge was less satisfactory than using it in the community for gardens and parks. Thus, different levels of treatment can influence the degree of public acceptability of recycled water.

Other possible factors affecting public agreement of recycled water include issues of choice, trust in authorities and scientific agencies, cost and socio-demographic factors (Po *et al*., 2003).

Treatment requirements in various countries

The United Sates: The majority of states in the US have guidelines and treatment standards for more than one type of wastewater reclamation. Other states impose effluent quality criteria. There are fail safe requirements in many states that prevent any distribution of reclaimed water that has not been treated effectively due to the dangers of equipment failures and power outages (US EPA., 2004). Also, dual-distribution systems exist in the US to provide protection by separating lines carrying reclaimed water from those carrying potable water.

In the US, buildings using recycled wastewater are required to have widely-used treatment technologies. A typical treatment system would have at least secondary treatment and disinfection technology for any type of reuse. According to US EPA (2004) guidelines, the selection of the treatment process is based on the following criteria: wastewater reclamation experience in the US and other countries, sound engineering practices, the existence of pilot plants or study data and the laws and guidelines pertaining to various states. The US EPA (2004) guidelines support the association of treatment with “quality requirements to produce acceptable water”. Reclaimed water is tested using pilot testing, a tool that is useful for comparing the quality of produced water with other water sources in the area. Treatment reliability is important and is measured using various techniques. In addition, the reclamation plants must assure reliability to conform to public health standards according to the USEPA’s equipment requirements. These are the class I reliability requirements for wastewater treatment plants (Binnie and Martin, 2008):

- A back-up bar screen for mechanically cleaned units
- A back-up pump in case of equipment failure
- Overflow bypass with bar screen
- Sufficient capacity in primary sedimentation basins
- Sufficient filtration capacity
- A minimum of two aeration basins
- A minimum of two mechanical aerators, two chemical flash mixer basins
- Final sedimentation tanks, each with the capacity to hold all sediment normally held by all tanks in case of equipment failure
- A minimum of two flocculation tanks
- Disinfection tanks with a capacity of 50%

Additional requirements for reclamation plants are piping and pumping flexibility, emergency storage or disposal, alarms and properly functioning instrumentation (Anonymous, 2005).

The standard parameter in both direct and indirect applications as per USEPA recommendations for fecal coliform concentration is <200 MPN/100 mL for reused water when there is any possibility of its cross-connection with potable water lines in dual distribution systems. Further limiting parameters are suggested in order to “produce reclaimed water free” of quantifiable levels of bacterial and viral pathogens. For example, turbidity must be equal to or <2 NTUs which falls within the limits set for fecal coliform in tertiary treatments. Moreover, a Total Suspended Solids (TSS) limit of 5 mg/L is recommended prior to disinfection. In addition, to guarantee reliable destruction of pathogenic microorganisms, decreasing the particulate matter to 2 NTUs is recommended prior to the disinfection process (Binnie and Martin, 2008; US EPA., 2004).

Regulations, guidelines and requirements in various countries

Legal frameworks (regulations) in the US: In the US, many states have their own regulations. The legal frameworks vary from state to state and include guidelines, regulations and incentives. Many states have developed their regulations based on the full spectrum of reuse applications in which reclaimed water is used as a water source alternative, especially, for water quality requirements and treatment processes. The primary intent for some states is to generate disposal alternatives to surface water discharge. Table 3-5 shows the “water quality criteria and treatment requirements” for various reuse applications that are identified by the 2004 USEPA guidelines for water reuse (Table 3-5).

The development of EPA guidelines is based on the assumption that the source of wastewater for reuse is limited to the effluent from municipal or domestic wastewater treatment facilities with a limited industrial waste input (Mckenize and Metzgar, 2005).

Water rights laws are necessary for states when water rights laws allocated by states to promote reuse measurement. Water rights laws can exclude using potable water for non-potable purposes in water-constrained areas, so that, the idea of wastewater reuse will be more attractive. Moreover, water rights regulations can limit the uses of recycled water in these areas to prevent the water being returned to the same body of water from which it came. There are two types of state water rights law in the US. The first one is the appropriative doctrine, more common in the western states and principally in water-constrained areas. These systems administer the amount of water given to consumers with the utilities receiving water on a first-in-rights basis. No appropriator can take more water than they can use, so that, no usable water is lost. The second kind of water rights is riparian. Users cannot withdraw any water that might cause significant decadence to the value of the stream and the water must be used for significant purposes. The water under riparian rights is used only for the area of riparian land for which a certain amount of water has been earmarked (US EPA., 2004).

In California, public health laws such as the health and “safety code, the water code and Titles 22 and 17 of the California code”of regulations have been in place since, 1978 to regulate the quality of reclaimed water. Furthermore, the Purple Book is established by the state

Table 3: Treatment needs and water quality requirements defined by the US AEPA guidelines for water reuse (2004) (Binnie and Martin, 2008; US EPA., 2004)

Types of reuse	Treatment	Reclaimed water quality[2]	Setback distance[3]
Urban reuse (landscape irrigation, vehicle washing, toilet flushing, fire protection systems, commercial air conditioners and uses with similar access of exposure to the water)	Secondray[4] Filration[5] Disinfection[5]	pH = 6-9 $\leq$10 mg/L BOD[7] $\leq$2 NTU[3] -No detectable fecal coli/100 mL[9, 10] 1 mg/L Cl_2 residual (minimum)[11]	15 m to potable water supply wells
Restricted access area irrigation (sod farms, slilviculture sites and other areas where public access is prohibited, restricted or infrequent)	Secondray[4] Disinfection[5]	pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mg/L [9, 13, 14] 1 mg/L Cl_2 residual (minimum)[11]	90 m to potable water supply wells 30 m to areas accessible to the public (if spray irrigation)
Agricultural reuse-food crops not commercially processed[15] (surface or spray irrigation of any food crops includig crops eaten raw)	Secondray[4] Filration[5] Disinfection[5]	pH = 6-9 $\leq$10 mg/L BOD[7] $\leq$2 NTU[8] No detectable fecal coli/100 mL[9, 10] 1 mg/L Cl_2 residual (minimum)[11]	15 m to potable water supply wells
Agricultural reuse-food crops commercially processed[15] (surface irrigation of orchards and vineyards)	Secondray[4] Disinfection[5]	pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mg/L [9, 13, 14] 1 mg/L Cl_2 residual (minimum)[11]	90 m to potable water supply wells 30 m to areas accessible to the (if spray irrigation)
Agricultural reuse-non food crops (pasture for milking animals, fodder, fiber and seed crops)	Secondray[4] Disinfection[5]	pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mg/L [9, 13, 14] 1 mg/L Cl_2 residual (minimum)[11]	90 m to potable water supply wells 30 m to areas accessible to the if spray irrigation)

Table 4: Recirculating cooling towers

Types of reusee	Treatment	Reclaimed water quality[2]	Setback distance[3]
Recirculating cooling towers	Secondray[4] Disinfection[5] (Chemical coagulation and filtration[5] may be needed)	Variables depends on recirculation ratio pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mg/L [9, 13, 14] 1 mg/L Cl_2 residual (minimum)[11]	90 m to areas accessible to the public. May be redced or eliminated, if a high level of disinfection is provided
Other industrial user	**Depends on site specific user**		
Environmental reuse (Wetlands, marshes, wildlife, habitat, stream, augmentation	Variable Secondray[4] and disinfection[5] (minimum)	Variable but not exceed pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$200 fecal coli/100 mg/L [9, 13, 14]	
Groundwater recharge (by spreading or irrigation into aquifers not used for public water supply)	Site-specific and use dependent Primary (minimum) for spreading Secondary[4] (minimum) for injection	Site-specific and use dependent	Site-specific
Indirct potable reuse (groundwater recharge by spreading into potable aquifers)	Secondray[4] Disinfection[5]-may also need filtration[5] and advanced wastewater treatment[16]	Secondray[4] Disinfection[5] Meet drinking water standars after percolation through vadose zone	150 m to extraction wells, may very depending treatment provided and site-specific condtions

Table 5: Water quality reuse

Types of reuse	Treatment	Reclaimed water quality[2]	Setback distance[3]
Recreational impoundments (incidental contact (e.g., fishing and boting) and full body contact with reclaimed water allowed)	Secondray[4] Filtration[5] Disinfection[6]	pH = 6-9 $\leq$10 mg/L BOD[7] $\leq$2 UTN[8] No detectable fecal coli/100 mL[9, 14] 1 mg/L cl2 residual (minimum)[11]	150 m to potable water supply wells (minimum) if bottom not sealed
Landscape impoundments (aesthetic impoundment were public contact with reclaimed water is not allowed)	Secondray[4] Disinfection[6]	pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mL[9, 13, 14] 1 mg/L Cl_2 residual (minimum)[11]	150 m to potable water supply wells (minimum) if bottom not sealed
Construction use (soil compaction, dust control, whshing gaggregate, making concrete)	Secondray[4] Disinfection[6]	pH = 6-9 $\leq$30 mg/L BOD[7] $\leq$30 mg/L TSS $\leq$200 fecal coli/100 mL[9, 13, 14]	

[1-15]Significant values

of California has a great deal of information on health laws pertaining to recycled water. This book has the following aims:

- To promote water reuse (represented by water rights)
- To implement operations that will ensure a high reliability for wastewater reuse
- To make reserve untreated waste water available for emergencies including methods by which it may be stored or disposed of within a 24 h period
- To construct pipelines to transport treated water and to set standards to prevent cross-connection with potable water
- To achieve public acceptance of treated water by providing public consultations

In California, there has been a development of regulations concerning Direct Potable Water Reuse (DPWR). DPWR refers to the injection of purified recycled water directly into potable water distribution systems. Two documents, the 2020 National Water Research Institute (NWRI) white paper by James Crook, titled "Regulatory Aspects of Direct Potable Reuse in California" which identifies the regulations applicable to DPWR and the issues that need to be addressed in California and "Public and Political Acceptance of Direct Potable Reuse" by Margret Nellor and Mark Millian, address the following issues:

- Determining whether dilution (blending recycled with non-recycled water) will be required as a safety factor
- Determining whether monitoring is needed to increase the efficiency of systems for removing chemical pathogenic constituents
- Clarifying the evaluation of public health risk for instance, the risk to public health of treatment system failure (Crook, 2010)

Existing regulations and guidelines in Arab Countries: The most important factor behind ensuring the safety of treated wastewater is enacting achievable and enforceable regulations for wastewater reuse. In general term, non-enforceable regulations can cause insignificance towards rules and regulations. In addition, microbiological guidelines and crop restrictions are vital for public protection in circumstances in which the required treatment of wastewater is impractical. "Wastewater reuse standards in the Middle East and North Africa" are modeled on international standards such as those of the USEPA or the "World Health Organization" (WHO). For instance, "Bahrain, Jordan and Morocco have adopted parts of the WHO's guidelines along with guidelines set by food and agricultural organizations". "Kuwait, Oman, Saudi Arabia and the United Arab Emirates have adopted the stringent health reuse guidelines" that have been practiced in some US states and have similar parameters such as the requirement that fecal coliforms have a concentration lower than 2.2 MPN/100 mL (Choukr-Allah, 2010). Some countries have enacted national health laws to regulate wastewater reuse projects while others lack any type of regulations or guidelines. Some have established treatment substructures to meet water quality requirements in their reuse practices. Some propose that the old WHO guidelines be replaced by the new WHO guidelines published in 2006 concerning the safe use of wastewater and gray water because these guidelines could be used to set national standards in Arab regions.

Though the Arab Countries have evolved various approaches to ensure the protection of "human health and the environment", the main factor in formulating "waste water reuse regulatory" strategies is economic. For instance, the Gulf Cooperation Council has implemented low-risk standards that rely on high-technology and high-cost methods. Some low-income Arab Countries have adopted approaches based on the WHO's recommendations for controlling health risks that rely on low-cost technologies with low operating costs while some have regulations under which they cannot meet their customer's demand for water. Egypt has strict "direct reuse standards" for the irrigation of some types of crops that are established in their code of use. However, these strict direct regulations are not applicable for indirect reuse through agricultural drainage canals. Moreover, the existing laws pertaining to agricultural drainage canals do not contain any limitations regarding the quality of effluent water; standards exist solely for the agricultural canal's discharges (Choukr-Allah, 2010). The Arab Countries may be divided into three categories based on their methods of wastewater disposal.

The first group consists of "Oman, Saudi Arabia, Qatar, Kuwait, Bahrain and the UAE. These countries follow the same methods for the disposal of wastewater effluent". Treated wastewater is used for irrigation and landscaping and a high percentage of the reclaimed water is utilized. The remaining effluent is discharged into the sea after undergoing further treatment, so as to meet the required standards of quality before disposal (Choukr-Allah, 2010).

The second group consists of "Egypt, Iraq, Jordan, Morocco and Syria". These countries do not use national or international standards for the disposal of their wastewater reuse effluent, though they follow moderate regulations. Treated wastewater is discharged into surface water until it is used for irrigation, industrial purposes or landscaping. Their regulations stipulate the kinds of crops that may be irrigated with reused wastewater. Their

Table 6: Regulations or guidelines related to water reuse in the Arab Countries

Countries	Legislation/Guidelines
Egypt	There are not yet specific regulations dealing with water reuse but comprehensive guidelines for managing reclaimed Water, focating on restricted irrigation are under development. Water pollution from municipal and industrial effluents is mainly regulated by three laws: Law NO. 48/11982 for the protection of the Nile River, Law No. 12/1984 on irrigation and drainage, Law No.43 (1982) require secondary treatment of effluent prior to discharge into the Nile River and irrigation canals and specific limits for maximum allowable fecal coliform of 5,000/100 mL and BOD of 60 mg/L. The 1984 martial law regulation prohibits the use of treated effluent for irrigating vegetables drainage water. There are no reuse standards
Iraq	Neither guidelines nor a code of practice for the use of wastewater in irrigation have been adopted so far
Jordan	The previous Jordanian quality stadard on reuse, J8893/1995, prohibited irrigation of vegetables eaten raw. It listed 47 specific constituents and prescribes quality standards on discharge to streams and catchment areas and on water reuse for each of the six following uses: irrigation of vegetables eaten cooked, irrigation of fruit trees, forests, industrial crops and grains, artificial recharge of groundwater, use in aquaculture (fish hatcheries), irrigation of public parks and irrigation of fodder. Fecal colifams:1u for irrigation of cooked vegetables had to be <1000/MPN '100 mL, BOD_s <150 mg/L and helminth egg <1 mg/L. Necessary presence of residual chlorine in treated effluent was required. New standards have recendy been approved and were enacted in 2003 under the title JS 893/2003 in which the irrigation of vegetables eaten raw with reclaimed water remains prohibited whatever treatment is applied. *E. coli* shouldnot exceed 100/count100 mL for cooked vegetables Groundwater recharge is not allowed where aquifers are used for drinking purposes. The helminth egg criterion has been maintained for all uses
Libya L	Under preparation
Morocco	There are not yet any specific water reuse regulations. Reference is usually made to the WHO recommendations. Reuse standards are under preparation. Relevant regulations are Decree No 2-97-875/2998 and water Law N 10-95. Quality standards for water to be used for irrigation have been issued: No 1276-01 of October 17, 2002
Tunisia	Water reuse is regulated by (1) the 1975 Water Law (2) the 1989 decree (Decree No. 89-1047) and other standards: reclaimed water quality standards for reuse (Tunisian standards 106.03,1989); Wastewater disposal standards (Tunisian standards 106.002,1989); Code for crop selection and agricultural practices
United Arab	Advanced treatment is required as well as strict effluent standards which are as follow: BOD_s <10mg/L, TSS <10 mg/L and toal colifroams
Emirates	<100/100 mL., complete nitrification is requested. In Sharjah: total coliforms <21:100 mL and 1 gm/L residual chlorine as Cl_2
Yemen	There are draft national water reuse standards proposine a uniform standard for all crops

governments do not allow raw wastewater to be disposed of in wadis or discharged onto the land. Defiance of these regulations may occur in rural areas because there are no connections in these regions with collection or sewer systems (Choukr-Allah, 2010).

The third group consists of the West Bank, Yemen and Lebanon. Wastewater effluent is used for irrigating crops after it is discharged into wadis without "any treatment. In the West Bank, raw sewage is disposed of in wadis and it is utilized for all kinds of crops and vegetables. There is no health or environmental considerations or guidelines for soil or groundwater contamination. In Yemen, raw sewage is used for agricultural irrigation without any treatment and without meeting any standards for wastewater reuse" (Choukr-Allah, 2010).

All of this indicates that the reuse of treated wastewater in Arab Countries requires to be addressed. Political support is needed for the protection of public health and the promotion of appropriate strategies for wastewater reuse. New standards for reuse are required in order to safeguard the public and institutional structures are needed. Regulations should be formulated according to each country's water resource management plan. Jordan is represented as an advanced country that has implemented standards and regulations for the reuse of wastewater effluent and has established a crop monitoring system that is considered as an initial strategy for achieving better cooperation among responsible authorities to improve their reuse systems. Moreover, Abu Dubai also has a strategy for wastewater reuse by which a WWTP treats reclaimed water for urban greening (ACWUA., 2010). Table 6 shows the regulations or guidelines in the Arab countries:

Technologies in use

The disinfection technology: The disinfection technologies have been in use for the past 20 years. Three kinds of disinfection technologies are exist and have been in use which are Ultra Violet (UV) disinfection, ozone and pasteurization respectfully. Perhaps in the UV technique, the wastewater flow rate, the power of the lamps and UV transmittance in the wastewater are all influenced by the size of the UV system in use (Salveson and Bandy, 2010).

New UV technologies have been developed to meet market demand, involving an increase in medium pressure and power density along with an "extended lamp life. These lamps are widely used in the western and southern United States"(Anonymous, 2010).

The UV disinfection technology has certain advantages. The UV systems are simple to operate. Maintenance such as changing the lamps once a year is minimal and easy to accomplish. With the UV technology, drinking water conditions are suitable, according to etiquettes established by "the National Water Research Institute" (NWRI) (Anonymous, 2010). The UV techniques have applied in various areas such as Arizona in USA and Victoria in Australia.

Meanwhile, the use of ozone technology is utilized for wastewater reuse in the United States. It is more expensive as compared to other technologies like UV disinfection. Other technique is pasteurization which has been in use, since, the 1860's and it is one of disinfection technology. It is an efficient option as demonstrated by the California pasteurization project in which wastewater passes through a waste heat recovery module to produce water for reuse. Solar heat is also utilized. Pasteurization is used in the South Florida Water Management District, Daly city, Florida, Kansas city, Missouri, Ventura, California and Dallas, Texas (Salveson and Bandy, 2010).

Soil Aquifer Treatment (SAT): Next, "Soil Aquifer Treatment" (SAT) is a method that can sterilize wastewater effluent to safe levels for drinking water fresh water that would be utilized in different ways. It is a regular and maintainable system that is accomplished by controlled aerobic and anoxic biodegradation. This technique is useful for both "direct and indirect potable reuse systems". "SAT technology has advantages in which including the ability to remove nitrogen and other contaminants such as viruses". SAT is an efficient method for the removal of pathogens such as Biological Oxygen Demand (BOD) and Total Suspended Solid (TSS), its operation is simple and it is inexpensive. It is used as a standard for the quality of wastewater treatment. Finally, the greatest advantage of SAT technology is that it utilized for directly reuseing treated wastewater in wastewater plants. This technology has been applied in the Middle East and in the South of Africa. Additionally, this technique shows suitable results in term of groundwater recharge and urban reuse.

Reverse Osmosis method: "Reverse Osmosis" (RO) technology is a method used in wastewater reclamation. RO is a separation membrane process and it is considered as a new application in wastewater reclamation. It has advantage for "removing organic, inorganic and microbiological contaminants". Furthermore, its operation and maintenance is suitable (Marinas, 1991). The reverse osmosisplant includes four main components: pretreatment, membrane treatment, permeate post-treatment and concentrate treatment or disposal treatment. In the pretreatment component, it is included "both Feed water microfiltration and chemical conditioning".

Membrane bioreactor technology: The "Membrane Bioreactor Technology" (MBR) technology is one of the most advanced methods in wastewater reclamation world- wide. It is utilized to treat wastewater that can be used for industrial and domestic purposes and potable water for human consumption. Membrane bioreactor systems comprise two components. First one is an activated sludge process "followed by secondary treatment such as clarification and filtration" and the second one is a separation membrane. Moreover, low-pressure, Micro Filtration (MF), an Ultra Filtration (UF) membranes are needed to separate the effluent from the activated sludge. Membrane bioreactors may be submerged or set up for external circulation (side-stream configuration). Submerged membranes may be hollow-fiber membranes or designed as plate membrane modules (Melin *et al*., 2006). MBR technology has been applied in Europe, especially, Western Europe and in the United States.

Double membrane systems: Double membrane processes can be an effective technique for reaching drinking water qualitysuch as a Mmicro Filtration (MF) membrane together utilized with RO. This process is utilized for both groundwater recharge and industrial processes. Several kinds of double membrane have been applied in various countries.

Additionally in Shah Alam, Malaysia, a case study has been done by Ujang *et al*. (2007) investigating the secondary wastewater reclamation April 29, 2019 using "Immersed-Type Crossflow Microfiltration (IMF) as a pretreatment". The target of this study is to examine the results of the process in terms of local environmental conditions. Ujang *et al*. (2007) report that fouling is a problem in membrane technology. Fouling is influenced by operating parameters and feed solution conditions. Based on the removal performance of IMF/RO membrane systems on secondary effluent treatment, results show that the RO permeate meets WHO's requirements and Malaysian Effluent Standards A for raw wastewater intake. Regardless of the high ammonia levels found in these systems, their average for ammonia nitrogen removal is 91.18% in a MF-RO membrane system. Water treated using this technology is safe for potable and industrial uses.

To avoid fouling problems a backwash process is needed. With an appropriate backwash process, IMF performs well hydraulically. The conductivity rejection of an RO membrane is 94%, meaning that even with changeable feed water quality, stable operation can be occurred with significant achievement. Also, chemical cleaning is required to avoid irremediable“fouling by microorganisms”. In short, “RO treatment” with an “IMF” pretreatment process is effective for treated wastewater reclamation and it is satisfactory for providing water that meets Malaysian’s requirements for water quality standards (Ujang *et al*., 2007).

Dual-membrane process using MBR/RO and MF/RO: Double membrane systems such as a microfiltration membrane followed by reverse osmosis or a membrane bioreactor system followed by RO are effective for treated wastewater reclamation. In China, a pilot study has been done by Tam *et al*. (2007) to evaluate the effluent quality from tertiary treatment such as that done with “MBR/RO” and “MF/RO” units and to investigate the feasibility of using treated water for potable and non-potable applications. The results show that both of these systems are efficient for treated water reuse. In addition, using MBR or MF alone is capable to reduce the concentrations of pollutants to “acceptable limits for non-potable reclaim” while with the operation of RO the effluent is potable. Moreover, the RO permeate meets both the USEPA’s and WHO’s water quality requirements for drinking water in terms of conductivity, turbidity, hardness and concentrations of ammonia, *E. Coli* and nitrates for both potable and non-potable uses. Finally, the removal of viruses by MBR and MF is influenced by chemical membrane cleaning and the presence of a membrane biofilm (Tam *et al*., 2007).

Title 22 benchmark technologies: The Title 2 Benchmark, named for the Title 2 wastewater regulations in California. This technique is comprised of coagulation/flocculation, sedimentation, filtration and disinfection treatment of secondary effluent to endeavor to achieve a 0-FC/100 mL (0 fecal coliforms per 100 mL) limit. Over 400 projects in the United States have been completed satisfactorily using this technology. European countries have obtained even greater benefits because their technology does not need to conform to guidelines such as California’s Title 22. Title 22 technology allows proceeding to direct filtration succeeding to disinfection processes without the obligation for coagulation processes. This is only can be occurred if the“effluent of the secondary treatment which is before the filtration basin has a turbidity of <5 NTU”.

CONCLUSION

On the whole, water is one of the most significant resources on Earth. Water is vital for human survival, “food security and the quality of life”. Some countries or regions do not have enough water or resources to cover the demand due to water scarcity, population size and climate change. One solution is to reuse wastewater to meet demands. The wastewater reuse offers many advantages for reducing the demand on “potable sources of freshwater”. It also minimizes the amount of wastewater discharged due to its valuable impact on the aquatic environment.

In the US, the largest projects exist in different states such as Florida, California, Texas and Arizona. Legislation, guidelines and regulations also existin each state that practice wastewater reuse for different purposes. The most significant use fortreated water is in agricultural irrigation, environmental uses and industrial uses. Furthermore, existing national water reuse guidelines have been developed for specific reuse application.

In the same way, in many Arab Countries, there is development on water reuse systems but some still face problems with poor facilities and equipment. Thus, they are not equally developed. Some countries like Yemen the disposal of untreated sewage into wadi’s is considered a serious problem for health risks and its effects ondownstream uses such as drinking water supplies and irrigation. Other use of raw effluent wastewater without any previous treatment for irrigation represents a problem forpublic health experts and environmental scientists. Much of the technology used is not efficient enough to meetnational or intentional standards even though some Arab Countries like Yemen still use it for potable purposes. Other Arab Countries do not have specific standards or guidelines such as Iraq and Libya. The lack of organization in wastewater reuse has existed in some Arab Countries for many years and this makes the enforcement and development of more advanced strategies for reuse systems difficult. The integrated management approach should be enforced in these undeveloped Arab Countries. They need to improve sewage and treatment facilities and establish targets from developed wastewater plans for producing wastewater collection systems and reuse operations. The water quality should be improved in order to prevent risks and health hazards because many regions and countries continue to use uncontrolled “direct and indirect reuse” of raw wastewater irrigation for industrial obligations. The control of contaminants should be applied in order to contribute to prompting wastewater reuse including unrestricted irrigation. In addition, a public awareness campaign directed at the general public should be introduced. More local arrangement with farmers to clarify their responsibilities should be offered. To solve the water scarcity and management problems, the implementation of an integrated water resources management strategy is necessary in order to enforce water quality standards and policy guidelines for wastewater reuse and reclamation. Next, public awareness is required and the selection of high treatment technologies for wastewater reuse and reclamation is essential.

There are many different perceptions about wastewater reuse held by the general public. Some countries have positive perceptions towards wastewater reuse like the US while others have negative views likesome Arab Countries. This is because of the risks which are associated with wastewater reuse. Regardless of these risks, the National Research Council (2012) reports that there is “new analysis proves that the risks of exposure to microbial and chemical contaminants from drinking reclaimed water does not exceed the risks faced from existing water supplies”. This report can increase public support for wastewater reuse and safeguards community health defense for both planned and unplanned wastewater recycle.

This international survey provides variety topics of wastewater reuse to highlight the diverse nature of wastewater reuse and reclamation practices that have been undertaken in the world. It is very important to recognize the diverse nature of reuse activities, whether applied intentionally or unintentionally or directly or indirectly. Therefore, the local needs, capabilities and limitations are identified for the application of planned and controlled water reuse projects. The effective thing for more water reuse schemes is to protect the health public and the environment. In the future, the planned and controlled water reuse should be premeditated as a part of workable “water resources management” approach worldwide.

REFERENCES

ACWUA., 2010. Wastewater reuse in Arab Countries: Comparative compilation of information and reference list. Arab Countries Water Utility Association (ACWUA), Amman, Jordan. http://webcache.googleusercontent.com/search?q=cache:B_FGi7AnUZ4J:www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/128/Jordan_Summary-Report-CountryCasestudies_final.pdf+&cd=1&hl

Abu-Madi, M., R. Al-Sa’ed, O. Braadbaart and G. Alaerts, 2008. Perceptions of farmers and public towards irrigation with reclaimed wastewater in Jordan and Tunisia. Arab Water Counc. J., 1: 18-32.

Anonymous, 2005. Queensland water recycling guidelines. Enviromental Protection Agency, Brisbane, Australia. https://www.hort360.com.au/wordpress/wp-content/uploads/2015/03/Queensland-Water-Recycling-Guidelines-Dec-2005.pdf

Anonymous, 2010. Wastewater reuse using UV disinfection. Halma PLC, Amersham, England, UK. http://halmapr.com/news/aquionics/wastewater-reuse-using-uv-disinfection/

Binnie, C. and K. Martin, 2008. Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA Publishing, London, UK., ISBN:9781843390893, Pages: 631.

Bogart, A., 2005. Wastewater reuse in Baghdad. Pollut. Eng., 37: 32-34.

Choukr-Allah, R., 2010. Wastewater Treatment and Reuse. In: Arab Environment: Water; Sustainable Management of a Scarce Resource, El-Ashry, M., N. Saab and B. Zeitoon (Eds.). Arab Forum for Environment and Development, Beirut, Lebanon, ISBN:9789953437316, pp: 107-125.

Crook, J., 2010. Regulatory aspects of direct potable reuse in California. National Water Research Institute, California, USA. https://www.adaptationclearinghouse. org/resources/regulatory-aspects-of-direct-potable-reuse-in-california.html

Marinas, B.J., 1991. Reverse osmosis technology for wastewater reuse. Water Sci. Technol., 24: 215-227.

Mckenize, C. and C. Metzgar, 2005. Wastewater reuse conserves water and protects waterways. National Environ. Serv. Cent., 1: 46-51.

Melin, T., B. Jefferson, D. Bixio, C. Thoeye and W. De Wilde *et al*., 2006. Membrane bioreactor technology for wastewater treatment and reuse. Desalination, 187: 271-282.

National Research Council, 2012. Water Reuse: Potential for Expanding the Nations Water Supply through Reuse of Municipal Wastewater. National Academies Press, Washington, DC., USA., ISBN:9780309224604, Pages: 261.

Po, M., J.D. Kaercher and E.N. Blair, 2003. Literature review of factors influencing public perceptions of water reuse. Master Thesis, Land and Water, CSIRO and Australia.

Salveson, A. and J. Bandy, 2010. New waves of disinfection for wastewater reuse. Water World USA, Missouri City, Texas, USA. https://www.waterworld.com/articles/print/volume-26/issue-5/editorial-features/new-waves-of- disinfection.html

Tam, L.S., T.W. Tang, G.N. Lau, K.R. Sharma and G.H. Chen, 2007. A pilot study for wastewater reclamation and reuse with MBR/RO and MF/RO systems. Desalin., 202: 106-113.

US EPA., 2004. Guidelines for water reuse. EPA/625/R-04/108, U.S. Agency for International Development, Washington, DC., USA.

Ujang, Z., K.S. Ng, T.H.T. Hazmin, P. Roger and M.R. Ismail *et al*., 2007. Application of Immersed MF (IMF) followed by Reverse Osmosis (RO) membrane for wastewater r eclamation: A case study in Malaysia. Water Sci. Technol., 56: 103-108.