Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2017.20383

65 (2017) 463–473
February

Sustainable development of water resources based on wastewater reuse and upgrading of treatment plants: a review in the Middle East

Vahid Kazemi Moghaddam[a], Fazlollah Changani[b,c], Aliakbar Mohammadi[a], Mostafa Hadei[d], Rabee Ashabi[b], Leili Ebrahimi Majd[b], Amir Hossein Mahvi[b,c,e,]*

[a]*Neyshabur University of Medical Sciences, Neyshabur, Iran, emails: vahidkazemi29@yahoo.com (V. Kazemi Moghaddam), mohammadi.eng73@gmail.com (A. Mohammadi)*
[b]*School of Public Health, Tehran University of Medical Sciences, Tehran, Iran, emails: ahmahvi@yahoo.com (A.H. Mahvi), changani_f@yahoo.com (F. Changani), r.ashabi069@gmail.com (R. Ashabi), majd.leili@yahoo.com (L.E. Majd)*
[c]*Center for Solid Waste Research, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran*
[d]*Sabzevar University of Medical Sciences, Sabzevar, Iran, email: mostafa.hadei@gmail.com*
[e]*National Institute of Health Research, Tehran University of Medical Sciences, Tehran, Iran*

Received 6 March 2016; Accepted 20 November 2016

ABSTRACT

Sustainable development of a country or area requires availability of different resources and their efficient application. Water resources are one of the most valuable resources of each country. The proper use of water resources depends on appropriate management. Water supply management is a multifaceted approach, and an important affecting factor on this approach is the use of potential resources. Effluent reuse is proposed as an efficient solution to improve the management of water resources, particularly in developing countries such as the Middle Eastern countries, because these countries are faced with water scarcity. However, reuse of wastewater in this region has limitations and advantages that are discussed in the present study. Policies related to wastewater reclamation are more important in the Middle East, due to technologic, fundamental, and cultural limitations in these countries. These policies can have a significant impact on wastewater reclamation and water resources management.

Keywords: Sustainable development; Water shortage; Middle East; Wastewater reuse

1. Introduction

World Commission on Environment and Development has described sustainable development as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Thus, sustainable development is a movement to progress toward different goals, without any economic or environmental damages to future generations. The process of development must be accomplished, so that economic growth would not lead to any losses in the environment and culture or other spiritual inheritance of a nation. In the past few decades, one of the most damaged resources during the development process is water resources [1–3].

Besides the important role of water in human and animal life, agriculture, and industry, it has a kinetic and dynamic role, and is even a vital factor in physical and geological systems. It participates in the adjustment of morphological properties of the earth's surface. It also has an impact on natural events such as earthquakes and tectonic movements. Furthermore, water-related changes can cause polar ice caps to move [4–9].

Due to inattention to problems of water resources, 20% of world population does not have access to clean water. Furthermore, 50% of the world population does not have enough and sustainable water resources [10].

* Corresponding author.

This inappropriate sanitation has caused a high rate of morbidity and mortality in children. According to the World Health Organization (WHO) report, there were 3.4 billion cases of water-related diseases in 1999, and more than half of these cases have happened in children [10]. Furthermore, it is predicted that the world will face a shortage in water resources for agricultural and industrial purposes when the world population doubles.

Most of these problems are due to population growth in the world, as humans have used water resources increasingly to satisfy their needs in the fields of agriculture, economy, and industry. In addition to a quality problem, human activities have polluted many water resources. This pollution has threatened water resources in terms of quality and eliminated the possibility to use them [11,12]. Due to the unavoidable process of development, scientists concentrate on a new approach of multidimensional management or, in other words, sustainable development of water resources [13–15].

In recent years, developed countries have done many activities in order to optimize water consumption, decrease water losses, and use potential resources. However, in developing counties, because of less financial support, protection of water resources has not been considered properly. The most highlighted issue in developing countries is drinking water supply. Wastewater treatment and reuse and optimization of wastewater collection systems have lower priorities [16,17].

Wastewater application includes agricultural irrigation, landscape irrigation, industrial and environmental use, improvement of recreational and tourist spaces, non-potable use, groundwater recharging, and even potable purposes. Given the region, level of development, and policies related to the management of wastewater reuse, this usage can be different for various parts of the world. For example, in the less-developed regions, the main objectives are agricultural irrigation, and feeding water bodies and plains [18,19].

In recent years, the Middle East has experienced a high rate of economic, social, and industrial development, but it is faced with extreme water shortage [20,21]. This area has a dry and semi-dry weather. Water resources are distributed in a chronologically and locally non-uniform manner [16,22,23]. Considering these situations, one of the requirements of sustainable development in the Middle East can be wastewater reuse. Nevertheless, it seems that no comprehensive study is done to evaluate water resources' development by wastewater recovery in this region. The present study is conducted to investigate requirements of sustainable development of water resources, especially in the case of wastewater recycling and upgrading of wastewater collection and treatment facilities.

2. Water resources and treatment level in the Middle East

The Middle East is suffering from a shortage of water resources in most parts. Furthermore, the distribution of resources in several regions is non-uniform [24]. Nevertheless, drinking water accessibility is relatively high. As presented in Table 1, in most countries, more than 80% of population has access to drinking water [25].

The ratio of consumed wastewater in agriculture to total irrigation water demand is low. The most conventional sources of agriculture water in the Middle East are freshwater and drinking water resources. Fig. 1 represents the percentage of irrigation water consumption in the region, which is very high, even compared with the European and North American countries that have no water shortage in most cases [26].

Table 1
Drinking water coverage in urban and rural areas of the Middle East countries

Country	Urban coverage (%)	Rural coverage (%)	Total coverage (%)
Algeria	92	80	87
Bahrain	–	100	–
Egypt	100	97	98
Iran	99	94	84
Iraq	88	56	77
Jordan	99	91	98
Lebanon	100	100	100
Libya	72	68	72
Morocco	99	56	80
Oman	85	73	82
Palestine	94	88	92
Qatar	100	100	100
Saudi Arabia	97	63	89
Syria	95	83	89
Tunisia	94	60	82
UAE	100	100	100
Yemen	68	65	66

For instance, the volume of treated wastewater in Tunisia, Jordan, and Kuwait are 7%, 8%, and 32%, respectively. The portion of collected and transferred wastewater to treatment plants is low, and most people use dry wells for wastewater disposal [16].

Lack of water, local habits, and poverty are introduced as obstacles to the development of sanitation facilities for rural and urban populations. Very few of these populations use septic tanks with floor drain; they often use a well for sewage disposal.

In this area, a small percentage of people have access to sanitary services and sewage collection network facilities, compared with developed countries. In addition, the present facilities do not have appropriate conditions in terms of sanitary quality. As shown in Table 2, only 18% of the urban population in Iran has wastewater collection system coverage. In Saudi Arabia, which is far better than most countries in the region, sewage collection network covers 45% of the country [27].

Another problem is the low ratio of treated wastewater to collected wastewater. As shown in Tables 2 and 3, this rate is less than 20% in many countries, and the remaining wastewater can be a potential danger to public health and water bodies [28].

In addition, untreated wastewater in some areas is used to irrigate trees and agriculture products, which have a high health and environmental risk. However, a few countries have taken effective actions to improve treatment and collection systems. For instance, Jordan is one of the leading countries in the field of wastewater treatment and reuse in agriculture [16,29,30].

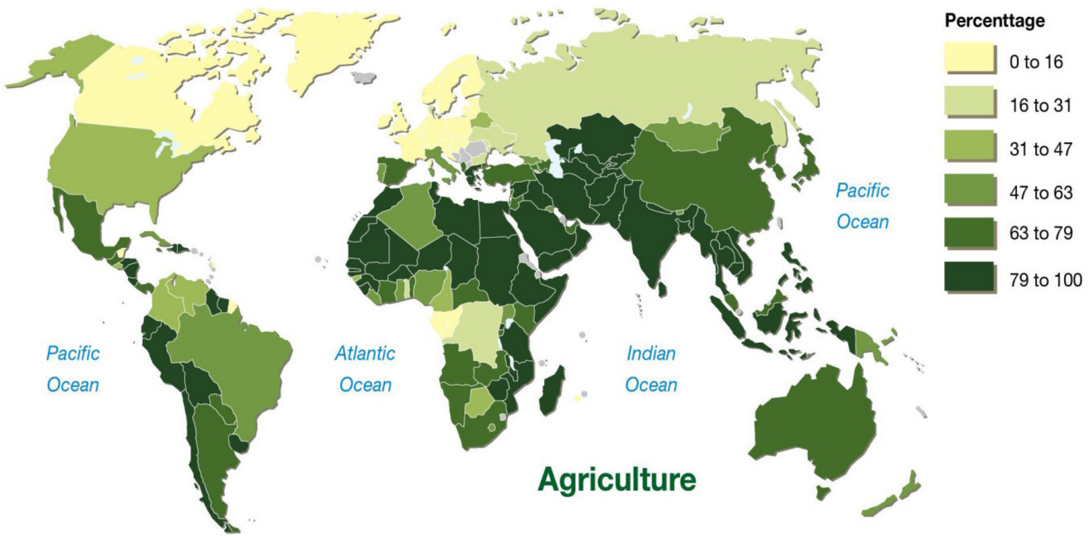

Fig. 1. The percentage of agriculture water usage in the world in 2000.

Table 2
The situation of wastewater collection and treatment in Middle East countries

Country	Wastewater systems facilities (%)		The ratio of treated wastewater to collected wastewater
	Urban	Rural	
Algeria	78–85	65	73
Bahrain	70–77	a	100
Egypt	68	42	79
Iran	17–20	11	4
Iraq	a	a	a
Jordan	70	50	88
Kuwait	a	85	87
Lebanon	a	40	2
Libya	54	54	7
Morocco	70	40	6–8
Palestine	25	23	34–54
Oman	90	81	13
Qatar	a	80	a
Saudi Arabia	45	37	75
Syria	96	71	57–67
Tunisia	68	50	79
UAE	91	87	22
Yemen	40	12	62

a – No information was available.

3. Wastewater reclamation problems in the Middle East

3.1. Lack of proper policy in the management of water resources and wastewater reclamation

In terms of water shortage, many countries in the Middle East are in critical and sub-critical conditions. However, these countries export virtual water (in the form of agricultural products with a high intake of water), which can cause a high usage of water in the agriculture section [31]. On the other hand, agriculture is the main consumer of clean water in these countries and, unfortunately, the present traditional and semi-traditional irrigation wastes a tremendous amount of clean water. Given these conditions, focus on efficient and more advanced irrigation systems is highly recommended. Lack of proper water pricing systems and accurate calculation of water consumption is another important problem within the field of water resources management [18].

Available resources are very important in water management policies, yet have not received much attention. Water resources are declining in Middle Eastern countries and are even exposed to contamination and salinization. In addition to inappropriate policies in water resources management, management of wastewater reclamation does not have a proper condition. In terms of policy, because of strict guidelines and cultural and religious constraints in the region, there is little interest in activities related to the reclamation of wastewater. In general, it can be stated that due to extreme contrast with factors such as culture, rainfall, religion, available technology, and policies, the reuse of wastewater is very difficult in the Middle East [18,19].

3.2. Unnecessary standards and guidelines

In developing countries, including Middle Eastern countries, discharge standards are based upon standards and guidelines of developed countries that are often very difficult and costly to meet. These standards and guidelines have nothing in common with the climatic, cultural, and social conditions of these countries. For example, biochemical oxygen demand (BOD) concentration of raw wastewater in the Middle East and tropical countries is five times greater than in western countries. In addition, wastewater temperature is higher in these countries. The mentioned characteristics can cause difficulty for the treatment process of wastewater [32,33].

As can be seen in Table 4, variation of wastewater quality in terms of wastewater treatment is very high in this area, even in neighboring countries. Designing and operation of wastewater treatment plants cannot be accomplished

Table 3
Summarized information on wastewater production, treatment and reuse in some countries of the Middle East region

Country	Potential production		Wastewater quantity treated		Reused		Treatment techniques employed	Degree of treatment	Reuse/agricultural withdrawal percentage	Reuse guidelines	Reuse aspects/practices/remarks
	mm^3/y	Year	mm^3/y	Year	mm^3/y	Year					
Bahrain	–	–	45	1991	8.03	1991	AS, AL, RBC, SF	S, T	6	WHO	Irrigation: dates, alfalfa, vegetables, fruits, forage crops, landscaping.
Egypt	3,600	1995	2,208.98	2000	200	1993	AS, WSP, TF	P, S	0.4	–	Irrigation: unofficial reuse with treated and untreated wastewaters is practiced.
Iran	–	–	237.25	1995	244.55	1995	AS, WSP, AL	S	0.38	–	Unofficial reuse with partially treated and raw wastewater, mixed with industrial effluents.
Jordon	232	1993	78.99	1998	72	2000	WSP, AS, TF	S	7	WHO, FAO	Fodder crops, forests, cereals, olive and fruit.
Kuwait	119	1994	103	1994	52	1993	AS, SF	T	16	USA	Fodder and food crops eaten raw.
Lebanon	165	1991	4	–	2	1991	–	–	–	–	Unlawful utilization of untreated wastewater is practiced.
Libyan Arab Jamahiriya	–	–	100	2000	100	–	–	–	3	–	–
Morocco	420	1999	33.6	1999	–	–	AS, WSP, TF	P, S	–	WHO, FAO	Reuse schemes for royal golf courses and hotels. Irrigation with raw wastewater is common.
Oman	58	1995	28.6	1995	26	1995	AS, WSP, RBC	S, T	2	USA	Vegetables, fodder crops, public parks and recreational areas. Aquifer recharge.
Qatar	–	–	43	2000	25.2	–	–	–	12	–	–
Saudi Arabia	–	–	710	2000	217	1992	AS, WSP, TF	S, T	1	USA	Reuse for industrial and agricultural purposes.
Sudan	–	–	–	–	–	–	WSP, AS	S	–	–	No formal reuse schemes exist.
Syrian Arab Republic	610	1993	370	1993	177[a]	2000	AS, WSP, AL, TF	S	3	–	Informal and uncontrolled irrigation reuse is practiced.
Tunisia	152	1999	145	1999	35	1998	AS, WSP, AL, TF	S	1	–	Cereals, fodder crops, golf courses. Aquifer recharge is being studied.
United Arab Emirates	500	1995	200	2000	108	1995	AS, SF	S, T	8	USA	Irrigation of public gardens, shrubs, trees and grass.
Yemen	–	–	36	2000	–	–	AS, WSP, TF	S	–	–	Controlled reuse: irrigation of green belts in coastal areas. Uncontrolled practices: irrigation of vegetables and fruit trees.

[a]Damascus only.
Note: AS – Activated sludge; AL – aerated lagoons; WSP – waste stabilization ponds; TF – trickling filter; RBC – rotating biological contactors; SF – sand filters; P – primary; S – secondary; T – tertiary; and ND – not determined.

Table 4
Typical influent and effluent characteristics in countries of the Middle East region

Country	BOD_5		COD		TSS		TDS		Total nitrogen		Total phosphorus		Turbidity (NTU)	
	In	Eff	In	Eff	In	Eff	In	Eff	In	Eff	In	Eff	In	Eff
Jordan	431	36	321	41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bahrain	219	2	410	42	179	3	ND	ND	ND	ND	ND	ND	ND	ND
Egypt	450	36	770	346	360	50	1,600	ND	ND	ND	ND	ND	ND	ND
Gaza (Beit-Lahia)	605	40	1,360	102	576	38	ND	ND	139	70	ND	ND	ND	ND
Iran (Tehran)	ND	ND	173	69	77	38	ND	ND	ND	ND	15.8	4.26	15.7	7.8
Saudi Arabia (Al-Khobar)	116	1.9	281	54	138	3.5	2,104	1,745	ND	ND	18.1	12	ND	0.41
Sudan (Soba)	226	45	573	137	294	51	ND	ND	ND	2.1	ND	ND	ND	ND
Tunisia	516	ND	635	ND	429	ND	ND	ND	87	ND	13.6	ND	ND	ND

In – Influent (Raw sewage or wastewater); Eff – Effluent (Wastewater effluent);
ND – Not determined; NTU – nephlometric turbidity unit.
Note: Units are in mg/L expect where noted.

without pilot- and full-scale studies. On the other hand, as specified in Table 4, there is not enough information for many areas [28]. In addition, countries within the region have more water stress than developed countries. Studies have shown that guidelines are substantially important to meet the needs associated with water stress. Hence, adjustment of unnecessary standards will increase wastewater reclamation and reduce water stress [18,19].

3.3. Improper operation of wastewater treatment plants

In many Middle Eastern countries, even if the design and construction of treatment plants are appropriate, facilities are not in good conditions for operation. In general, activities associated with wastewater treatment are classified in three levels. The initial level or primary treatment is supposed to remove suspended solids from wastewater, and the quality of the resulting effluent is poor. The second level, or secondary or conventional treatment, removes organic matter and ammonia nitrogen, and is considered in most countries. The third level of treatment or advanced treatment that is usually used in developed countries can remove specific contaminants [19].

Most treatment plants have various operational problems such as overloading of organic matter and suspended solids [27,32,33]. As shown in Table 5, in the countries of the region where data are available (e.g., Jordan and Yemen), overloading is one of the major problems [27,33–35]. However, it seems that because most countries have conventional treatment processes, they also face improper operations and, subsequently, overloading problems.

3.4. Improper methods of treatment and lack of facilities

In most Middle Eastern countries, there are no advanced facilities to achieve effluent discharge standards. Most equipment is outdated or has overloading problems compared with design criteria, and has an immediate need of upgrading.

3.5. Health and environmental risks of wastewater recovery

In terms of environmental issues, it should be noted that some types of wastewater can increase soil metal content in the long run. Furthermore, a number of toxic substances are present in the wastewater whose removal requires the use of advanced treatment methods, and these materials can reduce yields of crops and other plants [36].

Various health risks are posed in the reuse of wastewater. First, heavy metals and organic compounds can be found in sewage. A number of metals such as chromium and cadmium are present in wastewater, and their toxicity is proven [37,38]. Some metals in wastewater such as cobalt, zinc, and copper do not have proven effects; however, we need to take precautions in exposure to them [39]. The potentially toxic organic compounds in wastewater are pesticides, persistent organic pollutants, detergents, and residues of human pharmaceutical and endocrine-disrupting phenolic compounds [40–42].

Problems related to pathogens are very important in wastewater recovery and reuse, especially in the field of effluent irrigation [43]. Helminth eggs or eggs of intestinal worms are the most common pathogens that remain in the environment and are especially known as an indicator for effluent irrigation. Intestinal worms are very common in developing countries with an estimated population of 25%–33%, while it is below 1.5% in developed countries [44]. Among intestinal worms, *Ascaris* is the most common species and has an endemic prevalence in Latin America, Africa, and the Far East [45]. Other diseases associated with the use of sewage are cholera, typhus, shigellosis, giardiasis, and amoebiasis [46].

3.6. Lack of incentive and punitive policies by regional and international organizations

Unfortunately, countries with the highest water shortage have little desire to recover and reuse wastewater. In other words, countries with the highest water stress have the least use of treated wastewater. In addition, financial and community organizations based in Asia and Africa have a minor supervision on wastewater treatment and release of effluent into the

Table 5
A description of wastewater treatment plants in different countries of Middle East

Country	Process description	Problems
Algeria	Conventional treatment (secondary); mostly lagoons.	a
Bahrain	Conventional and advanced treatment in order to nutrient removal (tertiary); activated sludge and some advanced processes.	a
Egypt	Primary (19%) and conventional treatment; activated sludge, ponds and trickling filters.	a
Iran	Conventional treatment; mostly activated sludge.	Processes often have overloading problem. Also effluent contains parasite's eggs.
Iraq	a	a
Jordan	Conventional and advanced treatment in order to nutrient removal (tertiary); activated sludge and lagoon.	Overloading occurs frequently.
Kuwait	Advanced treatment in order to nutrient removal (tertiary) and special compounds (advanced).	a
Lebanon	Conventional treatment.	a
Libya	Conventional and advanced treatment in order to nutrient removal (tertiary).	a
Morocco	Conventional treatment.	Raw wastewater mostly discharges to sea or other water bodies.
Oman	Conventional treatment; activated sludge and aerated lagoons.	a
Palestine	Conventional and advanced treatment in order to nutrient removal (tertiary).	Raw wastewater mostly discharges to olive groves.
Saudi Arabia	Conventional treatment; activated sludge and aerated lagoons.	a
Syria	Conventional treatment; activated sludge and aerated lagoons (lagoons are updated in Damascus).	a
Tunisia	Conventional treatment; activated sludge and ponds. Tertiary treatment is developing.	a
UAE	Tertiary treatment in order to nutrient removal. Advanced treatment is developing.	a
Yemen	Conventional treatment; ponds.	Overloading.

a – No information was available.

environment. In contrast, European Union countries are moving toward progress in wastewater treatment and reuse due to financial incentives associated with European Union guidelines [19]. On the other hand, appropriate punitive policies do not exist in the Middle East to prevent the release of wastewater into national and international water bodies. For example, a very high volume of untreated or inadequately treated wastewater is discharged into the Persian Gulf, with no legal supervision by national or regional organizations [19,47–49].

4. Advantages of wastewater recovery

4.1. Reducing the risk of diseases and environment-related problems

Discharging untreated wastewater into the environment has numerous health risks and increases the risk of water-related diseases [50,51]. With treatment and then recovery, wastewater is not released into the environment, and its mentioned threat to public health and the environment can be reduced. However, according to some studies, after years of irrigation with untreated wastewater, certain health problems have not been reported [52].

4.2. Reducing the use of freshwater for farming

Wastewater can be a good source to irrigate agricultural crops and jungles and can reduce the use of freshwater for farming. For example, Egypt has begun an agricultural reform program that includes reuse of wastewater for forest parks [16,52].

Tables 6 and 7 represent the fees for water reuse in different sectors for many countries in this region [53]. The fees charged for reclaimed wastewater is much lower than that of freshwater. Yemen and Syria do not charge farmers for recycled water; prices in Kuwait are also very low (US$ 0.07/m^3) relative to the cost of supply. In many Middle Eastern countries, related data are not available.

4.3. Reducing the use of chemical fertilizers

Because of the higher content of nutrients in wastewater comparing with freshwater, the use of wastewater instead of freshwater reduces the need for chemical fertilizers to provide nutrients for plants. Nevertheless, it must be considered that not all types of wastewater are suitable for reuse purposes, because of high concentrations of heavy metals and

Table 6
Range of water fees from conventional, reuse sources for irrigators, and domestic users

Country	Conventional irrigation tariff ($/m^3, unless otherwise noted)	Other farm water supply costs ($/m^3, unless noted)	Domestic water tariff ($/m^3)	Marginal cost of raw water ($/m^3)	Recycled water tariff ($/m^3)
Algeria	0.03	None	0.16, 0.53 (Avg. = 0.51)	0.26	Na
Bahrain	None	Pumping cost (0.01–0.27)	0.08, 0.26	Pumping cost	Na
Egypt	None	Annual tax (~$3.5/fed-y)	0.05	Na	Na
Iran	0.04	Pumping cost	0.06 (Avg.)	0.32	Na
Iraq	Na	Pumping cost	0.01	Na	Na
Jordan	0.01–0.06 (Avg. = 0.03)	Pumping cost	0.70	0.37	No difference
Kuwait	None	Pumping cost	0.58	Na	0.07
Lebanon	None	Annual tax ($7 – 400/ hA-y)	0.15–0.51	Na	Na
Libya	None	Pumping cost only	0	Na	Na
Morocco	0.02–0.07	Pumping cost < 0.21	0.24–0.95	0.02–0.13	0.07–0.29
Oman	None	Pumping cost	1.75	Na	Na
Palestine	Na	Pumping cost	0.26	Na	Na
Qatar	None	Pumping cost	No charges for nationals	Na	Na
Saudi Arabia	None	Pumping cost	0.03, 0.04	Na	Na
Syria	None	Annual levy	0.07, 0.20	Na	0 (unplanned)
Tunisia	0.08	Pumping cost	0.3, 0.4	0.10–0.19	0.02
UAE	None	Pumping cost	1.37	Na	Na
Yemen	None	Pumping cost (0.07–0.27)	0.06	Pumping cost	0 (unplanned)

Na: Data not available (no information found).
Note: All costs are in US$ (2010). Most countries utilize increasing block tariffs, so it is difficult to derive an average tariff without information on the consumption per household. Therefore, prices for the first two blocks are listed, except where average tariffs are known and reported.

toxic compounds. Some studies showed farmers, who were informed about the risks of using untreated wastewater, used raw wastewater for irrigation due to its numerous advantages [52].

The use of treated wastewater can have a significant impact on the quantity and quality of agriculture products, but there is no published information about its related effects in the Middle East. Generally, application of wastewater for agricultural irrigation can cause an increase in the quantity of crops [53].

4.4. Contribution to revival of the deserts and preventing desertification

One of the influential factors in desertification control is preventing excessive water consumption, as it is effective in desertification and also land subsidence. On the other hand, wastewater can be used to restore forest and rangeland. This can improve and even restore rangeland condition and reduce the area of the desert. Thus, Yanqiu [54] suggested wastewater as one of the solutions to desertification and reclamation of vegetation areas. It should be noted that this is conditional on overcoming the consequences of environmental and health risks associated with the use of wastewater in rangeland irrigation.

4.5. Job creation and production for export markets

More agricultural production can cause development in tourism sectors, and this will lead to more wastewater reuse, economic growth, and job creation. For example, in a study conducted in Mexico, reuse of wastewater and seawater desalination are suggested as options for tourism development [55].

4.6. Reducing the influx of seawater into coastal area

In China, one of the problems associated with water resources is the influx of saltwater into coastal areas. With increased extraction of groundwater close to shores, saltwater moves into groundwater and increases water salinity in areas near the coast [56].

It is obvious that any activity in the field of reducing undergroundwater consumption can reduce the influx of seawater. For instance, in the island of Cyprus, wastewater is now used for irrigation of soccer fields, parks, hotels, etc.

4.7. Increasing the efficiency of agricultural lands

Use of wastewater for agriculture can help farmers to increase crop yields, and this provides the possibility of

Table 7
Wastewater tariffs in selected major cities in the MENA region in 2010

City	Piped water supply (US$/m^3)	Trend[a] (2007–2010)	Wastewater management (US$/m^3)	Trend (2007–2010)
Overall average cost estimate	0.35–0.85	Na	0.5–1.3	Na
Algiers, Algeria	0.16–0.52	No change	0.03	No change
Manama, Bahrain (2009)	0.07–0.22	No change	None	Na
Alexandria and Cairo, Egypt	0.05–0.07	–23%	0.02	+23%
Baghdad, Iraq (2008)	0.002–0.005	No data	None	No data
Tehran, Iran (2007)	Based on dwelling	No data	None	No data
Jerusalem, Occupied	1.87	+50%	Na	Na
Tel Aviv, Occupied	1.29–1.45	+50%	0.33	No change
Amman, Jordan	0.70	No data	Na	Na
Casablanca, Morocco	0.76–0.80	+2.4%	0.19	+160%
Rabat, Morocco	0.65–1.85	+5.7%	0.18–0.32	+19%
Muscat, Oman	1.22	–11%	Na	Na
Ramallah, Palestine (2009)	1.22–1.37		0.32	
Jeddah and Riyadh, Saudi Arabia	0.03–0.04	No change	None	Na
Damascus, Syria (2009)	0.06–0.17	–30%	0.02	No change
Tunis, Tunisia	0.29–0.39	+5.1%	0.09	No change
Dubai, United Arab Emirates (2009)	2.15–2.50	No change	0.36	Separate tariff only in 2010

Note: Data from Global Water Intelligence (2010) are in US$. Trends however are in nominal terms.
Na = Not applicable.
[a]Reported trend is for lowest consumption block only.

several plantings in a year, which is very important especially for arid area such as the Middle East [36].

5. Solutions to improve and increase the use of wastewater effluent

Activities related to the reuse of wastewater mainly depend on national economy and infrastructure and capacity of wastewater treatment facilities. Other factors can be: level of education, climate, water resources, balancing water demand and consumption, agricultural activity, population, and social behaviors such as religious and cultural prejudice. However, in the following section, methods of improving wastewater reuse in the Middle East are suggested.

5.1. The use of local standards

Most developing countries employ low-risk guidelines or standards based on high-tech and high-cost methods, whereas many others have adopted their own guidelines based on WHO guidelines that can be achieved with low-cost techniques and focus on health risks [57]. Hence, these countries can facilitate reuse of greater volumes of wastewater. Furthermore, these countries can perform comprehensive monitoring studies about local standards with regard to climate, culture, and social situations.

5.2. Promoting and modifying treatment facilities to improve quality

As noted above, on the basis of Table 3, lack of treatment capacity at an appropriate level and overloading are major problems in many wastewater treatment plants. The most fundamental need is to re-equip and upgrade the facilities. There are various reasons behind the need to improving and upgrading the facilities, e.g., the end of equipment's life, increase in the inlet flow or loading, changes in legal standards, weather, and cold seasons [58–60].

Biological wastewater treatment processes are normally divided into suspended and attached growth types. However, the most common process for municipal wastewater treatment in developing and developed countries is activated sludge. Although it is believed that removal of certain pollutants will improve the development of surface area of wastewater treatment plants, this can also be done by upgrading the overloaded activated sludge systems [61,62].

Area development can be performed in areas where there are no restrictions in terms of land prices, such as in rural and low-populated areas. On the other hand, treatment plant upgrading can be chosen in areas with high land prices and no possibility for area development. Even so, in the most sparsely populated areas of the Middle East, the prevalent method of wastewater disposal is dry wells; however, treatment plants have been used in densely populated places and urban areas. Therefore, it can be concluded that one of the most important strategies for a better wastewater reuse can be upgrading of treatment plants.

Around the whole world, and consequently in the Middle East, the most common process is conventional activated sludge. Several full- and lab-scale studies have been conducted to introduce different methods for upgrading existent treatment plants. Some of these

Table 8
Typology of MENA countries according to reuse situation

Cases	Case 1: Limited or unplanned reuse only	Case 2: Extensive mixing of recycled water	Case 3: Targeted provision of recycled water
Countries	Unplanned: Egypt, Syria, Morocco, Yemen Limited: Bahrain, Iraq, Iran, Lebanon, Libya, Tunisia	Jordan	Few schemes in Tunisia Heavily subsidized: Qatar, Kuwait, Oman, Saudi Arabia, UAE

methods include the use of lime powder, talcum powder, and changing mechanical aeration to micro-bubble diffuser systems [63–65]. However, systems with high cost-effectiveness are required in the Middle East because of financial problems. Systems recommended for this area, especially compatible with the conventional activated sludge process, are membrane bioreactor (MBR), upflow anaerobic sludge blanket (UASB), integrated fixed-film activated sludge (IFAS), moving bed biofilm reactor (MBBR), and others [35,58,66–68].

In order to have a better effluent quality from wastewater treatment plants, new technologies are being used in this field that makes the treated wastewater more applicable for many reuse purposes [68–71].

5.3. Quantitative development of wastewater reuse by improving the collection systems

Wastewater collection systems in many Middle Eastern countries are not in good conditions, and a high percentage of raw wastewater will be disposed into the dry wells. These wells have the potential for contaminating water resources. Furthermore, a high volume of wastewater, which can be recovered, will be spent out of the reach of people [72]. Because of low average rainfall and water shortage in the Middle East, improving wastewater collection systems provides an opportunity to revive water resources, develop wastewater reuse, and move forward on the path to sustainable development.

Countries such as Tunisia and Jordan have policies in place that address wastewater treatment through a range of instruments. Policymakers in these countries consider the use of treated wastewater to be an essential aspect of strategic water and wastewater planning and management. As shown in Table 8, with flexible policy frameworks addressing rapid demographic changes and increasing water scarcity in the Middle East and North Africa (MENA) region, water reuse has a great potential if integrated with resource planning, environmental management, and financing arrangements [34,53].

Saudi Arabia has created the National Water Company (NWC) to invest $23 billion into Saudi Arabia's sewage collection and treatment infrastructure over the following 2 decades and aims to increase wastewater network coverage to 100% through public–private partnership [73]. Consequently, Saudi Arabia is anticipated to become the third largest water reuse market in the world after the USA and China [73].

5.4. Modification of policies in management of water resources and wastewater reuse

Modification of water pricing policy could help the development of highly efficient agriculture and reduce water consumption. Optimizing agricultural water use has also been found effective in decreasing water needs at the national level. In comparison, reducing the water demand in agriculture by 5% can lead to a 4.2% reduction in the total water demand, while 5% reduction of the drinking water demand brings about only 0.7% reduction in the total water demand [18].

Policies related to national standards and legislation should be amended. National laws preventing discharge of wastewater into water bodies can be the driving force behind the development of wastewater management. Moreover, regional and international organizations should have the ability to apply the law on offending countries in case of pollution of the seas and gulfs. In addition, regional and international motivational policies can facilitate the development of wastewater reclamation. Furthermore, the attitude toward wastewater must be changed to a valuable commodity, especially in countries that face water crisis, because, on a global scale, regions with higher precipitation rates tend to recover wastewater, while dry areas are unfortunately less likely to pay attention [19].

6. Conclusion

One of the most useful factors in the sustainable development of water resources, especially in areas such as the Middle East, is wastewater reuse or, in other words, wastewater reclamation. Wastewater recovery in the Middle East is limited and faces various problems. One of the issues affecting development in reuse of wastewater is mismanagement and lack of appropriate management approaches. If policy makers change their approach to wastewater from a discarded material to a valuable commodity, substantial developments will occur within this area. Due to lack of proper operation of well-designed wastewater treatment plants, training operators and also improving and promoting wastewater treatment processes can be an effective step to improve the situation of wastewater reuse. The authors recommend that future studies be conducted about upgrading wastewater treatment systems with appropriate cost-effective processes, performance evaluation of standards, and designation of standards based on the climatic conditions of the region, the culture, and social status.

Acknowledgment

First of all, the authors would like to thank all the publisher providing the data and information in the tables and graphs. The authors want to thank authorities of Tehran University of Medical Sciences and Neyshabur University of Medical Sciences for their comprehensive support for this study.

References

[1] J. Butlin, Our Common Future, Report of the World Commission on Environment and Development, Oxford University Press, London, 1987, p. 383.
[2] C.-L. Huang, J. Vause, H.-W. Ma, C.-P. Yu, Using material/substance flow analysis to support sustainable development assessment: a literature review and outlook, Resour. Conserv. Recycl., 68 (2012) 104–116.
[3] C.J. Vörösmarty, P. Green, J. Salisbury, R.B. Lammers, Global water resources: vulnerability from climate change and population growth, Science, 289 (2000) 284–288.
[4] S.M. Mortazavi, K. Soleimani, M.F. Ghafari, Water Resource Management and Land Sustainable, The Case Study in Rafsanjan in Iran, Water and Wastewater, 22 (2011) 126–131.
[5] J. Kirkegaard, J. Hunt, T. McBeath, J. Lilley, A. Moore, K. Verburg, M. Robertson, Y. Oliver, P. Ward, S. Milroy, Improving water productivity in the Australian Grains industry—a nationally coordinated approach, Crop Pasture Sci., 65 (2014) 583–601.
[6] S. Gössling, P. Peeters, C.M. Hall, J.-P. Ceron, G. Dubois, D. Scott, Tourism and water use: supply, demand, and security. An international review, Tourism Manage., 33 (2012) 1–15.
[7] R.L. Wesson, Interpretation of changes in water level accompanying fault creep and implications for earthquake prediction, J. Geophys. Res. B: Solid Earth, 86 (1981) 9259–9267.
[8] C. Chen, R. Wu, S. Liaw, W. Sue, I. Chiou, A study of water-land environment carrying capacity for a river basin, Water Sci. Technol., 42 (2000) 389–396.
[9] C. Bao, C.-l. Fang, Water resources constraint force on urbanization in water deficient regions: a case study of the Hexi Corridor, arid area of NW China, Ecol. Econ., 62 (2007) 508–517.
[10] Y. Kataoka, Overview Paper on Water for Sustainable Development in Asia and the Pacific, Asia-Pacific Forum for Environment and Development, Bangkok, Thailand, 2002.
[11] I. Mariolakos, Water resources management in the framework of sustainable development, Desalination, 213 (2007) 147–151.
[12] A. Mahvi, H. Karyab, Risk assessment for microbial pollution in drinking water in small community and relation to diarrhea disease, Am. Eurasian J. Agric. Environ. Sci., 2 (2007) 404–406.
[13] C. Giupponi, J. Mysiak, A. Fassio, V. Cogan, MULINO-DSS: a computer tool for sustainable use of water resources at the catchment scale, Math. Comput. Simul., 64 (2004) 13–24.
[14] K. Brumbelow, A. Georgakakos, Optimization and assessment of agricultural water-sharing scenarios under multiple socioeconomic objectives, J. Water Resour. Plann. Manage., 133 (2007) 264–274.
[15] X. Ni, Y. Wu, J. Wu, J. Lu, P.C. Wilson, Scenario analysis for sustainable development of Chongming Island: water resources sustainability, Sci. Total Environ., 439 (2012) 129–135.
[16] O. Zimmo, N. Imseih, Overview of Wastewater Management Practices in the Mediterranean Region, Waste Water Treatment and Reuse in the Mediterranean Region, Springer, Berlin, Heidelberg, 2010, pp. 155–181.
[17] N. Looker, Municipal Wastewater Management in Latin America and the Caribbean: A Discussion Paper on Trends, Challenges and the Market, Canadian Environment Industry Association, The Round Table on Municipal Water, Vancouver, Canada, 1998.
[18] I.K. Kalavrouziotis, P. Kokkinos, G. Oron, F. Fatone, D. Bolzonella, M. Vatyliotou, D. Fatta-Kassinos, P.H. Koukoulakis, S.P. Varnavas, Current status in wastewater treatment, reuse and research in some Mediterranean countries, Desal. Wat. Treat., 53 (2015) 2015–2030.
[19] M. Kellis, I. Kalavrouziotis, P. Gikas, Review of wastewater reuse in the Mediterranean countries, focusing on regulations and policies for municipal and industrial applications, Global NEST J., 15 (2013) 333–350.
[20] P.H. Gleick, Water, war & peace in the Middle East, Environment, 36 (1994) 6–42.
[21] T.M. Yousef, Development, growth and policy reform in the Middle East and North Africa since 1950, J. Econ. Perspect., 18 (2004) 91–115.
[22] D. Fatta, S. Anayiotou, MEDAWARE project for wastewater reuse in the Mediterranean countries: an innovative compact biological wastewater treatment system for promoting wastewater reclamation in Cyprus, Desalination, 211 (2007) 34–47.
[23] A. Al-Omari, M. Fayyad, Treatment of domestic wastewater by subsurface flow constructed wetlands in Jordan, Desalination, 155 (2003) 27–39.
[24] M. Guardiola-Claramonte, T. Sato, R. Choukr-Allah, M. Qadir, Wastewater Production, Treatment and Reuse around the Mediterranean Region: Current Status and Main Drivers, Integrated Water Resources Management in the Mediterranean Region, Springer, Netherlands, 2012, pp. 139–174.
[25] E. Oluyemi, G. Feuyit, J. Oyekunle, A. Ogunfowokan, Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria, Afr. J. Environ. Sci. Technol., 2 (2008) 89–96.
[26] Rosen, Carol, L. Roberts, Eds., A Guide to World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life, World Resources Institute, Washington, D.C., USA, 2000.
[27] C. Kfouri, P. Mantovani, M. Jeuland, Water Reuse in the MNA Region: Constraints, Experiences, and Policy Recommendations, N.V. Jagannathan, A.S. Mohamed, A. Kremer, Eds., Water in the Arab World: Management Perspectives and Innovations, Duke Global Health Institute, Duke University, Durham, USA, and Institute of Water Policy, National University of Singapore, Singapore 2009, pp. 447–477.
[28] World Health Organization, A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005.
[29] Y. Özoguz, Efficient Management of Wastewater: Its Treatment and Reuse in the Mediterranean Countries EMWater E-learning Course Summary, Project Funded by the European Union.
[30] I.K. Kalavrouziotis, S. Rezapour, P.H. Koukoulakis, Wastewater status in Greece and Iran, Fresen. Environ. Bull., 22 (2013) 11–21.
[31] H. Yang, L. Wang, K.C. Abbaspour, A.J. Zehnder, Virtual water trade: an assessment of water use efficiency in the international food trade, Hydrol. Earth Syst. Sci. Discuss., 10 (2006) 443–454.
[32] J. Van Lier, P. Seeman, G. Lettinga, Decentralized Urban Sanitation Concepts: Perspectives for Reduced Water Consumption and Wastewater Reclamation for Reuse, EP&RC Foundation, Sub-Department of Environmental Technology, Agricultural University, Wageningen, The Netherlands, 1998.
[33] A. Mahvi, E. Kia, Helminth eggs in raw and treated wastewater in the Islamic Republic of Iran, East. Mediterr. Health J., 12 (2006) 137–143.
[34] M. Qadir, A. Bahri, T. Sato, E. Al-Karadsheh, Wastewater production, treatment, and irrigation in Middle East and North Africa, Irrig. Drain. Syst., 24 (2010) 37–51.
[35] H. Hazrati, J. Shayegan, Upgrading activated sludge systems and reduction in excess sludge, Bioresour. Technol., 102 (2011) 10327–10333.
[36] B. Jiménez, Irrigation in developing countries using wastewater, Int. Rev. Environ. Strat., 6 (2006) 229–250.
[37] M. Pescod, Wastewater Treatment and Use in Agriculture, Food and Agriculture Organization of the United Nations, Rome, 1992.
[38] K. Naddafi, R. Nabizadeh, R. Saeedi, A.H. Mahvi, F. Vaezi, K. Yaghmaeian, A. Ghasri, S. Nazmara, Biosorption of lead(II) and cadmium(II) by protonated *Sargassum glaucescens* biomass in a continuous packed bed column, J. Hazard. Mater., 147 (2007) 785–791.
[39] A.C. Chang, G. Pan, A.L. Page, T. Asano, Developing Human Health-related Chemical Guidelines for Reclaimed Waster and Sewage Sludge Applications in Agriculture, World Health Organization, Geneva, Switzerland, 2002, p. 105.

[40] H.-B. Lee, T.E. Peart, Organic contaminants in Canadian municipal sewage sludge. Part I. Toxic or endocrine-disrupting phenolic compounds, Water Qual. Res. J. Can., 37 (2002) 681–696.
[41] H. Karyab, M. Yunesian, S. Nasseri, A.H. Mahvi, R. Ahmadkhaniha, N. Rastkari, R. Nabizadeh, Polycyclic aromatic hydrocarbons in drinking water of Tehran, Iran, J. Environ. Health Sci. Eng., 11 (2013) 25–29.
[42] A. Fadaei, M.H. Dehghani, S. Nasseri, A.H. Mahvi, N. Rastkari, M. Shayeghi, Organophosphorous pesticides in surface water of Iran, Bull. Environ. Contam. Toxicol., 88 (2012) 867–869.
[43] J. Nouri, A.H. Mahvi, R. Saeedi, K. Dindarloo, M. Rafiee, S. Dobaradaran, Purification and removal of *Ascaris* and *Fasciola* hepatica eggs from drinking water using roughing filters, Korean J. Chem. Eng., 25 (2008) 501–504.
[44] R. Bratton, R. Nesse, Ascariasis: an infection to watch for in immigrants, Postgrad. Med., 93 (1993) 171–178.
[45] N. de Silva, M. Chan, D. Bundy, Morbidity and mortality due to ascariasis: re-estimation and sensitivity analysis of global numbers at risk, Trop. Med. Int. Health, 2 (1997) 519–528.
[46] U.J. Blumenthal, A. Peasey, Critical Review of Epidemiological Evidence of the Health Effects of Wastewater and Excreta Use in Agriculture, World Health Organization, Geneva, 2002 (Unpublished Document). Available at: www.who.int/water_sanitation_health/wastewater/whocriticalrev.pdf
[47] P.F. Sale, D.A. Feary, J.A. Burt, A.G. Bauman, G.H. Cavalcante, K.G. Drouillard, B. Kjerfve, E. Marquis, C.G. Trick, P. Usseglio, The growing need for sustainable ecological management of marine communities of the Persian Gulf, Ambio, 40 (2011) 4–17.
[48] P.-e. Darya, Water Pollution in the Persian Gulf and the Caspian Sea, The Shipping Organization of the Islamic Republic of Iran, 1995, pp. 13–20.
[49] R. Mirza, M. Mohammadi, A.D. Sohrab, A. Safahieh, A. Savari, P. Hajeb, Polycyclic aromatic hydrocarbons in seawater, sediment, and rock oyster *Saccostrea cucullata* from the northern part of the Persian Gulf (Bushehr Province), Water Air Soil Pollut., 223 (2012) 189–198.
[50] S. Dobaradaran, A.H. Mahvi, R. Nabizadeh, A. Mesdaghinia, K. Naddafi, M. Yunesian, N. Rastkari, S. Nazmara, Hazardous organic compounds in groundwater near Tehran automobile industry, Bull. Environ. Contam. Toxicol., 85 (2010) 530–533.
[51] M. Ghoochani, S. Shekoohiyan, A. Mahvi, B. Haibati, M. Norouzi, Determination of detergent in Tehran ground and surface water, Am Eurasian J. Agric. Environ. Sci., 10 (2011) 464–469.
[52] J.H. Ensink, W. Van Der Hoek, Y. Matsuno, S. Munir, M.R. Aslam, Use of Untreated Wastewater in Peri-urban Agriculture in Pakistan: Risks and Opportunities, International Water Management Institute (IWMI), Colombo, Sri Lanka, 2002.
[53] M. Jeuland, Challenges to wastewater reuse in the Middle East and North Africa, Middle East Dev. J., 7 (2015) 1–25.
[54] N. Yanqiu, Diverting municipal domestic sewage nearby to irrigate the forest for harnessing desert and preventing desertification, Tech. Equip. Environ. Pollut. Control, 6 (2003) 21.
[55] A. Pombo, A. Breceda, A. Valdez Aragón, Desalinization and wastewater reuse as technological alternatives in an arid, tourism booming region of Mexico, Frontera norte, 20 (2008) 191–216.
[56] X. Liu, X. Yua, K. Yu, The current situation and sustainable development of water resources in China, Procedia Eng., 28 (2012) 522–526.
[57] I. Arslan-Alaton, A. Tanik, S. Ovez, G. Iskender, M. Gurel, D. Orhon, Reuse potential of urban wastewater treatment plant effluents in Turkey: a case study on selected plants, Desalination, 215 (2007) 159–165.
[58] C. Brepols, E. Dorgeloh, F.-B. Frechen, W. Fuchs, S. Haider, A. Joss, K. de Korte, C. Ruiken, W. Schier, H. van der Roest, Upgrading and retrofitting of municipal wastewater treatment plants by means of membrane bioreactor (MBR) technology, Desalination, 231 (2008) 20–26.
[59] Y. Rahimi, A.H. Mahvi, A. Mesdaghinia, Process optimization of Khoy wastewater treatment plant aerated lagoons in cold climate conditions, Water and Wastewater, 17 (2006) 70–75.
[60] A. Mahvi, A. Mesdaghinia, R. Saeedi, Upgrading an existing wastewater treatment plant based on an upflow anaerobic packed-bed reactor, J. Environ. Health Sci. Eng., 4 (2007) 229–234.
[61] H. Andersen, H. Siegrist, B. Halling-Sørensen, T.A. Ternes, Fate of estrogens in a municipal sewage treatment plant, Environ. Sci. Technol., 37 (2003) 4021–4026.
[62] H. Schaar, M. Clara, O. Gans, N. Kreuzinger, Micropollutant removal during biological wastewater treatment and a subsequent ozonation step, Environ. Pollut., 158 (2010) 1399–1404.
[63] M.K. Stenstrom, Upgrading existing activated sludge treatment plants with fine pore aeration systems, Water Sci. Technol., 22 (1990) 245–251.
[64] J. Cantet, E. Paul, F. Clauss, Upgrading performance of an activated sludge process through addition of talqueous powder, Water Sci. Technol., 34 (1996) 75–83.
[65] P. Chudoba, M. Pannier, Use of powdered clay to upgrade activated sludge process, Environ. Technol., 15 (1994) 863–870.
[66] G. Mannina, G. Viviani, Hybrid moving bed biofilm reactors: an effective solution for upgrading a large wastewater treatment plant, Water Sci. Technol., 60 (2009) 1103–1116.
[67] J. Jafari, A. Mesdaghinia, R. Nabizadeh, M. Farrokhi, A.H. Mahvi, Investigation of anaerobic fluidized bed reactor/aerobic moving bed bio reactor (AFBR/MMBR) system for treatment of currant wastewater, Iran. J. Public Health, 42 (2013) 860–867.
[68] A. Naghizadeh, A. Mahvi, F. Vaezi, K. Naddafi, Evaluation of hollow fiber membrane bioreactor efficiency for municipal wastewater treatment, J. Environ. Health Sci. Eng., 5 (2008) 257–268.
[69] A. Mahvi, Sequencing batch reactor: a promising technology in wastewater treatment, J. Environ. Health Sci. Eng., 5 (2008) 79–90.
[70] A. Naghizadeh, A. Mahvi, A. Mesdaghinia, M. Alimohammadi, Application of MBR Technology in Municipal Wastewater Treatment, Arab. J. Sci. Eng., 36 (2011) 3–10.
[71] A. Mesdaghinia, A. Mahvi, R. Saeedi, H. Pishrafti, Upflow Sludge Blanket Filtration (USBF): an innovative technology in activated sludge process, Iran. J. Public Health, 39 (2010) 7.
[72] H. Heinonen-Tanski, R. Savolainen, Disinfection of septic tank and cesspool wastewater with peracetic acid, Ambio, 32 (2003) 358–361.
[73] G. Saudi, Mideast Steps up Drive for Water Reuse Technologies: Kingdom Third Largest Consumer of Water, The Saudi Gazette, Jeddah, 2010.