A regional overview of wastewater management and reuse in the Eastern Mediterranean Region

World Health Organization
Regional Office for the Eastern Mediterranean
Regional Centre for Environmental Health Activities
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1. Introduction

This publication is intended to delineate the status of wastewater management and reuse in the Eastern Mediterranean Region. It was prepared in response to a request by the Centre for Environmental Health Activities (CEHA) with the objective of compiling as much pertinent information and data as possible. Professional individuals submitted profiles of wastewater management and reuse in their respective countries. Country reports were presented for Egypt, Jordan, Morocco, Sudan, the Syrian Arab Republic and Tunisia, forming a foundation for the work. Information and data on other countries were included whenever possible, although the availability of such information was generally scarce, reflecting the lack of attention usually given to the wastewater sector in the majority of countries in the Region.

A brief summary of the demographic, geographic and economic features of the Region has been presented to stress the influence of population dynamics on wastewater management and reuse. About half a billion people live in the Region and population growth rates are among the highest in the world. Increasing urbanization, incomes and populations are imposing strains on the environment and the finite natural resources, particularly freshwater. Economically there are great variations among countries; at one end of the spectrum there are the prosperous oil-producing countries with gross domestic product averages comparable to those in industrialized countries, and at the other end there are countries that may be considered amongst the poorest in the world, such as Afghanistan and Somalia. Such economic conditions can impose strong limitations on the ability of nations and individuals to provide for appropriate wastewater management.

Most countries in the Region are classified as being semi-arid with dry and desert ecosystems. Average annual rainfall is so low that irrigation is necessary in the majority of countries of the Region. Consequently, freshwater availability is low with the average per capita share very much less than the world average. This makes water scarcity one of the most daunting challenges confronting the Region at present. The situation is likely to be exacerbated in the future if no drastic measures are taken to institute proper water supply and demand management practices. This indicates that in the national water budgets of these countries wastewater should be considered a resource rather than a waste. Furthermore, the objective of wastewater management in most countries should surpass the conventional aims of health and environmental protection; instead the aim should be to utilize treated effluents as a valuable resource that can augment national water resources.

In the Region a relatively large number of people lack access to improved water supplies and there are even more without improved sanitation facilities. The number of people who gained access to these services during the last decade has generally been less than the increase in the number of the population in most countries. Normally, priority has been given to the provision of water supplies over sanitation. The situation is relatively much harder in the rural areas compared with the urban ones. Lack of such provision has been cited in many countries as the one major obstacle hindering effluent reuse potential.

Overall sewerage coverage is modest in most countries of the Region due to the high costs involved. Poorly managed cesspools are the most common alternative for wastewater disposal. This has been a cause for concern as seepage from cesspools has contaminated scarce freshwater resources and created several negative health and environmental impacts. Moreover, reuse of water is a lost opportunity as wastewater is buried away in these pits so that the amount of wastewater collected and treated makes up a small percentage of the generated quantities, as do the reused amounts. Compared with agricultural withdrawals in the Region, water reuse quantities constitute very small percentages.

Wastewater management and reuse in Bahrain, Egypt, Islamic Republic of Iran, Jordan, Kuwait, Lebanon, Morocco, Saudi Arabia, Sudan, Syrian Arab Republic and Tunisia are discussed in some detail. However, little relevant information could be found on the remaining countries. The report ends with a list of conclusions and recommendations deemed necessary to improve wastewater management and reuse in the Region.

2. Demographic, geographic and economic indicators in the Eastern Mediterranean Region.

The population of the Eastern Mediterranean Region was estimated at 501 507 000 people in the year 2003, constituting about 8% of the total population of the world. The population growth rate for the area averaged at about 3.27% (2.73% if the population growth rate of the United Arab Emirates of 14.1%, is excluded), ranging from 1.1% in Tunisia to 14.1% in the United Arab Emirates (5.5% in Djibouti if the United Arab Emirates is excluded), with seven countries exceeding 3% (Table 1). The world's average rate is 1.25% and the equivalent rate in Europe is minus 0.1% [1]. Urban dwellers comprise an average of 64.7% of the population in the Region with the relatively smaller and more affluent countries having higher urbanization percentages; for example it is 100% in Bahrain, Kuwait and Qatar. Urban percentages are much less in lower income countries of the Region, such as Afghanistan and Somalia (25%) and Yemen (27%) respectively.

The total number of the population is a crucial parameter influencing water availability and wastewater generation. Population projections until 2025 (Figure 1) indicate that great challenges lie ahead in the Region to provide basic human needs for water and sanitation.

Table 1. Demographic characteristics of countries of the Eastern Mediterranean Region in 2003

Country	**Populations (2003)**		**Population growth rate**		**Infant mortality**		**Life expectancy**	
	Total (000)	Urban **(%)**			**(Per 1000 live births)**			
			%	**Year**	**Rate**	**Year**	**Years**	**Year**
Afghanistan	22 140	25	2.5	1996	165.0	1997	44.7	2000
Bahrain	689	100	2.7	2001	7.3	2003	73.8	2003
Djibouti	751	80	5.5	1996	102.0	2002	44.1	2000
Egypt	67 981	42	2.0	2003	23.2	2003	70.1	2003
Iran, Islamic Republic of	65 540	66	1.2	2002	28.6	2000	69.0	2000
Iraq	26 340	67	2.7	2002	107.0	2003	63.2	2000
Jordan	5 480	79	2.8	2003	22.1	2003	71.5	2003
Kuwait	2 484	100	5.1	2003	9.6	2002	78.4	2002
Lebanon	4 314	85	1.6	1997	27.0	2000	71.3	2000
Libyan Arab Jamahiriya	5 484	85	2.9	2002	24.4	2001	69.5	2001
Morocco	30 088	57	1.5	2003	36.6	1997	69.5	1999
Oman	2 538	75	2.2	2002	16.2	2002	73.8	2002
Pakistan	149 030	34	1.9	2003	82.0	2002	63.6	2002
Palestine [a]	3 738	59	2.4	2003	24.0	2003	72.3	2003
Qatar	616	100	3.2	2002	8.7	2002	74.7	2002
Saudi Arabia	21 890	85	3.3	2003	19.1	2001	71.4	1996
Somalia	7 852	25	3.4	2003	120.0	2003	47.0	1997
Sudan	33 648	36	2.6	2002	68.0	1999	56.6	2000
Syrian Arab Republic	17 765	50	2.5	2003	18.1	2003	71.5	2002
Tunisia	9 890	68	1.1	2002	22.8	2001	73.0	2002
United Arab Emirates	3 754	79	14.1	2002	8.1	2002	72.6	2002
Yemen	19 495	27	3.5	2001	67.4	2000	62.9	2002
EMR	501 507	–	3.27 (2.73) b	–	–	–	–	–
World	6 157 401	–	1.25	–	–	–	–	–

[a] Under the Palestinian National Authority; another 9.5 million reside in Arab countries, Israel and other non-Arab countries.

[b] Average excluding the United Arab Emirates. Source: [1]

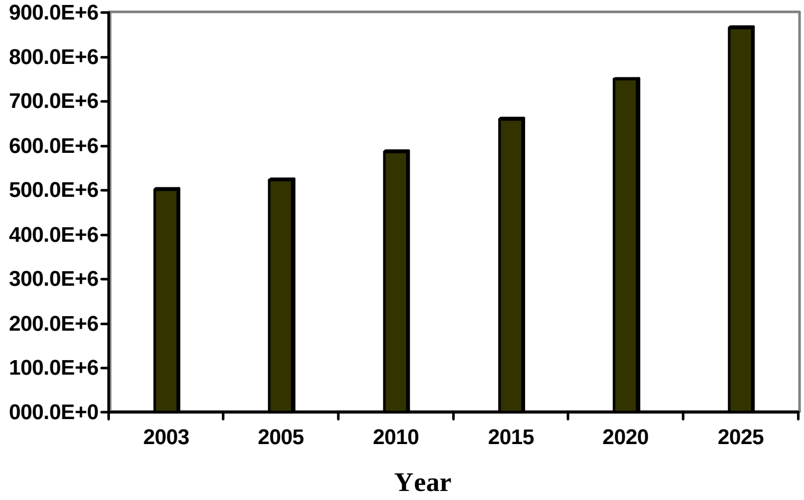


Figure 1. Population growth in the Eastern Mediterranean Region (2003–2005)

Infant mortality rates refer to the number of infants who die below the age of 1 year. They reflect the capability of a nation to take care of its people, particularly newly born babies. The average infant mortality rate in the Region is estimated at 45.8 per 1000 live births. The highest rate is in Afghanistan (165.0) and the lowest is in Bahrain (7.3). For reasons of comparison, the equivalent rates in industrialized countries are 5.0 in Japan and 4.0 in Sweden. The global infant mortality rate was 52.61 deaths per 1000 live births in 2001 [1].

Life expectancy varies from one nation to another depending primarily on public health status and the standard of living. The average in the Region is 66.7 years with the lowest being in Djibouti at 44.1 years. Life expectancy in developed countries can reach up to 82 years as in Sweden and Switzerland [1].

The total area of the Region is estimated at 13 180 998 square kilometres with the land area constituting 98.5% and water only 1.5%. The arable part of the land averages 9.52% and varies greatly, from 0% in Djibouti, Kuwait, Oman and the United Arab Emirates to a maximum of 28% in the Syrian Arab Republic. Irrigated areas are relatively small totalling 386 914 square kilometres. The Region has an average of 21.2% permanent pasture, ranging from zero in Egypt to 69% in Somalia. The world average is 26% [3]. Forests and woodland in the Region make up a mere 4.91% compared with a world average of 32%. This clearly shows the arid to semi-arid nature of the Region (Table 2).

The economic performance of a country is often indicated by its gross national product, which refers to the production of all goods and services produced by a country during a certain period of time excluding production by foreign-owned facilities within the country (1).

Average gross national product in the Region is estimated as US$ 5419 (Table 3), ranging from US$ 160 in Afghanistan to US$ 28 270 in Qatar. Excluding the oil-rich countries (Bahrain, Islamic Republic of Iran, Kuwait, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia and United Arab Emirates) the average gross national product becomes US$ 1148. The world average was US$ 7200 in 2001 [2].

The gross national product contribution in the Region by the economic sectors of agriculture, industry and services averaged 15% (0%–60%), 32% (10%–55%) and 53% (19%–81%) respectively. Lower income nations have higher percentages in the agricultural sector, for example Afghanistan (53%) and Somalia (60%), while the more affluent ones have higher percentages in the service sector and industrial sectors (Table 3).

Table 2. Area and land use in the Eastern Mediterranean Region

Country	Area (km²)			Land use (percentage)					Irrigated land
	Total	Land	Water	A	PC	PP	FW	Other	Km²
Afghanistan	647 500	647 500	0	12	0	46	3	39	30
Bahrain	620	620	0	1	1	6	0	93	10
Djibouti	22 000	21 980	20	0	0	9	0	91	ND
Egypt	1 001 450	995 450	6 000	2	0	0	0	98	32 460
Iran, Islamic Republic of	1 648 000	1 636 000	12 000	10	1	27	7	55	94 000
Iraq	437 072	432 162	4 910	12	0	9	0	79	25 500
Jordan	92 300	91 971	329	4	1	9	1	85	630
Kuwait	17 820	17 820	0	0	0	8	0	92	20
Lebanon	10 400	10 230	170	18	9	1	8	64	860
Libyan Arab Jamahiriya	1 759 540	1 759 540	0	1	0	8	0	91	4 700
Morocco	446 550	446 300	250	21	1	47	20	11	12 580
Oman	212 460	212 460	0	0	0	5	0	95	580
Pakistan	803 940	778 720	25 220	27	1	6	5	61	171 100
Palestine: West Bank	5 860	5 640	220	27	0	32	1	40	ND
Gaza Strip	360	360	0	24	39	0	11	26	120
Qatar	11 437	11 437	0	1	0	5	0	94	80
Saudi Arabia	1 960 582	1 960 582	0	2	0	56	1	41	4 350
Somalia	637 657	627 337	10 320	2	0	69	26	3	1 00
Sudan	2 505 810	2 376 000	129 810	5	0	46	19	30	19 460
Syrian Arab Republic	185 180	184 050	1 130	28	4	43	3	22	9 060
Tunisia	163 610	155 360	8 250	19	13	20	4	44	3 850
United Arab Emirates	82 880	82 880	0	0	0	2	0	98	50
Yemen	527 970	527 970	0	3	13	33.5	4	46.5	5 674
EMR	131 180 998	12 982 369	198 629	10	4	21	5	61	386 914
World	510 072 000	148 940 000	361 132 000	10	1	26	32	31	2 481 250

Source: [1,2,3]

ND, not determined

A: arable

PC: permanent crops

PP: permanent pastures

Table 3. Gross national product and composition percentage by economic sectors in the Eastern Mediterranean Region

Country	Gross national product				
	Per capita [a]		Composition by sector (percentage)		
	US$	Year	Agriculture	Industry	Services
Afghanistan	160	1990	53	29	19
Bahrain	12 564	2002	1	46	53
Djibouti	805	1999	3	22	75
Egypt	1 258	1999	17	32	51
Islamic Republic of Iran	1 140	2002	24	28	48
Iraq	1 200	2001	6	13	81
Jordan	1 656	2001	3	25	72
Kuwait	17 031	2001	0	55	45
Lebanon	4 000	1999	12	27	61
Libyan Arab Jamahiriya	8 220	1998	7	47	46
Morocco	1 310	1999	15	33	52
Oman	7 637	2002	3	40	57
Pakistan	492	2003	25	25	50
Palestine	1 020	2003	9	28	63
Qatar	28 270	2002	1	49	50
Saudi Arabia	8 485	2002	6	47	47
Somalia	168	1995	60	10	30
Sudan	282	1998	39	17	44
Syrian Arab Republic	1 170	2003	29	22	49
Tunisia	2 075	2002	14	32	54
United Arab Emirates	19 800	2001	3	52	45
Yemen	473	2003	20	42	38
EMR	5 419	–	15	32	53
World	7 200	–	4	32	64

Source: a [2,3]

From this demographic, geographic and economic data it may be concluded that the population growth rate is high, urbanization on the increase and agriculture on the decline, thereby increasing the necessity for more food imports. Economically, however, there are huge differences in the Region with the wealthier countries enjoying high living standards, comparable to those of industrialized nations and others being classified among the least developed countries of the world.

3. Water supply and sanitation

3.1 Renewable water resources

The amount of precipitation in any one country determines, to a large extent, its freshwater resources. Regions with high regular precipitation rates normally have plenty of surface and groundwater. For example, the United States of America (USA) is rich in water resources since the overall annual precipitation averages at 760 millimetres. However, large parts of the western region receive less than 250 millimetres, which makes irrigation a necessity without which little grass and few shrubs could grow.

For the majority of countries of the Eastern Mediterranean Region, which lie in the arid to semi-arid area, precipitation is even less than that in the western region of the United States. The mean of long-term annual average precipitation is estimated at 227 millimetres, ranging from as low as 18 millimetres in Egypt to 827 millimetres in Lebanon (Figure 2).

Rainfall variation within any one country can be high in time and place. In Jordan, for instance, annual rainfall ranges from 50 millimetres in the eastern and southern desert regions to as high as 650 millimetres in the northern highlands. More than 90% of Jordan has less than 200 millimetres of the annual rainfall. In Morocco, where the long-term annual average is 336 millimetres, 50% of the rainfall occurs over 15% of the country with the northern region receiving more than 450 millimetres and the southeast having less than 150 millimetres. Another example is the Islamic Republic of Iran where annual precipitation ranges from less than 50 millimetres in the deserts to more than 1600 millimetres on the Caspian Plain, with about two thirds of the country having an annual rainfall of less than 250 millimetres.

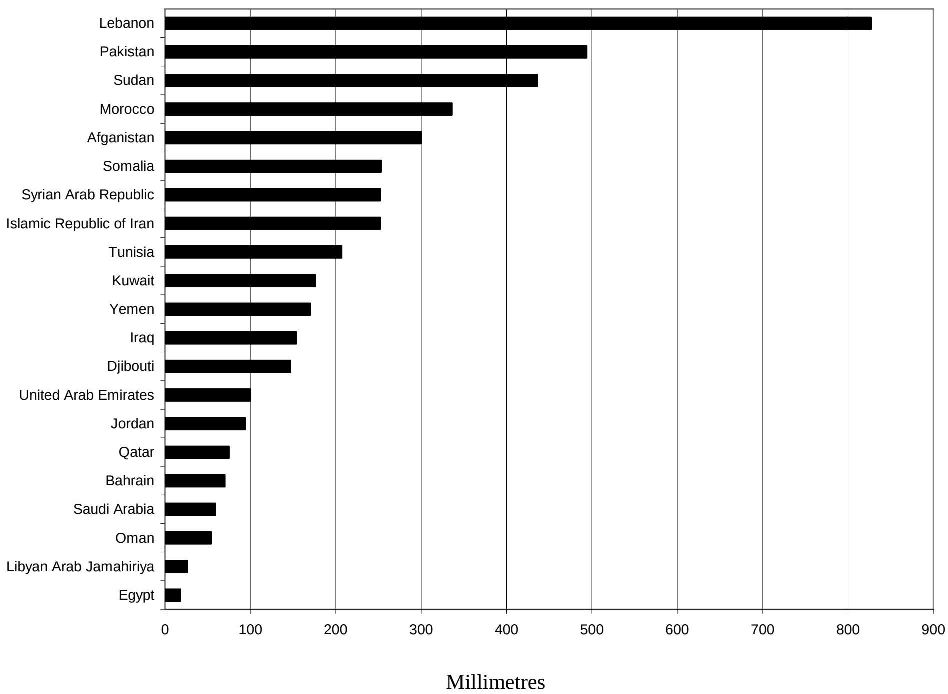


Figure 2. Average annual precipitation in Eastern Mediterranean countries [4]

This low and uneven distribution of rainfall is the main reason for the scarcity and irregular availability of the internal freshwater resources of the majority of countries in the Region. It has forced many countries to consider conveying water from areas having a water surplus to those in need. This means, inter alia, increasing the cost of water provision for domestic use, but more critically perhaps for irrigation uses. Other countries, for example, Jordan, the West Bank and Gaza and Yemen, have stretched their groundwater resources well beyond replenishment rates to satisfy increasing demands, while still others, for example Egypt, Jordan, the Libyan Arab Jamahiriya, Saudi Arabia, and Tunisia, have tapped non-renewable (fossil) groundwater resources. Annual freshwater withdrawals have exceeded the total renewable resources in many countries of the Region.

Droughts are another problem seriously affecting freshwater availability. Drought, defined as a substantial decrease below long-term average rainfall, is difficult to forecast and considered the least understood of natural phenomena. All water consuming sectors are affected but it is most acutely felt in the agricultural sector and livestock production activities. Human water needs are normally given priority. Intermittent water supply for domestic uses has become the normal management practice in many countries of the Region. This has been deemed necessary, during the summer season in particular, to satisfy increasing demands. An intermittent water supply policy can have negative impact on water quality and imposes further financial burdens on citizens, the poor in particular, who find themselves obliged to purchase water from private tanker contractors. The latter is more expensive than people are used to and there is no guarantee of the quality of the water supplied.

Average per capita freshwater availability in the Region is estimated at 1062 cubic metres per year, ranging from as much as 3232 cubic metres per year in Iraq to about 10 cubic metres per year in Kuwait (Figure 3). The world average equivalent is estimated at 7000 cubic metres per year [5]. About 173 million people in the Eastern Mediterranean Region, 35% of the entire Region, have less than the threshold level of 1000 cubic metres per capita per year. These include the countries of Bahrain, Djibouti, Egypt, Jordan, Kuwait, the Libyan Arab Jamahiriya, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, the United Arab Emirates and Yemen. Countries of the Eastern Mediterranean Region which may be considered below the water poverty line of 500 cubic metres per year total about 73 million people, 15% of the total population, and include Bahrain, Jordan, Kuwait, the Libyan Arab Jamahiriya, Oman, Qatar, Yemen, Saudi Arabia, Tunisia and the United Arab Emirates. The situation is certainly more critical for the non-oil producing countries of Jordan, Palestine, Tunisia and Yemen. From another perspective the per capita daily use in the majority of countries is considered rather low, for instance it is 50 litres per capita per day in Sana’a, approximately 80 in Amman and Tunis and 110 in Casablanca. Good practice is considered to be 120–150 litres per capita per day [5].

Moreover, a relatively large percentage of the water resources of the majority of countries in the Region originate outside their boundaries. This is known as the dependency ratio percentage. This averages at 30% in the Region. These resources can be in the form of groundwater, as in Kuwait and Bahrain, which have an estimated dependency ratio percentage of 100% and 96.6% respectively and receive groundwater by lateral underflow from the Damman aquifer, which is part of the Eastern Arabian Aquifer that extends from central to eastern Saudi Arabia and Bahrain. High dependency ratio percentages are also found in Egypt (96.9%), Syrian Arab Republic (80.3%), Sudan (77.3%), Iraq (53.3%), Somalia (61.9%), Pakistan (40.7%), Jordan (22.3%) and Tunisia (14.6%).

The agricultural sector is the largest water consumer in the Region as it utilizes 84% of the total renewable resources, ranging from 56% in Bahrain to 99% in Afghanistan. The industrial sector claims an average of 3% with the largest being in the United Arab Emirates (9%) and the least in Afghanistan and Somalia (0%). Figures for the domestic sector are 13%, ranging from as high as 39% in Bahrain to a mere 1% in Afghanistan. This is despite the fact that the agricultural contribution to the gross domestic product in the Region averages at 15% [4].

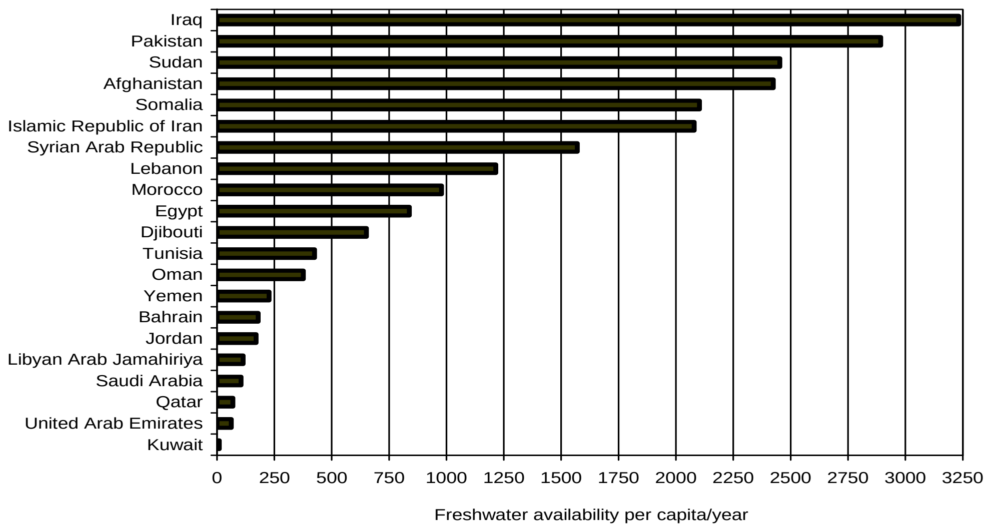


Figure 3. Freshwater availability in countries of the Eastern Mediterranean Region in 1999 [4]

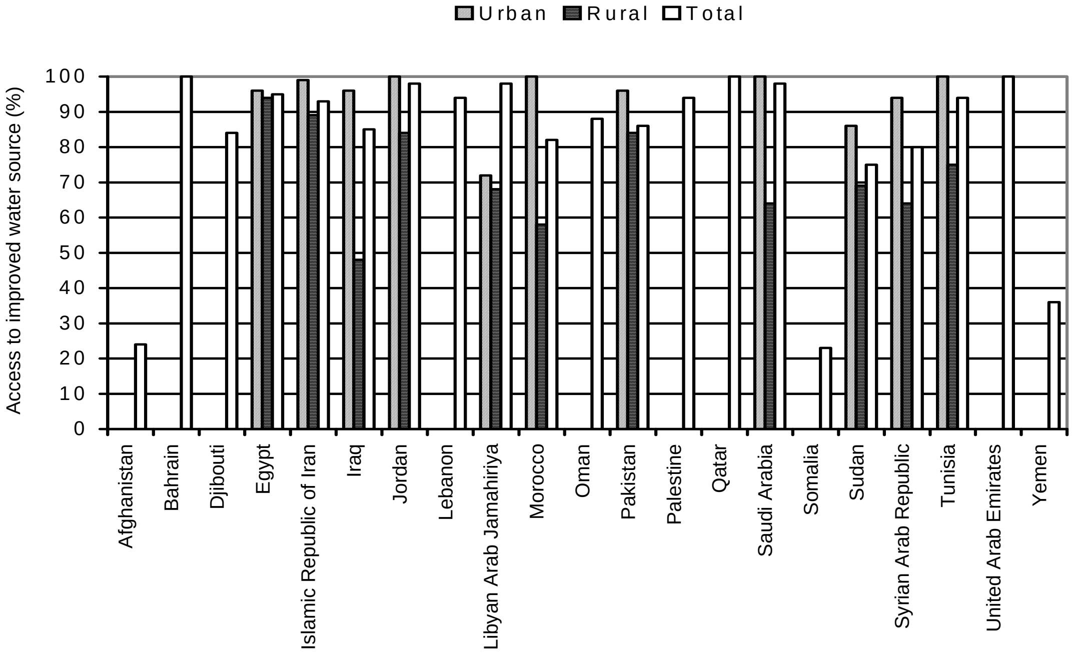
This demonstrates the hard realities of water scarcity and draws a gloomy picture for the future, especially with high population growth rates and increasing urbanization. It calls for more efficient management of conventional water resources and more exploration and use of non-conventional resources to augment the meager freshwater

3.2 Water supply coverage

It has long been established that access to appropriate means of water supply and sanitation is a basic human need, and moreover one of the essentials of human rights to safeguard human health, dignity and economic productivity. Access to improved water sources can have different interpretations in different countries; a water source that might be considered improved in one country might not be considered so in another. However, it is generally taken to mean people's accessibility to a sufficient quantity of water from an improved source, such as a piped connection, public standpipe, borehole, protected well or spring, or harvested rainwater, whereas an unimproved source refers to those from private water vendors and water sources susceptible to contamination. The availability of 20 litres per capita per day from a source that is less than 1 kilometre away is what may be considered reasonable accessibility.

Figure 4 shows the percentage of people with access to improved water supplies (various years, 1995–2003). The average coverage is 81%, ranging from as low as 13% in Afghanistan to 100% in Djibouti and Lebanon [5]. As expected, urban coverage is higher than that in rural areas. The average in the former is 87%, ranging from 19% to 100%, and 71%, from 11% to 100%, in the latter. In total the percentage of those without access to an improved water source in the Region is estimated at 19%, the equivalent of 94.8 million people who normally tend to secure their basic water needs from private suppliers which can mean paying a higher cost for water of uncertain quality.

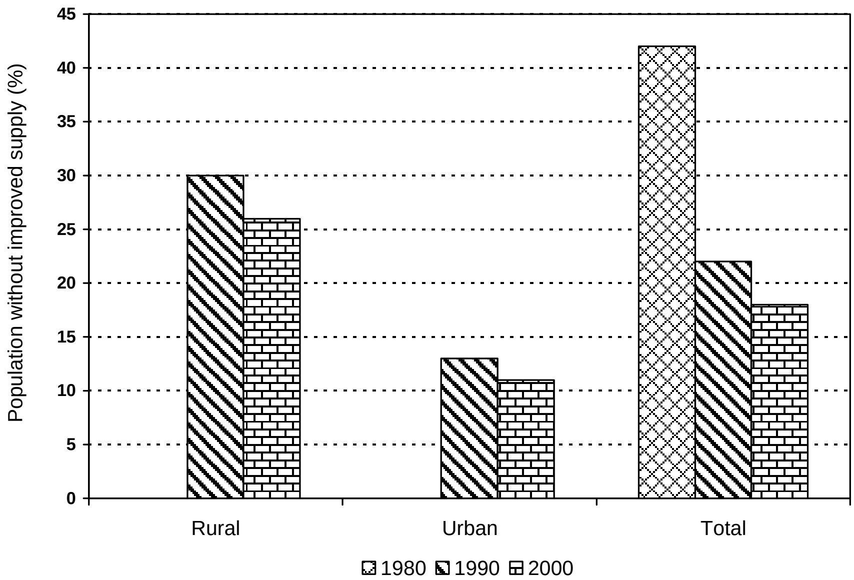
Water supplied through piped networks is intermittent in many cities of the Region, for example, Amman, Sana'a, Beirut and Damascus. In some cases, people have to wait for several days, and perhaps weeks, for their turn, so they use private vendors to secure their water needs. The high percentage of water that is unaccounted for is yet another serious problem facing piped water supply systems in most cities. This has been estimated to range from 30% to 40% in cities like Casablanca, Teheran and Beirut. The case is even worse in Damascus (approximately 64%), Amman



(approximately 46%) and Sana'a (approximately 50%). A good practice indicator range is from 15% to 25%. In the city of Tunis this has been 21% [5].

Figure 4. Access to improved water source in Eastern Mediterranean countries [2,6]

A comparison of the percentage of people without improved water supplies for those countries for which data is available for the years 1990 and 2000 (Egypt, Islamic Republic of Iran, Jordan, Libyan Arab Jamahiriya, Morocco, Oman, Pakistan, Sudan, Tunisia and Yemen,) is shown in Figure 5. A mere 2% of the urban and 4% of the rural populations gained access to improved water supplies during that decade. This is much less than that achieved during the International Drinking Water Supply and Sanitation (IDWSS) decade (1980–1990) the percentage of populations without an improved supply



decreased by 20%, from 42% in 1980 to 22% in 1990. The equivalent decrease from 1990 to 2000 was

Figure 5. Populations without improved water supply in ten countries of the Eastern Mediterranean Region during 1980, 1990 and 2000 [6]

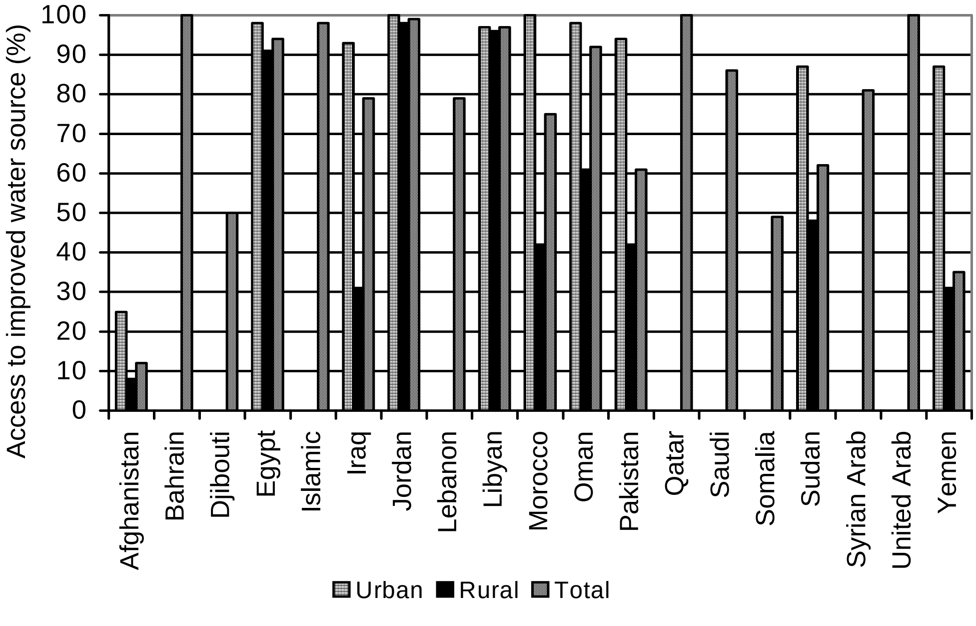
a comparatively low 4%, from 22% in 1990 to 18% in 2000, for the total population of the Region [6].

The increase in the number of population that gained access to improved water sources during the decade 1990–2000 is about 105 million, while the total increase in population in the Region for that decade is estimated at 109 million. This clearly demonstrates that the extra coverage was not proportional to the population increase, i.e. a further four million people were added to the 85.5 million lacking access in 1990. In urban areas about 66.4 million gained access while the urban population increased to 70.8 million. In rural areas 37.2 million gained access but the population rose to 38.5 million. This reflects yet again the more rapid increase in the urban population compared with that of the rural, thus the extra stress urbanization imposes on the limited water resources of the Region.

3.3 Sanitation coverage

Sanitation services have, understandably, been given less priority than water supply since people tend to grant more urgency to the provision of water. Access to improved sanitation can have different interpretations from one country to another. The extent of coverage of sanitation services in the Region is shown in Figure 6. The percentages refer to that part of the populations with access to sanitation provisions that may include waterborne sewerage, small bores, simple pits, septic tanks and ventilated improved pit (VIP) latrines. The average access percentage, in the year 2000, for the total population for the countries shown is 79% with 91% in urban areas and 63% in rural ones. This means that there are about 100.7 million people without any means of sanitation. The number of those without access in rural areas is 60.5 million and about 27 million in urban areas [6].

A comparison of the extent of progress made in decreasing the number of populations without



improved sanitation in the Region is shown in Figure 7 (various years, 1995–2003). The percentages represent available data from nine countries, Egypt, the Islamic Republic of Iran, Jordan, Libyan Arab

Figure 6. Access to improved sanitation in 19 countries of the Eastern Mediterranean Region [2,6]

Jamahiriya, Morocco, Oman, Pakistan, Sudan and Yemen, except for 1980 where respective data for Sudan and Yemen are not included. These percentages demonstrate that sanitation coverage has been much less during the 1990–2000 decade compared with 1980–1990, a 7% decrease in the former compared with an 18% in the latter.

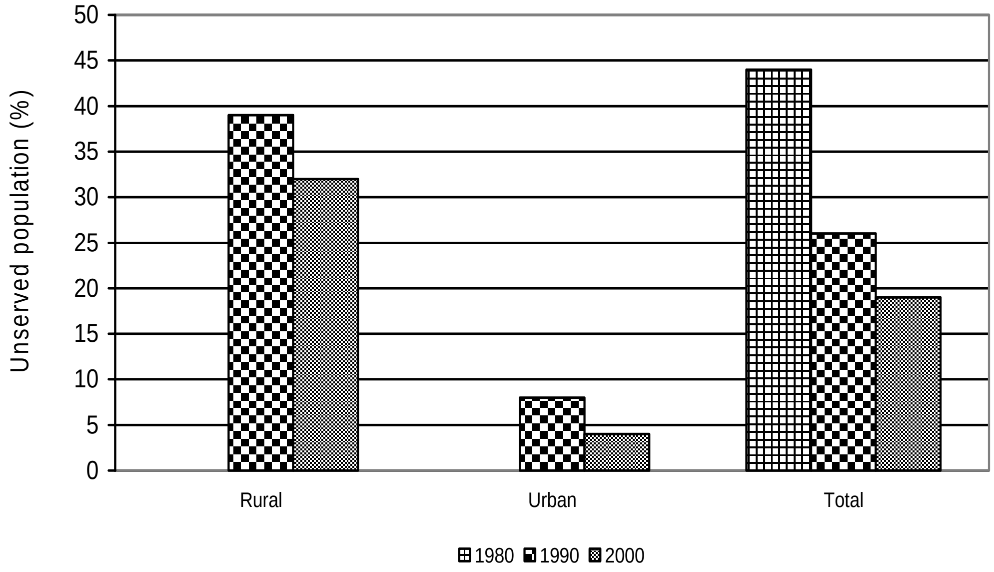


Figure 7. Populations without improved sanitation in nine countries in the Region during the years 1980, 1990 and 2000 [6]

The number of people who gained access to improved sanitation over the last decade is estimated at 115.8 million, 74.8 million of whom live in urban areas and 41 million in rural ones. Nonetheless, until the year 2000, about 94.6 million inhabitants of the Region remained without access, 81.7 occupants of rural areas.

4. Wastewater collection, treatment and reuse

4.1 Individual countries

Bahrain

Bahrain has a 70% sewerage connection in the major cities. The daily wastewater quantity collected and treated in the Tubli Water Pollution Control Centre is estimated at 150 000 cubic metres. Only municipal wastewater is allowed into the network; industrial wastewater is treated in separate utilities. Communities without sewers rely on cesspits to dispose of their sewage which is then hauled by municipal tankers to the Tubli plant. There are eight other wastewater treatment plants in Tubli: Nuwaidrat, North Sitra, Askar, Dumistan, Jao, Jesra, University of Bahrain and South Alba area. Three of these plants were reported to receive more than one and a half of the organic design loading. There are also a number of small wastewater treatment plants of varying sizes serving from 100 to 800 people; some of the effluent is reused for local irrigation. The majority of these wastewater treatment plants are based on the activated sludge extended aeration system. There is only 1 aerated lagoon plant and another biological rotating contactor.

Tubli is a tertiary wastewater treatment plant comprising bar screens, aerated grit chambers, 4 aeration tanks, 4 gravity clarifiers, 10 dual media (sand/anthracite) filters and disinfection facilities. Sludge treatment is handled in 2 thickeners and 36 drying beds. Design capacity of the plant is 60 000 cubic metres per day. However, only 25 000–35 000 cubic metres per day are treated and fully reused for agriculture and landscape irrigation during the summer [7]. A total of 722 hectares of dates, alfalfa, vegetables, fruits, forage crops and various trees are irrigated with tertiary treated effluent in various locations. The effluent quality guidelines implemented for irrigation reuse are those of the World Health Organization, despite belief that some of the parameters in the World Health Organization guidelines could be relaxed to enable more reuse of effluents treated to secondary levels. The use of untreated wastewater is definitely prohibited.

The Tubli wastewater treatment plants have been facing various operational and maintenance problems. One cited problem, at times, is the excessive inflow with highly fluctuating quality that is believed to cause the growth of filamentous bacteria and filter clogging. High salinity of about 4000 milligrams per litre in the incoming wastewater resulted in various operational problems and limited effluent reuse potential. Higher doses of ozone (12 milligrams per cubic metre) are applied at times to overcome a deteriorated plant effluent quality.

The raw wastewater influent and treated effluent characteristics at the Tubli wastewater treatment plants are shown in Table 4, from which it may be concluded that the raw wastewater in Bahrain is classified as weak since the 5–day biochemical oxygen demand (BOD_5) concentration is less than 220 milligrams per litre, chemical oxygen demand (COD) is less than 500 milligrams per litre and total suspended solids (TSS) is less than 220 milligrams per litre [8]. Effluent characteristics clearly demonstrate its high quality and suitability for unrestricted irrigation from a microbiological viewpoint provided that intestinal nematode eggs are duly removed by the sand filter as would be expected. Nonetheless, from a chemical perspective, the high salinity in the effluent imposes a medium to severe restriction on the irrigation of salinity-sensitive crops and plants. High salinity levels and helminth eggs are two major concerns encountered in the wastewater treatment and reuse sector in Bahrain. While the latter can be dealt with, albeit expensively, using sand filters, the high salinity requires desalination, which certainly implies further technical complications and even higher costs.

The total daily wastewater inflow in 1994 was 150 000 cubic metres, out of which 40 600 cubic metres of treated effluent was used in the irrigation of 580 hectares. It has been projected that this will be 200 000 cubic metres per day of inflow in the year 2010 and 181 895 cubic metres per day of treated effluent reused for the irrigation of 2598 hectares [7].

Agricultural water withdrawal in Bahrain was estimated at 133.84 million cubic metres per year in 1991. Potentially, treated wastewater could constitute 33% of this quantity, however, it only represented a mere 6% of the total water withdrawal for agriculture during the same year.

Table 4. Typical influent and effluent characteristics: Tubli wastewater treatment plant

Parameter	Influent	Effluent	
		Average	Range
Chemical oxygen demand	410	42	12–88
5-day biological oxygen demand	219	2	0–23
Total suspended solids	179	3	1–13
Volatile suspended solids	ND	1	0–4
Ammonia	24	1.4	0–16
Electrical conductivity (μs/cm)	ND	5200	3200–8600
Hydrogen Ion (pH)	ND	7.5	7.0–8.2
Alkalinity	ND	158	137–178
Calcium	ND	202	183–228
Magnesium	ND	110	89–136
Sodium	ND	633	515–733
Chlorine	ND	1493	1110–1665
Iron	ND	0.19	0.03–0.48
Copper	ND	0.11	0.02–0.28
Zinc	ND	0.2	0.13–0.31
Lead	ND	0.15	0.01–0.23
Nickel	ND	0.1	0.06–0.15
Cadmium	ND	0.01	0.02–0.03
Thermo-tolerant coliform count (MPN/100ml)*	ND	ND	0–2.5

Source: [7]; *

MPN: most probable number;

ND: not determined

All units are in mg/l except where noted

Water resources, including treated wastewater, are under the authority of the Ministry of Commerce and Agriculture which is responsible for the allocation and distribution of water for agricultural and landscape irrigation. Another entity, the Ministry of Works, Power and Water is responsible for production, transmission and storage. A steering committee made up of representatives from the aforementioned ministries in addition to the Ministry of Finance and National Economy and the Central Municipal Council, has been delegated the responsibility of suggesting priorities for planning and allocation of treated wastewater nationwide.

Egypt

In 1996 the urban areas of Cairo enjoyed the highest sewerage coverage at 78.8% compared to only about 6.9% in the urban areas of the Red Sea and north Sinai (Table 5). The overall average for all urban areas of Egypt is 53.8%. In the rural areas the average is 9.1%, ranging from 0.5% in Menia to 38.8% in Damietta. Areas of unconnected population use various onsite methods for wastewater disposal, such as cesspits, and some dispose of their raw sewage into adjacent drains and canals. In densely populated areas, the delta area for instance, such practices have created a grave state of affairs. Onsite units are used by 36 million people (about 60% of the total population), a small number of this population utilize septic tanks with unlined bottoms, while the majority rely on seepage pits. Overflowing onsite systems are a common phenomenon that has been the source of surface wastewater ponding conditions and contamination of surface water used for irrigation.

Table 5. Percentage of sanitation coverage by sewers and other means in Egypt in 1996

City/area	Urban areas		Rural areas	
	Sewer	Other	Sewer	Other
Cairo	78.8			
Alexandria	61.6	38.4	ND	ND
Port Said	55.8	44.2	ND	ND
Suez	71.5	28.5	ND	ND
Damietta	74.1	25.9	38.8	61.2
Dakahlia	77.0	23.0	35.4	64.6
Sharkia	66.3	33.7	22.6	77.4
Kalyoubia	54.2	45.8	11.2	88.8
Kafr Al Sheikh	64.3	35.7	4.1	95.9
Gharbia	73.9	26.1	2.4	97.6
Menoufia	27.7	72.3	2.1	97.9
Bahaira	45.1	54.9	3.2	96.8
Ismailia	54.7	45.3	8.7	91.3
Giza	68.5	31.5	17.3	82.7
Beni Suef	22.4	77.6	0.7	99.3
Fayoum	45.0	55.0	4.7	95.3
Menia	17.2	82.8	0.5	99.5
Assiut	15.0	85.0	1.1	98.9
Suhag	17.3	82.7	1.8	98.2
Qena	14.1	85.9	1.8	98.2
Aswan	31.7	68.3	3.0	97.0
Luxor	21.8	78.2	1.9	98.1
Red Sea	6.9	93.1	2.1	97.9
Al Wadi Al Gadid	71.5	28.5	20.2	79.8
Mattrouh	11.8	88.2	0.5	99.5
North Sinai	6.9	93.1	7.2	92.8
South Sinai	55.2	44.8	6.7	93.3
Average	53.8	46.2	9.1	90.9

Source: [10];

ND: not determined.

The costs of sewerage connection vary from one city to another. This is about US$ 22 per room for residential units in Cairo and US$ 1.0 per square metre for the commercial sector. In Alexandria, the cost is calculated by the area of the unit to be connected. For 60 square metres the cost is about US$ 26, US$ 44 for 60–80 square metres, and US$ 70 for 80–100 square metres. For apartments of more than 250 square metres the cost of sewerage connection is about US$ 437. Generally the cost depends on the length of the connection, pipe diameter and laying depth. For institutional and administrative expenses 10% is added to the total cost. A 6-inch diameter pipe laid at a depth of 1 metre would cost US$ 11 per metre. For an 8-inch pipe, 1.5–2.0 metres deep the cost per metre length would be US$ 22. For onsite disposal units the cost is between US$ 130–175, varying according to site conditions.

The total quantity of wastewater produced was estimated at 3600 million metres for 1995 to 1996 [9]. Produced per capita quantities vary significantly from one city to another according to the prevailing standard of living. This is 440 litres per capita per day in Alexandria (including rainfall which ends up flowing into the sewerage network). In most other cities, including Cairo, the estimated quantity is 200–250 litres per capita per day, while it is only 50–80 litres per capita per day in rural areas.

The total wastewater quantity treated was estimated at 5.228 million cubic metres per day in 2000 [10] compared with 1.78 million cubic metres per day in 1994 [4]. Some 1.150 million cubic metres per day of wastewater, 19% of the total quantity of wastewater treated, is done by primary treatment through two plants in eastern and western Alexandria and one in Abou-Rawash in greater Cairo, 65%, by activated sludge, 11% by waste stabilization ponds and 4.5% by trickling filters. Table 6 shows the type and capacity of existing and planned wastewater treatment plants in Egypt.

Table 6. Type and capacity of existing and planned wastewater treatment plants in Egypt

Station	Present capacity (1000 m^3/day)	Treatment system	Future capacity (1000 m^3/day)
Greater Cairo			
Al Gabal Al Asfar	1000	AS	500 Under construction 1500 by 2002 2000 by 2007
Al Berka	600	AS	Under study
Zenien	330	AS	–
Abou-Rawash	400	Primary	800 by 2004 1200 by 2006 (Secondary)
Helwan	350	AS	550 by 2005
Shoubra Al Khiema	600	AS	Under study
Alexandria	–	–	–
Eastern Alexandria	500	Primary	650 secondary by 2006
Western Alexandria	250	Primary	460 secondary by 2006
Canal Cities	–	–	–
Port Said	45	AS	Not operating
	120	OP	–
Ismailia	90	OP	–
Suez	90	OP	–
Kalyoubia	–	–	–
Banha	25	AS	–
Banha (New)	60	AS	Under construction
Kaha	10	AS	–
Kafr Shokr	10	AS	–
Sharkia			–
Zagazig	50	AS	–
Fakkous	20	AS	–
Monoufia	–	–	–
Shebien El Kom	48	TF	–
Monouf	22	AS	–
Kowesna	10	OP	–
Gharbia	–	–	–
Kafr Al Zayat	24	AS	–
	125	AS	–
Samannoud	17	TF	–
Al Mahalla Al Kobra	30	AS	–
Tanta	70	AS	90 by 2002 120 by 2010
Kafr Al Shiekh	–	–	–
Kafr Al Shiekh	40	AS	–
Sakha	15	AS	–
Damietta	–	–	–
Damietta	50	AS	–
Ras Al Barr	50	AS	–
Al Annayna	45	AS	–
Al Manzala	18	AS	Under construction
Dakahlia	–	–	–
Mansoura	135	AS	180 by 2006
Baheira	–	–	–
Damanhour	60	AS	–
Shoubrakheit	20	TF	–
Mansheyett Al Horreya	18	AS	–
Kafr Al Dawar	25	AS	–
Al Mahmoudia	10	AS	–
Abou Al Matamier	27	TF	–
Fayoum	–	–	–
Fayoum	20	TF	–
Kohafa	40	AS	
Beni Suef	40	TF	–
Menia	60	TF	–
Assiut	30	TF	–
	30	AS	–
Souhag	56	OP	Under construction by 2001
Qena	–	–	–

Table 6. Type and capacity of existing and planned wastewater treatment plants in Egypt

Station	Present capacity (1000 m^3/day)	Treatment system	Future capacity (1000 m^3/day)
Qena	15	OP	–
Luxor	13	TF	–
	15	OP	–
Aswan	–	–	–
Aswan	40	AS	–
Edfo	9	OP	–
Mattrouh	20	OP	–
Tenth of Ramadan	90	OP	–
Sixth of October	90	OP	–
Sadat City	90	OP	–

Source: [10];
AS: activated sludge;
TF: trickling filter;
OP: oxidation ponds

The cost of secondary treatment is reported as US$ 0.12 per cubic metre. This includes the cost of conveyance, pumping and treatment and does not account for different secondary treatment techniques, for example activated sludge or waste stabilization ponds. The cost of primary treatment has been estimated at US$ 0.013 per cubic metre [10].

The inspection and monitoring of wastewater works are the responsibility of the Ministry of Health and Population, the Ministry of Public Works and Water Resources and the Ministry of the Interior. However, the Ministry of Health, through its laboratories, is the only ministry entrusted with monitoring effluent quality and the enforcement of Law 48/1982 concerned with wastewater treatment plants' effluent quality regulatory requirements. The Ministry has well equipped laboratories capable of performing all the required analysis in Laws 48/1982 and 93/1962. Local municipalities perform operation and maintenance of wastewater treatment plants.

Training is required for technical as well as managerial personnel. This is particularly necessary for personnel involved in effluent reuse projects.

Industrial discharges into public sewers are controlled through the enforcement of Law 93/1962. Results of effluent quality analysis are submitted to the Ministry of Public Works and Water Resources and to the Ministry of Housing, with violations of regulatory standards handled by the former.

Several projects were included in the five-year plan (1997–2002) to expand wastewater treatment services, which aimed to cover 56% of the population compared with 37% in the year 2000. The Egyptian government has also assumed a policy of connecting villages to the nearest accessible sewerage network and upgrading the respective wastewater treatment plants to be able to accommodate the extra loading. It is expected that 1600 villages will be connected in two phases. This is likely to entail increasing the capacity of the existing wastewater treatment works to receive a hydraulic loading of 2.3 million cubic metres per day instead of the present 0.94 million.

There are two huge wastewater projects in Egypt, the greater Cairo wastewater project and the Alexandria wastewater project. The former serves some 20 million people residing in the governorates of Cairo, Giza and Kalyoubia. It serves a total area of 1100 square kilometres and should provide a treatment capacity of 6.28 million cubic metres per day by the year 2010. It includes the rehabilitation of old sewerage networks, pumping stations and treatment utilities. The Alexandria project contains two large wastewater treatment plants with a total capacity of 750 000 cubic metres per day, with a mechanical sludge treatment facility of 600 tons daily capacity of dry solids. This project includes seven pumping stations.

In 2000, available freshwater quantities were estimated at 55.5 billion cubic metres per year, while the total annual demand was 69.7 billion cubic metres with an annual agricultural withdrawal of 47.4 billion cubic metres. Egypt has adopted a policy of wastewater reclamation and reuse in irrigated agricultural land to alleviate the pressure imposed by increasing demands on freshwater resources. Reuse for irrigation has been practised since 1930 on Al Gabal Al Asfar farm where primary treated wastewater has been used in irrigating an area of 10 000 acres. Most of the wastewater generated in Egypt, treated or otherwise, flows into agricultural drainage canals. Some of it receives secondary treatment while the rest is either treated to a primary level or untreated. There is no coherent irrigation reuse policy to manage the utilization of this water. Recently, however, the Ministry of Agriculture and Land Reclamation has started an agricultural reform programme that includes effluent reuse for woodland forests. An estimated area of 1000 acres has been irrigated with reclaimed water in Luxor, Qena, New Valley, Edfu, Ismailia, Sadat City and South Sinai. Four reuse schemes are planned by the National Organization for Potable Water and Sanitary Drainage in locations in Nuweiba, Luxor, Nasr City, Komombo and Daraw. These schemes will be managed by the private sector on a build, operate and transfer basis. The four schemes will be served by four newly constructed wastewater treatment plants that will be built simultaneously. The total irrigated area of land through the schemes will be about 781 hectares at the beginning and about 1710 hectares by 2015. It is recognized that the present treatment technologies are insufficient for helminth egg removal and tertiary treatment techniques are not yet employed.

On the national level, both the Ministry of Agriculture and Land Reclamation and the Ministry of Water Resources and Irrigation have agreed on a plan to reclaim an area of 1.2 million hectares by the year 2017, utilizing both treated wastewater and drainage waters. However, an accurate estimation of the total quantity of reused effluent in Egypt is difficult to perform due to the many uncontrolled sources flowing into the same drainage canals. Treated wastewater from wastewater treatment plants, as well as untreated wastewater from cesspits emptied and hauled by vacuum tankers, end up in the same collection works. Furthermore, irrigation drainage waters are sometimes put into direct reuse, albeit unofficially, or directed towards canals. Unofficial reuse in the delta area alone has been estimated to range from 4 to 6 billion cubic metres per year.

Effluent reuse for industrial purposes is minimal because many industrialists have reservations about negative impacts treated wastewater might have on machinery. Nonetheless, industries have been prompted to treat and reuse their effluents whenever possible through the enforcement of Environmental Law 4/1994.

Law 48/1982 imposes legal constraints on effluent reuse for aquifer recharge purposes but there are several concerns about identifying the lines dividing aquifers of drinking water quality from those of non-potable quality.

The existing wastewater treatment plants in Egypt produce an estimated quantity of dry sludge of 950 000 tons per year and are expected to increase to 2 million tons by 2020. Various treatment techniques are employed for sludge. Presently in Cairo, at a wastewater treatment plant in the east bank area, produced sludge is treated in temporary drying beds. Later it is pumped to new treatment utilities in Al Gabal Al Asfar where thickeners, digesters and mechanical dewatering are employed. At the west bank wastewater treatment plant, sludge from primary and secondary treatment plants at Abou Rawash and Zenein is mixed and pumped to ponds located on the Alexandria Desert Road. At Helwan wastewater treatment plant sludge is treated in drying beds, which are inadequate, and thickeners that are out of order. In Alexandria, produced sludge is mechanically dewatered, composted, packed and sold to farmers as a fertilizer and soil conditioner.

Sludge analysis has shown that its moisture content is in the range of 94%–96% and heavy metals content is below allowable limits. It contains relatively high concentrations of iron and small quantities of copper and manganese. More importantly, perhaps, is the microbiological quality of the sludge. *Escherichia coli* and aerobacter species were identified in all samples. *Ascaris* spp. eggs amounting mostly to a range of 1–5 eggs per gram were identified, for example, at Al Berka. The maximum number was found at Zenien amounting to 25 eggs per gram.

Serious reservations have been expressed on the reuse of reclaimed wastewater due to concerns pertaining to possible negative public health and environmental implications. Increased concerns have been attributed to the uncontrolled discharge of untreated wastewater into irrigation canals and other water receiving courses. This is particularly so in rural areas where improved sanitation coverage is very low. Although wastewater reuse has been practised since 1930 in the irrigation of orchards, in sandy soil areas like Al Gabal Al Asfar and Abou Rawash, there are no programmes to monitor the quality of reclaimed wastewater, before or after reuse, for possible health risks on farm labourers and end users of products. So far there are no adopted guidelines or codes of practice to regulate reuse activities. The most critical concerns are to do with pathogens, which may either be in the untreated discharge or in the effluent of wastewater treatment plants that are not designed to ensure their removal. Such pathogens may include, but are not limited to, bacteria, protozoa, helminth eggs and viruses.

Concerns have also been expressed about the accumulation of heavy metals in plants irrigated with reclaimed effluent. They might increase health risks to animals and man, even though concentrations in the effluent are within acceptable limits. Some studies on the accumulation of certain heavy metals in alfalfa tops and corn leaves have shown concentrations to be twice the normal amounts of magnesium, zinc and lead, 3 times for copper and nickel and 7 times for cadmium when irrigated with reclaimed wastewater. In comparison with crops irrigated with freshwater from the Nile, when irrigated with reclaimed wastewater there were increases in micronutrients and heavy metal concentrations amounting from 2 to 36 times in alfalfa tops and 2 to 162 in corn leaves. Nonetheless, no metal toxicity was found.

An epidemiological study on the Helwan reuse project (17 500 acres) revealed that 38.2% of field labourers were infected with *Ascaris* spp, *Entamoeba histolytica* and *Giardia* spp. 18.4% were anaemic and 27% showed symptoms of gastrointestinal disorders (dysentery and enteritis). Abnormal increases in cadmium, chromium and lead were also identified in soils and plants irrigated with reclaimed wastewater. It has been attributed to the discharge of industrial wastewater of different origins into the system.

There are several ministries and institutes with different roles in the wastewater management and reuse in Egypt.

- The Ministry of Land Reclamation and Agriculture manages agricultural aspects.
- The Ministry of Housing Utilities and Urban Communities is concerned with the planning and construction of municipal wastewater treatment plants.
- The Ministry of Health and Population assumes responsibility for sampling and analysis of all wastewater effluents. It is also responsible for setting water and wastewater quality standards and regulations in addition to its central role as the custodian of public health.
- The Ministry of Water Resources and Irrigation allocates water for reclamation areas.
- The Ministry of the Environment and the Egyptian Environmental Affairs Agency caters for environmental aspects.
- Scientific institutions and universities conduct basic and applied research activities.

There are several laws and decrees regulating the disposal of wastewater in Egypt.

- Law 93/1962 regulates wastewater disposal and designates the responsibility of constructing public wastewater systems to the Ministry of Housing which is also responsible for issuance of permits regulating wastewater discharge into public sewerage networks or into the environment. The Ministry of Health determines the regulatory standards.

- Decree No. 649/1962 and Decree No. 9/1989: Decree No. 649/1962 of the Minister of Housing issues the executive regulations of Law 93/1962. It specifies regulatory standards for wastewater disposal. It was updated in 1989 by Decree No. 9/1989 in which a distinction was made between wastewater disposal on sandy soils and clay silt soils. Most prominent conditions included that wastewater treatment plants should be located more than three kilometres from the nearest residential area. Primary treatment was set as a minimum treatment level required before final discharge. Reuse of effluent in the irrigation of vegetables, fruits or any other crops eaten uncooked is strictly prohibited. The same restriction is imposed on grazing of animals or milking cattle on the fields irrigated with wastewater. In 1995 an amendment was made by both the Ministry of Irrigation and the Ministry of Agriculture and approved by the Ministry of Health. Nonetheless, it has not yet been issued by the Minister of Housing. This amendment determined the minimum degree required for wastewater treatment for the various reuse aspects. Tertiary treatment was set as prerequisite for unrestricted irrigation of crops eaten uncooked. Secondary treated effluents may be reused for irrigating palm trees, cotton flux, jute, cereals, forage crops, flower nurseries and thermally processed vegetables and fruits.
- Law 48/1982 was passed for the protection of the River Nile and watercourses from pollution. Decree 8/1983 is an executive regulation of Law 48/1982 that was issued by the Minister of Irrigation. Under this law discharges to the Nile, canals, drains and groundwater are controlled through licensing. The Ministry of Public Works and Water Resources issues licenses to industries, sanitary sewage treatment plants and riverboats. Licenses are issued provided that discharges satisfy regulatory standards and requirements. A grace period of three months is granted to violators to comply with the requirements. Failure to comply can mean withdrawal of the license. The Ministry of Public Works and Water Resources is empowered with administrative and policing means to enforce this law. The Ministry of the Interior’s water surfaces police have also powers to ensure its implementation. The Ministry of Health is entrusted with setting standards and monitoring the quality of discharges. Water quality standards in this law are specified for various categories that include the River Nile, treated industrial effluent to the Nile and canals, treated industrial and sanitary water discharge to drains, lakes and ponds, treated discharge from river vessels to the Nile and canals and drain waters to be mixed with the Nile or canals.
- Other pertinent laws include Law 12/1984 that regulates the authority of the Ministry of Public Works and Water Resources as the custodian of all water resources.

The proper enforcement of existing laws and bylaws needs well-trained personnel on both technical and managerial levels. Capacity building in this respect is required to ensure proper implementation.

Islamic Republic of Iran

Wastewater disposal practices in the Islamic Republic of Iran vary greatly from one region to another. Prior to 1995 some 200 towns comprising 34% of the total urban population practised drywell disposal, another 5% (about 70 small towns) had an old sewerage network (3500 kilometres) serving some 300 000 people. Only 6.5% (317 000 people) of the urban population was served by a modern wastewater collection system of 4700 kilometres. The remaining urban population (about 54.5%) resides in areas where the groundwater table is high and soil permeability is so low that drywell utilization is considered impractical [12]. In rural areas, wastewater sewerage and treatment are virtually non-existent.

The quantity of treated wastewater in the Islamic Republic of Iran was about 650 000 cubic metres per day in 1995, thus serving a total population of 3 400 000 which represented 9% of the total urban population. There were plans to increase the wastewater quantity treated by 5.304 million cubic metres per day through the installation of various wastewater treatment plants including 25 wastewater stabilization pond plants (total capacity 1.436 million cubic metres per day), 21 aerated lagoons plants and 46 activated sludge plants with a total daily capacity of 0.992 million cubic metres. There were also studies for another 134 wastewater treatment plants for urban areas.

Little information is available about the performance of the existing wastewater treatment plants in the Islamic Republic of Iran. However, it is generally reported that most of them are overloaded. The largest is that in Isfahan which has been reported to receive one and a half the original BOD design loading.

The reuse of partially treated wastewater and even raw wastewater mixed with industrial effluents is practised. The Department of Environmental Health reported that an estimated 240 288 hectares are being irrigated, utilizing insufficiently treated effluents and raw wastewater flowing in streams in six Iranian provinces [12]. The quantity reused is estimated at 670 000 cubic metres per day and was reused in the irrigation of cereals, vegetables, cone trees and green spaces.

There are many problems facing the expansion of the wastewater services in the Islamic Republic of Iran. Increasing urbanization is creating a real challenge to the provision of water supplies and sanitation services. Provision of such services has not been satisfactorily met due to the high costs entailed, costs which have been attributed to excessive reliance on foreign expertise and equipment.

Many authorities are assuming various roles in the wastewater sector. The Ministry of the Interior, through municipal departments, is responsible for managing sewerage construction and cleaning wastewater canals. The Ministry of Health assumes the responsibility for public health aspects and the sanitation programme in rural areas. The Ministry of Energy, through the Urban Water and Wastewater Company, is responsible for the design, construction and management of domestic wastewater collection systems and treatment plants and the Environmental Conservation Organization is responsible for industrial and domestic wastewater control and the setting of pertinent standards.

The Department of Environmental Conservation is responsible for the implementation of three national standards for the control of discharges affecting surface and groundwater resources and effluent reuse in irrigation. The Urban Water and Wastewater Company controls industrial discharges, which are required to have a similar quality to domestic wastewater before being permitted into the municipal sewerage networks. The Islamic Republic of Iran has pursued several approaches to improve water supply and sanitation services for urban and rural areas. Priority has been given to areas in which the situation is considered the most critical and particular attention is given to low-income communities. Industries that are located in cities and known for causing pollution are destined for transfer to out-of-city boundaries. Enforcement of environmental regulations, applying cost-recovery policies, promoting research activities, investment, promotional measures and encouraging the adoption of appropriate technological methods for wastewater collection and treatment are some approaches adopted to bring about tangible improvements in the wastewater sector. Other measures include evaluation of existing systems and repairing malfunctioning plants before investing in new systems, developing new technical standards for appropriate designs, capacity building for better data management and promotion of effluent reuse. Human resource development in the sector has received due attention through conducting training courses for all professional levels. Public awareness and community participation have also been part of the adopted policy for the development of the water and wastewater sector in the country.

Iraq

Until the year 2000, estimates showed that only 33.4% of the 14 140 760 urban population of Baghdad and southern central area of Iraq were connected to sewers conveying sewage to treatment facilities. In the mayoralty of Baghdad, about 80% were connected while in the southern central area only 10% had sewers. The Baghdad sewerage network that was established between 1960 and 1980 was of the separate type but a combined system has been adopted since 1980. Urban populations without sewers rely mainly upon onsite sanitation facilities like septic tanks and pit latrines. The latter are also the most prominent wastewater disposal techniques in rural areas where sewerage connections are virtually non-existent. Furthermore, there are communities that are connected to sewers but not to treatment facilities. Other disposal practices involve the use of storm drains and open defecation [11].

Quantities of sewage generated within the urban areas of the mayoralty of Baghdad are estimated at 1 426 013 cubic metres per day and in its rural areas at 2354 cubic metres per day. Recent reports by the United Nations Development Programme (UNDP) showed that each day 500 000 cubic metres of raw sewage are discharged into Iraqi waterways. The capacity of all wastewater treatment plants in the mayoralty of Baghdad is estimated at 789 200 cubic metres per day, representing 55% of the sewage generated in the mayoralty. The high deficiencies of the major wastewater treatment plants are shown in Table 7.

The southern central region of Iraq, which covers the governorates of Anbar, Babil, Baghdad, Basrah, Salahedin, Tameem, Thiqar and Wasit, has an urban population of about 5.6 million and a rural one of about 3.8 million people. Wastewater generated daily from the former is estimated at 1.263 million cubic metres and the latter at 0.571 million.

Table 7. Major wastewater treatment plants in the mayoralty of Baghdad

Project	Design capacity (m^3/day)	Efficiency percentage	Process
Rustamiyah 0 and 1	79 000	41	Pre-aeration, primary and final settling; aeration, sludge digestion and drying beds, and chlorination.
Rustamiyah 2	90 000	41	
Rustamiyah 3	300 000	33	
Kerkh	205 000	17	
Total	674 000		

Source: [11].

Table 8 shows the extent of sanitation coverage in the southern central region of Iraq. Sewerage is modest in the urban areas and virtually non-existent in the rural ones. Some people, the majority of whom reside in rural areas, have no sanitation means whatsoever. This is shown by data referring to Diala, Ninevah, Salahedin, Tameem and Thiqar.

Only 11.9% of the generated wastewater in the central southern region of Iraq is subjected to treatment (Table 9). Existing wastewater treatment plants are highly inefficient with some hardly functioning. This inefficiency has been attributed to lack of proper operation and maintenance and unavailability of spare parts. Extended aeration and trickling filter systems can normally be expected to have a BOD_5 removal efficiency of 75%–95% [8].

Table 8. Percentages for sewage disposal techniques in central southern Iraq in 2000

Governorate	Urban					Rural		
	Onsite sanitation			Sewerage	Sanitation	Onsite sanitation		
	Septic tank	Pit latrine	Total			Septic tank	Pit latrine	Sanitation
Anbar	29	65	94	4	98	43	47	90
Babil	10	72	82	5	87	10	75	85
Baghdad	18	49	66	0	66	ND	ND	ND
Basrah	43	22	65	22	87	12	9	22
Diala	16	84	100	0	100	0	0	0
Kerbala	11	44	55	33	88	50	28	78
Missan	15	38	53	13	66	100	0	100
Muthanna	59	14	73	0	73	10	0	10
Najaf	0	80	80	20	100	0	16	16
Ninevah	ND	ND	ND	ND	ND	0	0	0
Qadisiyah	52	31	83	12	95	76	10	86
Salahedin	0	87	87	13	100	0	0	0
Tameem	68	14	81	4	86	0	0	0
Thiqar	74	11	85	15	100	0	0	0
Wasit	41	34	76	0	76	100	0	100

Source: [11];

ND: not determined

Table 9. Urban generated wastewater, plant capacities and efficiencies in central southern Iraq in 2000

Governorate	Urban wastewater generated (m3/day)	Capacity (m3/day)	Wastewater treated to generated (%)	Type of treatment process	Project efficiency (%)
Anbar	136 039	16 000	11.8	N.D	0–5
Babil	140 301	12 000	8.6	N.D	33
Baghdad	106 705	18 000	16.9	N.D	5–7
Basrah	328 276	35 200	10.7	N.D	44
Diala	120 153	ND	0.0	ND	ND
Kerbala	110 537	90 000	81.4	E.A	17
Missan	117 642	30 000	25.5	T.F	7
Muthanna	54 556	ND	0.0	ND	ND
Najaf	161 856	43 000	26.6	T.F	20
Ninevah	370 728	ND	0.0	ND	—
Qadisiyah	117 642	12 000	10.2	E.A	13
Salahedin	99 271	ND	0.0	ND	28
Tameem	155 876	ND	0.0	ND	14
Thiqar	183 792	19 400	10.6	T.F & E.A	4–13
Wasit	113 121	ND	0.0	ND	ND
Total	2 316 495	275 600	11.9	—	—

Source: [11]

E.A: extended aeration

T.F: trickling filters

ND: not determined.

Due to Iraq's topography and prevailing hot climatic conditions, pumping stations constitute an essential component of the country's sewerage system. Nonetheless, like wastewater treatment plants, existing pumping stations in Iraq are also inefficient because of a lack of proper operation and maintenance and unavailability of spare parts. Despite this, effluents from most of them are used for irrigation. For instance, 240 hectares of wheat and barley are illegally irrigated with the partially treated effluent from Kerbala wastewater treatment plants. Effluents from the plants at Tameem, Rustamiyah and Babil are used to irrigate various types of crops. These treatment plants do not include any provisions for helminth removal. In a study to investigate incidences of infections with helminth among farm workers at the reuse site of the Rustamiyah wastewater treatment plant, 59.2% of the 250 stool samples analysed were shown to contain intestinal nematodes.

The water and wastewater sectors in Baghdad are managed by the mayoralty of Baghdad through the Baghdad Water Authority and Baghdad Sewerage Authority. The latter is responsible for wastewater collection, treatment and disposal in the capital. The directorates of the nine municipalities that make up the mayoralty of Baghdad assume the responsibilities of operation and maintenance of the sewerage network and pumping stations. Both the Baghdad Water Authority and Baghdad Sewerage Authority are under the direct authority of a deputy mayor while the 9 municipal directorates are under a deputy mayor for technical aspects and another deputy mayor for administration and finances. The Baghdad Water Authority and Baghdad Sewerage Authority were created in 1921 and 1945 respectively as governmental bodies. Until 1995 the Baghdad Sewerage Authority was responsible for the whole sewerage system. However, after that the responsibility for a total of 586 pumping stations was transferred to the municipalities. The General Corporation of Water and Sewerages assumes the responsibilities for water supply and sewerage operation in the other 15 governorates of the central southern region while the Ministry of the Interior is in charge of sector management in the region.

Sector planning, policies, regulations, tariffs and financing are done by the central government. Local and regional authorities are in charge of execution of public works, operation and maintenance. Other institutes include the hydrology department of the Ministry of Irrigation and Environmental Protection and Improvement Council who are in charge of water quality monitoring. The Ministry of Industry is responsible for monitoring industrial effluents and the Environmental Protection and Improvement

Council undertakes the responsibility of environment protection and improvement in the whole country in accordance with Law 3/1997.

There are several laws that govern the water and sanitation sector in Iraq.

- Law 25/1967 classifies water resources management criteria.
- Law 3/1997 and its amendment of 2001 established the National and Provisional Environmental Council.
- Law 148/1999 changed water and sanitation into a state owned corporation.
- The Constitution of the Baghdad Sewerage Authority.
- The drinking water standards of 1974 issued by the Ministry of Health.

Jordan

Jordan has one of the highest rates in sewerage connections (a nationwide average of approximately 50%) in the Region and the amount of wastewater collected reflects this. There were nineteen wastewater treatment plants in full operation in 2001. The total wastewater flowing into these plants was estimated at 88.637 million cubic metres during 2001, 85% of which were treated in seven wastewater stabilization pond plants with one plant at Al-Samra, handling 76.6%. However, recently there have been plans to expand Al-Samra and change the treatment technique to the activated sludge system. At present, activated sludge and trickling filter plants are employed for the treatment of 15% of the total wastewater collected in the country. Jordan has adopted a policy of including maturation (polishing) ponds as a final treatment stage in most of the mechanical wastewater treatment plants as shown in Table 10. This was deemed necessary for the removal of intestinal nematodes that could not be eliminated in earlier treatment stages.

Raw wastewater quality in Jordan is classified as strong. The average BOD_5 influent concentration in the largest wastewater treatment plant of Al-Samra is 709 milligrams per litre and the range in the inflow of all plants is 373–1231 milligrams per litre with an overall average of 777 milligrams per litre. These high concentrations are attributed primarily to the low per capita consumption imposed by water scarcity in the country. Consequently, the cost of wastewater treatment per cubic metre is generally in the higher range. It is also recognized that wastewater salinity in Jordan (average salinity in terms of TDS is about 951 milligrams per litre ranging from a minimum of 569 milligrams per litre in the outflow of the Salt wastewater treatment plant to 1596 milligrams per litre in Madaba wastewater treatment plant. This is higher than is normally found elsewhere and is attributed to the relatively high salinity in the domestic water supplies. However, few concentrations of toxic pollutants are found in Jordan’s raw wastewater since industrial discharges to sewers are controlled through pretreatment regulatory requirements. Biological pollution loadings of industrial origin are estimated to amount to 10% of the total raw biological load.

Table 10. Influent and effluent characteristics in some treatment plants in Jordan

Plant	System	Inflow (m^3/day)	BOD_5 (mg/l) in	BOD_5 (mg/l) out	TSS (mg/l) in	TSS (mg/l) out	TDS (mg/l) out
As-Samra	WSP	186 081	709	146	556	140	1120
Aqaba	WSP	9310	373	97	338	532	920
Irbid	AS+TF	5081.3	1174	21	1136	55	ND
Salt	AS+PP	3597.9	869	16	864	16	569
Jerash	AS+PP	2743	1231	46	756	87	715
Mafraq	WSP	1888.5	683	173	1132	84	1106
Baqa'a	TF+PP	11 515.8	1027	48	991	47	1047
Karak	TF+PP	1274.6	697	68	561	83	809
Abu-Nuseir	AS	1800	552	21	558	29	851
Tafila	TF+PP	735.9	630	20	574	31	582
Ramtha	WSP	1888.5	849	209	733	185	1234
Ma'an	WSP	1556.2	518	97	ND	278	879
Madaba	WSP	4611.0	1048	226	1738	652	1596
Kufranja	TF+PP	1863.5	1186	81	885	82	1080

Table 10. Influent and effluent characteristics in some treatment plants in Jordan

Plant	System	Inflow (m^3/day)	BOD_5 (mg/l) in	BOD_5 (mg/l) out	TSS (mg/l) in	TSS (mg/l) out	TDS (mg/l) out
Wadi Essir	Aerated WSP	1401.5	431	36	321	41	971
Fuheis	AS+PP	1216.6	750	18	612	17	842
Wadi Arab	AS	5734.7	653	11	758	15	ND
Wadi Mousa	AS	532.2	608	6	587	11	888
Wadi Hassan	AS	280	978	11	ND	ND	ND

Source:.[13];

BOD_5: 5–day biochemical oxygen demand

TDS: total dissolved solids

PP: polishing pond

WSP: waste stabilization ponds

TSS: total suspended solids

AS: activated sludge

TF: trickling filter

ND: not determined.

The performance of wastewater stabilization pond plants was lower than the mechanical activated sludge and trickling filter ones. The removal efficiency in terms of BOD_5 was reported in the range 74%–81% for all wastewater stabilization ponds during the year 2001 except for one plant with aerated ponds that achieved a 92% removal. Equivalent removal in trickling filter plants were in the range 90%–95% while activated sludge realized the highest removals ranging from 96%–99%. It is also essential to note the high TSS concentration in effluent of wastewater stabilization pond plants resulting from algal cell growth in the ponds. This can have a negative impact on the effluent reuse potential due to possible clogging of drip pipe emitters. An effluent with TSS concentration between 50 and 100 milligrams per litre imposes a slight to moderate degree of restriction on the use of drip (localized) irrigation techniques. If TSS concentration exceeds 100 milligrams per litre as in the wastewater treatment plants of As-Samra, Aqaba, Mafraq, Ramtha, Ma'an and Madaba, the restriction on the use of drippers is severe. Drip irrigation techniques are highly recommended for an efficient application of irrigation waters. This may, therefore, necessitate the addition of a further treatment stage for algal removal leading in turn to higher cost burdens.

The effluent quality of the nineteen plants varied greatly depending upon, inter alia, the method of treatment utilized. Fourteen out of the nineteen plants met the anticipated effluent design criteria while five failed. Eleven plants fulfilled the local regulatory effluent quality requirements as stipulated in the Jordan Standard 893/1995 (JS: 893/95) for discharge to *wadis*. In satisfying reuse requirements sixteen plants were compliant with the aforementioned standard while all plants were in full compliance with effluent quality reuse requirements for irrigating fodder crops.

There are plans in Jordan to upgrade overloaded wastewater treatment plants and to build new ones to expand wastewater management provisions, particularly in rural areas. It is expected that by the year 2010, the quantity of treated wastewater will amount to about 220 million cubic metres per year.

The cost of treatment varies, depending primarily on the treatment method used and plant capacity. For wastewater stabilization pond plants, the average cost ranged from US$ 0.021 per cubic metre in the largest plant, receiving 186 081 cubic metres per day during 2001, to US$ 0.179 in the Ma'an water stabilization ponds, the inflow to which was about 1556 cubic metres per day in the same year. For mechanical, activated sludge and trickling filter plants, the average cost during 2001 varied to a great extent (US$ 0.1–US$ 3.1 per cubic metre). The higher values were reported for new and relatively small wastewater treatment plants (daily capacity of 280 cubic metres) and therefore should be evaluated in that context. Furthermore, comparison of costs ought to be conducted taking into account whether the plant is realizing expected treatment level and required effluent quality. For instance, some plants like the Al-Samra wastewater stabilization ponds are heavily overloaded, thus if modifications are introduced to the plant to achieve the desirable levels of treatment the aforementioned cost could change drastically.

All public wastewater treatment plants are designed and constructed by private consultants and contractors under the auspices of the Ministry of Water and Irrigation and the Water Authority of Jordan, which also operate and maintain them upon commissioning. Privately owned wastewater treatment plants are operated and maintained by their respective owners but monitored for compliance by pertinent governmental agencies.

Lack of skilled personnel and equipment to conduct preventive and corrective maintenance and the absence of real incentives for employees in the wastewater sector have been generally reported as major obstacles facing the wastewater treatment sector in Jordan [13].

There are several programmes for wastewater surveillance nationwide. The most comprehensive is that conducted by the Water Authority of Jordan. Daily, weekly and monthly samples are collected and analysed for operation, process control and regulatory compliance purposes. Analyses that include hydrogen ion, electrical conductivity, total dissolved solids, total suspended solids, chemical oxygen demand, biochemical oxygen demand, sulphate, ammonia, nitrate, Methylene Blue Active Substance, phosphate and coliform bacteria are conducted at the Water Authority of Jordan central laboratories. Monthly and annual reports are prepared for evaluation and long-term planning.

In its capacity as the custodian of public health in the country, the Ministry of Health carries out its own surveillance programme intended to ensure compliance with pertinent promulgated regulatory standards. The Ministry of Health concentrates its efforts on the microbiological quality of wastewater treatment plant effluents. Coliforms and intestinal nematodes are extensively analysed for all the effluents of nearly all wastewater treatment plants in the country, in addition to other parameters with public health significance.

While the Water Authority of Jordan conducts its surveillance programme for operational purposes and the Ministry of Health for the protection of public health, the General Corporation for Environmental Protection (GCEP) is entrusted, by the Environment Law (1995) to enforce environmental regulatory standards. The GCEP contracts various independent laboratories to fulfil its responsibilities; one such contract is that with the Royal Scientific Society (RSS) in Jordan, which covers all public and private wastewater treatment plants. The primary objective of the GCEP–RSS contract is to monitor potential sources of pollution for public health and environment protection. RSS issues periodic reports to GCEP on the results of analysis with technical evaluation and recommendations for action to be taken by the latter as the law-enforcing agency. Reports are normally shared with other agencies, the Water Authority of Jordan and the Ministry of Health in particular. In addition to domestic and industrial wastewaters, the programme includes monitoring the quality of potable water sources, major groundwater and surface water sources in the whole country.

Cognizant of the challenges posed by water shortage in the country and the need to account for every drop, Jordan is committed to a policy of complete reuse of treated wastewater effluents. The policy is to ensure that wastewater is managed as a valuable resource rather than as a waste. There is, therefore, a clear commitment to collect, treat, manage and reuse the effluent efficiently and optimally. Nonetheless, there is equal commitment that effluent reuse is practised without compromising public health. All new wastewater treatment projects are required to include feasibility for effluent reuse. There are strict regulations prohibiting the use of raw wastewater for irrigation. Communities without sewers are required to pump out cesspools by private tankers that empty their loadings into prescribed wastewater treatment works. However, lack of organization within the sector means that the control of such practices is sometimes unsatisfactory. Jordan was one of the earliest countries to adopt World Health Organization and Food and Agriculture Organization effluent reuse guidelines for irrigation. These were essentially the basis for the Jordanian Standard for treated wastewater discharge and reuse (JS: 893/2002) shown in Table 11, Table 12 and Table 13.

Effluents from most wastewater treatment plants in Jordan have been utilized for irrigation purposes. Reservoirs are used to store treated wastewater that flows into *wadis* where it mixes with surface water of a higher quality, e.g. King Talal resevoir receives about 57 million cubic metres of treated effluents from the wastewater treatment plants of As-Samra, wastewater stabilization pond, Jerash, Baq'a and Abu-Nuseir. This has been necessary in order to augment the scarce water resources of the country. The criteria for effluent are largely applied in the implementation of all organized reuse schemes. There are many general provisions in JS: 893/2002 for when reclaimed wastewater may be reused for irrigational purposes.

- When the effluent is used in the irrigation of plenteous trees, irrigation should be halted two weeks prior to harvesting and no fruits should be picked off the ground.
- The use of sprinklers is not allowed except for irrigating golf courses.
- Direct reuse of treated wastewater is not allowed in irrigating vegetables that are eaten raw, such as tomatoes, cucumbers, carrots, lettuces, radishes, peppers, cauliflowers, cabbages, mint, parsley and coriander.
- It is not permitted to dilute the treated wastewater at the wastewater treatment plants' outlet for the purpose of meeting required regulatory standards.
- The use of treated wastewater is prohibited for aquifer recharge if the latter is utilized for drinking water purposes.

Table 11. Jordanian Standards (JS: 893/2002). Maximum acceptable limits for effluent discharge characteristics to streams, *wadis*, water-storage areas and recharge to ground

Parameter	Unit	Discharge	Groundwater recharge
BOD_5	mg/l	60[1]	15
COD	mg/l	150[2]	50
Dissolved Oxygen	mg/l	>1	>2
Total suspended solids	mg/l	60[2]	50
PH	unit	6-9	6-9
Turbidity	NTU	ND	2
NO_3	mg/l	45	30
NH_4	mg/l	ND	5
T-N	mg/l	70	45
E. coli	MPN/100ml	1000	<2.2
helminth eggs	egg/l	< or =1	< or =1
Fat, oil and grease	mg/l	8.0	ND
Group B			
phenol	mg/l	< .002	< .002
Methelene blue active substance	mg/l	25	25
Total dissolved solids	mg/l	1500	1500
Total PO_4	mg/l	15	15
Chlorine	mg/l	350	350
SO_4	mg/l	300	300
HCO_3	mg/l	400	400
Sodium	mg/l	200	200
Magnesium	mg/l	60	60
Calcium	mg/l	200	200
SAR	mg/l	6.0	6.0
Aluminium	mg/l	2.0	2.0
Arsenic	mg/l	0.05	0.05
Beryllium	mg/l	0.1	0.1
Copper	mg/l	0.2	0.2
Fluorine	mg/l	1.5	1.5
Iron	mg/l	5.0	5.0
Lithium	mg/l	2.5	2.5
Manganese	mg/l	0.2	0.2
Molybdenum	mg/l	0.01	0.01
Nitrogen	mg/l	0.2	0.2
Lead	mg/l	0.2	0.2
Selenium	mg/l	0.05	0.05
Cadmium	mg/l	0.01	0.01
Zinc	mg/l	5.0	5.0
Chromium	mg/l	0.02	0.02
Mercury	mg/l	0.002	0.002
Vanadium	mg/l	0.1	0.1
Cobalt	mg/l	0.05	0.05

Table 11. Jordanian Standards (JS: 893/2002). Maximum acceptable limits for effluent discharge characteristics to streams, *wadis*, water-storage areas and recharge to ground

Parameter	Unit	Discharge	Groundwater recharge
Boron	mg/l	1.0	1.0

Source:[14].

BOD5: measured as soluble for WSP and treatment plants with polishing lagoons.

Twice: this value is allowed for WSP and treatment plants with polishing lagoons.

NTU: nephlometric turbidity unit

MPN: most probable number

COD: chemical oxygen demand

SAR: sodium adsorption rate

DO: dissolved oxygen

Table 12. Jordanian Standards (JS: 893/2002), characteristics of effluent used for irrigation of crops

Parameter	Unit	Cooked vegetables, parking areas, playgrounds, side of roads and inside cities	Plenteous trees and green areas, side of roads outside cities	Field crops, industrial crops and forestry
BOD_5	mg/l	30	200	300
COD	mg/l	100	500	500
DO	mg/l	>2	ND	ND
TSS	mg/l	50	150	150
pH	unit	6-9	6-9	6-9
Turbidity	NTU	10	ND	ND
NO_3	mg/l	30	45	45
T-N	mg/l	45	70	70
E coli	MPN/100ml	100	1000	ND
helminth eggs	egg/l	< or =1	< or =1	< or =1

Source: [14];

NTU: nephlometric turbidity unit

COD: chemical oxygen demand;

TSS: total suspended solids;

DO: dissolved oxygen;

MPN: most probable number

ND: not determined.

Table 13. Guidelines for the use of reclaimed effluent for crop irrigation in Jordan

Parameter (mg/l)	Guidelines value (maximum permissible)
Fat, oil and grease	8
Phenol	< 0.002
Methylene blue active substance	100
Total Dissolved Solids	1500
Total PO_4	30
Chlorine	400
SO_4 (mg/l)	500
HCO_3 (mg/l)	400
Sodium	230
Magnesium	100
Calcium	230
SAR (mg/l)	9
Aluminium	5
Arsenic	0.1
Beryllium	0.1
Copper	0.2
Fluorine	1.5
Iron	5.0
Lithium	2.5 (0.075 for citrus crop)
Manganese	0.2
Molybdenum	0.01
Nickel	0.2
Lead	5
Selenium	0.05
Cadmium	0.01
Zinc	5
Chronium	0.1
Mercury	0.002
Vanadium	0.1
Cobalt	0.05
Boron	1.0

Source: [14].

Table 14 shows effluent reuse in restricted irrigation schemes where effluents from wastewater treatment plants are used in the irrigation of fodder crops, olive trees and forests in the vicinity of the treatment works. A total area of 665.4 hectares is irrigated through these schemes. A further 900 hectares are irrigated in the downstream of these wastewater treatment plants alongside watercourses. These reused effluents do not mix with base flow or any other type of water. However, when effluent mixes with base flow waters or any surface water of a better quality, unrestricted reuse is allowed and practised if the quality satisfies the required regulatory standards shown in Table 11, Table 12 and Table 13.

Table 14. Restricted irrigation in the vicinity of wastewater treatment plants in Jordan

Wastewater treatment plants	Type of crops and irrigated area (hectares)		
	Fodder	Olives	Forests
As-Samra	30	150.0	150.0
Aqaba	ND	5.0	150.0
Ramtha	50	0.5	1.5
Mafraq	25	3.0	1.5
Fuhais	ND	1.0	1.0
Madaba	60	1.0	2.0
Abu-Nuseir	ND	0.5	0.2
Ma'an	5.0	2.0	5.0
Irbid	ND	0.2	0.5
Jarash	ND	ND	0.5
Kufranja	7.0	1.0	1.0
Wadi Seer	ND	2.0	3.0
Salt	ND	1.0	0.5
Baqa'	ND	ND	0.5
Tafila	ND	1.5	ND
Karak	ND	1.0	1.5
Sub-total	177.0	169.7	318.7
Total		665.4	

Source: [14];

Unrestricted irrigation is practised in the Jordan Valley but only after the effluent flows over a long distance (about 50 kilometres) during which it mixes with surface water of a much better quality and is retained in a storage reservoir. By that time the effluent, in effect, loses its identity as the water quality improves to a degree that satisfies unrestricted irrigation requirements. Table 15 shows a summary of the extent of reuse applications in Jordan where unrestricted irrigation covers 9100 hectares whereas Table 16 shows the quantities produced, methods of treatment and final disposal. Total quantities reused amounted to 50.3 million cubic metres in 1998 while the total wastewater quantity treated was 79 million cubic metres in the same year. Agricultural withdrawal is estimated at 737 million cubic metres for the year 2000 [4]. Strict supervision is exercised by the Ministry of Health to ensure compliance with regulatory health standards, particularly when unrestricted irrigation is applied. The decision on the degree of restriction to apply and the appropriate irrigation method depends largely on the water quality characteristics and the soil and plants to be irrigated. Surface and drip irrigation methods are used but not sprinklers, as required by regulatory standards.

Table 15. Extent of restricted and unrestricted reuse of effluent in Jordan in 1998

Scope of application	Area (hectares)	Type of crop				Implemented/controlled by
		Cereal and fodder[1]	Forestry[2]	Fruit[3]	Vegetable[4]	
Restricted irrigation in the vicinity of wastewater treatment plants	665.4	177.0	318.7	169.7	ND	Water Authority of Jordan / Ministry of Health
Restricted irrigation in the downstream of wastewater treatment plants	900.0	200.0	50.0	650.0	ND	Ministry of Agriculture and General Corporation of Environmental Protection
Unrestricted irrigation after effluent is diluted with base flow and surface water of better quality	9100.0	650.0	100.0	2500.0	5850.0	Jordan Valley Authority and Ministry of Agriculture
Total	10665.4	1027.0	468.7	3319.7	5850	

(1) barley, Sudan grass, alfalfa, maize (forage)

(2) acacia, cassorina, eucalyptus, etc.

(3) olive, citrus, banana, other

(4) different vegetables; * mixing takes place in Jordan Valley;

Source: [13].

Table 16. Production, treatment and disposal of sludge from wastewater treatment plants in Jordan (1998)

Wastewater treatment plant	Dry sludge produced	Method of treatment	Disposal method
Waste stabilization ponds	26759	Anaerobic digestion in ponds	Storage-landfill
Activated sludge Trickling Filter	5381	Anaerobic digestion, thickening, drying.	Landfill
Kufranja–Trickling filter	654	Thickening, drying.	Landfill
Baqa'a –Trickling filter	3550	Thickening and transportation to anaerobic ponds in As-Samra	Storage-landfill
Abu-Nuseir–Activated sludge	285	Aerobic digestion, thickening, transport to anaerobic ponds in As-Samra	Storage-landfill

Source: [13].

ND: not determined.In Jordan most treated wastewater flows through valleys into storage reservoirs. However, in some locations the effluents require pumping to reuse sites e.g. effluents from wastewater treatment plants in Aqaba, Madaba, Kufranja and Ma'an. Some industries reuse treated wastewater for onsite irrigation or in their cooling systems but such practices are relatively rare compared with those reused for the purposes of irrigation. The industries concerned consider this reuse as one way of disposing of their wastewater that achieves compliance with regulatory requirements for industrial discharge which is governed by another standard known as JS: 202/1990 for industrial wastewater.

In 1998 it was estimated that 3650 tons of dry sludge were produced from all wastewater treatment plants in Jordan. About 74% of the generated quantities are formed in water stabilization pond plants which are normally desludged once every five to ten years.

Sludge characteristics in Jordan satisfy the United States Environmental Protection Agency (EPA) class B regulations for land application purposes. However, there are concerns about the presence of viruses and helminth eggs in enough counts to restrict sludge reuse for agricultural applications. Further treatment is, therefore, deemed necessary to satisfy the requirements of the Jordanian Standard for sludge uses in agriculture (JS: 1145/1996) [16] which bans untreated sludge reuse for agricultural activities. Standards also impose various other conditions including when, where and for which crops, treated sludge may be applied. They also stipulate the amount of sludge that may be applied and the maximum allowable limits, application rates and the maximum levels of elements' accumulation over a certain area.

JS: 1145/1996 has the following general conditions on sludge agricultural uses.

- It is prohibited to utilize untreated sludge for agriculture purposes.
- Sludge treated to "first degree" level (treatment by aerobic digestion or drying, anaerobic digestion, pH adjustment or any other method capable of reducing volatile solids and repelling disease transmission agents) may be used for agricultural purposes.
- Sludge may be used as a soil conditioner for uncultivated lands, provided that it is ploughed up immediately, and for forestry.
- Treated sludge applications should be done between the beginning of April and the end of June.
- Sludge treated to "second degree" level (treatment by fermentation, thermal drying, thermal treatment or aerobic thermal digestion) may be used in soil preparation before planting fruit trees, fodder and field crops. However, harvesting and allowing animals to feed on these crops is only allowed after a three month period has passed following the application of the sludge. It is also prohibited to apply such sludge on land used for growing vegetables, landscaping, public parks, and plant nurseries or in residential areas.
- Caution should be exercised to ensure that applications do not result in the contamination of susceptible ground or surface water resources.
- Sludge application may only be practised after the formal consent of the pertinent authority.

The maximum allowable heavy metal concentrations, application rates and accumulated levels as specified by JS: 1145/1996 are shown in Table 17. The Standard also imposes maximum concentrations on two levels; for faecal coliforms 2.0X106 most probable number per gram (MPN/g) for first degree treatment level and 1.0X103 (MPN/g) for second degree treatment level. Limits for Salmonella are less than 3/4 grams of total dry solids, while for viable nematode eggs and viruses they are less than 1/4 grams of total dry solids.

Studies on the effect of sludge use in agriculture are virtually non-existent in Jordan. There have also been few results of analysis regarding the constituents of sludge produced in the various wastewater treatment plants. This is, perhaps, because the scale of sludge application activities is also very insignificant. Nonetheless, an analysis of the accumulated sludge in the largest wastewater treatment plants of As-Samra wastewater stabilization pond plant, which supposedly receives the major quantity of industrial discharges in the country, revealed concentrations of trace elements as shown in Table 18. Almost all concentrations of shown elements are well below EPA limits specified for agricultural practices.

Table 17. Maximum allowable limits, application rates and accumulation levels for sludge reuse in agriculture

Element	Concentration (mg/kg of dry sludge)	Application rate (kg/ha/year)	Maximum accumulation level (kg/ha)
Arsenic	75	2	41
Cadmium	85	1.9	39
Chromium	3000	150	3000
Copper	4300	75	1500
Lead	840	15	300
Mercury	57	0.85	17
Molybdenum	75	0.9	18
Nickel	420	21	420
Selenium	100	5	100
Zinc	7500	140	2800
Cobalt	150	1.8	36

Source: [15].

Table 18. Trace element concentrations in sludge from As-Samra waste stabilization ponds (1993)

Element	Concentration (mg/kg)–dry weight basis		
	Geometric mean	Maximum	EPA limit
Aluminium	7800.0	13 207	ND
Silver	1.49	23.5	ND
Arsenic	1.31	2.9	41
Cadmium	3.65	8.1	39
Cobalt	4.63	50.7	ND
Chromium	222.0	669.0	1200
Copper	231.0	362.0	1500
Iron	436.0	23 676	ND
Mercury	2.49	5.3	17
Lithium	2.9	5.6	ND
Manganese	127.00	175.0	ND
Nickel	46.60	68.4	420
Lead	152.00	211.0	300
Selenium	1.46	6.3	36
Silicon	1.15	1028.0	ND
Tin	0.19	0.6	ND
Titanium	78.80	316.0	ND
Vanadium	22.10	141.0	ND
Zinc	2163.00	3850.0	2800
Boron	33.60	88.8	ND

Source: [15];

ND: not determined.

Table 19. Reclaimed water standards in Kuwait

Parameter	Irrigation of fodder and food crops not eaten raw, and forest land	Irrigation of food crops eaten raw
Level of treatment	**Advanced**	**Advanced**
Total suspended solids (mg/l)	10	10
Biochemical oxygen demand–5 days (mg/l)	10	10
Chemical oxygen demand (mg/l)	40	40
Chlorine residual (mg/l) After 12 hours at 20°C	1	1
Coliform bacteria (count/100ml)	10 000	100

Source: [13]

Kuwait

About 85% of Kuwait’s population is connected to a central sewerage system. In 1994 from a total quantity of 119 million cubic metres of wastewater produced, 103 million cubic metres were treated.

Irrigation reuse is practised after tertiary treatment techniques that include activated sludge, filtration and chlorination. Stringent reuse regulatory standards are implemented as shown in Table 19. In 1991 there were plans to utilize all treated wastewater from three wastewater treatment plants having a total daily capacity of 302 400 cubic metres.

Lebanon

Lebanon produced 165 million cubic metres of wastewater in 1991 but the amount treated was estimated at a mere four million. About 130 million cubic metres were classified as of domestic origin and the rest comprised industrial discharges.

Cesspools constitute the most dominant wastewater disposal technique for communities without sewers. Seepage of wastewater from cesspools into groundwater has been reported and is of increasing concern. Also of concern is the direct outflow of raw sewage from small communities and inland villages into natural watercourses. There are no formal reuse schemes implemented. Only 2 million cubic metres were informally reused for irrigation purposes in 1991. However, unlawful reuse of raw wastewater for irrigation is taking place [4].

Morocco

The amount of wastewater collected varies greatly in Morocco depending upon the rate of connection to the sewerage network, which also varies from large to medium-sized cities. The rate of connection was the highest at 45% to 77% in small urban centres in the year 2000. These rates did not improve proportionally to the increase in population growth over the 1994–2000 period as only 1.2 million people were connected to the sewerage network compared with a population increase of 2 million. Table 20 shows connection rates for 1994 and 2000. Figures for the latter were projected for an annual population growth rate of 2.6%.The extent of coverage in the urban areas depends mainly on the standard of living and socioeconomic status in general. In one urban area in the southern region, the coverage rate is about 50% while it is as high as 80% in another urban centre. Populations not connected rely mostly on individual onsite sanitation systems. Less than 30% of the rural population had any means of sanitation until 1994, with open defecation being the usual practice. At present, some 39% of the rural population has access to improved sanitation means. In the rural areas 90% of the onsite systems were cesspools and the remaining 10% septic tanks. It is also to be mentioned that the availability of an onsite sanitation facility in a household does not necessarily mean that all family members make use of it. It was learnt that in 13% of the villages the household sanitation facilities are only utilized by guests, women using them exclusively in 11% of these villages. Lack of piped water supplies, local habits and poverty have all been cited as major obstacles hindering the provision of improved sanitation facilities for the rural populations.

Table 20. Rate and total population connected to the sewerage network in Morocco

	1994			2000		
Urban area	**Population**	**Rate of connection (%)**	**Connected population (millions)**	**Estimated population (millions)**	**Rate of connection (%)**	**Connected population (millions)**
Large/medium-sized towns	12.0	75	9.0	14.0	77	10.8
Small centres	1.30	45	0.6	1.5	45	0.7
Subtotal	13.3	75	9.6	15.5	77	11.5
Rural area	12.8	0	0	14.9	0	0
Total	26.1		10.5	30.4		11.5

Source: [18]).

Sewerage connection cost is structured so that the beneficiary bears part of the expenses of the wastewater system that includes collection, conveyance, treatment and/or disposal. In Morocco this fee charging system is known as the participation for the first settlement (PFS), which is calculated according to the following equation:

$$\mathbf{PFS = (T_1 + KT_2)\ (R + nr)^{1/2}\ I/I_0}$$

Where:

$(R+nr)^{1/2}$:	represents the length equivalent taken as the basis for the contribution
T_1:	unit part of participation to the sewerage infrastructure located down stream of the tertiary network, "hors-site";
T_2:	unit part of participation to the tertiary network, "in-site";
R:	area of land occupied by the house, in square metres;
n:	number of the floors minus 2 (n= 0 for 2, 1 for 3 and 2 for 4 floors);
K:	a coefficient to account for the sewerage system adopted at the level of the tertiary network;
K=1	for a unitary system, collection of sewage and storm water by the same pipe;
K=1.5	for a dual network (separate collection of sewage from rain water);
R:	covered area at each floor;
I/I_0:	price revision coefficient that depends on the construction costs index.

A typical PFS amount ranges from US$ 50–88 per metre length. Low-income housing, less than 120 square metres, and properties in small urban centres were usually exempt from the PFS charging system. However, the present trend is to apply the PFS system because of increased demands to accelerate the expansion of services and the ensuing investments required.

Connected households are also charged for operation and maintenance costs through a binomial tariff system that takes into consideration not only the need for waste minimization but also the amount of water consumption in the different socioeconomic categories. The amount collected is a fixed fee plus the quantity of water consumed multiplied by a proportionality coefficient. The fixed or variable fee amounts are normally determined through a contract between the municipality and the sanitation engineer, countersigned by the Ministry of the Interior.

Wastewater treatment in Morocco is limited. Only 8% of the urban population is connected to treatment utilities, some of which are either out of service due to lack of maintenance or the absence of a sewerage network connection. In 1999, out of a total generated quantity of 420 million cubic metres only 33.6 were treated. Untreated wastewater amounting to 250 million cubic metres was dumped into the Atlantic and the Mediterranean. This is expected to reach 390 million cubic metres by 2010. Presently about 6.5 million people (48% of the urban population) and 0.65 million people (5% of the urban population) dispose of their wastewater into the Atlantic and Mediterranean respectively. The remaining amount (47% of the urban population) is discharged into rivers and *wadis* inside the country.

Table 21 shows projected wastewater quantities that will be disposed of in this manner by 2020 unless efforts are made to ensure safer environmental disposal and/or reuse. The bulk of wastewater (66.8%) is produced by the main 10 cities while the rest (33.2%) is generated by the 305 medium-sized cities and small urban centres. Average per capita wastewater production was estimated at 80% of the water consumed. In other studies, per capita production was shown to vary depending upon the size of the city or community. In a community with a population of less than 20 000 people, wastewater production was estimated at 68 litres per capita per day, while it was 75 litres per capita per day for medium-sized cities and 118 litres per capita per day for cities with populations exceeding 100 000. Other surveys put the national wastewater production figure at 60 litres per capita per day [18].

Wastewater characteristics vary according to, among other things, standard of living and quantity of water consumption. Generally, wastewater concentration tends to be stronger in smaller communities whose water consumption is normally less than that in the big and medium-sized urban centres. In terms of BOD_5, COD and TSS concentrations, wastewater in Morocco may be described as medium to strong in concentration. Table 22 shows wastewater concentrations in communities with three different sizes of urban populations. Clearly, wastewater concentration is stronger in the smaller sized centres. In terms of BOD_5 and COD concentrations, the difference could be as high as 33%. For example,

BOD_5 is 400 milligrams per litre in the smaller communities and 300 milligrams per litre in the big cities.

Until 1993, there were 55 wastewater treatment plants serving small centres and medium-sized cities. Most of these were aging plants that were built during the 1950s. Only 18 of them were operating normally while 31 plants were out of service and the remaining six were not connected to the sewerage network since pumping stations could not be financed.

More recent wastewater treatment plants include five activated sludge plants handling 94% of an estimated total daily flow of 229 393 cubic metres, while the rest is treated by wastewater stabilization ponds (5%) and a trickling filter (less than 1%). Activated sludge plants are not operated regularly due to lack of maintenance and the high energy costs needed for continuous operation. The need to allocate necessary funds to sustain the operation of these plants is not properly understood by local governmental boards. Most of the new plants built in the 1990s employ extensive technologies, such as wastewater stabilization ponds, high rate ponds and sand infiltration percolation [18]. Table 23 shows all of the wastewater treatment plants in the country. The Al Houceima wastewater treatment plant has been reported to be encountering several problems including a misconception in the design, non-adapted equipment, lack of maintenance and high energy bills.

Table 21. Wastewater produced in 1999: quantity projected for 2020

Receiving bodies of water	Wastewater quantity (million cubic metres)		
	1999	2020	Percentage
Atlantic coast	228.4	355.7	53.95
Mediterranean coast	18.8	29.3	4.45
Rivers and *wadis*	176.0	274.3	41.60
Total	423.2	659.3	100.0

Source: [18].

Table 22. Wastewater characteristics in Morocco

Parameter (mg/l)	Urban population		
	<20 000	20 000–100 000	>100 000
BOD_5	400	350	300
COD	1000	950	850
TSS	500	400	300

Source: [18]

Table 23. Wastewater treatment plants in Morocco

Plant	Type and level of treatment	Population	Capacity (m3/d)	Year of construction	Operation
Khouribga-OCP	Trickling filter (P and S)	4 000	500	1962	Normal
Nador	Activated sludge (P and S)	50 000 100 000	7 500	1980 (extended in 1991)	Normal
Bouznika	Waste stabilization ponds, duckweeds (50/50) (ponds)	17 000	1 500	1982	Problem in duckweeds part
Ben Guérir-OCP	Activated sludge (P and S)	8 000	1 500	1982	Normal
Khouribga Municipality	Activated sludge (P and S)	60 000	ND	1984	Irregular
Ben Sergao	Anaerobic pond plus sand infiltration percolation (P and S)	6 000	750	1985	Normal
Boujâad	Waste stabilization ponds (P and S)	35 000	3 800	1992	Irregular
Al Houceima	Activated sludge (P and S)	60 000 85 000	4 800 6 700	1996	Normal
Benslimane	Waste stabilization ponds, aerated facultative/deep reservoirs (P and S)	37 000	5 600	1997	Normal
Beni Mellal	Activated sludge (P and S)	140 000	6 000	1998	Irregular
Drarga	Anaerobic/sand infiltration-percolation/ recirculation (P and S)	7 300	243	2000	Recently put in service

Source: [18].

OCP: National agency for phosphate exploitation

ONEP: National agency for drinking water.

P: Primary treatment

S: Secondary treatment

Although the 1995 Water Law included provisions requiring polluters to pay for wastewater disposal, no bylaws or regulations have been promulgated to enforce these requirements to date. Owners and operators of wastewater treatment plants are still neither obliged to demonstrate effluent quality compliance to the law nor plant operational efficacy.

Well-planned effluent reuse schemes are implemented on a small scale in tourist areas and hotels in addition to the royal golf courses. Conversely, untreated wastewater usage is quite common in Morocco; it is used directly for irrigation whenever disposal to the sea is not possible. There is also extensive indirect reuse through taking water from rivers and *wadis* carrying wastewater that can make up more than 90% of the total flow in dry periods. Reuse is predominantly for irrigation purposes while industrial reuse is insignificant. In 1994, a report that was put forward to the National Council for Water and Climate revealed that about 7235 hectares were irrigated with raw wastewater to grow fodder crops, wheat, fruit trees, and various industrial crops. Consequently, the Council advocated the adoption of regulated wastewater reuse in agriculture. It also recommended that national sanitation agencies should be prompted to include the evaluation of effluent reuse potentials in all wastewater management studies.

From a public health and environment protection perspective, a need to promulgate the regulatory standards for treated wastewater effluent quality and reuse applications is understood. These should be derived from local and international experience and be in line with the World Health Organization and Food and Agriculture Organization guidelines. All concerned agencies in the wastewater sector should consult to formulate these standards. The capabilities of the various wastewater treatment techniques ought to be defined, stressing that the removal of helminth eggs is necessary to determine effluent suitability for unrestricted irrigation. Geographical boundaries of reuse schemes should be defined in order to identify farmer awareness and training programmes held on effluent reuse. Treated effluent quality, irrigated soils and water resources in the vicinity of fields where wastewater is being reused, should be put under steady surveillance and regular reports submitted to the Ministry of Health and other concerned governmental agencies.

From an institutional and organizational point of view, a holistic approach is deemed necessary to combat water scarcity, pollution, and protect public and environment health. There are particular requirements for improved management of wastewater treatment and reuse, including better operation and maintenance of the existing wastewater treatment plants. Improved organization of effluent reuse schemes to account for better use of fertilizers, more efficient use of water and checking soil salinity have been called for. There are also concerns regarding the awareness of farmers towards the possible public health risks that may occur due to malpractices (e.g. fruits come in contact with effluent utilized for irrigation, farm labourers not wearing appropriate protective clothing and effluent distribution pipes not distinguished from other drinking water distribution networks).

Cost recovery is perceived as an essential aspect in wastewater reuse projects in Morocco. The cost is seen as a shared responsibility among wastewater producers, municipalities and users of treated effluent. The share of each of the various parties could be based upon rules such as the “polluter pays rule”, and treated wastewater considered a resource that ought to be included in the overall national water budget, rather than a waste.

So far, except perhaps for the requirement in the 1995 Water Law, which affirms the need for reused effluents to comply with the national norm, there are no regulatory standards for treated wastewater reuse in Morocco. In 1996, however, the rural engineering department of the Ministry of Agriculture released the draft of limit-values for the evaluation of the quality of irrigation water, which included maximum limits for pertinent physical and chemical parameters in accordance with Food and Agriculture Organization’s guidelines. It also adopted the 1989 World Health Organization’s microbiological guidelines for agricultural reuse.

In 1990 the viability of wastewater reuse in Morocco was studied in Ouarzazate in the south of the country. This city has a north-Saharan climate with a mean annual rainfall of about 108 millimetres and an annual evapotranspiration of more than 3000 millimetres. The project consisted of two phases with the first covering the treatment part, a train of wastewater stabilization ponds and a parallel train of high rate pond technology, while the second phase dealt with the institutional, organizational and epidemiological aspects of effluent reuse. The experimental site was selected in an area where irrigation with raw wastewater had been practised for more than twenty years. For experimental purposes treated wastewater was supplied to those farmers who had been irrigating with untreated wastewater. The main outcome of the project may be summarized as follows.

- Drip irrigation and sprinklers may be utilized but only after filtering the effluent by a sand filter and a screen to rid the effluent of its algae content.
- Crop yield was higher when the treated effluent was utilized compared with the use of groundwater.
- The collaboration between farmers, local government, Ministry of Health, Local Agricultural Board and other concerned bodies was highly commendable in the smooth running of the project. The projects steering committee, comprising representatives from the pertinent authorities, was the local governing entity and could decide whether to supply effluent to farmers or not depending on its microbiological quality in particular.

Another study on wastewater reuse was carried out in Agadir in 1991. A three-hectare piece of land was divided into two. One half was irrigated with freshwater while, for purposes of comparison, the other was irrigated with treated wastewater effluent. Treatment was based on an infiltration–percolation plant. Crops were grown in a greenhouse. Sludge potential as a fertilizer was also studied.

No details of the study are available but results were said to be so encouraging that the system was adopted and applied in the greater Agadir area where the effluent was fully reused for irrigating golf courses and landscaping.

Since only 8% of wastewater in Morocco is treated, produced sludge is small. It has been estimated at 6500 tons per year. Sludge treatment facilities are also insufficient as drying beds are undersized and there is no mechanical treatment. Less than 10% of the sludge is utilized by the gardening service of the local municipality while the remainder is simply left to accumulate within the vicinity of wastewater treatment plants.

The only sludge analysis conducted in Morocco was on that of dried sludge of the anaerobic ponds in the Ouarzazate project. Results have shown the sludge to be rich in organic matter which can be used as a soil conditioner. When applied to soil at a rate of 15 tons per hectare, the nutrient supplied value was estimated at 248, 48 and 38 kilograms per hectare of nitrogen, phosphorus and potassium respectively, corresponding to an estimated saving of US$ 189 per hectare of fertilizer.

Results of research on the effect of treatment using drying beds have demonstrated that numbers of *Ascaris* spp. eggs, which were counted at 8–9 eggs per gram of dry matter originally, decreased to zero after a period of 8 months of exposure to the sun. Moisture content also went from 99%–3.5% on average. Heavy metals' content was within the acceptable limits recommended by the Food and Agriculture Organization and European Union regulations.

Epidemiological studies were conducted to establish possible implications on human health from using untreated wastewater for irrigation rather than freshwater. It was concluded that risk of infection increased three to four times when untreated wastewater was used over a long period of time, and no improvement was realized after 6 months of being substituted by treated wastewater. High incidence rates of helminthic infections were also identified in Marrakech and Beni Mellal areas where untreated wastewater was used compared with areas where freshwater irrigation is practised.

No measures are implemented to protect public health in areas where untreated wastewater is used for irrigation. However, local authorities normally uproot any type of crops that may be eaten raw if found being irrigated with untreated wastewater. From another perspective, helminth eggs were found in soils and alfalfa crops that were irrigated with raw wastewater and animals grazing in these areas were infected. Furthermore, groundwater resources in the vicinity were contaminated with bacteria and nitrates to the extent that they could no longer be used for potable purposes.

The only major effort made to promote and regulate wastewater reuse in Morocco after the 1994 National Council for Water and Climate principles was a 1999 United Nations Development Programme supported study for the Rural Engineering Department of the Ministry of Agriculture. The study, "Consolidation of the National Strategy for Wastewater Reuse in Agriculture", aimed at establishing a better understanding of wastewater reuse potential for the next 10 years. It also aimed at introducing an institutional mechanism to enable the improvement of existing reuse practices and advancement of the wastewater reuse sector in general, based on the 1995 Water Law and associated decrees for enforcement. Decree 2.97.875 of 1997 was issued to regulate wastewater reuse in Morocco through outlining permission procedures for wastewater reuse, its objectives and implications. The study presented a proposal for an institutional framework defining the role of the various governmental departments. Table 24 shows a summary of the proposed institutional setup. Responsibilities for wastewater collection, treatment and delivery of treated effluent for reuse are split between four ministries, those of the Interior, Public Works, Agriculture and Health. A central role was given to the River Basin Authority of the Ministry of Public Works in accordance with the 1995 Water Law.

Table 24. Institutional scheme for the development and management of wastewater reuse in agriculture

Activity	Government level	Institution/agency	Role	Associated agencies	Objective
Wastewater collection	Ministry of the Interior	Municipal and rural collectivities	Optimal collection, transportation, preliminary or primary treatment based on the population contribution capacity	Intercommunal, Régies, ONEP private operator)	Protection of water resources and public health
Wastewater mobilization	Ministry of Public Works	River Basin Agency (RBA)	Adequate complementary treatment, transportation to the reuse site, storage during low water demand	—	Mobilization of a non-conventional additional water resource
Treated wastewater effluent supply	Ministry of Agriculture and Ministry of Health	Local agricultural board Local health representative Water user association (non governmental)	Equipment of irrigated areas, water management, effluent quality monitoring, (health parameters) farmer and population health status surveillance, water cost recovery	—	Valorization of a non-conventional additional water resource

Source: [18].

In Morocco, management responsibilities in the wastewater sector are divided between a large number of departments and agencies. Sanitation comes under the responsibility of some 1547 local municipalities, 1298 of which are rural while the remaining 249 are urban. A responsibility may be handed over to another public entity or to a private contractor. Water resources are the responsibility of the Ministry of Public Works while water and wastewater quality issues are under the jurisdiction of the Ministry of Health and the municipal council of local collectives. Effluent reuse is under the authority of the Rural Engineering Department of the Ministry of Agriculture. The Ministry of Regional Planning, Environment and Housing is the central coordinator for all environmentally related issues in the country.

The National Agency for Drinking Water (ONEP) of the Ministry of Public Works assumes a major role in the development of potable water supplies and sanitation. ONEP is financially and managerially independent. It carries out water and wastewater quality surveillance and monitoring programmes through its well-equipped central laboratory. The role of ONEP has been institutionalized by the government in an endeavour to improve water supply and sanitation provisions to medium-sized cities and small urban centres.

As already mentioned, local municipalities have traditionally managed the water and wastewater sectors. However, since 1987 this has gradually changed as responsibilities were assigned to special state agencies known as “régies”. A second shift has been pursued since 1997 as a policy of greater private sector involvement was adopted by the central government due to the régies’ huge financial difficulties. Thirty-year concession management contracts were given to international firms and consortiums e.g. Lyonnaise des Eaux for Casablanca, a Portuguese-Spanish consortium for Rabat and lately Vivendi was awarded the Tangier-Tétouan contract. Nonetheless, local governments remained the owner of the works. Most of the funding for the wastewater sector comes through loans, loan guarantees, or commercial credits, in addition to grant assistance. Future strategies entail the implementation of the polluter pays rule in an endeavour to ensure the sector’s required finances. Huge investments are anticipated in the wastewater sector for the next decade. Private companies are expected to invest about US$ 2.18 billion in large city projects that they themselves manage, while US$ 0.43 billion will be supplied by intercommunal companies, also on big city projects and US$ 0.13 billion by ONEP on medium-sized cities and small urban centres. These investments are intended to improve the sanitation services of an estimated population of 9.3 million, amounting to 60% of the total urban population.

Research and training in sanitation in general, wastewater characterization and treatment, effluent reuse and environmental impact, are given due attention by a myriad number of governmental and nongovernmental institutes. These include engineering and agricultural schools at universities, ONEP, the Moroccan Royal Engineering Department, the Ministry of Health and others.

Palestine (West Bank and Gaza)

The following overview covers only the West Bank (including East Jerusalem) and Gaza Strip parts of Palestine. These parts are physically separate and have a total area of 6067 square kilometres with a total population of 3.27 million people in 2001.

Rainfall varies greatly in the West Bank, from a mean annual amount of 700 millimetres in the northwest to less than 100 millimetres in the Jordan valley. In Gaza, it is about 415 millimetres. Water is scarce in Palestine and its accessibility is severely exacerbated by Israeli occupation.

Sewerage connections of households have been estimated at 34% in the urban areas of the West Bank. Sewerage systems are hardly found in the rural areas and people rely mostly on cesspools and, to a lesser extent, septic tanks for wastewater disposal. Some 40% of industries discharge their effluent into existing sewer systems and those unconnected utilize cesspools. In Gaza, 53.5% are connected to the sewerage network while unconnected homes use cesspools. About 58% of generated wastewater in refugee camps is discharged through open sewers [19]. About 60.2% of industrial effluents are discharged into Gaza sewers [20].

The total amounts of wastewater generated annually in the West Bank and Gaza (Palestinian populations only) are 40 and 45 million cubic metres respectively. However, the respective collected quantities are 14 and 24 million cubic metres [20]. The potential for reuse was estimated at 35 million cubic metres per year. However, since effluent water quality is poor most treated wastewater is dumped into the sea, in the case of Gaza, and to adjacent *wadis* in West Bank cities. This is despite the availability of 50 000 hectares of irrigable land [19].

From a quality perspective, wastewater is classified as strong in Palestine. In the West Bank BOD_5 was reported to be about 900 milligrams per litre. Water consumption has been estimated at 50 litres per capita per day. In Gaza, where water consumption is known to be generally higher than in the West Bank, BOD_5 was reported to have a value of 560 milligrams per litre [20].

Until 1995, there were about eight old wastewater treatment plants in the West Bank and Gaza. Those in the West Bank (5 plants) were built in the 1970s in the cities of Ramallah, Al-Bireh, Tulkarem and Jenin (rebuilt in 1994). The Jerusalem wastewater treatment plant was constructed before 1967. In Gaza there are three wastewater treatment plants that were mostly built in the 1980s. Plans to build, rebuild, expand or rehabilitate wastewater treatment plants have been hindered either by financial (e.g. Tulkarem) or political (e.g. Nablus) constraints. None of the 425 West Bank rural communities has any sewerage or treatment facilities.

Two wastewater treatment plants in Gaza have been reported to be operating reasonably well. These are the Gaza City and the Beit-Lahia wastewater treatment plants. The former receives about 40 000 cubic metres per day (300 000 population equivalent) and comprises 2 sedimentation ponds, 1 anaerobic pond, 2 trickling filters, 1 aerated lagoon, a disinfection contact basin, 8 sludge drying beds and a sludge holding tank. Effluent has a BOD_5 of 30 milligrams per litre, TSS less than 30 milligrams per litre and TKj-N less than 50 milligrams per litre. Most of the effluent is discharged into the Mediterranean. The Beit-Lahia wastewater treatment plant is relatively smaller with a daily capacity of 10 000 cubic metres (120 000 population equivalent) and comprises bar screens, 2 sedimentation ponds, 2 aerated ponds, 2 facultative ponds and a holding reservoir. Its effluent also discharges to the Mediterranean. Typical influent and effluent characteristics of the Beit-Lahia wastewater treatment plant are shown in Table 25.

Table 25. Typical influent and effluent characteristics at the Beit-Lahia wastewater treatment plants in Gaza

Parameter	Influent	Effluent
Temperature (ºC)	24.8	24.8
Hydrogen Ion (-)	7.7	8.0
Biochemical oxygen demand – 5	605	40
Chemical oxygen demand	1360	102
Total suspended solids	576	38
Ammonium (as nitrogen)	113	56
Nitrate	26.6	14.5
Sulfate	243	127
Total faecal coliform (MPN/100ml)	$4.1x10^8$	$1.2x10^5$

Source: [20].

All units are in mg/l except where noted MPN most probable number.

It was reported that only 10% of the wastewater treatment plants in Palestine meet the effluent criteria of their original designs. In fact, most wastewater treatment plants were described as being environmental hazards. The wastewater treatment plants at Rafah, Jabaliah and Ramallah employ aerated ponds and chlorination units that are mostly out of order. There is an activated sludge plant at Bir Zeit University and extended aeration at Al-Bireh City. The wastewater treatment plant in Tulkarem City has three anaerobic ponds while that in Hebron comprises three sedimentation ponds. Local municipalities and village councils assume the responsibility of collection, treatment and disposal of wastewater in the West Bank and Gaza, except for refugee camps that are being managed by the United Nations Relief and Work Agency. Planning, design and construction of wastewater utilities are conducted by engineering departments in large municipalities and engineering consultants in the private sector. The municipalities normally undertake operation and maintenance. Several obstacles, such as a lack of well-trained operators, the unavailability of spare parts, or reliable tools, standby pumps and financial constraints, hinder the wastewater sector in Palestine.

Irrigation with raw wastewater has been practised in many sites of the West Bank. Crops and vegetables like parsley, mint, peppers, eggplants, squash, cauliflower, radishes and olive trees are being irrigated with untreated wastewater without any official health control or due consideration to possible health or environmental implications. The only controlled reuse practice is at Bir Zeit University where treated effluent is used in the irrigation of the University's garden. Health and agricultural officials see great potential for reuse in agriculture and landscape irrigation, groundwater recharge, aquaculture and in industry (stone cutting).

Saudi Arabia

In 1991 the amount of treated wastewater in Saudi Arabia was estimated at 454 million cubic metres per year (1.2 million cubic metres per day) in twenty-two wastewater treatment plants. An upgrading scheme was in place to increase the treatment capacity to 1.8 million cubic metres per day by the year 2000. In 1992, reuse of effluent constituted 48% (217 million cubic metres per year) of the treated quantity. By the year 2000, reused effluent was expected to make up about 10% of the demand. The most prominent wastewater treatment and reuse schemes are those in Riyadh, Jeddah, Mecca and Jubail industrial city. The Riyadh project includes a 113 560 cubic metres per day trickling filter treatment plant. Of the treated wastewater, 15% is reused for industrial purposes by the General Petroleum and Minerals Organization. The remaining quantity is also reused for agricultural purposes and 100 hectares are irrigated. The Jeddah project is rather unique in the region as it comprises a 37 854 cubic metres per day activated sludge treatment plant followed by filtration, reverse osmosis and disinfection. Its effluent quality exceeds the World Health Organization's reuse standards and is akin to those of drinking water quality criteria. In the industrial city of Jubail, plans were set in 1992 to install a facility of 113 562 cubic metres per day, the effluent of which would be reused for industrial purposes, urban landscaping and other purposes. There were also plans to install more wastewater treatment plants with a long-term view of extensive effluent reuse in municipal, industrial and agricultural fields. Full utilization of reclaimed wastewater for non-potable uses is taken seriously and considered part of the water policy in Saudi Arabia [21].

The wastewater treatment plant at Al-Khobar is a 133 330 cubic metres per day activated sludge extended aeration (carrousel) utility. The effluent is chlorinated before eventual discharge to the Arabian Gulf. Only 10% of the effluent is reused for landscape irrigation. Sludge is treated in drying beds and used as a fertilizer. Typical characteristics of the wastewater influent and effluent at Al-Khobar and Dammam wastewater treatment plants are shown in Table 26. These data represent the analysis conducted during May 1995 for Al-Khobar and an annual average (1990–91) for Dammam. It may be seen that while the organic content has been reduced by 98.4%, fulfilling expectations of such a wastewater treatment system, the effluent may only be reused for restricted irrigation due to the presence of faecal coliforms at more than 1000 MPN (most probable number) per 100 millilitres. Salinity concentration is very restrictive for the irrigation of many salinity sensitive crops especially in the case of the effluent from the Dammam wastewater treatment plant.

By 1995 there were 40 wastewater treatment plants serving the 23 major cities in Saudi Arabia. At least 10 of these plants are wastewater stabilization pond plants, the rest being activated sludge and trickling filters. Towns and other smaller cities are served by septic tanks, percolation fields and small package treatment plants [21].

The major difficulties facing the operation and maintenance of wastewater treatment plants in Saudi Arabia are to do with odour emissions from sludge drying beds, which are particularly experienced during conditions of high humidity. Such problems are not encountered with wastewater treatment plants with mechanical sludge treatment techniques. High temperatures have been reported to increase denitrification causing the growth of filamentous bacteria in the activated sludge extended aeration systems, thus creating poor settling conditions.

Reclaimed water standards for unrestricted irrigation in Saudi Arabia, shown in Table 27, are stringent compared with World Health Organization and Food and Agriculture Organization guidelines. However, no values have been specified for intestinal nematodes. In the World Health Organization guidelines, effluents with thermo-tolerant coliform count of less than or equal to 1000 MPN per 100 millilitres and intestinal nematodes less than or equal to one may be used for unrestricted irrigation (World Health Organization Report No. 778, 1989). The equivalent Saudi Arabian criterion is a coliform count of 2.2 per 100 millilitres.

The Ministry of Municipalities and Rural Affairs, Water and Sewage Authority, Arabian American Oil Company and the Royal Commission of Jubail and Yanbu are the main bodies responsible for various aspects in the wastewater sector in Saudi Arabia.

Table 26. Typical characteristics of influent and effluent at Al-Khobar and Dammam wastewater treatment plants

Parameter (mg/l)	Al-Khobar (May 1995)		Dammam (1990–1991)	
	Influent	Effluent	Influent	Effluent
Electrical conductivity (µs/centimetre) at 25ºC	3180	ND	ND	ND
Total suspended solids	138.2	3.5	203	22.5
Turbidity (NTU)	ND	0.41	ND	ND
Total dissolved solids	2104	1745	5533	4979
Chloride	840	790	2293	1250–2400
Biochemical oxygen demand – 5 day	116.3	1.9	103	<5
Chemical oxygen demand	281.5	54.15	427	231
Ammonia (as nitrogen)	20.7	0.0	14.12	0.46
Total phosphorus	18.1	12	13	12.1
Thermo-tolerant coliform count (MPN/100ml)	ND	$79x10^3$	$4.02x10^7$	$4.17x10^5$

Source: [21] and [22]

ND: not determined.

All units are in mg/l unless noted otherwise

MPN: most probable number

NTU: nephlometric turbidity unit.

Table 27. Reclaimed water standards for unrestricted irrigation in Saudi Arabia

Parameter	Maximum contaminant level
Biochemical oxygen demand–5 day	10.0
Total suspended solids	10.0
Hydrogen ion (-)	6–8.4
Coliform (count/100ml)	2.2
Turbidity (NTU)	1.0
Aluminum	5
Arsenic	0.1
Beryllium	0.1
Boron	0.5
Cadmium	0.01
Chloride	280.0
Chromium	0.1
Cobalt	0.05
Copper	0.4
Cyanide	0.05
Fluoride	2.0
Iron	5.0
Lead	0.1
Lithium	0.07
Manganese	0.2
Mercury	0.001
Molybdenum	0.01
Nickel	0.02
Nitrate	10.0
Selenium	0.02
Zinc	4.0
Oil and grease	Absent
Phenol	0.002

Source: [17].

Units are in mg/l unless specified otherwise

MPN: Most probable number;

NTU: nephlometric turbidity unit

Sudan

Wastewater collection in Sudan is low as only 0.6% of the population is connected to a sewerage network. Those connected are in the urban part of Khartoum. The majority of urban dwellers (about 70%) are served with pit latrines, septic tanks and aqua privies. In rural areas, only 25% have acceptable means of excreta disposal. On the national level, about 40% of the population is still without any means of excreta disposal (Table 28).

Selection of an appropriate disposal technique depends largely on prevailing soil characteristics and groundwater table levels in the area of concern. It should also be mentioned that Sudan has a wide spectrum of socioeconomical, geological, climatological and hydrogeological attributes which highly influence the selection of an appropriate excreta disposal technique. For instance, in the western part of Sudan where water is relatively scarce, people tend to employ pit latrines as soil is mostly sandy and groundwater is known to be generally deep. In areas where the groundwater table is high, bottom-sealed pits are constructed and a reasonable distance from water sources ensured. In the Omdurman where groundwater is deep (less than 30 metres) and soil is described as stable, the tendency is to dig seepage pits more than 20 metres deep. However, no regulations exist to control the use of onsite disposal units and therefore construction of these units is left to the discretion of home or utility owners.

Table 28. Wastewater disposal methods in Sudan

Means of excreta disposal	State	Percentage of total population	Number of population (millions)
Bucket	Upper Nile, northern Darfur, northern, Gedarif	0.2	0.06
Aqua privy	Urban centres and big towns	2.2	0.66
Pit latrine	All over the country	55.0	16.50
Septic tank	Capitals of the states and big towns	2.0	0.60
Sewerage network	Khartoum state	0.6	0.18
None	Majority in rural areas	40.0	12.00
Total		100.0	30.0

Source: [24].

Sewerage connections in the past were free. In more recent times, however, citizens have been required to pay for the connection and a monthly charge, in compliance with the 1998 Khartoum State Law, for sewerage services. Sewerage connection charges include a building inspection and map approval and network habilitation fee of about US$ 14 plus US$ 19.4 in the case of a one-storey building. For multi-storey buildings a monthly charge is calculated as US$ 0.19 per square metre. For single households the monthly charge is a fixed amount of about US$ 0.29 (estimates made for the year 2000). The cost for onsite systems is estimated at about US$ 30 for a pit latrine (10x1.5x1 metre) and about US$ 250 for a proper septic tank (3x2x2.25 metres).

There are only 2 wastewater stabilization pond plants in Sudan, Soba and El-Haj Yousif, with a total capacity of 45 920 cubic metres per day (16.76 million cubic metres per year), both in Khartoum State. These 2 plants have been described as malfunctioning. Other wastewater treatment plants including some activated sludge (and their modifications) are employed by various industries with various degrees of operational success. Some industries have also employed evaporation beds to treat generated wastewater.

Commissioned in 1981, the Soba wastewater treatment plant replaced the oldest plant in the country, El Gozae, constructed in 1959 and utilizing the trickling filter technique. El Gozae wastewater treatment plant had been malfunctioning and thus was retired and replaced by Soba wastewater treatment plant. The latter has a capacity of 31 420 cubic metres per day (11 468 300 cubic metres per year) and was restored in 1991. It comprises 2 parallel trains, each of 2 anaerobic ponds, 1 facultative and 1 maturation pond. The effluent was intended for reuse in irrigating the green belt in the south of Khartoum. However, the belt does not exist anymore which means that effluent disposal is a problem that needs tackling.

El-Haj Yousif project was started in 1969 and was to be executed in two phases. Financing was provided by an external aid grant. It consisted of a sewerage network and a wastewater treatment plant. The first phase comprised a sewerage network for north Khartoum industrial wastewater and was completed in 1971 when the wastewater treatment plant was also commissioned. The second phase, meant for the residential area, was never completed. The present wastewater treatment plant is therefore receiving industrial wastewater and has been reported as malfunctioning. The plant has a capacity of 5 292 500 cubic metres per year and consists of screens, an aerated grit chamber, a sedimentation tank and a system of stabilization ponds. Sludge produced in the sedimentation tank was to be treated in an anaerobic digester and drying beds. It was also anticipated, by the designers, that the effluent quality would meet reuse requirements but this was never realized. The plant is presently in need of immediate restoration. Wastewater characteristics in the Soba wastewater treatment plant are as shown in Table 29. These figures demonstrate a medium to strong raw wastewater.

Future plans include the restoration of El-Haj Yousif wastewater treatment plant and upgrading the Soba plant within the next five years. Long-term plans incorporate four schemes to serve the cities of Omdurman, Wadi Medani, Khartoum and Port Sudan. Waste stabilization ponds will most likely be adopted for wastewater.

Table 29. Wastewater characteristics in Soba wastewater treatment plants in Sudan (2000)

Parameter (mg/l)	Raw wastewater	Treated wastewater
Biochemical oxygen demand–5 day	226	45
Chemical oxygen demand	573	137
Total suspended solids	294	51.4
Dissolved oxygen	ND	4.6
Ammonia	6.1	7.2
Nitrate	ND	2.1

Source: [24].
ND: not determined.

There are no formal reuse schemes for treated wastewater at present. In the past, treated effluents were used to irrigate a green belt south of Khartoum, but that was stopped as the Soba plant replaced the wastewater treatment plant in 1981. Nonetheless, there is informal small-scale reuse of treated effluent for building activities. The relatively small quantity of sludge produced from individual industries is disposed of in open dumping sites. There are no provisions for the treatment of sludge and the only studies to have been carried out on the possible impact of its disposal on industrial sludge are those performed by postgraduate students. The only two municipal wastewater treatment plants in the country are monitored by the environment and construction laboratories of the Khartoum State Ministry of Engineering Affairs. Other than that, monitoring programmes on a national level are virtually nonexistent. Also, there are no systematic studies on possible health implications of treated or untreated wastewater disposal and/or reuse. Water quality testing laboratories are in need of essential equipment like atomic adsorption spectrometer, gas chromatographs, and flame photometer. Training is also needed for personnel, particularly at the lower technical and managerial levels.

The drinking water supply sector is administered by the Federal Ministry of Irrigation and Water Resources which comprises a national water corporation and a state corporation for each of the 26 states in the country; they are divided into urban and rural administrative entities. The wastewater sector is managed by the Ministry of Engineering Affairs, Housing and Public Utilities through the Sewerage and Drainage Administration department, which has a sewerage and drainage company and constructional and environmental laboratories. There are separate departments for operation and maintenance and another for quality monitoring purposes. This administrative setup is under revision at present.

Syrian Arab Republic

Populations served with sewers in the Syrian Arab Republic amount to about 71% of the total population of the country. However, the total quantity of treated wastewater is estimated at 228.891 million cubic metres per year, serving 2 587 000 people, which is about 16% of the total population of the Syrian Arab Republic. Table 30 shows existing wastewater treatment plants in the Syrian Arab Republic, while Table 31 shows wastewater treatment plants under construction.

Activated sludge is the dominant wastewater treatment technique. More than 98% of the total wastewater treated is accomplished by two wastewater treatment plants, Damascus (177.025 million cubic metres per year) and Homs (49.275 million cubic metres per year). The remaining 2% is treated by wastewater stabilization ponds and aerated lagoon plants. Raw wastewater is classified as very strong, as may be concluded from the analyses results at the inlet of the treatment plant in Homs, where the average of 94 measurements of BOD_5 concentration is 612 milligrams per litre, ranging from 250 to 1250 milligrams per litre, during the period from August to November 2000.

Table 30. Some wastewater treatment plants in Syrian Arab Republic in 2000

Wastewater treatment plants	Treatment technique	Flow (m^3/day)	Number of population served
Damascus	Activated sludge	485 000	2 500 000
Al-Salameih	Oxidation ponds	8 500	80 000
Homs	Activated sludge	135 000	645 000
Ras Al-Ein	Aerated lagoons	3 000	25 000
Total		631 500	3 250 000

Source: [25].

Table 31. Wastewater treatment plants under construction in Syrian Arab Republic

City	Treatment technique	Flow (m^3/day)	Number of population served	Design effluent quality (mg/l)	
Aleppo	Aerated lagoons	255 000	2 000 000	BOD_5 20	TSS 20
Hamaa	Activated sludge	70 000	404 000	BOD_5 30	TSS 50
Edlib	Aerated lagoons	54 000	182 000	BOD_5 25	TSS 25
Dara’a	Activated sludge	46 000	124 000	BOD_5 25	TSS 25
Sweida	Biological filter	35 000	138 000	BOD_5	TSS 25
Latakia	Activated sludge	117 000	500 000	ND	
Tartous	Activated sludge	42 000	200 000	ND	
Total		619 000	3 548 000		

Source: [25]

TSS: total suspended solids

BOD_5: 5–day biochemical oxygen demand

ND: not determined.

About 177 million cubic metres per year of treated wastewater are reused for irrigating 9000 hectares in Damascus. Flood irrigation is the most commonly used technique. Treated wastewater is given to farmers at no cost. Wastewater disposal is normally made to rivers, valleys or to the sea [25]. Sludge produced from the wastewater treatment plant in Damascus is separated into that from primary settlers and from aeration tanks. Treatment is perceived to be through batch thickening and dewatering by filter belt presses. Wastewater quality monitoring before reuse is conducted by the Ministry of Agriculture and public companies operating the plants. However, trained personnel and equipment are needed in order to conduct microbiological analysis.

A committee has been formed for wastewater management and reuse from the Ministry of Housing and Utilities, Ministry of Irrigation, Ministry of Agriculture, Ministry of Health and Ministry of the Environment. Sewerage works are the responsibility of the various municipalities while wastewater collection and treatment utilities are under the Ministry of Housing and Utilities. In recent years an endeavour has been made to introduce tariffs on the generation of wastewater in order to meet increasing needs for investment in the sector, as well as covering expenses entailed for operation and maintenance.

Tunisia

A total of about 4.15 million people in urban areas were connected to the sewerage network in Tunisia in 1998. In rural areas, however, only 64 500 people were connected. By the end of 1998, an estimated 68% of urban dwellers had sewerage connection. Due to the absence of developmental plans for rural sanitation only 1.8% of the rural population had sewerage connection in 1994 and there is little evidence that this percentage has significantly increased. In 1994, an estimated 2.58 million people were using onsite sanitation units that would mostly consist of a cesspit.

Wastewater per capita daily production was estimated to range from 80 to 125 litres in the Greater Tunis area in 1993, while the national average was about 99 litres. Characteristics of the Tunisian raw wastewater are summarized in Table 32. It may be classified as strong since BOD_5 concentration was greater than 400 milligrams per litre during the years 1997–1999. The national BOD_5 concentration was 454 milligrams per litre in 1999. It is noticeable that this concentration has been increasing during the aforementioned period.

Table 32. Raw wastewater characteristics in Tunisia (1991–1999)

Parameter (mg/l)	1990/91	1997	1998	1999
Biochemical oxygen demand –5 day	366	427	483	516
Chemical oxygen demand	ND	736	757	635
Total suspended solids	ND	393	401	429
Total nitrogen	87	ND	ND	ND
Ammonium (as nitrogen)	58	ND	ND	ND
Total phosphorus	13.6	ND	ND	ND

Source: [26]
ND: not determined.

There were 55 wastewater treatment plants in Tunisia in the year 1999 with a total annual capacity of 194 million cubic metres; 25 of these plants are activated sludge, 14 oxidation ditches, 8 wastewater stabilization ponds, 6 aerated lagoons and 2 trickling filters. The quantity of wastewater collected in 1999 was estimated at 152 million cubic metres, of which 145 million cubic metres were treated, compared with 96 million cubic metres in 1993. The estimated mean of total cost for secondary treatment is US$ 0.11 per cubic metre with the direct operating cost constituting 42% of this amount.

Onsite laboratories conduct wastewater quality analysis for influent and effluent of wastewater treatment plants. Effluent is analysed to ensure compliance with discharge regulatory requirements. An estimated 65 000 analyses were performed on 22 000 samples in 1998. Wastewater treatment plant operators are required to prepare monthly and annual reports that include information on the quantity and quality of influent and effluent as well as pertinent operational parameters, consumed energy, personnel and general maintenance actions. The Ministry of Public Health has its own programme in which it conducts analyses of effluents from wastewater treatment plants with particular attention to those discharged to coastal areas, other receiving bodies and those that are reused for irrigation. An estimated 6882 and 2807 analyses were performed in 1998 on raw and treated wastewater respectively, for pathogen control purposes. The identification of helminth eggs is not included in the routine analysis programmes. However, it was concluded from research conducted in Tunisia that wastewater stabilization ponds are more effectual in removing these eggs than conventional mechanical wastewater treatment plants.

There are plans to promote services in the Tunisian sanitation sector. Some of these plans have been within the national economic and social development plan (1997–2001) and aim at improving sanitation coverage in both urban and rural areas, with particular emphasis on poorer sectors. They also include provision to enhance further wastewater treatment reuse and control. In this plan, US$ 270 million were invested in the sanitation sector. Estimated investments of US$ 1387 million are needed to achieve 95% connection coverage, treat all wastewater produced and implement rainwater drainage projects during the period from 1997 to 2011.

Treated effluents are reused in about 35 irrigated districts. An estimated quantity of 35 million cubic metres was reused in 1998. There are provisions in each wastewater treatment plant to dispose of that part of the treated effluent that is not reused to receiving water bodies. Conveyance and distribution utilities have been established in wastewater treatment plants and include pipelines, pumping stations and regulation reservoirs. All irrigation techniques are employed, including sprinklers. However, certain restrictions are imposed when the latter is used, for example, sprinklers should be far from public roads, residential areas and water supply reservoirs. Sprinklers are not allowed in arboricultural schemes. An estimated area of 6603 hectares is equipped for irrigation while the part actually irrigated with treated effluents is about 4380 hectares from which 1020 are planted with cereals, 2060 with fodder crops and 1300 with arboriculture.

Reuse of treated wastewater for irrigating golf courses has been successfully implemented. This success has been attributed to the fact that these courses are located near tourist areas, which are normally adjacent to the coast where effluent discharge is undesirable. Eight golf courses are irrigated with treated effluent consuming about 4 million cubic metres (15% of the total reused quantity in 1997) [26].

Aquifer recharge by treated wastewater is still being experimented on by the Ministry of Agriculture, which is conducting studies on its feasibility on Oued Souhil. Another study, a pilot project investigating infiltration techniques on the coastal aquifer, has also been followed by the Ministry of Environment.

Treated effluent reuse for industrial purposes is virtually non-existent as demand for such water is minimal. However, with increasing stress being imposed on water resources and subsequent increases in the cost of water, some industries are opting for the option of using reclaimed water. For instance, Menzel Bourguiba steel works requested 1.3 million cubic metres of treated wastewater, thus decreasing its water bill. Future industrial effluent reuse is expected to increase in Tunisia due to regulatory requirements to save water and an incentives policy for such programmes.

An estimated quantity amounting to 15 million cubic metres of untreated wastewater was discharged in the areas of the National Sanitation Agency in 1998 [26]. Such wastewater is normally collected from small remote communities or periurban areas. Plans are reported as underway to construct wastewater treatment plants to handle these quantities. The use of untreated wastewater for irrigation is strictly prohibited and the usual punishment for violators is the destruction of their crops by ploughing them into the ground. Such incidences normally take place during periods of drought.

There have been many applied research projects on wastewater treatment and reuse during the last fifteen years. Most of them were conducted by the Ministry of Agriculture, Centre for Rural Engineering and Research, National Institute for Rural Engineering, Water and Forestry Research (INGREF) and INRST. They concentrated on various aspects of wastewater treatment efficiency, characteristics of irrigated soils, the effect of nitrogen on the growth of irrigated crops, quality changes of treated effluent due to storage, impact of different irrigation techniques and potential health risks in aquifer recharge schemes. There have also been three demonstration projects with the World Bank, one on mixing fresh water from a dam with treated effluent and the other two on aquifer recharge to enable unrestricted reuse.

An estimated quantity of 30 000 cubic metres of dry sludge is produced annually. Sludge is treated employing aerobic digestion, stabilization and anaerobic digestion. Drying beds are normally used for dewatering in most wastewater treatment plants; very few have facilities for mechanical dewatering.

Nearly 50% of produced sludge is applied to land. Disposal of sludge is not regulated. However, lately there have been efforts, by a technical group from the concerned authorities and research institutes, to draft guidelines to regulate land applications of sludge.

Sludge characterization and environmental implications of its use have been among the subjects under research since the 1980s. Involved institutes included the Agricultural Engineering Research Centre and INGREF. Health implications were studied by the Ministry of Health. There is no routine monitoring of the quality of sludge. Nonetheless, the following are the most prominent conclusions from a study that was conducted by INGREF on 11 wastewater treatment plants based on data collected during a period of 9 years (1984–1993):

- there is great variation in the concentration of sludge chemical constituents from one treatment facility to another;
- pH is somewhat basic and salinity is high;

- calcium concentration is relatively high while considered moderate for magnesium and low for sodium and potassium;
- organic content ranges from 17%–42%;
- nitrogen content is in the range 1%–3% while the calcium/nitrogen ratio varied between 5%–15% indicating sufficient sludge stabilization;
- total phosphorus ranged between 0.3%–1.3%;
- concentrations of trace elements were within limits specified in French, European and Environmental Protection Agency guidelines.

Monitoring the quality of treated wastewater before reuse is given considerable attention in Tunisia in order to evaluate the efficiency of wastewater treatment plants, ensure compliance with regulatory standards, assess impact on soil, plant and irrigation technique and ultimately to ensure public health and environmental protection. Several institutes have assumed the monitoring role, the most prominent of which are ONAS, the Ministry of Health and the Ministry of Agriculture. The Ministry of Health monitors effluent quality to make certain that discharged and reused effluents comply with the regulatory health and environmental norms. It also conducts epidemiological studies and executes pertinent health education programmes in cooperation with the World Health Organization. Weekly analysis of biological parameters is performed by the environmental health division of the Ministry of Health which passes on any violations to ONAS. In general, water and wastewater related diseases have decreased in the last twenty years. The Ministry of Health has been conducting epidemiological studies to assess potential health implications on the population as a result of using treated effluent and sludge reuse in agriculture. Potential health risks were also investigated on milk produced from cows grazing on field crops irrigated by treated wastewater. The Ministry of Agriculture has also carried out studies on sludge quality used in agriculture and on aquifers recharged by reclaimed waters.

Every reuse project is subjected to an environmental impacts assessment (EIA). The national state of the environment report contains a section on the actual effect of reuse schemes on health and the environment. No worrying health or environmental implications were reported in a study conducted in 1995 except for the times when effluent quality was impaired and reuse managers were not instantly informed.

Reuse of reclaimed water is controlled in Tunisia through legislation and promulgated quality standards. As stipulated in the Water Code of 1975, irrigation of vegetables eaten uncooked is strictly banned even by treated wastewater. Decree No. 89/1047 regulates the responsibilities and interrelationships of institutes. It further asserts the conditions under which reuse may be practised, the acceptable effluent quality criteria and the necessary control measures to be taken with such practices. Among some of the more important conditions are:

- irrigation water is not to cause any health risk nor be a source of environmental pollution of any kind;
- authorization from the Ministry of Agriculture, Ministry of Health and Ministry of the Environment is to be obtained before treated wastewater may be reused in agriculture;
- only restricted reuse is allowed i.e. for the irrigation of industrial crops (cotton), fodder crops, trees and sport fields (golf courses);
- it is prohibited to use treated wastewater to irrigate vegetables that are eaten uncooked.

The restrictions have been attributed to effluent quality as well as socioeconomic reasons and are rendered necessary to protect public health, field labourers, consumers and the public at large. In one study there were two areas where treated effluent was discharged to a dry *wadi* and infiltration to the local aquifer was highly probable; one case of typhoid and five cases of hepatitis were reported in the first area. In the second area with a population of about 150 000 people, 39 cases of hepatitis were reported. However, no direct linkage could be made to attribute these cases to the effluent infiltrating groundwater resources. The advantages of water reuse were felt as a result of increasing the land cultivated, augmenting available water resources and evading effluent discharge to freshwater bodies.

ONAS is responsible for sanitation services in urban areas and owns all of the wastewater treatment plants in Tunisia. Municipalities cater for sanitation services in areas outside the jurisdiction of ONAS. The Ministry of Agriculture is in charge of the management of water resources, planning of irrigated land, storage and conveyance infrastructure. Regulatory and policy matters are under the responsibility of the Ministry of Environment while effluent quality and other control activities are with the Ministry of Health. ONAS is the treated effluent provider and also owns regional laboratories for operational and effluent quality control.

The availability of trained personnel in the environmental field is not a problem, at least in urban areas, as specialized training programmes are implemented by institutions like International Eco-technology Centre. Such programmes have been tailored to suite National Sanitation Agency requirements. However, the case is not the same in the rural and periurban areas where certain training needs have been identified in the fields of low-cost sanitation, appropriate technologies for small communities and public health and environmental management. Training is required for both public and private sector personnel.

Sanitation and treated wastewater reuse are controlled by the following regulations and standards.

- Law No. 75–16 promulgates the water code.
- Decree No. 79–768 regulates connection to and discharge into the public sewers.
- Decree No. 85–6 regulates discharges into receiving bodies.
- Decree No. 89–1047 regulates reuse of wastewater in agriculture.
- Decree No. 93–2447 regulates reuse of treated wastewater in agriculture.
- Decree No. 94–937 regulates discharge of non-domestic wastewater in the public sewerage networks.
- Departmental order of the Ministry of Agriculture dated 21 June, 1994, lists crops which could be irrigated by treated wastewater.
- Joint departmental order of the Ministry of Agriculture, Ministry of the Environment, and the Ministry of Public Health dated 28 September 1995, approves requirements for treated wastewater reuse in agriculture.
- Tunisian Norm No. NT 106.02 specifies norms for effluent discharge in the hydrographical network.
- Tunisian Norm No. NT 106.03 specifies norms for wastewater reuse.

In 1999, 44 wastewater treatment plants were being designed and a further 14 studies were completed. It is perceived that by 2006, 13 new irrigated areas will be established by ONAS and the Ministry of Agriculture. An estimated area of 3113 hectares is expected to be developed, 1000 of which will be served by wastewater treatment plants in western Tunis. It is further anticipated that 5000 hectares will be cultivated and served by these wastewater treatment plants in the coming 15 years. Treated wastewater reuse is also being promoted by ONAS through the cultivation of a 360-hectare area in seven different localities.

Incentives have been introduced to encourage farmers to utilize reclaimed water through cost reductions. The cost of one cubic metre of reclaimed water is about US$ 0.015 per cubic metre compared with US$ 0.0818 per cubic metre charged for freshwater supplies (1998). However, farmers still prefer to use freshwater to avoid restrictions imposed by reclaimed water reuse.

4.2 Regional profile

Population pressures and provision of services

The safe disposal of excreta is essential to safeguard human health and the environment. Provision of improved water supplies can only result in the advancement of public health if accompanied by improved waste collection and proper treatment services. However, improvement of water supply services is often given priority over sanitation. This is thought to have been because the collection and disposal of human wastes is considered aesthetically unpleasant and, conventionally, assumed not to result in any economic benefit. There is relatively less public pressure for the provision of proper wastewater collection facilities because the implications of the absence of such amenities are not understood. Governments, in most developing countries have lacked enthusiasm for sanitation projects because it is presumed that huge investments are entailed. This is because the vast majority of planners, engineers and decision-makers consider conventional sanitary sewers as the best way to collect wastewater. Advancements in the provision of sanitation services have, therefore, lagged behind those of water supply, particularly in developing countries. This is predominantly evident in urban areas where population increase and density are normally higher than in the rural ones. During the 1990–2000 decade, urban populations in the Eastern Mediterranean Region increased by 41% (172 102 000–242 874 000) while the increase was about 28% (216 727 000–255 251 000) in rural areas. On an overall basis, total rural population numbers in the Region exceeded urban population during the period 1950–1990. This has been reversed due to migration from rural areas to urban ones and to high population growth rates (Table 1), increasing the pressure to provide basic services that should include the expansion of wastewater collection and treatment provision. With the exception of the oil-rich countries of the Region (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), the response to meet increasing demands for such services has been modest, particularly for sanitation services, which were given less priority so that the responsibility was left to the discretion of homeowners in most countries of the Region.

Wastewater collection

Available statistics on sewerage coverage in the Region are rather scarce. Nonetheless, it may be clearly concluded that coverage in urban areas is incomplete and unlikely to be achieved. Naturally, the situation is much worse in rural areas where coverage can at best reach a maximum of 5%. Although sanitation utilities in the Region vary greatly from one nation to another, performance indicators reveal achievement in this sector to be far below good practice levels. (Wastewater collection methods in some countries are shown in Table 33.)

In urban areas communities without sewers opt for various individual sanitation units to dispose of their sewage; cesspools are mostly employed. Regardless of the shape or size of these cesspools, they are normally installed to ensure that wastewater seeps into the soil as much as possible in order to decrease the frequency of pump-outs which can prove costly to most homeowners. Maximum seepage is ensured through the spaces in, or perforations of, the cesspool walls and/or its base. A reinforced concrete slab cover, with a manhole opening, is normally placed on the top of the steel perforated barrel, concrete or brick walls of the cesspool to ensure access for pumping out. There are many problems associated with the use of cesspools. This is mainly because of the lack of regulations and management programmes needed for the design, operation and maintenance of individual sanitation units. It is rare that the suitability of soil characteristics and bedrock depth, groundwater table depth and the topography of the surrounding area are accounted for when cesspools are designed and installed. Most common problems are to do with contamination of freshwater resources, negative environmental impact during storage and pumping out and their effect on existing foundations of structures. Unfortunately this means that the opportunities for water reuse are totally missed.

Data on rural areas are generally scarce and whenever available lack reliability, not only in the Region but also in the majority of developing countries. Nonetheless, judging by available data, wastewater collection in rural areas is very low compared with urban areas. This is demonstrated by the low sanitation coverage percentages shown in Table 33 33 and Figure 6. As rural populations are mostly low-income communities, they tend to adopt the least costly alternatives to dispose of their wastewater. The existing practices in rural areas are, at best, to employ cesspools and, rarely, septic tanks. Other means include the use of buckets, aqua privy, pit latrines and open defecation as in countries like Afghanistan, Morocco, Somalia, Sudan and Yemen. Lack of improved water supplies is a major obstacle hindering the provision of sanitation services. The logical consequences of such practices are an increase in the risk to public health, contamination of ground and surface water resources, environmental degradation and decrease in the potential for water reuse.

Wastewater treatment reuse

The amount of treated wastewater depends largely on the extent of wastewater collected, regardless of the collection method. Conventionally, however, treated wastewater quantities are assumed to be associated with the amounts collected and conveyed through sewerage networks and tank-mounted trucks to treatment works. Since the extent of sewerage network coverage is low, as shown in Table 33, the collected and treated wastewater quantities are proportionately low. Treated wastewater quantities for 9 countries in the Region (Egypt, Jordan, Kuwait, Lebanon, Morocco, Oman, the Syrian Arab Republic, Tunisia and the United Arab Emirates) are estimated at 38% of the total wastewater generated in these countries. Figure 8 illustrates the variation in these quantities between eleven countries. (Egypt is not included in the graph.) The quantities shown can only be indicative as direct comparison is not possible since some values refer to potential wastewater production while others refer to amounts actually collected or those received at collection works.

Table 33. Percentage of sewerage coverage in the Eastern Mediterranean Region

Country	Year	Sewerage network			Onsite sanitation			Others		
		Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
Bahrain	—	—	70	—	—	—	—	—	—	—
Egypt	1996	—	74	5	60	—	—	—	—	—
Jordan	1997	49.2	64.7	2.8	50	35	95	0.8	0.3	2.2
Morocco	1994	—	75	0	—	—	<30	—	—	70
Oman	1995	—	20(3)	—	—	—	—	—	—	—
Saudi Arabia	—	—	35(4)	—	—	—	—	—	—	—
Somalia	—	—	0(4)	—	—	—	—	—	—	—
Sudan	2001	0.6	ND	ND	—	59.4	—	40	ND	ND
Syrian Arab Republic	—	—	—	—	—	—	—	—	—	—
Tunisia	1994	—	68(1)	1.8	—	—	23.6	—	—	74.6
Yemen	2000	—	229(2)	—	—	—	—	—	—	—

(1) end of 1998

(2) for the city of San'a [5]

(3) for Muscat only [27]

(4) Source: [23]

ND: not determined.

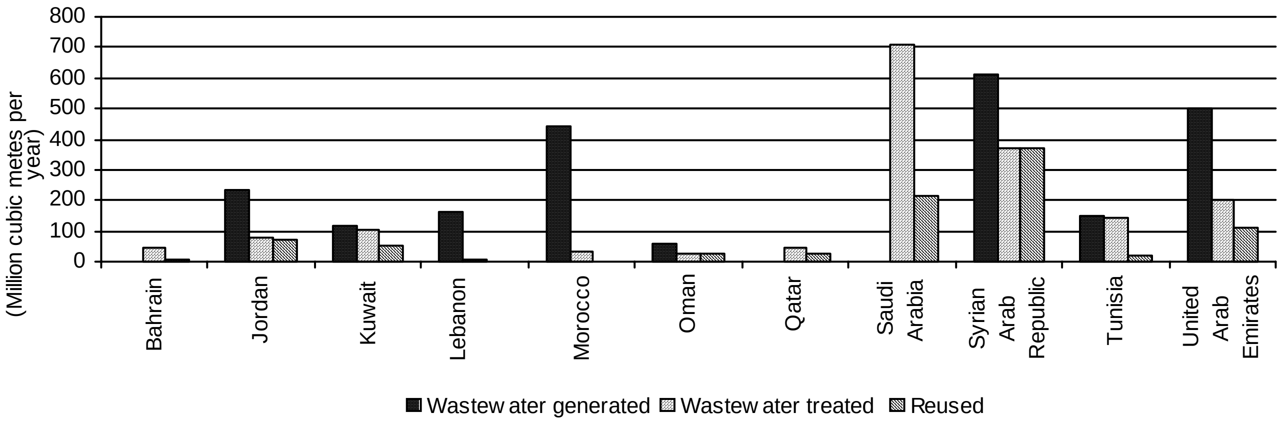


Figure 8. Quantities of wastewater generated treated and reused in eleven countries of the Eastern Mediterranean (various years: 1991-2000)

The total amount of treated wastewater in 16 countries in the Region is estimated at 4408.4233 million cubic metres (referring to different years, mostly 1999–2000). An analysis of employed treatment techniques for countries with available data (Egypt, Jordan, Morocco, Oman, Sudan and the Syrian Arab Republic) shows that 67% of treated wastewater in these countries is treated to secondary levels by activated sludge. Waste stabilization ponds are the second most popular treatment technique at 13% and trickling filters at about 4%. The remaining 16% are treated to primary levels (in Egypt).

The design of most, if not all, wastewater treatment plants is carried out using foreign criteria and expertise. Local design standards are virtually non-existent. The adoption of foreign design criteria does not necessarily suit local prevailing conditions. This is particularly true for lagoon systems, the second most popular wastewater technique in the Region.

Table 34 summarizes the potential of wastewater production, actual quantities treated and extent of reuse in the Region. It is clearly seen that the potential for treated wastewater reuse is not fully utilized by most countries. This is demonstrated by comparing the quantities of reused treated wastewater with potential wastewater quantities' production as a percentage of agricultural withdrawal. Approximately one third of this potential is being used.

All countries of the Region have various practices of irrigation reuse of some sort. However, few have regulated and controlled reuse schemes. Fodder crops, cereals, alfalfa, olive and fruit trees are the most widely grown types in such schemes. Nonetheless, the majority still lack properly managed reuse programmes. Reuse malpractices were reported in Egypt, the Islamic Republic of Iran, Lebanon, Morocco, Sudan, the Syrian Arab Republic and Yemen. The use of raw wastewater for irrigation is the most common malpractice.

No country in the Region has developed health guidelines for water reuse although some countries, for example Bahrain, Jordan and Morocco, adopted fully or partially the World Health Organization and Food and Agricultural Organization guidelines. The oil-producing countries, like Kuwait, Oman, Saudi Arabia and the United Arab Emirates have adopted stringent health reuse guidelines similar to those employed in some USA states (e.g. faecal coliforms less than 2.2 MPN/100ml). Such countries have established the treatment needed to achieve those requirements. The other countries either employ national public health laws relevant to the control of reuse practices or still lack any kind of regulatory guidelines.

Table 29. Summarized information on wastewater production, treatment and reuse in 16 countries of the Eastern Mediterranean Region

Country	Wastewater quantity: Potential production mm³/year	Potential production Year	Treated mm³/year	Treated Year	Reused mm³/year	Reused Year	Treatment techniques employed	Degree of treatment	(Reuse/ agricultural withdrawal) percentage	Reuse guidelines	Reuse aspects/practices/remarks
Bahrain	—	—	45	1991	8.03	1991	AS, AL, RBC,SF	S, T	6	WHO	Irrigation: dates, alfalfa, vegetables, fruits, forage crops, landscaping-
Egypt	3600	1995/6	2208.98	2000	200	1993	AS, WSP, TF	P, S	0.4	—	Irrigation: unofficial reuse with treated and untreated wastewaters is practised
Islamic Republic of 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
Jordan	232	1993	78.99	1998	72	2000	WSP, AS, TF	S	7	WHO and 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 practised.
Libyan Arab Jamahiriya**	—	—	100	2000	100	—	—	—	3	—	—
Morocco	420	1999	33.6	1999	—	—	AS, WSP, TF	P, S	—	WHO and 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*	2000	AS, WSP, AL, TF	S	3	—	Informal and uncontrolled irrigation reuse is practised.
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.

N.B/ References: as per respective countries cited previously.* Damascus only. ** [4] Ref for Gulf states and Yemen: [23] unless indicated otherwise. 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; ND, not determined

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5. Conclusions

The Eastern Mediterranean Region has one of the highest population growth rates in the world. There are increasing pressures to expand water supply and sanitation services to rural areas and growing urban centres. The Region is short of water and conventional water resources are dwindling in quantity and quality, consequently agriculture, the biggest water user, is declining, resulting in less food production. Non-conventional water sources should inevitably be utilized to augment water availability and alleviate the stress imposed on conventional water resources. Wastewater recovery and reuse is considered a viable non-conventional water resource, the utilization of which can augment available water resources and safe effluent disposal. The latter has to be achieved anyway for health and environmental protection purposes. However, there are several indispensable prerequisites to the successful utilization of treated wastewater as a valuable resource in countries of the Region.

Sanitation coverage in the Region remains inadequate, particularly in rural areas. Consequently, collection and treatment of quantities of wastewater constitute a modest percentage of potentially generated amounts. Cost is a major constraint hindering the expansion of conventional sewerage networks and wastewater treatment utilities.

Despite the prevailing water scarcity the potential of wastewater as a resource is far from being fully utilized in the Region. Existing water reuse practices in most countries are, to a large extent, improper, so sound management schemes are needed to remedy the situation. Untreated wastewater is used for irrigation in several countries and very few investigations have been conducted to evaluate impact on public health and the environment. Also, the majority of countries still lack well-adapted reuse guidelines.

The legal and institutional status of wastewater management and reuse in the Eastern Mediterranean Region is weak for wastewater collection and treatment and virtually non-existent for reuse in most countries. Few have issued the necessary laws, statutes, regulations and codes of practice required. Moreover, most of the existing pertinent statutes and regulations have been adopted from international experiences without being tailored to local social or economic, levels of available expertise and prevailing environmental conditions.

Unsewered communities amount to more than half the population of the Eastern Mediterranean Region; a public participatory approach seems to be particularly important yet there is little public involvement in the management of wastewater and reuse schemes. Wastewater disposal in such communities is normally left to the discretion of homeowners. It is thus vitally important that they be involved from the early stages of planning wastewater collection, treatment and reuse.

In addition to relentless efforts made by the Centre for Environmental Health activities to make available as much information as possible about the subject to Member countries and others, sharing experiences between concerned institutes in the Region should be further enhanced and facilitated. Data on wastewater management in the Region are generally inadequate, often contradictory, difficult to find and can hardly be utilized with a satisfactory degree of confidence. This is a major obstruction impeding the development of the wastewater sector in all aspects, particularly planning and management.

6. Recommendations

1. Efforts should be made to advance policies that advocate the allocation of funds to expand improved water supply and sanitation services.
2. Appropriate, low-cost, viable options of sewerage and wastewater treatment that suit local conditions should be considered as a first solution.
3. Conventional, centralized, wastewater collection and treatment systems should not constitute the only acceptable option as this has decelerated service expansion due to the high costs entailed.
4. Appropriate and affordable wastewater collection and treatment systems should be applied instead of the expensive, imported technologies that have delayed the provision of services.
5. Design of wastewater collection and treatment utilities should be done with contingencies for effluent reuse.
6. Designing for helminth egg removal should be an essential requirement for safe effluent reuse.
7. Provision of design, operation and maintenance manuals for wastewater management systems should supply information on centralized and decentralized concepts, targeting planners, engineers, utility managers as well as individual homeowners.
8. A holistic wastewater management approach should consider properly treated wastewater as a valuable resource that constitutes an integral part of the national water budget.
9. Commitment to full reuse should be part of the proclaimed water policy and strategy in all countries of the Region, particularly those suffering from water scarcity.
10. Industrial wastewater should be pretreated to domestic wastewater quality levels prior to discharge into public sewers. This should help avoid many complications in the treatment and reuse of wastewater.
11. Well-prepared design and management manuals on water reuse for planners, design engineers and farmers should be issued. They should include prudent, economic approaches to water reuse conducive to water conservation, increased agricultural production and pollution prevention.
12. Environmental impact assessment studies to all water reuse projects should be applied before any commitment to implementation is made.
13. Periodic evaluations of actual impacts after completion and during operation are recommended in order that experience gained is utilized for other reuse projects.
14. Local epidemiological studies should be conducted to evaluate the impact of water reuse projects on public health and the environment. The appropriateness of applied guidelines should be evaluated and adjusted in accordance with the results of such studies.
15. Water quality reuse guidelines should neither be restrictive nor lenient in order to expand water reuse without compromising health or the environment.

16. Statutes, laws, bylaws, regulatory standards and codes of practice that can promote the expansion of wastewater systems, control of wastewater discharges and effluent reuse should be provided or strengthened.

17. There should be systematic execution of water and wastewater quality monitoring programmes and enforcement of pertinent regulations and standards.

18. The dilution of responsibility that has emerged in most countries of the Region should be avoided by reducing the overlapping undertakings of many authorities and departments.

19. Training and periodic retraining for operation and maintenance personnel to improve efficiency and decrease reliance on expensive foreign expertise should be provided.

20. Educational programmes in universities and community colleges should be available for sanitary engineers, analytical chemists and microbiologists.

21. The proper private sector involvement in wastewater management and reuse projects should be carefully considered.

22. Homeowners should be involved in public workshops and the review and scoping sessions of the environmental impact assessment studies of large projects.

23. Professionals at all levels; decision-makers, planners, engineers, laboratory analysts, plant operators and other concerned parties should be brought together at periodic seminars and workshops.

24. The provision of an Internet discussion list on the subject is recommended.

25. Well-designed and properly managed databases should be created in concerned institutes in countries of the Region. The integrity and credibility of data entered in such a system would guarantee user confidence. Such databases should be made accessible to interested professionals and researchers.

7. References

1. *2001 World Book*, 2002 edition. Illinois, USA, World Book Inc, 2002.

2. *The Work of the World Health Organization in the Eastern Mediterranean Region. Annual Report of the Director General (1 January–31 December 2003)*, Cairo, World Health Organization, 2004.

3. *The World Factbook*. United States Central Intelligence Agency Publications, 2001. (http://www.cia.gov/cia/download2001.htm accessed 7 April, 2005).

4. *AQUASTAT: Food and Agricultural Organization Information System on Water and Agriculture*, 2002 (http://www.fao.org/ag/agl/aglw/aquastat accessed 18 April 2002).

5. *Data and statistics*. World Bank, 2000. (http://www.worldbank.org/data, accessed 7 April, 2005).

6. *Global water supply and sanitation 2000 report*. World Health Organization, WHO sites, Water Sanitation and Health (WSH), http://www.who.int/water_sanitation_health/Globalassessment/, accessed 7 April, 2005).

7. Al-Ayobi S. *Wastewater treatment and reuse in Bahrain*. Country presentation in a Regional Training Course, Center for Environmental Health Activities, World Health Organization, Amman, 1995. (unpublished data).

8. Tchobanoglous G, Burton FL, Metcalf and Eddy, eds. *Wastewater engineering, treatment, disposal and reuse*. 3rd ed. McGraw Hill International Editions, 1991.

9. Bayoumy et al., *A study on developing a revised and integrated land and water plan*. APRP–DRI, Report No. 24, Ministry of Public Works and Water Resource, Egypt, 1997.

10. Hendy S, Yousef R. *Wastewater management and reuse in Egypt*. Country Profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2000 (unpublished data).

11. Abdel Rahman K, Mahdi A, Jamil N. *The special report on wastewater reuse in agriculture in Iraq*. Country Profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2002. (unpublished data).

12. Alaie M. *Wastewater treatment and reuse in Iran*. Country presentation in a Regional Training Course, Center for Environmental Health Activities, World Health Organization, Amman, 1995 (unpublished data).

13. *Operation report*. Water Authority of Jordan. Directorate of Sanitary Systems, 2001 (unpublished data).

14. *Water–reclaimed domestic wastewater, JS893:2002*. 3rd ed. Amman, Jordanian Institute of Standard and Meteorology, 2002.

15. Al-Najjar M. *Wastewater management and reuse in Jordan*. Country profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2000 (unpublished data).

16. *Sludge–sludge used in agriculture, JS1145:1996*. Jordanian Institute of Standards and Meteorology, Amman, 1996.

17. *Guidelines for water reuse manual*. US Environmental Protection Agency, 1992 (EPA/625/R-92/004).

18. El-Hamouri B. *Wastewater management and reuse in Morocco*, Country profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2001 (unpublished data).

19. Humeidy S, Tahboub M, Basaitah N. *Wastewater management in the West Bank and the Gaza Strip–needs and assessment*. Country presentation in a Regional Training Course, Center for Environmental Health Activities, World Health Organization, Amman, 1995 (unpublished data).

20. Salem Z. *Wastewater management in Palestine*. Presented at an international conference: Wastewater management and its effect on the environment in hot and arid countries, 2002 (unpublished data).

21. Al-Mussaid M. *Wastewater treatment and reuse in Saudi Arabia*. Country presentation in a regional training course, Center for Environmental Health Activities, World Health Organization, Amman, 1995 (unpublished data).

22. Al-Sa'ati A. *Planning for water reuse in Saudi Arabia*. Presentation in a workshop: utilization of treated wastewater in agricultural projects. College for Science and Technology, Ajman University by UNICEF/WHO 1994 (unpublished data).

23. Abu Rizaiza O. *Proposed regional institute of water resources and environmental research*. Ajman University, 1995 (unpublished data).

24. El Hasan B, Hussein I. *Wastewater management and reuse in Sudan.* Country profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2001 (unpublished data).

25. A. Dakheil. *Wastewater management and reuse in Syria.* Country profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2001. (unpublished data).

26. Ghariani F, Helaoui L. *Wastewater management and reuse in Tunisia.* Country profile report presented to the Center for Environmental Health Activities, World Health Organization, Amman, 2001 (unpublished data).

27. Al-Qasimi S. *Wastewater management in Muscat.* Country presentation in a regional training course on wastewater treatment and reuse, Center for Environmental Health Activities, World Health Organization, Amman, 1995 (unpublished data).

8. Bibliography

Al-Salem S. *Potential and existing treated wastewater reuse in selected ESCWA countries.* ESCWA, Amman, Jordan, 1993.

General census of population and habitat, GRPH Morocco, 1994.

Gur A. *An overview of wastewater collection, treatment and reuse in the Eastern Mediterranean Region*. Presentation at a regional training course on wastewater treatment and reuse, sponsored by WHO–CEDARE/CEHA, Amman, Jordan, 1995.

Saghir J, Schiffler M, Woldu M. *Urban water and sanitation in the Middle East and North African Region: the way forward.* The World Bank, Middle East and North Africa Region Infrastructure Group, 2000.

Sbeih M. *Proper management, measures as well as laws and by-laws needed toward effluent wastewater reuse in Palestine*. (Cited references as in country reports submitted to CEHA).

Egypt

Youssef G, Seham MH, Hendy, Ragaa. Wastewater management and reuse. Country profile, Egypt, March, 2000.

Helwan wastewater reuse, phase in: a situation analysis. Academy of Scientific Research and Technology. USAID (Project 263–0140.1), 1993.

Environmental action plan. Government of the Arab Republic of Egypt, 1992.

Environmental Action Plan, Government of the Arab Republic of Egypt, 1992.

Bayoumy et al. *A study on developing a revised and integrated land and water plan, APRP–DRI*, Report No. 24, 1997.

Revision of Law 48 of 1982. APRP Water policy activity. Ministry of Water Resources and Irrigation, Report No. 21, Cairo, 1999.

National water resources plan for Egypt, inception report. NWRP Project, Ministry of Water Resources and Irrigation. Cairo, 1999.

National water resources plan for Egypt, Technical Report No. 5. NWRP Project, Ministry of Water Resources and Irrigation, Cairo, 2000.

The National Specialized Councils' report, 1998.

Design of an integrated water quality-monitoring network in Egypt, Hydrology, monitoring objectives and design criteria. T.R. No. 1. Ministry of Public Works and Water Resources, 1996.

Reuse of low quality water for sustainable agriculture in Egypt. Country case study, Ministry of Agriculture and Land Reclamation, 1996.

Statistical year book 1992–1998. CAPMAS, Egypt, 1999.

Abo Soliman M S M. *Country case study: reuse of low quality water for sustainable agriculture in Egypt.* Agriculture Research Centre, Soils, Water and Environment Research Institute.

Final report on drainage water irrigation project. AFDB and GOE, DRI, 1997.

Fahim O. *Data and information re-municipal wastewater management in Egypt, present and future plans.* (http://www.changegroup.biz/en/cgosd.psp last accessed August 17, 2005).

Agriculture use of sewage sludge in Cairo–final report, phase 2. 1999.

El-Mowelhi. *Effect of long-term Cairo sewage water application on soil and plants.* 1994.

Jordan

Al-Najjar M. *Wastewater Management and Reuse.* Country profile, Jordan. May 2000.

General water management policy. Ministry of Water and Irrigation, 1998a.

Irrigation water policy. Ministry of Water and Irrigation, 1998b, 1998.

Wastewater water management policy. Ministry of Water and Irrigation, 1998c.

Water utility policy. Ministry of Water and Irrigation, 1997a.

Jordan's water Strategy, Ministry of Water and Irrigation, 1997b.

Water sector investment programme, Ministry of Water and Irrigation, 1997d.

Various technical data files. Ministry of Water and Irrigation.

Various technical data files. Water Authority of Jordan.

The Hashemite Kingdom of Jordan. Water sector review, 1997. World Bank, 1997.

Annual environmental statistics 1997, Department of Statistics. The Hashemite Kingdom of Jordan, November 1998.

Proposed work plan for sludge removal and disposal, As-Samra WSP Emergency Short Term Improvement. CDM, USA. 1996.

WHO health guidelines for the use of wastewater in agriculture and aquaculture. Technical Report No. 778, World Health Organization, Geneva, 1989.

Morocco

El Hamouri B. *Wastewater management and reuse.* Country profile, Morocco, 2001.

Projet des valeurs limites pour l'évaluation de la qualité des eaux d'irrigation. AGR/SEEN, 1996.

Epuration et réutilisation des eaux usées à des fins agricoles. principaux résultats du Projet MOR 86/018 mené à Ouarzazate, AGR/ORMVAO–PNUD/FAO/OMS, Morocco, 1998.

Consolidation de la stratégie nationale en matière de réutilisation des eaux usées en agriculture. AGR/UNDP, 1999.

L'assainissement liquide au Maroc et ses perspectives de développement, synthèse des communications et des débats, cahiers de l'AMEPA, N°2. AMEPA, 1999.

Bahalloul, Agadir. *Utilisation des eaux usées épurées pour l'irrigation des cultures de tomate et de pomme de terre.* Study done under the supervision of Dr El Fadl, professor at the Institut Agronomique et Vétérinaire Hassan II, 1991.

Réutilisation des eaux usées en agriculture, 8éme session. CSEC, 1994.

Comité Technique des Travaux publics Norme NM 03.7.002 "Contrôle et surveillance de l'eau dans les réseaux d'approvisionnement public" BO N°4057 du 1/8/90. CTT/TP 1990.

Norme NM 03.7.001 Qualité des eaux d'alimentation humaine. BO N°4090 du 20/3/91. CTT/TP 1991.

Séminaire national sur l'assainissement liquide Rabat. DGCL/DEA /ONEP, 1993.

L'épuration des eaux usées au Maroc, synthèse des études. DGCL/DEA, 1995.

Réutilisation des eaux usées au Maroc, synthèse des études expérimentales. DGCL/DEA, 1996.

Schéma Directeur National d'Assainissement liquide (SDNAL). DGCL/DEA/ONEP/UNDPD, 1999.

El Hamouri B, et al., Use of wastewater for crop production under arid and saline conditions: yield and hygienic quality of the crop and soil contamination; *Water Science and Technology*, 33 (10-11), 327-334, 1996.

Intervention de l'ONEP pour les collectivités Locales. ONEP, 1994.

Etude de tarification de l'assainissement: cas des villes de Khénifra et de M'Rirt. ONEP, 1997.

Approche de typologie des eaux usées urbaines au Maroc. ONEP, 1998.

Résultats des expérimentations agronomiques, station expérimentale Ben-Sergao, campagne 1991-1992. ORMVASM/CRREUA, 1992.

Health guidelines for the use of wastewater in agriculture and aquaculture. Technical reports series 778. World Health Organization, 1989.

The Hashemite Kingdom of Jordan. Water sector review. World Bank, 1997.

National master plan for sanitation, Morocco.

Sudan

El Hasan B, Hussein I. *Wastewater management and reuse.* Country profile, Sudan, 2001.

Sudan National Water policy. Ministry of Irrigation and Water Resources. November, 1999.

Ministry of Finance Economics, the administrative and technical unit for drinking water and sanitation. *The status of drinking water in Northern States*. December, 2000.

Makhtar A.R, *Water Supply Provision in Sudan*, Unpublished paper presented in a national seminar on water quality standards, 2000.

Mamoun A A. *Risk assessment of health hazards, A study of stabilization ponds workers, and casual wastewater reuse in Soba wastewater treatment plants.* M.Sc. thesis (FPEM), University of Khartoum, 1999.

Adeela A. Azim Eldawi. *Reference of waste stabilization ponds in hot climates with references to Sudan.* M.Sc. thesis (I.E.S), University of Khartoum, 1995.

Syrian Arab Republic

Abu Watfa S. et al,. 2001. *Wastewater management and reuse.* Country profile, Syrian Arab Republic.

No reference list was provided.

Tunisia

Ghariani F, Helaoui L. *Wastewater management and reuse.* Country profile, Tunisia, 2001.

No reference list was provided