Reuse of Wastewater in Mediterranean Region, Egyptian Experience

Naglaa Mohamed Loutfy

Abstract Water scarcity in the Mediterranean region is one of the most serious issues. A number of reasons are behind this situation, which include, but are not restricted to, the relatively uneven distribution of precipitation, high temperatures, increased demands for irrigation water, and impacts of tourism. Climate change is expected to aggravate the situation even more. The use of wastewater is one of the most sustainable alternatives to cope with water shortage. It would have a number of advantages that include closing the gap between supply and demand, stopping the pollution of fresh water resources, providing sound solution to water scarcity and climate change, and helping to achieve Millennium Development Goals. With Egypt, trying to cope with water shortage issues, The Ministry of Water Resources, MWRI has developed a National Water Resources Plan, with wastewater reuse as a central mechanism. At present, there are more than 200 wastewater treatment plants in the country. Urban coverage of improved sanitation gradually increased from 45% in 1993 to 56% in 2004. In contrast, rural sanitation coverage remains incredibly low at 4%. The low coverage, in combination with a sub-optimal treatment, results in some problems of water pollution and degradation of health conditions because the majority of villages and rural areas discharge their raw domestic wastewater directly into the waterways. Drainage water reuse is practiced on a very large scale. The official reuse of agricultural drainage water in irrigation amounted to 4.84 km^3/year in 2001. The present aim of the Government of Egypt is to reuse up to 8 km^3/year in new reclamation areas in the near future. Meanwhile, El Salam canal, one of the mega projects in Egypt is transferring a mix of fresh Nile water and wastewater to Sinai, to irrigate thousands of newly reclaimed areas.

Keywords Mediterranean, Wastewater, Egypt, Water scarcity, Climate change, EI-Salam canal

N.M. Loutfy (✉)
Plant Protection Department, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt
e-mail: naglamag@yahoo.com

D. Barceló and M. Petrovic (eds.), *Waste Water Treatment and Reuse in the Mediterranean Region*, Hdb Env Chem, DOI 10.1007/698_2010_76,
© Springer-Verlag Berlin Heidelberg 2010

Contents

1 Introduction

Water is one of the most valuable resources on Earth. Water and sanitation have a great effect on human health, food security and quality of life. Demands on water resources for household, commercial, industrial, and agricultural purposes are increasing greatly. Yet water is becoming scarcer globally, with many indication that it will become even more scarce in the future. More than one-third of the world's population – roughly 2.4 billion people – live in water-stressed countries and by 2025 the number is expected to rise to two-thirds [1]. Growing demand for water due to the growing world population is creating significant challenges to both developed and developing countries.

The world populations have grown 1.5 times over the second half of the twentieth century, but the worldwide water usage has been growing at more than three times the population growth. In most countries, human population is growing while water availability is not [2]. World population growth is projected to reach over 8 billion in 2030 and to level off at 9 billion by 2050. The United Nations has challenged the international community to work together to improve the situation, and one of the main objectives of the Millennium Development Goal (MDG) is to halve the number of people without access to safe drinking water and adequate sanitation by 2015.

The Mediterranean region is one of the most populated areas of the globe. About half a billion people live in the Eastern Mediterranean 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 [3].

According to [43], Mediterranean countries suffer different levels of water scarcity, and water availability is declining to a crisis level especially in the Middle East and North Africa region (MENA).The present imbalanced water demand versus supply is due mainly to the relatively uneven distribution of precipitation, high temperatures, increased demands for irrigation water and impacts of tourism.. The annual rainfall in much of the southern Mediterranean countries including Egypt ranges between 0 and 340 mm. With high potential evaporation, the rainfall is generally insufficient to meet the water demand of crops. Sharp variations between years and among different seasons within a year exacerbate the situation [4]. Moreover, rapid development and industrialization in the area, besides increasing population growth are seriously affecting water resources, posing an extra burden on the already limited stocks.

Another major challenge that is aggravating water scarcity in most of the region, as well as impacting human health and ecological systems, is the continuous deterioration in the quality of the limited surface and groundwater resources because of industrial, domestic, and agricultural effluent discharges. Furthermore, groundwater resources are being over-exploited to meet the ever-increasing domestic, agricultural, and industrial sectors' water demands.

The critical nature of the current water situation in the Mediterranean region is expected to be further aggravated by the impacts of climate change. The direct impacts of climate change registered in the Mediterranean basin consist of lower levels of precipitations, a modification of the intensity and distribution of the precipitations, an increase of floods, and a raise of temperatures. Climate change will amplify its substantial destabilizing effect on the hydrological cycle and will have a pervasive influence on the future demand, supply, and quality of fresh water resources in the region [5]. Imbalances between availability and demand, degradation of surface and groundwater quality, inter-sectorial competition, and inter-regional and international conflicts often occur, and are mostly obvious in the Mediterranean region. Innovations are therefore required particularly relative to irrigation management and practice as the agriculture sector is far ahead in demand for water in the region. Agriculture is therefore forced to find new approaches to cope with water scarcity, but coping in a sustainable way.

Rapid growth in the demand for high quality water, coupled with natural shortage and continuous restrictions in supply, has accelerated the search for alternative sources. The additional sources include fresh high quality run-off water, brackish water, and treated wastewater. In regions with limited natural water sources, treated wastewater, primarily in urban areas, can be utilized for agriculture, industry, recreation, and recharge of aquifers. Wastewater is a resource of growing global importance and its use in agriculture must be carefully managed in order to preserve the substantial benefits while minimizing the serious risks. Multiple complementary factors drive the increased use of wastewater in agriculture. Water scarcity, reliability of wastewater supply, lack of alternative water sources, livelihood and economic dependence, proximity to markets, and nutrient value all play an important role [6].

The Arab countries on the Mediterranean are Morocco, Tunisia, Algeria, Libya, Egypt, Palestine, Lebanon, Syria, and partially Jordan. They considerably differ with respect to their level of development, population, and natural resources. The common feature of all these countries is the mixture of human activities that produce liquid waste that has no other place to get rid of but the Mediterranean. The second common feature is that they all suffer from water scarcity in varying levels, which means that treated sewage could provide a source that could bridge part of the gap between supply and demand and therefore help to achieve MDGs through increased water availability and poverty reduction, besides contributing to food security, better nutrition, and sustenance of agricultural employment for many households [7].

Box 1. Water Scarcity in Southern Mediterranean Region

Málaga [5] reported that fresh water resources in the Mediterranean are under increasing pressure in terms of both quantity and quality and could be seen as follows:

- *Northern Mediterranean* countries with higher, more regular rainfall also face climate-induced natural hazards, flooding and water shortages, in basins susceptible to periodic drought. As a consequence, human and natural systems sensitive to water availability and water quality are increasingly stressed, or coming under threat. Those countries will have to face water quality degradation and meet the increasing needs of environmental protection and restoration.
- *South and East Mediterranean* counties where utilization is now approaching hydrological limits, and the combined effects of demographic growth, increased economic activity, and improved standards of living have increased competition for remaining resources. Water resources are already overexploited or are becoming so with likely future aggravation where demographic growth is strong. The Eastern countries will be more sensitive to short term or structural shortages in certain areas.

Average annual supply of water for the MENA region as a whole is now well under 1,500 m^3 per capita, and many nations fall below 500 m^3 [8]. The volume of per capita freshwater resources is an important indicator of the water endowment of a country. Morocco, Egypt, Algeria, Tunisia, and Libya are some of the southern Mediterranean countries. Taking into account both internal and external sources, their annual supply of water is about 1,000, 880, 470, 430, and 100 m^3 per capita respectively (Table 1). Water resources in the remaining countries are all below 500 m^3 per capita, per year, a threshold of severe water stress in the commonly cited water criticality classification [9]. At those levels, chronic water scarcity can be expected unless water is managed carefully and the economy is directed to low-water-consuming activities.

Table 1 The volume of per capita freshwater resources in six of the southern Mediterranean countries

	Algeria	Egypt	Israel	Libya	Morocco	Tunisia
Water resources, m^3 per capita, per year (1998)						
Internal	460	43	289	100	1,071	371
External	13	841	20	0	0	64
Total	473	884	309	100	1,071	435
Water withdrawal, m^3 per capita, per year						
	180 (1990)	921 (1993)	407 (1989)	880 (1994)	433 (1992)	376 (1990)
Irrigated areas, 1,000 ha						
1980	253	2,445	203	225	1,217	243
1985	338	2,497	233	300	1,245	300
1990	384	2,648	206	470	1,258	300
1995	555	3,283	199	470	1,258	361
1999	560	3,300	199	470	1,305	380
Changes %	121.34	34.97	−1.97	108.89	7.23	56.38
Irrigated area as % of total crop land						
	7	100	45.5	22	13	7.8

Source: [9]

2 Why Wastewater Reuse in Mediterranean Region?

The Mediterranean region is considered as one of the world's most water-stressed regions. Wastewater production is the only potential water source which will increase as the population grows and the demand on freshwater increases. Therefore, wastewater should be viewed as a resource which must be recovered and added to the water budget. If wastewater is recognized as part of the total water cycle and managed within the integrated water resources management (IWRM) process, this will help meet the requirement.

2.1 Help Closing the Gap Between Supply and Demand

In the last few years of the twentieth century, 3 billion people around the world lacked adequate sanitation and up to 95% of the wastewater was discharged in the environment without treatment. Around 5.5 billion people are expected to be without sanitation in 2035. The discharge of untreated wastewater is a waste of resources Euro-Mediterranean Regional Programme for Local Water Management (MEDA) Water International Conference on Sustainable Water management, see: http://www.semide.net/thematicdirs/events/sev802988).

In the Mediterranean region, nearly 70% of the available water resources are allocated to agriculture. The percentage decreases to 50% of the total available resources in the northern countries, and accounts for as much as 80% of the water consumed, especially in the southern countries like Egypt (Fig. 1). Wastewater reuse therefore could have a direct influence on a region's food security [10].

Wastewater reuse will continue to be a first option to augment the water resources for many years in the Region [11].

Wastewater reuse in the region can partially contribute to solving the problem of quality and quantity. Reusing of wastewater is considered one of the effective adaptation strategies in the water sector, which helps closing the demand−supply gap in water resources, through sustainable reclamation of wastewater, especially in agricultural sector [5]. This would also have a major role in agricultural economy, both on qualitative and quantitative basis, and also in the well-being and the health of the society.

The Mediterranean basin is nowadays depending for its economic and social development on agriculture, and secondarily on industry and other economic activities. Irrigated agriculture in competition with other sectors will face increasing problems of water quantity and quality, considering increasingly limited conventional water resources, growing future requirements, and a decrease in the volume of fresh water available for agriculture.

Agriculture will remain an important sector of economy in all Mediterranean countries. This is particularly true for the developing countries on the Mediterranean, which use export opportunities to neighboring countries and the European Union, but in order to satisfy the demand of these populations, agricultural production has still to be increased. This is not possible without available water resources for irrigation. Therefore, alternatives like the reuse of waste water in agriculture have to be seriously considered.

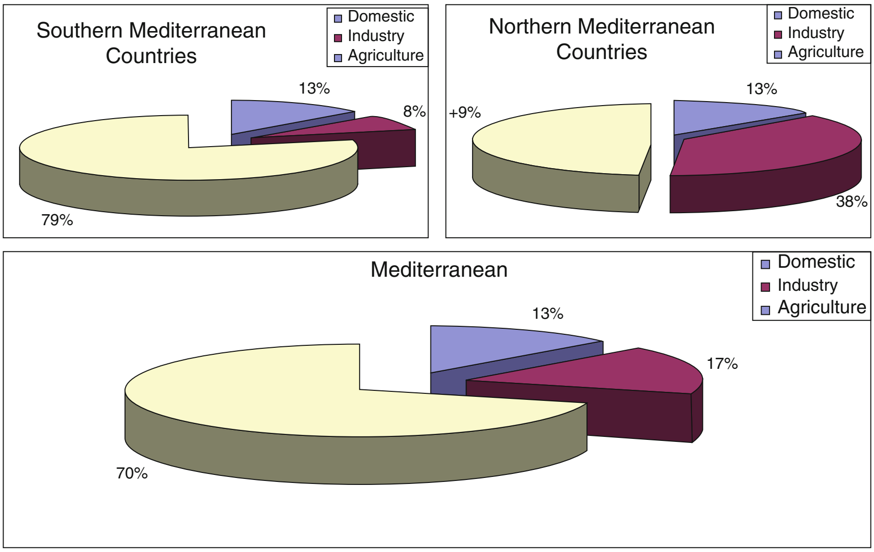

Fig. 1 Water use per sector in the Mediterranean
Source: [10]

2.2 Applying the Concept of Sustainability

One of the greatest challenges facing humanity is how to use scarce resources in an equitable and sustainable way. The Mediterranean region is undergoing rapid local, global, social, and environmental changes. All indicators point to an increase in environmental and water scarcity problems with negative implications towards current and future sustainability [12]. As the demand for water continues to rise, it is imperative that this limited resource is used efficiently and in sustainable way for agriculture and other purposes. Water recycling and reuse is meant to help close the gap in water cycle and therefore enable sustainable reuse of available water resources.

The responsible use of the water can be described in terms of sustainability or sustainable development. Many present day systems are “disposal-based linear systems.” The traditional linear treatment systems must be transformed into the cyclical treatment to promote the conservation of water and nutrient resources. The reuse of the wastewater decreases the expenditure on fertilizers and it is considered safe as it has been treated for pathogens. Use of organic waste nutrient cycles, from point-of-generation to point-of-production, closes the resource loop and provides an approach for the management of valuable wastewater resources. Failing to recover organic wastewater from urban areas means a huge loss of life-supporting resources that instead of being used in agriculture for food production fill rivers with polluted water [13].

2.3 Prevents Fresh Water Resources and Water Bodies from Pollution

The world’s freshwater resources are under strain. Reuse of wastewater, in concert with other water conservation strategies, can help lessen man-made stresses arising from pollution of receiving waters. Reuse will provide relief to the Mediterranean from the hazards of directing this water to its basin. Irrigation with treated municipal wastewater is considered an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies. There are concomitant environmental risks with wastewater reuse, such as transport of harmful contaminants in soils, pollution of groundwater and surface-water, degradation of soil quality, e.g., salinization, impacts on plant growth, and the transmission of disease via the consumption of wastewater-irrigated vegetables. The challenge facing wastewater reuse is to minimize such risks so as to maximize the net environmental gain. Egypt’s second urgent problem after scarcity is water quality. The Nile which is the major drinking water source is often below the minimum quality standards. A major reason is that only 36.1 % of the population is connected to the sewage network [14]. Therefore, a lot of untreated wastewater is released into the Nile. The amount of wastewater that is released into the Nile is 3.8 billion m/year, out of which only 35 % is treated properly [15].

Table 2 Impacts of some of Arab countries on the Mediterranean

Volume of wastewater/million cubic meters	Egypt	Syria	Jordan	Libya	Morroco	Tunisia
Treated and disposed in the Mediterranean	73					25
Untreated and disposed in the Mediterranean	12,000	210			40	50
Impacts on the Mediterranean (high-medium-low)	High	Low	Nil		Low	Low

Source: CEDARE [7]

At regional level, coastal cities of Mediterranean dispose their sewage both treated and untreated to the Mediterranean (in Morocco and Tunisia, 60% to 80% respectively of wastewater is discharged into the sea often without treatment).

As can be seen in Table 2, the mixture of land drainage, domestic, and industrial wastewater in Egypt is carried through the drainage network to the Mediterranean either directly or indirectly via the coastal lakes which are connected to the sea directly through sluices (such as Lakes Manzala, Borollous, and Edko) or by lifting (Lake Mariout). Finally almost 12 billion m^3 of drainage water takes its way to the Mediterranean every year [7].

However, the waste water treatment systems in developing countries (e.g., Egypt) are not successful and therefore unsustainable because they were simply copied from Western treatment systems without considering the appropriateness of the technology for the culture, land, and climate [44]. To ensure a high level of protection, the requirements of the respective legislations must be met, particularly where authorizations and monitoring is concerned. Furthermore, levels of pollutants in treated wastewater must be reduced to safe levels as determined through a risk management approach and, where appropriate, through the application of best available techniques [16].

Industry in most Mediterranean countries is still emerging. Most of the waste disposed into the Mediterranean is composed of domestic and municipal sewage except in the case of Egypt where agricultural land drainage, mixed with both industrial and municipal wastewater, is also disposed to the sea [7].

2.4 Provides a Mitigation Solution to Water Scarcity and Climate Change

Adapting to climate change will have close resonance with adapting to water scarcity and is likely to require implementation of water demand management strategies which may require capacity building and awareness raising across institutions and society. Adaptation measures on the supply-side include ways to improve rain-harvesting techniques, increasing extraction of ground water, water recycling, desalination, and improving water transportation. Climate change has many effects on the hydrological cycle and therefore on water resources systems. Global warming could result in changes in water availability and demand, as well as in the redistribution of water resources and in the structure and nature of water consumption, and exasperate conflicts among water users.

Wastewater reuse could provide a mitigation solution to climate change through the reduction in green house gases by using less energy for wastewater management compared to that for importing water, pumping deep groundwater, seawater desalination, or exporting wastewater [10]. Reuse increases the total available water supply and reduces the need to develop new water resources and therefore provides an adaptation solution to climate change or population density induced water scarcity by increasing water availability. It may also contribute to desertification control and desert recycling. As compared to industrialized countries, Egypt's CO_2 emissions are still considered low and are marginal on a global level. Further development of projects to reduce greenhouse gases emissions would offer Egypt an opportunity to upgrade its energy, transportation, and industrial sectors. One such project has been CO_2 "Sink" action. This is the action of planting trees that will capture carbon, thereby leading to an increase in Egypt's CO_2 absorptive capacity. At the turn of this decade, Egypt focused on afforestation with the aim of carbon sequestration, optimizing the use of scarce water resources and reducing sources of pollution through wastewater. In consequence, the Egyptian Environmental Affairs Agency (EEAA) has focused on the implementation of the national program in water reuse for forest plantation. This program has been implemented in 24 different regions in 16 governorates. Around 5,500 and 5,700 feddans were planted during 2004 and 2005, respectively. A further 890 and 1,000 feddans were added in 2006 and 2007, respectively. This means that the current share of land area covered by forests is around 5.41% of the total area of the country [17].

2.5 Help Achieving Millennium Development Goals

Treated sewage could provide a source that fills part of the gap between supply and demand and therefore help to achieve MDGs through increased water availability and poverty reduction through the use of appropriate technology solutions. It contributes to food security and better nutrition, and sustains agricultural employment for many households [7].

3 Egyptian Water Policies and the Right to Water

Access to a regular supply of safe water is a basic human right, as is the access to unadulterated food. But as with other human rights, too many people miss out. Of the world's population of 6 billion people, at least 1.1 billion do not have to access to safe drinking water and more than 2 billion people lack proper sanitation. Making more water available to communities can improve families' incomes, for instance by boosting crop production and the health of livestock.

As the former United Nations Secretary-General Kofi Annan said [45] "Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people."

It is an affront to human dignity. The right to water has been mentioned early in 1948 in Article 25 of the Universal Declaration of Human Rights. In 1992, the United Nations proclaimed that water should be considered to be a human right. This position, however, has not been accepted by many developed and developing countries.

To date, the right to water has been recognized in a number of non-binding UN resolutions and declarations, the most important of these being the 2002 General Comment #15 by the UN Committee on Economic, Social, and Cultural Rights, which defines the human right to water as "entitling everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses."

At present, nearly all the discussions on water as a human right have been almost exclusively targeted to drinking water and sanitation-related issues. While unquestionably, availability of clean drinking water and access to sanitation are important societal and environmental requirements, water also has other equally important uses in terms of agriculture, energy production, industrial and regional development, environmental conservation, tourism, etc.

In response to all the challenges that are facing water resources management in Egypt, the Egyptian Ministry of Water Resources and Irrigation (MWRI) has adopted new IWRM policies to achieve sustainability in water resources utilization for current and future generations. The water policies adopted by MWRI consider water primarily as a human right, and contain several measures to ensure this consideration. One of the major challenges facing the water sector in most Mediterranean countries including Egypt is closing the rapidly increasing gap between the limited water resources and the escalating water demands in the municipal, industrial, and agricultural sectors. To cope up with this challenge, the MWRI has developed a National Water Resources Plan (NWRP) with three major steps: (1) development of additional water resources and cooperation with the Nile Basin Riparian countries; (2) making better use of the existing water resources and increasing water use efficiency; and (3) protection of water quality and the environment. This national plan describes how Egypt will safeguard its water resources (quantity and quality) under the conditions of an increasing population and a fixed water availability and how it will use the resources in a sustainable and responsible way from a socio-economic and environmental point of view. The planning horizon covers a period of 20 years from 1997 up to 2017 [18].

The concept of water as a human right is not a trivial task, especially in a country like Egypt with a lot of pressure on its water resources. Pressure on Egypt's water resources comes from several sides, and delays achieving the whole right to water to some extent.

As shown in Fig. 2, there has been a rapid decline in the per capita share of water in light of Egypt's fixed Nile water quota, which is currently 55.5 BCM annually. Average annual per capita share, which was almost 1,000 m^3 in the early 1990s, will reach 600 m^3 in 2020, and decline to 400 m^3 by 2030 if the current birth rate continues [17].

Government policy has aimed at increasing the efficiency of water utilities and to implement its National Water Quality Management Program.

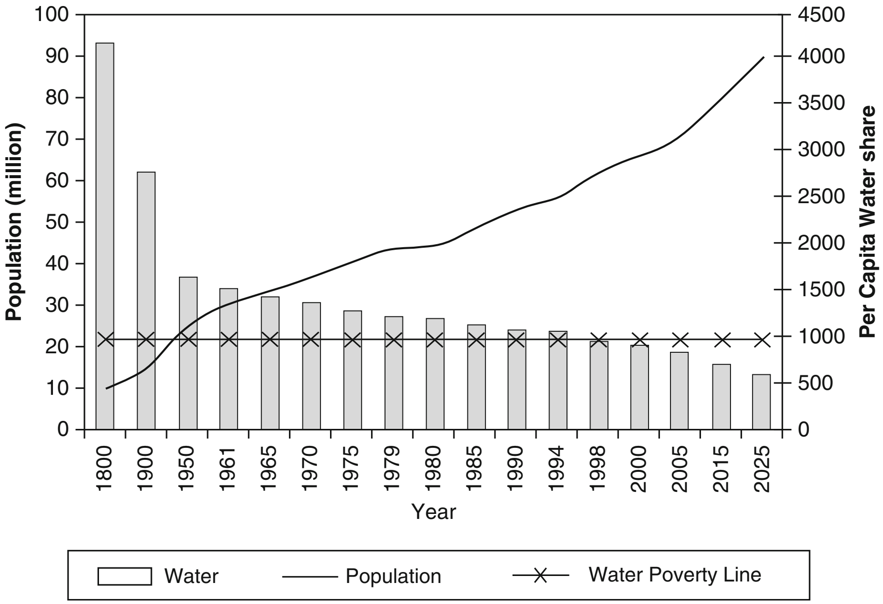

Fig. 2 Population growth and per capita water share in Egypt (m^3/year)
Source: [18]

Finally revision of consumption patterns, introduction of new methods to evaluate the financial efficiency of water projects, introduction of simpler and/or cleaner technologies, fostering public participation, and dissemination of information and education are all concepts to be put to work together to achieve the goal of universal access to safe water and adequate sanitation [19].

Box 2. Pressure on Egypt's Water Resources

- Geopolitical dimension: Egypt receives about 98% of its fresh water from the Nile, originating outside its international borders. This is considered a major challenge for Egyptian water policy and decision makers.
- The physical scarcity of water to satisfy and sustain the life and development. The demand is rocketing and the available renewable quantity is diminishing because of unsustainable extraction, weather changes, population growth, urbanization, and agricultural and industrial expansions.

The population is expected to grow to 88.8 million persons by 2017. Urban water demand is expected to grow by about 47%, from 4.5 km^3 in 2000 to 6.6 km^3 in 2017. Growth in industrial capacity is expected to increase industrial demand for water by about 40%, from 7.6 km^3 in 2000 to 10.6 km^3 in 2017. An aggressive horizontal expansion program plans to increase irrigated lands about 44%, from 7.8 million feddans in the year 2000 to 11.2 million feddans by the year 2017. Expansion areas are underway or are completed for a total 2.4 million feddans. In 2000, 38 km^3 of water was consumed by vegetation and soil surface evapotranspiration and about 2.1 km^3 of water evaporated from the Nile River and irrigation canal [20].

- Non-existence of the economic value for water in the country; this is promoting the misuse and exhausting the resources, and exacerbates water pollution.
- Institutional inefficiency is one of the major constraints in managing the sector. Lack of bylaws or their enforcement, political domination of the decision-making, and short-term planning are instances.
- Inadequate financing systems exist in most of the countries of the region, which mainly depend on subsidy. There is a need to reform the sector to operate on self-sufficient principles and cost recovery.

Saqer Al Salem (2003) available at: http://www2.mre.gov.br/aspa/semiar-ido/data/Palestra%20Saqer%20Al%20Salem%20texto.doc

4 Climate Change and Egyptian Water Resources

As water affects human lives, mankind also has an effect on the hydrological cycle of the planet, in all dimensions from the very local to the global scale. Climate change is now a scientifically established fact. There is scientific consensus that the global climate is changing mainly due to man-made emissions.

The current water scarcity will be intensified by a further decrease in water availability due to reduced rainfall, which is projected to decrease by 20% over the next 50 years [21]. Meanwhile, water demand will increase as a result of rising temperatures that lead to increase in evapotranspiration from irrigated agricultural zones and natural ecosystems [22]. A decrease in rainfall and an increase in temperatures are projected to contribute to increased evaporation and decreased groundwater recharge. Projections strongly indicate that the large river basins in the Middle East region (e.g., river Nile) will experience major decreases in water levels. Results from an EU Mediterranean project supported these projections and indicated that there will be general and continuous drought conditions with increases in water deficits in the Mediterranean region [23].

It is expected that such dry conditions and rainfall decreases will put more pressure on available water resources, especially in the major river basins of the region, which will also be influenced by the increase in water demands in the upstream areas of these rivers. This phenomenon will trigger more competition over water resources. Finally, increasing temperatures and the associated sea level rise will result in seawater intrusion in these rivers deltas and coastal groundwater aquifers [12].

Recent studies, including the 2007 IPCC assessment report, indicate that MENA region (including Egypt), despite its less than 5% contribution to gas emissions, will be significantly affected by climate change. In the eastern Mediterranean in particular, there is a consensus that climate change and the frequency of some extreme weather events like drought and floods will continue to rise [24]. There is a consensus that most of the arid and semi-arid regions of the world can expect an increase in water stress because of the impacts of climate change.

Climate change will put additional pressures on stressed ecosystems in Mediterranean region. As a result of the temperature rise, the water demand will increase. The evaporation from water bodies will reduce the available supply, and the increased evapotranspiration from crops and natural vegetation as well as the water demand for irrigation or industrial cooling systems will add pressure on water resources. Water quality will be affected by higher runoff which will increase pollution because of agricultural chemicals and less capacity to assimilate pollution with lower flows. The intensification of rainfall will primarily be responsible for soil erosion, leaching of agricultural chemicals, and runoff of urban and livestock wastes and nutrients into water bodies. Watershed conditions will suffer from erosion and desertification processes due to hotter and dryer summers, as well as more frequent and prolonged droughts coupled with rainfall events. The higher temperatures would dry soils and increase salinization and generate a higher incidence of wind-blown soil erosion [5].

Probably, the biggest impact of climate change in the Mediterranean region will be on food security due to the projected decrease in the available water resources and agricultural production. It is therefore necessary to prepare and appropriately respond to the potential negative impacts of climate change, many of which have already materialized, by considering these potential impacts on the water resources planning and integrating the appropriate adaptation measures in the water programs.

The management of the decreasing water resources, as a result of the climatic changes within the Mediterranean region, is challenged in particular, as climate change coincides with high development pressures, increasing populations, and high agricultural demands.

Egypt appears to be particularly vulnerable to climate change, because of its dependence on the Nile River as the primary water source, its large traditional agricultural base, and its long coastline, already undergoing both intensified development and erosion. Equally serious is the potential effect of the sea-level rise resulting from the thermal expansion of seawater and the melting of land-based glaciers. Even a slight rise in the sea-level will exacerbate the already active process of coastal erosion along the shores of the Delta, a process that accelerated after the building of the Aswan High Dam. Sea level rise will also accelerate the intrusion of saline water into the surface bodies of water (the lagoons and lakes in the northern Delta). The rise in the base level of drainage will further increase the tendency toward water logging and salinization of low-lying lands, with the consequence that significant areas will become unsuitable for agriculture. At the very least, the costs of drainage will increase [12].

Adaptation strategies of Mediterranean regions to threat of climate change on water resources require an optimization of water management for each use, as well as efficiency improvements. One of the effective adaptation strategies in the Water Sector is closing the demand−supply gap in water resources by optimizing reclamation of wastewater in a sustainable manner, especially in agricultural sector which accounts for about 79% in southern Mediterranean region [5]. Much can be done to mitigate the potential dire consequences of climate change and the earlier the task is recognized and undertaken, the more likely it is to succeed. A few essential changes in resource management would lead not only to adaptation to climate change, but also to the overall improvement of the Egyptian agricultural system.

5 Egyptian Water Policy and the Millennium Development Goals

MDGs are a set of quantified objectives with concrete target times that arise from the Millennium Declaration that has been adopted by all members of the United Nations in 2000. All the 191 UN member countries have pledged to meet these goals by the year 2015. The UN Millennium Project in 2004 highlighted that water is an essential element in achieving most of the MDGs; therefore, good quality water should be available to all to meet their needs and this objective should be achieved in a manner that is secure and sustainable and does not damage the ecosystems.

Using 1990 as a baseline, goal 7 of MDGs seeks to reduce by half the proportion of people without sustainable access to safe drinking water by 2015. At the global level, countries are on track to meeting the target for improving access to safe drinking water. But some areas are performing better than others, highlighting a growth in regional disparities in access to safe drinking water (MDG Progress on Access to Safe Drinking Water by Region: available at: http://www.worldwater.org/www/data20082009/Table5.pdf).

In North Africa, the overall situation with respect to the trends and to achieving the MDGs is fairly positive. This is particularly the case in Tunisia, Egypt, and Libya. Morocco and Algeria have not been progressing at the required rate in order to reach the MDGs, and the two countries must reverse the direction of development in order to achieve the targets.

The UNDP made a comprehensive assessment of the trends and prospects of the world's countries to achieve the MDGs in the Human Development Report of 2003 [25]. The progress in achieving the MDGs in relation to water within the MENA region was reported by Egyptian Ministry of Economic Development [17]. The MENA region consists of 23 countries including Egypt. The region faces huge challenges in achieving the MDGs and improving the water and sanitation coverage in the way required. The implementation of the MDGs appears to be extremely difficult for all countries in the region especially with respect to sanitary sewage projects [7].

Egypt believes that improved water resources management and access to water supply and sanitation have benefits for each of the eight MDGs. Egypt is facing a number of environmental challenges mainly because of rapid population growth and the necessity for extensive development to meet the needs of the growing population. This has placed pressure on natural resources following expansion in industrial, agricultural, and tourism activities. Consequently, Egypt has directed significant concern to resolve the pressing environmental problems by taking several measures – including ratifying various international environmental conventions and treaties – that are to be harmonized into the national legislative framework. In 2000, Egypt agreed to achieve the MDG by the year 2015.

As indicated in the fourth follow-up report on achieving the MDGs for Egypt, at the national level, Egypt is on the right track to realizing most of the MDGs by the set date of 2015, but regional disparities still need to be adequately addressed. Egypt is making significant strides towards achieving these MDGs starting from the National Environmental Action Plan (2002–2017) which emphasizes the changes needed in the areas of water, sanitation, energy, and biodiversity. Egypt has taken serious steps towards achieving the MDG by investing heavily in the water sector, through major irrigation projects, drinking water supply, and sanitation infrastructure. It has also played a central role in cooperating with other Nile riparian countries on water resources [17].

The MDGs call for halving the proportion of people without access to improved sanitation or water by 2015. In this regard, drinking water in Egypt, is well supplied with a high rate of satisfaction of the demand, reaching 100% in urban areas and 95% in rural areas (Fig. 3a). The rural population that has access to adequate drinking water has increased from 45% in 1993 to about 95% in 2004, distributed over 4,617 villages in Egypt [18].

The per capita share of service increased from 130 l/day for drinking water in 1982 to 275 l/day in 2004. According to the data published by the Cabinet Information and Decision Support Center, the total installed capacity of drinking water treatment plants is 21 million m^3/day in 2004 (Fig. 3b) [18]. In rural Egypt, problems of low continuity or reliability of piped water supply can be found.

Sanitation services in Egypt are less developed than water supply services. At present, there are more than 200 wastewater treatment plants in the country. Urban coverage with improved sanitation gradually increased from 45% in 1993 to 56% in 2004. In contrast, rural sanitation coverage remains incredibly low at 4% (Fig. 4a). The low coverage, in combination with a sub-optimal treatment, results in serious problems of water pollution and degradation of health conditions because the majority of villages and rural areas discharge their raw domestic wastewater directly into the waterways [18].

The capacity of wastewater treatment plants has increased by 10 times in the last two decades (Fig. 4b). The existing capacity of 11 million m^3/day serves about 18 million people in mainly urban areas. The total capacity will reach 16 million m^3/day by 2007, serving all urban areas. Population with access to improved sanitation has decreased over the period from 2004 to 2006. Disparities are apparent between and within governorates and the latter disparities are due to discrepancy between urban and rural regions [18].

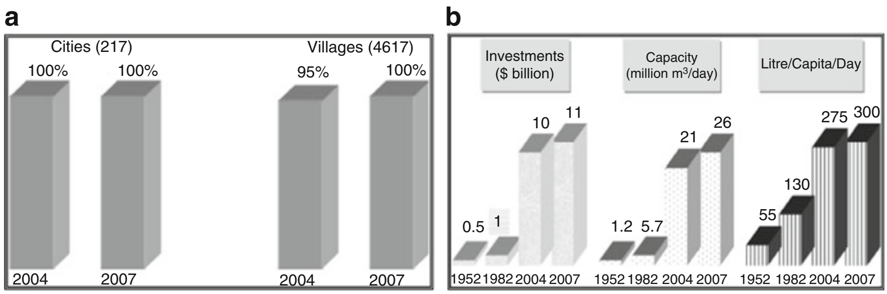

Fig. 3 (**a**) Drinking water service coverage in Egypt. (**b**) Drinking water service development in Egypt
Source: [18]

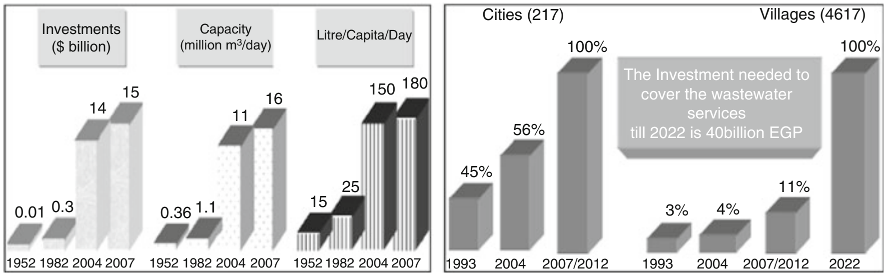

Fig. 4 (**a**) Wastewater service development in Egypt. (**b**) Wastewater service coverage in Egypt
Source: [18]

Unfortunately, the story is not so positive for rural areas which need more intensive programs and policies in order to reach the MDG target. However, recent figures from the 2006 Population Census reveal a decrease in coverage. Therefore, in spite of continuous government efforts to extend water service to all urban and rural population, the service does not catch up with rapid population growth, and hence service coverage is worsening. Though the access level still meets the 2015 target, the challenge facing the government is to sustain it. Moreover, these figures do not reveal the disparities that exist between governorates [17].

6 Wastewater Reuse in the Mediterranean

6.1 History of Wastewater Reuse in the Region

Wastewater in the Mediterranean is widely recognized as a significant, growing, and reliable water source, and reuse is increasingly becoming integrated in the planning and development of water resources in the region [26]. Many MENA countries practice wastewater treatment and reuse, whether planned or un-planned. According to World Bank [27], on average, across the region of MENA, 2% of water use comes from treated wastewater. The Gulf countries use about 40% of the treated wastewater to irrigate non-edible crops for fodder and landscaping. The management and reuse of wastewater in the Mediterranean varies from country to country (Jordan is reusing up to 85% of treated wastewater and Tunisia 20–30%), as do the criteria and their enforcement [28]. Some countries have no wastewater treatment facilities and direct reuse of raw wastewater is occurring with serious health hazards and environmental problems. Others have a well-established national reuse policy. Moreover, wastewater treatment and reuse criteria differ from one country to another and even within a given country such as in Italy and Spain. Some of the main discrepancies in the criteria are, in part, due to differences in approaches to public health and environmental protection. For example, some countries have taken the approach of minimizing any risk and have elaborated regulations close to the California's Title 22 effluent reuse criteria, whereas the approach of other countries is essentially a reasonable anticipation of adverse effects resulting in the adoption of a set of water quality criteria. This has led to substantial differences in the criteria adopted by Mediterranean countries. However, the current situation in some developing countries in the region is the direct use of untreated wastewater for irrigation without taking into account the stated guidelines and standards, and associated risks.

At present, wastewater is mainly reused in the Mediterranean for agriculture. Other uses, like industry and urban use, are being developed at a good pace; but especially golf courses and some industries are increasingly using waste water [29]. In addition to providing a low cost water source, the use of treated wastewater for irrigation in agriculture combines three advantages. First, using the fertilizing properties of the water eliminates part of the demand for synthetic fertilizers and contributes to decrease in the level of nutrients in rivers. Second, the practice increases the available agricultural water resources and third, it may eliminate the need for expensive tertiary treatment. Irrigation with recycled water also appears to give some interesting effects on the soil and on the crops. As a result, the use of recycled wastewater for irrigation has been progressively adopted by virtually all Mediterranean countries. Because irrigation is by far the largest water use in the region and the quality requirements are usually the easiest to achieve among the various types of wastewater reclamation and reuse, it is by far the largest reuse application in terms of volume.

However, in various Mediterranean societies, some constraints need to be overcome, such as (a) recycled wastewater quality prior to reuse in relation to public health, (b) public awareness, (c) the absence of water law, regulating bodies and guidelines, and/or criteria for reusing water [7]. Not every country in the region has established its national guidelines which is a necessity for planning safe reuse of treated wastewater for irrigation. Most of the wastewater reuse standards in MENA are on the basis of either United States Environmental Protection Agency (USEPA) or World Health Organization (WHO) guidelines. However, most of the time, these standards are not reinforced in the countries of the region [28].

6.2 *Wastewater Reuse, Egyptian Experience*

6.2.1 Background

In many ways, Egypt is a typical developing country, characterized by a high population growth (78.7 million until May 2008, [30]), accompanied by increased rates of water consumption. These features tend to elevate water demand, which has an adverse influence on water resources. Water is the fundamental element for sustainable and integrated development in Egypt. Horizontal expansion in agriculture is connected to the country's ability to provide the water required for that expansion. Moreover, the economics of water use and its future on the long run require searching for alternatives and determining the water resources available at present and additional resources we can obtain in the future. The water sector in Egypt is facing many challenges including water scarcity and deterioration of water quality because of population increase and lack of financial resources. Fragmentation of water management and lack of awareness about water challenges are also a problem. Further, more technical and financial assistances might be essential at this stage for numerous ambitious programs. The national water balance prepared for Egypt indicated that there was an overall deficit of approximately 8 billion m^3. This shortage was compensated for by raising the efficiency of available water resources utilization through reuse of drainage water and the use of ground water [31].

The present per capita water share is below 1,000 m^3/year (see Fig. 2) and it might reach 600 m^3/year in the year 2025, which would indicate water scarcity (water scarcity level starts at 1,000 m^3/year). In addition, rapid degradation in surface and groundwater quality results in less water being available for different uses [18]. Figure 6 illustrates the future water requirement till year 2017 in Egypt.

6.2.2 Major Use of Wastewater in Egypt

Wastewater Reuse History

Treated wastewater (after primary treatment) has been in use since 1911 in agriculture (Gabal Al Asfar farm: 3,000 feddans). Yet, experience of large scale, planned and regulated reuse project is still limited. Large scale pilot projects (167,000 feddans) are in East Cairo, Abu Rawash, Sadat City, Luxor, and Ismailia. In the mean time, most of the sewage water drained to the agricultural drains is actually reused in one way or another (*indirect reuse*). No industrial reuse schemes and no groundwater recharge exist in Egypt [32].

Egypt practices the use of various types of marginal quality water, such as agricultural drainage water, treated domestic wastewater, and desalinated brackish water. Egypt is a unique country in the region and agriculture depends mainly on irrigation. The environment conditions controlling agriculture, e.g., clay soil, arid climate, and intensive agriculture, need an intensive efficient drainage system. This results in huge amounts of agricultural drainage water. Wastewater includes treated

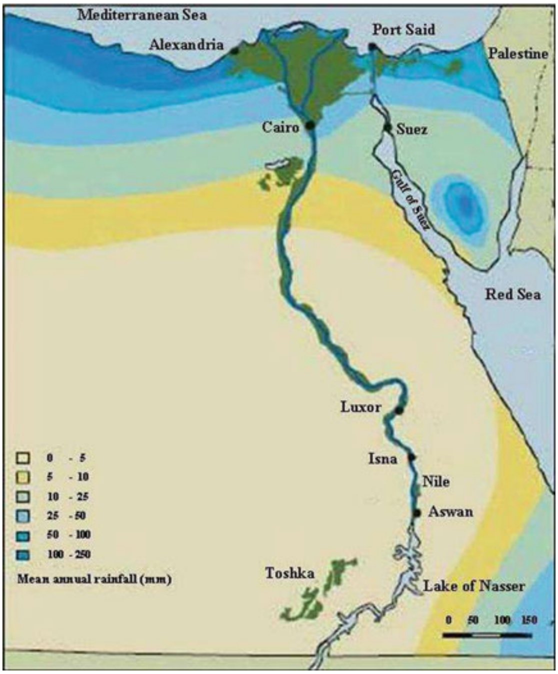

Fig. 5 Distribution of rain in Egypt
Source: [46]

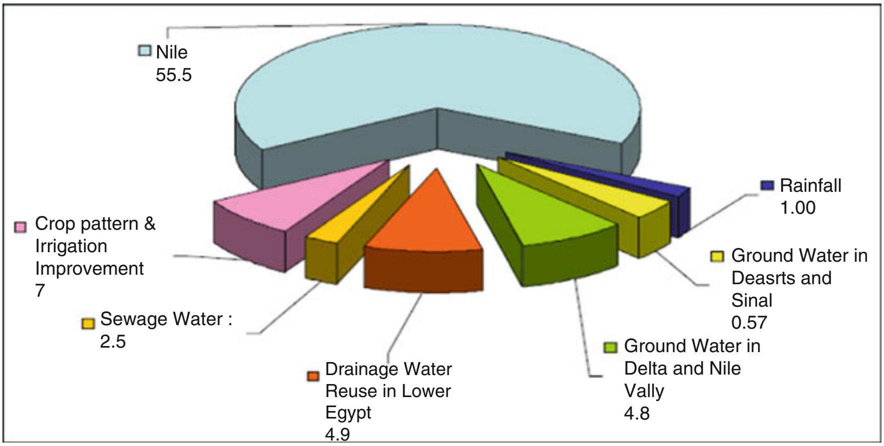

Fig. 6 Future water requirement till the year 2017 in Egypt
Source: [31]

and untreated municipal sewage and industrial effluents, in addition to agricultural drainage, which are considered as non-conventional water resources. Drainage water reuse is practiced on a very large scale. The official reuse of agricultural drainage water in irrigation amounted to 4.84 km^3/year in 2001. The present aim of the Government of Egypt is to reuse up to 8 km^3/year in new reclamation areas in the near future. In addition, there exists significant unofficial wastewater reuse estimated between 2.8 and 4 km^3. This unofficial water reuse is not controlled by the government and poses threats. If adequate regulations are not enforced, the quality of drainage water is threatened [28]. The strategy for the reuse of treated effluents in Egypt is on the basis of the fact that adequately treated wastewater effluents are a precious resource. No reuse guidelines have yet been adopted in Egypt, but the 1984 martial law regulation prohibits the use of effluent for irrigating crops, unless treated to the required standards for agricultural drainage water. The irrigation of vegetables eaten raw with treated wastewater, regardless of its quality level, is also forbidden. The Ministry of Agriculture advocates the restricted reuse of treated wastewater for cultivation of non-food crops such as timber trees and green belts in the desert to fix sand dunes. But on the other hand, the farmers use waste water as a source to irrigate all kinds of crops if alternative irrigation water is not available.

From the institutional standpoint, seven ministries are involved in wastewater treatment and reuse in the country, with unclear delineation of responsibilities and limited coordination among them. The situation is further worsened by the absence of clear policies and action plan on wastewater management as well as by standards that are practically impossible to enforce and which limit the effectiveness of pollution control abatement efforts. Dissemination of information among various organizations and to the public is limited, which substantiates the need for increased awareness and capacity strengthening regarding water quality management issues [33].

The Egyptian water strategy comprises the treatment and reuse of treated wastewater. Treatment of domestic wastewater is either primary or secondary (Table 3). At present, wastewater is estimated at 4,930 Mm/year, with 121 operational wastewater treatment plants, and about 150 plants under construction. The total capacity of the installed treatment plants amounts to about 1.752 billion m/year [4]. However, an accurate estimation of the total quantity or reused effluent is difficult to perform because of the many uncontrolled sources flowing into the same drainage canals. 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 m^3/year. There are gaps between the available treatment capacity and the demands for treatment, so full treatment of urban wastewater will not be possible soon. The total wastewater quantity treated was estimated at 5.228 million cubic meters (MCM) per day in 2000 compared with 1.78 MCM per day in 1994 [34]. Table 3 shows the type and capacity of existing wastewater treatment plants in Egypt. 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. It serves a total area of 1,100 square kilometers and should provide a treatment capacity of 6.28 MCM per day by the year 2010 [3].

Table 3 Operational wastewater treatment facilities

Region treatment plant/facility	Type of treatment	Discharge towards	Capacity (1,000 m^3/day)
Upper Egypt			
8 Treatment plants	Aerated oxidation pond 7 trickling filter	Mainly agricultural drains, few to the River Nile	120
Greater Cairo			
Helwan	Activated sludge	Agricultural drains	420
Alberka	Activated sludge	Agricultural drains	300
Shoubra El-Kheima	Activated sludge	Agricultural drains	300
Zenin	Activated sludge	Agricultural drains	300
Abu Rawash	Primary	Agricultural drains	500
Gabal El-Assfar	Activated sludge	Agricultural drains	500
Delta			
Zagazig	Trickling filter, aerated oxidation ponds	Agricultural drains	95
			300
35 Other facilities	Extended aeration, trickling filter, activated sludge	Agricultural drains and lake Manzala	
EL – Mansoura			102.2
Alexandria			796

Source: [47]

According to Shaalan [48], the major problems and issues related to the current use of treated sewage water in Egypt are the following: (a) not enough infrastructure (treatment plants) to treat the amounts of wastewater produced, (b) only about 50% and 3% of the urban and rural populations, respectively, are connected to sewerage systems, (c) a significant volume of wastewater enters directly into water bodies without any treatment, (d) many wastewater treatment facilities are overloaded and/or not operating properly, (e) some industries still discharge their wastewater with limited or no treatment into natural water bodies, (f) domestic and industrial solid wastes are mainly deposited at uncontrolled sites and/or dumped into water bodies (especially outside Greater Cairo), (g) the quality of treated wastewater differs from one treatment station to another, depending on inflow quality, treatment level, plant operation efficiency, and other factors, and (h) negative impacts of the above problems on both health and environment [35].

Agricultural Drainage Canals (Indirect Reuse of Waste Water)

The majority of sewage water, amounting to more than 2 BCM/year, is discharged into agricultural drainage canals (Table 3). Part of this water receives secondary treatment while the rest is drained after primary treatment or raw. The present water management system strongly depends on the reuse of drainage water, as all the drainage water of Upper Egypt is discharged into the Nile (about 2.6 BCM/year). Drainage water in the Delta is recycled for irrigation by mixing part of the flow of the main drainage system with water in the main irrigation canals. Various reuse pumping stations in the Delta and Fayoum convey drainage water back into the irrigation canal system and into the Nile. Using the water twice or even three times increases the salinity up to the order of 3,000 ppm or more in drains near the lakes boarding the Mediterranean Sea. The mixing of drainage water with relatively clean irrigation water further diffuses all kinds of constituents, and negative environmental and health impacts are very much related to the big load of municipal wastewater discharge [36].

Since the mid 1970s drainage water reuse in irrigation became an official policy and a component of the NWRP. Institutional arrangements were set in place for implementing the drainage water reuse policy. Law 48 of 1984 was issued with bylaws and water quality standards that govern the disposal and reuse of drainage water. Network for monitoring drainage water quantity and quality was established since 1976 (Fig. 7) to provide real time information for drainage water disposal and reuse management on safe and sustainable basis [49]. According to MWRI/USAID, Appendix 2 [36], full treatment of wastewater is far from reality. Agricultural drainage reuse is a mainstay and will continue in the Delta. An alternative to agricultural drains as wastewater dumping sites is not available and long-distance diversion of wastewater is impractical. Given these factors, a central need for minimizing wastewater or separating it from general irrigation water remains. Separation of wastewater will require the following measures:

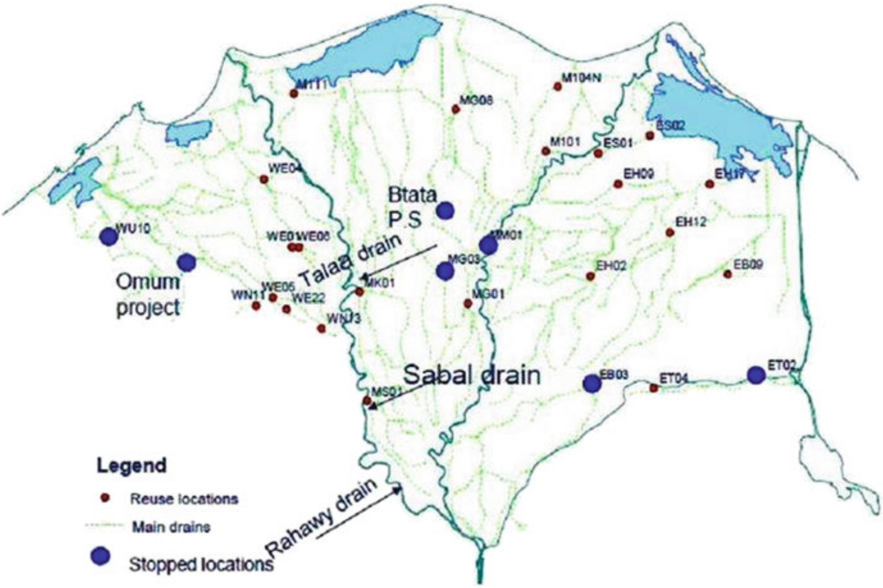

Fig. 7 Drainage network
Source: [37]

Classifying Drains into Two Categories: Reuse Drain and Discharge Drain

Drainage water is loaded with different sorts of pollutants from agricultural, industrial, or domestic sources. Salts, nutrients, and pesticides run off of irrigated fields and are carried by drainage water. Untreated industrial effluents discharged into the drains contain heavy metals and organic materials. Similarly, untreated domestic wastewater containing organic materials, bacteria, and pathogens is disposed into drains.

On the national level, both the Ministry of Agriculture and Land Reclamation (MALR) and the MWRI 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 because of the many uncontrolled sources flowing into the same drainage canals. 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. The national legislation on effluent reuse has also recently been revised by Decree 44/2000 to bring the standards for effluent quality and conditions of reuse in line with those adopted internationally. 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 [38].

On the basis of Egyptian National Committee on Irrigation and Drainage (ENCID) [20], the strategies for drainage water reuse include the following measures:

- Increasing the reuse of drainage water from about 4.5 BCM/year to 9.0 BCM/year by year 2017 with average salinity of 1,170 ppm. This could be achieved through implementing several projects to expand the reuse capacity at different areas. Main future projects include the El-Salam canal project, the El-Omoom, and El-Batts drainage project.
- Improving the quality of drainage water especially in the main drains.
- Separating sewage and industrial wastewater collection systems from the drainage system.
- Draining 50% of the total generated drainage water in the delta into the sea to prevent seawater intrusion, and to maintain the salt balance of the system.
- Implementing an integrated information system for water quality monitoring in drains using the existing data collection network after updating and upgrading. Continuous monitoring and evaluation of the environmental impacts due to the implementation of drainage water reuse policy especially on soil characteristics, cultivated crops, and health conditions.
- Limiting the use of treated wastewater to cultivated non-food crops such as cotton, flax, and trees.
- Separating industrial wastewater from domestic sewage, so that it would be easier to treat domestic sewage with minor costs and avoid the intensive chemical treatment needed for industrial wastewater.

El-Salam Canal, an Egyptian Case Study

El-Salam canal is an example for using drainage water on large scale projects. The cultivated and cropped areas have increased over the past few years and will continue to increase because of the government policy to add more agricultural lands. To overcome the increased demand for food, the MWRI in collaboration with the MALR has planned an ambitious program to reclaim approximately 7,170 km^2 by 2010. Some of the reclaimed areas will be irrigated by mixing the Nile water with drainage water, such as that of the El-Salam Canal, which will cross the Suez Canal to reclaim 2.605 km^2 in Northern Sinai [31].

The Government of Egypt implemented El-Salam Canal project to reuse drainage water, to create new communities along the Canal, and to re-charting Egypt's population map. The Canal is designed to serve as the main source of irrigation water to the newly developed areas of the North Sinai Peninsula and the desert land to the west of the Suez Canal (643,560 acres of new lands). The Project is perhaps one of the most significant and controversial irrigation projects currently underway in the Eastern Nile Delta. Under the proposed management scheme, approximately 4 BCM/year will be delivered by the canal. Water supplied by this important new waterway will be composed of one part drain water and one part fresh water diverted from the River Nile (2 BCM/year). The ratio of Nile water to drainage water is about 1:1. This ratio is determined to reach total dissolved solids (TDS) not more than 1,000–1,200 mg/L to be suitable for cultivated crops [39].

Figure 8 shows the location of El Salam Canal Irrigation project, and the three sources of water to feed the canal [40]:

- Domietta Branch, which supplies the canal with 9 MCM per day.
- Hadous drain, which supplies the canal with 5 MCM per day, to be increased to 7 MCM per day.
- Serw drain, which supplies the canal with 2 MCM per day.

The Canal and its branches extend over a length of 262 km. The Canal project is divided into two phases:

First Phase: (West of Suez Canal) El-Salam Canal extends at a length of 87 km from the River Nile till the Suez Canal. It serves 220,000 feddans.

Second Phase: (East of the Suez Canal in Sinai) this phase includes establishing El-Salam Lake culvert below the Suez Canal to transfer the Nile water to Sinai. It serves an area of 400,000 feddans in Sinai.

The total amount of industrial wastewater feeding into the Salam canal through these sources is estimated at 170 MCM per year. These waters come to the drain through a group of secondary drains. These secondary drains are the receiving bodies of the industrial discharge from 14 large industrial facilities located in the Dakahlia Governorate, east of the Domietta Branch. These plants discharge about 27 MCM annually (15 MCM of industrial discharge, 10 MCM cooling waters, and 2 MCM of domestic sewage) [40].

Table 4 shows the water quality and estimated pollution load in El Salam canal after receiving waters from the three main sources.

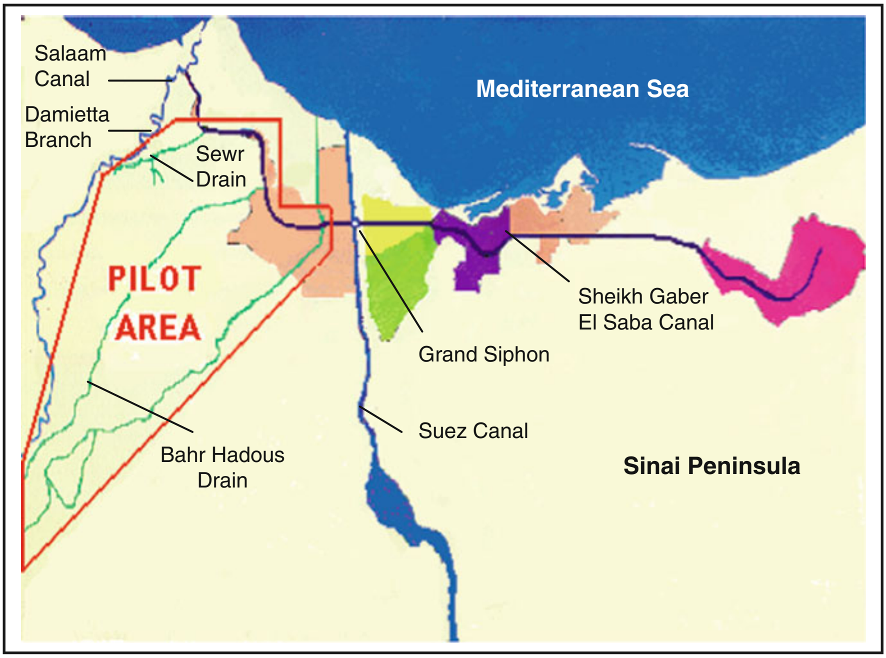

Fig. 8 Location of El Salam Canal irrigation project and the three sources of water to feed the canal
Source: [40]

Table 4 Water quality along El Salam canal

Pollutant	Load (tons/day)	MOH analysis, Mar 2000
BOD	35	22
COD	100	37
Oil & Grease	25	5
Suspended Solids	80	–
Total dissolved solids	160	1,140

Source: Appendix 4 [41]

The water of El Salam canal receives high loads of pollutants every day. However, through its long journey of about 180 km, most of the suspended matter, oils, and grease are precipitated; in addition to the partial removal of COD and BOD. Because of this natural cleaning process, testing of the quality of the canal's waters before crossing of the Suez canal revealed a high degree of transparency [41].

The MWRI adopted a policy aimed at improving the quality of waters feeding the El Salam canal from the drains of the East Delta region and the reused drainage water in the Middle Delta region. This policy is on the basis of encouraging/forcing industrial facilities in these regions to control their industrial pollution [41].

Forest Plantation

The use of sewage water to develop forests in deserts represents a challenge for the Undersecretary for Afforestation and Environment, MALR. Since the early 1990s, the Undersecretary, with support of donors and international agencies for development, has actively conducted many activities in promoting desert forest plantation with wastewater irrigation throughout Egypt to reduce the wood and timber imports (estimated at LE 3 billion per year). The benefits to the country are numerous. Wastewater irrigation on forests encourages desert land reclamation, conserves the valuable Nile freshwater for food or forage crops, and also, helps urban areas to reduce the burden of increasing sewage waters.

Building on the experience of the pilot forest plantations, MALR agrees with the Agricultural Policy Reform Program to establish a new policy for the Government to sell or lease desert lands adjacent to wastewater treatment plants to private investors for forest plantations. Private sectors can be profited in the business of wastewater safe discharge and reuse in forest plantations.

MALR has a clear policy for the reuse of wastewater effluents: Use the wastewater effluents for irrigating and producing timber trees planted in the desert, and never use the water for irrigating any other crops like fruits, vegetables, and field crops.

The rationale for this policy includes the following:

- Egypt's timber resources need bolstering, as there are no natural forests in Egypt because of the lack of rainfall (Fig. 5).
- Egypt is currently exporting some fruit and vegetable crops abroad, and the use of effluent water in irrigating such crops would prevent it from competing with neighboring countries producing similar crops.
- While treatments are expected to improve during the coming few years, most sewage water treatment stations in Egypt currently have only primary or secondary treatment facilities. Thus, only in due course and with the availability of new facilities could effluent water be used for purposes such as the production of ornamental plants, cut flowers, and fiber crops.
- Egypt's current water needs are not critical enough to necessitate use of the effluent water in sensitive crops such as fruits, vegetables, etc.

MALR suggests the following formula for the reuse of wastewater effluents:

WASTE WATER (treated sewage) + WASTE LAND (sandy desert soil) = GREEN TREES (Forest Plantation)

The wastewater-irrigated forest plantation was started in Luxor on 100 feddans of desert sandy soil, right behind the main sewage station of Luxor City. Initially, 40 feddans of the land were planted with the following tree varieties: Eucalyptus, Casuarina, Acacia, Mulberry (Morus Japonica, and Alba), Khaya, and Caprrisus. The area was irrigated with treated sewage water from the nearby treatment station in flood irrigation system [42].

Active pilot wastewater-irrigated forest projects are listed in Table 5 below. These forests were developed in five years, and they are all exclusively irrigated by wastewater effluents.

Table 5 Wastewater-irrigated forest plantation pilot projects in Egypt

Site Names	Area (feddans)	Planted trees	Soils	Irrigation methods
1. Ismalia	500	Caprrisus and Pinus	Desert sandy	Drip
2. Sadat	500	Cuprrisus, Mulberry, and Pinus	Desert sandy	Drip
3. Luxor (close to airport)	1,000 (including a nursery for Mahogany seedlings)	African Mahogany (Khaya)	Desert sandy	Modified flood (a new area uses drip irrigation)
4. Qena	500	Eucalyptus and Mahogany	Desert sandy	Modified flood
5. Edfu	500	African mahogany	Desert sandy	Modified flood
6. New Valley (El Kharga)	800	Eucalyptus, African Mahogany, and Terminalia	Desert sandy	Modified flood
7. New Valley (Paris)	50	African Mahogany	Desert sandy	Modified flood
8. South Sinai	200	Acacia and Eucalyptus	Desert sandy	Drip
9. Abu Rawash	50	Experiment of Neem trees (controlling for insects)	Desert sandy	Modified flood

Source: Appendix 3 [42]

Urban Greenland Irrigation

Wastewater irrigation for urban greenland development is a step towards non-agricultural secondary reuse in cities. Given the heavy agricultural activities in the Delta, the potential for forest development in the Delta is limited. But newly developed cities and towns badly need public parks and street trees to build their green areas. Wastewater effluents should have a great reuse potential for this purpose.

Again, the Ministry of Housing, Utility, and Urban Communities (MHUUC) Decree 44/2000 provides wastewater reuse specifications for park grass, street trees, and other urban green lands to minimize human health risks. There are some kind of cooperation between the Afforestation Department of MALR, and some Governorates, to use wastewater for tree irrigation on highways. This kind of non-crop reuse represents a new way to dispose and absorb urban wastewater in the Delta, and should be encouraged and supported.

Finally there are some priority actions to enhance reuse potential in Egypt as Fahmy [32] mentioned:

- Separation of industrial effluent disposal systems
- Provision of adequate treatment facilities to those communities connected to sewer systems

- Provision of collection stations for the vacuum trucks (rural areas)
- Search for simple low cost treatment technology
- Horizontal expansion based on reuse of treated sewage
- Awareness of the health risks involved with direct or indirect contact with the water

Egypt is now taking a step forward towards future development by reforming the water and wastewater sector. The change concerned institutional and financial aspects. Thus, a Holding Company for Water and Wastewater along with its subsidiary companies was established in 2004 by a presidential decree to develop and implement a holistic policy, which includes expansion of the service delivery, the introduction of modern technology in operations and maintenance as well as management, and increasing the private sector participation in activities which are not core to its mission [20].

Box 3. Egyptian Water Resources
Egypt receives about 98% of its fresh water from the Nile, originating outside its international borders. The availability of fresh water resources in the country is limited mainly to the Nile River, groundwater from both renewable and non-renewable aquifers, limited rainfalls along the northern coast, and flash floods in the Sinai Peninsula. Egypt's share from the Nile is fixed at 55.5 BCM per year by the 1959 agreement with Sudan. The river contributed about 82% of the available water from different resources in the year 2000. It is expected that by the year 2017, it will contribute about 62%. Groundwater is an important source of fresh water in Egypt, both within the Nile system and in the desert. However, ground water occurs at great depths and the aquiferis are generally non-renewable. The renewable groundwater aquifer of the Nile system is recharged from excess irrigation water as well as leakages from the Nile and the distribution network. Current abstraction from the Nile aquifer is about 4.8 BCM/year and is expected to reach 7.5 BCM/year by the year 2017. Groundwater also exists in the non-renewable deep aquifers in the Western Desert and Sinai. The total extraction potential of groundwater is estimated at 3.5 BCM/year. Rainfall is rather negligible as a source of water for agriculture except for a small area along the Mediterranean coast with less than 200 mm/year at Alexandria. It also declines inland to about 25 mm/year near Cairo (Fig. 5). Source: [18].

References

1. Ceres and Pacific Institute (2009) Water scarcity & climate change: growing risks for businesses & investors. A Ceres Report, February 2009. Available at: http://www.pacinst.org/reports/business_water_climate/full_report.pdf
2. Vigneswaran S, Sundaravadivel M (2004) Recycle and reuse of domestic wastewater. In: Vigneswaran S (ed) Wastewater recycle, reuse, and reclamation. Encyclopedia of life support

systems (EOLSS) (developed under the auspices of the UNESCO). Eolss Publishers, Oxford, UK [http://www.eolss.net]
3. WHO/CEHA (World Health Organization/Centre for Environmental Health Activities) (2005) A regional overview of wastewater management and reuse in the Eastern Mediterranean CEHA, WHO-EM/CEH/139/E. Available at: http://www.emro.who.int/Ceha/pdf/A%20regional%20overview%20of%20wastewater%202005.pdf
4. FAO (2000) Water quality management and pollution control in the Near East: an overview. Paper Presented at the regional Workshop on Water Quality Management and Pollution Control in the Near East, Cairo, Egypt
5. Málaga (2003) Climate change and water resources in the Mediterranean Water: a vital resource threatened by climate change, a needed adaptation of its management December 2003, Málaga, Spain
6. Scott C, Faruqui NI, Raschid L (eds) (2004) Wastewater use in irrigated agriculture, confronting the livelihood and environmental realities. Wastewater use in irrigated agriculture: management challenges in developing countries. CABI/IWMI/IDRC, 2004, 206 pp. Available at: http://www.idrc.ca/openbooks/112-4/
7. CEDARE (Center for Environment and Development for Arab Region and Europe) (2004) Wastewater management and reuse assessment in the Mediterranean. Part I Final Report Prepared by Dia El Din El Quosy
8. UNESCO (2003) World water assessment programme. Water for people; water for Life: the United Nations world water development report. Berghahn Books, Oxford and New York
9. Yang H, Zehnder AJB (2002) Water scarcity and food import: a case study for Southern Mediterranean Countries. World Dev 30(8):1413–1430
10. De Wrachien D, Ragab R, Hamdy A, Trisorio Liuzzi G (2005) Global warming water scarcitiy and food security in the Medeterranean environment. In: Food security under water scarcity in the Middle East: problems and solutions. Options Méditerranéennes, Série A n. 65, pp 29–48. Available at: http://www.iamb.it/download/options/options_A65.pdf
11. Bakir HA (2001) Sustainable wastewater management for small communities in the Middle East and North Africa. J Environ Manage 61:319–328
12. Iglesias A, Garrote L, Flores F, Moneo M (2007) Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Resour Manage 21:775–788
13. Volkman S (2003) Sustainable wastewater treatment and reuse in urban areas of the developing world. M.Sc., Michigan Technological University, Available at: http://www.cee.mtu.edu/sustainable_engineering/resources/technical/Wastewater_treatment_and_reuse_FINAL.pdf
14. Lallana C, Krinner W, Estrela T, Nixon S, Leonard J, Berland JM (2001) Sustainable water use in Europe, Part 2: Demand Management, European Environment Agency (EEA), Environmental Issue Report, No. 19, Copenhagen, 2001
15. Carr RM, Blumenthal UJ, Mara DD (2004) Health guidelines for the use of wastewater in agriculture: developing realistic guidelines. In: Scott C, Faruqui NI, Raschid L (eds) Wastewater use in irrigated agriculture, confronting the livelihood and environmental realities, CABI/IWMI/IDRC, 206 pp, http://www.idrc.ca/openbooks/112-4/
16. MED WWR WG (Mediterranean Wastewater Reuse Working Group) (2007). Available at: http://www.emwis.net/topics
17. Egyptian Ministry of Economic Development (2008) Egypt achieving the millennium development goals, a midpoint assessment. Available at : http://www.undp.org.eg/Portals/0/MDG%20Links/Egypt%20MDG%20Mid%20Term%20Assessment%20Report%202008.pdf
18. Abdel-Gawad S (2008) Actualizing the right to water: an Egyptian perspective for an action plan. In: Water as a human right for the Middle East and North Africa. International Development Research Centre, Ottawa, Canada, pp 133–146. Available at: http://www.idrc.ca/openebooks/380-5/#page_147
19. Stagnitti F, Sherwood J, Allinson G, Evans L et al (1998) Investigation of localised soil heterogeneities on solute transport using a multisegement percolation system. NZ J Agric Res 41:603–612

20. ENCID (Egyptian National Committee on Irrigation and Drainage) (2001) Adopted measures to face major challenges in the Egyptian water sector. From the HAGUF 2 ND world water forum 2000 to the kyoto 3 RD world water forum 2003
21. Khordagui H (2007) Climate change in ESCWA region: reasons for concern. In: Proceedings of an expert group meeting on trade & environment priorities in the Arab region. Cairo, Egypt, 11–13 November
22. IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability - Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds). Cambridge University Press, Cambridge and New York. http://www.ipcc.ch/ipccreports/ar4-wg2.htm
23. Hanson CE, Palutikof JP, Livermore MTJ, Barring L, Bindi M, Coret-Real J, Durao R, Giannakopoulos C, Good P, Holt T, Kundzewicz Z, Leckebusch GC, Moriondo M, Radziejewski M, Santos J, Schlyter P, Schwarb M, Stjernquist I, Ulbrich U (2007) Modelling the impacts of climate extremes: an overview of the MICE project. Clim Change 81(Suppl 1):163–177
24. IPCC (2007) Climate Change 2007: The Physical Science Basis – Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds). Cambridge University Press, Cambridge and New York. http://www.ipcc.ch/ipccreports/ar4-wg1.htm
25. UNDP (2003) The human development report 2003. United Nations Development Programme, New York
26. Angelakis AN, Marecos Do Monte MHF, Bontoux L, Asano T (1999) The status of wastewater reuse practice in the Mediterranean basin. Wat Res 33(10):2201–2217
27. World Bank (2007) Making the most of scarcity: accountability for better water management results in the Middle East and North Africa. MENA development report. The World Bank, Washington DC
28. CIDA (Canadian International Development Agency), WaDImena (2008) Wastewater Reuse for Water Demand Management in the Middle East and North Africa
29. Salgot M (2007) Wastewater reuse in the Mediterranean region: state of the art and perspectives. Available at: http://www.inwaterman.eu/file/documenti/Salgot_relazione.pdf
30. CAPMAS (Central Agency for Public Mobilization and Statistics) (2008) National Population Conference June 2008 available at: http://www.sis.gov.eg/En/Land&people/Population/030900000000000001.htm
31. Alnaggar D (2003) Water resources management and policies for Egypt. Presented at the workshop on policies and strategies options for water management in Islamic countries (Tehran), Ministry of Water Resources & Irrigation. Available at: http://www.rcuwm.org.ir/events/workshop/03/files/Dalal-AlNaggar.pdf
32. Fahmy H (2009) Marginal water reuse: Egypt's experience. PPT, Available at: http://www.onas.nat.tn/fr/download/egyptian.pdf
33. Shaalan NS (2001) Egypt country paper on wastewater reuse. Joint FAO/WHO consultation for launching the regional network on wastewater reuse. Amman, Jordan
34. Saqer, S. Al salem (2005). A regional overview of wastewater management and reuse in the Eastern Medeterranean region. Available at: http://sarvab.com/Portals/7/Cod%20194.pdf
35. Bazza M (2002) Wastewater recycling and reuse in the Near East Region: experience and issues. In: Proc. of IWA-Regional Symposium on Water Recycling in Mediterranean Region. Iraklion Greece, 26–29 September 2002; 1: 43–60
36. MWRI/USAID (Ministry of Water Resources and Irrigation/US Agency for International Development) (2000) Policies and procedures for improved urban wastewater discharge and reuse. Report No. 34, Appendix 2. Health impact and water quality standards in wastewater irrigation

37. Abdel-Dayem S, Abdel-Gawad S, Fahmy H (2007) Drainage in Egypt: a story of determination, continuity, and success. Irrigat Drain 56:S101–S111
38. WHO (World Health Organization) (2005) Regional Office for the Eastern Mediterranean Regional Centre for Environmental Health Activities CEHA, WHO-EM/CEH/139/E. A regional overview of wastewater management and reuse in the Eastern Mediterranean Region
39. Hafez A, Khedra M, El-Katiba K, Gad Allaa H, Elmanharawy S (2008) El-Salaam Canal project, Sinai II. Chemical water quality investigations. Desalination 227:274–285
40. MWRI/USAID, (Ministry of Water Resources and Irrigation/US Agency for International Development) (2001) Egypt water quality management country report. Draft September 2001
41. MWRI/USAID (Ministry of Water Resources and Irrigation/US Agency for International Development) (2000) Policies and procedures for improved urban wastewater discharge and reuse. Report No. 34. Appendix 4, Report No. 34, Appendix 4, industrial wastewater management
42. MWRI/USAID (Ministry of Water Resources and Irrigation/US Agency for International Development) (2000) Policies and procedures for improved urban wastewater discharge and reuse. Report No. 34. Appendix 3, Wastewater irrigation for forest plantation
43. World Bank (1996) From Scarcity to Security, Averting a Water Crisis in the Middle East and North Africa. Washington DC: The World Bank
44. Abdel-Halim W, Weichgrebe D, Rosenwinkel K-H, Johan Verink (2008) Sustainable sewage treatment and re-use in developing countries. Twelfth International Water Technology Conference, IWTC12, Alexandria, Egypt
45. WHO (2003) The right to water; Chapter one: water as a human right. Available at: http://www.who.int/water_sanitation_health/rightowater/en/
46. EUROMED (2009) Identification and removal of bottlenecks for extended use of wastewater for irrigation or for other purposes (country report Egypt), RG/2008-01/FTF.ppt presentation
47. Fahmy H (2009) Marginal water reuse: Egypt's experience. PPT, Available at: http://www.onas.nat.tn/fr/download/egyptian.pdf
48. Shaalan NS (2001) Egypt country paper on wastewater reuse. Joint FAO/WHO Consultation for launching the Regional Network on Wastewater Reuse. Amman, Jordan
49. Abdel-Dayem S (1997) Drainage Water Reuse: Conservation, Environmental and Land Reclamation Challenges. IXth World Water Congress of IWRA, A special session on Water Management Under Scarcity Conditions: The Egyptian Experience, Montreal, Canada