Overview on water reuse in Egypt: Present and Future

Use of treated wastewater is of tremendous potential importance to Egypt, particularly for restricted irrigation and forest trees.

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Abstract

Egypt is extremely dependent on the River Nile, in fact, 97% of the population lives on 4% of the land, around the river Nile. The renewable water resources were 2189 m^3/capita/year in 1966. This will drop to 500 m^3/capita/year by the year 2025. Effluents from municipalities have been used in Egypt since 1922 in sandy soil areas like Al-Gabal Al-Asfar and Abou-Rawash. Currently, 0.7 billion m^3 (BCM) per year of treated wastewater is being used in irrigation, of which 0.26 BCM is secondary treated and 0.44 BCM is primary treated wastewater. The agricultural sector is utilizing about 86% of the available water supplies. The drainage water from agriculture is collected, by an extensive drainage network. Currently about 5.5 BCM of drainage water are being reused after mixing with fresh water. This amount is expected to increase up to 9.6 BCM by the year 2017. In general, treated wastewater use is of tremendous potential importance to Egypt.

Introduction

Egypt is an arid country, which covers an area of about 1,001,450 km^2 of which only 4% is occupied by its population. The population has tripled during the last 50 years from 19 million in 1947 to about 83.5 million in 2012 of whom about 99% are concentrated in the Nile Valley and Delta. The population is estimated to be about 100 million by the year 2025 (Abdel-Lateef et al., 2011). One of the important issues in the future is to redistribute the population over a larger area. To reach this objective, it is essential to reclaim new lands in order to provide the required food for the new communities. The agriculture requirements exceed 80% of the total demand for water (Abdel-Shafy and Aly, 2002). In view of the expected increase in water demand from other sectors, such as municipal and industrial water supply, the development of Egypt‘s economy strongly depends on its ability to conserve and manage its water resources.

Meanwhile, water demand is continually increasing due to population growth, industrial development, and the increase of living standards. The per capita share of water has dropped dramatically to less than 1000 m^3/capita, which is classified as „Water poverty limit“. It is projected that the value decreases to 500 m^3/capita in the year 2025 (Abdel-Wahaab, 2003) (Figure 1).

Most cultivated lands are located close to the Nile banks, its main branches and canals. Currently, the inhabited area is about 5.3 million ha and the cultivated agricultural land is about 3.3 million ha.

The per capita crop area declined from 0.17 ha in 1960, 0.08 ha in 1996 to about 0.04 ha in 2012 (World Bank, 2007, Abdel-Shafy and Aly, 2002). The sharp decline of the per capita of both cultivated land and crop area resulted

Key factors:

- It is essential to reclaim new lands in order to provide the required food for new communities.
- Nowadays the per capita share of water has dropped to 633 m^3/capita/year, i.e. below the water poverty limit
- The per capita crop area declined from 0.168 hectare in 1960 to 0.042 hectare in 2012.
- The capacity of wastewater treatment plants has increased by 10 times in the last two decades.
- Separating sewage and industrial wastewater is important for safe water reuse.
- Currently there are 63 man-made forest trees irrigated with water reuse in Egypt

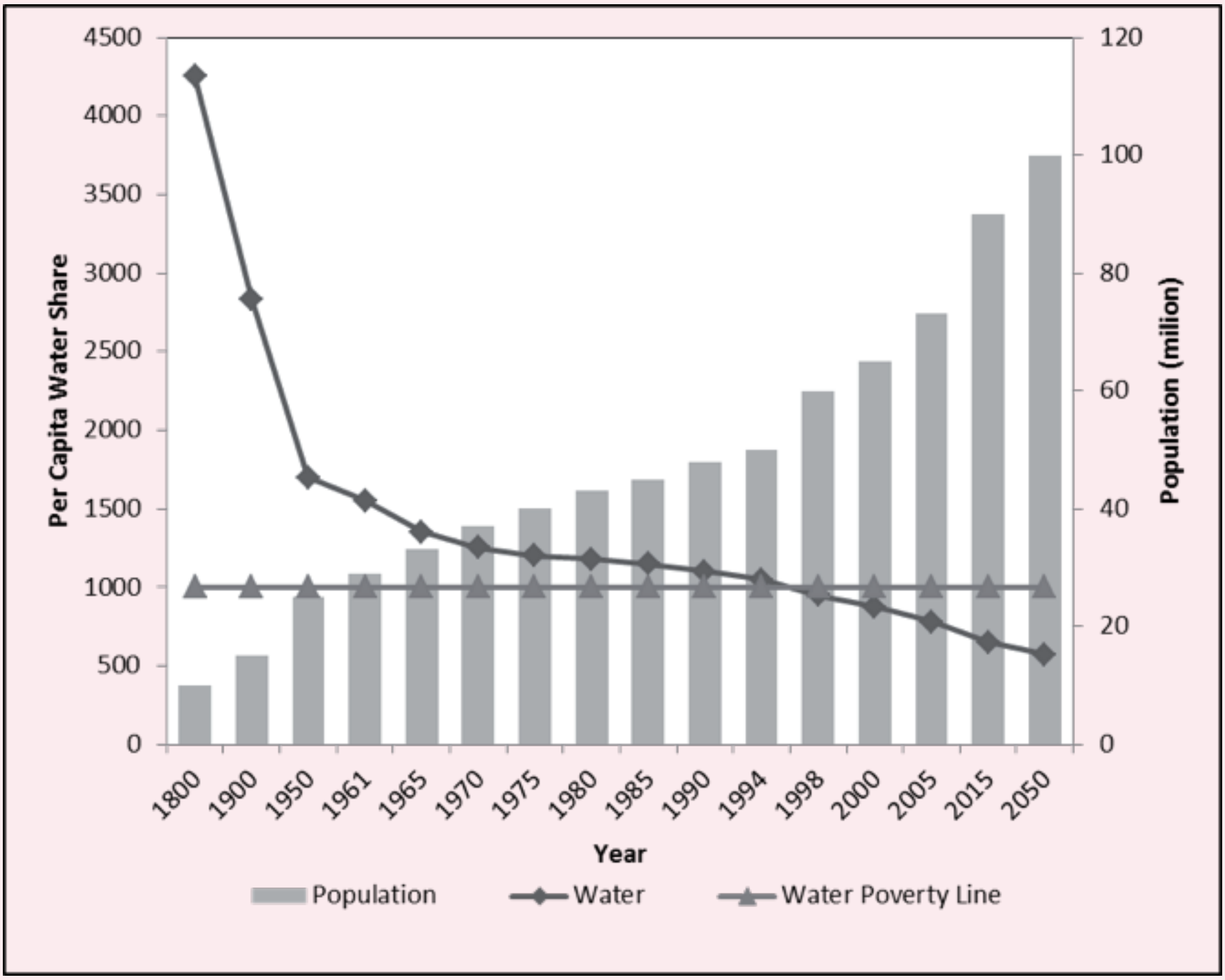

Figure 1: Population growth and per capita water share in Egypt in m^3/year (Abdel-Wahaab, 2003).

in the decrease of the per capita crop production. This affects directly the food security at individual, family, community and country levels (World Bank, 2009).

Water resources

Water resources in Egypt are limited to the following resources:

- Nile River
- Rainfall
- Groundwater in the deserts and Sinai and
- Desalination of sea water

Each resource has its limitation on use, whether these limitations are related to quantity, quality, space, time, or use cost. The following is a description of each resource.

Nile River Water

Nile water budget is 55.5 x 109 m^3/yr to Egypt and 18.5 x109 m^3/yr to Sudan according the agreement between both countries in 1959 (Dijkman, 1993). The Nile River inside Egypt is completely controlled by Aswan dam in addition to series of seven barrages between Aswan and the Mediterranean Sea. Egypt relies on the available water storage of Lake Nasser to sustain its annual share of water. Nile water comprises about 91.5% of the total fresh water supply and the 97% of renewable water supplies in Egypt (Abdel-Shafy and Aly, 2007). Water supplies and demands in Egypt are given in Table 1.

Rainwater

Rainfall in Egypt is very scarce, with an annual average of 12 mm (Abdel-Shafy et al. 2010). The mean annual rainfall ranges from 0 mm/year in the desert to 200 mm/year in the north coastal region (Figure 2). Rain falls only in the winter season in the form of scattered showers (Abdel-Shafy and Aly, 2002). Rainwater is concentrated on the northern part of the country. It is between 150 - 200 mm, and decreases gradually to the south reaching around 24 mm.

The maximum total amount of rain does not exceed 1.8 billion m^3 (BCM) per year. At present, the average annual amount of rainwater that is effectively utilized for agricultural purposes is about 1 BCM per year (Abdel-Shafy et al. 2010).

Table 1: Water supplies and demands in Egypt in BCM per year (Abdel-Shafy and Aly, 2002).

	1990	2000	2025
Water supplies			
Nile water	55.5	55.5	57.5
Ground water:			
- in the Delta and New Valley	2.6	5.1	6.3
- in the desert	0.5		
Reuse of agricultural drainage water	4.7	7.0	8.0
Treated sewage water	0.2	1.1	2.4
Management and saving wasted water	-	1.0	-
Total	**63.5**	**69.7**	**74.2**
Water demands			
Agriculture	49.7	59.9	61.5
Households	3.1	3.1	5.1
Industry	4.6	6.1	8.6
Navigation	1.8	0.3	0.4
Total	**59.2**	**69.4**	**75.6**

Groundwater

In the western desert, groundwater is non-renewable fossil origin and occurs in the geological layers of the Nobian limestone. It supplies the New Valley’s Oasis. It has been estimated that about 200,000 BCM of fresh water are stored in this aquifer. The water is at the depth of 60-100 m around the area of East-Oweinat (NWRP, 2005).

In Sinai groundwater is mainly encountered in three different water-bearing formations: i) the shallow aquifers in northern Sinai, ii) the valley aquifers, and iii) the deep aquifers. The shallow aquifers in the northern part of Sinai are composed of sand dunes that hold the seasonal rainfall (heavy storms), which helps to fix these dunes. The annual rainfall on Sinai varies from 40 mm to 200 mm/year. Although most of the shallow aquifers are renewable, only 10 to 20% of the deep aquifers are renewable by rainfall and flash floods. The aquifers in the coastal area are subject to salt-water intrusion. The total dissolved solids in this water range from 2,000 to 9,000 ppm which can be treated to reach a suitable salinity level to be used for irrigating certain crops (Abdel-Shafy and Aly, 2002).

The total groundwater abstraction in the western desert is 0.5 BCM/year and in Delta, Sinai and New Valley is estimated to be 5.1 BCM/year .

Desalination of Sea Water

Desalination of seawater in Egypt has been given low priority. The reason is due to the cost of treating seawater which is high compared with other sources, even the unconventional sources such as drainage reuse (El-Kad and El-Shibini, 2001; Abou Rayan et al. 2004). The future use of such resource for other purposes (agriculture and industry) will largely depend on the rate of improvement in the technologies used for desalination and the cost of power. The amount of desalinated water in Egypt now is in the order of 0.03 BCM/year.

Non-conventional water resources

Non-conventional water resources include:

- the renewable groundwater aquifer in the Nile basin and Delta
- the reuse of treated sewage water
- the reuse of treated agricultural drainage water

These recycled waters cannot be added to Egypt‘s fresh water resources. The renewable Groundwater Aquifer in the Nile Valley and Delta was estimated at about 500 BCM but the maximum renewable amount (the aquifer safe yield) is only 7.5 BCM. The existing rate of abstraction in regions is about 4.5 BCM/year, which is still below the potential safe yield of the aquifer (WHO, 2005).

Sanitation in Egypt

Existing situation

Sanitation services in Egypt are less developed than water supply services. At present, there are more than 323 wastewater treatment plants in the country. The capacity of wastewater treatment plants has increased by 10 times in the last two decades. The existing capacity is 12 million m^3/day. Length of wastewater collection networks / sanitation pipelines increased from 28,000 km in 2005 to 34,000 km in 2010 (Abdel-Kader and Abdel-Rassoul, 2010).

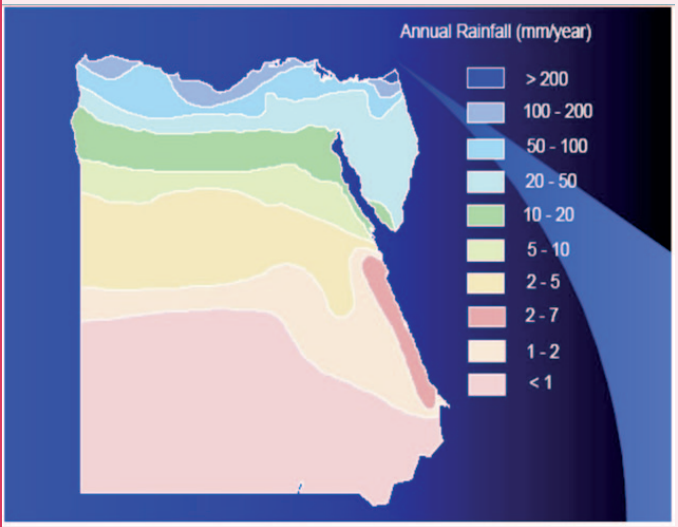

Figure 2: Annual rainfall in Egypt (Abdel-Shafy et al., 2010)-

Urban coverage with improved sanitation gradually increased from 45% in 1993 to 56% in 2004, reaching 100% in urban and 40% in rural areas by the end of 2012. The low coverage in rural sanitation results in serious problems of water pollution and health conditions due to the discharge raw domestic wastewater directly into the waterways (MWRI/USAID, 2000).

Wastewater treatment technologies

Wastewater treatment aims at the removal of biodegradable organic compounds, suspended and floatable material, nutrients and pathogens. However, the criteria for wastewater treatment intended for reuse in irrigation differ considerably. While it is intended that pathogens are removed to the maximum possible extent, some of the biodegradable organic matter and most of the nutrients available in the raw wastewater need to be maintained.

The main criteria affecting selection of the technology are:

- Availability of land
- Skilled labour
- Cost for operation and maintenance
- Power supply
- Performance efficiency
- Implementing costs.

The low-cost treatment systems that can be implemented in Egypt include:

- Up-flow Anaerobic Sludge Blanket
- Modified septic tank
- Stabilization Ponds
- Constructed Wetlands
- Rotating Biological Contactor

Recent studies indicated that it may not be possible, due to economic reasons, to provide sewerage facilities for all residents of rural and peri-urban areas, either now or in the near future. Therefore, the decentralized wastewater treatment facilities are the best solution (MWRI/USAID, 2000; Abdel-Shafy and Aly, 2007; MED WWR WG, 2007).

Why wastewater reuse?

Compared to freshwater in water-stressed regions, treated wastewater (TWW) reuse is considered a beneficial and attractive option for several reasons:

- Prevent surface water pollution, if the wastewaters were discharged into rivers or lakes
- Postpone potentially more costly water supply approaches (storage, transfer, or desalination schemes).
- Eliminate the need for costly and complicated wastewater treatment processes. In particular the removal of nutrients (i.e. nitrogen and phosphorus) is unnecessary
- The quantity of TWW generated will rise with population and increased industrial activity.
- Potential non-agricultural uses for TWW include industrial cooling; landscapes irrigation; fire fighting and toilets flushing in non-residential buildings.
- For agriculture, TWW can be mixed with fresh water, and can be used to grow non-food crops in the desert areas, where it would otherwise serve no useful purpose (i.e. it enables horizontal expansion with little or no cost, at least with respect to two key inputs – land and water).
- The nutrients in TWW reduce the need for applying chemical fertilizers, thereby reducing costs and environmental problems associated with run-off of such chemicals.
- Where well planned, TWW can serve as an environmentally superior alternative to disposing of wastewater in the desert, the sea, or other water bodies.
- Soil Aquifer Treatment provides the potential to recharge TWW to groundwater, thereby supplementing fresh water supplies for irrigation and other purposes, while storing water without evaporation losses or the risks associated with dams. Meanwhile, many contaminants in the effluent, including suspended solids, nitrogen, phosphorus, heavy metals, bacteria, viruses and other microorganisms are reduced or removed through an inexpensive process.

However, there are risks, which refer to the quality of TWW which can be summarized as follows:

- Health risks resulting from human exposure to pathogens in inadequately treated wastewater. These risks affect farm workers, processors of agricultural products and the consumers.
- Contamination of soils and plants through introduction of harmful chemicals.
- Groundwater pollution from infiltration of contaminated source water.

Reuse of Treated Wastewater

The increasing demands for domestic water due to population growth, improvement in living standards and the growing industrial sector will increase the total amount of wastewater available for reuse as an important source. The major issues include public health and environmental hazards as well as technical, institutional, socio-cultural and sustainability aspects.

The future policy for using sewage water can be summarized as follows:

- Increase the amount of secondary treated wastewater use from 1.1 BCM/year by 2000 to 4.5 BCM/year by 2017 (Abdel-Shafy and Aly, 2007);
- Limit the use of treated wastewater to cultivated non-food crops such as cotton, flax, and trees (Abdel-Wahaab, 2003);
- Separate 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 (Abdel-Shafy et al., 2003);.

Reuse of treated wastewater in agriculture

Sewage Water

Currently, Egypt produces an estimated 5.5–6.5 BCM of sewage water per year. Of that amount, about 2.97 BCM per year is treated, but only 0.7 BCM per year is utilized for agriculture (0.26 BCM is undergoing secondary treatment and 0.44 BCM undergoing primary treatment), mainly in direct reuse in desert areas or indirect reuse through mixing with agricultural drainage water (Abdel-Shafy and Abdel-Sabour, 2006).

Treated wastewater (after primary treatment) has been in use since 1922 in agriculture (Gabal-Al-Asfar farm: ca. 1,200 ha). Yet, experience of large scale, planned and regulated reuse project is still limited. Large scale pilot projects (ca. 80,000 ha) are in East Cairo, Abu-Rawash, Sadat City, Luxor, and Ismailia. In the meantime, most of the sewage water drained to the agricultural drains is actually reused in one way or another (indirect reuse) (Abdel-Shafy and Aly, 2002; Abdel-Wahaab, 2003). This practice has been accelerated since 1980 as tremendous potential importance to Egypt.

Agricultural Drainage

The amount of water that returns to drains from irrigated lands is relatively high (about 25 to 30%). This drainage flow comes from three sources; tail end and seepage losses from canals; surface runoff from irrigated fields; and deep percolation from irrigated fields (partially required for leaching salt). None of these sources is independent of the Nile River. The first two sources of drainage water are considered to be fresh water with relatively good quality.

The agricultural drainage of the southern part of Egypt returns directly to the Nile River where it is mixed automatically with Nile fresh water which can be used for different purpose downstream. The total amount of such direct reuse is estimated to be about 4.07 BCM/year in 1995/96. In addition, it is estimated that 0.65 BCM/year of drainage water is pumped to the El-Ibrahimia and Bahr Youssef canals for further reuse (Abdel-Shafy and Aly, 2007). Another 0.235 BCM/year of drainage water is reused in Fayoum while about 0.65 BCM/year of Fayoum is drained to Lake Qarun. Moreover, drainage pumping stations lift about 0.60 BCM/year of Giza drainage from drains to the Rossita Branch just downstream of the delta barrages for further downstream reuse.

Drainage water in the Delta region (Figure 3) is then emptied to the sea and the northern lakes via drainage pump stations. The amount of drainage water pumped to the sea was estimated to be 12.41 BCM in 1995/96. This decreased and will continue to decrease in the future according to the development of the reuse of agricultural drainage water.

Regulation of Agricultural Drainage Reuse

The regulation includes the following measures:

- Increasing the reuse of drainage water from about 5.5 BCM/year to 7.0 BCM/year by year 2014 and to 9.6 BCW/year by year 2017 with average salinity of 1170 ppm (Abdel-Lateef et al., 2011). This could be achieved through implementing several projects to expand the reuse capacity at different areas. Main future projects include El-Salam canal project (Figure 4), El-Omoom and El-Batts drainage.
- Improving the quality of drainage water especially in the main drains.
- Separating sewage and industrial wastewater collection systems.
- 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.

Figure 3: Main drainage Canal in the Delta region, Egypt (Abdel-Wahaab, 2003).

- Updating and implementing an integrated information system for water quality monitoring in drains.
- 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.

Guidelines for the reuse of treated wastewater in agriculture

Irrespective of the treatment level the Egyptian Code prohibits use of TWW for the production of vegetables eaten raw or cooked, export-oriented crops (i.e. cotton, rice, onions, potatoes, and medicinal and aromatic plants) as well as citrus fruit trees, and irrigating school gardens, respectively (EEAA, 2000).

Plants and crops irrigated with treated wastewater are classified into three agricultural groups that correspond to three different levels of wastewater treatment. The Code further stipulates conditions and restrictions for type of crops, irrigation methods and health protection measures for farm workers, consumers, and those living on neighbouring farms.

The Code classifies wastewater into three grades (designated A, B, and C), depending on the level of treatment it has received (Table 2) and specifies the maximum concentrations of specific contaminants consistent with each grade, and the crops that can,

Figure 4: Crossing El-Salam Canal with Suez Canal through a siphon.

and importantly cannot, be irrigated with each grade of treated wastewater (Table 3).

- Grade A represents advanced or tertiary treatment that can be attained through upgrading the secondary treatment plants to include sand filtration, disinfection and other processes.
- Grade B represents secondary treatment performed at most facilities serving Egyptian cities, townships and villages. It is undertaken by any of the following techniques: activated sludge, oxidation ditches, trickling filters, and stabilization ponds.
- Grade C is primary treatment that is limited to sand and oil removal basins and use of sedimentation basins.

Forest trees irrigated with treated wastewater

In 14 governorates and 2 districts, with more than 30,000 ha of marginal desert land allocated, 63 forests are growing thanks to the irrigation with the effluents of WWTPs, whose designed daily discharge is about 1.9 million m^3/day (Abdel-Shafy et al., 2003). The cultivated area is about 5,000 ha (FAO, 2005) and the fallow land area is about 25,000 ha. An overview is presented in Figure 5.

Wastewater reuse constraints

The main constraints facing use of treated wastewater are:

- Financial constraints (related to high treatment costs and sewerage networks)
- Health impacts and environmental safety linked to soil structure deterioration, increased salinity and excess of nitrogen

Table 2: Requirements for treated wastewater reused in agriculture (in mg/l)

Treatment Grade requirements		A	B	C
Effluent limit values for BOD ans Suspended Solids (SS)	BOD_5	<20	<60	<400
	SS	<20	<50	<250
Effluent limit values for faecal coliform and nematode cells of eggs (per liter)	Faecal coliform count (2) in 100cm^3	<1000	<5000	Unspecified

Excerpted from: „Egyptian Code for the Use of Treated Wastewater in Agriculture." February 2005

Table 3: Classification of Plants and Crops Irrigable with Treated Wastewater

Grade	Agricultural Group	
A	G1-1: Plants an trees grown for greenery at touristic villages and hotels	Palm, Saint Augustin grass, cactaceous plants, ornamental palm trees, climbing plants, fencing bushes and trees, wood trees and shade trees.
	G1-2: Plants and trees grown for greenery inside residential areas at the new cities.	Palm, Saint Augustin grass, cactaceous plants, ornamental palm trees, climbing plants, fencing bushes and trees, wood trees and shade trees.
B	G2-1: Fodder/ Feed Crops	Sorghum sp
	G2-2: Trees producing fruits with epicarp.	On condition that they are produced for processing purpose such as lemon, mango, date palm and almonds.
	G2-3: Trees used for green belts around cities and afforestation of high ways or roads.	Casuarina, camphor, athel tamarix (salt tree), oleander, fruit-producing trees, date palm and olive trees.
	G2-4: Nursery Plants	Nuresry plants of wood trees, ornamental plants and fruit trees
	G2-5: Roses & Cut Flowers	Local rose, eagle rose, onions (e.g. gladiolus)
	G2-6: Fiber Crops	Flax, jute, hibiscus, sisal
	G2-7: Mullberry for the production of silk	Japanese mulberry
C	G3-1: Industrial Oil Crops	Jojoba and Jatropha
	G3-2: Wood Trees	Caya, camphor and other wood trees.

Excerpted from: „Egyptian Code for the Use of Treated Wastewater in Agriculture." February 2005

- Standards and regulations (too strict to be achievable and enforceable).
- Low sanitation coverage
- Large-scale centralized treatment facilities are often discharge the produced wastewater into receiving water bodies
- Lack of political commitment and of national policies/strategies to support treatment and reuse of wastewater
- Public acceptance and awareness, related to limited awareness of both farmers and consumers of crops grown with reclaimed wastewater (and/or sludge)
- Consequently, reuse of water is a lost opportunity, as wastewater is either buried away in cesspools, or discharged into receiving water bodies
- In Egypt many people remain suspicious of reuse since they are uncertain of the quality of treated water.

Conclusions and recommendations

1. The use of treated wastewater should be considered an integral component in country's national water strategic plan.
2. Wastewater management should change from the regional sewerage systems to decentralized wastewater treatment facilities.
3. Decentralized systems will increase the opportunities for localized reclamation/reuse of treated wastewater.
4. Separation of industrial effluent disposal systems, provision of adequate treatment facilities to those communities connected to sewer systems.
5. Search for simple cost-effective treatment technology, horizontal expansion based on reuse of treated sewage. This will increases the coverage of sanitation systems.
6. Awareness of the health risks involved with direct or indirect contact with the water.

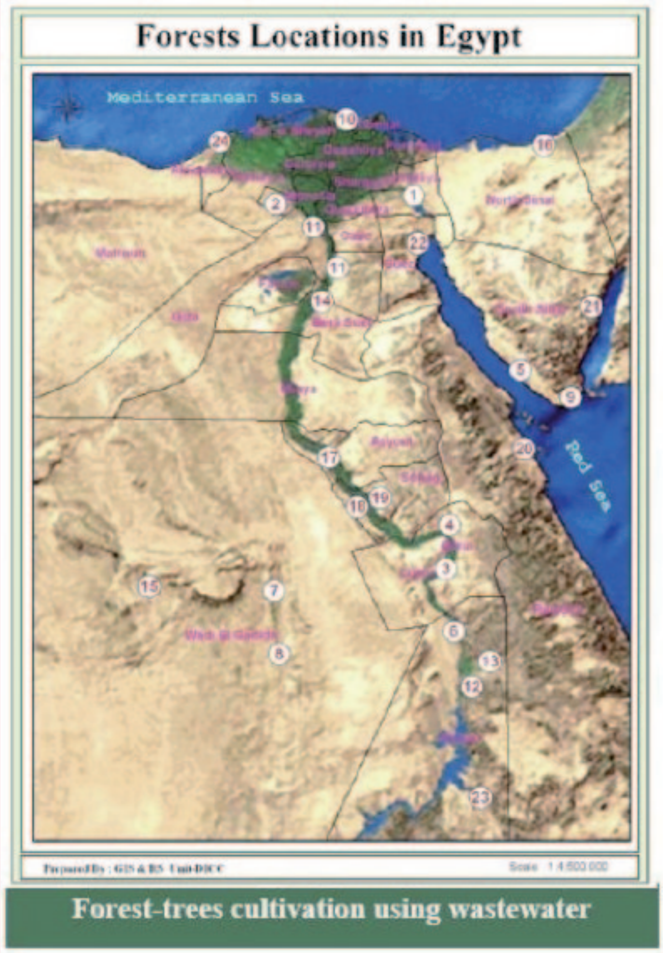

Figure 5: Locations of manmade forests in Egypt (Abdel-Wahaab, 2003).

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