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A 2030 STRATEGIC VISION FOR WASTEWATER REUSE IN EGYPT

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ABSTRACT

With the renewable groundwater and surface water resources of Egypt currently fully exploited, the need of alternative water resources has never been of profound urgency as it is nowadays.

The domestic water supply coverage in Egypt has reached 100% in 2008, yet it dropped back to 99% in 2011 due to population growth. The annual production from surface water is 6.624 Billion Cubic Meters (BCM), with Groundwater plants providing an additional 1.38 BCM annually.

As of 2011, the national produced wastewater amounted to about 7 BCM, about 3.7 BCM of which were untreated, 2.4 BCM were secondary treated, 0.9 BCM were primary treated, and only 0.068 BCM were tertiary treated. Out of all the 3.368 BCM of treated wastewater, only 0.271 BCM were reused directly for Agriculture, while the remaining amount was disposed to the national drainage network.

Different laws, codes and decrees related to treated wastewater reuse have been identified; some of them present an obstacle to the progress of wastewater reuse on a wide national level.

This strategic vision provides options for reuse specific to each governorate indicating the future projection for reuse, in terms of recommended levels of wastewater treatment, and projected amounts of produced wastewater, and suggested mode of reuse and whether it should be directly reused or conveyed by drains or canals for reuse further downstream.

For the purpose of developing this 2030 strategic vision for reuse, the Egyptian Governorates were divided into two categories, with different strategies for each category, the first category consists of governorates without agricultural expansion plans which includes the six delta governorates (Menoufia, Dakahlia, Kafr El-Sheikh, Gharbia, Kalyoubia) in addition to Cairo, Alexandria , and Port Said, and the other Category consists of all governorates with a desert front and/or a future agricultural expansion plan.

The year 2011 was considered to be the baseline for developing the strategic future vision; such vision will be to maintain the tertiary treatment level of 2011 until 2030

without expansion due to the extreme financial burden it would otherwise put on the government at the expense of under-served areas, and social inequality. As for Secondary treatment, the assessment of the current status showed that the quantities of wastewater that are secondarily treated are already far exceeding those that are primarily treated in all governorates. Therefore, it was safe to assume that all current primary treatment facilities should be upgraded to secondary level in 2030 to ensure that all wastewater is equally treated all over the country to a reasonable level by 2030.

A projected population for 2030 has been estimated for each governorate based on an annual growth rate of 2.2 %, and adopting an out of valley population scenario which suggests that all the population increase in the Delta governorates and the governorates without agricultural Expansion plans will be uniformly distributed on all other governorates. The total population of Egypt in 2030 is estimated to reach a little less than 115 Million inhabitants. Recent census after this vision was developed showed that this population projection was underestimated.

The main difference between the two geographical divisions, is that in case of the Delta governorates that have already exploited their agricultural land potential, the secondary treated wastewater will be directed to the main drainage network allowing reuse downstream through agricultural drainage mixing pumping stations to be conveyed to Northern planned agricultural expansion areas such as North Sinai in the North East and Hammam area and others in the North West. Whereas, in case of the Desert front governorates and/ or those with identified agricultural expansion plans, the secondary treated wastewater will be used directly for agriculture.

The total national amount of produced wastewater in 2030 according to this strategic vision will be about 11,673 BCM. Assuming that all primary treatment plants will be upgraded to secondary, the total expected amounts to be secondary treated at the national level in 2030 is 11,606 BCM which is almost the whole produced amount, as the small remaining margin represents the current amount of 67.7 MCM that is subject to tertiary treatment and will be maintained through 2030.

According to this strategic vision, 5.82 BCM will be used directly in agricultural expansion areas, while 5.53 BCM will be disposed into drains. According to the Ministry of Agriculture and Land Reclamation, 1.4 Million feddans will be reclaimed for cultivation, according to the 2030 Sustainable Agriculture Strategy, with total average annual water requirements of about 5.42 BCM. According to this vision, these water requirements can be satisfied by the secondary treated wastewater produced in 2030. The Strategic Vision estimates an additional 1.45 Million Feddans that could be reclaimed based on the remaining potential of secondary treated wastewater of 0.4 BCM from desert front governorates and 5.53 BCM from delta governorates at an estimated water requirements of about 4100 CM /feddan/year.

The implementation costs of the proposed strategic vision requires, over a time span of 19 years, a total budget of about 15.05 Billion Euro (150.5 Billion EGP), divided into an investment cost of about 8.57 billion Euro (85.7 Billion EGP), and an operational and maintenance cost of about 6.48 Billion Euro (64.8 Billion EGP). This would roughly mean that an annual total budget of about 0.79 Billion Euro (7.9 Billion EGP) would be needed, an investment budget of about 0.45 Billion Euro (4.5 Billion EGP) and about 0.34 Billion Euro (3.4 Billion EGP) of recurrent costs would be needed for O&M.

Accordingly, and if a strategy of full cost recovery from potential users is implemented, treated wastewater could be offered to agriculture developers in the Northern Coasts at the downstream end of the drainage system at an investment cost of 0.85 €/m3 (8.5 EGP/m3) of annual allocated treated Wastewater amount, and at an O&M cost of 0.025 €/m3 (0.25 EGP/m3) of utilized amounts. On the other hand, treated wastewater could be offered to agriculture developers in the desert fronts governorates at an investment cost of 0.95 €/m3 (9.5 EGP/m3) of annual allocated treated Wastewater amount, and at an O&M cost of 0.035 €/m3 (0.35 EGP/m3) of utilized amounts.

INTRODUCTION

Water resources in Egypt are becoming scarce. Surface-water resources originating from the Nile are now fully exploited, while renewable groundwater sources are being brought into full production. Egypt is facing increasing water needs, demanded by rapidly growing population, increased urbanization, higher standards of living, and by an agricultural policy which emphasizes expanded production in order to feed the growing population.

With a population of more than 90 million and growing, and with limited renewable water resources from a single water source being the Nile River, which provides an average annual flow of 55.5 BCM/year, the per capita share is 630 Cubic meters which is well below the water scarcity limit of 1000 m3/year. As population and water demands increases, more freshwater may need to be reallocated to domestic uses, especially at inland cities and villages where they may be far from coastal areas that may resort to desalination of seawater. This leaves existing agriculture at a vulnerable situation of not being able to satisfy its water requirements.

On the other hand, most of the ground water that may be available in the desert areas is practically non-renewable and does not provide a sustainable resource for agriculture, and may be better used for drinking water and domestic uses. Coupled by the challenges and timeliness associated with developing additional Nile waters from upstream reaches, this puts any future plans for agriculture expansion at risk of not having the necessary sustainable water resource.

Meanwhile, and as long as water supply to domestic uses due to the increase in population, will continue to grow, more wastewater will be generated at about 80% of domestic water supply.

Improved planning and management procedures to allocate and use water are key measures generally prescribed to make the optimum use of available water.

Satisfying future demands in Egypt depends on better utilization and efficient use of present water resources. Optimal water management is an essential prerequisite for sustainable development of Egypt. The future may carry lots of risks if Egypt does not succeed in formulating and implementing a water policy which can match the limited freshwater supply and the developed alternative water resources with the increasing demand.

The overgrowing water tension in Egypt should be the motive to develop alternative water resources. In satisfying the ever growing water demands in all sectors, treated wastewater reuse will provide the perfect, and may be the only practical solution for the agriculture sector, that faces a lot of challenges to achieve food security in Egypt. Treated waste water is defined as former wastewater that has been treated to remove solids and impurities, and pollutants to be used in agriculture, landscape irrigation, artificial groundwater recharge, dust control, and fire suppression, depending on which not only conserves fresh water but also avoids the ecological harms associated with the discharge of untreated wastewater to surface waters such as rivers and oceans.

In most cases, treated wastewater is intended to be only used for non-potable uses. There are continuous debates about possible health and environmental effects associated with its uses. Using reclaimed water for non-potable uses saves potable water for drinking, since less potable water will be used for non-potable uses.

Due to the technology involved, the cost of treated wastewater, also known as reclaimed water, exceeds that of potable water in many regions of the world, especially where a fresh water supply is conveniently available. However, reclaimed water is usually sold to citizens at a cheaper rate to encourage its use.

Different countries tend to setup codes for using treated wastewater in irrigation; these codes usually link the type of crop to the degree of treatment. Skinless fruits and raw edible vegetables require the highest degree of treatment.

With the increasing population in Egypt, and as more water will eventually need to be supplied to meet the basic human needs of domestic water demand, the growing amounts of wastewater will make treated Wastewater on top of the list of Egypt’s alternative water resources. However, treated wastewater reuse in Egypt encounters several limitations.

It is obvious that a “national plan for wastewater reuse” that would become part and parcel of a national Integrated Water Resources Management (IWRM) plan is very important not only for Egypt, but also for the Mediterranean Environment due to the benefits that it will have on the quality of Mediterranean waters.

CURRENT WATER AND WASTEWATER SITUATION IN EGYPT

a. Water Supply

The river Nile is the main source of drinking water in Egypt, 83 % of produced domestic water originates from the Nile, 18.15 Million Cubic Meters (MCM) are produced daily from water treatment plants that are fed by Nile Water, the equivalent annual production is 6.624 Billion Cubic Meters (BCM). There are two other secondary sources for domestic water production in Egypt; artesian plants provide 17.14 % of the national domestic water with 3.79 MCM daily (1.38 BCM annually). The remaining 0.76% is provided by seawater desalination, the annual amount of desalinated water does not exceed 61 MCM. The total domestic water produced annually in Egypt is 8 BCM (Moawad, 2011).

The water supply coverage in Egypt has reached 100% in 2008, yet it dropped back to 99% in 2011 due to population growth.

Figure 1. shows the national estimated Domestic water capacity through 2030. The total number of Water Treatment plants is 2612 including 31 desalination plants and 1580 well plants.

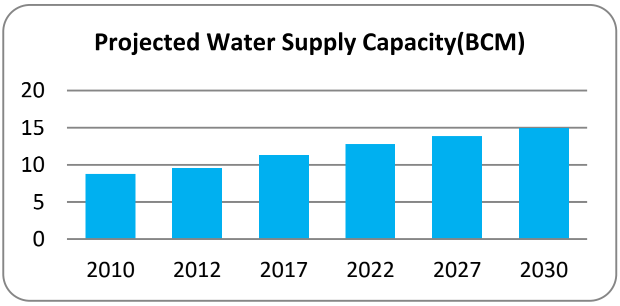

Figure 1. Projected Water Supply Capacity (BCM) (modified from HCWW, 2011).

The agricultural sector is the largest water user in Egypt with its share exceeding 80-85% of the total demand for water. The total cultivated area of Egypt is about 3.45 % of the total area of the country.

Figure 2 shows the national water supply in 2011 for different Egyptian governorates. The sum for all governorates is 8.162 BCM which agrees with the collective national production of 2011, considering the fact that there are a few governorates that are not under the direct operation of HCWW, therefore, their data are not provided in Figure2.

Egypt produces about 7 BCM/Yr of waste water as of 2011. In 2010, treated wastewater was estimated at 2.97 BCM, of which 0.7 BCM were used for agriculture, mainly for direct reuse in desert areas, or indirect reuse through agricultural drainage canals. In 2011, the amount of treated wastewater reached 3.1 BCM.

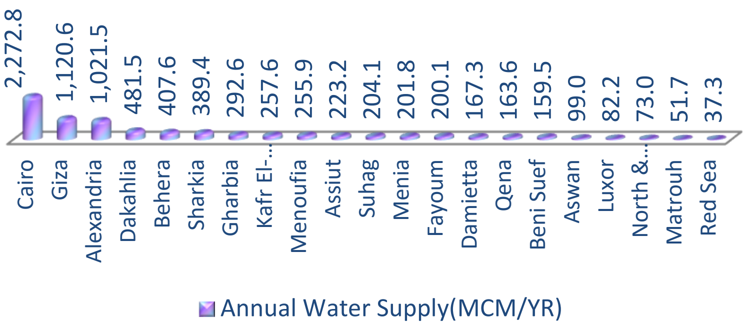

Figure 2. Annual Water Supply per Governorate, (AbuZeid, K., *et al* 2014)

Utilizing wastewater for agricultural and landscape irrigation has been practiced in many countries such as the USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan, and Tunisia. This concept has been practiced since 1911 in Egypt on the sandy soil of El-Gabal el-Asfar farm, which consists of an area of 3,000 feddan, 25 km northeast of Cairo. It has been irrigated by treated wastewater from Cairo treatment plants and produces citrus, date palm, and pecan nuts, in addition to some field crops.

b. Wastewater Production

According to yearly averaged data provided by HCWW, the average annual collected waste water during the last five years amounts to 6.5 BCM, which is about 81 % of the total produced domestic water. Also, on average, about 44% of the nationally produced wastewater is not treated, which is equivalent to 2.85 BCM. This huge amount is equal to 5% of Egypt's annual share from the Nile River. On the other hand, 3.65 BCM of wastewater are treated annually, 0.73 BCM of which (20%) are treated primary treatment, and 2.92 BCM (80%) are treated secondary treatment. The wastewater collection network has a total length of 39,000 KM. Figure 3. shows the projected collected wastewater capacity through 2030.

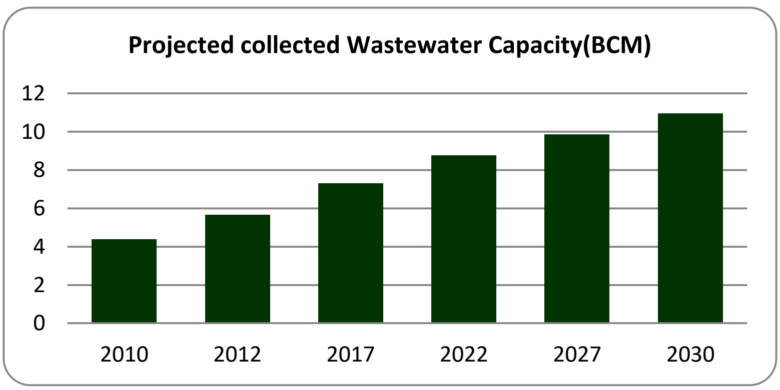

Figure 3. Projected Wastewater collection Capacity (BCM)(modified from HCWW, 2011)

In Egypt the indicator of access to sanitation is measured by connectivity to sewerage systems which comply with the Law 48/1982 and its executive regulations regarding the protection of the Nile and waterways from pollution. In that sense, the total Sanitation coverage in Egypt is 50%, more specifically; it is 90% in urban areas and 12% in rural areas. Wastewater Treatment is an essential process for benefiting from the produced wastewater, there are different types and levels of treatment, but the two main types commonly used in Egypt are primary and secondary treatment.

The Ministry of Health and Population is responsible for analyzing wastewater samples. In the first half of 2012, 773 samples were collected from wastewater treatment plants, 401 of which do not comply with the standards. Also, 843 samples were collected from Industrial establishments, 307 of which were found to be un-complying to the predefined standards stated in the laws and codes that will be presented (Ministry of Health, 2012).

c. Wastewater Treatment

Wastewater is either treated in treatment plants, or disposed of in latrines, septic tanks, or waterways. Conventional wastewater treatment is made up of three phases; primary, secondary, and tertiary treatment.

On the governorate level, the three different degrees of treatment are available, with the tertiary treatment being the least used option due to its high cost.

Figure 4 shows the quantities of Primary treated wastewater in different Egyptian governorates in 2011, while figure 5 shows the secondary treated quantities for the same governorates for the same year. As for the tertiary treatment, it is only applied in four governorates as shown in Figure 6 Figure 7 shows the untreated quantities of wastewater in different governorates. From the figures, the discrepancy between the amount and degrees of wastewater treatment among different governorates is clear. While in Cairo, the untreated effluent is about 24% of the total produced wastewater, in governorates like Matrouh, Assuit, and Kafr El-Sheikh, most of the produced wastewater goes untreated.

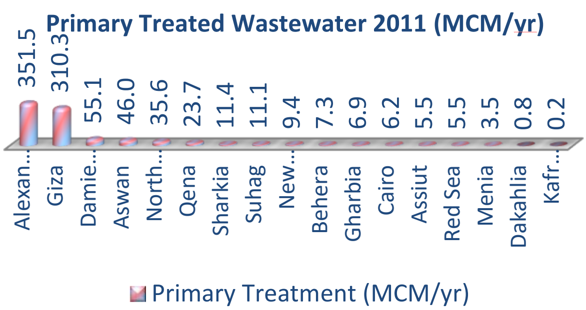

Figure 4. Primary Treated Wastewater in Egyptian Governorates in 2011, (AbuZeid, K., *et al* 2014)

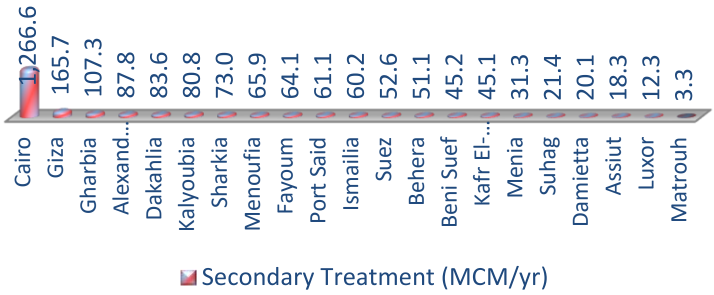

Figure 5. Secondary Treated Wastewater in Egyptian Governorates in 2011, (AbuZeid, K., *et al* 2014)

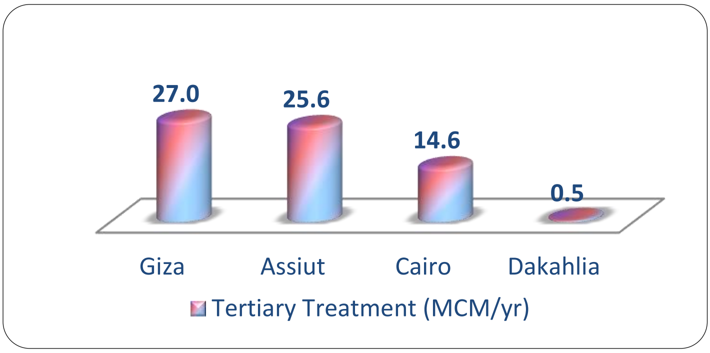

Figure 6. Tertiary Treated Wastewater in Egyptian Governorates in 2011, (AbuZeid, K., *et al* 2014)

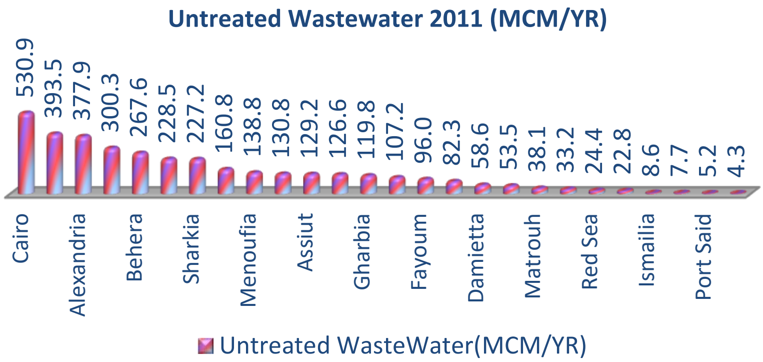

Figure 7. Untreated Wastewater in Egyptian Governorates in 2011, (AbuZeid, K., *et al* 2014)

d. Wastewater Reuse

The use of treated wastewater is one of the strategies adopted for increasing the water supply in Egypt as a non-conventional resource to meet the increasing demand for water. Use of wastewater should be managed within certain restrictions imposed for environmental protection and to safeguard public health. A set of guidelines and control measures for treated wastewater reuse has been developed and issued in the Egyptian Code for Reuse of Treated Wastewater in Agriculture. Treated wastewater can be used directly as a source for agriculture or used indirectly through recharging partially treated wastewater into groundwater aquifers to be withdrawn for future use.

According to HCWW, 300 MCM of the treated wastewater is used annually for irrigation all over Egypt (Alsayed, 2011). The average cost for cultivating one Feddan is about 10,000 Egyptian pounds, which includes the cost of networks and seeding without the pump stations, generators, and adjusting land levels.

HCWW lead an initiative for using treated wastewater for forests agriculture. The current and potential locations of HCWW treated wastewater related forests in Egypt amount to a total of 82000 feddans, with about 24,000 feddans already cultivated.

Nationally, there are two main options for treated effluent, either direct reuse in agricultural areas or drainage to the main national agriculture drainage network. Figure 8. shows disposal to the main Drainage network in Egyptian governorates in 2011, and Figure 9. shows direct reuse of wastewater in Egyptian governorates in 2011.

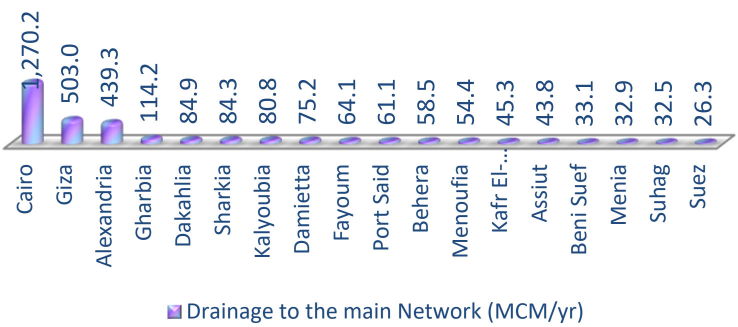

Figure 8. Disposal to the main Drainage Network in Egyptian Governorates (2011), (AbuZeid, K., *et al* 2014)

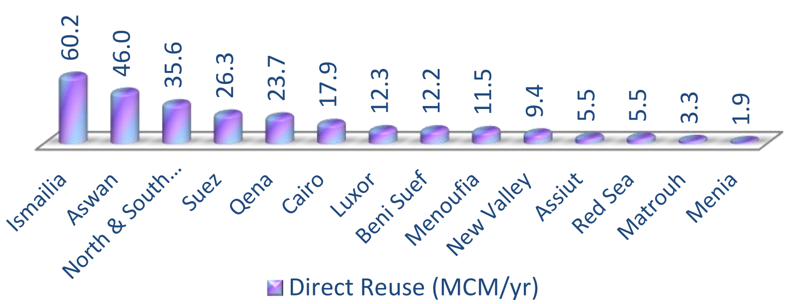

Figure 9. Direct Reuse of Wastewater in Egyptian Governorates (2011), (AbuZeid, K., *et al* 2014)

e. Mixed Agricultural Drainage and Wastewater Reuse

There are three different drainage trends in Egypt. The Nile River is currently the main drain for the Upper Egypt area, whereas the Mediterranean Sea is the main drain for the delta region and the red sea is the drain for the eastern part of Egypt.

The importance of gravity reuse of drainage water is evitable; it has been realized since the 1930s that all drains should be given the same attention given to canals.

In the late 70s and 80s, agricultural drainage reuse became an official policy to augment irrigation water supplies. In the early 1990s, a huge agricultural reuse expansion plan was implemented in desert areas like the eastern desert.

The total amount of officially reused agricultural drainage is 6.3 BCM (NWRC, 2008). About 13.5 BCM of mixed agriculture drainage and wastewater flow annually to the sea, the latter amount consists of about 7 BCM of agricultural drainage of very poor quality due to multiple re-use, as well as 6.5 BCM of municipal and industrial wastewater.

Decision makers in Egypt have been also aware of the limiting factors of agricultural drainage. Some of these factors are:

- Excessive reuse causes the accumulation of salts in the root zone.
- Drainage water may include toxic pollutants, due to the mixing with domestic waste water and industrial wastewater.
- The presence of Agricultural chemicals could cause the deep percolated water to harm groundwater reservoirs.
- The close proximity between drains outfalls and canals tail ends could make the appropriate mixing ratio difficult to reach.

f. Overall Current Assessment

As the Strategic plan for 2030 needs a starting point, figures 10. and 12. show an overall summary of the current status of Wastewater production, treatment, and reuse in Egypt as of 2011, based on actual data on the governorates level. Figure 10. shows the total amount of treated waste water directed to drains for disposal as well of the total amount used directly for agriculture in all governorates, the latter is a relatively small amount compared to the amount of wastewater disposed into drains, which shows that more expansion in agriculture on treated wastewater has to be considered for the future in order not to waste such an important resource. On the other hand, Figure 11. shows the current available degrees of treatment on the national level, which is equally important for a strategic plan that considers expansion in agriculture on treated wastewater, as the degree of treatment will directly dictate the types of crops to be cultivated. While it is clear that the Tertiary treatment needs a serious boost, secondary treatment is becoming the norm as far as wastewater treatment is concerned, which is a good starting point for a future wastewater treatment strategy that will have agricultural expansion as one of its main pillars.

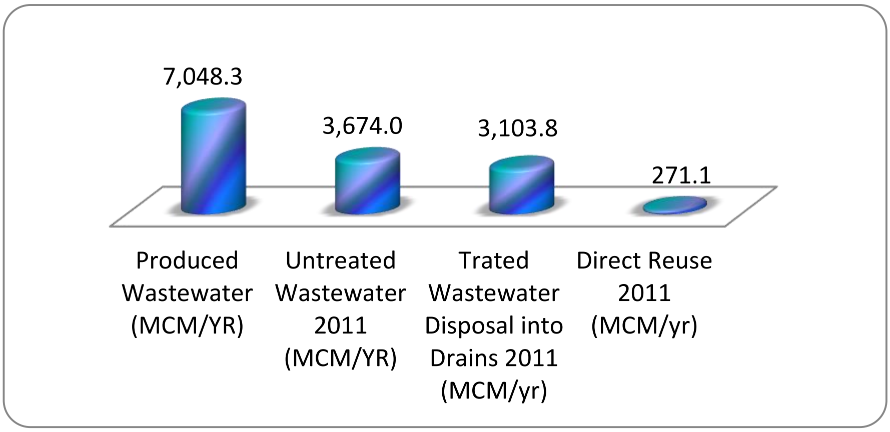

Figure 10. National Wastewater Production, Treatment, and Reuse in 2011, (AbuZeid, K., *et al* 2014)

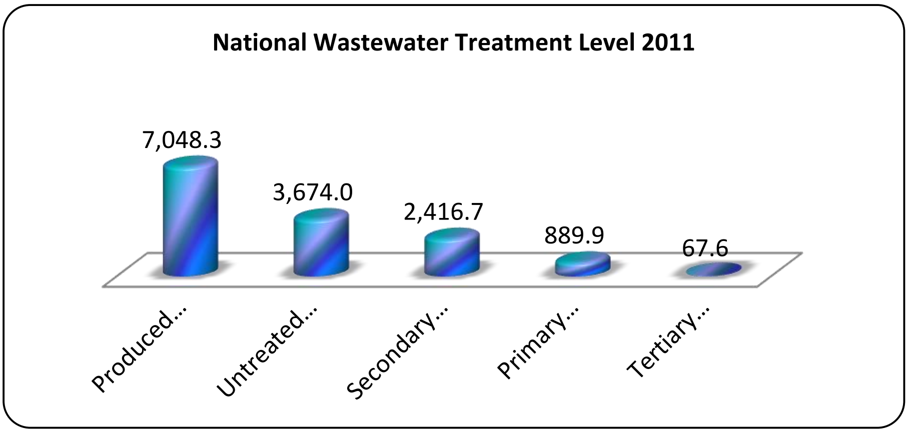

Figure 11. National Wastewater Treatment Levels in 2011, (AbuZeid, K., *et al* 2014)

BACKGROUND ON EXISTING PLANS/ REGULATIONS FOR REUSE WITHIN SECTORS

The 2017 National Water Resources plan that was developed by the Ministry of water Resources and Irrigation anticipates an annual treatment capacity of 5.475 BCM by 2017. The 2050 National Strategy for Development and Management of Water Resources, on the other hand, recognizes wastewater treatment as a possible solution in relation to one of the assumed future scenarios. According to the national strategy, expansion in wastewater re-use is conditioned on the involvement of the private sector.

The 2017 National Water Resources Plan (NWRP) anticipates an agricultural horizontal expansion of about 250,000 feddans based on treated wastewater. Apart from 20,000 feddans in Middle Egypt, most of the planned area is located in the eastern and western desert, with greater Cairo and Alexandria as the main suppliers of treated wastewater. It has also been assumed arbitrarily that 160,000 feddans in the new industrial cities and the Canal cities will be irrigated using treated wastewater. Moreover, the 2017 NWRP has identified drip irrigation as the most suitable irrigation method for reuse of treated wastewater, and assumed an irrigation efficiency of 80%.

The NWRP has also made some speculations regarding amounts of treated wastewater that will be used in Irrigation. The NWRP estimated a water balance for Egypt in 2017 that featured an amount of 2.4 BCM of re-used wastewater. According to the NWRP, the total amount of treated wastewater needed to irrigate a hypothetical area of about 300,000 feddans at a relatively high efficiency rate is 1.4 BCM annually. Therefore, it can be assumed that the anticipated wastewater reuse amount of 2017 could be enough to irrigate 515,000 feddans, which is about 105,000 feddans more than what has been preliminarily allocated. The NWRP also assumed two cropping patterns as model examples for crops that can grow on treated wastewater (NWRP, 1999).

It is worth mentioning that the NWRP refers to Egypt's National Development policy which indicates an agricultural expansion of 3.4 million feddans between 1997 and 2017. Another important official document is the 2030 Sustainable Agricultural Development Strategy which aims to reclaim 1.05 million feddans between 2010 and 2030, and also looks forward to expansion in cultivating wooden trees, especially in marginal areas, with adequate use of treated wastewater and treated agricultural drainage.

In the year 2000, the Centre for Environment and Development for the Arab Region and Europe (CEDARE) collaborated with the United Nations Food and Agriculture Organization (FAO) in formulating an Inter-Agency Task Force including UNESCO, WHO, and ESCWA, and produced what can be referred to as a manual for the use of treated wastewater in Irrigation. Multiple aspects of wastewater reuse were discussed in that manual. Different crops have been divided into several categorizes and different treatment schemes were suggested for each category. The manual even explored sophisticated areas such as the appropriate fertilization of crops that would be irrigated by treated wastewater (FAO, 2000).

Under the Framework of the EU funded project SWITCH that lasted from February 2006 to April 2011, a 2030 Integrated Urban Water Management (IUWM) Strategic Plan was developed by CEDARE and emphasized the challenges and opportunities of wastewater reuse in Alexandria; under an overall objective of "Satisfying Future Urban Water Demand", the plan explored the waste water reuse potential in Alexandria. The plan formulated strategies for wastewater management and reuse in Alexandria. The strategies took into account different scenarios, in terms of population growth, wastewater flows, wastewater composition, expansion of the sewer system, demand for effluent in industry, urban and agricultural uses, climate change, saltwater intrusion, regulations and effluent standards. Among the different strategic options that have been studied treated wastewater was one of the promising options, the plan suggested that wastewater reuse in agriculture should be started in Alexandria by the year 2025, while the use of treated wastewater for industry should be initiated by the year 2028 according to the same plan. (CEDARE, 2012), (AbuZeid, K., *et al* 2014)

At present the wastewater treatment plants are of the primary type. Treated water is diverted to Lake Maryut, and then pumped to the Mediterranean Sea.

The following rules and regulations are the main rules that govern the wastewater re-use process in Egypt:

- Law 93/1962 regulates wastewater disposal and designates the responsibility of constructing public wastewater systems to the Ministry of Housing, which is also responsible for issuance of permits regulating wastewater discharge into public sewerage networks or into the environment. The Ministry of Health determines the regulatory standards.
- 99/2000: This amendment determined the minimum degree required for wastewater treatment for the various reuse aspects. A code of practice for reuse was issued, stating the limit values for treated wastewater reused in agriculture and the approved list of crops to be irrigated with treated wastewater. Law 48/1982: With respect to the discharge of wastewater into waterways, No. 48/1982 and its executive regulations prohibit the discharge of wastewater into waterways (including all sorts of drains)
- Law 48/1982: With respect to the discharge of wastewater into waterways, No. 48/1982 and its executive regulations prohibit the discharge of wastewater into waterways (including all sorts of drains)
- Egyptian Code No. 501/2005 for wastewater reuse which classified the treated wastewater into three grades according to the level of treatment and accordingly assigns agricultural groups that can be irrigated by treated wastewater depending on the grade. This code was very limiting in allowing using treated wastewater for agriculture and has been further modified in 2015 as per the recommendation of this study to allow for cultivation of edible crops according to the degree of treatment.
- Decree No. 603/2002 for minister of agriculture, which prohibits the use of treated and untreated wastewater in irrigating conventional plants, but allows its use in wood trees, ornamental trees, and fuel-production trees (eg. jatrova, jujoba,…). However, it can be argued that the decree somehow contradicts the reuse code, as many of the conventional plants are enlisted within grade B groups.

It is worth mentioning that the World Health Organization has its own Guidelines for Wastewater Reuse in Agriculture. Table 1 shows the different health-based targets for wastewater Reuse in agriculture in terms of Helminth eggs per liter and the log to the base 10 of the pathogen reduction required for different crops under different irrigation circumstances.

Table 1. WHO Guidelines for Wastewater Reuse (modified from WHO, 2006)

Table 3. Health-based targets for wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤ 1[b,c]
Onion		7	≤ 1[b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤ 1[b,c]
Labour intensive		4	≤ 1[b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤ 1[c]

OBSTACLES AND INSTITUTIONAL CONSTRAINTS TO IMPLEMENTING STRATEGIES

Treated wastewater reuse in Egypt encounters several limitations including but not limited to the following:

- The huge financial resources required to increase the national coverage of west water collection, and to upgrade the level of treatment of wastewater.
- The proximity of potential arable land to the wastewater treatment facilities and the different national and physical conditions surrounding each treatment plant.
- The environmental and health concerns and perception associated with using treated wastewater for agriculture.
- The Egyptian wastewater re-use code that prohibits using secondary and tertiary treated wastewater for edible crops.
- The Irrigation & Drainage Egyptian law that prohibits conveyance of any level of treated wastewater through irrigation canals.
- The Environmental & health regulations & laws.
- The generation of new water demands by the wastewater companies due to directing the collected wastewater to Wood and Bio-fuel tree plantations.
- The anticipated competition over treated wastewater by the irrigation sector that needs to satisfy national water demands, and the agriculture sector that needs to satisfy agriculture expansion plans, and the water and wastewater sector that needs to generate income from treated wastewater produced to cover its operation and maintenance costs.

- The risk of not being able to market the agriculture products for export to neighboring markets such as the EU and the Gulf states due to the use of treated wastewater.
- The Health & Environmental hazards associated with improper handling of the different levels of treated wastewater by users.

STRATEGIC DIRECTIONS FOR WASTEWATER TREATMENT AND REUSE

The broader concept of IWRM involves integrating land and water, upstream and downstream, groundwater, surface water, and coastal resources. One of the main pillars of IWRM is optimizing supply, which in turn, involves conducting assessments of surface and groundwater supplies, analyzing water balances, adopting wastewater reuse, and evaluating the environmental impacts of distribution and use options. Also, Utilizing an inter-sectorial approach to decision-making, where authority for managing water resources is employed responsibly and stakeholders have a share in the process, is another important IWRM component (GWP, 2013).

It is generally accepted that IWRM should be applied at catchment level, recognizing the catchment or watershed as the basic hydrological unit of analysis and management. At implementation level, there has been a growing conviction that integrated urban water management (IUWM) could be pursued as a vital component of IWRM within the specific problematic context of urban areas. Cities are dominant features in the catchments where they occur, and successes in IUWM will make important contributions to the theory and practice of integrated IWRM in the broader basin context. Thus, IUWM is not seen as a goal in itself, rather a practical means to facilitate one important sub-system of the hydrological basin (AbuZeid and Elrawady, 2009).

For the proposed strategic vision, the 2011 data will be used to reflect the current situation as a baseline. The proposed national strategic vision was divided into two strategies, the first strategy is for governorates without agricultural expansion plans which include the six delta governorates, and the other strategy is for governorates with a desert front and/or a future agricultural expansion plan. The governorates without agricultural expansion plans are: Cairo, Gharbia, Menoufia, Dakahlia, Kafr El-Sheikh, Kalyoubia, Alexandria, and Port Said. All the remaining governorates belong to the other division. As the vision is for the year 2030, a projected population for that year has been estimated for each governorate (Figure 12) based on an annual growth rate of 2.2 %, and adopting an out of valley population scenario which suggests that all the population increase in the Delta governorates will be uniformly distributed on all other governorates. The total population of Egypt in 2030 is expected to reach a little under 115 Million inhabitants. The projected water supply for each governorate in 2030 has been formulated based on an annual per capita share of 125 cubic meters for the domestic sector, while the produced wastewater amounts for each governorate were assumed to be 80% of the water supply.

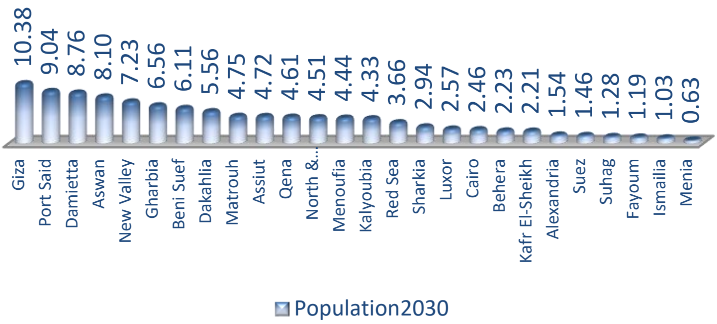

Figure 12. 2030 Governorates Population based on the out of valley scenario (Millions), (AbuZeid, K., *et al* 2014)

a. Upgrade Treatment level to Secondary Level

As the main purpose of this vision is to draw on realistic, affordable, and feasible scenarios, the current situation of 2011 will be the baseline for developing strategic goals; such goals will not be too ambitious to be achieved in less than two decades. Given the current level of tertiary wastewater treatment, it will be too ambitious to set objectives higher than the current level; therefore one of the realistic objectives of this vision will be to maintain the tertiary treatment level of 2011 in 2030. As for Secondary treatment, the assessment of the current status shows that the quantities of wastewater that are secondarily treated are already far exceeding those that are primarily treated in all governorates as shown in figures 4 and 5. Therefore it is safe to assume that all current primary treatment facilities will be upgraded to secondary in 2030. Figure 13 shows the projected treated amounts in 2030 for the Delta governorates based on the increased water supply that will accompany the expected increase in population as per the target population scenario shown in Figure 12. Figure 13 shows the same treated amounts for Desert front governorates.

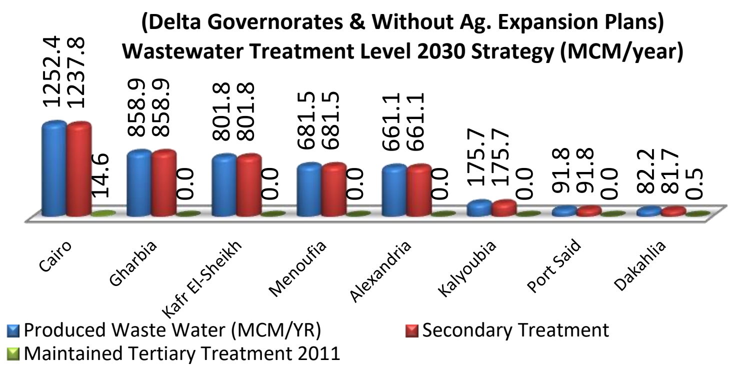

Figure 13. 2030 Produced and Treated Wastewater in Delta Governorates in 2030, (AbuZeid, K., *et al* 2014)

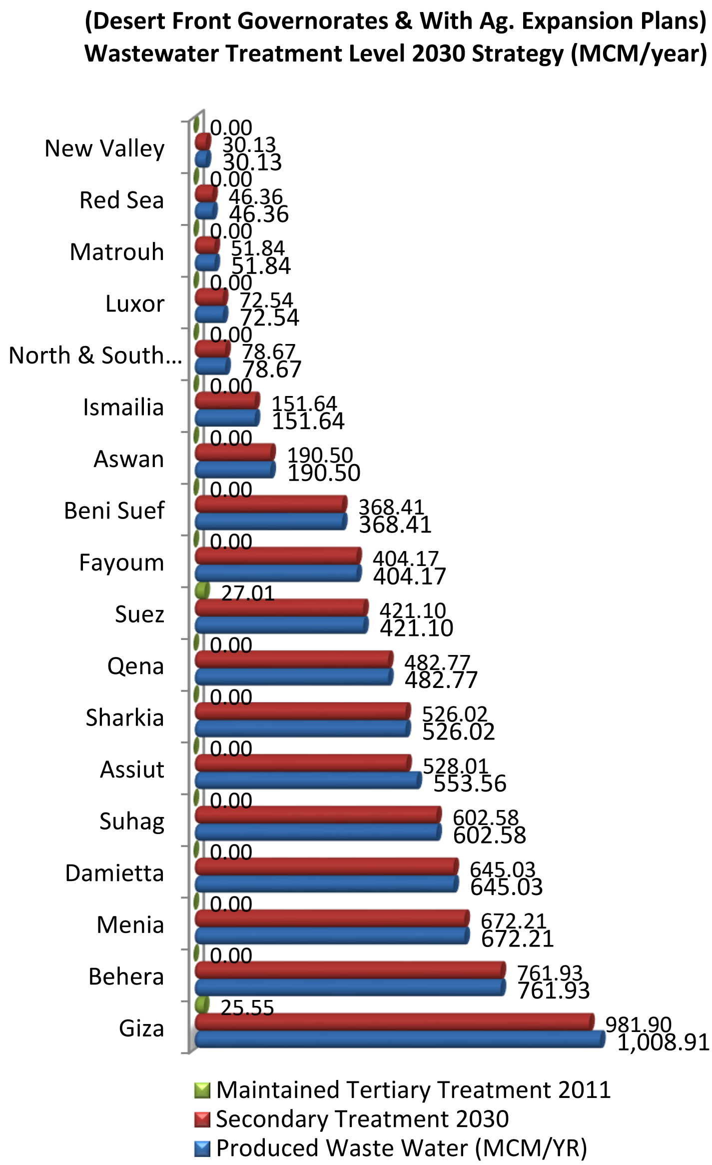

Figure 14. 2030 Produced and Treated Wastewater in Desert Front Governorates, (AbuZeid, K., *et al* 2014)

In summary, the total national amount of produced wastewater in 2030 according to this strategic vision is about 11673 BCM. Assuming that all primary treatment plants will be upgraded to secondary, the total expected amounts to be treated secondarily in the whole republic in 2030 is 11606 BCM which is almost the whole produced amount, as the small remaining margin represents the current amount of 67.7 MCM that is subject to tertiary treatment and will be maintained through 2030 as shown in figure 15.

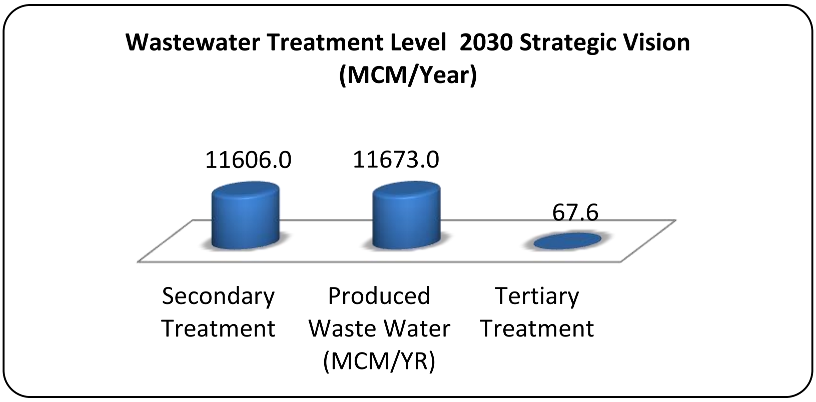

Figure 15. National Treated Wastewater in 2030, (AbuZeid, K., *et al* 2014)

b. Conveyance of Treated Wastewater Out of the Delta Governorates

The main difference between the two geographical divisions presented in the previous section, is that in case of the Delta governorates that have already exploited their agricultural land potential, the treated wastewater will be directed to the main drainage network allowing reuse downstream through agricultural drainage mixing pumping stations to be conveyed to Northern planned agricultural expansion areas such as North Sinai in the North East and Hammam in the North West. Figure 16 shows the secondary treated quantities that will be disposed in agricultural drains in Delta governorates in 2030. Direct reuse amount for 2011 will be maintained throughout 2030.

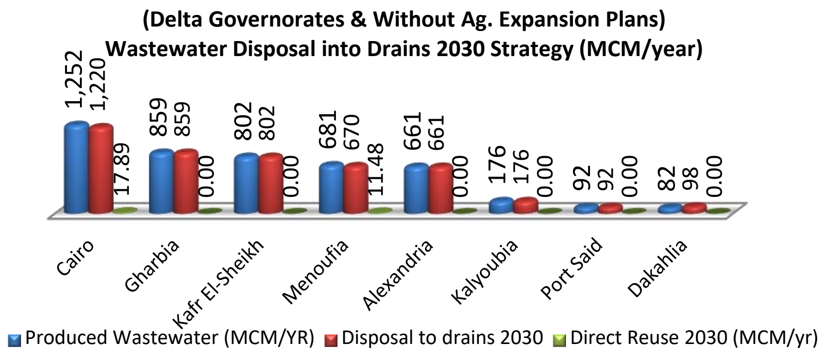

Figure 16. Strategic Vision for treated wastewater for Delta Governorates in 2030, (AbuZeid, K., *et al* 2014)

c. Direct Use of Treated Wastewater in Desert Front Governorates

In case of the Desert front governorates and/ or those with identified agricultural expansion plans, the treated wastewater will be used directly for agriculture. Figure 17 shows the quantities that will be directly used in desert front governorates and /or those with agricultural expansion plans. Wastewater disposals into drains for 2011 will be maintained throughout 2030.

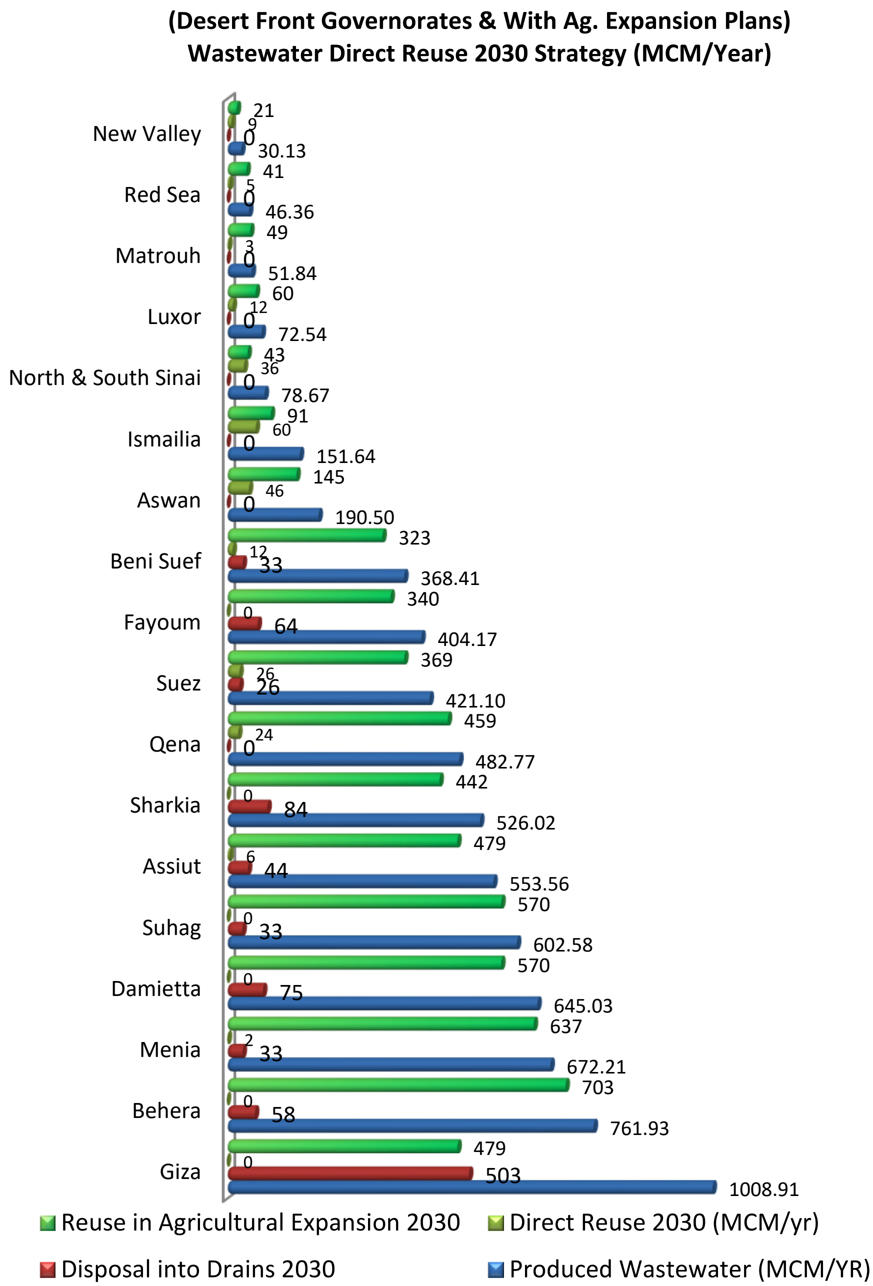

Figure 17. Strategic Vision for treated wastewater for Desert Front Governorates in 2030, (AbuZeid, K., *et al* 2014)

d. Direct Treated Wastewater to the 2030 Agriculture Development Strateg

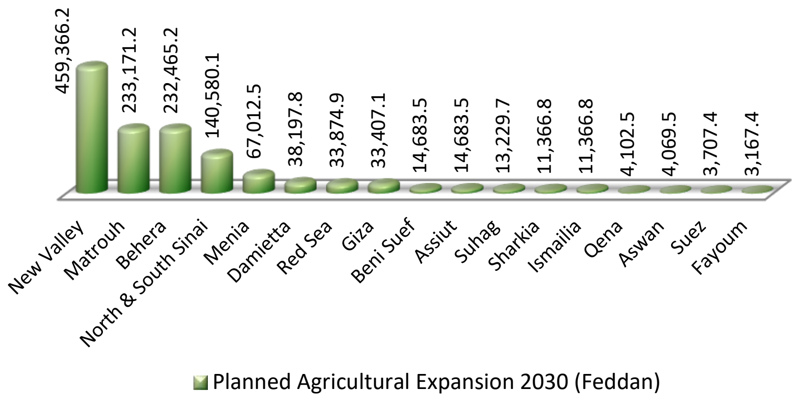

Figure 18. Planned Agricultural Expansion in different Egyptian Governorates in 2030, (AbuZeid, K., *et al* 2014)

This Strategy suggests that the wood production forests areas of 2011 will be kept as is without further future expansions, so as to direct future treated wastewater to agricultural expansion areas, instead, which coincides with the future agricultural expansion plan declared by the Ministry of agriculture and Land Reclamation. Figure 18 shows the areas of potential agricultural expansion in different governorates in 2030, according to the Ministry of Agriculture and Land Reclamation which amounts to 1.4 million feddans.

According to this strategic vision, 5.82 BCM will be used directly in agricultural expansion areas, while 5.53 BCM will be disposed to drains (Figure 19). According to the Ministry of Agriculture and Land Reclamation, 1.4 Million feddans will be reclaimed for cultivation, according to the Sustainable Agriculture Strategy of 2030, with total average annual water requirements of about 5.42 BCM (Figure 20) based on an estimated water requirements of about 4100 CM /feddan/year. According to this vision, these water requirements can be satisfied by the secondary treated wastewater produced in 2030. The Strategic Vision estimates an additional 97,560 Feddans that could be reclaimed based on the remaining potential of secondary treated wastewater of 0.4 BCM in the desert front governorates. An additional area of 1,349,780 feddans could be also reclaimed based on the disposed treated wastewater of about 5.53 BCM into the drains, at an estimated water requirements of about 4100 CM /feddan/year.

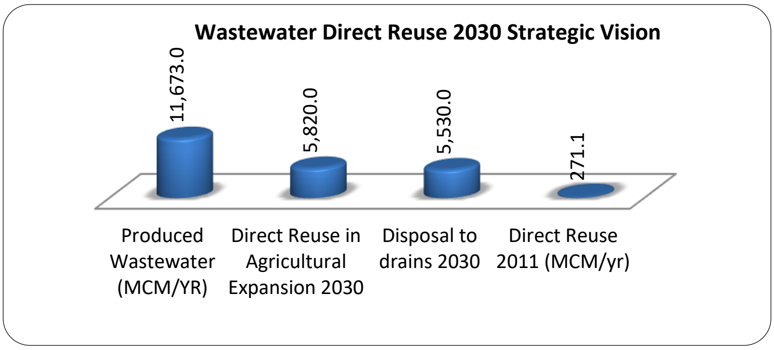

Figure 19. Treated Wastewater Reuse in 2030, (AbuZeid, K., *et al* 2014)

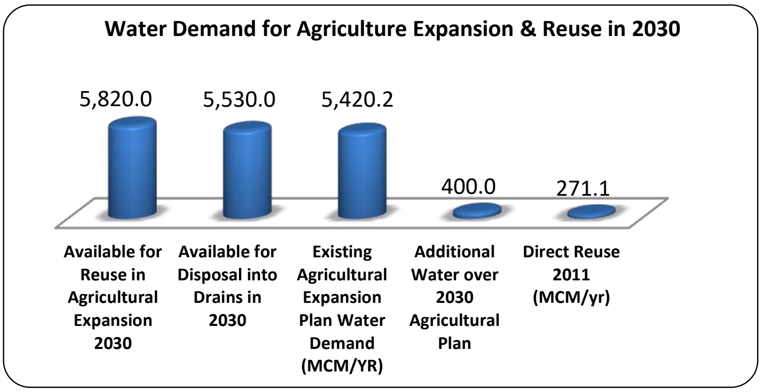

Figure 20. Treated Wastewater for Agricultural Expansion, (AbuZeid, K., *et al* 2014)

e. Revised Reuse Code

The 501 Wastewater Reuse code has been recently revised and modified in 2015 after a recommendation from the Vision developed and presented in this paper. The revised code introduces more variety of crops that could be cultivated on treated wastewater, and according to the level of treatment as shown in Table 2 & Table 3. Awareness about the new code is needed and agriculture, irrigation, and water management plans need to incorporate the new code.

Table 2. Grades of treated wastewater (Wastewater Re-use 501/2015 Code)

Requirements and Standards		Treatment Degree			
		Grade A	**Grade B**	**Grade C**	**Grade D**
Maximum limit for physical and chemical standards	TSS Mg/l	15	30	50	300
	Turbidity NTU	5	N/A	N/A	N/A
	BOD_5 Mg/l	15	30	80	350
Maximum limit for pathogens standards	Potential count of the colonic (E. coli) in 100 cm^3	20	100	1000	N/A
	No. of eggs of nematode Intestinal Intestinal nematodes/liter	1	N/A	N/A	N/A

Table 3. Agricultural groups by grade (Wastewater Re-use 501/2015 Code)

Grade	Agricultural Group	Description
A	G1-1: Green spaces for educational facilities and public and private parks	Palm trees of all kinds, Fence plants and flowers of all kinds
	G1-2: Fruit crops	Fruits eaten fresh without peeling such as: apples, apricots, plums, grapes, etc.
B	G2-1: Dry cereals, cocked and processed vegetables crops	Vegetables of all kinds (processed) and dry strategic crops of all kinds such as: wheat - corn - barley - rice - beans - lentils - sesame
	G2-2: Fruit crops	All types of fruit trees are permanent and leafy, such as citrus, olive, palm, mango, pomegranate, and fig for drying.
	G2-3: Medicinal plants crops	Such as: Anise - Hibiscus - Cumin - Marjoram - Khallet - Fenugreek seeds - Mogat - Barley - Chamomile - Almamriya
C	G3-1: Dry cereals crops, fruit crops and medicinal plant crops in Group B	The same varieties in addition to sunflower plants and sugar beet plants provided that sprinkler irrigation method is not used
	G3-2: Non-edible seeds for edible crops	All reproduction seeds of major edible crops such as: wheat, maize and vegetable seeds of all kinds provided that these seeds are planted in their permanent places later
	G3-3: All types of seedlings that are then transferred to the permanent fields	Such as: Olive seedlings - pomegranate - citrus fruits - bananas- palm trees - fig seedlings - mango - apples - pear
	G3-4: Roses and flowers	Such as: Roses - Eagle Rose - a set of bulbs such as Gladiolas and bird paradise and all kinds of ornamental plants
	G3-5: Trees suitable for landscaping highways and green belts	Such as: Casuarina - camphor - dapella - atoll - types of ornamental palms
	G3-6: All fiber crops	Such as: Cotton - linen - jute - Tal plant
	G3-7: Fodder crops and legumes	Such as: Types of sorghum and types of Nafl
	G3-8: Mulberry to produce silk	Such as: All varieties of berries
	G3-9: All Nurseries Ornamental Plants & Trees	Such as: Ficus Decora - Phyllis nite - Spender - Acacia
D	G4-1: Solid biomass crops	All crops that are converted into charcoal (compact discs) such as: willow, poplar and mornage
	G4-2: Liquid biomass crops	All crops produce biodiesel and energy oils such as: soybean - rapeseed - jojoba - jatropha - castor
	G4-3: Cellulose production crops	All non-food crops produce glucose and its derivatives such as: ethanol and acetic acid - ethanol gel
	G4-4: Wood trees	All trees for timber production are: kaya - camphor - mahogany

f. Identifying Wastewater-fit Irrigation Canals

One of the main concerns related to wastewater Reuse is the fact that Law 48 for the year 1982 prohibits the discharge of treated wastewater to canals that has drinking water intakes. While, the law is currently interpreted such that no treated wastewater should be discharged at any section of a canal that has drinking water intakes, it will be both realistic and beneficial if all drinking water intakes in all governorates are studied, and points of introduction of treated wastewater are proposed downstream of all drinking water Intakes, such sections of Irrigation Canals will be identified as Treated Wastewater-fit Irrigation Canals. In some cases, it would be suggested to shift Drinking Water Intakes further upstream if possible, or find an alternative water source such as groundwater or desalination in coastal areas. This would allow for introducing the treated wastewater downstream in a manner that would be beneficial for adjacent agricultural lands that have been identified in the wastewater Reuse Plan for a given Governorate.

STRATEGIC VISION IMPLEMENTATION COST ESTIMATE

Between 2011 and 2030, the amount of wastewater that will need to be treated up to the secondary level or upgraded from No-treatment to Secondary treatment is projected to be 9.2 BCM. At a unit investment cost for treatment of 0.75 Euro/m3 (7.5 EGP/m3) (AbuZeid, K. 2008), a total investment of 6.9 Billion Euro (69 Billion EGP) is needed over the next 19 years.

Between 2011 and 2030, the amount of wastewater that will need to be upgraded from primary to secondary treatment is estimated at 0.89 BCM per year. At an investment cost of 0.3 Euro/m3 (3 EGP/m3) (Hidalgo & Irusta, 2009), a total investment of 0.269 Billion Euro (2.69 billion EGP) is needed over the next 19 years.

Between 2011 and 2030, the amount of additional secondary treated wastewater that will need to be conveyed to the nearest drainage or irrigation network for reuse is estimated at 2.427 BCM per year. The cost of conveyance pipes and pumping, if needed, will depend on the distance away from the treatment plants and the difference in elevation. But, at an approximate estimated investment cost of 0.1 Euro/m3 (1 EGP/m3), the total investment could be roughly estimated at 0.2427 Billion Euro (2.427 Billion EGP) over the next 19 years.

The amount of secondary treated wastewater that this strategic vision suggests to be reused directly in the desert front governorates is projected to be 5.82 BCM per year. The conveyance distances from the location of treatment plants in desert front governorates to planned agriculture expansion locations are expected to be longer than those distances where the treated wastewater is to be directly disposed in nearby drainage networks. The associated investment costs for conveyance infrastructure are estimated at 0.2 Euro/m3 (2 EGP/m3). This will result in a total investment cost of roughly 1.16 Billion Euro (11.6 Billion EGP) over the next 19 years until 2030.

The Operation & Maintenance (O&M) cost for the reuse of wastewater conveyed through the drainage and/or canal network is estimated at 0.025 Euro/m3 (0.25 EGP/m3) which would require an annual budget of about 0.138 Billion Euro (1.39 Billion EGP) for an annual amount of wastewater reuse of 5.53 BCM/year. The Operation &

Maintenance cost for the reuse of wastewater conveyed directly to the agriculture expansion areas is estimated at 0.035 Euro/m3 (0.35 EGP/m3) which would require an annual budget of about 0.203 Billion Euro (2.03 Billion EGP) for an annual amount of reuse of 5.82 BCM/year. This would result in total expenditures over the next 19 years on O&M of about 2.622 Billion Euros (26.22 Billion EGP) and 3.857 Billion Euros (38.57 Billion EGP) for conveyed and direct reuse respectively.

The above analysis shows that the implementation costs of the proposed strategic vision requires, over the next 19 years, a total amount of about 15.05 Billion Euro (150.5 Billion EGP), divided into an investment cost of about 8.57 Billion Euro (85.7 Billion EGP), and an operational and maintenance cost of about 6.48 Billion Euro (64.8 Billion EGP). This would roughly mean that an annual investment budget of about 0.45 Billion Euro (4.5 Billion EGP) would be needed, and about 0.34 Billion Euro (3.4 Billion EGP) of recurrent costs would be needed for O&M.

Accordingly, and if a strategy of full cost recovery from potential users is implemented, treated wastewater could be offered to agriculture developers in the Northern Coasts at the downstream end of the drainage system at an investment cost of 0.85 €/m3 of annual allocated treated Wastewater amount, and at an O&M cost of 0.025 €/m3 of utilized amounts. Whereas treated wastewater could be offered to agriculture developers in the desert fronts governorates directly from the treatment plants at an investment cost of 0.95 €/m3 of annual allocated treated Wastewater amount, and at an O&M cost of 0.035 €/m3 of utilized amounts.

Figure 21 shows the total investment and recurring cost for the period from 2012 until 2030. Figure 22 shows on average the annual required investment and recurrent costs (O&M) until 2030.

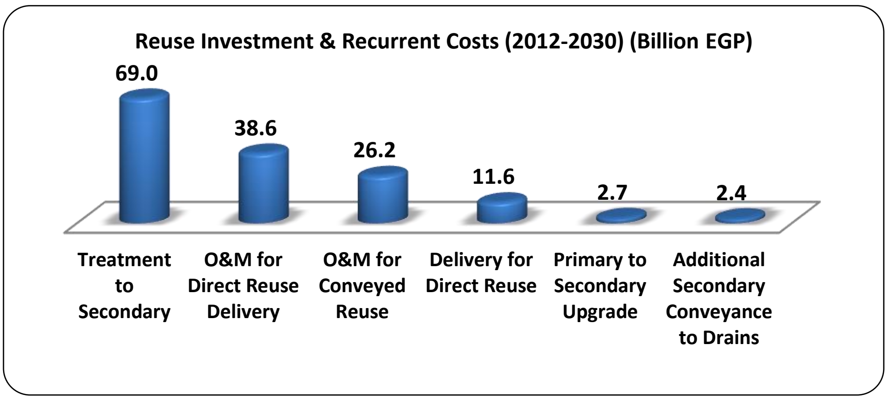

Figure 21. Wastewater Reuse Investment and Costs (2012-2030), (AbuZeid, K., *et al* 2012)

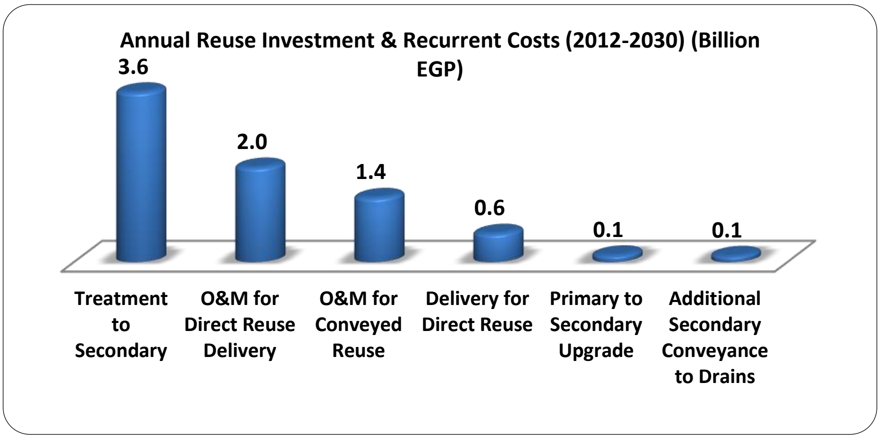

Figure 22. Annual Wastewater Reuse Investment & Recurrent Costs (Billion EGP), (AbuZeid, K., *et al* 2012)

RECOMMENDATIONS FOR IMPLEMENTATION

A strategic vision has been developed for the Re-use of treated wastewater in Egypt until 2030. The following is a summary of the main pivots of the strategy and recommended actions:

- Delta and Nile Valley Governorates Plants shall dispose secondary treated Wastewater into Agriculture drains, and reuse downstream through Agricultural Drainage Mixing Pumping Stations
- Desert front and Agriculture Expansion Governorates shall direct future treated wastewater directly to agriculture expansion areas, while maintaining existing 2011 disposal into drains.
- Desert landscaping need to be widely implemented to save on water and wastewater used for irrigating conventional urban landscapes.
- Treated Wastewater, that necessarily need to be allocated for urban landscaping, should to be considered in the detailed planning at the city and governorate level, and should be deducted from the treated wastewater amounts that are expected to be potentially available for Agriculture under this strategic vision.
- Agriculture expansion developers should be encouraged to utilize produced treated wastewater and should pay for the costs of treatment and conveyance infrastructure as well as operation and maintenance. This could be an attractive alternative for new developers or for existing agriculture investors whose agriculture investors’ hat are at risk due to water shortage and are suffering for groundwater exploitation problems.
- Industries should be forced to install their own treatment facilities, and its disposed wastewater into the waterways should be strictly monitored for following the water quality standards.

- Solid waste disposal in the waterways should be strictly prohibited and an efficient solid waste management system should be implemented.
- All treatment plants shall be upgraded to secondary treatment level by 2030.
- Existing tertiary treatment levels of 2011 shall be maintained through 2030 without further expansion in tertiary treatment at government expense.
- Maintain existing wood production forest areas of 2011 without further expansion and direct future treated wastewater to Agriculture Expansion areas to satisfy the increasing Agricultural water demands.
- Modified 2015 Wastewater Reuse Code should be implemented to allow for expansion in permissible agriculture crops cultivation on treated Wastewater.
- Develop governorate specific plans by matching Agriculture expansion plans with urban development plans, WSS plans, and Water Resources Management plans.
- Encourage development outside the Nile Valley and the Delta and into the desert areas.
- The importance of continuous collaboration between the Ministry of Water Resources and the Ministry of housing for better planning for Wastewater Reuse.
- The inter-ministerial committee representing the Ministries of Water Resources and Irrigation, Housing, Health, Industry, Environmental affairs, and Agriculture and Land Reclamation must continue its work to assure the coordination of efforts and plans.
- There is a need to accurately asses how much of the produced wastewater could feasibly be collected until 2030, and how much will not be collected due to being is remote areas using septic tanks, and whether it should be enforced to have communities develop in clusters where wastewater could be collected.
- New treatment technologies could bring estimated investment, operation & maintenance cost down.
- Water disposal regulations, water treatment standards, and reuse code and restrictions should be enforced to protect human health.
- Ministerial decrees and prohibitive regulations to effective wastewater reuse should be modified for better wastewater reuse.
- Incentives for treated wastewater users should be encouraged.
- The Egypt 2030 agriculture development strategy was considered as the basis for targeting secondary treated wastewater by 2030. Since it addressed edible crops & table oil products, therefore, this strategic vision recommends full secondary treatment of all wastewater produced in 2030, other scenarios for primary, secondary,

and tertiary treated amounts need to be explored to match the planned agricultural products.

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