Wafeer Initiative: enabling a market for water efficiency in Saudi Arabia

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Wastewater Treatment and Reuse

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I. INTRODUCTION

In most Arab countries limited water resources pose severe constraints on economic and social development and threaten the livelihood of people. Available surface water is declining and the over-pumping of groundwater, beyond natural recharge rates, has resulted in lowering the water table and causing an increase in groundwater salinity, ground water depletion, and ecological degradation (World Bank, 2009).

In the last three decades the Arab world has witnessed growing water stress, in terms of both water scarcity and deterioration of its quality. This looming crisis has prompted many governments to seek a more efficient use of water resources and develop interventions to narrow the gap between supply and demand in the region.

Municipal wastewater reuse is believed to be one potential intervention strategy for developing nonconventional water resources. In most Arab countries, "agriculture is by far the main water consumer, accounting for about 80% of the total water supply in Tunisia and up to 90% in Syria" (AHT Group AG, 2009). Therefore, the extended reuse of reclaimed (treated) wastewater for irrigation and other purposes could contribute considerably to the reduction of 'water stress' and 'water scarcity' in Arab countries as part of an Integrated Water Resources Management (IWRM) approach (Qadir et al., 2007). In fact, it has been argued that "in terms of quantity, the greatest potential for wastewater reuse is through using properly treated wastewater for irrigation purposes, as substitute for conventional ground and surface water sources" (AHT Group AG, 2009).

The reuse of treated wastewater in the Arab region targets agriculture predominantly, particularly in Tunisia, Syria, and Jordan. Irrigation for landscaping and golf courses is also on the rise in member countries of the Gulf Cooperation Council (GCC) as well as in North Africa (World Bank, 2007). However there are economic, institutional, health, and environmental constraints that hamper the sustainable and safe re-use and recycle of wastewater. To address these limitations will require concerted effort and commitment by Arab governments as well as support from regional and international organizations to boost the volumes of wastewater treated as well as the fraction of treated wastewater that is reused.

The scarcity of water and the need for protecting the environment and natural resources have motivated Arab countries to introduce wastewater treatment and reuse as an additional water resource in their national water resource management plans. In some Arab states, treatment and reuse of wastewater has become an institutional practice to a certain extent, but there is still a great scope for extending its application.

This paper reviews wastewater reuse practices, experiences, and applications in Arab countries. The data are based on conventional literature surveys, an in-depth survey of a large number of Arab water reuse projects, and on the findings of scientific papers. This assessment indicates that for an increased utilization of reclaimed wastewater, clearer institutional arrangements, more dedicated economic instruments, and the establishment of water reuse guidelines are needed. Technological innovation and the establishment of best practices will certainly help, but what is greatly needed is a change in stakeholders' perception of the water cycle.

II. POTENTIAL OF WASTEWATER REUSE IN THE ARAB REGION

The major challenge for most Arab countries is to secure access to safe water and clean

TABLE 1 **TOTAL WATER WITHDRAWAL, RAW WASTEWATER GENERATED, AND TREATED WASTEWATER IN THE DIFFERENT ARAB COUNTRIES**

Country	Total water withdrawal (10^9 m^3/year)	Total wastewater produced (10^9 m^3/year)	Volume of Treated Wastewater (10^9 m^3/year)
Algeria	6.070 (2000)	0.8200 (2002)	-
Saudi Arabia	23.670 (2006)	0.7300 (2000)	0.5475 (2002)
Bahrain	0.357 (2003)	0.0449 (1991)	0.0619 (2005)
Comoros	0.010 (1999)	-	-
Djibouti	0.019 (2000)	-	0.0000 (2000)
Egypt	68.300 (2000)	3.7600 (2001)	2.9710 (2001)
United Arab Emirates	3.998 (2005)	0.5000 (1995)	0.2890 (2006)
Iraq	66.000 (2000)	-	-
Libya	4.326 (2000)	0.5460 (1999)	0.0400 (1999)
Jordan	0.941 (2005)	0.0820 (2000)	0.1074 (2005)
Kuwait	0.913 (2002)	0.2440 (2003)	0.2500 (2005)
Lebanon	1.310 (2005)	0.3100 (2001)	0.0040 (2006)
Morocco	12.600 (2000)	0.6500 (2002)	0.0400 (1999)
Mauritania	1.700 (2000)	-	0.0007 (1998)
Oman	1.321 (2003)	0.0900 (2000)	0.0370 (2006)
Qatar	0.444 (2005)	0.0550 (2005)	0.0580 (2006)
Syria	16.700 (2003)	1.3640 (2002)	0.5500 (2002)
Somalia	3.298 (2003)	-	0.0000 (2003)
Sudan	37.320 (2000)	-	-
Palestine	0.418 (2005)	-	-
Tunisia	2.850 (2001)	0.1870 (2001)	0.2150 (2006)
Yemen	3.400 (2000)	0.0740 (2000)	0.0460 (1999)

Source: FAO AQUASTAT Database

sanitation. The Arab Water Council (AWC) (2006) estimates a further 83 million need to be supplied with safe water and 96 million are still in need of clean sanitation services in order to meet the Millennium Development Goals (MDGs). The needs of a rising population, estimated at 343.8 million (AOAD, 2009), has put an added pressure on total water withdrawal. The agriculture sector consumes 86% of this total (Qadir et al., 2009). Furthermore, water demand for domestic, municipal, and industrial use is slated to increase fuelled by rapid urbanization, industrialization, and rural migration to towns and cities.

Based on estimates by the Food and Agriculture Organization of the United Nations (FAO AQUASTAT), the volume of wastewater generated by the domestic and industrial sectors in the different Arab countries is shown in Table 1. Qadir et al. (2009) have reported that the ratio by volume of treated wastewater to that generated in the Arab region (54%) "is higher than Asia (35%), Latin American/Caribbean (14%), and Africa (1%)."

III. REUSE PRACTICES IN THE ARAB REGION

Within the Arab world Tunisia, Jordan, and the GCC counties are the leaders in the area of wastewater reclamation and reuse.

a. Tunisia

Tunisia has long experience (since 1965) in using treated wastewater to irrigate the citrus orchards and olive trees of the Soukra irrigation scheme (8 km North East of Tunis) covering an area of 600 hectares (Bahri, 2008a).

In 2008, the number of wastewater treatment plants operating in Tunisia were 61, collecting

0.24 billion km[3] of wastewater, of which less than 30% is reused to irrigate vineyards, citrus (Chenini, 2008), trees (olives, peaches, pears, apples, pomegranates), fodder crops (alfalfa, sorghum), industrial crops (cotton, tobacco), cereals, and golf courses in Tunis, Hammamet, Sousse, and Monastir. The wastewater effluent is treated to secondary levels and farmers pay subsidized prices for the treated wastewater they use to irrigate their fields (Bahri, 2008a).

b. Jordan

Wastewater has been used for irrigation in Jordan for several decades. The inclusion of wastewater reuse in the country's National Water Strategy since 1998 was a signal of placing high priority on the value of reclaimed water. Wastewater represents 10% of Jordan's total water supply (WaDImena, 2008) and up to 85% of its treated wastewater is being reused (MED WWR WG, 2007). It should be noted however that treated wastewater is mixed with freshwater and then used for unrestricted irrigation in the Jordan Valley.

In 2009, the new National Water Strategy was published. To further support wastewater reuse in irrigation, the 2008-2022 plan proposes, among others, to:

- Introduce appropriate water tariffs and incentives in order to promote water efficiency in irrigation and higher economic returns for irrigated agricultural products;
- Manage treated wastewater as a perennial water source which shall be an integral part of the national water budget;
- Ensure that health standards for farm workers as well as consumers are reinforced and that all treated wastewater from all municipal or industrial wastewater treatment plants meets relevant national standards and is monitored regularly;
- Periodically analyze and monitor all crops irrigated with treated wastewater or mixed waters;
- Design and conduct programmes on public and farmer's awareness to promote the reuse of treated wastewater, methods of irrigation, and handling of produce.

Jordan claims 21 domestic wastewater treatment plants which in 2008 have generated more than 100 million m^3 of treated wastewater (JMWI, 2009a). The treatment plants are located in large cities but do serve large areas surrounding these cities. All effluents from treatment plants are either directly used for irrigation or are stored first in reservoirs/dams that are used for irrigation. The Ministry of Water and Irrigation forecasts that the amount of treated wastewater used for irrigation will reach 223 million m^3 by 2020 (FOEME, 2010). Since 2002, the government of Jordan, with the support of international organizations, has been implementing several direct water reuse activities in Aqaba and Wadi Musa whose objective is to demonstrate that reclaimed water reuse can be reliable, commercially viable, socially acceptable, environmentally sustainable, and safe.

The Wadi Musa pilot farm project near the historic city of Petra uses the treated effluent of the Petra Regional Wastewater Treatment plant to grow a variety of agricultural crops including alfalfa, maize, sunflowers and Sudan grass, tree crops including pistachio, almond, olives, date palms, lemons, poplars, spruce, and junipers, and many varieties of ornamental flowers (iris, geraniums, petunias, and daisies).

c. Lebanon

In 2001, 310 million m³ of wastewater were produced in Lebanon by the domestic and industrial sectors (FAO AQUASTAT). In 2006, 4 million m³ of wastewater were treated and 2 millions m³ were used for informal irrigation (FAO AQUASTAT). Raw wastewater is also being reused for irrigation in several regions of Lebanon. Such is the case in the Bekaa region where some of the sewers are purposely blocked to allow sewage to be diverted for irrigation. In other regions, wastewater is being discharged in rivers or streams used for irrigation such as in Akkar and Bekaa (Ras El Ain, Zahleh).

The illegal and uncontrolled reuse of raw sewage, directly or indirectly, is sometimes a common practice in Lebanon dating back to ancient times. Reuse for agricultural irrigation dominates and crop restrictions are not respected. Farmers or workers who handle untreated wastewater do not always follow public health recommendations and often neglect to wear protective boots and gloves. Experience has shown that contact with secondary-treated wastewater can provoke allergies and other serious dermatological or gastrointestinal illnesses. The consumption of produce irrigated by untreated wastewater can pose substantial health risks to consumers. Untreated wastewater used to irrigate produce and vegetables eaten uncooked could cause transmission of helminthic diseases caused by Ascaris and Trichuris. Further evidence has demonstrated that cholera could be transmitted through the same channel. To avoid the spread of these diseases, wastewater should be suitably treated to match the type of crop to be irrigated in compliance with the adapted health protection measures.

d. GCC countries

In the GCC countries, about 40% of treated wastewater is used to irrigate non-edible crops and fodder as well as for landscaping (Al-Zubari, 1997). In Kuwait, the Sulaibiya Wastewater Treatment and Reclamation Plant is considered by far the largest facility of its kind in the world to use reverse osmosis (RO) and ultrafiltration (UF) membrane-based water purification systems. The plant's initial daily capacity is 375,000 m³, which could be expanded to 600,000m³/day in the future. It is believed that treated wastewater will contribute to 26% of Kuwait's overall water demand, reducing the annual demand from non-potable sources from 142 million m³ to 26 million m³.

e. Syria

According to the World Health Organization (2005), the Damascus and the Homs wastewater treatment plants in Syria account for more than 98% of all treated wastewater with capacities of 177 million m³/year and 49 million m³/year, respectively. Since then, new wastewater treatment plants under construction may have come on line in other cities such as Allepo and Latakia. According to the World Health Organization (2005), "About 177 million cubic meters per year of treated wastewater are reused for irrigating 9000 hectares in Damascus."

f. Egypt

Egypt produces about 3.5 billion m³/year of municipal wastewater, while current treatment capacity is in the range of 1.6 billion m³/year. An additional treatment capacity of 1.7 billion m³ is targeted by 2017 (Tawfic, 2008). Although the capacity increase is significant, it will not be sufficient to cope with the future increase in wastewater production from municipal sources and therefore, the untreated loads that will reach water bodies are not expected to decline in the coming years. The Delta Region alone generates more than 2 billion m³/year, mostly originating from Egypt's two greatest urban centers, Cairo and Alexandria. Treatment plants serve 55% of the population in towns and cities (Tawfic,

GREYWATER: EXPERIENCES IN MENA RURAL COMMUNITIES

Boghos Ghougassian

As freshwater is increasingly becoming scarce in the Middle East and North Africa (MENA), the region is being faced with a dire need for alternative sources of water. As a non-conventional water source, treated greywater (GW) can potentially be used by households to irrigate their backyard gardens on a decentralized basis, particularly in rural and peri-urban areas.

Greywater is generated in every house as the less polluted wastewater from kitchen sinks, washing machines, dishwashers, hand washing basins, and showers. It does not include "black" wastewater from toilets that contain large concentrations of fecal matter and urine. Even though its contribution to the national water budget is modest, GW is considered a tool for water demand management (WDM). It is similar to rainwater harvesting, where one can generate useful water at one's own premises, particularly in rural areas.

Since 1998, the International Development Research Centre (IDRC) of Canada has supported and funded ten research projects on GW treatment and reuse in MENA, namely in Palestine, Jordan, Lebanon, and Yemen between 1998 and 2008. The total IDRC investment has exceeded US$2,000,000. With the application of GW treatment systems, families in water-stressed areas generate from 100 to 150 m^3 of GW per year, which is enough to irrigate 20 to 30 trees in their backyards and produce additional crops. GW accounts for 50%-70% of wastewater generated by households and its treatment and reuse contributes towards improvement of public health and the environment, in addition to generating economic benefits to its users.

Many different technologies have been used in various countries based on their effectiveness in treating GW. IDRC-supported projects in the MENA region have developed the 4-barrel and confined trench (CT) types of treatment systems, which are simple to use and have a low cost. These systems are now considered dependable GW treatment units for decentralized use. Their performance complies with the 2006 World Health Organization (WHO) Guidelines for the Safe Use of Wastewater, Excreta and Greywater, which look at health-based targets and proper management of GW, rather than water quality standards.

To date, IDRC's research partners have outfitted more than 2,000 homes in Jordan, Palestine, and Lebanon with GW treatment systems, and the results generated have been

promising. Installing a GW system in every poor household with a backyard, every school with a patch of land for a garden, and every mosque across the MENA could have a significant impact on poverty, food security, and water availability.

The treatment system is simple. No mechanical equipment is involved. Four plastic barrels, each with a capacity of 160-200 liters, make up the GW treatment kit. The 4 barrels, interconnected with PVC pipes, are lined up next to each other. GW flows from the house gravitationally into the first barrel, which traps the floating and settleable material. As GW rises to the top of the first barrel, relatively clear GW then flows into the bottom of the 2nd barrel and then to the bottom of the 3rd barrel. During the upward flow of GW in those two barrels, the anaerobic bacteria digests organic pollutants found in GW. The forth barrel acts as a storage tank for treated GW from which it is automatically pumped into the drip irrigation network, to irrigate trees and other plants.

The GW treatment system is airtight and watertight, and no mosquitoes or other insects can bread in the system. No odor is detected at the site. The gases that are produced during the digestion process in the barrels are vented above the roof level of the house. However, during the pumping cycle, which lasts for 10 minutes per day, some odor is released through the drip irrigation network.

The 10 GW research projects that have been implemented in 4 MENA countries have revealed that there are no health risks associated with the use of treated GW for irrigation. But public acceptance of GW treatment is seen as the cornerstone to successful adoption of GW reuse at the household level. Fortunately, after initial hesitation, beneficiaries have usually adopted the use of GW, when the accepted norms for effluent quality were met. No taboos have been revealed in the use of treated GW. And those who have done proper maintenance to their GW systems have produced more crops and benefitted economically. They have also been highly satisfied with the performance of their GW systems.

In the case of Lebanon, the satisfactory results of the two IDRC-supported GW research projects, implemented in 2002-2008, have motivated other communities and donors to replicate GW technology applications in other towns. For instance, in 2008-2010 three new GW projects were implemented in South Lebanon, where 100 units of the 4-barrel type were installed at households in three towns, and 5 confined trench (CT) units were installed in 4 mosques and a kindergarten. And because of the observed benefits that were realized, new homes are now being built with proper GW separation and reuse in mind.

From a public policy perspective, successful implementation of GW treatment projects in Lebanon has led into a fruitful cooperation with the Lebanese Ministry of Energy and Water (MEW), which recently integrated the concept of GW reuse in its Ten Year Water Plan for Lebanon. On the other hand, various municipalities are now interested in the promotion of GW reuse. A case in point is the Union of the Municipalities of Bint Jebail Caza, which in March of 2010 decided to promote GW reuse in their 12 towns.

In Jordan, the implementation of three GW projects has led to efforts to include in the country's building code language pertaining to greywater treatment. The Jordanian Institution for Standards and Metrology is working now on adopting the Uniform Plumbing Codes (2006 & 2009) which includes in one of its chapters specifications to separate greywater from blackwater.

In Yemen, after the successful implementation of pilot GW treatment and reuse projects at gardens adjacent to mosques "miqshama", the concept of GW reuse is being promoted in many other mosque-adjacent gardens in the country, in cooperation with the government, the National Water Resource Authority, and local NGOs.

The GW research projects in all countries of Middle East have proven that there are net benefits to reusing nutrient-rich treated GW for irrigating crops, especially if the alternative is to dump the GW into cess-pits, valleys, and surface waters.

GW reuse has brought three types of benefits to users who demonstrated ownership for their units. It has provided them with irrigation water for additional crop growing. It has contributed towards food security of households and has addressed the septic tank overflow and sanitary problems.

Research projects that have been implemented in the MENA region indicate that an average net annual benefit of more than $300 per family has been achieved for households who properly maintain their GW systems, without even considering indirect benefits, such as reduced capital investment in septic tanks, environmental and other benefits.

The financial feasibility of GW reuse has been demonstrated as well as its technical feasibility and ethical soundness. However, there are barriers that hinder further use, acceptance, and wide scale replication of GW reuse technologies. The barriers include:

- Short project lives of 2-3 years, not enough to realize tangible results for beneficiaries;
- Lack of a sense of ownership by some beneficiaries;
- Lack of valuation of irrigation water by households, due to their traditional rain-fed dry farming habits. But those who maintain their GW kits, get good results and adopt the GW systems;
- Unhelpful washing habits of household occupants such as permitting oil, grease, and large particulates in kitchen sinks to be mixed with water channeled for treatment;
- From a technical perspective, the performance of GW treatment systems needs further improvement, to allow trouble free operation and less maintenance; and
- Odor is a major criterion for evaluating GW treatment system by some beneficiaries. Odor is released at the beginning of pumping.

Government action is needed to:
- Include greywater treatment and reuse as an integral part of water reuse programmes in ministries;
- Provide economic incentives to potential users of GW, by municipalities, and ministries of water resources;
- Develop national guidelines for GW treatment and reuse, based on the 2006 WHO guidelines and local GW research results;
- Encourage GW applications in rural areas, through appropriate building codes; and
- Set standards for the proper construction of GW treatment system, and encourage research on greywater treatment and reuse.

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TABLE 2 **WASTEWATER REUSE GUIDELINES FOR SOME ARAB COUNTRIES**

	E. Coli Or Fecal Coli /100ml	Nematode eggs/l	Other[1] parameters	Crops eaten uncooked is allowed	Code of practice
WHO	1000	<1	No	Yes	Yes
Jordan	100	<=1	Yes	No	Yes
Morocco	1000	Absence	Yes	Yes	No
Palestine	1000	<1	Yes	No	Yes
Syria	1000	<1	Yes	No	Yes
Tunisia	-	<1	Yes	No	Yes
Kuwait	20	<1	Yes	No	Yes
Oman	200	<1	Yes	Yes	
Saudi Arabia	2.2	<1	Yes	No	Yes
Yemen	No specific standard				
Egypt	Decree 44/2000, but no specific standard				

1. BOD5, COD, NO_3, TSS, EC
Source: Xanthoulis, 2010

2008). Most of the treated wastewater is reused to irrigate food, industrial, fuel, and cosmetic crops, green belt, trees along the desert roads, and woodland forest. The regulation of water reuse in Egypt is based on Decree 44/2000 specifying the kind of soil, the method of Irrigation, and the crops to be irrigated.

IV. CONSTRAINTS TO WASTEWATER REUSE IN THE ARAB REGION

a. Policy and political factors

The lack of political commitment and of a national policy and/or strategy to support wastewater treatment and reuse act as significant constraints in most Arab countries.

For instance in Morocco, in addition to financial constraints and the lack of awareness within public authority institutions, there is no national policy for wastewater reuse. Recently, a National Master Plan for sanitation has been launched in order to protect water resources. In fact, with assistance from international organizations, Morocco has allocated a budget of about 4 billion Euros for sewerage projects to be completed by 2015. Experimental trials to irrigate several crops (vegetables, forages, cereals, and ornamental crops) have demonstrated the benefit of utilizing treated wastewater in increasing crop production, saving fertilizers, and protecting the environment (Choukr-Allah, 2005). However, the acquired experience in wastewater treatment and reuse projects has generated little progress in practice due to political and policy constraints (Chenini, 2009). In 2008, the Moroccon government launched several reuse projects focusing mainly on providing irrigation water for golf courses and for landscaping purposes in Marrakech, Benslimane, and Agadir cities covering a surface area of 3000 ha.

In the Arab region, many people remain suspicious of reuse since they are uncertain of the quality of treated water. The availability of untreated wastewater free of charge makes it difficult to convince farmers to pay fees for reclaimed water that is perceived not to be of high quality. Numerous projects indicate that demand for reclaimed water by farmers is generally lower than it is for alternative sources of freshwater. This distrust is apparent in Tunisia, where the price charged to farmers for reclaimed wastewater is four times lower than fresh water prices. Perhaps most importantly, the fact that reclaimed water cannot be used for high-value vegetable crops is discouraging to nearly half of all eligible farmers (Bahri, 2002). Shetty (2004) has indicated that social acceptance, regulations concerning crop choices, and other agronomic considerations strongly influence decisions about water reuse.

In Palestine, wastewater reuse projects in the West Bank are associated with political obstacles, in addition to financial, social, institutional, and technical ones. "Wastewater reuse is still tied to the political issues concerning Palestinian water rights" (Samhan, 2008), since Israel considers reused wastewater as part of Palestinian total freshwater allotment. An integrated vision for wastewater reuse issues is still missing, which should include political and institutional aspects, water policy, awareness, marketing, and tariffs (Samhan, 2008).

For all of these reasons, wastewater recycling in Arab countries usually requires a long-term government commitment. Greater effort should be devoted in producing good quality treated wastewater to be used for non-restrictive irrigation. Public awareness, regulatory compliance, and monitoring should be reinforced.

b. Health impacts and environmental safety

According to Fatta et al. (2005), "concerns for human health and the environment are the most important constraints in the reuse of [treated] wastewater." It is frequently the case that sewage treatment plants in Arab counties do not operate satisfactorily and, in most cases, treated wastewater discharges exceed the legal and/or hygienically acceptable maxima. This is attributed to the lack of adequately trained staff with the technical skills to operate these plants, as well as the lack of an adequate budget for plant maintenance and operation.

Irrigation with inadequately treated wastewater poses serious public health risks, as wastewater is a major source of excreted pathogens - bacteria, viruses, protozoa, and helminths (worms) that cause gastro-intestinal infections in human beings. "Inappropriate wastewater use poses direct and indirect risks to human health caused by the consumption of polluted crops and fish. Farmers in direct contact with wastewater and contaminated soil are also at risk" (WaDImena, 2008). Reuse of unsuitable wastewater in agriculture may also lead to livestock infections.

The concerns of reusing reclaimed wastewater is not limited to "the relevant treatment infrastructure and applied treatment technology", but extend to "other key parameters such as the quality of the influents as well as the subsequent reuse options according to current quality standards as defined in the national legislation" (AHT Group AG, 2009). Wastewater in the Arab region is increasingly loaded with further potentially harmful substances such as heavy metals, trace pollutants including organic and inorganic compounds, and emerging contaminants such as pharmaceutical substances, all of which must be removed prior to wastewater reuse. Dissolved inorganic constituents, such as calcium, sodium and sulphate, may also have to be removed for wastewater reuse. The discharge of untreated industrial streams into the sewerage network causes an additional burden on the quality of treated wastewater (ultimately to be reused in agriculture). This is the case of the fishery industries in Agadir, Morocco, which discharge high loads of salt leading to increased salinity in the Lamzar plant effluent.

In environmental safety terms, unregulated irrigation with wastewater may lead to problems such as deterioration in soil structure (soil clogging due to high content of suspended solids in treated wastewater), which results in poor infiltration, soil salinization, and phytotoxicity (Choukr-Allah and Kampa, 2007). In Jordan, salt levels in the soil tended to increase in some areas that have been irrigated with treated wastewater, which was attributed to the salinity of wastewater as well as on-farm management (Fatta et al., 2004). Higher salinity implies that a certain number of less resistant crops cannot be irrigated by wastewater.

Potential environmental impacts from the reuse of wastewater in agriculture may also include groundwater and surface water contamination as well as degradation to natural habitat and ecosystems. In Tunisia, for instance, the main environmental quality constraint to the reuse of wastewater is the excess of nitrogen.

c. Standards and regulations

An important element in the sustainable treatment and reuse of wastewater is the formulation of standards and regulations that are achievable and enforceable (AHT Group AG, 2009). Unrealistic standards and non-enforceable regulations may do more harm than having no standards and regulations at all, because they create an attitude of indifference towards rules and regulations in general, both among polluters and administrators. For instance, “the cost of treating wastewater to high microbiological standards can be so prohibitive that use of untreated wastewater is allowed to occur unregulated” (Fatta et al., 2004) to meet throughput goals.

Without question, the enforcement of microbiological guidelines or crop restrictions remains important, but a better balance between safeguarding consumers’ (and farmers’) health and safeguarding farmers’ livelihoods should be made, especially in situations where the required water treatment or agronomic changes are unrealistic (Choukr-Allah and Kampa, 2007).

Usually, the makeup of standards and regulations is based on other international practices. Most wastewater reuse standards in the Middle East and North Africa region “are based either on the United States Environmental Protection Agency (USEPA) or World Health Organization (WHO) guidelines” (WaDImena, 2008). In some cases, however, there is need for establishing more adapted standards and guidelines that take into consideration the scheme- and country-specific conditions (Abu-Madi, 2004).

Some countries in the region have developed health guidelines for water reuse as detailed in Table 2. For example, Bahrain, Jordan, and Morocco have adopted fully or partially World Health Organization and Food and Agricultural Organization guidelines. Other countries, namely, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates have adopted stringent health reuse guidelines similar to those employed in some USA states (e.g., fecal coliforms less than 2.2 MPN/100ml). Such countries have established the treatment infrastructure needed to achieve those requirements. Still, other countries employ national public health laws to regulate reuse practices, while some lack any kind of regulatory guidelines (MED WWR WG, 2007).

Arab countries have developed different approaches to protect public health and the environment. However, the main factor driving wastewater reuse regulatory strategy is economic, specifically the cost of treatment and monitoring. Most Gulf Cooperation Council (GCC) countries have established conservatively low risk guidelines or standards (e.g., California standards) based on a high technology, high-cost approach. However, high standards and high-cost technologies do not always guarantee low risk because insufficient operational experience, high operating and maintenance costs, and regulatory control can have adverse effects.

Low-income Arab countries advocate another strategy for controlling health risks by adopting

RECYCLING ABLUTION WATER FOR THE IRRIGATION OF A MOSQUE GARDEN IN OMAN

Researchers in Oman's Sultan Qaboos University (SQU) have designed a cost-effective system for recycling ablution water to be reused for irrigating the garden of a mosque. Ablution water is "greywater" (GW) since it is not mixed with "black" sanitary wastewater.

Ablution water passes first through a sand layer for trapping solid matter, then through a layer of enriched carbon for deodorization. Water is then disinfected by passing through a chlorine pump. Treated water is gathered in a ground storage tank connected to a sprinkler irrigation system.

The filter, designed by an SQU Department of Soil, Water and Engineering research team, cost only $390, which is far less expensive than imported GW treatment units. The overall cost of the imported system was $3,900.

Engineer Sayf Al-Adawi, who was involved in devising the homemade filter, said that the annual maintenance costs do not exceed $200 including scrapping off a 5 cm layer of the sand filter and replacement of enriched carbon. He added that the service life of the filter was ten years.

The new treatment system was dubbed "WWW", an acronym that stands for "Wadu' [ablution] Water Works".

It is presently operated at Mohammed Hamoud Mosque in Al-Sib, near the Omani capital, Muscat. The system treats an average of around 1,000 liters of GW per day, with additional quantities on Fridays and during the month of Ramadan. Its maximum capacity is 4m^3, which is enough to meet any possible future increase in utilization.

This inexpensive system, if used on a large-scale in the Gulf states and other Islamic countries, will potentially lead to considerable water saving, in countries that are in arid and semi-arid belt and suffer from water scarcity.

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a low technology, low-cost approach based on WHO recommendations. Attention should also be paid to cases where existing regulations are not adequate to deal with the demand of water reuse activities. For instance in Egypt, strict direct reuse standards are set in the Code of Use and the types of crops which can be irrigated with treated wastewater are very limited. However, none of these strict regulations are applicable to the indirect reuse of wastewater via agricultural drainage canals, which is a common practice in Egypt. Here, relevant laws only regulate the standards for discharge into agricultural drainage canals. In practice, the effluent quality of many treatment plants and direct dischargers does not comply with these standards. In addition, no restrictions of the crops irrigated with drainage canal water are stipulated (AHT Group AG, 2009).

d. Wastewater Reuse Guidelines

Arab countries can be divided into three main categories according to their wastewater disposal practices as follows:

Category 1: This group includes Bahrain, Oman, Saudi Arabia, Qatar, Kuwait, and UAE. All countries in the GCC follow similar methods in the disposal of wastewater effluent. A high percentage of wastewater after post treatment is reused in irrigation of agriculture land or in landscaping while the remainder is disposed into the sea after many advanced treatment steps. This practice is common in the Gulf region due to the availability of well-equipped and advanced treatment plants. Strict quality standards are followed before disposal and reuse, but it is thought that certain criteria parameters could be relaxed in order to fully utilize the ever-increasing volume of secondary treated effluent.

Category 2: This group includes Egypt, Iraq, Jordan, Morocco, and Syria. These countries follow moderate regulations for the disposal of wastewater effluent. Effluent from wastewater

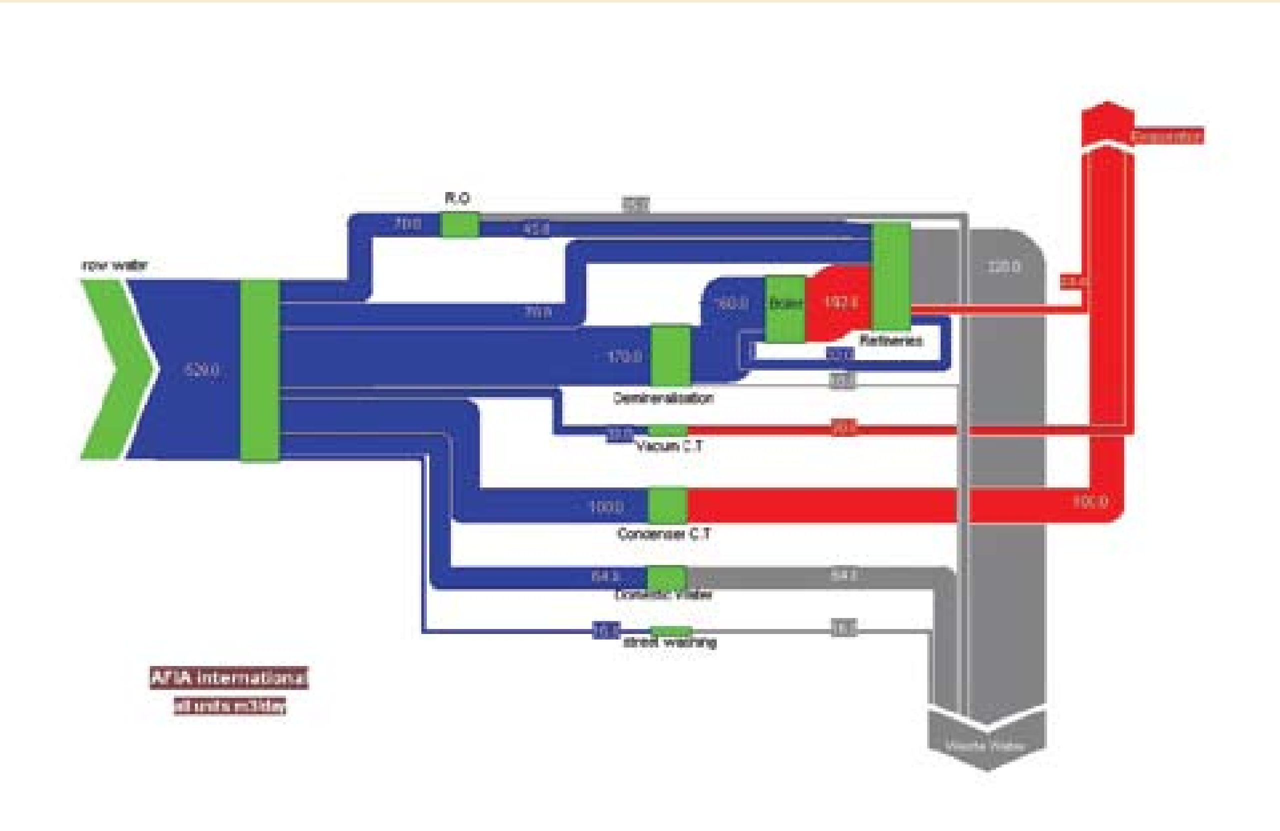
WAFEER INITIATIVE
ENABLING A MARKET FOR WATER EFFICIENCY IN SAUDI ARABIA

Tareq Emtairah

Significant saving potential is believed to exist in all economic activities of the private sector of MENA countries. However this potential is hardly explored in systematic ways. Particularly in the context of a country like Saudi Arabia, where the cost of water production is among the highest in the world, the incentives to examine this potential should be high. In 2007, a group of private sector actors and with support from the Saudi Ministry of Water and Electricity (MoWE) launched Wafeer Initiative mainly for this purpose of exploring the potential of water efficiency in the Saudi Arabian industrial sector.

Faced with lack of data and local technical expertise in industrial water efficiency, the organizers of the initiative developed a pilot program in collaboration with international partners to work with selected companies from the industrial city of Jeddah to test a systematic methodology for water rationalization in industrial facilities and to identify the economic and technical opportunities for water savings through reduce, recycle and reuse measures. The lessons from working with the pilot companies and the results of intervention measures were then to be documented for dissemination purposes and possibly for expansion of the program into other cities in the Kingdom. Another objective from the pilot programs is also linked to the component on capacity building and training of local engineers on water audits and water accounting tools.

The initiativeís pilot program kick started in early 2008 and concluded in October 2009. During this period, the program attracted thirteen companies to participate in voluntary water audits. These audits were designed to map the water flow cycle and to enable the program team to draw visual water maps showing the in-flows and out-flows in each facility (e.g. Sankey Diagram). In discussions with the participants, the program team found the diagrams to be very useful in communicating with company managers about the potential for water



saving in their facilities.
Example Sankey Diagram for one of the participating facilities

Following the mapping step, the program team worked with seven facilities from the pilot companies to further identify and assess water rationalisation measures through, for instance, good house keeping measures, internal reuse of clean process water, internal recycling before discharge, and/or opportunities for use of externally recycled water. In some cases the program team also looked into the feasibility of investing in alternative process technologies that are less water intensive, for instance, alternative cooling tower technologies.

Based on these assessment it was possible to develop water efficiency management plan for five facilities. Common across the assessment results is the potential for water saving through simple measures with little or moderate investments and a pay back of less than one year. While the potential for closing the water cycle through internal reuse and recycling is high, these measures on the other hand require more investments and longer pay back periods. These along with other documented results from the initiativeís program are published on the initiative website (www.wafeer.net). Some of the key observations and lessons drawn from this initiative point to missed opportunities for efficient water management and to key institutional barriers that are most likely to extend across the MENA region.

On the practice side, the program experience shows a lack of systemic approach to water management and clear understanding of the water cycle in nearly all audited facilities. For instance it was difficult to get answers from production personnel on questions such as:

- Which operations require the most water?
- What are the water losses in process steps or pipes?
- Are there opportunities for internal re-cycle and re-use?
- Which of the operations can be connected to recycled water?
- Do you see a need to separate waste water streams to increase the potential for re-use?

In such cases, the use of water accounting and systematic mapping tools like the one used above helped the participants to assess the cost associated with water use in every step of the production process and to examine where the highest potential lie for intervening in the water cycle.

What also became apparent from the assessment results are some of the barriers related to the institutional context. For instance, the weak enforcement of regulations regarding industrial waste water discharges in the industrial estate does not encourage investments in water saving measures. This combined with lack of trained and qualified staff in industrial water management and shortage of water characterization facilities in the industrial estate made it even more difficult to proceed with many of the suggestions made in the assessment reports.

If the right measures are put in place in terms of stringent enforcement of waste water discharge tariffs, curbing of illegal dumping, and provision of technical support incentives, investments in water efficiency and related services can be very promising in a country like Saudi Arabia. Building on the initiativeís conclusions, the annual water saving potential from investments related to internal improvements, within existing small to medium industrial facilities alone, is estimated to be around 30-50 million cubic meter for a country like Saudi Arabia. Given the current market prices and waste water discharge fees, the savings in monetary terms can range between $60-100 million per year. Reaching these goals surely will require investments in capacity building and implementation measures. Even if these investments reach the level of $200 million as projected by the program, a natural market for industrial water efficiency is most likely to emerge given that key distortions are corrected.

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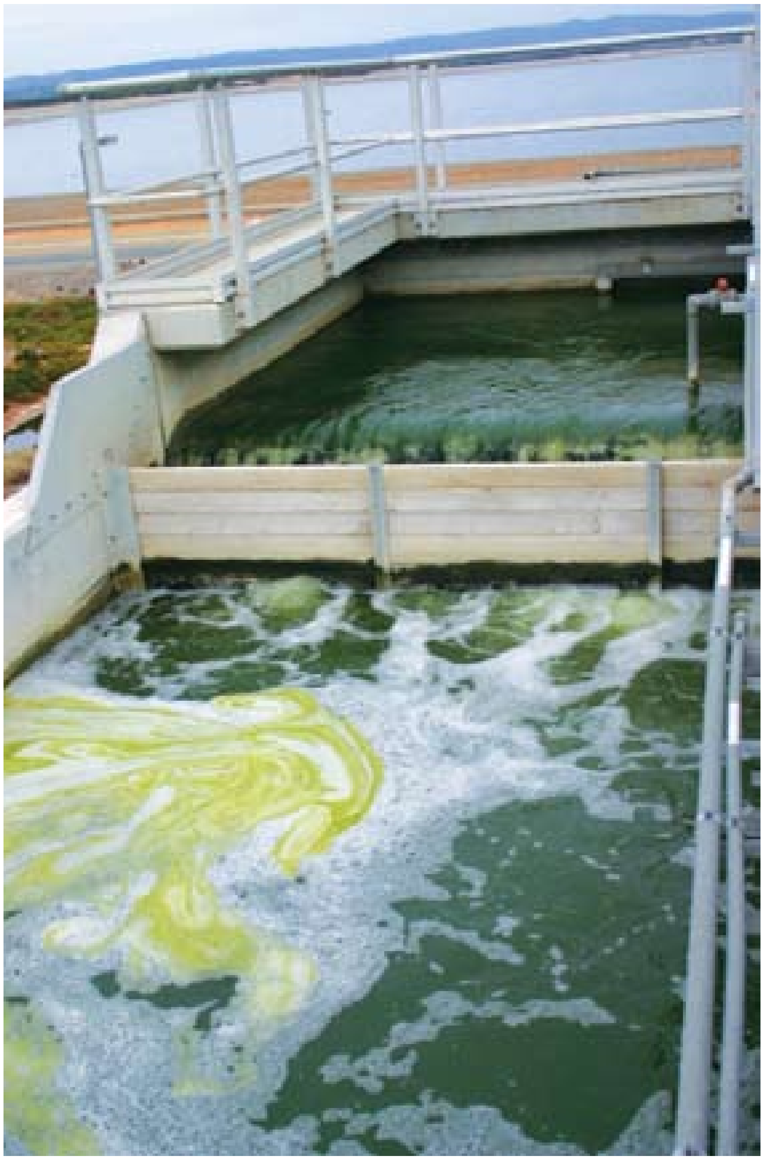

treatment plants doesn't meet national or international standards. This may be due to the less than ideal condition or inability of existing treatment plants to cope with high loads of raw wastewater influent. Based on this fact a high percentage of the effluent wastewater is disposed to surface water bodies for later use in irrigation. The regulations in these countries specify the types of crops that can be irrigated using this type of treated water. Moreover, this water may be used for landscaping and for industrial purposes. The government does not allow the disposal of raw wastewater in wadis or by land discharge. Violation of this regulation may appear in the rural areas since they are not served or connected to the sewer (collection) system.

Category 3: This group includes the West Bank, Yemen, and Lebanon, where a large fraction of wastewater effluents is disposed of in wadis and subsequently used for irrigation of cropped lands without treatment. In the West Bank, raw sewage is disposed of in wadis from where it is used for irrigation of all kinds of crops and vegetables. No environmental or health control consideration is given to the workers, products, soil, or the possibility of groundwater contamination. In Yemen, raw wastewater is used for irrigation wherever it exists without any treatment necessary to meet standards of wastewater reuse.

e. Monitoring and evaluation

In several cases, the outflow of wastewater treatment systems does not meet specified quality standards, either because standard operating procedures are not followed (as mentioned above) or because technically qualified personnel to control and monitor plant operations is unavailable. Wastewater authorities in most of the countries in the Middle East and North Africa region are unable to monitor continuously operational parameters in the treatment plant. Trained operators is a prerequisite for the control and monitoring of all treatment and reuse operations (Fatta et al., 2004).

Monitoring and evaluation of wastewater reuse systems in many Arab countries are irregular and not well developed. According to Choukr-Allah and Hamdy (2004), "this is mainly due to weak institutions, the shortage of trained personnel, lack of monitoring equipment, and the relatively high cost required for monitoring processes". Neglecting monitoring procedures and/or performing monitoring irregularly and incorrectly could bring about "serious negative impacts on health, water quality, and environmental and ecological sustainability" (Choukra-Allah and Hamdy, 2004). In addition, it is important to introduce appropriate technical and organizational measures that can systematically and reliably issue warning of impending breakdowns in wastewater treatment plant operations to wastewater reuse managers, in order to avoid the flow of untreated wastewater into the distribution network (Choukr-Allah and Kampa, 2007).

The choice of appropriate wastewater technology could alleviate the finance and monitoring problems. Wastewater plants are generally capital-intensive and require highly trained, specialized operators. Therefore, before selecting and investing in a wastewater treatment technology, an analysis of cost effectiveness needs to be made and evaluated against other available options. Simple solutions that are easily replicated, that allow further up-grading as needs change, and that can be operated and maintained by a local trained workforce are often considered the most appropriate and cost effective. The choice of a technology should be dependant on the type of reuse. The selection of a reuse option should be made on a rational basis. Reclaimed water is a valuable but limited water resource; investment costs should be proportional to the value of the resource. In addition, reuse site must be located as close as possible to the wastewater treatment and storage facilities. Wastewater treatment technologies should be environmentally sustainable, appropriate to local conditions, acceptable to users, and affordable to those who have to pay for them.

Arab countries should allocate the required funds to support applied research geared to the development of sustainable wastewater treatment processes adaptable to the socioeconomic and climatic conditions of the Region.

V. RECOMMENDATIONS

It is desired to bring attention to actions and research needs which are seen as priorities for overcoming the key constraints, discussed earlier, to wastewater treatment and reuse in Arab countries. The recommendations are based on a review of the relevant literature as well as on expert exchange in the context of several European Union (EU) Coordination Actions projects.

These recommendations seek to develop a common Arab framework of guidelines for treated wastewater reuse planning, water quality recommendations, and treated wastewater applications. This framework moreover would provide a consistent approach to the management of health and environmental risk. Although not mandatory and having no formal legal status, the proposed framework shares a common objective while allowing flexibility of approach suited to national, regional, or local contexts.

a. Political and organizational aspects

The reuse of treated wastewater in the Arab region needs fervent political support and the development of appropriate strategies promoting reuse in the context of each country's overall water resources management plan. Commitment to wastewater reuse should be part of proclaimed water policy and strategy in all countries of the Arab region. The lack of organization in the reuse sector should be addressed as a matter of urgency in order to identify the proper institutional structure needed to develop the sector and its regulatory regime. Standards in line with existing or new regulations need to be enforced to preserve the environment and protect consumer health. Arab countries are urged to develop a comprehensive plan of action for reusing treated wastewater with clearly assigned executive roles. The plan should be periodically reviewed and adapted as learning is gained.

Tunisia and Jordan are good examples of countries that made important steps towards garnering political support for wastewater reuse (WaDImena, 2008; MED WWR WG, 2007). Notably, these two countries have achieved the highest rates of wastewater reuse in the region so far.

b. Health and the environment

To mitigate health and environmental risks, common norms and standards for the reuse of treated wastewater in Arab region should also be established (Al Salem and Abouzaid, 2006). So far, different Arab countries have taken different regulatory approaches and standards to manage the reuse of treated wastewater and sludge. In this context, it is important to comply with the framework criteria given in the WHO guidelines for the safe use of wastewater.

To be relevant and responsive, the WHO guidelines need to be adapted to conditions local to each Arab country. In fact, different levels of accepted quality standards will give incentives for improvement in wastewater quality over time. Viable options based on different treatment levels and different end-uses of wastewater (including food and non-food crops, landscaping, or groundwater recharge) should be assessed in order to define the parameters for social acceptance in the Arab region.

Besides mandatory requirements, it is recommended to set up codes of best practices for the use of wastewater in the different countries for various applications. The codes of best practice should contain certain provisions for not impairing the quality of groundwater, for the prevention of leaching from storage, and for the selection of application periods in terms of weather conditions. Best practices should also include selection criteria for crops and for appropriate irrigation methods. The choice of wastewater irrigation application method depends on the quality of the effluent, crops to be grown, farmers' tradition, background, and skills, and finally the potential risk to workers and public health. Localized irrigation techniques (e.g., bubbler, drip, and trickle), offer farm workers the most health protection because they apply wastewater directly to the plants.

Jordan was one of the earliest Arab countries to adopt WHO and FAO effluent reuse guidelines for irrigation (Al-Uleimat, 2008), which served as the basis for the Jordanian Standard (current version 893/2006) on "Water-Reclaimed Wastewater" and "Domestic Wastewater" (GTZ/JVA, 2006). With the support of the Reclaimed Water Project, additional guidelines for irrigation water quality and crop quality and for monitoring and information systems were proposed (GTZ, 2009). The Project also developed agronomic guidelines for the safe use of reclaimed water in the Jordan Valley (Abdel-Jabbar, 2008), seeking to reduce the use of commercial fertilizers and associated costs. In addition, the implementation of monitoring activities has contributed to more transparency regarding health and the environmental impacts of irrigation with reclaimed water (Vallentin, 2006).

Detailed plans are also needed for reducing the amount of potentially hazardous materials, elements, or compounds that end up in the sewer, and therefore in wastewater or sewage sludge. These chemicals owe their presence in wastewaters to daily use of cleaning products, detergents, personal care products, and medicines (Oller et al., 2009). Therefore, consumers should be informed of the composition of these substances or materials that could end up in the sewer and how to dispose of them in a manner that does not pollute wastewaters.

c. Water Demand Management

According to Kfouri et al. (2009), "demand management and water conservation strategies clearly are the most cost effective approaches to reduce withdrawals", and therefore, "for reuse to make sense, it must be part of a larger water strategy" that manages and regulates demand effectively. A good example is Kuwait's Sulaibiya Wastewater Treatment and Reclamation Plant, which will contribute 26% of Kuwait's overall water demand, reducing the annual demand from non-potable sources from 142 million m^3 to 26 million m^3.

Wastewater reuse should be oriented to demand-driven planning by focusing on projects that are committed to reuse. A good example is illustrated by the partnership between the water distributor agency of Marrakech (RADEEMA), the state of Morocco, and the owners of 24 golf courses. The distributor agency will contribute up to US$46.7 million, the golf course owners US$36.7 million, and the state US$16.1 million. The plant will produce 24 million m^3 of tertiary treated wastewater to be used for irrigation. Another good example is the partnership developed between the golf courses of Agadir and Marrakech in Morocco and the water agencies in those cities to supply them with continuous treated wastewater. The demand for treated effluent is driven by the scarcity of this resource in Marrakech, and to the high salinity of the ground water in Agadir area.

d. Awareness

Arab countries should develop a platform for disseminating knowledge gained from existing wastewater treatment facilities in the Arab region. Knowledge sharing would lead to improved availability of information on the economic and financial benefits, the volumes of treated and reused wastewater, benefits to the water economy, and cost recovery of water reuse systems.

Policy-makers should develop national

dissemination plans and awareness campaigns to educate about and advocate using treated wastewater. It is also necessary to communicate up-to-date information on appropriate processing and crop protection technologies to authorities responsible for wastewater treatment and reuse as well as to the end users.

VI. CONCLUSION

The Arab population in 2008 stood at about 343.8 million (AOAD, 2009) with 55% located in urban areas (World Bank, 2007) producing around 10 billion m^3 of wastewater. We urge Arab governments to devote serious effort and clear commitment to promote the reuse of this non-conventional water as an integral part of their water resources management (AOAD, 2007).

All Arab countries of the region have programs for reusing treated wastewater in irrigation. Fodder crops, cereals, alfalfa, olive, and fruit trees are most widely irrigated with treated water. However, few countries have institutional guidelines for regulating the reuse of treated wastewater (MED WWR WG, 2007).

It appears from several reuse projects in the Arab region that we should examine thoroughly whether reuse of treated wastewater outside of agriculture might also be economically feasible and ecologically sustainable. In fact, the reuse of wastewater in industry, for recreational areas, in forestry, and to meet the needs of golf courses seems to be more economical, and could also increase the percentage of reused wastewater. This could contribute to increasing the efficiency of national overall water use.

Still, the full value of treated wastewater has been recognized in only a few water stressed Arab countries (Tunisia, Jordan, and the GCC countries). In these countries, fully-fledged local or state regulations supported by national guidelines, set the basic conditions for wastewater treatment and safe reuse.

The use of treated wastewater should be regarded as a means of increasing water availability. Therefore, water reuse should be considered an integral component in every country's national water strategic plan.

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