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Wastewater Reuse in Agriculture: A Way to Develop the Economies of Arid Regions of the Developing Countries

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Abstract

Choosing the most appropriate technology for wastewater treatment should be based on two issues: affordability and appropriateness that relates to the economic conditions of the community and to the environmental and social conditions, respectively. The community should be able to finance the implementation, operation and maintenance of the system. For a system to be environmentally sustainable, it should ensure the protection of environmental quality, conservation of resources, and the reuse of water. Social aspect mainly relates to factors that can affect the operation and maintenance of the system, and these include local community habits, public acceptance, life style, public health protection, government policy and regulations. The main driving forces for the selection of a treatment technology are performance requirements, site conditions, and wastewater characterization. Proper management of the system helps in protecting public health and local water resources, and avoiding expensive repairs. For widening the base of wastewater reuse in agriculture and to achieve the requirements for unrestricted irrigation, there are needs for optimizing wastewater treatment plants performance with a correction program as well as the low cost technology transfer. Many impediments and challenges concerning wastewater management in developing countries can be overcome by suitable planning and policy implementation.

Keywords

Wastewater Reuse in Developing Countries, Guidelines for Reuse, Health Impact, Selection of Treatment Technology

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1. Introduction and Background

Water scarcity is one of the major constraints to socio-economic development in the arid and semi-arid regions. In addition to low rainfall and frequent droughts, increasing demand for water resources, urbanization, population growth (UNEP, 2003), changing consumption patterns, industrialization and supply-side limiting factors, such as water pollution, exacerbate water resources scarcity. Currently, water consumption in most of these areas is higher than the available water and the water are being met at the expense of the ecological requirements (Boelee, 2011). With climate change, there is a 10-20% reduction in precipitation and increasing variability in some regions by 2050 are expected (IPCC, 2001). The increasing water scarcity of water will lead to intense competition for the resource across sectors; therefore strategies for efficient allocation of the resources will become paramount. Currently, the agriculture sector consumes >70% of available freshwater resources and 93% of water consumption worldwide (Turner *et al.,* 2004), therefore strategies for improving water use efficiency are paramount for reducing water scarcity.

The use of wastewater in agriculture is a possible strategy for addressing water scarcity and nutrients deficiency. In many developing countries, only a small proportion of the wastewater is treated due to financial constraints, lack of

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knowledge about low cost treatment technologies and ignorance about the economic benefits of wastewater reuse (Mara, 2004). Few developing countries depend largely on wastewater primary treatment system, but most of the wastewater is often directly disposed into water bodies thereby contaminating the environment and posing health risks. More than half of the global water bodies are seriously polluted by untreated wastewater (UNEP, 2002). The current growing population and increasing urbanization is exacerbating the wastewater management as this often increase the volume of wastewater. Low cost treatment is generally preferred by any country, especially developing countries (Sato, 2007). Recent evidence has shown that the reuse of partially treated wastewater especially in agriculture could have high economic benefits. However, there are also negative impacts related to wastewater reuse and these include ill-health of farmers; consumers, public acceptability, marketability of products, and economic feasibility and sustainability of wastewater irrigation (WHO, 2006; Raschid-Sally & Jayakody, 2008).

2. Wastewater Treatment Technology

Municipal wastewater composition varies over time, sites and regions. In addition, socio-economic levels of the residential communities and number and types of industrial and commercial units also have implications for environmental health protection and wastewater governance approaches (Hanjra *et al.,* 2012). Municipal wastewater treatment is a well developed engineering science and various techniques are available to efficient treatment (Hussain *et al.,* 2002). Wastewater treatment objectives and properties as well as the available investment resources have to be considered in the choice of the treatment alternatives. Although wastewater treatment improves water quality, its adoption in developing countries is limited by the high capital investment needed and high operation and maintenance costs. The level of treatment also depends a lot on norms and standards of society. Poor institutional framework in developing countries limits the wastewater treatment and that there are less considerations for the environment. The level of treat-ment ranges from primary, producing the lowest water quality, to tertiary which produces the best water quality (Devi, 2009). By primary treatment, at least 30% of BOD, 25% of Kjeldahl-N and total P, 50 to 70% of TSS, and 65% of oil and grease are removed. Faecal coliform numbers are reduced by one or two order of magnitude only, whereas five to six orders are required for safe agricultural reuse. Secondary treatment mainly converts biodegradable organics and some of the nitrogen from wastewater (USEPA, 2004). Stabilization ponds have an advantage that they are efficient and inexpensive and disadvantages that they are land intensive and there is high water loss through evapotranspiration. Wastewater from ponds can only be used for restricted irrigation (Hussain *et al.,* 2002). Tertiary treatment is not suggested for wastewater that is planned to be reused for agricultural irrigation because it is designed to remove the nutrients, which are needed for plants. Basically, industrial wastewater should be treated on the site in order to discard the need for advanced treatment.

The removal of helminth eggs is a concern in developing countries. Helminth ova possess a shell and are responsible on the high resistance under severe conditions. Large size and sticky characters of helminth ova's determine their behavior during treatment (Jimenez, 2005). By treatment, it is not common to inactivate helminth ova but to remove them through sedimentation, coagulation or filtration. Actually, there are correlations between the helminth ova content and the removal by different treatment processes (Chavez *et al*., 2004) as shown on Table 1.

Table 1. Reduction or inactivation of Helminth ova/eggs achieved by selected wastewater treatment processes.

Treatment process	Helminth ova/eggs removal
Waste Stabilization ponds	Excellent
Waste storage and treatment reservoirs	Good
Constructed wetlands	Good
Primary sedimentation	Medium
Advanced Primary treatment	Excellent
Anaerobic up flow sludge blanket	Medium
Activated sludge + secondary sedimentation	Good
Trickling filter + secondary sedimentation	Good
Aerated lagoon or oxidation ditch + settling pond	Excellent
Tertiary coagulation flocculation	Excellent
High rate or slow rate sand filtration	Excellent

Source: El-Gohary *et al*., 1993; Feachem *et al*., 1983; Jiménez 2003; 2005; Jiménez *et al*., 2001; Landa *et al*., 1997; Mara, 2003; Rivera *et al*., 1995; Rose *et al*., 1996; Schwartzbrod *et al*., 1989; Strauss, 1996; von Sperling & Chernicharo, 2005.

The results of Bunani *et al*. (2015) showed that management of conventionally bio-treated wastewater and its reverse osmosis (RO) effluent could be helpful to produce reliable and significance source of reusable water for agricultural irrigation when blended with secondary treated effluent. For developing countries treatment cost should be considered as it will be discussed below.

3. Wastewater Treatment Cost

In developing countries, wastewater treatment systems must fulfill many requirements, such as simple, high efficiency, and low capital; maintenance and operation costs. The cost varies significantly depending on the time frame, location, size of the community and/or climatic conditions of the area. The average wastewater treatment process operating costs ratio between the treatment types was estimated as 1, 2, and 3 for primary, secondary and tertiary treatment, respectively (Molinos-Senante *et al.,* 2010).

Figure 1 below shows the variation of treatment cost versus the target efficiency of secondary treated wastewater in Jordan (plants with capacity of 1000-5000 m^3/day). The lowest efficiency came from stabilization pond whereas the highest came from activated sludge with extended aeration technology.

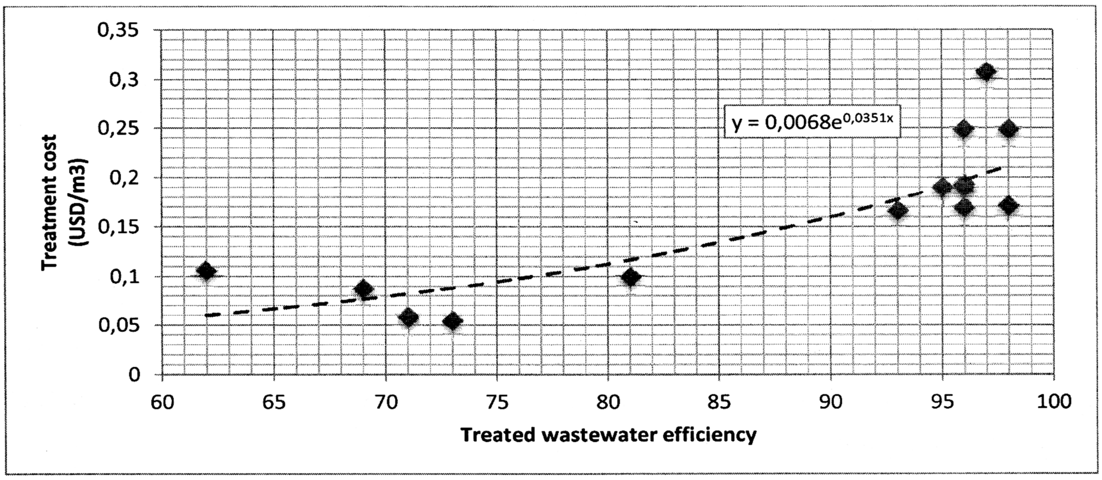

Fig. 1. Variation of treatment cost versus the target treated wastewater efficiency In Jordan (based on secondary data listed by UN, 2003).

Table 2. Advantages and disadvantages of the various wastewater treatment techniques.

	Criteria	Preliminary or primary treatment	Stabilization ponds	Aerated lagoons	Oxidation ditch	Trickling filter	Activated sludge
Plant performance	BOD removal	Poor	Good	Good	Good	Fair	Fair
	SS removal	Poor	Fair	Fair	Good	Good	Good
	FC removal	Poor	Good	Good	Fair	Poor	Poor
	Helminth removal	Poor	Good	Fair	Fair	Poor	Fair
	Virus removal	Poor	Good	Good	Fair	Poor	Fair
Economic factors	Simple & cheap	Good	Good	Good	Fair	Poor	Poor
	Simple operation	Good	Good	Fair	Fair	Fair	Poor
	Land requirement	Good	Poor	Fair	Good	Good	Good
	Maintenance costs	Good	Good	Poor	Poor	Fair	Poor
	Energy demand	Good	Good	Poor	Poor	Fair	Poor
	Sludge removal costs	Good	Good	Fair	Poor	Fair	Fair

BOD: Biological oxygen demand (represent the original load). SS: Suspended solids
FC: Faecal coliform bacteria (represent the microorganisms present in wastewater)
(Perscprd, 1992)

According to table 2, acceptable effluent quality can be achieved from stabilization pond. The exponential relation between efficiency and cost reflects the possibility to get acceptable efficiency within the available budget.

Although it is generally desirable to have higher wastewater quality adopted for non-restricted irrigation, a high capital cost constrains its adoption. Fine *et al.* (2006) showed that, in Egypt, it might not be economically feasible to upgrade wastewater quality to the requirements of non-restricted irrigation as this would increase costs. In other studies by Hussain *et al.* (2002) and Devi (2009), they found that though marginal costs of higher level treatments are very high, sometimes these costs are justified by the crop value, degree of water scarcity, public concern and environmental benefits.

4. Wastewater Reuse in Agriculture

Though there is no comprehensive global data on wastewater reuse, it is estimated that about 20 million hectare use wastewater for irrigation (WHO, 2006), only 10% uses treated wastewater. Wastewater reuse in agriculture under proper agronomic and management practices has many economic benefits which include alleviating freshwater scarcity, providing a drought resistant source of water and nutrients which cut on fertilizer costs, increase water productivity by cultivation multiple crops through the year and confers environmental benefits.

Variability in composition of wastewater causes risks to soil, ecosystems, plants, animals and human beings. So it is necessary to monitor wastewater quality regularly and come up with maximized benefits while minimizing impact of the negatives to make wastewater irrigation sustainable (Grant *et al.,* 2012). The effluent quality varied based on the waste-water treatment technology and efficiency as well as the target level of treatment. Nutrients in wastewater can meet 75% of the fertilizer requirements of a typical farm in Jordan (Carr *et al.,* 2011). On the other hand, excess nutrients can also reduce crop productivity, so there is need for careful nutrient management (Hanjra *et al.,* 2012).

5. Health Impact from Wastewater Irrigation

Wastewater contains pathogenic microorganisms that may have the potential to cause disease, and impact human health. Protozoa and helminth eggs are most virulent and they are most difficult to remove by treatment processes (Hanjra *et al*., 2012). Improved waste-water irrigation is considered as the most effective factor in reducing the hazard of microbial exposure. Improvement process depends on the implementation of suitable farm-level practices and post-harvest intervention, which are classified as non treatment options and can be divided into the following major categories: (i) crop selection and diversification in terms of market value, irrigation requirements, and tolerance of ambient stresses; (ii) irrigation management based on water quality and irrigation methods rates, and scheduling; and (iii) soil-based considerations such as soil characteristics and preparation practices, application of fertilizers and amendments if needed, and soil health aspects.

Flood irrigation is the lowest cost method and will be successful where water is not a limiting factor. Furrow irrigation provides a higher level of health protection, but requires favorable topography. Irrigation with sprinklers and watering cans are not recommended as these spreads the water on the crop surface. Sprinklers require pump and hose, have medium to high cost, and medium water use efficiency, irrigation at night and not during windy condition are important considerations. Drip irrigation, especially with subsurface drippers, can be safe by minimizing crop and human exposure, but pre-treatment of wastewater is needed to avoid clogging of emitters (Oadir *et al.,* 2010).

6. Locally Appropriate Health-Protection Measures

A flow diagram of a decision-making process on locally appropriate health protection measures has been developed (Figure 2). This process considers experience in Ghana and elsewhere where wastewater is used directly for urban and peri urban agriculture, and where municipal wastewater treatment is not a realistic option in the short or medium term. The elements of the decision strategy are as follows: (*numbers in the text refer to the diagram*):

* Where monitoring of wastewater treatment is possible from institutional and financial point of view, the microbiological guidelines for wastewater should be applied. In this situation (1) the guidelines should assist design engineers in the standard of the treatment system from the perspective of crop setting production.

* Where the establishment or maintenance of a functional wastewater treatment facility is not a realistic option, the concerned authorities still have different possibilities for reducing health risks to farmers and consumers. First of all, they are asked to explore alternative water sources or cropping areas (2) with higher quality water (e.g. groundwater). In Cotonou, for example, the authorities alloc-ated new land for urban farmers with the possibility of groundwater access while in Accra; the Water Research Institute is currently exploring groundwater use in wastewater irrigated urban areas. To be successful, these alternatives have to be explored together with the farmers. Additional measures might be recommended if post-harvest contamination is likely (3).

* If alternative land and safe water sources are available and accepted by the farmers, it might be possible to apply the microbiological guidelines (4). If water quality, however, cannot be guaranteed, agricultural engineers should investigate possibilities of (5a, 5b):

a) alternative irrigation technologies and methods reducing:

1) farmer's exposure (e.g. during water fetching and application),

2) crop contact (e.g. surface instead of overhead irrigation), and

3) microbiological water contamination levels (e.g. through shallow wells);

b) crop selection and patterns taking market demand, cultural preferences and gender parlance in cultivation/marketing into account;

c) on-farm water treatment options, such as simple sedimentation tanks, taking into account tenure arrangements, labor constraints and farmers' interest and ability for on-site investments; and

d) awareness campaigns for farmers on their own and on consumers' health risks, plus guidance on health protection measures.

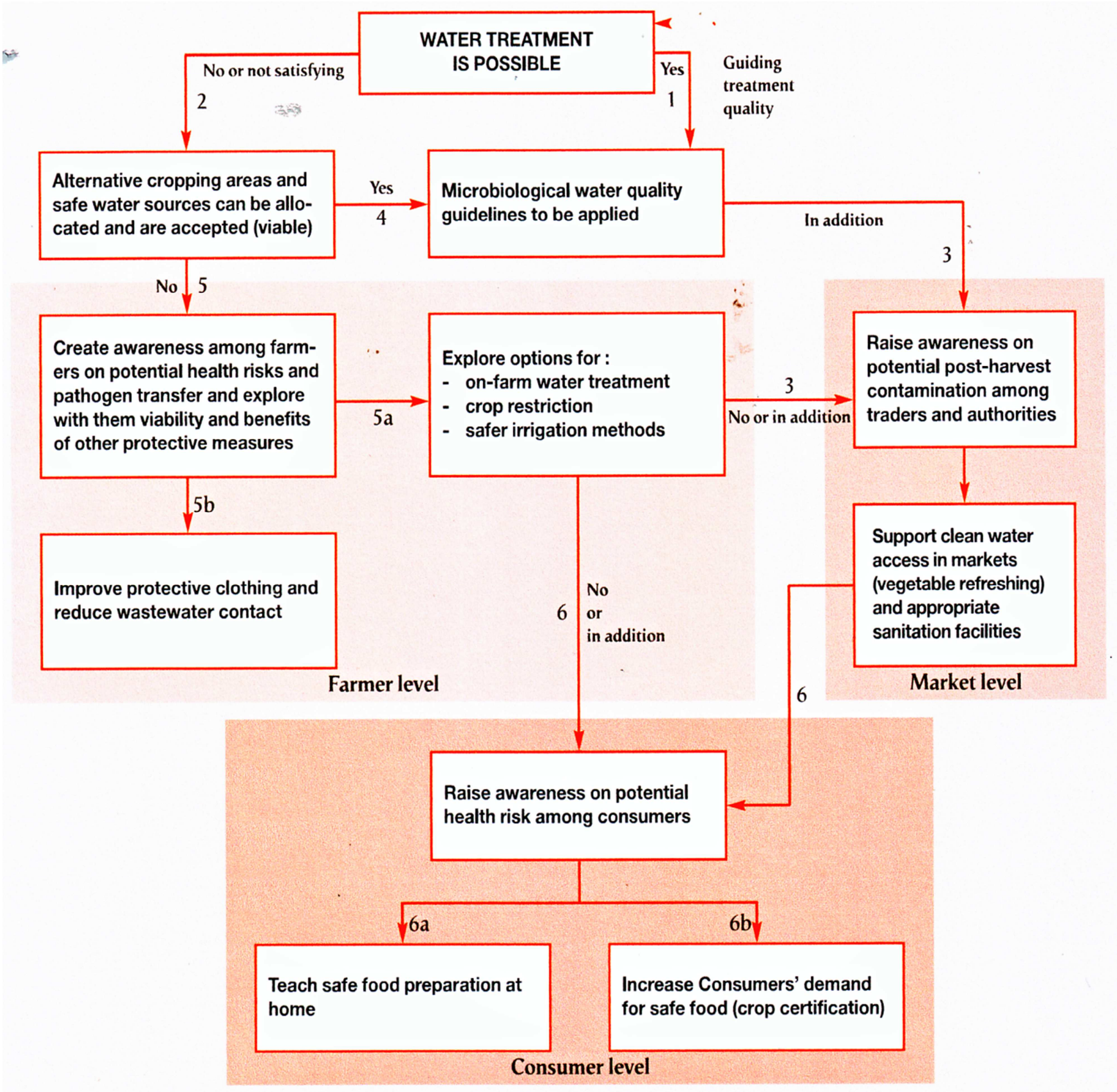

Fig. 2. Flow diagram of a decision-making process on locally appropriate health-protection measure (Drechsel *et al*. 2002).

In all of these cases, alternative risk reducing approaches have to be technically as well as socio-economically and culturally viable. No implementation should be suggested without consideration of farmers' perceptions, attitudes, suggestions and constraints.(1). It can also be crucial to focus on postharvest contamination on markets (3); i.e. on the availability of clean water for vegetable handling, especially crop washing and "freshening up" as well as general hygienic conditions for traders (e.g. availability of sufficient sanitation facilities). This must also be combined with related education and awareness campaigns. Authorities should also consider the well established but often officially ignored informal vegetable markets (e.g. in upper class suburbs), and insist on the availability of clean water. Related costs are likely to be insignificant in comparison with effective wastewater treatment (2). Risks to consumers (6) should be addressed by sensitizing households on the health implications related to polluted irrigation water, and to unhygienic produce handling. Recommendations will have to consider local diets and food preparation behavior and options. Improved vegetable washing and (if possible) cooking can significantly reduce health risks through wastewater irrigation or post-harvest contamination (6a). A related (long-term) target is to raise consumers' demand and willingness to pay for safe food (6 b).

This could catalyze awareness shifts also among traders, farmers and authorities. Crop certification could become an option (Westcot, 1997). However, this transition has still a long way to go in many countries, keeping in mind the dominance of more obvious health risks such as HIV and lack of drinking water as well as general sanitation facilities (Danso *et al.*, 2002a). The strategies related to markets and especially consumers should also receive attention in situations of functional treatment and applied wastewater-irrigation guidelines. The reason is that post-harvest contamination through unhygienic crop handling might take place independently of enforced or non-enforced irrigation guidelines.

7. WHO Guidelines

The WHO recommended a microbial guideline of not more than 1000 faecal coliforms/ 100 ml for unrestricted irrigation, with special emphasis on the removal of helminth eggs (Fine *et al.,* 2006). There are many studies on the farmers' exposure and risk of intestinal nematode infections, and possible links between the consumption of crops irrigated with wastewater. Post-harvesting contamination in markets can be an important factor affecting public health. Beside pathogens, chemical contaminants can be of concern in those countries where industrial development has started and industrial effluent enters domestic wastewater and natural stream (Oadir *et al.,* 2010). This shades cost of the public health impact can be evaluated based on the degree of risk might be affected the farmers or the consumers. Vulnerability factors are irrigation system, farmer behavior, crop types, wastewater quality, harvesting system, consumer behavior, and public awareness effectiveness. In this case, best cost will be at minimum risk. Fine *et al*. (2006) argues zero-risk approach through pathogen removal at the wastewater treatment plant followed by farm protective means that are aimed to block pathogen transfer to others.

8. Application of the Guidelines

In many low-income countries, <10% of the urban wastewater is collected in sewerage systems and treated. Usually, large volumes of wastewater end up in gutters and open drains, and used in dry season for irrigation of perishable cash crops, taking advantage of market proximity. This urban and peri-urban agriculture is more exposed to environmental pollution, including wastewater, compared to other farming systems. Due to the common lack of larger industries in poor countries, health risks are mostly related to microbiological contamination. The application of the guidelines, however, has been found to be difficult in many field situations. To take into account urban and peri-urban agriculture, adjustments were suggested, especially in relation to the following points:

* In many countries, wastewater treatment is not possible due to low resources, and small, old or non-extendable sewerage systems. As the WHO microbiological guidelines expect certain levels of wastewater treatment, their enforcement in situations without any realistic option for treatment would stop hundreds or thousands of farmers from irrigating along increasingly polluted streams, and put their livelihoods at risk, but would also affect food traders and general market supply.

* Especially in market-oriented urban agriculture, it is difficult to apply the recommended additional health protection measures. Farmers use every free space with water access to cultivate crops, especially those of a perishable nature. Although their plots are often small, irrigation allows for year-round farming and these farmers are able to escape from the poverty trap (Danso *et al*. 2002b), while a contribution to the overall urban vegetable supply and diversified diets is made as well. The small land size and insecure land tenure are however significantly constraining farmers' ability to invest in farm infrastructure, such as drip irrigation or on-farm sedimentation ponds. Crop restriction is also often unrealistic as only cash-crop production corresponding to market demand provides the profit on which farmers' livelihoods are based. Thus a change like from vegetables to tree crops would be unrealistic from the land-tenure perspective and also ignores farmers' livelihood strategies. In addition, recommendations to change irrigation systems or cease irrigation before harvest usually do not work out, as products would become damaged by lack of water. Finally, many field interviews show that farmers do not perceive the need for protective clothing.

* Finally, the microbiological part of the WHO guidelines has often been used in isolation from the other protective measures. A reason might be that the defined critical levels appear easier to apply for authorities than the support of other safety measures for health-risk reduction.

9. Adjusting the Guidelines

With regards to these difficulties, it was suggested that the WHO guidelines need to be adjusted for better application in wastewater exposed urban and peri-urban agriculture in resource-poor countries. The overall goal should be to find a better balance between safeguarding consumers' (and farmers') health and safeguarding farmers' livelihood. A stepwise implementation approach for the guidelines was thought to be helpful in that it considers different levels of wastewater treatment and recommendations for regions or countries where (improved) treatment is no realistic option (von Sperling & Fattal, 2001). To achieve this, greater emphasis should be placed further on protective measures, which could include better land allocation, and also targeting post-harvest contamination of crops during transport and marketing.

10. Wastewater Reuse Practices in the Mediterranean Region

Hot and dry summer with mild winter receiving the major part of the annual precipitation characterizes the Mediterranean climate. The most of this region, wastewater recycling and reuse is increasingly integrated in the planning and development of water resources. Cyprus, France, Israel, Italy, Tunisia, and Turkey are the only countries to have established regulations and/or guidelines. Regional guidelines exist also in Spain. Other countries such as Algeria, Egypt, Greece, Lebanon, Libya, Malta, Morocco, and Syria are contemplating guidelines and regulations concerning wastewater recycling and reuse. The following is a brief overview on the situation of some of the non EU countries in the Mediterranean region.

10.1. Tunisia as a Country with Regulations and/or Guidelines Concerning Wastewater Recycling and Reuse

Tunisia has a population of over 10 million with arid to semi-arid climate. Tunisia has a Total Actual Renewable Water (TARWR) per capita of 443 m^3 yr^{-1}, well below 750 m^3 yr^{-1} so it is already apparent that food production cannot be sustained. Moreover the Millennium Development Goal Water Indicator (MDGWI) last reported in 2001 for Tunisia was 57% meaning that Tunisia is going to be facing severe water shortage problems in the forth coming years and decades. Tunisia has a long history of wastewater reclamation and reuse for irrigation. Guidelines were established in the eighties. Tunisia is among the first countries in the Mediterranean Basin to have established and implemented wastewater reuse policy (Kellis *et al*., 3013).

Wastewater from la Cherguia treatment plant has been used since 1965 to irrigate the 1200 ha of la Soukra (8 km North East of Tunisia) and save citrus fruit orchards as aquifers had become overdrawn and suffered from saline intrusion. The effluents from the treatment plant were used, exclusively or as a complement to groundwater.

Water from la Cherguia's secondary sewage treatment plant is pumped and discharged into a 5800 m^3 pond before storage in a 3800 m^3 reservoir. The water is then delivered by gravity to farming plots through an underground pipe system. A Regional Department for Agricultural Development supervises the operation and maintenance of the water distribution system and controls the application of the Water Code.

After this experience, a wastewater reuse policy was launched at the beginning of the eighties. The 6,366 ha involved in 1996 was expanded to 8,700 ha in 1998 and ultimately to 20,000 ha. Wastewater reuse in agriculture is regulated by the 1989 Decree No. 89-1047, by the Tunisian standard for the use of treated wastewater in agriculture (NT 106-003 of 18 May 1989), by the list of crops that can be irrigated with treated wastewater (Decision of the Minister of Agriculture of 21 June 1994) and by the list of requirements for agricultural wastewater reuse projects (Decision of 28 September, 1995). They prohibit the irrigation of vegetables that might be consumed raw. Therefore, most of the recycled wastewater is used to irrigate vineyards, citrus and other trees (olives, peaches, pears, apples, pomegranates, etc.), fodder crops (alfalfa, sorghum, etc), industrial crops (cotton, tobacco, sugar-beet, etc), cereals, and golf courses. Some hotel gardens in Jerba and Zarzis are also irrigated with recycled wastewater (Angelakis, 2002 and Abu-Madi, 2004).

The 1989 decree stipulates that the use of recycled wastewater must be authorized by the Minister of Agriculture, in agreement with the Minister of Environment and Land Use Planning, and the Minister of Public Health. It sets out the precautions required to protect the health of farmers and consumers, and the environment. Monitoring the physical-chemical and biological quality of recycled wastewater and of the irrigated crops is planned. In areas where sprinklers are used, buffer areas must be created. Direct grazing is prohibited on fields irrigated with wastewater.

Specifications determining the terms and general conditions of recycled wastewater reuse, such as the precautions that must be taken in order to prevent any contamination (workers, residential areas, consumers, etc.), have been published. The Ministries of Interior, Environment and Land Planning, Agriculture, Economy and Public Health are in charge of the implementation and enforcement of the decree.

It is important to note that in Tunisia, the farmers pay for the treated wastewater they use to irrigate their fields (Angelakis, 2002).In addition to the reuse of treated wastewater for irrigation it is currently reused for recharge of the aquifer and the protection of biodiversity in wetlands (INNOVA, 2009).

10.2. Countries Implementing Regulations and/or Guidelines Concerning Wastewater Reuse

10.2.1. Algeria

Algeria is presently looking at improving water availability (600m^3/inh/yr) by adopting a new water resources policy and new alternatives that enable to ease the crisis. Treated wastewater represents a promising alternative that is not only constantly available but also increasingly available with the development of cities, tourism and industry. In the agricultural sector, reuse of wastewater is a technique that adds to the value of the water resources while it protects the environment.

In Algeria, the total wastewater disposal has expected to reach $1.5x10^9$ m^3 in 2010 from 15 treatment plants, but due to sewerage networks conditions, the population rate connected to the network and the availability of wastewater treatment facilities, projections suggest the possibility of reusing not more than 6.0 $x10^8$ m^3 in that same year (Tamrabet, 2002). The Algerian authorities have initiated a program that enables the rehabilitation of 28 treatment stations, the construction of new wastewater treatment stations and wastewater stabilization ponds. For the success of the program an efficient follow up and periodic evaluation is necessary to safeguard the water resources and the environment from negative impacts of pollution (Kalavrouziotis and Arslan-Alaton, 2008).

The Algerian laws prohibit the reuse of the raw or treated wastewater for the irrigation of raw-eaten vegetable crops; but it is allowed in the production of fodder crops, pasture and trees (Kamizoulis *et al*., 2003). The Algerian laws oblige also the cities of more than 10^5 inhabitants to treat their effluents in treatment plants, prior to any disposal or reuse, and in less populated areas through wastewater stabilization ponds or sedimentation basins. Consequently, in the last few years, the Algerian authorities have initiated an ambitious program that enables mainly: (a) the rehabilitation of 28 wastewater treatment stations, (b) the construction of 35 new wastewater treatment stations for the cities of more than 10^5 inhabitants, and (c) for small populated areas, the construction of 8 wastewater stabilization ponds and 435 sedimentation basins. For the success of the program, there must be an efficient follow up and periodic evaluation so that the wastewater valorization becomes fruitful, and to safeguard the water resources and the environment from negative impacts of pollution (Tamrabet, 2002).

10.2.2. Libya

Libya has a population of over 6 million. Libya has a Total Actual Renewable water (TARWR) per capita of 95.8 m^3 yr^{-1}, the lowest in all Mediterranean countries and well below 750 m^3 yr^{-1} so it is already apparent that food production cannot be sustained. Moreover the MDGWI last reported in 2001 for Libya was 793%, meaning that Libya has already withdrawn all available resources from its territory. Despite the direct need of the country for water there are no guidelines for wastewater reuse in Libya. Less than 10% of the wastewater generated in Libya (546 Mm^3 yr^{-1} in 1999) is treated (40 Mm^3 yr^{-1}) and it is reused in restricted agricultural applications only (Asano *et.al.*2007).

10.2.3. Egypt

The Egyptian water strategy comprises the treatment and reuse of treated wastewater. Treatment of domestic wastewater is either primary or secondary. In 2013, wastewater volume is 6.5 Bm^3/yr, with 357 operational treatment plants. The total amount of treated waste is 3.65 Bm^3, of this 20% (0.73 Bm^3) is primary treated and 80% (2.92 Bm^3) is secondary treated. The treatment technologies used are: 79% activated sludge and oxidation ditches, 11% stabilization ponds, 5% trickling filters and 0thers 5% (Abdel-Wahab, 2013).

Since year 1900, sewage water has been used to cultivate orchards in El-Gabal Elasfar Village, near Cairo. The area gradually increased to about 4,500 ha. By law, reuse of treated wastewater is prohibited for food and fiber crops. The Ministry of Agriculture advocates the restricted reuse of treated wastewater for cultivation of timber trees and green belts in the desert.

The major problems and issues related to the current use of treated sewage water in Egypt are summarized below (Shaalan, 2001):

(a) insufficient infrastructure to treat all wastewater produced,

(b) approximately 50% and 3% of the urban and rural populations, respectively, are connected to sewerage systems,

(c) a significant volume of raw wastewater enters directly into water bodies,

(d) many treatment facilities are overloaded and/or not operating properly,

(e) some industries still discharge their wastewater with limited or no treatment into natural water bodies,

(f) domestic and industrial solid wastes are mainly deposited at uncontrolled sites and/ or dumped into water bodies,

(g) the quality of treated wastewater differs from one station to another, depending on inflow quality, treatment level, plant operation efficiency, etc. and

(h) negative impacts of the above problems on both health and environment (Bazza, 2002).

From the institutional standpoint, seven ministries are involved in wastewater treatment and reuse, with unclear delineation of responsibilities and limited coordination among them. The situation is further worsened by the absence of clear policies and action plan on wastewater management as well as standards that are practicably impossible to enforce and which limit the effectiveness of pollution control abatement efforts. Dissemination of information among various organizations and to the public is limited, which substantiates the need for increased awareness and capacity strengthening regarding water quality management issues (Shaalan, 2001).

• *Decree No. 603/ 2002*—Decision of the Deputy Prime Minister and Minister of Agriculture and Land Reclamation prohibits the use of wastewater, whether treated or untreated, for irrigating traditional field crops. Irrigation is only used in the limited cultivation of trees for timber and ornamental trees, taking into account the measures to protect the health of workers in agriculture.

• *Decree No. 1038/2009* Decision of the Minister of Agriculture and Land Reclamation to prohibit the use of wastewater for the irrigation of all food crops. No permission to own new lands would be approved, unless the Ministry of Water Resources and Irrigation (MWRI) confirmed the existence and suitability of a source for irrigation.

Egyptian Code for the Reuse of treated Wastewater in Agriculture (501/2005)

The Ministry of Housing, Utilities, and New Communities, supported by seven technical committees, issued the Code for the Reuse of Treated Wastewater in Agriculture. The Code stipulates exact requirements in planning and approval procedures, responsibilities, permitted use, and monitoring.

According to the Code, the reuse of treated wastewater is prohibited for the production of vegetables, whether eaten raw or cooked; export-orientated crops (i.e. cotton, rice, onions, potatoes, and medicinal and aromatic plants); as well as citrus fruit trees; and irrigating school gardens.

The Code classifies wastewater into three grades (A, B, and C) as follows, depending on the level of treatment, and specifies the maximum contaminants level with each grade, and the crops that can be irrigated with each grade. The Code further stipulates conditions for irrigation methods and health protection measures for farm workers, consumers, and those living on neighboring farms (Tables 3 & 4).

Table 3. Limit values for Treated Wastewater Reused in Agriculture.

Treatment Grade Requirements		A	B	C
Effluent limit values for physic-chemical parameters (mg/L)	BOD_5	<20	<50	<250
	SS	<20	<60	<400
Effluent limit values for biological parameters	Fecal coliform count in 100 mL	<1000	<5000	Unspecified
	Nematode cells or Eggs per liter	< 1	< 1	Unspecified

Excerpted from "Egyptian code for the use of treated wastewater in agriculture" February, 2005.

Table 4. Classification of Plants and Crops Irrigable with Treated Wastewater. (Back to the original copy for Table format).

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

Excerpted from "Egyptian code for the use of treated wastewater in agriculture" February, 2005.

Grade A is advance, or tertiary treated that can be attained through upgrading the secondary treatment plants to include sand filtration, disinfection and other processes.

Grade B represents secondary treatment performed at most Egyptian facilities. It is undertaken by activated sludge, oxidation ditches, trickling filters, and stabilization ponds.

Grade C is primary treatment that is limited to sand and oil removal basins and use of sedimentation basins.

10.2.4. Morocco

The actual total volume of sewage in morocco is about 750 M m^3; 48% are discharged into the rivers or applied to land; the rest is discharged as raw wastewater into the sea. The pollution load from wastewater is estimated at about 131715, 42131 and 6230 tons of organic, nitrogen and phosphorous, respectively. Most of the wastewater produced by towns is reused, mainly as raw or insufficiently treated, to irrigate about 7500 hectares. This could represent a source of public health hazards, beside the possible degradation of ground water quality. In urban area, only 70% of the population is connected to the sewerage system and about 4.5 millions using autonomous purification systems (ADB, 2006). Morocco has 100 wastewater treatment plant, more than half of them are not functional for technical, financial or human reasons (Mandi, 2012). This situation represents contamination risks for receiver environment in general, and for water resources in particular. Therefore, a national sanitation program is developed to improve the sewerage system, domestic and industrial wastewater treatment, and development of the reuse practices.

In 2005, the National Sanitation Program was approved a plan to treat 60% of the collected wastewater; connecting 80% of urban houses to sewers by 2020; reduce pollution caused by wastewater at least 60% and increase the reuse (Royaume du Maroc, 1995).

Since 1950s, Morocco has introduced biotechnologies for urban wastewater treatment; these included activated sludge, trickling filter and bio-disc. Activated sludge plants faced problems of lack of maintenance and the high energy costs. The necessary fund for sustaining the operation of these plants was not governmentally allocated. In 1990s, ponds as well as sand filters technologies were employed in most of wastewater treatment plants. Until 1993, there were 55 wastewater treatment plants. Only 18 of them were operating normally, while 31 of them were out of service and pumping stations could not be financed for the remaining 6 plants (Mandi, 2000). For low investment and operating costs, natural stabilization ponds were recommended in the early 2000 by the National Sanitation Master Plan. For large area required for ponds, activated sludge technology has been chosen to be applied in large cities. Actually Morocco has more than 100 wastewater treatment plants of which more than 77% are natural lagoons which prove their effectiveness for both small as well as large municipalities (Ouazzani *et al.,* 1995). In Morocco, combined pond systems (aerated lagoons and storage reservoir as well as anaerobic, aerated lagoons, facultative, and maturation ponds consecutively) produce an effluent that meets the non-restricted irrigation requirements.

The new Marrakesh WWTP, is receiving 120,000 m^3 /d of wastewater (pre-treatment, primary treatment in sedimentation tank, secondary treatment employing activated sludge, tertiary treatment by sand filter and disinfection by UV). Biogas produced from sludge used for electricity generation (10.5 GWh/year) representing a part of the electricity consumed by the plant (30 GWh/year). About more than 70% of the treatment plant effluent are reused for recreational purposes. The treatment and reuse of Marrakech's wastewater is a milestone in sustainable development, which made significant progress towards attaining Morocco's national target of 60% treated wastewater by 2020.

The majority of the biotechnologies for domestic wastewater treatment implemented in several small and medium communities still not functional for financial, social, capacity building (experience staff), the production of final effluent does not comply with specified quality standards.

The application Decree (No. 2-97-875 dated Feb. 4, 1998) related to the use of wastewater stipulated that untreated wastewater use is prohibited and banished. The Norms and Standards Committee (NSC) is setting objectives for the quality of receptor medium. Among the suggested norms, there is a project related to quality standards of wastewater designed for irrigation.

The discharge of raw wastewater to the sea without proper outfalls may affect the development of tourism by degrading the sanitary quality of beaches and generating unpleasant odors and aesthetics. Major improvements are needed urgently because of the strong migration of the rural population towards the towns and the very fast demographic expansion. Studies of sanitation master plans for the main towns are currently in progress and are a first step towards meeting these requirements. The setting-up of a Liquid Sewage National Master Plan is a way of extending this procedure over the whole territory.

10.2.5. Syria

The total volume of industrial and municipal wastewater effluent is estimated at 400, 700 and 1600 Mm^3/yr for years 1990, 2000, 2025, respectively. The discharge of these wastes in a non-treated form into watercourses and rivers led to water quality deterioration. The most important results of this noticeable pollution of rivers and other water bodies were the disappearance of living organisms, the appearance of undesirable plants and weeds, hateful odors and the abundance of insects and rodents. The health conditions of the population living in the areas of intensive use of untreated wastewater also degraded. Diseases such as typhoid and hepatitis spread at a much greater rate (Angelakis, 2003). Animals were also subjected to several waterborne diseases such as tapeworm and tuberculosis and other infectious diseases (Bazza, 2002). The total area irrigated with wastewater is estimated at around 40000ha, with 20000 ha in Aleppo (Zulita & Abboud, 2001).

Several WWTP have been already implemented, such as Damascus (Adra), Aleppo, Homs, Salamyeh, Ras El Ein, and Haramil Awamid. The treated wastewater potentially available for reuse is estimated at 400 Mm^3/yr by which an area > 40,000 ha could be irrigated. Several other WWTP are under planning or construction such as Tartus, As Sweida Idleb, Al Raqqua, Al Nabik and Dar'a. Thus, the treated wastewater is expected to increase substantially in the near future.

To face this alarming situation and at the same time secure treated water for use in agriculture, the Syrian government launched a programme for constructing several WWTP two of which are already operational in Damascus and Aleppo. The total area irrigated by treated and untreated water is 18,000 ha located in the outskirts of Damascus. With the exception of a large share of wastewater produced in Damascus and Aleppo, the collected raw sewage is used either for direct irrigation of agricultural crops or disposed of in the sea or water bodies that are used for unrestricted irrigation. The use of wastewater is restricted to fodder, industrial crops and fruit trees on smaller areas. The situation is expected to improve when the treatment plants under construction in all large cities of the country will be operational. In towns and areas where traditional sewerage systems have been inefficient, people are reluctant to pay wastewater connection fees. The shortage of information and awareness on wastewater risks and benefits is also evident (Bazza, 2002).

10.2.6. Lebanon

Way back in 1991, the total volume of wastewater generated in the country was 165 Mm^3, of which 130 Mm^3 from domestic uses and 35 Mm^3 from industry. It was therefore evident that this huge potential for wastewater treatment and reuse has been lost. At present, only 4 Mm^3 of wastewater are treated, of which 2 Mm^3 are used for irrigation, and the rest is disposed of in the marine environment, or infiltrated by deep seepage to groundwater. Present estimates indicate that 35 to 50% of the untreated urban sewage are infiltrated to the aquifers due to the lack of adequate discharge networks, and pumped again for irrigation and domestic uses. Further, recent studies show that 89.6% of the industrial and domestic solid waste are untreated and put in natural places as rubbish, and 10.4% are dumped in the rivers. This non-point source of pollution constitutes a direct threat to the vulnerable underground water (Karam, 2002).

Due to this situation, corrective measures are now carried out by the government, aiming at implementing in different locations sewage treatments plants, with the aim to provide second-class water, suitable for irrigation and industrial use.

11. Impact of Wastewater Reuse on Soil

Wastewater irrigation may lead to transport of heavy metals to soils, affecting soil flora and fauna and may result in crop contamination. Some of heavy metals may accumulate in the soil while others such as Cd and Cu may be redistributed by soil fauna such as earthworms (Dikinya & Areola, 2009; Kruse & Berrett, 1985). The impact of wastewater irrigation on soil may depend on a number of factors such as soil properties, plant characteristics and sources of wastewater. The impact of wastewater from industrial, commercial, domestic, and dairy farm sources are likely to differ widely. Wastewater irrigation may have long-term economic impact on the soil, which in turn may affect market prices and land values of water logged soil (Hussain *et al.* 2002).

12. Wastewater Reuse Constraints

The main constraints facing use of wastewater are:

- Financial constraints related e.g. to high costs (of treatment systems, sewerage net-works, operational) and low prices of freshwater compared to reclaimed wastewater, low user willingness to pay for reclaimed wastewater.
- Health impacts and environmental safety especially linked to soil structure deterioration, increased salinity and excess of nitrogen.
- Standards and regulations, which are in some cases too strict to be achievable and enforceable and, in other cases, not adequate to deal with certain existed reuse practices.
- Monitoring and evaluation in both treatment and reuse systems, often related to lack of qualified personnel and monitoring equipment or high cost required.
- Technical constraints, including, for instance, insufficient infrastructure for collecting and treating wastewater, inappropriate set up or improper function of existing infrastructure.
- The low coverage with sanitation systems in combination with a sub-optimal treatment.
- The implementation of large-scale centralized treatment facilities which produce large amounts of wastewater which cannot be used for irrigation and is often discharged into water bodies.

• Institutional set-up (especially poor coordination at relevant intra- and intersect oral levels) and lack of appropriate personnel capacity.

• Lack of political commitment and of national policies/ strategies to support treatment and reuse of wastewater.

• Lack of communication and coordination among the many authorities working in wastewater treatment and reuse.

• Absence of programs to monitor the quality of reclaimed wastewater, before or after reuse, for possible health risks for farm laborers and end users of products.

• Public acceptance and awareness, related to low involvement and limited awareness of both farmers and consumers of crops grown with reclaimed wastewater.

• Consequently, reuse of water is a lost opportunity, as wastewater is either buried away in cesspools, or discharged into receiving water bodies.

It is worth mentioning that in Egypt many people remain suspicious of reuse since they are uncertain of the quality of treated water. Perhaps most important, reclaimed water cannot be used for high-value vegetable crops. It has been indicated that social acceptance, regulations concerning crop choices, and other agronomic considerations strongly influence decisions about water reuse. Finally, psychological and social factors associated with wastewater reuse should be considered as they may represent negatives facing wastewater reuse (Julia *et al*., 2015).

13. Conclusions

1. Water has a precious value and each drop must be accounted-for in water scarce regions such as the Middle East and North Africa. Therefore, wastewater has to be reclassified as a renewable water resource rather than waste as it helps increase water availability and, at the same time, prevents environmental pollution. In most of the developing countries in arid and semi-arid regions, the additional water resources brought by wastewater reuse can bring significant advantages to agriculture (e.g. crop irrigation) and tourism (e.g. golf course irrigation). The full use of all generated wastewater in developing countries means development in their economy.

2. In the developed countries much work has been done in the field of wastewater reuse system but we can't say the same about developing countries. In developing countries wastewater reuse is still in the begin-ning stage and much work is needed in that field.

3. Wastewater treatment performance now a day is a big problem, if we improve our methodology we will definitely solved large problem.

4. Developing countries are unequally developed; several being already equipped with wastewater treatment plants while others have virtually no equipment. Therefore, all countries can not be expected to be able to meet the reuse guidelines in the same time. There are plenty of emerging technology which are making increase performance of wastewater in reused system, but we use only appropriate technology whom suitable.

5. In most developing countries, stabilization ponds and aerated lagoons are more economical and more efficient wastewater treatment which produces effluent suitable for agricultural irrigation. It is totally a biologic process.

6. In developing countries there is a need for a holistic approach with respect to water resources management and this imposes the need for wastewater reclamation and reuse criteria. Some countries such as Tunisia have established national regulation or guidelines. Others such as Algeria, Libya, Egypt, Morocco and Lebanon are considering guidelines and/or regulations concerning wastewater reuse.

7. Establishing unified developing countries guidelines for municipal water reuse is a challenge because of the lack of comprehensive international guidelines, and of an agreement on the scientific approach that should be adopted to issue such guidelines. Thus, it is expected that providing minimum requirements, which should provide the most basic water reuse regulations, in every country will encourage compliance by all countries and will reduce the threat of water scarcity.

8. In most of the developing countries in arid and semi-arid regions, the additional water resources brought by waste-water reuse can bring significant advantages to agriculture (e.g. crop irrigation) and tourism (e.g. golf course irrigation). The full use of all generated wastewater in developing countries means development in their economy.

9. A regional committee should be established with internationally recognized water reuse experts, practitioners and regulators from developing countries to periodically re-evaluate and update the guidelines in order to ensure that they are supported by the best available scientific data and risk assessment methods, and to validate the effectiveness of recycled water management practices.

10. Perhaps most important, reclaimed water cannot be used for high-value vegetable crops. It has been indicated that social acceptance, regulations concerning crop choices, and other agronomic considerations strongly influence decisions about water reuse. Finally, psychological and social factors associated with wastewater reuse should be considered as they may represent negatives facing wastewater reuse.

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