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Choukr-Allah R.

in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 2]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.II

2007
pages 115-128

TREATED WASTEWATER SOURCES: ACTIONS TOWARDS SUSTAINABLE AND SAFELY USE IN THE NEAR EAST AND ACHIEVING FOOD SECURITY IN WATER-SCARCE POOR RURAL COMMUNITIES

R. Choukr-Allah
Head of the salinity and plant nutrition laboratory I.A.V Hassan II Agadir, Morocco BP 773
E-mail: redouane53@yahoo.fr or choukrallah@iavcha.ac.ma

SUMMARY- Near East and North Africa countries (NENA) are characterized by severe water imbalance uneven rainfall, and at the same time, are unable to meet their food requirements using the available water resources. Treated and re-used sewage water is becoming a common source for additional water. Some of these countries have included wastewater re-use in their water planning. This will narrow the gap between freshwater supply and demand in different water-use sector.
Wastewater recycling and reuse have become increasingly important for two reasons in the NENA region. Firstly, properly treated municipal wastewater often is a significant water resource rich in nutrients for crop production. Secondly, discharge of sewage effluent into surface effluent into surface water is becoming increasingly difficult and expensive as treatment requirements become more stringent to protect receiving waters such as rivers, estuaries, and beaches.
In small communities, the quality of the effluent from wastewater treatment plants (WWTP) is limited by the low feasibility of investment in construction of small-scale WWT facilities and in their operation. Using the treated effluent for irrigation purposes adds an economical driving force for investments in WWT. Another economic advantage of choosing agricultural irrigation, as a final disposal solution for the treated effluent is that it permits low quality demands, especially in regard to nutrients removal. Final disposal by irrigation is usually combined with non-compromising hygienic demands. Controlled utilization of the treated effluent reduces the environmental risks of polluting lakes, rivers and/or other land and water resources, which might be caused by other alternatives of effluent disposal.
Governments in NENA should assess the reuse of treated wastewater with an integrated approach taking into account not only the monetary cost and benefits in terms of ecological, social and economic concerns, but more to consider a systemic perspective of the sustainability impacts. Moreover such a systemic perspective should be developed in a participatory process with a specific focus on the local or regional conditions. Furthermore the acceptance for the reuse and the costs of treating the wastewater and transporting it to the reuse location should be taken into account and handled appropriately.

This paper will address the integrated approach for reclamation and reuse of treated wastewater? The criteria and standard that should be applied for wastewater reuse in agriculture? What are the appropriate treatment technologies to be used for poor rural areas? What are the viable options for reuse of waste water, what are the most salient constraints (both technically, institutionally and financially), and how can we move forward with the use of treated waste water for agriculture within the parameters of rural development in the NENA region, including sustainability issues?

INTRODUCTION

Near East and North Africa countries (NENA) are characterized by severe water imbalance uneven rainfall, and at the same time, increased demands for irrigation and domestic water supply have been occurred in recent last two decades as a result of expending urban population and tourist industry. . This region is the driest on earth, containing only 1% of the world's freshwater resources and will become water-stressed because of increased water scarcity (Seckler et al., 1998; FAO, 2003) (*Table 1*). Although water is recycled in the global hydrologic cycle for millenniums; much smaller-scale planned local water recycling and reuse have become increasingly important for two reasons in the NENA regions.

Evaluating the challenges and opportunities for using marginal-quality waters will help in guiding investment and management decisions pertaining to land and water management in agriculture. Considering the growing water shortage in the Near East and North Africa countries and history of water use, it is expected that the use of marginal-quality waters for various purposes will be more common in the foreseeable future. Key decisions are needed in the short and long terms in relation to the use of such water resources to support achievements of the United Nations' Millennium Development Goals to enhance food security and environmental quality during the next 50 years. In addition, there is a need to address the current situations where marginal- quality waters are already used for food production especially in resource-poor environments, where regulations need to be realistic and feasible

Agriculture reuse of treated wastewater should be integrated into comprehensive land and water management strategy taking into count water supply, type of treatment technology, final reuse, social and economic context. The reuse of treated waste water enhance agriculture productivity in several NENA countries, however it will require public health protection, appropriate treatment technology, public acceptance and participation. This paper assesses the current situation regarding the use and significance of wastewaters in agriculture and also provides insight into the technological, institutional, and policy options that might help in increasing its advantages and opportunities while reducing possible negative impacts on people and the environment.

Table 1. Estimates of populations and natural renewable water resources (NRWR) per capita in selected NENA countries during the year 2002 and projections for the year 2025.

Country	Population (× 10^3)		NRWR (m^3 $capita^{-1}$ yr^{-1})[b]	
	2002	2025[c]	2002	2025[d]
Kuwait	2023	3219	10	6
United Arab Emirates	2701	3468	56	43
Qatar	584	754	91	70
Libya	5529	7972	109	75
Saudi Arabia	21701	40473	111	59
Jordan	5196	8666	169	102
Bahrain	663	887	175	131
Yemen	19912	48206	206	85
Israel	6303	8486	265	197
Oman	2709	5411	364	182
Algeria	31403	42738	460	338
Tunisia	9670	12343	577	452
Egypt	70278	94777	830	615
Morocco	30988	42002	936	691
Lebanon	3614	4581	1220	962
Syria	17040	27410	1541	958

Source: Qadir and al 2006. (based on databases of the AQUASTAT Information System of Food and Agriculture Organization of the United Nations, the World Bank, and the World Resources Institute; modified from World Resources Institute, 2003)[a]

[a] Selected countries from West Asia and North Africa and Sub Saharan Africa.
[b] NRWR include Internal Renewable Water Resources plus or minus the flows of surface and groundwater entering or leaving the country, respectively.
[c] UN medium variant population projections for the year 2025.
[d] Based on the assumption that the NRWR in the countries in 2025 will remain the same as in 2002.

POTENTIAL OF TREATED WASTEWATERS

The volume of wastewater increases with increasing population, urbanization, and improved living conditions (Raschid-Sally et al., 2005). Considering 20% as the depleted fraction from urban water use and anticipating growth in urban water supply coverage as a proxy for amounts of wastewater generated, it is revealed that in spite of reliance on onsite sanitation, wastewater from Near East and

North Africa cities will pollute large volumes of water for the downstream agriculture (Scott et al, 2004). In most developing countries, urban drainage and disposal systems are such that wastewater generated by different activities gets mixed and the resulting effluent may be disposed of in a wastewater treatment plant, in another water body, or diverted to farmers' fields in treated, partly treated, diluted and/or untreated form (Qadir et al.2006).

Table 2. Volume of wastewater generated annually in some NENA countries

Country	Reporting year	Wastewater volume ($\times 10^6$ m^3 yr^{-1})
Algeria	2004	600
Bahrain	1990	45
Egypt	1998	10012
Jordan	2004	76
Kuwait	1994	119
Lebanon	1990	165
Libya	1999	546
Morocco	2002	650
Oman	2000	78
Saudi Arabia	2000	730
Syria	2002	825
Tunisia	2001	240
Turkey	1995	2400
United Arab Emirates	2000	881
Yemen	2000	74

Source: (Aquastat, FAO, 1997, Qadir and al. 2006)

WASTEWATER AS ADDITIONAL WATER RESOURCE

There are several benefits of treated wastewater reuse. First, it preserves the high quality, expensive fresh water for the highest value purposes–primarily for drinking. The cost of secondary-level treatment for domestic wastewater in NENA, an average of $US 0.2 to 0.5/m3, is the cheaper, in most cases much cheaper, than developing new supplies in the region (WB, 2000). Second, collecting and treating wastewater protects existing sources of valuable fresh water, the environment in general, and public health. In fact, wastewater treatment and reuse (WWTR), not only protects valuable fresh water resources, but it can supplement them, through aquifer recharge. If the true, enormous, benefits of environmental and public health protection were correctly factored into economic analyses, wastewater collection, treatment and reuse would be one of the highest priorities for scarce public and development funds. Third, if managed properly, treated wastewater can sometimes be a superior source for agriculture, than some fresh water sources. It is a constant water source, and nitrogen and phosphorus in the wastewater may result in higher yields than freshwater irrigation, without additional fertilizer application (Papadopoulos, 2000). Research projects in Tunisia have demonstrated that treated effluent had superior non-microbiological chemical characteristics than groundwater, for irrigation. Mainly, the treated wastewater has lower salinity levels (WB, 2000, pg.8).

Estimates of the extent to which wastewater is used for agriculture worldwide reveal that at least 2×10^6 ha are irrigated with treated, diluted, partly treated or untreated wastewater (Jimenez and Asano, 2004). The use of untreated wastewater is intense in areas where there is no or little access to other sources of irrigation water and is being practiced in several North African countries.

Table 3. Annual domestic and industrial water use and potential treated wastewater for reuse in some NENA countries.

	Total Potential Irrigation Savings	Domestic Savings Potential	industrial/Commercial Savings Potential	Treated Wastewater Potential for use	Water Savings l Potential
	M m3/year	M m3/year	M m3/year	M m3/year	M m3/year
Syria	1,360.0	174.1	3.5	135.9	1,673.5
Lebanon	95.0	99.7	1.9	286.3	482.9
Jordan	73.8	71.0	0.4	89.7	234.9
Egypt	4,773.0	1,079.4	55.5	5,108.1	11,016.0
Libya	400.2	161.9	1.2	248.0	811.2
Tunisia	270.6	91..5	1.2	201.1	564.3
Algeria	270.0	368.3	8.4	1,138.6	1,785.4
Morocco	1,016.1	186.5	4.1	553.9	1,760.6
Turkey	2591.5	1,818.8	48.8	6,173.9	10,633.0
Total	16,976	10,250	781	65,968	93,974

WASTEWATER REUSE IN THE NEAR EAST AND NORTH AFRICAN COUNTRY

Countries in the region which practice wastewater treatment and reuse include Jordan; Lebanon, Tunisia, Israel, Kuwait, Emirates, Saudi Arabia, and Egypt (Choukr-Allah and Hamdy 2004). However, only Tunisia, and to a certain extent, Jordan, already practice wastewater treatment and reuse as an integral component of their water management and environmental protection strategies.

In Tunisia, treated effluent with a total flow 250 m3/day is used to irrigate about 4500 ha of orchards (citrus, grapes, olives, peaches, pears, apples, and pomegranate), fodder, cotton, cereals, golf courses and lawns (Abu-Zeid, 1998). The agricultural sector is the main user of treated wastewater. Mobilisation of treated wastewater, and transfer or discharge is an integral part of the national hydraulic equipment program and is the responsibility of the State, like all related projects. The advantage of this water resource is that it is always available and can meet pressing needs for irrigation water. Indeed use of wastewater saved citrus fruit when the resources dried up (over-exploited groundwater) in the regions of Soukra (600 inhabitants) and Oued Souhil (360 inhabitants) since 1960 and contributed among other things to the improvement of strategic crop production (fodder and cereals) in new areas.

Technical and economic criteria enabled the irrigation of more than 6600 ha mobilising 30% of discharged effluent. The average effective utilisation rate of treated wastewater is 20%. The volume consumed differs greatly from one area to another, according to climatic conditions (11 to 21 Million m^3 per year.) At present, treated wastewater is an available source of water for farmers, but on the one hand, it is not suitable for crops that are economically profitable, and on the other hand it poses some health risks. The best levels of utilisation are found in fruit crops areas, in areas with a tradition of irrigation and in semi arid areas.

With a projected volume of 215 million m^3 by the year 2006, the utilisation potential of this water will be about 20,000 hectares, which is 5% of the areas that can be irrigated, if we assume intensive inter-seasonal storage and a massive introduction of water saving systems that would increase the mobilisation rate to 45%. It is expected that additional treatment of treated wastewater will improve the rate of use in irrigated areas (ONAS 2001).

Agricultural reuse however will not see marked improvement, unless restrictions are lifted on pilot wastewater treatment plants with complementary treatment processes. This can only be decided when the stations are functioning with acceptable reliability. This will take a few years of experience. Nonetheless, in all cases, and regardless of the treatment method, technical and organizational measures should be introduced in order to systematically warn those managing the reuse of any breakdowns that may occur in the wastewater treatment plants and to avoid the flow of treated wastewater into the distribution network.

In Jordan, Treated wastewater generated at nineteen existing wastewater treatment plants is an important water resources component. About 72 MCM per year (2000) of treated wastewater are effectively discharged into the watercourses or used for irrigation, 76% is generated from the biggest waste stabilization pond Al-Samra treatment plant serving a population of 2 million (approximately 70% the total served population) in 2000. By the year 2020, when the population is projected to be about 9.9 million, about 240 MCM per year of wastewater are expected to be generated. All of the treated wastewater collected from the As-Samra wastewater treated plant is blended with fresh water from the King Talal reservoir and used for unrestricted irrigation downstream in the Jordan Valley.

In Kuwait, the Government strategy for implementation of the Effluent Utilization Project was to give the highest priority to development of irrigated agriculture by intensive cultivation in enclosed farm complexes, together with environmental forestry in large areas of low-density, low water-demand tree plantations. , the Ministry of Public Works initiated the preparation of a Master Plan for effective use of all treated effluent in Kuwait, covering the period up to the year 2010 (Cobham and Johnson 1988). The overall plan recommendations for the western and northern sites (Jahra and Ardiyah effluents, respectively) it was suggested that the first priority should be devoted to developing an integrated system of forage (used in a high concentrate ration dairy enterprise) and extensive vegetable production on the UAPC (the United Agricultural Production Company) farm, so that full utilization would be made of existing and potential facilities as soon as possible. The ultimate project design provides for the development of 2700 ha of intensive agriculture and 9000 ha of environmental forestry (Agriculture Affairs and Fish Resources Authority, Kuwait 1988).

Saudi Arabia is currently reusing about 20 percent of its treated wastewater in refineries, for flushing the toilets and for irrigating forage and landscape crops.

In Morocco, the reuse of raw wastewaters has become a current and old practice. They are reused in agriculture in several parts the country. These practices are mainly localized to the periphery of some big continental cities where agricultural lands are located in the downstream of effluent discharge, and also in small parts around the wastes of the treatment networks. The climatic constraints had pushed farmers to irrigate their crops with raw wastewater when water resources are not available.

During the last years, the reuse of wastewaters has also developed around some suburbs recently provided with a treatment network. A total of 7000 ha is directly irrigated with raw wastewaters discharged by towns, i.e. about 70 million m^3 of wastewater is used every year in agriculture with no application of the sanitary precaution (HWO standards for example). This second use concerns a diversity of cultivation types (fodder, cereals, fruit threes…).

The irrigation of vegetable crops with raw wastewaters is forbidden in Morocco, but this banning is not respected, which makes the consumer of agricultural products and the farmer face risks of bacteria or parasite contaminations. In general, the volume of wastewaters that have been recycled does not represent more than 0.5% of the water used in Agriculture.

This situation tends to be generalized in all the suburbs that are provided with a treatment system where wastewaters are discharged. Following an investigation carried out within the framework of NSLC (1998), a total of 70 areas using wastewaters are spread out in the territory. This practice is not free of dangerous consequences on human health and on environment. For example:

1- Spread of water diseases (more than 4000 cases of Typhoid and more than 200 case of malaria have been noted in 1994, some cholera sources in the Sebou basin).
2- Difficulty and high cost in processing potable water.

3- Many section of water courses in the country present a largely weak quantity of dissolved oxygen, and even a deficit in oxygen when these discharges are important, which causes massive fish mortality, and;
4- Many dam volumes present marks of eutrophication, as a consequence of the important phosphor and nitrogen wastes.

Since early nineties, many multidisciplinary projects concerning the treatment and reuse of wastewater in irrigation have been launched in Morocco. The aim was to answer the major agronomic, health, and environmental concerns. The results of these researches have made the local collectivities and the regional agriculture services benefit from reliable data necessary to conceive and to size the treatment plants of wastewaters adapted to the local contexts and to disseminate the best practices for reusing treated wastewaters in agriculture.

In Egypt an ambitious programme is running for municipal wastewater treatment that will provide by the year 2010 nearly 3 billions m^3 /yr of treated wastewater as an additional water source to be used in agriculture (Abu-Zeid, 1992).

WASTEWATER TREATEMENT TECHNOLOGY

The rural sector the entire Near East and North Africa has suffered from much neglect as far as its sewage, wastewater treatment and wastewater reuse. The problem has become more acute in recent years due to the sharp increase in the domestic water demand, due to the continued water shortage and due to the strive to raise standard of living.

Falling behind in the wastewater management and reuse caused raw sewage to flow in the public roads, thus causing contamination of ground water, local wells and drinking waters, creation of nuisances and danger of public health with frequent outbreaks of water-borne diseases. Unauthorized irrigation was the main source of cholera outbreaks in NENA countries with many hospitalized people and many fatalities. Such outbreaks also caused a severe reduction in the tourism to some countries and may have affected the tourist industry in these countries for several years.

Rural area communities in Near-East and North African countries have several features in common that guide the design and operation of wastewater treatment plants, as follows:

1. Need for wastewater reuse for irrigation during the long dry summer months and the need for seasonal storage of wastewater from winter to summer.
2. Usually enough inexpensive land area around and adjacent to the community is available.
3. Sunlight is usually abundant in these regions, giving advantage to photosynthetic and other solar-energy-dependent processes.
4. Relatively concentrated wastewater due to limited per-capita water consumption rate.
5. Relatively high pathogenicity of the wastewater due to endemicity of certain diseases and high proportions of carriers.
6. Shortage of capital investment.
7. Absence, shortage or unreliability of electrical power.
8. Need for minimal, simple and inexpensive operation and maintenance of facilities.

Using the treated effluent for agricultural irrigation can increase the motivation for investments in wastewater treatment plants. This will add an economical value force both for increasing capital investments and the expenses needed for proper operation and maintenance of the wastewater treatment facilities. Effluent quality aspects are also influenced by the decision to use the effluent for irrigation, since the demand for high removal efficiency of pollutants like nitrogen and phosphorous does not exist, while the treatment technology should be directed for high hygienic demands. By using the effluent for controlled irrigation much of the environmental risks caused by other effluent disposal alternatives (e.g. disposal to rivers, lakes, sea etc.) are prevented, so it is obvious that both the farmers and the environment can be benefited from effluent reuse in small communities.

The selection of technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the users, and affordable to those who have to pay for them. In developing countries, western technology can be a more expensive and less reliable way to control pollution from human domestic and industrial wastes. Simple solutions that are easily replicated, that allow further up-grading with subsequent development and that can be operated and maintained by the local community are often considered the most appropriate and cost effective. The choice of a technology will depend to the type of reuse. The selection of reuse option should be made on a rational basis. Reclaimed water is a valuable but a limited water resource; so investment costs should be proportional to the value of the resource. Also, reuse site must be located as close as possible to the wastewater treatment and storage facilities.

Indeed, the selection of the best available technology is not an easy process: it requires comparative technical assessment of the different treatment processes, which have been recently and successfully applied for prolonged periods of time, at full scale. However, this is not sufficient, the selection should be carried out in view of well-established criteria comprising: average, or typical efficiency and performance of the technology; reliability of the technology; institutional manageability, financial sustainability; application in re-use scheme and regulation determinants. Furthermore, for technology selection, other parameters have to be carefully considered: wastewater characteristics, the treatment objectives as translated into desired effluent quality which is mainly related to the expected use of the receiving water-bodies.

Presently there are a limited number of appropriate treatment processes for small communities, which should be considered. These include stabilization ponds or lagoons, slow sand filters, land treatment systems, and constructed wetlands. All of these fit the operability criteria discussed above, and to varying degrees, are affordable to build and reliable in their treatment performance. In order to illustrate the viability of these systems, the following example is provided. In this example, a small sewered community collects its wastewater at the treatment site, and the effluent will be required to meet WHO standards for unrestricted agricultural irrigation.

If a pond system were chosen, WHO offers a waiver from the criteria. However, many researchers have found a high variability in their capability to consistently meet WHO microbiological criteria. Therefore, the designer may wish to supplement the ponds with a tertiary system to meet the criteria consistently. Appropriate stabilization pond upgrading methods to meet WHO reuse standards include free-water-surface (FWS) constructed wetlands, which can provide both the detention time of required maturation ponds of the same size and removal of algae from the pond effluent which can clog some irrigation systems; intermittent sand filters, which remove the parasite eggs and faecal coliforms, and slow-rate infiltration (SRI) and rapid infiltration (RI) systems. The latter two systems, however, transport their purified effluent to the groundwater, where it normally must be pumped back to the surface for irrigation use. A stabilization pond system can also be upgraded by a floating aquatic plant system in the same manner as the FWS constructed wetland. Such a system will, however, significantly increase operational requirements.

Intermittent sand filters (ISF) are capable of meeting the parasite and faecal coliforms criteria, but the recirculating sand filters (RSF) have not yet been shown to do so. The latter are more compact and capable of significant nitrogen removal, but require mechanical equipment in the form of pumps. Subsurface soil infiltration (SWIS), slow rate infiltration (SRI) and rapid infiltration (RI) systems can also meet the criteria, but will require pumping energy, since all three transport their effluents to the groundwater. A listing of potential cost effective alternatives which accomplish the example treatment task by providing reusable water at the surface without the need for electrical equipment are:

1. Stabilization ponds + FWS constructed wetland
2. Anaerobic (high rate) ponds + ISF
3. Imhoff tanks + ISF

Analysis of the above appropriate treatment technology systems in greater depth can assist future designers of small community wastewater systems to understand some of the tradeoffs and areas of uncertainty. Among the issues, which may sway the choice of treatment systems are performance, reliability, area requirements, capital and construction costs, and socio-economic issues.

Area requirements for these systems to treat 100 m^3/d of wastewater are estimated and reported in Table 4.

Table 4. Area required for the three systems.

System	Area Required (m^2)
Stabilization ponds + FWS constructed wetland	13,300
Anaerobic (high rate) ponds + ISF	1,950
Imhoff tanks + ISF	1,850

Both filter based systems require only a small fraction (about 15%) of the area required for the pond/constructed wetland system. Even if one were to accept the conclusion that a series of ponds can meet unrestricted irrigation standards, the area requirement is still about 7-times that required by the ISF systems.

In terms of performance or removal of pollutants the two options can only be compared when the ultimate use of the effluent is known, thus providing a specific need. In the case of irrigation reuse this involves the crop(s) to be irrigated, the aquifer characteristics below the crop, the soil, the method of irrigation and the irrigation water demand pattern. Each type of crop has different tolerances for certain pollutants, specific patterns for nutrient demand and limitations, and different patterns of demand for irrigation water. Unconfined aquifers of limited capacity will be much more sensitive to irrigation water constituents which escape the root zone and are flushed to the aquifer surface, than would be a confined aquifer or one of greater volume. Similarly, certain soils are more capable of removing dissolved constituents than others due to their physical and chemical characteristics and prior history of use. Also, the microbiological requirements for subsurface drip irrigation are far less severe than surface distribution methods.

Traditional criteria used for pond design are not normally of great importance in water-short areas like North Africa, since ponds are designed for BOD removal, not faecal coliforms or parasitic egg removal, the removals of faecal coliforms and nematode eggs control the design. Only when a wastewater with a very high BOD (800 mg/l or more) should BOD removal model be considered. Since the removal of pathogens is a time-related relationship, substitution of a FWS constructed wetland for some of the maturation-pond time required in the lagoon system should be feasible, however no studies have yet determined exactly what the equivalency ratio is.

To meet WHO standards the total required retention times for a typical stabilization pond-treated influent to meet WHO standards, and for different parameters at 20°C are reported in Table 5.

Table 5. Required retention times for different parameters regarding WHO standards

Parameter	Days	Reference
BOD, mg/l	5	Reed and Middle brooks. 1995
Fecal Coli, per 100 ml	16	Marais, GVR. 1970
Nematode Eggs, per liter	18	Ayres, and al. 1992

In summarizing the options for a small community the choice of treatment for ultimate reuse will hinge on the following:

- Reuse Requirements - If the reused wastewater is to be used for vegetables, citrus or other crops to be eaten raw, the options employing stabilization ponds and intermittent filters can be used, or a recirculating filter may be substituted with subsurface drip irrigation only. This last restriction may be lifted if it can be proven that the RSF effluent is free of nematode eggs, or if disinfection of the effluent is employed.

- Land Availability - If sufficient land is available the other limitations stated above and below will control the options evaluated. If land availability is limited by economics or terrain or surrounding development, one of the filter options should be chosen.

- Operational Capability - If a sufficiently skilled management program with electricity is available, all options are possible. If, as is often the case, only unskilled labour is locally available, only the pond-wetland or anaerobic lagoon-intermittent filter options are viable.

Table 6. Comparison of the two passive alternative technologies

	Lagoon-Wetland	Anaerobic Lagoon-ISF
Land requirement, m^2	13,000	2,000
Energy KWH/d	0	0
Capital cost, US$	200,000 250,000	150,000 200,000
O&M cost, US$/yr.	5,000-7,000	7,000-10,000
Effluent Quality		
BOD_5 (in=200), mg/l	10	5
TSS (in=100), mg/l	10	5
TN (in=50), mg/l	10-35	35-40
TP (in=10), mg/l	7-8	7-9
FC (in=10^6), per 100 ml	10^2-10^3	10^1-10^2
Virus (in=10^3), per L	10^1-10^2	0-10
Parasite Ova (in=10^3), per L	0-10	0

Finally, when the viable options which pass the above tests are evaluated against each other, experience in the Morocco has shown that they are very similar in present worth cost, so local availability or cost of components, climatic and social conditions, and support infrastructure may be the deciding factor between them. For example, the lack of suitable sand or substitute media locally will significantly increase the cost of the filter options. Very close proximity of housing to the treatment site may make odour concerns a key issue, and add costs to certain options to control odours. Therefore, engineering decisions of which method of treatment or sitting of the facility may be skewed to suit local needs. However, in all cases the appropriate technology options presented herein are significantly more sustainable than the use of sophisticated urban wastewater treatment technologies such as activated sludge with tertiary treatment for small communities of NENA region.

CONSTRAINTS OF THE REUSE

Bearing in mind that treated wastewater could be used for agricultural purposes, it is important to realize that such wastewater must be adequately treated and used appropriately. The main constraints of using treated wastewaters are related to health issues, the absence of effective wastewater standards, the of law enforcement, lack of awareness and scarcity of funds.

Wastewater quality and health issues

Irrigating with untreated wastewater poses serious public health risks, as sewage is a major source of excreted *pathogens* - the bacteria, viruses, protozoa- and the helminths (worms) that cause gastro-intestinal infections in human beings (Blumentha and al 2000).

Unregulated and continuous irrigation with sewage water may also lead to problems such as soil structure deterioration (soil clogging), salinization and phytotoxicity.

The ideal solution is to ensure full treatment of the wastewater to meet WHO guidelines prior to use, even though the appropriateness of these guidelines are still under discussion. However, in practice most rural villages in NENA countries are not able to treat their wastewater, due to low financial, technical and/or managerial capacity. In many rural areas a large part of the wastewater is disposed of untreated to rivers and cesspools, with all related environmental consequences and health risks. The perspectives regarding treatment of their wastewater are bleak. It may safely be assumed that the farmers increasingly will use wastewater for irrigation, irrespective of the national regulations and quality standards for irrigation water.

In any case, usually, sewage treatment plants rarely operate satisfactorily and, in most cases, wastewater discharges exceed legal and/or hygienically acceptable maxima. This does not necessarily lie in the treatment plants themselves, but in the frequent lack of adequately trained technicians capable of technically operating such treatment plants.

The discharge of untreated wastewater and/or minimally treated in water sources has resulted in a substantial economic damage and has posed serious health hazards to the inhabitants, particularly in the low income NENA countries.

This is now the case in many mega-cities where the drinking water supplies from rivers or local groundwater sources are no longer sufficient, mostly because of their poor quality.

The lack of sanitation facilities and the too often associated unsafe drinking waters remain among the principal causes of disease and death, especially in rural areas. Specific measures to counteract water-related threats are often needed, but, lack of investments and inadequate local management often lower their effectiveness.

Institutional manageability

The scope and success of any effluent use scheme will depend to large extent on the administration skills applied. Wastewater reuse is characterised by the involvement of several departments and agencies, either governmental or private or both. In the NENA countries, few governmental agencies are adequately equipped for wastewater management. In order to plan, design, construct, operate and maintain treatment plants, appropriate technical and managerial expertise must be present. This could require the availability of a substantial number of engineers, access to a local network of research for scientific support and problem solving, access to good quality laboratories and monitoring system and experience in management and cost recovery. In addition, all technologies, included the simple ones, require devoted and experienced operators and technicians who must be generated through extensive education and training.

For adequate operation and minimization of administrative conflicts, a tight coordination should be well defined among the Ministries involved such as those of Agriculture, Health, Water Resources, Finance, Economy, Planning, Environmental Protection and Rural Development. The basic responsibilities of such inter-ministerial committees could be outlined in:

- Developing a coherent national policy for wastewater use and monitoring of its implementation;
- Defining the division of responsibilities between the respective Ministries and agencies involved and the arrangements for collaboration between them;
- Appraising proposed re-use schemes, particularly from the point of view of public health and environmental protection;
- Overseeing the promotion and enforcement of national legislation and codes of practice;
- Developing a national staff development policy for the sector;

Financial considerations

The lower the financial cost, the more attractive is the technology. However, even a low cost option may not be financially sustainable because this is determined by the true availability of funds provided by the polluter. In the case of domestic sanitation, the people must be willing and able to cover at least the operation and maintenance cost of the total expenses. The ultimate goal should be full cost recovery although, initially, this may need special financing schemes, such as cross subsidization, revolving funds and phased investment programmes.

In this regard, adopting an adequate policy for the pricing of water is of fundamental importance in the sustainability of wastewater re-use systems. Subsidizing re-use system may be necessary at the early stages of system implementation, particularly when the associated costs are very large. This would avoid any discouragement to users arising from the permitted use of the treated wastewater.

However, setting an appropriate mechanism for wastewater tariff is a very complex issue. Direct benefits of wastewater use are relatively easy to evaluate, whereas, the indirect effects are “non monetary issues” and, unfortunately, they are not taken into account when performing economic appraisals of projects involving wastewater use. However, the environmental enhancement provided by wastewater use, particularly in terms of preservation of water resources, improvement of the health status of poor populations in rural areas, the possibilities of providing a substitute for freshwater in water scarce areas, and the incentives provided for the construction of sewerage networks, are extremely relevant. They are also sufficiently important to make the cost benefit analysis purely subsidiary when taking a decision on the implementation of wastewater re-use systems, particularly in poor and rapidly growing rural villages.

Monitoring and Evaluation

Monitoring and evaluation of wastewater use programmes and projects is a very critical issue, hence, both are the fundamental bases for setting the proper wastewater use and management strategies. Ignoring monitoring evaluation parameters and/or performing monitoring not regularly and correctly could result in serious negative impacts on health, water quality and environmental and ecological sustainability.

Unfortunately, in many MENA countries that are already using or start using treated wastewater as an additional water source, the monitoring and evaluation programme aspects are not well developed, are loose and irregular. This is mainly due to the weak institutions, the shortage of trained personnel capable of carrying the job, lack of monitoring equipment and the relatively high cost required for monitoring processes.

Public awareness and participation

This is the bottleneck governing the wastewater use and its perspective progress. To achieve general acceptance of re-use schemes, it is of fundamental importance to have active public involvement from the planning phase through the full implementation process.

Farmers will need to be convinced that treated wastewater can provide an attractive resource and they can save money through reducing the fertilizer application.

Some observations regarding social acceptance are pertinent. For instance, there may be deep-rooted socio-cultural barriers to wastewater re-use. However, to overcome such an obstacle, major efforts are to be carried out by the responsible agencies.

Responsible agencies have an important role to play in providing the concerned public with a clear understanding of the quality of the treated wastewater and how it is to be used; confidence in the local management of the public utilities and in the application of locally accepted technology, assurance that the re-use application being considered will involve minimal health risks and minimal detrimental effects on the environment.

In this regard, the continuous exchange of information between authorities and public representatives ensures that the adoption of specific water re-use programme will fulfill real user needs and generally recognized community goals for health, safety, ecological concerns programme, cost, etc.

In this way, initial reservations are likely to be overcome over a short period. Simultaneously, some progressive users could be persuaded to re-use wastewater as supplementary source for irrigation. Their success would go a long way in persuading the initial doubters to re-use the wastewater available.

Realistic Standards and Regulations

An important element in the sustainable use of wastewater is the formulation of realistic standards and regulations. However, the standards must be achievable and the regulations enforceable.

Unrealistic standards and non-enforceable regulations may do more harm than having no standards and regulations because they create an attitude of indifference towards rules and regulations in general, both among polluters and administrators. 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.

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. However, further research is needed into hygienic food marketing as well as the safe food preparation at home as important options to tackle the wastewater problem in low-income countries.

Most often, WHO guidelines have often been used, or cited in isolation from the other protective measures. If water quality, however, cannot be guaranteed, agricultural engineers should investigate possibilities of alternative irrigation technologies and irrigation methods reducing farmer's exposure. Also, in certain case additional treatment (up to tertiary level) to remove crop restrictions will help change farmers attitude, as this will allow them to grow cash crops (vegetables).

STRATEGIES FOR SUSTAINABLE REUSE IN RURAL AREAS

In order to achieve safe and successful wastewater reuse schemes for irrigation purposes, WHO health guidelines should be integrated with FAO for water quality guidelines for irrigation purposes. Accordingly there are common multi strategies ultimately combined the optimisation of crop production and protecting the human heath. These are related to wastewater treatment level, restriction of the crop to be grown, irrigation techniques and scheduling, as well as to control of soil salt accumulation, ground water nitrogen pollution.

Adequate treatment technology

The implementation of low cost treatment is recommended. Properly designed, adequately implemented wastewater reuse is an environmental protection measure that is superior to discharge treated wastewater to its end use of the reclaimed effluent need to meet the guidelines, taking into consideration the economic constrains. Usually the wastewater of rural population does not contain heavy metal, which means that the main concern of treatment will focus on the pathogens removal. Several technologies have been described in this paper to be adapted on the socio-economic conditions of the local population.

Crop selection

Based on the WHO guidelines, crops to be used grouped in three categories (A, B, and C) depending on the degree to which health protection measures are required. Secondary effluent allow the cultivation of green fodder, olives, citrus, bananas, almonds, and even to be used as supplement irrigation for cereal crops. However, crop selection should be subject to their tolerance to salinity, soil characteristics, and the risks of ground water pollution.

Irrigation techniques and scheduling

The selection of irrigation techniques mainly depends on the quality of the effluent, the crop patterns, and the potential health risks. Irrigation techniques, which wet only the roots and not the leafy part of vegetables, were suggested as good practice for minimizing risk of contamination. Bed and furrow irrigation, drip systems and any other technique applying water close to the root systems was suggested. There is a further advantage in that there will be less infiltration of nitrogen into groundwater (Mojtahid and al 2001). Rotating wastewater application over fields if this is possible is another means to limit over-fertilisation and pollution of groundwater. Avoiding irrigation with wastewater in the two weeks before harvest can minimize the risk from pathogen contamination of leafy vegetables, but this necessitates a fresh water source accessible to farmers, which is rarely possible in these rural situations.

Control of nitrogen pollution and salt accumulation

Farmers should calculate the amount of nitrogen needed taking into account the amount of nitrogen supplied by the treated wastewater. Some crops are highly effective in removing nitrogen from soil, which may contaminate underground water. Sudan grass, Rhodes grass, maize, sorghum remove nitrogen efficiently from the soil.

High sodium levels in treated wastewater can reduce water infiltration in heavy clay soil, and could not be tolerated by salt sensitive crops. Gypsum and organic amendment will reduce the negative effect of the sodium on the soil structure and improve crop productivity under these conditions. Also the use of more tolerant species, associated with some good practices (irrigation techniques, leaching ….) will reduce the salt effect on the crop yield.

CONCLUSION AND RECOMMENDATIONS

Domestic WWTR is one tool to address the food and water insecurity facing many countries in the Near East and North Africa. In coming years, in most NENA countries, valuable fresh water will have to be preserved solely for drinking, very high value industrial purposes, and for high value fresh vegetables crops consumed raw. Where feasible, most crops in arid countries will have to be grown increasingly, and eventually solely, with treated wastewater. The economic, social and environmental benefits of such an approach are clear. To help the gradual and coherent introduction of such a policy, which protects the environment and public health, governments shall have to adapt an Integrated Water Management approach, facilitate public participation, disseminate existing knowledge, and generate new knowledge, and monitor and enforce standards.

Awareness and information efforts targeted at farming communities, including in particular at women, improved specialized extension services and assistance in marketing crops grown under safe planned reuse schemes be useful steps in improving reuse.

To ensure the sustainability of the system, a cost recovery analysis should not be neglected. The low income of most farmers, it is not realistic to expect farmers to pay any portion of the treatment cost, but tariffs should cover the cost of transferring and distribution of the reclaimed water.

On the technology side, small-scale decentralized sanitation technology, such as lagoons, sand filters, constructed wetland, and even septic tanks combined with small-bore sewers, offer great potential in small rural areas. As far as irrigation technologies are concerned, bubbler irrigation may be considered the preferred method of application particularly for tree crops. It provides some water savings, and also provides some degree of protection against clogging and contamination exposure.

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