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Wastewater Treatment and Reuse in Mediterranean Region as a Potential Resource for Drought Mitigation

R.Choukr-Allah[1] and A. Hamdy[2]

Abstract

Mediterranean region, especially the southern and eastern countries are facing major challenges related to water resources scarcity, accessibility, and environmental degradation. Treated and re-used sewage water is becoming a common source for additional water in some water scarce regions and many countries have included wastewater re-use in their water planning. Agricultural reuse of wastewater have to be integrated into comprehensive land, and water management plans taking into account water supply, wastewater collection, reclamation, and reuse. Policies have been formulated but few have had the capacity to implement them in their water management practices in terms of actions to deal with water pollution control and waste disposal. In arid and semi-arid countries, particularly the developing ones, the full utilization and re-use of sewage water is still far from our final goal, i.e. to be used as a water source, in spite of the vital role it could play in reducing the high pressure imposed on the limited available freshwater. Health and environmental problems are the major obstacles restricting the sustainable and safe re-use and recycle of wastewater which require concerted efforts supported by regional and international organizations, if real change and beneficial results are to be realized in the near future.

Introduction

Mediterranean regions 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 decades as results of expending urban population and touristy industry. 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 Mediterranean regions. Firstly, properly treated municipal wastewater often is a significant

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water resource that can be used for a number of beneficial purposes; such as agricultural and landscape irrigation. 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.

Expansion of urban population and increased coverage of domestic water supplies and sewage network will give rise to greater quantities of municipal wastewater which can become a new water source, particularly for irrigation. The water recycling and re-use provide a unique and a viable opportunity to increase traditional water supply. Water reuse can help to close the loop between water supply and wastewater disposal. The successful development of this reliable water resource depends upon close examination and synthesis of elements from infrastructure and facilities planning, wastewater treatment plant sitting, treatment process reliability, economic and financial analysis, water utility management, and public acceptance.

Consequently, the re-use of municipal wastewater will require more complex management practices and stringent monitoring procedures than when good-quality water is used. Treatment and re-use of sewage waters is becoming a common source for additional water in some water scarce regions. Re-use of sewage waters, when properly managed, has the benefit of reducing environmental degradation.

For many of those arid and semi-arid countries, re-use of wastewater may contribute more future water availability than any other technological means of increasing water supplies. Treated wastewater can be used effectively for irrigation, industrial purposes and groundwater recharge and for protection against salt intrusion in groundwater aquifers. Furthermore, the wastewater treatment and possible use of sewage effluents is a health and environmental necessity to the civil society, specially in urban areas. Therefore, for those countries, the use of appropriate technologies for the development of alternative sources of water is, probably, the single most adequate approach for solving the problem of water shortage, together with the improvements in efficiency of water use and adequate control to reduce water consumption. Our water management policy should be fundamentally directed to support that "no higher quality, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade". This is what we are challenging for and we have to find the key-recommendations and solutions for action.

Potential of Saving by Using Treated Wastewater

Globally, demands on freshwater resources are increasing due to population growth, increased per capita consumption, and the demands of the industrial and agricultural sectors. Greater water consumption is directly associated with increased wastewater generation that requires adequate treatment to prevent health risks and environmental degradation. Recently, the development of reclaimed domestic wastewater reuse projects has emerged as a potential non-conventional resource to satisfy the continuously increasing demand for water.

Since several activities do not require water of potable quality, reclaimed water may be substituted for conventional resources. Treated wastewater effluents may be reused for purposes such as non-agricultural irrigation (parks, green areas, golf courses, etc.), industrial recycling and reuse (cooling water, boiler feed, process water), fire fighting, and groundwater recharge.

Wastewater treatments provides opportunities to increase the use of wastewater in agriculture (GWP/Med, 2000). The percentage of population served with water supply and sanitation varies from one country to another. The table 1 below indicate that the annual water use in domestic and industrial sectors could reach 83 BMC. Assuming 80% of wastewater will be collected and treated, the annual collected wastewater could reach 66.7 BMC. The existing wastewater reuse is estimated at 0.75 BMC in the Mediterranean countries (FAO, 1997). The potential treated wastewater for reuse can therefore be estimated at 66 BMC/year in the Mediterranean region.

Based on the water demand of year 2025, and assuming that this water could be satisfied, the saving using treated wastewater could reach 70 BMC / year. The cost to achieve this saving is estimated to 55 billions euros which include the need to fill the gap in water supply and sanitation coverage for 25 million people without access to water and to treat the wastewater effluents.

Table 1. Annual domestic and industrial water use and potential treated wastewater for reuse (M m^3/year)

	Potential Total Irrigation Savings	Potential Total Domestic Savings	Potential Total industrial/ Commercial Savings	Potential Treated Wastewater for use	Total Potential Water Savings
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
Egypte	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
Albania	99.4	129.3	0.0	221.4	450.1
Croatia	0.0	121.7	4.8	506.9	633.3
Cyprus	15.6	16.1	0.1	20.1	51.8
France	488.0	1,947.9	371.1	26,776.5	29,583.5
Greece	569.4	359.0	2.6	779.2	1,710.3
Italy	2,537.6	2,136.9	197.5	16,135.3	21,007.4
Malta	0.7	15.5	0.0	25.3	41.4
Spain	2,415.4	1,472.1	79.9	7,567.3	11,534.7
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 as an Additional Water Resource

Benefits

Treated wastewater may be considered as a 'new' water resource, which can be added to the general water balance of a region. This 'new' source can substitute conventional water (potable water) used for irrigation or for other purposes that do not require water of drinking quality, while releasing some of the pressure on the conventional water resources.

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 the Mediterranean regions, average $US 0.5/m^3, is cheaper, in most cases, 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).

One of the economic benefits of wastewater reuse in arid and semi-arid areas is the boosting of agriculture development that would not be possible without a constant and reliable supply of water. This component (agriculture development) is generally neglected in the cost–benefit since the analysis is generally limited to investment and operational costs on the one hand and potential revenues from selling the treated wastewater on the other. Other issues, which are generally overlooked, are the resulting environmental and public health protection even if they are conspicuous, due to the difficulties to assign economic values to these parameters. The cost–benefit analysis usually is performed for a 20 years period, while the lifetime of wastewater storage reservoirs and similar units is at least 40 years (and may be much more.

Thus, the annual repayment for capital recovery is in practice lower than the one usually calculated.

Case-studies

Countries in the region which practice wastewater treatment and reuse include Spain, France, Cyprus, Malta, Tunisia, Israel, Italy, Greece, Portugal, and Egypt. However, only Israel, Cyprus and 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 of 250 m^3/d is used to irrigate about 4500 ha of orchards (citrus, grapes, olives, peaches, pears, apples, pomegranate), fodder, cotton, cereals, golf courses and lawns (Abu-Zeid, 1998).The agricultural sector is the main user of treated wastewater. Mobilization of treated wastewater, and transfer or discharge are an integral part of the national hydraulic equipment program and are 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 mobilizing 30% of discharged effluent. The average effective utilization 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 utilization are found in arboricultural 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 utilization potential of this water will be about 20,000 hectares, that 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 mobilization 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 Israel reuse up to 1982 amounted to about 25% of the wastewater generated. Since that time several large projects lead to a large increase in water reuse. In 1987 some 230 reclaimed water projects produced about 0.27 x 106 m^3/day of reclaimed water from a population of over 4 million people (Argarnan, 1989). About 92% of the wastewater was collected by municipal sewers and of this 72 % was reused for irrigation 42%) or groundwater recharge (30%). Reuse constitutes approximately 10 % of the water in Israel but by 2010 it is projected that reuse will account about 20%, with about 33% of the total water resource allocated to agricultural irrigation.

In Israel of the various advanced treatment options used in Israel, sewage treatment systems, employing conventional biological treatment, followed by a long detention reservoir, as a system of choice, provides in the mean time a superior conventional method of treatment for wastewater and reuse for arid and semi-arid regions. This practice is generally recognized at the moment as an economically feasible strategy for developing a crucial water source for irrigation replacing freshwater to be reallocated for urban/domestic use, while also having public health advantages. About eighty percent of Israel's treated wastewater is reused in irrigation.

Despite all efforts in practice and research however, the associated health and environmental risks and the implications of the increase in the quantities of wastewater effluents in the human environment are not fully understood. Furthermore, the inclusion of sewage effluents as part of "water irrigation rights" and the associated institutional and pricing adjustments need to be analyzed as well as the modifications in the agricultural production systems. Extensive engineering and academic research is being conducted in an attempt to elaborate the consequences and effects of large scale and expanded use of treated effluents of varying degree of quality on the human and natural environment, in general, and the soil/water/crop relationship, in particular. Subsurface trickle irrigation in large field scale was tried and no yield benefits or deficits were found as compared to surface trickle irrigation. However the E.coli pathogens in the surface soil was the same as background samples suggesting a safer method of irrigation though not always the maximum yields are obtained.

In Cyprus wastewater generated from the main cities is collected and following tertiary treatment is used for irrigation. It is expected that the irrigated agriculture will be expended by 8-10% and an equivalent amount of water will be conserved for other sectors (Papadopoulos. 1995).

In Italy, in the areas near the treatment plants of the towns Castiglione, Cesena, Cesenatico, Cervia and Gatteo an intensive programme of reuse of treated wastewaters has been carried out. Wastewater irrigation now covers an area of over 4000 ha and a very interesting results both in terms of the effects on the soil and on the irrigated crops are shown. The first survey of Italian treatment plants estimated the total treated effluent flow at 2 400 Mm^3 /yr of usable water. This gives an estimate of the potential resource available for reuse.

The reuse of treated wastewater in Spain is already a reality in several regions of the country for four main applications: golf course irrigation, agriculture irrigation, groundwater recharge and river flow augmentation. In Tenerife, the treated water reused in irrigation amount to 17 00 m^3/day. These waters are stored in two reservoirs of a capacity of 250 00 m^3 and 50 000 m^3 respectively in San Lorenzo and Sen Isidro. The main crops irrigated are banana, vineyards, tomatoes, and cut flowers.

In Portugal, treated wastewater is a valuable potential resource for irrigation and should soon reach 580 Mm^3/yr, which is approximately twice as much as today. Even without storage, this amount could be enough to cover about 10% of the water needs for irrigation in a dry year. Roughly, between 35 000 and 100 000 ha, depending on storage capacity could be irrigated with recycled water.

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 locate 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 of processing for the production of 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).

Most nations in the region are already importing virtual water, in the form of food, and will likely have to increase specific imports, such as cereal crops. Despite this, many countries wish to increase fresh water supplies to domestic, and industrial usages, and at the same time, expand irrigated agriculture. For example, Tunisia wishes to increase the area of irrigated agriculture by at least 30,000 hectares (ha), and

Egypt, by 880,000 ha. How can these seemingly contradictory objectives be reconciled? The answer is water demand management more efficient water use within all sectors. One specific component is to increasingly reuse domestic wastewater, for industry, for some municipal purposes, such as flushing toilets and irrigating green spaces, but above all, for agriculture, to offset the fresh water being taken out of this sector.

Wastewater Reuse Considerations

Wastewater reuse applications

In the planning and implementation of wastewater reclamation and reuse, the reuse application (see Table 2) will usually govern the wastewater treatment needed, and the degree of reliability required for the treatment processes and operations. Because wastewater reclamation entails the provision of a continuous supply of water of consistent quality, the reliability of the existing or proposed treatment processes and operations must be evaluated in the planning stage (Tchobanoglous and Burton, 1991). Specific reuse categories and treatment technologies that may be applicable will depend on the location and type of wastewater management employed (e.g., centralized versus decentralized, as discussed subsequently). Worldwide, the most common use of reclaimed wastewater has been for agricultural irrigation. Recently, groundwater recharge and potable reuse have received considerable attention in the United States. The repurification project in San Diego, CA, in which it is proposed to blend repurified wastewater with local runoff and imported water in a local water supply storage reservoir, is an example of such a project (Montgomery/Watson and NBS Lowry, 1994.)

Table 2. Categories of municipal wastewater reuse and potential issues/constraints

Wastewater reuse categories	Issues/constraints
Agricultural irrigation	
Crop irrigation	
Commercial nurseries	
LANDSCAPE IRRIGATION	
Parks	
School yards	(1) Surface and groundwater Pollution if not managed properly,
Freeway medians	(2) marketability of crops and public acceptance, (3) effect of water
Golf courses	quality, particularly salts, on soils and crops, (4) public health concerns
Cemeteries	related to pathogens (bacteria, viruses, and parasites), (5) use for control of
Greenbelts	area including buffer zone, (6) may result in high user costs.
Residential	

Wastewater reuse categories	Issues/constraints
Industrial recycling and reuse Cooling water Boiler feed Process water Heavy construction	(1) Constituents in reclaimed wastewater related to scaling, corrosion, biological growth, and fouling, (2) public health concerns, particularly aerosol transmission of pathogens in cooling water.
Groundwater recharge Groundwater replenishment Salt water intrusion control Subsidence control	(1) Organic chemicals in reclaimed wastewater and their toxicological effects, (2) total dissolved solids, nitrates, and pathogens in reclaimed wastewater.
Recreational/environmental uses Lakes and ponds Marsh enhancement Streamflow augmentation Fisheries Snowmaking	(1) Health concerns of bacteria and viruses, (2) eutrophication due to nitrogen (N) and phosphorus (P) in receiving water, (3) toxicity to aquatic life.
Nonpotable urban uses Fire protection Air conditioning Toilet flushing	(1) Public health concerns on pathogens transmitted by aerosols, (2) effects of water quality on scaling, corrosion, biological growth, and fouling, (3) cross-connection.
Potable reuse Blending in water supply Pipe to pipe water supply	(1) Constituents in reclaimed wastewater, especially trace reservoir organic chemicals and their toxicological effects, (2) aesthetics and public acceptance, (3) health concerns about pathogen transmission, particularly viruses

Source: Tchobnoglous and Burton, 1991

Wastewater treatment technology

Technology, particularly in terms of performance and available wastewater treatment options, cannot be expected to find a solution to each problem. Wastewater systems are generally capital-intensive and require expensive, specialized operators. Therefore, before selecting and investing in wastewater treatment technology, an analysis of cost effectiveness needs to be made and compared with all conceivable alternatives.

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.

In the developing countries usually characterized by high population density and notable shortfall in available water resources, the proper waste water technology to be adopted under the prevailing local conditions is one of the critical issues which should be well defined. Technologies available are many and well known, but any choice should rely on those not entailing excessive costs and providing the best environmental practice and option.

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.

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.

Wastewater may also contain highly poisonous chemical toxins from industrial sources as well as hazardous material from hospital waste. Relevant groups of chemical contaminants are heavy metals, hormone active substances (HAS) and antibiotics. The risks associated with these substances may, in the long run, turn out to constitute a greater threat to public health and be more difficult to deal with than the risks from excreted pathogens. Unregulated and continuous irrigation with sewage water may also lead to problems such as soil structure deterioration (soil clogging), salinization and phytotoxicity.

These risks are not limited to 'official' wastewater but often also apply to rivers and other open water sources, as indicated by figures gathered by Westcott: 45% of 110 rivers tested carried faecal coliform levels higher than the WHO standard for unrestricted irrigation (FAO, unpublished, cited in Birley).

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 cities in low income countries are not able to treat more than a modest percentage of the wastewater produced in the city, due to low financial, technical and/or managerial capacity. The rapid and unplanned growth of cities with multiple and dispersed wastewater sources makes the management more complex. In many cities a large part of the wastewater is disposed of untreated to rivers and seas, with all related environmental consequences and health risks. The perspectives regarding the increase in wastewater treatment capacity in these cities are bleak. It may safely be assumed that urban and peri-urban farmers increasingly will use wastewater for irrigation, irrespective of the municipal regulations and quality standards for irrigation water.

Only a few large cities in developing countries and newly industrializing countries have adequate sewer systems and treatment plants, which is not the case for the majority of developing countries. In any case, usually, only a small portion of the wastewater is treated and purified even when it is channeled through a sewer system. Existing 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 municipal ones in water sources has resulted in a substantial economic damage and has posed serious health hazards to the inhabitants, particularly in the developing countries. In many countries, various diseases are particularly prevalent and the consequential costs for the health care system are considerable.

Considerable sums have been spent on water and wastewater treatment in both the developing and developed regions of the world to substantially reduce waterborne diseases and meet commonly accepted environmental and ecological objectives. Yet, statistics indicate that in spite of such enormous investments in water quality improvement and protection, in the less developed countries, nearly 2 billion people are suffering from the lack of clean drinking water and sanitation facilities.

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.

As a matter of fact, water quality problems are certainly not restricted to urban areas. 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

Wastewater reuse is characterized by the involvement of several departments and agencies, either governmental or private or both. In the southern part of the Mediterranean 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 costs, the more attractive the technology is. 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.

The incremental cost basis, which allocates only the marginal costs associated with re-use, seems to be a fair criteria for adoption in developing countries.

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 developing countries, the possibilities of providing a substitute for freshwater in water scarce areas, and the incentives provided for the construction of urban sewage works, 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 developing and rapidly industrializing countries.

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 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.

In the developing countries, two types of monitoring are needed: the first, process control monitoring to provide data to support the operation and optimization of the system in order to achieve successful project performance; the second, compliance monitoring to meet regulatory requirements and not to be performed by the same agency in charge of process control monitoring.

In the developing countries, to avoid failure in wastewater use and attain the desired success, the monitoring programme should be cost effective, and should provide adequate coverage of the system. Equally so, it must be reliable and timely in order to provide operators and decision making officials with correct and up-to-date information that allows the application of prompt remedial measures during critical situations.

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.

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.

Major Needs for Recycling and Reuse of Wastewater

Wastewater reuse for agricultural irrigation is becoming a common and rapidly increasing practice in arid and semi-arid regions around the world, where treated wastewater serves as an extra source of water available for the rural sector. New projects for reclamation and reuse of wastewater are reported almost every year in countries all over the Mediterranean region.

Applying 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. In arid and semi-arid countries where wastewater is recognized additional water source standards, guidelines and regulations in the majority of developing countries do not consider the re-use aspect as an integrated part of the treatment process; they are only intended to control and protect the quality of water bodies where the reclaimed water is discharged. In reality, in the arid regions of the Near-East, North-Africa and Southern-Europe, not all countries have developed guidelines and regulations for reclaimed water use. For those countries, standards and regulations for the re-use should be tailored to match the level of economic and administrative capacity and capability standards should cope with the local prevailing conditions and should be gradually tightened as progress is achieved in general development and in the economic and technical capability of the involved institutions and of the private sector as well.

Cyprus, France, Israel, Italy, Jordan and Tunisia are the only Mediterranean countries to have established national guidelines for the use of reclaimed wastewater. Regional guidelines exist in Spain. The existence of guidelines is necessary for the planning and safe implementation of wastewater reuse for irrigation. It also contributes to a sustainable development of landscape and agricultural irrigation. Guidelines must also clearly promote the development of best practices. This does not need to be defined in great detail but must take into account important specific local conditions, such as the quality of reclaimed wastewater, the type of soil, the climate, the relevant crops and the local agricultural practices. However, the need for sharing a common rationale for developing wastewater reclamation and reuse standards on both sides of the Mediterranean is obvious.

Formulation of national policies and strategies

It is now widely recognized that wastewater re-use constitutes an important and integral component of the comprehensive water management programs of the majority of countries, more so in the water scarce ones.

This implies that these countries should have national policies and strategies relating to wastewater management in general and wastewater re-use for agriculture, in particular, in order to guide programmes, projects and investments relating to wastewater collection, treatment, re-use and disposal in a sustainable manner.

This requires the establishment of a clear policy with regard to wastewater management.

This policy should be compatible with a number of related sectorial or sub-sectoral policies such as national water management and irrigation policy, national health, sanitation and sewage policy, national agricultural policy and national environmental protection policy.

Such policy should give guidance on the following issues:

- the current and future contribution of treated wastewater to the total national water budget;

- criteria required to achieve maximum benefit of wastewater-reuse for the different water sectoral uses;

- modalities for strengthening the national capacity building in this sector.

Such policy should be accompanied by an appropriate national strategy for wastewater reuse characterized by the following features:

- spelling out ways and means of implementing policy directives;

- defining the nature and mechanisms of inter-institutional collaboration, allocation of funds, establishment of pilot wastewater reuse demonstration sites of good management practices and phasing the implementation of wastewater programmes;

- fostering the share of responsibilities between involved ministries, agencies and authorities, and the way to link and integrate the activities among them, individually and in combination;

- identifying an economically feasible, safe and socially acceptable set of standards, regulations and codes of practices for sustainable use.

Ideally, policies of wastewater reuse and strategies for its implementation should be part of water resources planning at the national level. At the local level, individual reuse projects should be part of the overall river basin planning effort.

Institutional, legal and political aspects of wastewater reuse

Safe water treatment, disposal and reuse are the responsibility of different organizations such as authorities, cooperatives and communities operating under the jurisdiction of the ministries of agriculture, water resources and others. The responsibilities of these organizations must be considered and reconciled.

To tackle the range of institutional levels involved and to allocate responsibilities in both treatment and reuse stages, several actions are needed, including:

1. A well-defined policy and strategy for the comprehensive management and reuse of treated wastewater is a precondition to success.

2. Many different stakeholders are involved, so roles and responsibilities (who does what) need to be clearly defined, along with mechanism to ensure the active co-ordination of the various institutions.

3. Inadequate legislation often hinders the effective reuse of treated wastewater. Integrated legal arrangements can be of great value, along with provisions for active enforcement of all laws and regulations, without exception.

4. A comprehensive plan of action for reusing treated wastewater, with clearly assigned roles, needs to be complemented by periodic reviews and follow-up. Adequate funding is essential.

5. Capacity building is required to analyze staff needs and provide suitable training.

6. More participatory approaches are needed, including raising the awareness of the general public (whose cultural and religious perceptions sometimes regard treated wastewater as impure). Irrigators also need to be involved in the planning and utilization of this resource.

7. More co-ordination is needed between donors and national institutions involved in wastewater reuse.

To reinforce and help consolidate improved arrangements in countries with many ministries involved, the possible formation of a « higher council » to create policy and strategies should be considered. This body could oversee implementation and obtain necessary funding.

Where many different laws complicate wastewater reuse, consideration could be given to consolidated legislation that would cover all aspects of water resources planning, management and utilization.

Awareness raising, education, and best practices

Targeted health education is the most realistic, practical and cost effective measure to reduce health risks associated with wastewater use in agriculture. The following categories should be addressed:

- Policymakers: convince them that the use of wastewater is a reality that has to be accepted; provide them with data on the food security, income generating capacity, health and nutrients aspects of wastewater use in agriculture; show trade-offs of costs and benefits of wastewater treatment and reuse in agriculture, co-management of water provision, sanitation, treatment and reuse, and strategies for handling wastewater from the source to the users.

- Farmers: provide information through interactive learning methods on health risks associated with wastewater use, information and technical assistance on proper crop selection in relation to wastewater quality, irrigation techniques, protective clothing (boots), personal hygiene, washing crops before marketing, group organization for on field sanitation and washing facilities; preventing damage to soils and ground water

- Consumers: Inform them on proper washing; cooking or blanching of vegetables; and sufficient cooking time for fish raised with wastewater; necessity of paying for treatment of household wastewater as they are the generators.

- Tradesman: use of clean water for freshening products (vegetables) on the market; ways for minimizing contamination risks during transport and processing.

- Local authorities: to help them understand the implications of wastewater use and the role they can play in minimizing the risks.

- The NGO's and media may have to play a vital role in this exercise, if authorities are slow to take the lead.

  Best practices should include:

Crop selection and certification of produce (labeling)

Variations in absorption of certain chemicals by crops, makes crop selection a suitable strategy, in the absence of market forces, which discourage crop restriction. Offering financial incentives i.e. labeling clean products, which will fetch higher prices, is also a possibility provided customers are willing to pay more and certification programs, which are costly processes, can be set up.

Improving irrigation practices

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 into groundwater. Rotating wastewater application over fields if this is possible is another means to limit over-fertilization 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 peri-urban situations.

Concluding Remarks and Recommendations

Domestic WWTR is one tool to address the food and water insecurity facing many countries in the Mediterranean. In coming years, in most Mediterranean countries, valuable fresh water will have to be preserved solely for drinking, very high value industrial purposes, and for high value fresh vegetables and salad crops consumed raw. Where feasible, most other 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.

- One of the prerequisites for any cure is an adequate information base. This includes inventorying water stocks, on one hand, and ascertaining the demand at local and regional level, in quantitative and qualitative terms within the framework of national water strategy, on the other one. Economic, social and environmental concerns must all be taken into account in accordance with the goal of sustainability.

- It is important to strengthen the capacity of national and local hydrological research institutes to improve their links to environmental research as well as to institutes in the field of economic and social science, particularly in the field of urban studies and planning. The transfer of knowledge to local government decision-makers must be improved.

- Local governments must focus their policies on treating municipal wastewater to eliminate the rapid degradation in both surface and groundwater quality. In this regard, simple methods of wastewater treatment are to be recommended as realistic solutions; equally so, governments have to operate as well to strengthen the capacity of both institutions and users. Efforts concerning domestic sewage must center on promoting and further developing low cost, easy-to-handle and, in general, regionally developed technologies with a low degree of complexity. Special weight must be placed on minimizing the energy needs for these technologies.

- The failure of governance at local government level should be counteracted by improving the efficiency of public administration at the local level. The measures required include the building of responsibilities, combining management and financing functions, improving environmental legislation and monitoring, dismounting bureaucraticism, decentralizing tasks to the lowest levels possible, increasing the transparency of government activities as well as enhancing the skills of the public administration employees.

- Enhancing and improving cooperation between local governments and the informal sector which is far below the level required. The informal sector should be exploited to a greater extent and integrated with decentralized public administration to find more rapid, appropriate and flexible solutions to the existing and raising problems. In this regard, the involvement of the NGOs has to be strengthened in the management of infrastructural institutions and the mobilization of public participation and individual responsibility within the framework of urban supply and wastewater treatment and use projects.

- Existing water charges must be changed so that they reflect scarcities and increase the reliability of supply. Most of the water tariff systems in both developed and developing countries do not reflect the economic and environmental scarcity of water. To be environmentally and economically viable, water tariff systems should ensure that the costs of collecting, treating and using water are recovered. Low income users should be able to reduce the amount they have to pay through active participation in systems of water collection, water supply and wastewater disposal and treatment.

The demand of major polluters or large consumers should be controlled using the instrument of marginal cost tariffs. Taxing consumption in this way is a financial incentive to water sustainability.

Where many different laws complicate wastewater reuse, consideration could be given to consolidated legislation that would cover all aspects of water resources planning, management and utilization.

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