

The cost of wastewater reclamation and reuse in agricultural production in the Mediterranean countries

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Abstract

Many countries have the problem of a severe water imbalance. This imbalance in water demand versus supply is due mainly to the relatively and uneven distribution of precipitation, high temperatures, increased demands for irrigation and the impacts of tourism. To alleviate water shortages serious consideration must be given to wastewater reclamation and reuse. Reclaimed wastewater can be used for a number of options including agricultural irrigation. Water quality requirements for reuse alternatives vary extensively depending on the extent of potential public exposure and, as a consequence, wastewater reclamation costs are usually not well-documented, calculated or, even, known. In this paper, some good examples of the potential benefits of wastewater reuse in different countries are presented, giving special consideration to the costs associated to the processes. The criterion for selecting these cases has been the contribution of the system into the overall increase of wastewater reuse in the country implemented. The effect of potential success factors and parameters has been looked into in order to realize why the implementation of these systems was proven to be highly efficient and successful.

Keywords

Irrigation; Mediterranean countries; municipal wastewater reuse; reclamation; water scarcity

INTRODUCTION

Many examples of the potential benefits of wastewater reuse in different countries will be present in this document. Naturally, they are most obvious for the arid areas but the general increasing pressures on water resources all over the world should also make wastewater reuse attractive in other areas. This examination has been carried out in the frame of the MEDAWARE project (<http://147.102.83.100/projects/meda/meda.htm>) funded by the Euro-Mediterranean partnership and more specifically by its Regional Program for Local Water Management whose main objectives are the development of the appropriate tools for the effective control and monitoring of the operation of the wastewater treatment plants and the development of relevant guidelines to ensure the safe operation of the wastewater treatment plants and also the safe reuse of the effluent.

Focusing our study on the Mediterranean countries, these are characterized by a severe water imbalance, especially the ones located in the North Africa and Middle East region. Irrigational reuse appears as an adequate strategy to dispose of the effluents of conventional wastewater treatment plants. In Mediterranean countries there are many coastal and southern regions where there is a severe pressure on freshwater resources, due to low and seasonally uneven precipitation and high run-off. In some cases this is exacerbated by especially high demand from tourism and agriculture during the summer months. The main reasons are very high population density and low to medium precipitation (Marecos *et al.*, 1996).

The most off-stream water uses in Mediterranean countries are industrial cooling, agriculture for irrigation and domestic and industrial process water. On the other hand, there major losses from

water delivered to agriculture for irrigation and domestic consumption. Notice should also be taken that Mediterranean countries have high agricultural use.

There are many countries in the world and many different approaches have been developed for water recycling regulations and guidelines to provide effective measures to protect against risk to public health and the environment. Clearly economics is a key factor in the choice of philosophy. The developed countries have tended to adopt an approach which leads to conservative high technology/high cost/low risk guidelines or regulations of which California's water recycling regulations are the best known examples. Some countries have endeavoured to follow this regulatory approach to guidelines, but have not always achieved low risk in practice because of insufficient money, experience or regulatory controls. Limits of affordability have led some developing countries to follow the low technology/low cost/controlled risk path of the attributable risk approach that is embodied in the World Health Organisation (WHO) Guidelines (Meulengracht, 2001).

In this paper, the analysis of a series of examples of successful wastewater systems which include sustainable treated wastewater reuse is presented. Special attention is paid to the cost associated to the global process of reclamation and reuse.

CURRENT SITUATION ON WASTEWATER REUSE

The use of wastewater for irrigation is a way of disposing urban sewage water with several advantages. Recycled water can be cost-effective means of supplying nutrients for agricultural irrigation and of possibly avoiding the need for nitrogen removal at wastewater works in sensitive areas. Furthermore, sewage water is an alternative water source in arid and semi-arid areas where water is scarce. Besides these advantages, wastewater can contain heavy metals, organic compounds and a wide spectrum of enteric pathogens which have a negative impact on the environment and human health.

In 1989 WHO set guidelines for the maximum number of bacteria and helminth eggs in wastewater used for irrigation to protect farmers and consumers of crops. Treatment methods were developed to reduce the hazardous elements in wastewater before its use on agricultural fields. However, in many developing countries wastewater is still used without any treatment, as treatment plants are expensive and farmers are willing to use this nutrient rich water without treatment. Knowledge about costs and benefits of treatment in developing countries is limited, as is knowledge about the actual environmental and health risks of irrigation with untreated urban wastewater (Feenstra *et al.*, 2000).

Wastewater reuse can be a matter of choice in general water management strategy. Worldwide, wastewater reclamation and reuse is estimated to represent a potential extra water resource amounting to approximately 15% of existing water consumption. On a local basis this proportion can be significant higher (e.g., 30% of agriculture irrigation water and 19% of total water supply in Israel in the future). In view of the increasing pressure on all water resources, both in industrialized and in developing countries, supplementing water resources with reclaimed wastewater can not longer be neglected (Asano, 1998).

The Mediterranean region is characterised by the low level and irregularity of water resources, both through time (summer drought, interannual droughts) and through space (dry in the South). The region includes 60% of the world population with renewable national natural resources of less than 1.000 m³ water/inhabitant/year. The strong growth in urbanisation, tourism, irrigation and

population can only increase tensions in many countries and regions where consumption has already reached the amount of available resources.

According to the Blue Plan (Margat and Vallée, 2002), renewable water resources are very unequally shared across the Mediterranean basin with around 72% located in the North (Spain, France and Monaco, Italy, Malta, Bosnia-Herzegovina, Croatia, Slovenia, R.F. of Yugoslavia, Albania and Greece), 23% in the East (Turkey, Cyprus, Syria, Lebanon, Israel, Palestinian Territories of Gaza and the West Bank and Jordan), and 5% in the South (Egypt, Libya, Tunisia, Algeria and Morocco). Countries of the Southern Mediterranean and Middle East region are facing increasingly more serious water shortage problems. Some of them have few naturally available fresh water resources and rely mainly on groundwater. Surface waters are already in most cases utilized to their maximum capacity. Groundwater aquifers are often over-drafted and sea and brackish water intrusion in coastal areas has reached threshold limits in some locations. Non-renewable deep or fossil aquifers are being tapped to varying degrees. Exploitation of non-renewable resources of Saharan aquifers is intensive in Libya, Egypt, Tunisia and Algeria. Desalination of brackish and seawater is already under implementation or planned in some countries despite its high cost. National exploitation ratios over 50%, or even nearing 100% in several Mediterranean countries (Egypt, Gaza, Israel, Libya, Malta, Tunisia) show that actual water consumption already exceeds the renewable conventional water resources. As a consequence, several problems appear all around the basin such as water and soil salinization, desertification, increasing water pollution and unsustainable land and water use.

Water recycling and reuse is meant to help close the water cycle and therefore enable sustainable reuse of available water resources. When integrated to water resources management, water reuse may be considered as an integral part of the environmental pollution control and water management strategy. It may present benefits to public health, the environment and economic development. Recycled water may provide significant additional renewable, reliable amounts of water and contribute to the conservation of fresh water resources.

It may be considered as a valuable source of water and nutrients in agriculture schemes and therefore contributes to reducing chemical fertilizers utilization and to increasing agricultural productivity. Reuse of recycled water, if properly managed, may alleviate pollution of water resources and sensitive receiving bodies. It may also contribute to desertification control and desert recycling. Other social and economic benefits may result from such schemes such as employment and products for export markets. It is, however, essential that the development of reuse prevents negative effects on environment and public health. Adequate treatment has therefore to be provided for the intended reuse (Kamizoulis *et al.*, 2003).

The main reuse projects in the Mediterranean region are related to agricultural and landscape irrigation and groundwater recharge. The management of wastewater in the Mediterranean varies from country to country, as do the criteria and their enforcement. Some countries have no wastewater treatment facilities and direct reuse of raw wastewater is occurring with serious health hazards and environmental problems. Others have a well-established national reuse policy. Moreover, wastewater treatment and reuse criteria differ from one country to another and even within a given country such as in Italy and Spain. Some of the main discrepancies in the criteria are, in part, due to differences in approaches to public health and environmental protection. This has led to substantial differences in the criteria adopted by Mediterranean countries.

The Water Framework Directive (Directive 2000/60/EC) makes a special mention referring cost of water and charges for water use. Securing adequate supplies of a resource for which demand is

continuously increasing is one of the drivers behind what is arguably one of the Directive's most important innovations: the introduction of an economic analysis of water use within river basins and an obligation to charge for recovery of costs for water services. Water must be priced and users must take adequate contributions to the costs of using water, divided at least into industrial, agricultural and household users. The requirement for a detailed economic analysis of the cost of water use will also create new incentives for changes by exposing the real figures for investments, running costs, environmental impact and for the distribution of the costs between user groups for water use.

COST EFFECTIVE CASES ON AGRICULTURAL REUSE OF URBAN WASTEWATER

Water reuse has recorded indisputable progress in recent years in the Mediterranean. Some concrete recent noteworthy examples can be pointed out in some Mediterranean countries, both nationally and locally. These examples show the considerable benefits of wastewater reuse. These benefits are both financial (savings in very costly heavy infrastructures), economic and social (wastewater reclamation and reuse processes, if they are well managed, may for example allow agricultural incomes to be improved and give better access to water for the least well-off) and environmental (reducing pressure on, and even restoring, ecosystems and resources).

In Cyprus the wastewater generated by the main cities, about 25 million m³/yr, is planned to be collected and used for irrigation after tertiary treatment. Because of the high transportation cost, it is anticipated that most of the recycled water, about 55 to 60%, will be used for amenity purposes used as hotel gardens, parks, golf courses, etc. A net of about 10 million m³ is conservatively estimated to be available for agricultural irrigation. This will reportedly allow irrigated agriculture to be expanded by 8-10% while conserving an equivalent amount of water for other sectors (Papadopoulos, 1995).

An interesting case in Cyprus is the Larnaca wastewater reuse system. Since the plant has been in operation (year 2000), the effluent is being used for irrigation of 150 hectares of agricultural land at Dromolaxia Village where corn and alfalfa are cultivated. The treated water is also used by the hotels, International Airport and Larnaca Municipality for the irrigation of gardens, parks and fields during the summer season. For that purpose, the effluent is being discharged through pumping stations. The total cost of the project is 50 million €, out of this, 9,3 million € is the cost of the tertiary treatment plant with the reuse network and pumping station. The cost for the production of tertiary treated water is around 0,5 €/m³ (Hidalgo *et al*, 2004).

Another remarkable case in Cyprus is the reuse system in Cavo Greco area. Since the plant has been in operation, the effluent is being used for irrigation of agricultural land in Paralimni where potatoes are mostly cultivated. The treated water is also used by the hotels and the Municipalities for the irrigation of gardens and parks during the summer season. The total cost of the plant has been 14,4 million €, out of this 5,9 million €, is the cost of the tertiary treatment plant with the reuse network and pumping station. The cost for the production of tertiary treated water is around 0,50 €/m³ (35 cents for secondary treatment and 15 cents for tertiary treatment). The Sewerage Board of Paralimni and Ayia Napa sells this water at the price of 0,25 €/m³ for the hotels and 0,10 €/m³ for agriculture (Hidalgo *et al*, 2004).

Few projects have in fact been carried out up to now in France, mainly because of problems relating to the cost of tertiary treatments. The projects implemented cover more than 3.000 hectares of land, and quite a wide variety of applications: market gardening crops, orchard fruit, cereals, tree plantations and forests, grasslands, gardens and golf courses. The Clermont-Ferrand recycling

scheme for irrigation of over 700 hectares of maize is today considered to be one of the largest projects in Europe. The recent development of new treatment processes, such as membrane bioreactors (ultrafiltration, microfiltration), to obtain very high quality purified water, disinfected and with no suspended solids, could change the approach to the problem and could open the door to recycling for domestic purposes (cleaning, toilet flushing, etc.). The reuse of industrial wastewater after purification to supply cooling water, wash water or even process water after sophisticated complementary treatment is widely developed in France (Kamizoulis *et al.*, 2003).

Since 1996, municipal wastewater is reuse in agriculture in the French island of Noirmoutier (Atlantic coast). La Salaisière secondary effluents are stored in a series of 4 reservoirs, with an overall storage capacity of 220.000 m³, making water available for irrigation and improving the microbiological quality of the stored water. Stored water that cannot be used for irrigation is disposed of to the sea. Between May and July, most of the stored water is used for irrigation and no water is discharged into the sea. Primary effluents of La Casie wastewater treatment plant are stored in 90.000 m³ stabilisation ponds. The four communities of the island have constituted an association which is in charge of water supply and wastewater collection, treatment, reuse and disposal. This association purchases the treated water and sells it to the consumers. It also sells treated wastewater to the farmers (Xu *et al.*, 2001). Prices listed in Table 1 vary with the quantity, quality and usage of water.

Table 1. Average water prices in Noirmoutier (including the cost of subscription and meters)

Purchased	Potable water (€/m ³)			Reclaimed water (€/m ³)
	Sold			Sold
	Domestic, hotel, etc.	Landscape	Agriculture	Agricultural irrigation
0,60	4,57*	0,67	1,54	0,23-0,30

Note: *including the price for sewage treatment and disposal: 2,21 €/m³

Source: Xu *et al.*, 2001

In Israel about 92% of the wastewater is collected by municipal sewers. Subsequently, 72% is used for irrigation (42%) or groundwater recharge (30%). Cost-benefit analysis indicates that recycled wastewater is a very low cost source of water in this country. As a result, treated wastewater within the overall water supply, particularly for irrigation, has risen to 24,4% of the allocations. The water crisis in Israel and the relatively low cost of treated wastewater, rather than pure environmental considerations, are the main driving forces behind the high percentage of reuse (Angelakis *et al.*, 2003). Dan Region project in Israel seems to be the largest and most remarkable one with 120 million m³/yr capacity. An average agricultural area of 16.000 ha is irrigated with this reclaimed water. The price of the water is 0,36 €/m³.

Agriculture is the largest water-consuming sector in Italy. In fact, it has been evaluated that water consumption is about 50 billions m³/y, about 50% is used for irrigation purposes, 20% for industry, 20% for drinking purposes and 10% for other uses (Barbagallo *et al.*, 2001). The medium to large-sized plants (>100.000 inhabitants served), accounting for approximately 60% of urban wastewater flow can provide re-usable effluents with a favourable cost/benefit ratio. One of the largest Italian projects was implemented in Emilia Romagna where over 450.000 m³/yr of treated effluents are used for irrigation of more than 250 ha. The real costs for the distribution of recycled wastewater (power, labour, network maintenance) are covered by the users (Angelakis *et al.*, 2003).

Two interesting examples, where plants intend to use their effluent in irrigating ornamental trees, reeds and bamboos, are founded in Lebanon in the regions of Hasbaya and Yanta. The plants of Hasbaya cover a built up area of about 2.000 m². Even though two municipal wastewater treatment plants were designed for this town, only one was completed and became operational by the year

2002. The construction of the other plant was completed but has not been put into operation. The actual total cost of construction for both plants was set at about 250.000 €. The plants are located at the lowest part of the Hasbaya area adjacent to two existing open channels in order to reduce pumping needs. Two plants are located also in Yanta village. Their capacities are 240 m³/day and 120 m³/day, respectively. The quality of the effluent from the smaller plant is quite acceptable and there are plans for using this effluent in irrigation. The total cost of the 2 plants was 91.000 €. It was also necessary to construct a wastewater collection network for the whole village at a cost of 245.000 € (Ayoub and El Fadel, 2004).



Figure 1. The Hasyaba (left) and Yanta (right) plants. Source: Ayoub and El Fadel, 2004

Most Moroccan towns are equipped with sewerage networks, frequently collecting also industrial effluent. However, out of the 60 largest towns only 7 have a municipal wastewater treatment plant, but both their design and operation are considered insufficient. As a consequence, most of the wastewater produced by the inland towns is used to irrigate crops after insufficient or even no treatment. Anyway, some cases of reuse can be pointed out in this country. One of them is the Ben Slimane reuse system (80 km South West of Rabat). The reclaimed water is used in irrigation of an average of 100 hectares of golf courses by sprinkling. In this case, the total cost of the project reached the amount of 8 million € while the exploitation cost are 78.000 €/year. The cost of the clean water produced is 0,12 € and the selling price of the purified water is 0,17 € (Mountadar and Assobhei, 2004).

Palestine has some guidelines applied to the reuse of treated wastewater from housing, municipalities, industry and commercial enterprises in the Gaza-Strip. The main objective is to reuse all treated wastewater to improve the water balance and the ground water quality as well as protecting soil and the public health. The Al-Beirah wastewater reuse system, developed in 2000, is an example of water reclamation and reuse in Palestine. The final effluent is discharged through Wadi Al-Ein, by 5 km pipeline, to be reused for irrigation in Dir-Dabwan land where large uncultivated areas exist. The construction cost of the wastewater reuse system is about 7 million €. The total cost for treating one cubic meter is 0,32 €. The results of the three-year operation of the plant have indicated that use of treated wastewater for food crops (pilot scale) irrigation is safe and acceptable. No adverse impacts in terms of soil or groundwater quality degradation were observed. Conventional farming practices were shown to be adequate and the marketability of the produce did not appear to pose any problems, and no project-related health problems were detected through medical examinations (Salem *et al.*, 2004).

In Tenerife Island (Spain) reclaimed municipal wastewater from the highly urbanized areas in the North is reused for crop irrigation (775 hectares) in the South of the island, an area with plenty of agricultural activities (mainly banana plantation but also potatoes and tomatoes). The reclaimed

wastewater undergoes a complete treatment in order to achieve quality standards for crop irrigation. Reclamation includes filtration, desalination and chlorination of the effluent. Water is reused fairly far from the city of Santa Cruz. It is then necessary to transport water through a 61 km pipe and to store it in two deep reservoirs of 50.000 and 250.000 m³, respectively. The price of the final reclaimed water is 0,45 €/m³. Economical influence of reclamation on the final price of irrigated agricultural products is reported to be high (Delgado *et al.*, 2001).

In Tunisia, nowadays, out of 61 treatment plants that treat 140 million m³/yr total are operating, 41 have a daily capacity less than 3.500 m³ and 10 above 10.000 m³, Choutrana being the largest with 120.000 m³/d. Municipal wastewater is processed biologically up to a secondary treatment stage. The treatment processes vary from plant to plant depending on wastewater origin and on local conditions. The water reuse application is restricted irrigation, fodder (alfalfa, sorghum, berseem, etc.) (45,3%), fruit trees (citrus, grapes, olives, peaches, pears, apples, grenades, etc.) (28,5%), cereals (22,4%) and industrial crops (sugar beet) (3,8%). In La Soukra irrigation area (8 km North East of Tunis) restricted irrigation of citrus trees and forage is carried out. Higher annual and perennial crop yields were achieved with the usage of treated wastewater compared to groundwater irrigation. The cost of this water is about 0,27 €/m³.

Most of the current wastewater reuse applications for agricultural irrigation are of small scale in Turkey but facilities tailored towards wastewater reuse in agriculture are gaining importance. However, such projects are currently in the design and construction stages. An integrated project has been proposed in the town of Siverek that includes the renewal and construction of a sanitary sewer system, a wastewater treatment plant and an irrigation network for wastewater reuse. It is intended to irrigate 350 ha of land, of which 250 ha are crops (cotton, wheat, eggplants, pepper, tomato, cabbage, carrot, spinach) and 100 ha are fallow land, with the reclaimed wastewater. The initial capital costs are estimated as 3,90, 0,27 and 3,80 million euros for the wastewater treatment plant, irrigation system, and sewage system, respectively (Aksoy *et al.*, 2004).

CONCLUSIONS

The increasing scarcity of water in the world along with the rapid population increase in urban areas is the reason for concern and the need for appropriate water management practices. Inadequate investment has been made in the past on sewage treatment facilities; water supply and treatment often received more priority than wastewater collection and treatment. However, due to the trends in urban development, wastewater treatment needs greater emphasis.

The cost of water reuse involves the extra treatment needed to reach the reuse quality requirement above and beyond the mandatory baseline treatment required to protect the community safety, health and environment and extra conveyance of the effluent to reuse sited. On the other hand the benefit of reuse includes the value of fresh water saved and the cost of the alternative safe final disposal of the effluent when reuse is not practiced. But the wide variation in projected and real reuse costs, both as a function of treatment level and facility capacity, makes difficult to develop a correct planning before design and construction and the result is that the real cost of the projects are usually considerably higher than the estimated previously. While technical, environmental and social factors are considered in project planning, monetary factors tend to control the ultimate decisions of whether and how to implement a wastewater reuse project.

Most water prices are either subsidised or do not include the true cost of water such as the environmental, social and economic impact of the process. There are the direct costs of headworks, storage, treatment, distribution etc., but there are also the externalities such as the impacts on public

health, water resource, phosphates, nitrates, soil salinisation, environmental biodiversity, flood mitigation etc.

Successful development of a water reclamation and reuse project requires careful planning and depends on many factors, not all of which are under the control of the project owner or manager. Identification of large customers of reclaimed water and a realistic assessment of their water demand is crucial for project development. Water quality requirements of all customers must be evaluated. If these requirements cannot be met, especially for large potential customers, project feasibility may be doubtful.

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