View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by HAL-Ecole des Ponts ParisTech

HAL archives-ouvertes.fr

Wastewater reuse in the Mediterranean region: Case of Morocco

Abdelaziz Hirich, Redouane Choukr-Allah

To cite this version:

Abdelaziz Hirich, Redouane Choukr-Allah. Wastewater reuse in the Mediterranean region: Case of Morocco. Daniel Thevenot. 13th edition of the World Wide Workshop for Young Environmental Scientists (WWW-YES-2013) - Urban waters: resource or risks?, Jun 2013, Arcueil, France. HAL-ENPC, WWW-YES-2013 (16), 2013, WWW-YES. <hal-00843370>

HAL Id: hal-00843370

https://hal-enpc.archives-ouvertes.fr/hal-00843370

Submitted on 11 Jul 2013

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Wastewater reuse in the Mediterranean region: Case of Morocco

Abdelaziz HIRICH and Redouane CHOUKR-ALLAH

Department of Horticulture, Complex of Horticulture of Agadir, 80150, Ait melloul, Morocco.
(E-mail: hirich_aziz@yahoo.fr ; redouane53@yahoo.fr)

Abstract

The southern Mediterranean region being one of the most dry and water scarce regions in the world. It is also expected that by 2025, due to population increase, the regional average water availability is projected to be just less than 500 cubic meters per person per year. Many countries in the region are mining groundwater, a temporary and risky expedient. The extended reuse of reclaimed (treated) wastewater could contribute considerably to the reduction of 'water stress' and 'water scarcity' in the Mediterranean countries as part of an Integrated Water Resources Management (IWRM) approach, focusing on the component wastewater reuse for irrigation and other purposes. The present article deals with the experiences carried out in Morocco in this domain. In spite of the progress that has been achieved in the last decade on technical, institutional, financial and legislative levels as regards the development of the process "sewage network-treatment-re-use", obstacles still hinder the deployment of the re-use of treated wastewater. In the current state of affairs, no project integrating the three components has been realized. This paradoxical situation is due to several constraints.

Keywords

Treated wastewater; Morocco; Irrigation; environment; benefit

INTRODUCTION

The Mediterranean region is characterized by the limited and irregular availability of water resources, both in time and in space. The region accounts for 10% of the world population with renewable water resources of less than 1000 m^3 water/inhabitant/year (Hamdy and Lacirignola, 2005). Water resources in the Mediterranean region are irregularly distributed in both time and space. 76% of precipitations and 85 % of renewable resources for the Mediterranean basin are concentrated in the Northern Mediterranean countries including turkey. The southern part of the Mediterranean basin is the most suffering from water scarcity (AQUASTAT, 2012).

The continuous growth in urbanization, tourism, irrigation and population increases tensions among sectors and causes conflicts in many countries and in regions where consumption has already reached or exceeded the amount of available water resources (Simonet, 2011). The Mediterranean countries are also, the most vulnerable to global climate change. Studies have shown that the people of the Mediterranean can expect more forest fires and loss of agricultural land than any other region in the world. In the future, the region is expected to deal with more frequent and severe water shortages (Senatore et al., 2011; García-Ruiz et al., 2011).

POTENTIAL OF TREATED WASTEWATER REUSE IN THE MEDITERRANEAN REGION

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 increasing demand for water (Choukr-Allah and Hamdy, 2004). In the Mediterranean basin, wastewater has been used as a source of irrigation water for centuries (MWRWG, 2007). In addition to providing a low cost water source, the use of treated wastewater for irrigation in agriculture combines three advantages. First, using the fertilizing properties of the water (fertigation) eliminates part of the demand for synthetic fertilizers and contributes to decrease the level of nutrients in rivers (Singh et al., 2011; Ribasl et al., 2010; Hussain and Al-Saati, 1999). Second, the practice increases the available agricultural water resources and third, it may eliminate the need for expensive tertiary treatment (Angelakis et al., 1999). However wastewater use poses serious risks to human health and the environment (Ganoulis, 2012; Iglesias et al., 2011). These risks arise from the occurrence of a great variety of microbial pathogens (Kayikcioglu, 2012) and chemical pollutants (Al Salem, 1996) in wastewater. However, the various existing national guidelines on wastewater reuse tend to focus mainly on risks from pathogens and there is little mention of other trace pollutants (Angelakis et al., 1999; Marecos do Monte et al., 1996).
According to (Choukr-Allah, 2012a), Wastewater produced (WWP) quantity in the Mediterranean region is equal to 35 $10^9 m^3 yr^{-1}$, about 64% of wastewater produced is treated (WWT) and only 18% is reused (WWR). This numbers indicate that there is a big potential of wastewater reuse in the Mediterranean region.

Table 1 Volumes of wastewater produced treated and reused

Country	Wastewater produced $10^6 m^3 yr^{-1}$	Year of WWP	Wastewater treated $10^6 m^3 yr^{-1}$	Year of WWT	Reuse of treated wastewater $10^6 m^3 yr^{-1}$	Year of WWR
Algeria	820	2011	700	2011	26	2011
Cyprus	24.0	2005	22.4	2005	25	2008
Egypt	4930	2008	2971	2001	2971	2001
France	7910	2004	7200	2004	410.9	2004
Greece	719	2000	450	2000	7.3	2008
Israel	450	2005	283	2005	280	2008
Italy	7731		2400	2004	270.6	2008
Jordan	82	2010	74	2010	70	2010
Lebanon	249	2001	4	1990	2	1991
Libya	546	1999	110	1999	40	1999
Malta	19	2003	22	2006-7	9.5	2008
Monaco	7.3	2009	6.02	2009	0	2009
Morocco	700	2011	177	2011	80	2007
Palestinian territories	50		26.9	2004	10	1998
Slovenia	168.5	2009	115.3	2009	6.9	2009
Spain	5204.4	2007	4515.6	2008	525.5	2008
Syria	825	2002	550	2002	550	2002
Tunisia	240	2001	215	2006	33.8	2001
Turkey	4289	2008	2484	2008	1000	2006

Source: (Choukr-Allah, 2012a)

OPTIMAL STRATEGIES OF WASTEWATER REUSE

Contamination of crops and risks to farm workers vary depending on the method used to apply irrigation water. The most hazardous option is spray irrigation, followed by general inundation of the area to be irrigated. Ridge and furrow irrigation reduces risks to some extent but the best irrigation option from a health point of view is allow water to drip from pipes laid along the ground (Mojiri and Amirossadat, 2011; Pereira et al., 2002). Drip irrigation is also advantageous in that it minimizes the amount of irrigation water required and health risks to farmers and product consumers due to contact with the wastewater. The performance of drip irrigation systems using wastewater is mainly limited by emitter clogging, and this discourages farmers from introducing it (Puig-Bargués et al., 2005; Palacios-Díaz et al., 2009). The best option of treated wastewater reuse is that adopted in landscape and golf courses irrigation especially they are considered as big consumers of water in tourist areas particularly demanding in water resources during summer. The irrigation of public parks, schools yards, highway, for fire protection and toilet flushing in commercial and industrial buildings (Schaefer et al., 2004; Choukr-Allah and Hamdy, 2004; Sengupta, 2006). Using treated wastewater also to irrigate non-food crop as forage, pasture and ornamental crops or to irrigate industrial crop can be a good option since the final product of those crops will not destined directly to human consumption but it will be subjected first to industrial transformation eliminating all pathogenic risks (Choukr-Allah and Hamdy, 2004; Schaefer et al., 2004; Sengupta, 2006; Kalavrouziotis and Apostolopoulos, 2007). Irrigation of perennial crops and cereals with wastewater is widely practiced in many areas. Using drip irrigation to irrigate those crops can be the best option to reuse wastewater since the health risks is minimized because of the consumed part in the plant is generally higher and far of drippers and cereals grains are subjected to transformation which eliminates contaminations (Angelakis et al., 1999; Kalavrouziotis and Apostolopoulos, 2007; Nassar and El-Korashey, 2003; Salgot et al., 2006).

Cooling systems and construction sector are major water consumers in many industries; therefore, using reclaimed wastewater for this purpose may bring considerable saving in fresh water consumption (Choukr-Allah and Hamdy, 2004; Ammary, 2007; Peng et al., 1995). Using reverse osmosis membrane for treating wastewater or desalinating saline water produced clean boiler feed water which can be used for multiple industrial purposes (Liu et al., 2008; Koo et al., 2011; Bill et al., 2008). Wastewater could be also for environmental issues such as pod and lakes recreation, creating artificial wetland and also stream flow augmentation (Sengupta, 2006). Wastewater can be used for aquaculture to produce both fish and aquatic plants and there are a number of models that can be adapted to suit individual situations and resources (Liu et al., 2007; El-Gohary et al., 1995; Sengupta, 2006). Aquifer recharge is also a practical key solution to reuse treated wastewater (Van Oorschot and French, 1996; Salgot et al., 2006). This operation can be made by 2 options, by surface infiltration basin or by borehole injection. The last option was shown more efficient (Van Oorschot and French, 1996).

THE REUSE OF WASTEWATER IN MOROCCO

Since the 1960.s, Morocco has largely contributed to the mobilization of its hydraulic capacities in order to face the demographic increase and sustain its social and economic development.

Nonetheless, and in addition to the continuation of the efforts directed to mobilization, and the control of demand, the limited hydraulic potential requires Morocco to resort to unconventional resources (wastewaters and brackish waters). Due to the more and more pronounced hydraulic deficit, the use of treated wastewaters in irrigation is necessary for conservation of water resources. Moreover, the experience of Morocco in this domain has proved the feasibility of the reuse procedure (Choukr-Allah, 2005). In addition, farmers have already resorted to raw wastewaters in areas where these waters are available close to agricultural lands. This is supported by the increasing demand for food, which is easily sold due to the proximity of the urban areas.

At present, about 700 million m^3 of raw wastewaters are discharged in the receptor milieu. Around 60% are discharged to sea; the remaining quantity is divided between draining-off of surface waters that represent the major part and a reuse operation concerning more than 7000 ha (Choukr-Allah, 2012b). The continuation of these discharges may lead to a deep degradation in the water resources and dangerous consequences on the potable water supply for many regions of the country. In parallel, continuing the reuse of raw wastewaters may have serious impacts on public health (Choukr-Allah and Hamdy, 2004).

In the last three decades, the annual volume of wastewaters has almost tripled. It has increased from 48 in 1960 to 500 million m^3 in 1999. It is expected that this volume may reach about 900 million m^3 in 2020 (Choukr-Allah, 2005). The trend in urban wastes generated is presented in Fig. 1.

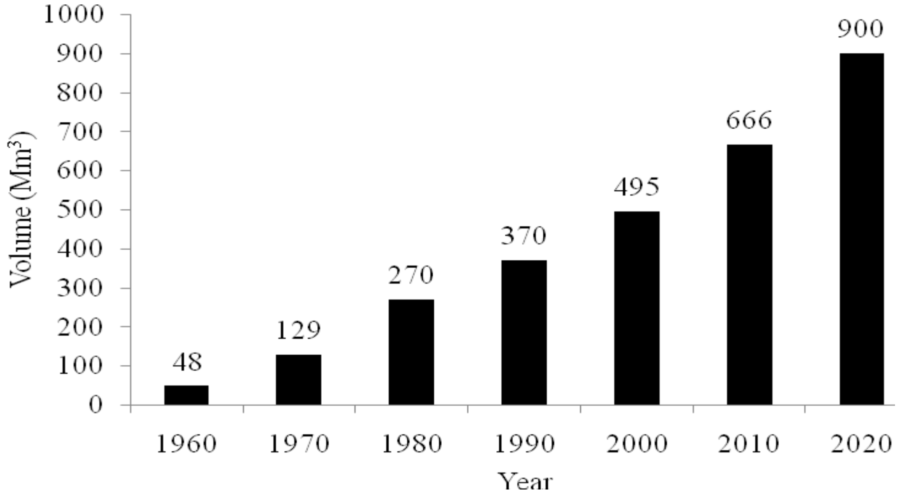

Figure 1: Trend of wastewater production in Morocco (Choukr-Allah, 2005)

The main factors that contribute to this increase are:

- The increase in the urban population by a rate that varies from 4.4 to 5%;
- The increase in the rate of the potable water network in urban areas, which has moved from 53% in 1972 to 79% in 1993 and to 85% in 2000;
- The increase in the rate of sewerage network which has reached 75% in big cities in 1999, and;
- The increase in the water consumption per capita. This increase jumped from 85 to 116 liters per inhabitant per day in the period between 1972 and 1992.

The reuse options

Artificial recharge of the aquifer

The treated wastewater is used to recharge the aquifer in the Gharb region (North-West of Morocco) in order to cope with the sea water intrusion due to overexploitation of groundwater (El Oualja, 2013). In Agadir city the treated wastewater in Ben Sergao station is used for the artificial recharge of the aquifer using an amount of about 10 Mm^3/year through filtration basing (Benzine, 2012)

Industrial recycling

Treated wastewater is recycled for some industrial process purpose in the Sidi Yahia Gharb region especially in the cooling. This project is realized by the ONEP (Office National d'Eau Potable).

Sylviculture

In the Kenitra Region the treated wastewater is used to irrigate trees (Eucalyptus) in the forest in order to fix the dunes and produce wood. It is also used to irrigate pastures in the zones where livestock activity is dominant (El Oualja, 2013). In the Ait Melloul city (Agadir region) there is a possibility to irrigate 400 ha of Argania forrest using about 4 Mm^3/year of treated wastewater generated by the M'zar station (Benzine, 2012)

Golf courses and Landscape

In the Ben Slimane city the wastewater plant treats about 5600 m^3/day until the tertiary level. The treated wastewater is used to irrigate a golf course with an area of about 100 km by sprinkler irrigation and supplying about 308 kg of Nitrogen. This allows a saving of about 3000 to 5000 m^3/day of water and 2 DH/m^3 (0.2 Euro/m^3) of costs in case of using fresh water. The reuse should be oriented to demand-driven planning of reuse projects, and commitment to the reuse. A good example is illustrated by the partnership between the water distributor agency of Marrakech (RADEEMA), the state of Morocco, and the 24 golf owners. The Agency will contribute up to 46.7 million US dollars, the golf course owners with 36.7 million US dollars and state with a subsidy of 16.1 million US dollars. The plant will allow the production of 24 million m^3 of tertiary treated wastewater to be used for the irrigation of these golf courses (Choukr-Allah, 2013). In Agadir city there is about 500 ha of golf course where a quantity of 20 Mm^3/year of the treated wastewater can be valorized , currently only the Golf de l'Océan (90 ha) who is using treated wastewater as source of irrigation water. There is also about 576 ha of landscapes for which 8 Mm^3 of treated wastewater could be supplied (Benzine, 2012).

Agriculture

In the Drarga city (Agadir region) the treated wastewater is used to irrigate about 16 ha of some cereals, forage and vegetable crops using the drip irrigation system. This practice allows a saving of about 120 to 361 Euros/ha in terms of fertilizer and 61 to 150 Euros/ha in terms of water use. Generally the yield of irrigated crop was doubled. This indicates that the use of unconventional water allowed getting higher water use efficiency without decrease in yield. As matter of fact, yields were higher for plants irrigated with treated wastewater (table 2). The increase of yield for plants receiving 20% more water is mainly due to more supply of nitrogen and lower salinity in the roots zone. The water use efficiency was significantly different between treated wastewater and saline well water. Water use efficiency was the highest for the plants receiving treated wastewater at 120% ETM (Choukr-Allah and Hamdy, 2003).

Table 2 Response of several crops to irrigation using treated wastewater

Treatments	Chrysanthemum	Zucchini	Egg plant	Maize	Bread wheat	Durum wheat
	Flower/plant	Kg/plant	Kg/m²	Qx/ha	Qx/ha	Qx/ha
Control*	69	1.29	3.17	12.43	5.107	0
Treated wastewater	80	2.18	3.41	12.62	48.69	31.83

Source: (Choukr-Allah and Hamdy, 2003)

* In the case of vegetable and flower control correspond to well water with added fertilizers and for cereals control correspond to rainfed conditions.

In the Tiznit city (South of Agadir), the wastewater treatment plant treats about 5000 m^3/day. This quantity of water is used to irrigate about 430 ha of olive, wheat, barley, alfalfa, faba bean and bean using drip irrigation (Benzine, 2012).

The treated wastewaters contain fertilizing elements and allow the farmer to save fertilizes inputs. The Table 3 is based on the performances obtained in Ouarzazate and Ben Sergao projects (Choukr-Allah, 2005).

Table 3 Economic gain from treated wastewaters irrigation

Crops	Net gain of water (DH/year.inhab)*	Benefit in fertilizers (DH/year.inhab)**	Total Benefit (DH/year.inhab)
Tender wheat	750	1492	2242
Unground corn	1588	3614	5202
Fodder corn	1568	3572	5140
Clover (Berseem)	774	1539	2313
Zucchini	677	1545	2222
Marrow	611	1216	1827
Tomato	1553	3542	5095
Potato	940	2140	3080

Source: (Choukr-Allah, 2005)

*Calculated on the basis of pumping water of Sous Massa (0.7 DH/m3) and of the selling price of treated wastewaters (0.5 DH/m^3).

** Calculated on the basis of the total value of fertilizing elements in treated wastewaters.

Irrigation Techniques

Numerous irrigation methods have been tested in the pilot projects. These include flood, furrow, sprinkler, and drip irrigation. In Morocco, most of the problems encountered were not linked to the irrigation method but rather to the irrigation scheduling, which should take into consideration the quality of treated wastewaters generally loaded with salt (Ouarzazate) and with nitrogen (Case of BenSergao). In Bensergao plant, it was proved that the choice of a good drip system might significantly improve the distribution of wastewaters at the level of the plot. Also, it is necessary to set up a double filtration system (sand and filter screen) to avoid the clogging of the drip system (Choukr-Allah, 1993).

Valorization of the Residual Sludge

The experiences conducted in the reuse of residual sludge have been less developed than those conducted on the reuse of treated wastewaters. Meticulous tests have been carried out in Ouarzazate and Bensergao. In Ouarzazate, the sludge emanating from the drying beds have given satisfactory results. In an agronomic experience concerning the cultivation of the Italian Ray Gras, the increase of dry products was by 200%. No heavy metal accumulation was found in neither the soil nor in the plants. In the case of Ben Sergao, the sludge was composted and used for the organic enrichment of two grass species. The height and production parameters of the dry materials have been significantly improved. The composting operation allowed the total drainage of the sludge, and thus wiped out any risk of biological contamination (Choukr-Allah, 1994).

Legal aspects

In Morocco, the legal statute of water was instituted in several phases. The legislative intervention through the creation of the new legal regulations in the field of water goes back to the period of the French Protectorate in Morocco. Several texts were adopted in this respect, mainly:

- law of July 1, 1914 (repealed by the new law on water) supplemented by the law dated November 8, 1919 on the public domain which institutes the principle of water and its sources as public domain.
- law and ministerial decree of August 1, 1925 (repealed by the new law on water) relative to the regulation of water, modified by the laws of July 2, 1932, March 15, 1933, September 18, 1933 (repealed by the new law on water), of October 9, 1933, July 25, 1939, and September 24, 1952.

This old legislation ceased to correspond to the country's modern organization and could no longer meet the needs for its socio-economic development, which required the creation of a modern regulation of water through the adoption of law No: 1-95-154 of 18 Rabii I 1416 (corresponding to 16 August 1995) promulgation of the law No. 10-95 on water. This Law aims at the elaboration of a national water policy based on a forward vision that takes account of the evolution of resources and of national water needs.

In the field of wastewater, this new Law 10-95 on water, in its chapter VI, regulates the reuse of wastewater and its texts constitute the legal basis of the institutional framework for reuse, in particular articles 51, 52, 56, 57, 59 and 84 (Choukr-Allah, 2005).

Impact on Health

Reusing raw wastewater is likely to imperil human health and to contaminate the environment. Indeed, wastewater can transport many pathogenic germs (parasitic, bacteria, viruses and fungi) that possess high resistance to the medium and can harm humans. Wastewater is therefore a significant transmitter of biological and chemical agents resulting from human and/or industrial activities. Agriculture that is irrigated with wastewater concentrates many infectious and toxic agents. In addition, it represents a medium for the proliferation of certain pathogenic agents emitted in human or animal waste. In addition, wastewater resulting from hospital discharge or other infected mediums may be a dangerous source of contamination (Ganoulis, 2012).

Social and political aspects

There are reservations related to the use the treated wastewater (which is often perceived as unclean). This is paradoxical when one considers the quantities of wastewater re-used in its raw state. Wastewater goes through a treatment station where the influx of raw wastewater is clearly visible. The origin of used water is thus known. There is therefore natural hesitation to consume fruit and vegetables irrigated with used water. In the region of Agadir, farmers whose products are exported to foreign markets are very reticent to use treated wastewater lest this compromises their markets (Choukr-Allah, 2005).

CONCLUSION

Although agriculture will remain the dominant user of water, in water-scarce countries intense competition for good quality water among the different water-use sectors is expected to reduce the amount of freshwater allocated to agriculture in the foreseeable future. Whatever the case, there should be no anxiety in any region of the world, including Southern Mediterranean region, about the availability of water for drinking and domestic use and for the needs of almost all of the industrial and service sectors. In fact, these sectors use less than 25% of the freshwater resources available. This additional water resource is considered somewhat attractive, being renewable and accessible in peri-urban areas, cheap source that be disposed-off, its quantity grows with the expansion of sanitation networks installed for urban or rural communities and being not affected by the climate change. The current overall contribution of treated wastewater to agriculture in Morocco could hardly exceed 4% of this sector demand of freshwater. This small percentage, however, should be reckoned with when drafting water master plans, not only for satisfying some irrigation requirements, but also for the fact that reuse of treated effluent is safe, feasible, and environmentally-sound method of wastewater disposal. Furthermore, for most arid and semi-arid countries, reuse of wastewater may have a greater impact on future usable sources of water than any of technological solutions available for increasing water such as water harvesting and desalination.

REFERENCES

Al Salem S. S. (1996). Environmental considerations for wastewater reuse in agriculture. *Water Science and Technology* 33 (10–11),345-353.

Ammary B. Y. (2007). Wastewater reuse in Jordan: Present status and future plans. *Desalination* 211 (1–3),164-176.

Angelakis A. N., Marecos Do Monte M. H. F., Bontoux L., Asano T. (1999). The status of wastewater reuse practice in the Mediterranean basin: need for guidelines. *Water Research* 33 (10),2201-2217.

AQUASTAT (2012) Revue des statistiques sur les ressources en eau par pays. Food and Agriculture Organization FAO,

Benzine L. (2012). Réutilisation des eaux usées épurées dans le bassin de Souss Massa. Paper presented at the *Journée de sensibilisation sur Les Potentialités et Perspectives de la Réutilisation des Eaux Usées Dans la Région du Sous Massa*, Complexe Horticole d'Agadir,

Bill H., Xie X., Yan D.-c. (2008). New technology for heavy oil exploitation wastewater reused as boiler feedwater. *Petroleum Exploration and Development* 35 (1),113-117.

Choukr-Allah R. Municipal wastewater reclamation and reuse: Moroccan experiences. In: hamdy A (ed) *Advanced short course on sewage: treatment-practices-management for agriculture use in the Mediterranean countries* Cairo, Egypt, 1993. pp 301-310

Choukr-Allah R. Unconventional water resources management in southern Morocco. In: Hamdy A (ed) *International conference on land and water resources management in the Mediterranean region*, Bari, Italy, 1994. pp 403-416

Choukr-Allah R. (2005) Wastewater treatment and reuse in Morocco: situation and perspectives. In: El Gamal F. (ed.) LNe, Bogliotti C. (ed.) , Guelloubi R. (ed) Options Méditerranéennes : Série B. Etudes et Recherches, vol 53. CIHEAM, Bari, Italy, pp 271- 287

Choukr-Allah R. Perspectives of Wastewater Reuse in the Mediterranean Region. In: Choukr-Allah R, Ragab R, Rodriguez-Clemente R (eds) *MELIA PROJECT FINAL CONFERENCE on "Integrated water resource management in the Mediterranean: Dialogue towards new strategy" 19-22 June, 2011*, Agadir, Morocco, 2012a. Springer,

Choukr-Allah R. (2012b) Perspectives of Wastewater Reuse in the Mediterranean Region. In: Choukr-Allah R, Ragab R, Rodriguez-Clemente R (eds) Integrated Water Resources Management in the Mediterranean Region. Springer Netherlands, pp 125-137.

Choukr-Allah R. (2013). Interventions to increased efficiency and effectiveness of treated wastewater reuse in Agriculture in the Mediterranean Region Paper presented at the *International Conference on: Sustainable Water Use for Securing Food Production in the Mediterranean Region under Changing Climate*, Agadir, Morocco, March 10 - 15, 2013, Choukr-Allah R., Hamdy A. Sus tainability and optimis ation of treatments and reus e of was tewater in agriculture: cas e of Morocco. In: Hamdy A (ed) *Regional Action Programme (RAP) : Water resources management and water saving in irrigated agriculture (WASIA PROJECT)*, Bari, Italy, 2003. Options Méditerranéennes : Série B. Etudes et Recherches. CIHEAM-IAMB, pp 77- 87

Choukr-Allah R., Hamdy A. (2004). Wastewater Treatment and Reuse in Mediterranean Region as a Potential Resource for Drought Mitigation. *Options Méditerranéennes : Série B* 47,219-243.

El-Gohary F., El-Hawarry S., Badr S., Rashed Y. (1995). Wastewater treatment and reuse for aquaculture. *Water Science and Technology* 32 (11),127-136.

El Oualja H. (2013). Étude de trois projets de réutilisation des eaux usées épurées (REUE) en valorisation industrielle, en sylviculture et en recharge de nappe. Paper presented at the *CAC, Rabat - 4 février 2013*,

Ganoulis J. (2012). Risk analysis of wastewater reuse in agriculture. *Ganoulis International Journal Of Recycling of Organic Waste in Agriculture* 1 (3),1-9.

García-Ruiz J. M., López-Moreno J. I., Vicente-Serrano S. M., Lasanta–Martínez T., Beguería S. (2011). Mediterranean water resources in a global change scenario. *Earth-Science Reviews* 105 (3–4),121-139.

Hamdy A., Lacirignola C. (2005) Coping with water scarity in the Mediterranean: What, why and how? CIHEAM-IAMB, Bari, Italy

Hussain G., Al-Saati A. J. (1999). Wastewater quality and its reuse in agriculture in Saudi Arabia. *Desalination* 123 (2–3),241-251.

Iglesias A., Garrote L., Diz A., Schlickenrieder J., Martin-Carrasco F. (2011). Re-thinking water policy priorities in the Mediterranean region in view of climate change. *Environmental Science & Policy* 14 (7),744-757.

Kalavrouziotis I. K., Apostolopoulos C. A. (2007). An integrated environmental plan for the reuse of treated wastewater effluents from WWTP in urban areas. *Building and Environment* 42 (4),1862-1868.

Kayikcioglu H. H. (2012). Short-term effects of irrigation with treated domestic wastewater on microbiological activity of a Vertic xerofluvent soil under Mediterranean conditions. *Journal of Environmental Management* 102 (0),108-114.

Koo C. H., Mohammad A. W., Suja F. (2011). Recycling of oleochemical wastewater for boiler feed water using reverse osmosis membranes — A case study. *Desalination* 271 (1–3),178-186.

Liu C. C. K., Xia W., Park J. W. (2007). A wind-driven reverse osmosis system for aquaculture wastewater reuse and nutrient recovery. *Desalination* 202 (1–3),24-30.

Liu H., Yang C., Pu W., Zhang J. (2008). Removal of nitrogen from wastewater for reusing to boiler feed-water by an anaerobic/aerobic/membrane bioreactor. *Chemical Engineering Journal* 140 (1–3),122-129.

Marecos do Monte M. H. F., Angelakis A. N., Asano T. (1996). Necessity and basis for establishment of European guidelines for reclaimed wastewater in the Mediterranean region. *Water Science and Technology* 33 (10–11),303-316.

Mojiri A., Amirossadat Z. (2011). Effects of Urban Wastewater on Accumulation of Heavy Metals in Soil and Corn (Zea mays L.) with Sprinkler Irrigation Method. *Asian Journal of Plant Sciences* 10,233-237.

MWRWG (2007) Mediterranean Wastewater Reuse Report. MEDITERRANEAN WASTEWATER REUSE WORKING GROUP,

Nassar A., El-Korashey R. (2003). SUSTAINABLE DEVELOPMENT AND REUSE OF WASTEWATER. Paper presented at the *Seventh International Water Technology Conference, 1-3 April 2003*, Egypt, Palacios-Díaz M. P., Mendoza-Grimón V., Fernández-Vera J. R., Rodríguez-Rodríguez F., Tejedor-Junco M. T., Hernández-Moreno J. M. (2009). Subsurface drip irrigation and reclaimed water quality effects on phosphorus and salinity distribution and forage production. *Agricultural Water Management* 96 (11),1659-1666.

Peng J., Stevens D. K., Yiang X. (1995). A pioneer project of wastewater reuse in China. *Water Research* 29 (1),357-363.

Pereira L. S., Oweis T., Zairi A. (2002). Irrigation management under water scarcity. *Agricultural Water Management* 57 (3),175-206.

Puig-Bargués J., Arbat G., Barragán J., Ramírez de Cartagena F. (2005). Hydraulic performance of drip irrigation subunits using WWTP effluents. *Agricultural Water Management* 77 (1–3),249-262.

Ribasl M. M. F., CeredaII M. P., Bôas R. L. V. (2010). Use of cassava wastewater treated anaerobically with alkaline agents as fertilizer for maize (Zea mays L.). *Braz arch biol technol* 53 (1),55-62.

Salgot M., Huertas E., Weber S., Dott W., Hollender J. (2006). Wastewater reuse and risk: definition of key objectives. *Desalination* 187 (1–3),29-40.

Schaefer K., Exall K., Marsalek J. (2004). Water Reuse and Recycling in Canada: A Status and Needs Assessment. *Canadian Water Resources Journal* 29 (3),195–208.

Senatore A., Mendicino G., Smiatek G., Kunstmann H. (2011). Regional climate change projections and hydrological impact analysis for a Mediterranean basin in Southern Italy. *Journal of Hydrology* 399 (1–2),70-92.

Sengupta A. K. (2006). Wastewater Management and Reuse for Agriculture and Aquaculture in India. Paper presented at the *CSE Conference on Health and Environment*, New Delhi, India, 24-25 March 2006,

Simonet S. (2011) Adapting to climate change in the water sector in the Mediterranean: situation and prospects. Blue Plan Papers, vol 10. UNEP/MAP Regional Activity Center,

Singh S., Rekha P. D., Arun A. B., Huang Y. M., Shen F. T., Young C.-C. (2011). Wastewater from monosodium glutamate industry as a low cost fertilizer source for corn (Zea mays L.). *Biomass and Bioenergy* 35 (9),4001-4007.

Van Oorschot R., French M. (1996). Wastewater 2040 — alternative effluent disposal and reuse options for Perth and southern regions. *Desalination* 106 (1–3),157-163.

16-WWW-YES-2013-Hirich-Paper-2013-06-25-HAL.doc