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URBAN WASTEWATER: PROBLEMS, RISKS AND ITS POTENTIAL USE FOR IRRIGATION

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BACKGROUND ABOUT MEDITERRANEAN REGION

The Mediterranean region comprises the Mediterranean Sea and its coastal area. It can be roughly located between 30°N – 50°N latitude and 10°W -40°E longitude. The Mediterranean countries can be grouped according to similar climatologically and socio-economic characteristics: northern basin countries (Spain, France, Monaco, Italy, Former Yugoslavia, Albania, and Greece) and southern basin countries (Turkey, Cyprus, Syria, Lebanon, Palestine, Egypt, Libya, Malta, Tunisia, Algeria, and Morocco) (Rosenzweig and Tubiello, 1997; Massoud, Scrimshaw and Lester, 2003).

Total population of the region is actually around 427 million inhabitants with 145 million living near the sea and an additional 180 million tourists each year. By 2025, the population is expected to increase by 17-19% and the tourist population by 40%. The demographic evolution of population is fundamentally different in Eastern and Southern countries (intensively growing) compared to the Northern ones (stabilizing or decreasing). It is aggravated by a very intensive urbanization often along the coastal areas (Kamizoulis *et al.*, 2003; Massoud *et al.*, 2003).

Climatically, it is characterized by mild temperature, winter-dominated rainfall, and dry summer (Wigley, 1992). Annual precipitation ranges between 275 and 900 mm, the average temperature in winter months is below 15ºC and the hours per year at which the temperature falls below freezing (0ºC) do not exceed 3% of the total. Northern regions are relatively more temperature and humid. While southern regions are warmer and drier with endemic water shortages due to the interaction of relatively low seasonal rainfall and high evapotranspiration rates (Rosenzweig and Tubiello, 1997).

WATER RESOURCES IN THE MEDITERRANEAN BASIN

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 countries of the Southern Mediterranean and Middle East region 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 (Margeta and Vallée, 2000; Shelef and Azov, 1996; Kamizoulis *et al.*, 2003)

Due to rapid population growth, the average annual per capita renewable water is rapidly decreasing since 1950 (Fig. 1). It varies across a wide range from a little over 100 to more than 1000 cubic meters per year (Margeta and Vallée, 2000). All the Mediterranean countries of the EU are expected to maintain themselves at or above 3000 m^3/inh.yr when in the major part of the other

Mediterranean countries, the projected water availability is below the level of “chronic water scarcity” (< 1000 m^3/inh.yr) (Massoud *et al.*, 2003; Hamoda, 2004; Wigley,1992).

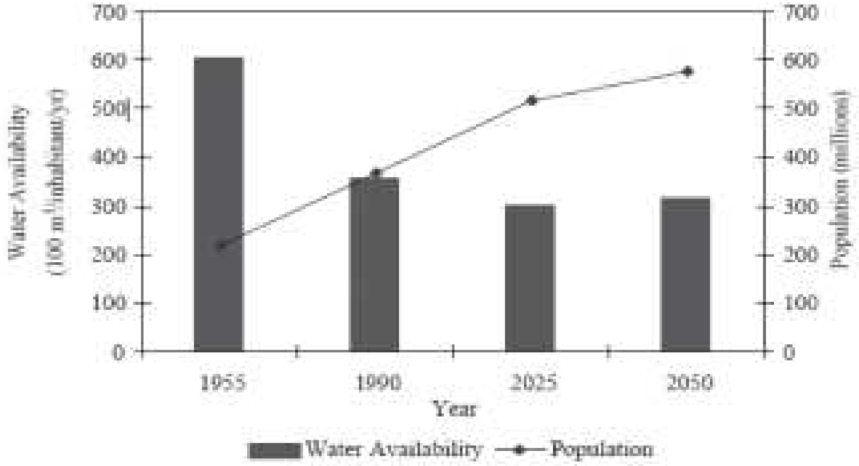

Figure 1.Population growth and annual renewable freshwater availability / inhabitant in the Mediterranean region

In the Mediterranean basin as a whole, 72 % of water resource is used for irrigation, 18 % by industry, and 10% for domestic consumption (Massoud *et al.*, 2003; Redwood, 2004).

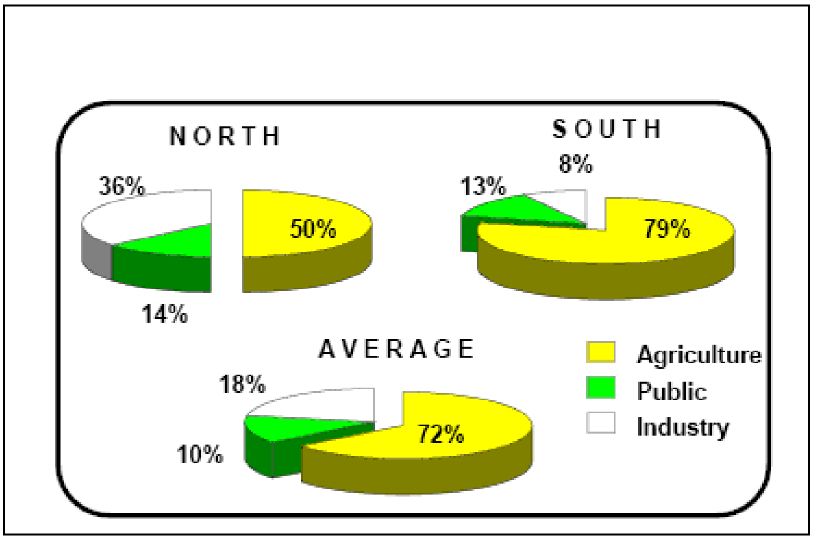

Figure 2.Water use in the Mediterranean countries (Hamdy and Lacirignola, 2005)

Agriculture is the main water-consuming sector. It accounts for 72% of the total demand in the Mediterranean Basin (48% in the North and approximately 80% in the South and East), (Plan Bleu, 2006).

WASTEWATER DEFINITIONS AND CHARACTERISTICS

-Definitions of wastewater

It is assumed that urban wastewater maybe a combination of some or all of the following: Domestic effluent consisting of black water (excreta, urine, and associated sludge) and grey water (kitchen and bathroom wastewater) water from commercial establishments and institutions, including hospitals industrial effluent Storm water and other urban runoff (Hamdy . and Ragab, 2005).

In irrigation, sometimes the term marginal quality water is used. This is refers to water whose quality might pose a threat to sustainable agriculture and or human health, but which can be used safely for irrigation provided certain precautions are taken. Marginal water quality water is water that has been polluted as a consequence of mixing with wastewater or agriculture drainage (Cornish *et al.*, 1999). The term can also refer to water with a high salt content. Marginal quality water can also be considered wastewater (Hamdy and Ragab, 2005).

Also wastewater is defined by (AL-Shreideh, 2001), it is the water that results from domestic use and could be mixed industrial wastewater of a quality which meets the connection requirements set by the official body.

-Characteristics of wastewaters

Municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. (Table1) shows the levels of the major constituents of strong, medium and weak domestic wastewaters. In arid and semiarid countries, water use is often fairly low and sewage tends to be very strong (Pescod, 1992; Crites and Tchobanoglous, 1998).

Table 1.Major of typical domestic wastewater (Pescod, 1992)

Constituent	Concentration, mg/l		
	Strong	Medium	Weak
Total solids	1200	700	350
Dissolved solids (TDS)	850	500	250
Suspended solids	350	200	100
Nitrogen	85	40	20
Phosphorus	20	10	6
Chloride	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50
BOD_5	300	200	100

Municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use. However, from the point of view of health, a very important consideration in agricultural use of wastewater, the contaminants of greatest concern are the pathogenic micro- and macro-organisms. Pathogenic viruses, bacteria, protozoa and helminthes may be present in raw municipal wastewater (Table 2) and will survive in the environment for long periods. Pathogenic bacteria will be present in wastewater at much lower levels than the coliform group of bacteria, which are much easier to identify and enumerate (as total coliforms/100ml). Escherichia coli are the most widely adopted indicator of fecal pollution and they can also be isolated and identified fairly simply, with their numbers usually being given in the form of fecal coliforms (FC)/100 ml of wastewater (Crites and Tchobanoglous, 1998; WHO, 2006; Pescod, 1992).

Table 2.Type of Pathogens in Wastewater (Pescod, 1992)

Type of pathogen	
Viruses	Enteroviruses
Bacteria:	Pathogenic E. coli
	Salmonella spp.
	Shigella spp.
	Vibrio cholerae
Protozoa	Entamoeba

Wastewater treatment

The aim of wastewater treatment could be described as the process required to enable wastewater to be disposed safely, without being a danger to public health, and without polluting watercourses or causing other environmental nuisance. The necessary quality of reclaimed water varies according to the use, and consequently different unit processes and combination of unit processes are required for the achievement of the required quality (Fatta *et al.*, 2005; Crites and Tchobanoglous, 1998; Tchobanoglous Angelakis, 1996). Steps and objectives of wastewater treatment process are given in (Table 3).

Table 3.Steps and objectives of wastewater treatment process (Pescod, 1992)

Step	Objective
Preliminary treatment	The removal of coarse solids and other large materials often found in raw wastewater to enhance the operation and maintenance of subsequent treatment units
Primary treatment	The removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float by skimming.
Secondary treatment	The further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes
Tertiary and/or advanced treatment	Employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. As individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, and heavy metals and dissolved solids.
Disinfection	Involves the injection of a chlorine solution at the head end of a chlorine contact basin. Ozone and ultra violet irradiation can also be used
Effluent storage	Storage facility is, a critical link between the wastewater treatment plant and the irrigation system

Some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements (Arar, 1988; Pescod, 1992; Asano *et al.*,1985).

DRIVING FORCES FOR THE DEVELOPMENT OF WASTEWATER RESOURCES

-Water resources problems

In the majority of developing countries of the Mediterranean, the legacy of past and current practices that threat water as an unlimited resource is leading to fast depletion of this valuable resource on which human life, food security and ecosystems survival depend (Hamdy and Lacirignola, 2005; Pereira *et al.*, 2002).

The mismanagement of the water resources and the notable water losses in all sectors, in particular, agriculture where efficiency below the 50% is a very clear indication of how weak the water sector in the majority of the Mediterranean countries. This also leads us to the conclusion that the current water crisis is mainly of water governance. The water sector is still characterized by ill funded and badly organized institutions. Legislation is generally incremental and out-dated and relevant rules and regulations are poorly enforced. Water activities are fragmented and divorced from the environmental management where ecosystem functions and services are ignored. Data and information on hydraulic, meteorological and socio-economic features are often inadequate, inconsistence and unreliable (Hamdy and Lacirignola, 2005; Pereira *et al.*, 2002).

-Structural imbalance

The dominant fact that will be strongly evident over next few decades is the structural imbalance between the constantly increasing demand for water to meet the needs and the natural available resources (Fig. 3).

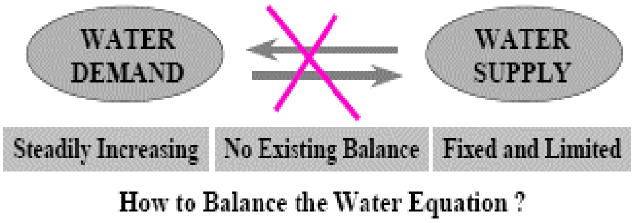

Figure 3.Water resources dilemma in the Mediterranean region (Hamdy and Lacirignola, 2005)

In the majority of countries in the region, the imbalance has appeared around the year 2000 and beyond. These countries will be facing similar problems that could outlines as follows:

i. Decline water resources per inhabitants both in terms of water availability and water withdrawals. It is expected that the available water per capita will be reduced by nearly 50% of the present one.
ii. Exploitation of water at a relatively high rate with the risk of water quality deterioration
iii. Excusive reduction in water withdrawals per capita
iv. Progressive degradation in the quality of available water resources because of increase waste load discharged in to water bodies and the atmosphere.

Water demand for the years 1990 together with the projections for 2010 and 2025 are given in (Fig. 4). This figure clearly indicates that there will be a progressive increase in the water demand within the next 25 years. Globally for the whole Mediterranean countries, it is expected that the water demand will be increased by nearly 50% in the year 2025 with respect to actual demand values (1990), (Hamdy, 2003).

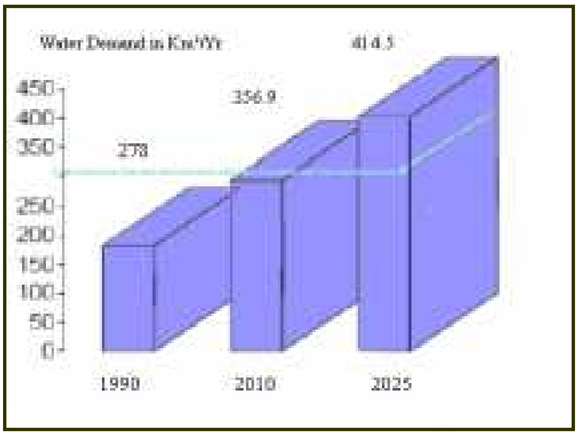

Figure 4. Actual water demand in 1990 and foreseen water demand for 2010 and 2050, in km^3/year (Hamdy, 2003)

The question emerging nowadays is how to meet this water demand at a time when pressures on resources are increasing and becomes increasingly. The solutions of those problems require new management strategies towards a more balanced approach (Hamdy, 2003).

-Water scarcity

Water in the Mediterranean region is a rare, fragile and unevenly distributed resource. Water demands are increasing; in numerous Mediterranean countries water use is approaching the limit level of available resources. Pressures on water resources will increase significantly in the South and East, and it is expected that, by 2025, 63 million people in the Mediterranean will be limited to less than 500 m^3 per capita per year (defined as the “shortage” threshold). The increase in water demand for agriculture and for urban use and the scarcity of resources signify that one out of every three Mediterranean countries will withdraw over 50% of the annual volume of its renewable natural resources (Plan Bleu, 2006; Massoud *et al.*, 2003; Pereira *et al.*, 2002).

Due mainly to very high population growth some countries, such as Jordan, Tunisia, and Malta, experience “absolute water stress” with per capita water availability of less than 500 m^3/inh/yr. In Malta, domestic water consumption exceeds 50% of the available water resources. In such places, the conventional water resources will be insufficient to even meet the domestic water demand, indicating that major developing countries in the region are experiencing chronic and absolute water stress (Hamdy, 2003).

Table 4.Mediterranean countries experiencing water scarcity in 1955, 1990 and 2025 projected, based on availability of less than 1,000 m^3 renewable water/ person/year. (Hamdy, 2003)

Water scarcity countries in 1955	Countries added to scarcity categories by 1990	Countries added to scarcity categories by 2025 (UN population projections)
Malta	Israel	Libya
Jordan	Tunisia	Morocco
	Algeria	Egypt
		Syria
		Cyprus

-Population trends and explosive urban growth

It is estimated that the population of the countries of the Mediterranean basin as a whole, currently around 400 million, will have reached between 520 and 570 million by 2025. The northern countries of the basin, from Spain to Greece, will account for only about one-third of the total population in 2025, whereas the countries in the south and east of the basin, from Morocco to Turkey, will contribute almost two-thirds of the total Mediterranean basin population in 2025, (Kamizoulis *et al.*, 2003; Plan Bleu, 2006).

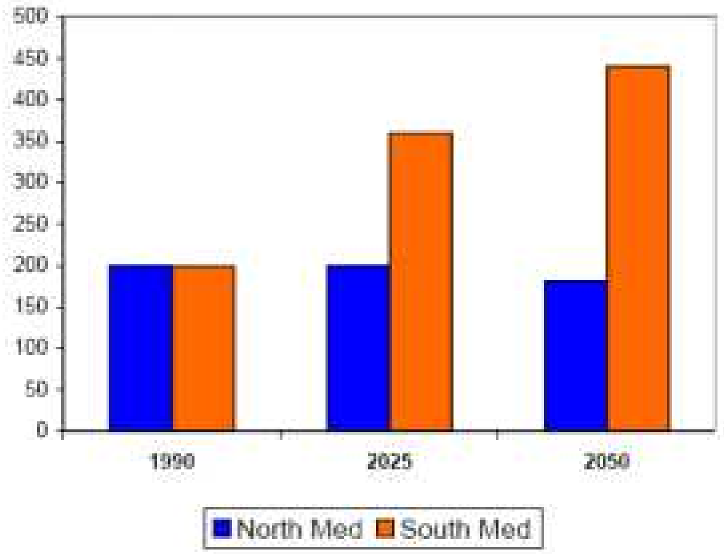

Figure 4. Population in the Mediterranean countries (Hamdy, 2003)

Rapid population is always linked with rapid urbanization. Urban growth will be explosive in the southern and eastern countries, where it is, on average, five times faster than it was in Europe last century. The rate is not the only factor to be considered. The size of urban population will be very large: 200 million more urban inhabitants in 2025 in the south and east of the basin. The urban population of the Mediterranean basin could in fact amount to between 380 and 440 million compared to a little over 200 million today. Generally, the annual growth of urbanization is high in the Mediterranean region, but it is much higher in the south (4.5%) compared to the north (2.8%). This population increase with a high urbanization rate will place serious stress on fresh-water resources, particularly with consumptive uses in the developing countries of the Mediterranean region. Under such conditions, Southern and Eastern Mediterranean countries will experience difficulties in ensuring self-sufficiency in meeting agricultural, domestic and industrial water needs. The supply of drinking water to urban areas will be one of the most critical problems in those countries (Hamdy and Lacirignola, 2005; Plan Bleu, 2006).

BENEFITS AND NEGATIVE EFFECTS OF USING TREATED WASTEWATER

A. Benefits

- *Environmental benefits*

Treated wastewater may be used for different purposes without endangering human health or damaging the environment (AL-Shreideh, 2001).

Reusing treated wastewater, rather than disposing of it, may help improve the environment by:

- Prevention of surface water pollution which could occur when wastewater is not used but is discharge in rivers and lakes. Planned reuse of wastewater for irrigation will greatly help in the elimination of several environmental pollution problems: dissolved oxygen depletion, eutrophication, foaming, fish deaths, etc. (Friedler, 2001).
- The use of treated wastewater for irrigation will help in reducing the over-pumping and exploitation of groundwater, thus avoiding sea-water intrusion and deterioration of exploitation of ground water quality, groundwater being main source of drinking water supply (Choukr-Allah and Hamdy, 2003; Cornish *et al.*, 1999).
- Better rational use of the water resources with low quality being used for irrigation purposes and good quality freshwater is being used for potable water and other special uses (Hamdy and Ragab, 2005).

- The use of treated wastewater serves also as a nutrients source; this reduces the use of artificial fertilizers with a reduction in energy expenditure and industrial pollution elsewhere (Hamdy and Ragab, 2005).
- Helping control dust storms and desertification in arid zones through irrigating and fertilizing tree belts (AL-Shreideh, 2001).
- Improving the soil quality by reusing treat and wastewater in poor desert soils (AL-Shreideh, 2001).

- ***Social benefits***

Much of the population growth has been attributed to rural urban migration in search of jobs and better living conditions. Reusing reclaimed wastewater can alleviate unemployment of unskilled laborers, improving the quality of life and income distribution of the rural population and providing jobs and settlement opportunities in rural areas (AL-Shreideh, 2001).

- ***Economic benefits***

In the developing countries of the region, the value added locally to production in agriculture is normally high, giving a further advantage to agricultural use of wastewater over other potential uses. Reclaiming and reuse of wastewater has a clear positive impact in sustaining tourism and related activities which otherwise would be adversely affected by disposing of untreated or partly treated sewage. It will also lower costs incurred otherwise in treating epidemics and diseases (AL-Shreideh, 2001; Friedler, 2001).

B. Negative effects

- ***Health risk***

Irrigation with untreated wastewater can represent a major threat to public health, food safety and environmental quality (Hamdy and Ragab, 2005). As a consequence, its acceptability to replace other water resources for irrigation is highly dependent on whether the health risks and environmental impacts entailed are acceptable (Asano *et al.*, 1985). Examples of the different microbial pathogens and the major diseases they cause are given in (Table 5),

Table 5. Microbial pathogens detected in untreated wastewaters (Toze, 1997)

Microbial type	Major diseases
VIRUSES	
Poliovirus	Poliomyelitis
Enterovirus	Gastroenteritis
Echovirus	Heart anomalies, Meningitis
Hepatitis A virus	Hepatitis
Adenovirus	Respiratory disease, conjunctivitis
Reovirus	Not clearly established
Norwalk agent	Gastroenteritis
SSRV	Diarrhoea, vomiting, fever
Rotavirus	Gastroenteritis
Astrovirus	Gastroenteritis
BACTERIA	
Vibrio cholerae	Cholera
Salmonella typhi	Typhoid, Salmonellosis
Enteropathogenic E.coli	Gastroenteritis
Campylobacter jejunei	Gastroenteritis
Shigella dysinterae	Dysentery
Yersinia enterocolitica	Yersiniosis
PROTOZOAN	
Giardia intestinalis	Giardiasis

Cryptosporidium Parvum	Diarrhea, fever
Entamoeba histolytica	Amoebic dysentery
HELMINTHS	
Ascaris lumbricoides (Round worm)	Ascariasis
Trichuris trichiura (Wrip worm)	Trichuriasis

Wastewater does carry pathogenic organisms and, in general, modern treatment methods (for example, activated sludge) are not designed to eliminate them. Wastewater disinfection eliminates them, but it is relatively costly and beyond the technological and financial capabilities of most developing countries in many regions. Organisms that can survive wastewater treatment (without disinfection) include bacteria, protozoa, helminths, and viruses. Most of these pathogens affect the human body only through ingestion of waste-contaminated water and food. The major factors that control the degree of microbial health risk include, (Khouri, 1994): i) the ability of pathogens to survive or multiply in the environment, ii) the dose required for infection, iii) the need for, and the presence or absence of, intermediate hosts and iv) the susceptibility of the person at risk (constant exposure may have created (immunity) (Fatta *et al.*, 2005; FAO, 2000).

The health conditions of the population living in the areas of intensive use of untreated wastewater also degraded. Diseases such as typhoid and hepatitis spread at a much greater rate in these regions. Animals were also subjected to several waterborne diseases such as tapeworm and tuberculosis and other infectious diseases, (Bazza, 2002; Angelakis, 2003).

-Negative environment impacts

The use of wastewater in agriculture has the potential for negative environmental impacts on soil and water bodies:

-Impact on soil

The most important negative effect on the environment caused by agricultural wastewater use is the increase in soil salinity, which, if not controlled, can decrease productivity in the long term. There are four ways in which salinity affects soil productivity: (WHO, 2006; Pereira *et al.*, 2002).

- It changes the osmotic pressure at the root zone due to high salt content.
- It provokes specific ion (sodium, boron or chloride) toxicity.
- It may interfere with plant uptake of essential nutrients (e.g. potassium and nitrate) due to antagonism with sodium, chloride and sulfates.
- It may destroy the soil structure by causing soil dispersion and clogging of pores spaces.

In the long term, wastewater use will always increase salinity of the soils and groundwater, as it contains more salts than fresh water. And therefore, it is necessary to combine the use of wastewater with practices to control salinization, (WHO, 2006).

-Impact on water bodies

Application of wastewater in agriculture may cause percolation of wastes to the ground water or flushing into surface water. A high organic load will affect the dissolved oxygen levels, thus impacting aquatic organisms. Additionally, the nitrogen or phosphorus washed into water bodies will lead to eutrophication and subsequent oxygen depletion and will facilitate the growth of toxin-producing algae. Nitrogen can contaminate ground water and surface water bodies by infiltration and agricultural runoff. High concentrations of biodegradable organic matter in agricultural runoff water can lead to the consumption of dissolved oxygen in lakes and rivers (WHO, 2006; Choukr-Allah and Hamdy, 2003). The discharge of the wastewater in a non-treated form into watercourses and rivers led to the degradation of surface water quality to the point where it became unsuitable for direct use for drinking purposes. The most important results of this noticeable pollution of rivers and other water bodies were the disappearance of living organisms because of the lack of oxygen, the appearance of undesirable plants and weeds that clog water canals in certain regions, hateful odors resulting from decomposition of organic materials and the abundance of insects and rodents.

WASTEWATER USE: MAJOR CONSTRAINTS

-Institutional manageability

In most 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 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 (Choukr-Allah and Hamdy, 2005).

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 (Choukr-Allah and Hamdy, 2005).

-Public awareness and acceptance of wastewater

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 (Choukr-Allah and Hamdy, 2005).

Gaining public acceptance is easier once the need to use wastewater is established. If a community is aware of water scarcity and the need to conserve high quality water sources for domestic purposes, they will be more willing to accept wastewater use (WHO, 2006).

-Financial aspects

Financial factors are important especially when studying and appraising the feasibility of a new scheme for the use of wastewater. Even an economically worthwhile project can fail, however, without careful financial planning.

Economic and financial considerations are critical for encouraging the safe use of wastewater. Economic analysis seeks to establish the economic feasibility of a project and enables comparison between different options. The (often hidden) cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) need to be included in a cost analysis (Choukr-Allah and Hamdy, 2005; WHO, 2006).

POLICIES AND GUIDELINES

Guidelines on wastewater recycling and reuse are essential. They help protect public health, increase water availability, prevent coastal pollution and enhance water resources and nature conservation policies. Unifying wastewater recycling and reuse regulations around the Mediterranean basin would contribute to secure economic and touristic exchanges in the region (Kamizoulis *et al.*, 2003).

The existence of such guidelines means an important step in the planning and implementation of safe use of reclaimed wastewater for irrigation, because it contributes to sustainable development of landscape and agricultural irrigation. Guidelines for reclaimed wastewater use for irrigation must clearly define what is allowed and what is forbidden to execute (Ursula *et al.*, 2000). This can be defined in great detail or in a broad manner, but must take into account some important specific local conditions, such as the quality of reclaimed wastewater, soil, climate, relevant crops and agricultural practices (Helena *et al.*, 1996; Papadopoulos, 1997).

There is not a common regulation of wastewater reuse in the world due to various climatic, geological and geographical conditions, water resources, type of crops and soils, economic and social aspects, and country policies towards using wastewater influents for irrigation purposes (Fatta *et al.*, 2005).

International guidelines for use and quality standards of wastewater exist but policies for each country are necessarily to reflect local conditions. In many countries where wastewater use in agriculture takes place, national polices and guidelines are lacking (Van der Hoek, 2004; Kypris, 1988).

Some countries and organizations have already established reuse standards such as US.EPA, California, WHO and FAO. Most of the developing countries have adopted their own standards from the leading standards set by either FAO, WHO, California, etc. Most countries where wastewater irrigation is practiced have public health regulations to protect both the agricultural workers and the irrigated crops consumers (Fatta *et al.*, 2005).

International policy may affect the creation of national wastewater use policies. Countries agree to treaties, conventions, international development targets, etc. that may commit them to carry out certain actions (WHO, 2006).

Some countries have taken the approach of minimizing any risk and have elaborated regulations close to the California's and US.EPA criteria, but because these criteria are strict, expensive and take specific conditions into account, other countries adopted the wastewater criteria based on the guidelines of (WHO, 1989), which are more flexible. But some guidelines were not sustainable and would lead to reduced health protection, because they would be viewed as unachievable under local circumstances. According there was a particular need to conduct a review of these guidelines, so the WHO published the volume of the guidelines *for the safe use of wastewater, excreta and greywater (2006),* so many countries can adopt or adapt them for their wastewater excreta use practices (WHO, 2006; Fatta *et al.*, 2005).

However, it is now widely recognized that treated wastewater reuse 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 reuse for agriculture, in particular, in order to guide programs, projects and investments relating to wastewater collection, treatment, reuse and disposal in a sustainable manner (Hamdy and Karajeh, 2001; Angelakis, 2003).

This requires the establishment of a clear policy with regard to wastewater management (Hamdy and Karajeh, 2001), the policy should be compatible with a number of related sectoral 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 treated wastewater reuse for the different water sectors uses.
- Modalities for strengthening the national capacity building in this sector (Hamdy and Karajeh, 2001).

International guidelines

-WHO Guidelines

WHO (1989) Guidelines for the safe use of wastewater in agriculture took into account all available epidemiological and microbiological data and specified the microbiological quality and the treatment method required to achieve this quality, such quality is limited to the use of stabilisation ponds since it is cheap, simple and ensure removal of parasites which is the most infectious agent in the developing world. WHO (1989) guidelines are presented in (Table6).

Table 6. Guidelines for the use of treated wastewater in agriculture (Source: WHO, 1989)

Category	Reuse conditions	Exposed group	Intestinal nematode. eggs per litre[a]	Fecal coliforms (MPN per 100ml)[a]	Wastewater treatment expected to achieve the required microbiological guideline
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks [b]	Workers, consumers, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees [c]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by irrigation technology, but not less than primary sedimentation

a During the irrigation period.

b A more stringent guideline (200 fecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may cone into direct contact.

c In the case of fruit trees, irrigation should cease two weeks before fruit is picket, and no fruit should be picked off the ground. Sprinkler irrigation should be used.

The main features of the WHO (1989) guidelines for wastewater reuse in agriculture are as follows:

- Wastewater is considered as a resource to be used, but used safely.
- The aim of the guidelines is to protect exposed populations (consumers, farm workers, populations living near irrigated fields) against excess infection.
- Fecal coliforms and intestinal nematode eggs are used as pathogen indicators.
- Nematodes are included in the guidelines since infectious diseases in developing countries are mainly due to the presence of parasites which are more resistant to treatment.

It was necessary to update the 1989 WHO guidelines to take into account recent scientific evidence concerning pathogens, chemicals and other factors, including changes in population characteristics, changes in sanitation practices and better method for evaluating risk. There was a particular need to conduct a review of both risk assessment and epidemiological data. And for better package the guidelines the third edition (WHO 2006) of *the "Guidelines for safe use of wastewater,* *excreta and greywater"* is presented in four separate volumes: volume 1: Policy and regulatory aspects, volume 2: Wastewater use in agriculture, volume 3: Wastewater and excreta use in aquaculture, and volume 4: Excreta and greywater use in agriculture. These updated guidelines are based on scientific consensus and best available evidence and designed to protect the health of farmers, their families, local communities and product consumers.

These guidelines were published following an expert meeting in Stockholm, Sweden (1999), that based on the Stockholm framework which is an integrated approach that combines risk assessment and risk management to control water-related disease. The framework is flexible, allows countries to take into consideration associated health risks that may result from microbial exposures (Fig. 6) and provides the conceptual framework and integrated approach to the WHO 2006 guidelines.

Figure 6. The Stockholm framework for developing harmonized guidelines for the management of water-related infectious disease.

For *assessment of health risk*, associated with human exposure to pathogens in wastewater, three types of evaluations are used: microbial analysis, epidemiological studies and quantitative microbial risk assessment (QMRA).

A health based targets (which is adopted in WHO guidelines 2006) uses the tolerable risk of disease as a baseline to set specific performance targets that will reduce the risk of disease to this level (WHO, 2006). Such WHO guidelines define a level of health protection that is expressed as health based target of 10^{-6} DALYS (loss of 1 healthy life year per million people or 31.5 seconds of a person life per year) to provide the level of health protection that is relevant to each hazards. Health based target can be reached when all protection measures are used. Usually a health-based target for agriculture can be achieved through a combination of health protections measures targeted at different components of the system, result in pathogens reduction 6-7 log units, and helminthes eggs reduction to a value around ≤ 1 egg/l (Table 7).

Table 7.Health-base targets for treated wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log 10 pathogen reduction	Number of helminth eggs per liter
Unrestricted irrigation			
Lettuce	≤ 10^{-6} [a]	6	≤ 1[b,c]
onion		7	≤ 1[b,c]
Restricted irrigation			
Highly mechanized	≤ 10^{-6} [a]	3	≤ 1[b,c]
Labor intensive		4	≤ 1[b,c]
Localized irrigation			
High-growing crops	≤ 10^{-6} [a]	2	No recommendation [d]
Low-growing crops		4	≤ 1[c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6-7 log unit pathogen reduction obtained by a combination of wastewater treatment and other health protection, including an estimated 3-4 log unit pathogen reduction as a result of natural die-off of pathogens.

[b] when children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per liter, protective equipment such as gloves or boot

[c] the mean value of ≤1 egg per liter should be obtained for at least 90% of samples

[d] no crops to be picked up from the soil.

The most effective means ensuring safety in wastewater use in agriculture is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process, from generation and use of wastewater to product consumption. Three components of this approach are important for achieving the health based targets: system assessment, identifying protection control measures and methods for monitoring them.

-FAO guideline

FAO irrigation and drainage paper number 47 presents a guide to the use of treated effluent for irrigation and aquaculture, which is based on the WHO guidelines for the health protection measures (Table 8), (Pescod, 1992).

Table 8.Recommended microbiological quality guidelines for wastewater use in agriculture

Category	Reuse conditions	Exposed group	Intestinal nematode (eggs per litre)	Fecal coliforms (MPN 100ml)[a]	Wastewater treatment expected to achieve the required microbiological guideline
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by irrigation technology, but not less than primary sedimentation

FAO suggested water quality guidelines, are equally applicable to evaluate wastewater for irrigation purposes in term of their chemical constituents, such as dissolved salts, relative sodium content and toxic ions (Table 9). (Table 10) presents phototoxic threshold levels of some selected trace elements.

Table 9.Water quality guidelines for maximum crop production (example)

Potential irrigation problem	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity	ds/m	< 0.7	0.7- 3.0	> 3.0
Na, surface irrigation	me/l	< 4.0	4.0-10.0	>10.0
Na, sprinkler irrigation	m^3/l	< 3.0	>3.0	
Nitrogen (NO_3-N)^3	mg/l	< 5.0	5.0- 30.0	>30.0
pH		Normal range 6.5-8		

Table 10.Threshold levels of trace elements for crop production (example)

Element	Recommended maximum concentration (mg/l)	Remarks
Cd	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Cu	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions
Zn	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils
Pd	5.0	Can inhibit plant cell growth at very high concentrations.

-EPA water reuse guidelines

In 1992, Environmental Protection Agency (EPA) developed the Guidelines for water reuse (US-EPA, 1992). The guidelines were updated in 2004, by a committee, made up of national and international experts in the field of water reclamation and related subjects (US-EPA, 2004).

The major reuse categories are: urban, industrial, agricultural, environmental and recreational, groundwater recharge and augmentation of potable supplies. EPA's guidelines for each water reuse are given in (Table 11).

Table 11.EPA's guidelines for water reuse; source (US-EPA, 2004)

Types of reuse	Treatment	Reclaimed water quality	Reclaimed water monitoring
Urban reuse: all types of landscape irrigation(e.g., golf courses, parks, vehicle washing, toilet flushing, use in fire protection)	• Secondary • Filtration • Disinfection	• pH=6-9 • ≤10mg/l BOD • ≤2 NTU • No detectable fecal coli/100ml • 1 mg/l Cl_2 residual minimum	• pH= weekly • BOD - weekly • Turbidity-continuous • Coliform-daily • Cl_2 residual-continuous
Restricted Access area	• Secondary	• pH=6-9	• pH= weekly

irrigation where public access is prohibited or restricted	- Disinfection	- ≤30mg/l BOD - ≤30 mg/l TSS - ≤200 fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Industrial reuse:Cooling (once-through)recalculating cooling towers	- Secondary - Disinfection	- pH=6-9 - ≤30mg/l BOD - ≤30 mg/l TSS - ≤200 fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Agricultural reuse – Food crops not commercially processed (surface or spray irrigation)	- Secondary - Filtration - Disinfection	- pH=6-9 - ≤10mg/l BOD - ≤2 NTU - No detectable fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - Turbidity-continuous - Coliform-daily - Cl_2 residual-continuous
Agricultural Reuse – Food Crops Commercially Processed Surface Irrigation of Orchards and Vineyards	- Secondary - Disinfection	- pH=6-9 - ≤30mg/l BOD - ≤30 mg/l TSS - ≤200 fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Agricultural Reuse – Nonfood Crops Pasture for milking animals; fodder, fiber, and seed crop	- Secondary - Disinfection	- pH=6-9 - ≤30mg/l BOD - ≤30 mg/l TSS - ≤200 fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Recreational Impoundments Incidental contact (e.g., fishing and boating) and full body contact with reclaimed water allowed	- Secondary - Filtration - Disinfection	- pH=6-9 - ≤10mg/l BOD - ≤2 NTU - No detectable fecal coli/100ml - 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - Turbidity-continuous - Coliform-daily - Cl_2 residual-continuous
Landscape Impoundments Aesthetic impoundment where public contact with reclaimed water is not allowed	- Secondary - Disinfection	pH=6-9 ≤30mg/l BOD ≤30 mg/l TSS ≤200 fecal coli/100ml 1 mg/l Cl_2 residual minimum	- pH= weekly - BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Environmental reuse Wetlands, marshes, wildlife habitat, stream augmentation	- Variable secondary and disinfection (minimum)	Variable but not exceed: ≤30mg/l BOD ≤30 mg/l TSS ≤200 fecal coli/100ml	- BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-continuous
Groundwater recharge by spreading or injection into aquifers not used for public water supply	- Site-specific and use dependent - Primary (minimum) for spreading - Secondary (minimum) for injection	- Site-specific and use dependent	- Depends on treatment and use

Indirect potable reuse Groundwater recharge by spreading into potable aquifers	- Secondary - Disinfection	- Secondary - Disinfection - Meet drinking water standards after percolation through vadose zone	- Includes but limited to the following: - pH= weekly - BOD - weekly - TSS-daily - Coliform-daily - Cl_2 residual-Continuous - Turbidity-continuous - Drinking water standards quarterly
Indirect Potable Reuse Groundwater recharge by injection into potable aquifers	- Secondary - Filtration - Disinfection - Advanced wastewater treatment	- Includes, but not limited to, the following: - pH = 6.5 -8.5 . - < 2 NTU 8. - No detectable total coli/100 ml. - 1 mg/l Cl2 residual (minimum) - Meet drinking water standards	- Includes, but not limited to, the following: - pH - daily . - Turbidity continuous - Total coliform daily. - Cl2 residual continuous. - Drinking water standards quarterly. - Other - depends on constituent
Indirect Potable Reuse Augmentation of surface supplies	- Secondary - Filtration - Disinfection - Advanced wastewater treatment	- Includes, but not limited to, the following: - pH = 6.5 -8.5 . - < 2 NTU 8. - No detectable total coli/100 ml. - 1 mg/l Cl2 residual (minimum) - Meet drinking water standards	- Includes, but not limited to, the following: - pH - daily . - Turbidity continuous - Total coliform daily. - Cl2 residual continuous. - Drinking water standards quarterly. - Other - depends on constituent
Construction Use Soil compaction, dust control, washing aggregate, making concrete	- Secondary - Disinfection	- 30 mg/l BOD 7. - < 30 mg/l TSS. - < 200 fecal coli/100 ml. - 1 mg/l Cl2 residual (minimum)	- BOD - weekly. - TSS - daily. - Coliform - daily. - Cl2 residual continuous

-European water directives

The legal status of wastewater reuse is not uniform across Europe. Many European countries do not have specific regulations. Some of them have national regulations, laws, recommendations and other (Helena *et al.*, 1996). So far no regulation of wastewater reuse exists at the European level. The only reference made by the EU on the matter of wastewater is Article 12 of the European Wastewater Directive (91/271/EEC), which specifies that "treated wastewater shall be reused whenever appropriate. Disposal routes shall minimize the adverse effects on the environment". The directive specified standards for discharge into fresh water and their catchments but no standards for reuse. It provides though regulations and permits for all discharge (Council of European Union, 1991; Kretschmer *et al.*, 2002).

Table 12.Requirements for discharges from urban waste water treatment plants: concentration and percentage of reduction values

Parameters	Concentration	Minimum percentage of reduction	Reference method of measurement
BOD_5	25 mg/l	70-90	Homogenized, unfiltered, undecanted sample.
COD	125 mg/l	75	Homogenized, unfiltered, undecanted sample Potassium dichromate
TSS	35 mg/l	90	Filtering of a representative sample.

Comparative analysis between international guidelines

-EPA vs. WHO

The EPA guidelines discussed in details the reclaimed water quality limits and wastewater treatment process. For the quality of reclaimed water, they have put limits to BOD, TSS, NTU and fecal coliform. WHO guidelines address concern of developing counties and thus are preserving limits for fecal coliforms and intestinal nematodes.

EPA (2004) has recommended the use of strict guidelines for wastewater use in irrigation of crops likely to be eaten uncooked, which are no detectable fecal coliforms/100ml, and for irrigation of commercially processed crops, fodder crops, etc. The guideline of EPA is 200 FC/100ml, and no nematode egg guideline is specified by EPA . In WHO 1989 guidelines, water quality of 1000 FC/100ml is allowed to irrigate crops likely to be eaten uncooked, and for irrigation of commercially processed crops, fodder crops, only a nematode egg is set by WHO 1989.

Regarding the treatment process, the WHO guidelines say that the microbiological water quality requirements can be met by a series of stabilization ponds whereas EPA stipulates secondary treatment followed by disinfection. Microbiological monitoring requirements also vary: the WHO guidelines require monitoring of intestinal nematodes, whereas the EPA guidelines rely on the sole monitoring of the total coliform count to assess microbiological quality and fecal coliforms removal (Table 13).

Table 13.Comparison of water quality guidelines between EPA 2004 and WHO 1989, for water reuse in agriculture

Agent	Type of reuse	Treatment required	BOD_5 (mg/l)	Helminths (egg/100ml)	Total coliform per100 ml	Fecal coliform per 100 ml	Type

EPA (2004)	Food crops not commercially processed (eaten uncooked)	Secondary (filtration and disinfection)	10	-	0	Not detectable	Guidelines
	Agricultural reuse food crops commercially processed	Advanced (filtration and disinfection)	30	-	-	200	
WHO (1989)	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Stabilization bonds	-	≤ 1	-	≤1000	Guidelines
	Irrigation of cereal, fodder, industrial crops, pasture and trees	Stabilization bonds	-	≤ 1	-	-	

-FAO vs. WHO

FAO guidelines are based on the WHO guidelines in respect to the microbial quality for health protection on one hand. On the other hand FAO suggested water quality guidelines for maximum crop production as (salinity, N and pH), and it recommended threshold levels of the trace elements, whereas WHO guidelines are only microbial guidelines and have put limits for fecal coliforms and intestinal nematodes.

-EPA vs. FAO

The EPA guidelines discussed in details the reclaimed water quality limits and wastewater treatment process. For the quality of reclaimed water, they have put limits to BOD, TSS, NTU and fecal coliform. FAO have put limits for fecal coliforms and intestinal nematodes and suggested some water quality for maximum crop production and recommended threshold levels of trace elements as (Cd, CU, and Zn).

Regarding to the treatment process, EPA stipulates secondary treatment followed by disinfection. In FAO guidelines, the treatment method required to achieve the microbial quality is limited to the use of stabilization ponds.

For the microbiological monitoring requirements, EPA guidelines rely on the monitoring of the total coliform count to assess microbiological quality and fecal.

EXPERIENCE OF SOME MEDITERRANEAN COUNTRIES

Background overview

Land application of recycled water is an old and common practice, which has gone through different development stages with time. In the Mediterranean basin, wastewater recycling and reuse are practiced since the Ancient Greek and Roman civilizations (Angelakis, 2003), also wastewater been used by the Mediterranean civilizations in the 14th and 15th centuries (Kamizoulis *et al.*, 2003; Hidalgo and Irusta, 2005).

Mediterranean countries are unequally developed; several being already equipped with wastewater treatment plants while others have virtually no equipment. wastewater at different level of treatment (secondary or tertiary) is used alone or mixed with fresh water, mostly on forage and cereals, fruit trees and vegetables, depending on national legislation and its enforcement and in many cases, raw or insufficiently treated wastewater is applied (Fatta *et al.*, 2005; Kamizoulis *et al.*, 2003). In other cases, wastewater treatment plants are often not functioning or overloaded and thus discharge effluents not suitable for reuse applications. This leads to the existence of health risks and environment impacts and to the prevalence of water-related diseases. In some other situations where conditions for reuse are met, wastewater is then submitted to adequate recycling systems and treated effluents are being reused for different purposes without presenting any risk for human health. In these cases, recycled water is an important alternative resource for sustainable development and food production. In Tunisia, recycled water accounted for 4.3% of available water resources in the year 1996, and may reach 11% in the year 2030. The volume of treated wastewater compared to the irrigation water resources is actually about 7% in Tunisia, 8% in Jordan. Approximately 20-30% of the treated effluent is being reused in Tunisia, 85% in Jordan (Angelakis *et al.*, 1999; Barrio *et al.*, 2005; Petta *et al.*, 2004).

The main reuse operations in the Mediterranean region are for agricultural and landscape irrigation and groundwater recharge. As a result, and because of chronic acute local water shortages, irrigation with domestic wastewater is a common practice, even without appropriate treatment or disinfection. Industrial reuse is very seldom practiced (Bahri, 2002; Kamizoulis *et al.*, 2003; Fatta *et al.*, 2004). Applications of treated wastewater reuse practices are shown in (Table 14).

Table 14.Application of wastewater use practices in Mediterranean countries (Source: Kamizoulis *et al.*, 2003)

Country Practices	Urban and residential uses	Unrestricted irrigation industrial use	Restricted agricultural irrigation	No reuse
Albania				X
Algeria	X			
Bosnia and Herzegovina				X
Croatia				X
Cyprus	X	X	X	
Egypt	X		X	
France	X	X	X	
Greece	X		X	
Italy		X	X	
Jordan		X	X	
Lebanon			X	
Libya			X	
Malta			X	
Monaco				X
Morocco			X	
Slovenia				X
Spain	X	X	X	
Syria			X	
Tunisia	X	X	X	
Turkey			X	

Wastewater recycling and reuse: National guidelines categories

However many countries now consider the beneficial use of reclaimed water, in case of the northern European countries which have abundant water resources, they all give priority to the protection of water quality. A very limited number of European Mediterranean countries have guidelines or regulations on wastewater reclamation and reuse because first they usually do not need to reuse water and second their rivers have a sufficient dilution factor. The situation is different in the southern European countries, where the additional resources brought by wastewater reuse can bring significant advantages to agriculture (Kretschmer, et al, 2002; Papadopoulos, 1995).

Also, in most Mediterranean countries, wastewater recycling and reuse is increasingly integrated in the planning and development of water resources. Cyprus, France, Italy, Tunisia, Jordan, Spain and Turkey are the only Mediterranean countries to have established national regulation or guidelines. Other countries such as Lebanon and Greece are contemplating guidelines and/or regulations concerning wastewater recycling and reuse. While some countries don't have guidelines or regulation on wastewater recycling and reuse as Albania. There are three categories in respect to the water reuse guidelines in the region which are in (Table 15) as follows:

Table 15.Legislation for treated wastewater reuse in Mediterranean countries (Source: Kamizoulis *et al.*, 2003)

Country	Existing of legislation	Contemplating legislation	No legislation
Albania			X
Algeria		X	
Bosnia and Herzegovina			X
Croatia			X
Cyprus	X		
Egypt		X	
France	X		
Greece		X	
Italy	X		
Jordan	X		
Lebanon		X	
Libya		X	
Malta		X	
Monaco			X
Morocco		X	
Slovenia			X
Spain	X		
Syria		X	
Tunisia	X		
Turkey	X		

WASTEWATER RECYCLE AND REUSE: THE CASE OF JORDAN

Jordan is an arid to semi-arid country with scarce rainfall which is the most variable and the most important limiting factor in the rainfed agricultural system in Jordan. The total rain fall in Jordan is estimated at 8.5 billion cubic meters of which about 85% is lost to evaporation with the remainder flowing into wadis and partially infiltrating into deep aquifer (Mc Cornick *et al.*, 2004; Duqqah *et al.*, 2001). Low rainfall areas cover an area of approximately 81 million dunums, of which 9.1 million dunum receives between 100 to 200 mm rainfall, 12.8 million dunums receive 50 to 100 mm, and 58.7 million dunums receive less than 50 mm of rainfall annually. Rainfed lands constitute the largest cultivable area in Jordan, which is used mainly for cereals and fruits. Water resources come from three sources: surface water, groundwater and wastewater being used on an increasing scale for irrigation. Renewable water resources are estimated at about 750 MCM per year, consisting of approximately 275 MCM per year from groundwater, 505 MCM per year from surface sources. An additional 140 MCM per year are estimated to be available from fossil aquifers and about 79 MCM per year (2005) from treated wastewater (Shannag *et al.*, 2000).

Water in Jordan is used primarily for agriculture, which accounts for 63.4% of all water consumed (MWI, 2005), the rest being for domestic 31.8% and industrial use 4.8%. Annual growth in demand for water in Jordan is estimated at 25 Mm^3/year. This growth is related to urbanization and industrial expansion, as well as to increased domestic use, mainly as a result of population growth. In Jordan, the per capita share of renewable water resources is ranked among the world's ten most water scarce countries, and is declining with time. It is projected to fall from150 m^3/capita/year at present to 90m^3/capita/year by 2025 (WAJ, 2007).

Development of wastewater sector

Wastewater collection has been practiced in Jordan in a limited way since 1930 in the town of Salt. Some treatment was achieved by utilizing primitive physical processes. Mostly, however, septic tanks and cesspits were used with gray water often discharged to gardens. This practice resulted in major environmental problems, especially groundwater pollution. The pollution problems were complicated by the rapid urban growth (Malkawi, 2003; Duqqah *et al.*, 2001).

Modern technology to collect and treat wastewater was introduced in the late 1960s when the first collection system and treatment plant was built at Ain Ghazal utilizing the conventional activated sludge process (MEDAWARE, 2003).

However, due to the high strength of the raw sewage (i.e. the BOD_5 of the incoming sewage was greater than 600 mg/l) the effectiveness of the activated sludge process was drastically reduced. In deed the quality of the effluent of Ain Ghazal deteriorated the quality of surface, ground and irrigation water in the region (MWI, 1998; MEDAWARE, 2004).

Since the year 1980, the Government of Jordan carried out significant and comprehensive plans with regard to the different issues of wastewater management primarily related to the improvement of sanitation. About 52% of the total population (at that time) gained access to wastewater collection and treatment systems. This has raised the sanitation level, improved public health, and strengthened pollution control of surface and groundwater in the areas served by wastewater facilities, then direct reuse of treated wastewater in Jordan has been on the increase since about 1985, when Khirbet As-samra (the biggest wastewater treatment plant in Jordan) was established (MEDAWARE, 2005).

Presently, there are 19 domestic wastewater treatment plants (WWTPs) these treatment plants were established in big cities that actually serve big areas surrounding these cities. The largest plant is the Al Samra plant that serve, beside the capital Amman, several more relatively big cities which altogether called (Greater Amman). However, Jordan is currently planning to establish several new treatment plants that will serve the rest of the areas not covered by the current 19 plants which can be classified as communities (WAJ, 2004; Malkawi, 2003; MEDAWARE, 2004)). At 2005, it was estimated that about 68% of the total population of Jordan has an access to wastewater collection and treatment systems. Those can treat up to 88.5 MCM per year (Influent) as shown in (Table 16). The quantity of treated wastewater is about 79 MCM per year (2006) used for restricted and unrestricted agriculture (WAJ, 2007)

Table 16. Amount of influent, effluent (Mm^3) generated, (source: WAJ, 2007)

Year	Influent Mm^3	Effluent Mm^3	% used for irrigation
2004	102	74	67
2005	107	79	72
2006	109	86	79

Wastewater strategies, policies and legislations

The Water Strategy for Jordan 1997

The strategy places a high priority on the resource value of reclaimed water (MWI, 1997). The strategy states clearly:

"Wastewater shall not be managed as waste; it shall be collected and treated to standards that allow its use in unrestricted agriculture and other non-domestic purposes, including groundwater recharge."

The main objectives of water strategy are outlined in the followings:
1. Meeting water supply needs
2. Providing sanitation services that protect the public health
3. Preserving the resource value of reclaimed water
4. Ensuring environmental protection
5. Ensuring that the long-term export of Jordanian produce is not endanger

The national water strategy defined the goals for the water sector, and formulated the following four policies:

- Water utility policy
- Irrigation water policy
- Groundwater management policy
- Wastewater management policy

Wastewater management policy of 1998

In June 1998, the official wastewater management policy of 1998 was issued. The official policy demands that treated effluent should be considered as a water resource and not separated from other water resources. It stresses the improvement of the quality of treated effluent by blending with higher quality water, and suggests that crop selection should be made to suit the irrigation water, soil type, soil physical and chemical properties (MWI, 1998).

The Wastewater Management Policy institutionalizes 67points regarding the future use and management of wastewater, the following are parts of the national policy:

- Wastewater shall not be disposed, instead it shall be a part of the water budget
- Use of recycled and reclaimed water for industrial use shall be promoted
- Fees for wastewater treatment may be collected from those who use the water
- Any crops irrigated with wastewater or blended water should be monitored
- The role of government should be regulatory and supervisory and private operation and maintenance of utilities shall be encouraged.

Public health law no. 54/2001

The basic public health framework for wastewater is control by Public Health Law No. 54/2001, the law gave the ministry of health the authority to monitor and regulate wastewater discharges and the design of wastewater facilities. The law makes it necessary for developers to build all sewers and treatment plants according to the standards issued by the ministry of health. The law also regulates the development of sewers in many municipal areas. The law gave the ministry of health the power to approve the plants and specifications for sewers and treatment plants and to supervise all sewers and treatment plants and to supervise all sewer and treatment plant construction (MOH, 2001).

Wastewater reuse standards in Jordan

Prior to 1995, professionals in the water authority of Jordan relied on World Health Organization standards for wastewater plant design and effluent control. The usual practice was to obtain a BOD and TSS of 30 mg/l for effluent from treatment plants. By 1995, it was recognized that a comprehensive national standard was needed (Nazzal *et al.* 2000; MWI, 2001).

In 1995 Jordanian's Department for standards published a comprehensive reuse standard for treated domestic wastewater principally developed by the Water Authority of Jordan (The standard 893/ 1995).

In the standard of 893/ 1995, BOD_5 were limited to 150 mg/l for most forms of agriculture reuse and more stringent standard was created for amenity in areas that can be accessed by the public. Further more the standard 893/1995 prohibited the recharge of groundwater used for drinking with reclaimed water, although the Jordan Water Strategy (MWI, 1997) includes groundwater recharge as one of the desirable uses of reclaimed water. Updating the Standard attempted to resolve this discrepancy, but, protecting the drinking water supply remained the prime concern of stakeholders.

Table 17. Part of Jordanian standards for use of treated wastewater (893/1995)

Quality parameters	Vegetables eaten uncooked	Fruit trees, forest and grain	Discharges to wadis	Artificial recharge	Fisheries	Public parks	Fodder
BOD_5	150	150	50	50	Na	50	250
COD	500	500	200	200	NA	200	700
DO	>2	>2	>2	>2	>5	>2	>2
TDS	2,000	2,000	2,000	1,500	2,000	2,000	2,000
TSS	200	200	50	50	25	50	250
pH	6-9	6-9	6-9	6-9	6.5-9	6-9	6-9
Color	NA	NA	75	75	NA	75	NA
FOG	8	8	8	Nil	8	8	12
FCC (MPN/100ml)	1,000	NA	1,000	1,000	1,000	200	NA
Pathogens	NA	NA	NA	NA	100,000	Nil	NA
Giadara (cyst/l)	<1	NA	NA	NA	NA	Nil	NA
Nematodes (egg/l)	<1	NA	<1	NA	NA	<1	<1

In 2002 the government replaced the original JS 893:1995 standard with the new standard No. 893:2002. The primary purpose of this standard is to protect public health while still making the maximum use of reclaimed water, and this supported by Public Health Law No. 54 of 2001 which charges the Ministry of Health with undertaking all actions necessary to safeguard the health of the people.

The general structure has two groups. The first group is legally enforceable water reclamation standards aimed to protect public and farm-worker. (Table 18) is the standards for reuse in irrigation and (Table 19) concerns the standards for reuse artificial recharge and discharge to wadis, streams and water bodies.

Table 18.Standards for reuse in irrigation (893/2002)

Allowable limits per end use				
Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits	Fruit Trees, Sides of Roads outside city limits, and landscape	Field Crops, Industrial Crops and Forest Trees
		A	B	C
BOD_5	mg/l	30	200	300
COD	mg/l	100	500	500
DO	mg/l	>2	-	-

TSS	mg/l	50	150	150
pH	unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70
Escherishia Coli	MPN /100 ml	100	1000	-
Intestinal Helminthes	Egg/l	≤ 1	≤ 1	≤ 1

Table19. Standards for reuse artificial recharge and discharge to wadis, streams and water bodies (893/2002)

Allowable Limit			
Parameter	Unit	water discharge to wadis, streams and water bodies	artificial discharge of groundwater aquifers
BOD_5	mg/l	60	15
COD	mg/l	150	50
DO	mg/l	>1	>2
TSS	mg/l	60	50
pH	mg/l	6-9	6 – 9
Turbidity	NTU	_	2
NH_4	mg/l	_	5
NO_3	mg/l	45	30
T-N	mg/l	70	45
Escherishia coli	MPN /100 ml	1000	<2.2
Intestinal Helminthes Eggs	egg/l	≤ 1	≤1
FOG	mg/l	8	8

The 2002 standards defined conditions for each end use. The strictest standards are for artificial recharge of aquifers, while there is a range of standards for irrigation uses depending on the nature of the plants being irrigated. The three irrigation categories are:

- Class A: cooked vegetables, parks, playgrounds and sides of the road within the city.
- Class B: fruit trees, sides of roads outside city limits and landscape
- Class C: field crops, industrial crops and forest trees.

- Standards for each category focus on BOD_5, COD, DO, TSS, pH, turbidity, nitrates, total nitrogen, E.coli and intestinal helminth eggs. These standards are binding limits (JS, 2002).

Standards for discharge to streams, wadis and water bodies are more or less the same as those for Class A irrigation.

The second Group is a set of guidelines aimed at protecting the soil and maintaining the highest possible level of crop productivity. Unlike the Group 1 Standards, these guidelines are not legally enforceable. Rather, they are intended to assist the decision on a given use of an available source of reclaimed water. A list of guideline parameters and their limits is presented in (Table 20).

Table 20.Jordanian guidelines for reuse in Irrigation (893/2002)

No.	Group B	Unit	Allowable Limit	No.	Group B	Unit	Allowable Limit
1	FOG	mg/l	8	17	F	mg/l	1.5
2	Phenol	mg/l	<0.002	18	Fe	mg/l	5.0
3	MBAS	mg/l	100	19	Li	mg/l	2.5
4	TDS	mg/l	1500	20	Mn	mg/l	0.2
5	PO_4	mg/l	30	21	Mo	mg/l	0.01
6	Cl	mg/l	400	22	Ni	mg/l	0.2
7	SO_4	mg/l	500	23	Pb	mg/l	5.0
8	HCO_3	mg/l	400	24	Se	mg/l	0.05
9	Na	mg/l	230	25	Cd	mg/l	0.01
10	Mg	mg/l	100	26	Zn	mg/l	5.0
11	Ca	mg/l	230	27	Cr	mg/l	0.1
12	SAR	-	9	28	Hg	mg/l	0.002
13	Al	mg/l	5	29	V	mg/l	0.1
14	As	mg/l	0.1	30	Co	mg/l	0.05
15	Be	mg/l	0.1	31	B	mg/l	1.0
16	Cu	mg/l	0.2	32	CN	mg/l	0.01

-The future of wastewater reuse standard and law

Although much progress has been made in Jordan on laws and standards for wastewater reuse, the critical water situation suggests the need for further evolution of wastewater reuse standards and related law and due to the expected rapid growth of traded wastewater supplies, it will be necessary for Jordan to expand the agricultural reuse of wastewater and to enhance industrial recycling of water in the future (CDM, 2006).

In the long term, Jordan's standards for wastewater treatment may be modified to achieve even greater flexibility to meet specific conditions of effluent reuse. Such modifications may include suggest ranges of constituent concentrations in standards rather than single maximums, as well, there is a need to revise these standards (Nazzal *et al.*, 2000; CEHA, 2005). In deed such standard were established on the characteristics of wastewater after the treatment process, but this is not enough since the process is in continuation, when it is passing through the soil (in irrigation). Accordingly, the new modification should respect the criteria of treated wastewater after passing the soil (WHO, 2006). However, this requires the development of applicable intensive research combining the cost of treatment and safety use. Our thesis here is a part of the needed research. Recently this type of research is receiving the attention of several researchers; (Gilbert *et al.*, 1999; Tayim and Al-Yazouri, 2005; Chabaud *et al.*, 2006), the findings of the carried out researches all highlighted the important role the soil could play in improving the quality of the effluent and the irrigation with treated municipal effluent is a completion and continuity of the waste treatment process.

REFERENCES

Al-Shreideh B. (2001). Reuse of treated wastewater in irrigation and agriculture as a non-conventional resource in Jordan. In: *Water saving and increasing water productivity: challenges and options.* University of Jordan, Jordan, pp 18.1-18.30.

Angelakis, A. (2003). *Water resources management in Syria, with emphasis on non-conventional resources.* FAO, Cairo.

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

Arar, A. (1988). Background to treatment and use of sewage effluent. In: *Treatment and use of sewage effluent for irrigation.* Pescod, M. and Arar, A. (eds). Butterworths, Sevenoaks, Kent.

Asan, T., Smith, G. and Tchobanoglous, G. (1985). Municipal wastewater: treatment system and reclaimed water characteristics. In: *Irrigation with reclaimed municipal wastewater: A guideline manual*. Pettygrove G. and Asano T. (eds). Lewis publishers, Chelsea.

Bahri, A. (2002). *Water reuse in the Middle East, North Africa and Mediterranean countries*. National research institute for agricultural engineering. Water and forestry, Tunisia.

Barrio, D., Irusta, R., Fatta, D., Papadopoulos, A., Mentzis, A. and Loizidou, M. (2005). *Analysis of best practices and success stories for sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries*. [on line]. <http://www.eng.ucy.ac.cy//>.

Bazza, M. (2002). Wastewater recycling and reuse in the Near East region: experience and issues. In: *Proc. of IWA-regional symposium on water recycling in Mediterranean region*. Iraklion, Greece, pp. 43-60.

CDM (2006). *Reclaimed water reuse in agriculture, impact assessment of RIAL project, reuse for industry, agriculture and landscaping (RIAL) project.* Amman-Jordan.

CEHA (2005). *A regional overview of wastewater management and reuse in the eastern Mediterranean region*. Regional centre for environmental health activities CEHA, WHO.

Chabaud, S., Andres, Y., Lakel, A. and Le Cloirec, P. (2006). *Comparisons of packing materials in on-site wastewater treatment.* [on line]. <http://www.iwaponline.com//>.

Choukr-Allah, R. and Hamdy, A. (2003). Wastewater recycling and reuse in Mediterranean region as a potential resource for water saving . In: Hamdy A. (ed.). *Regional Action Program (RAP): Water resources management and water saving in irrigated agriculture (WASIA PROJECT).* CIHEAM-IAMB, Valenzano, pp. 89-101. Options Méditerranéennes, Series B *44.* .

Choukr-Allah, R. and Hamdy, A. (2005). Wastewater recycling and reuse in some islamic countries as potential resource for water saving. In: *International workshop on environmental consequences of irrigation with poor quality waters*. Ragab R. and Koo-Oshima S. (eds). Center for ecology and hydrology. Kuala Lumpur, Malaysia, pp. 89-110.

Cornish, G., Mensah, E. and Ghesquire, P. (1999). *Water quality and peri-urban irrigation. As assessment of surface water quality for irrigation and its implications for human health in the peri-urban zone of Kumasi, Ghana*. Report OD/TN 95. Wallingford Ltd, Walling, UK.

Council of European Union (1991). *Council directive 91/271/EEC, concerning urban waste-water treatment.* [on line]. <http://ec.europa.eu//>.

Crites, R. and Tchobanoglous, G. (1998). *Small decentralized wastewater management systems.* McGraw-Hill, New York.

Duqqah, M., Shatanawi M., Mazahrih N., Fardous A. and Mazahrih S. (2004). Reclaimed wastewater treatment and reuse in Jordan: policies and practices. In: *International workshop, non-conventional water use, Egypt*. [on line]. <http://wasamed.iamb.it//>

FAO (2000). *Water quality management and pollution control in the Near East: An Overview.* Regional workshop on water quality management and pollution control in the Near East. Fao, Cairo.

Fatta, D., Moustakas, K., Loizidou, M., Mountadar, M. and Assobhei, O. (2005). *Wastewater treatment technologies and effluent standards applied in the Mediterranean countries for reuse in agriculture*. WATMED, Marrakesh.

Fatta, D., Papadopoulos, A., Mentzis, A., Loizidou, M., Irusta, R., Sandovar, A. and Barrio, D. (2004). *The urgent need for sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries*. The MEDAWARE Project, Marrakech.

Friedler, E. (2001). Water reuse- an integral part of water resources management: Israel as a case study. *Water Policy,* 3(1): 29–39.

Gilbert, R., Rice, R., Bouwer, H., Gerba, C., Wallis, C. and Melnick, J. (1976). Wastewater renovation and reuse: virus removal by soil filtration, *Water science and technology*, 3(2): 57-65.

Hamdy, A. (2003). PAR- PROGRAMME: WASIA Project is a realistic step towards a soft path water management approach. In: Hamdy A. (ed.). *Regional Action Programme (RAP): Water resources management and water saving in irrigated agriculture (WASIA PROJECT),* CIHEAM-IAMB, Valenzano, p. 31-54. Options Méditerranéennes, Series B 44.

Hamdy, A. and Ragab, R. (2005). Reuse of treated wastewater in irrigation: challenges and perspectives. In: Ragab R. and Koo-Oshima S. (eds*). International workshop of environmental consequences of irrigation with poor quality waters*. Center for Ecology and Hydrology. Kuala Lumpur, Malaysia. pp. 5-28.

Hamdy, A. and Karajeh, F. (2001). Treated wastewater as an additional source: challenges and perspectives In: *Water saving and increasing water productivity: challenges and options*. University of Jordan, Jordan. pp. a 7.1-a 7.21.

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

Hamoda, M. (2004). Water strategies and potential of water reuse in the south Mediterranean countries. *Desalination*, 165: 31-41.

Helena, M., Do Monte, M., Angelakis, A. and Asano, T. (1996). Necessity and basis for establishment of European guidelines for reclaimed wastewater in the Mediterranean region. *Water sciecnce technology*, 33(10-11): 303-316.

Hidalgo, D. and Irusta, R. (2005). *The cost of wastewater reclamation and reuse in agricultural production in the Mediterranean countries*. Environmental division, CARTIF.

J.S. Jordan standard (1995). *Jordan standard for reclaimed domestic wastewater* No. 893/1995. The Institution for Standard and Metrology, Amman.

J.S. Jordan standard (2002). *Jordan standard for reclaimed domestic wastewater* No. 893/2002. The Institution for Standard and Metrology, Amman.

Kamizoulis, G., Bahri, A., Brissaud, F. and Angelakis, A. (2003). *Wastewater recycling and reuse practices in Mediterranean region: recommended guidelines*. [on line]. <http:med-reunet.com/docs_upload/angelakis_cs.pdf//>.

Kretschmer, N., Ribbe, L. and Gaese, H. (2002). *Wastewater reuse for agriculture*. University of Applied Sciences, Germany.

Kypris, D. (1988). Considerations for the quality standards for the reuse of treated effluent. In: *Proc. Wastewater reclamation and reuse, Cairo*.

Malkawi, S. (2003). *Wastewater management and reuse in Jordan*. First regional water reuse conference (7-9 Dec). Amman-Jordan.

Massoud, M., Scrimshaw, M. and Lester, J. (2003). Qualitative assessment of the effectiveness of the Mediterranean action plan: wastewater management in the Mediterranean region. *Ocean & Coastal Management,* 46: 875–899.

Mc Cornick, P., Hijazi, A. and Sheikh, B. (2004). *From wastewater reuse to water reclamation: progression of water reuse standards in Jordan*. [on line]. <http://www.idrc.ca//>.

MEDAWARE (2003). *Development of tools and guidelines for the promotion of the sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean Countries, Task 1: Determination of the countries profiles*. [on line]. <http://www.uest.gr/medaware//>.

MEDAWARE (2004). *Development of tools and guidelines for the promotion of the sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries, Task 3: Analysis of best practices and success stories*. [on line]. <http://www.uest.gr/medaware//>.

MEDAWARE (2005). *Development of tools and guidelines for the promotion of the sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries, Task 5-Jordan: Development of specifications for urban wastewater utilization*. [on line]. <http://www.uest.gr/medaware//>.

MOH Ministry of Health (2001). *Public Health Law No. 54/2001.* Amman, Jordan.

MWI Ministry of water and irrigation (1997). *Jordan's Water Strategy.* Amman, Jordan.

MWI Ministry of water and irrigation (1998). *Wastewater management policy*. Amman, Jordan.

MWI Ministry of water and irrigation (2001). *Water resource policy support, Standards, regulations & legislation for water reuse in Jordan*. Amman, Jordan.

Nazzal, K., Mansour, M., Al Najjar, M. and McCornick, G. (2000). *Wastewater reuse law and standards in the Kingdom of Jordan*. Presented at Aqua Abu Dhabi 2000 wastewater management for a better environment, Abu Dhabi Municipality.

Papadopoulos, I. (1995). Present and perspective use of wastewater for irrigation in the Mediterranean basin. In: Angelakis A. (ed). *Second international symposium on wastewater reclamation and reuse*. Greece, 2: 735-746.

Papadopoulos, I. (1997). Case Study XI - Cyprus, Water pollution control. In: Helmer R. and Hespanhol I. (eds). *A guide to the use of water quality management principles*. WHO/UNEP.

Pereira, L., Cordery, I. and Iacovides, I. (2002). *Coping with water scarcity*. UNESCO, Paris. Technical documents in hydrology, 58.

Pescod, M. (1992). *Wastewater treatment and use in agriculture*. FAO, Rome. FAO irrigation and drainage paper, 47.

Petta, L., Giordano, A., Farina, R. and Al Baz, I. (2004). Efficient management of wastewater, its treatment and reuse in the Mediterranean countries: the EMWATER project. In: Hamdy A. and Monti R. (eds.). *Food security under water scarcity in the Middle East: Problems and solutions*. CIHEAM-IAMB, Valenzano, p. 303-309. Options Méditerranéennes, Ser. A.

Plan Bleu (2006). *Regional activity center environment and development in the Mediterranean*. [on line] <http:www.planbleu.org/>

Redwood, M. (2004). *Wastewater use in urban agriculture : assessing current research and options for national and local governments, International development research center*. [on line]. <http:www.idrc.ca/>.

Rosenzweig, C. and Tubiello, F. (1997). *Impact of global change on Mediterranean agriculture: current methodologies and future directions (An introductory essay).* [on line]. <http:www.springerlink.com//>.

Shannag, E. and Al-Adwan, Y. (2000). *Evaluating water balances in Jordan,* Chapter 5. [http://www.idrc.ca/en.html].

Shelef, G. and Azov, Y. (1996). The coming era of intensive wastewater reuse in the Mediterranean region. *Water science and technology*, 33(10-11): 115-125.

Tayim, H. and Al-Yazouri, A. (2005). Industrial wastewater treatment using local natural soil in Abu Dhabi, U.A.E. *American journal of environmental sciences,* 1(3): 190-193.

Tchobanoglous, G. and Angelakis, A. (1996). Technologies for wastewater treatment appropriate for reuse: potential for applications in Greece. *Water science and technology*, 33(10-11), 17-27.

Toze, S. (1997). *Microbial pathogens in wastewater*, technical report no. 1/97, Literature review for urban water, systems multi-divisional research program. CSIRO, Land and Water, Australia.

Toze, S. (2006). Reuse of effluent water—benefits and risks. *Agriculture water management*. 80(1-3), 147–159.

US-EPA Environment Protection Agency (1992). *Guidelines for water reuse*. EPA/625/R-92/004.

US-EPA Environment Protection Agency (2004). *Manual guidelines for water reuse*, EPA/625/R-04/108.

Van der Hoek, W. (2004). A framework for a global assessment of the extent of wastewater irrigation: The need for a common wastewater typology. In: *The international development research centre* (IDRC). [on line]. <http://www.idrc.ca>.

WAJ Water Authority of Jordan (2004). *Annual report of water authority of Jordan*. Amman-Jordan.

WHO (1989). *Health guidelines for the use of wastewater in agriculture and aquaculture.* World Health Organization, Geneva. Technical report series, 778.

WHO (2006). *Guidelines for the safe use of wastewater, excreta and grey water. vol.2 Wastewater use in agriculture.* World Health Organization, Geneva.

Wigley, T. (1992). Future climate on the Mediterranean basin with particular emphasis on changes in precipitation. In: *Climatic change and the Mediterranean*. Jeftic J., Milliman J. and Sestini G. (eds). UNEP, New York.