REVIEW OF WASTEWATER TREATMENT AND REUSE IN THE MOROCCO: ASPECTS AND PERSPECTIVES

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ABSTRACT: *Wastewater reuse in agriculture has been identified as a way to alleviate water scarcity, improve crop productivity and improve environmental sustainability. Since the sixties, 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 the demand, the limited hydraulic potential requires the resort to unconventional resources. The use of treated wastewater in irrigation is necessity for a better water resources economy. 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-reuse", 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: Wastewater Reuse, Morocco, Wastewater Treatment, Agriculture, Effluent Quality, Technical.

Introduction

The potential of natural water resources are estimated at 22 billion m^3 per year, or about 730 m^3 / inhab / year. More than half of these resources are concentrated in the northern basins and Sebu covering nearly 7% of the national territory. According to forecasts, the potential water resources will tend to decrease as a result of climate change. Indeed, in recent decades, Morocco has experienced this phenomenon with an aggravation of extreme events and a significant reduction in rainfall and hence runoff.

In this context and accompanying the development of the country, Morocco has long been involved in the way of controlling these water resources through the construction of 128 large dams with a total capacity of nearly 17 billion m3 and more thousands of boreholes and wells capturing groundwater. The water sector continues to face the challenges of water scarcity in the effects of climate change, over-exploitation of groundwater resources, the weakness of the recovery of water resources mobilized especially in agriculture and the deterioration of the

quality of water resources due to the delay in sanitation, sewage treatment and reuse of treated wastewater. The baseline scenario shows that most basins will eventually deficit in 2030.
To consolidate gains and address the above challenges, the development strategy in the water sector in 2009 in the management and development of axis supply has set a target for 2030, three hundred (300) Mm^3 / year of treated wastewater reuse in irrigation of golf courses and parks and irrigation of crops that are ready.

Unconventional water resources, such as wastewater reuse, gained increasing role in the planning and development of additional water supplies. This paper discusses in some details the challenges of Kingdom of Morocco water resources, specifically:

- The limited water resources,
- The potential of wastewater reuse,
- The institutional, socio-economical, legal, and environmental framework of wastewater reuse.

PRESENT CONTEXT AND SITUATION OF WATER AND WASTEWATER

Morocco (Location)

Morocco is located in the northwestern corner of the African continent. It is bordered by the Atlantic Ocean to the west, the Mediterranean Sea to the north, and Algeria to the east and southeast. The Strait of Gibraltar separates it from Spain at its northern tip. Its southern border is the Sahara Desert. With an area of 446,550 square kilometers (172,413 square miles) and a coastline of 1,835 kilometers (1,140 miles), Morocco is slightly larger than California. Morocco's capital city, Rabat, is located in the northwest of the country overlooking the Atlantic Ocean.

Other major cities are Casablanca on the Atlantic Ocean, Marrakech (the business capital) in the center, and Tangier in the north, on the Strait of Gibraltar (Fig.1). Morocco's population was estimated at 30,122,350 in July of 2000, an increase of 1.2 percent from the 1990 population of 24,043,000. In 2000, Morocco's birth rate stood at 24.6 births per 1,000, while the death rate was reported at 6.02 per 1,000. The majority of the population are Muslim. Almost one-third of the population are Berbers, who are mostly concentrated in the Rif and Atlas mountains. Morocco has a sizeable community (1.7 million) of expatriates living abroad, mostly in France, Spain, and Italy.

Figure 1. Geographical Location of Morocco.

The growth rate of Morocco's population has slowed down since the 1990s, averaging 1.6 percent between 1995 and 1999, down from 2.5 percent in the preceding decade. With a projected growth rate of 1.4 percent between 2000 and 2015, the population is expected to reach 41 million by 2029. The population is generally young, with some 23 percent under the age of 15. Like people in many developing countries, a majority of Moroccans live in urban areas. The population of urban areas has grown significantly since the 1960s. Casablanca, Marrakech, and other major urban centers are home to some 54.5 percent of the country's people (Fig.2).

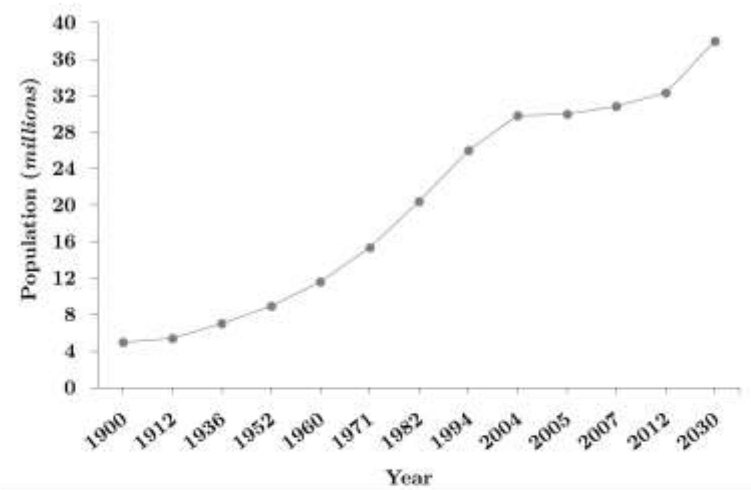

Figure 2. Evolution of the Population of Morocco.

ISSUE OF WATER RESOURCES IN MOROCCO

In Morocco, the volume of water available per inhabitant per year, an indicator of a country's wealth or shortness in terms of water, reaches about 1000 m^3/inhab/year. This rate is commonly considered as the critical threshold before the move to scarcity. At present, this rate varies between 180 m^3/inhab/year for the areas known to be poor in terms of water resources (Souss Massa, Atlas South, and Sahara) and 1850 m^3/ inhab/ year for areas of the basin of Loukkos, Tangiers and Mediterranean Coast, known to be relatively rich.
It is probable that the water resources per inhabitant can reach around 580 m^3/ inhab/ year towards 2020. At this date, about 14 million inhabitants, i.e. almost 35 % of the total population of the Kingdom, will not dispose of more than 500 m^3/ inhab/ year (Fig.3) (AGR/DDGI, 1999).

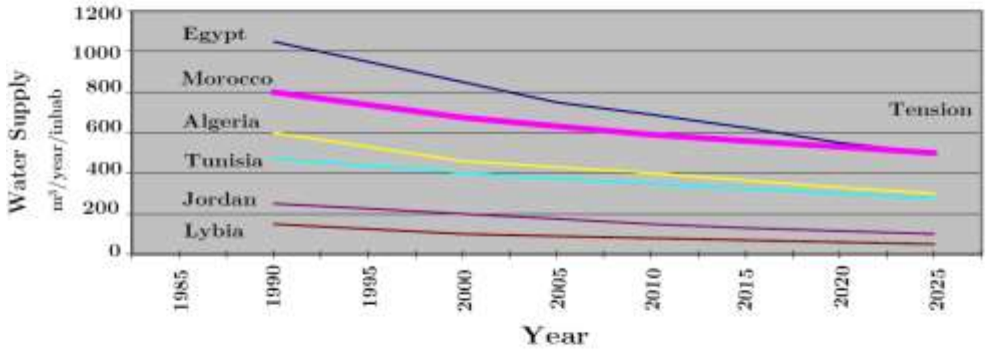

Figure 3. Evolution of Supply of Available Waters per Inhabitant and Per Year in Comparison with Some.

The chronic water scarcity is thus becoming a permanent situation that can no longer be ignored to draw the strategies and policies concerning the management of water resources in Morocco (Table. 1).
On the other hand, the hydraulic assessments prepared within the framework of the planning studies, carried out at the level of all the hydrologic basins, have proved that many of these basins are showing a shortfall. In addition, the quality of these resources has undergone a considerable degradation during the last decades due to the different sources of pollution (domestic, industrial, agricultural wastewaters etc.).

Table 1. Water Resources Availability.

Basin	Population (Millions of inhabitants)	Water resources avaibility (m^3/ Capita /year
Loukkos, Tangiers and coasts	3.645	1353
Mouloya	2.448	1065
Sebou	7.918	0996
Bou Regreg	9.076	0109
Oum Er-Rbia	6.171	1232
Tensift	3.131	0546
Souss-Massa	3.250	0362
Atlas South	2.606	0735
Sahara	0.625	0168

On the basis of the climatic and geographic context, the resort to non-conventional waters, namely treated wastewaters, constitutes an alternative, especially in basins suffering from droughts. The treated wastewaters are said to constitute a national development factor through extending irrigated areas, exploiting arid lands, improving public health, controlling environment pollution and managing the quality of water resources at the level of hydrographic basins.

Wastewater Effluents

Wastewater refers to different qualities which range from raw to diluted wastewater. In this study Wastewater is a combination of domestic effluents, industrial effluent, storm water and water from commercial institutions; that are released into the common sewerage network of a city. The composition of wastewater varies; in addition to water (which is 99%) it also has 1% suspended, colloidal and dissolved solids. Municipal wastewater contains organic matter and nutrients (N, P, K); inorganic matter or dissolved minerals; toxic chemicals; and pathogens. The composition of the non-pathogenic components in wastewater vary over time and sites and regions, so it is necessary to monitor wastewater quality regularly and come up with risk mitigation and reduction strategies. The composition of typical raw wastewater depends on the socioeconomic characteristics of the residential communities and number and types of industrial and commercial units, such that global demographic and economic change also has implications for environmental health protection and wastewater governance approaches (Hanjraa et al, 2012; Husain et al, 2002).

The Potential of Wastewaters in Morocco

The annual volumes of wastewater discharges have risen sharply over the past three decades. They went from 48 million to 600 million m^3 between 1960 and 2005 to reach 700 million by the year 2010. According to forecasts, these releases will continue to rapidly grow to 900 million m^3 in 2030 (CSEC, 1994). The trend in urban wastes generated is presented in figure 4.
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.

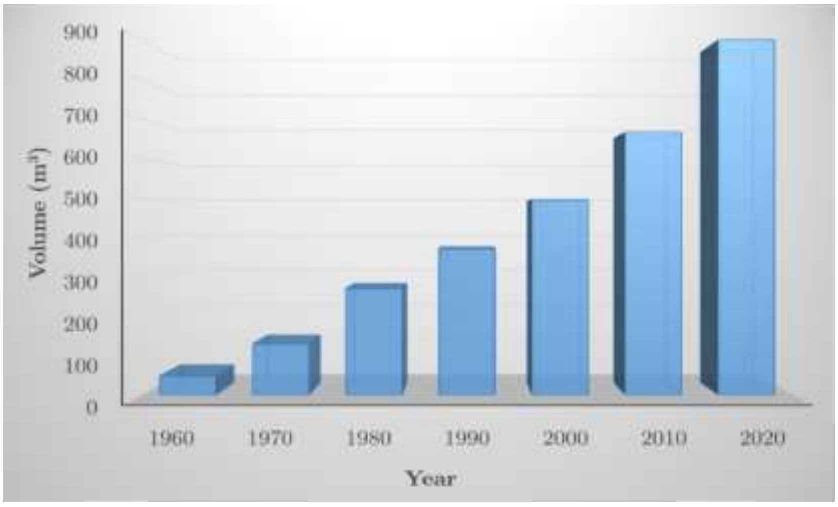

Figure 4. Trend of Urban Waste Volume in Morocco.

In 1999, the volume of wastewaters produced by urban pollution was 546 million m^3. More than 58% of this volume will be discharged at the coast and the rest in the rivers and valleys with no prior processing (Table. 2).

Table 2. Distribution of Wastewaters Discharged Following the Receptor Milieu.

Receptor Milieu	Discharged Volume in Millions of m^3	%
Mediterranean Atlantic Coast	316	57.8
Queds (rivers) and Talwegs	230	422
Total	546	100

Source: CSEC, (2001)

In comparison with the conventional waters, the volume of wastewaters will not surpass 4.2% of water resources in Morocco in 2020. In addition, this volume cannot be totally mobilized for the following reasons:

- Absence of irrigable sites downstream of the discharges in numerous centers, especially coastal cities.
- The high cost of the water conveyance system at the time when the reuse site involves costs for pumping and channelling.
- The availability of conventional waters.

A classification of the urban wastewater quality in Morocco has been carried out for ONEP (1998).
The results of this study provide a precise idea about the quality of wastewaters in Morocco, of the evolution of ratios and the restitution rates, on the basis of agglomeration size (Table. 3).

Table 3. Wastewater characteristics in Morocco.

Parameters	Small centers (less than 20.000 inhabitant)	Average Centers (Between 20.000 and 100.000 inhabitant)	Large cities (more than 100.000 inhabitant)	National average
BOD_5 (mg/L)	400	350	300	350
COD (mg/L)	1000	950	850	900
TSS (mg/L)	500	400	300	400
Restitution rates (%)	50	75	80	65
Supply x restitution rate (L/inhab)	40	70	80	60

The bigger the city is, the more the concentration of polluting elements explained in terms of BOD_5, COD, and MES decreases. In fact, big cities use a more important quantity of water, which leads to a more considerable dilution of wastewaters.

Wastewater treatment

Municipal wastewater treatment is a well-developed engineering science and various processes and techniques are available to efficiently treat the waste (Hussain et al, 2002). Wastewater treatment objectives and priorities as well as the available investment resources have to be considered in the choice of the treatment alternatives. Although wastewater treatment improves water quality its adoption in developing countries is limited by the high capital investment in this technology, high energy costs and operation and maintenance problems. The major drivers of wastewater treatment and reuse is generally physical water scarcity and studies show in addition to this; the level of water treatment also depends a lot on norms and standards of a society. Findings of studies showed that in India wastewater is indirectly treated by reuse in agriculture whilst in Australia, the treatment done is just enough to meet environmental standards for safe disposal. Also poor institutional frameworks in developing countries limit the wastewater treatments and that there less considerations for the environment. The level of treatment ranges from primary which produces the lowest water quality to tertiary which produces the best water quality (Hussain et al, 2002; Devi, 2009).

Primary treatment generally consists of physical processes involving mechanical screening, grit removal and sedimentation which aim at removal of oil and fats, settle able suspended and floating solids; simultaneously at least 30% of biochemical oxygen demand (BOD), 25% of Kjeldahl-N and total P are removed, 50 to 70% of the total suspended solids (SS), and 65% of the oil and grease are removed during primary treatment. Faecal coliform numbers are reduced by one or two orders of magnitude only, whereas five to six orders of magnitude are required to make it fit for agricultural reuse. Secondary treatment mainly converts biodegradable organic matter (thereby reducing BOD) and Kjeldahl-N to carbon dioxide, water and nitrates by means of microbiological processes (Helmer and Hespanhol, 1997; Pescod, 1992). Secondary treatment processes can remove up to 90% of the organic matter in wastewater by using biological treatment processes. The two most common conventional methods used to achieve secondary treatment are attached growth processes and suspended growth processes (EPA, 2004). Activated sludge process is a biological treatment process that utilizes a suspended growth of organisms in order to remove BOD and suspended solids. Trickling filters are one of the biological treatment processes that are used to remove organic matter from wastewater by degrading the organic matter and can also be used for nitrification and denitrification. Trickling filters are an attached growth system in which the biological process uses an inert medium to attach microorganisms and remove organic matter from wastewater (Suleaman, 2009).

In some treatment plants, primary and secondary stages may be combined into one basic operation. At many wastewater treatment facilities, influent passes through preliminary treatment units before primary and secondary treatment begins (EPA, 2004). Waste stabilization ponds are the first choice for treating the wastewater in many parts of the world, especially in small rural communities. There are three categorizations of waste stabilization ponds depending on their dissolved oxygen depth profile, namely: aerobic ponds, anaerobic ponds, and facultative ponds. In aerobic ponds, there is a varying concentration of oxygen throughout its depth while in an anaerobic ponds; there is lack of oxygen at any depth except with very few top centimeters at the air liquid interface. In facultative ponds, there is a support of oxygen aerobic condition in its top zone and the pond is anaerobic or lack oxygen at the lower depths or bottom zone (Suleaman, 2009). Waste stabilization ponds are recommended by the WHO for the treatment of wastewater for reuse in agriculture and aquaculture, especially because of its effectiveness in removing nematodes (worms) and helminthes eggs (WHO, 2006). Aerated Lagoons / oxidation ponds are artificial bodies for wastewater treatment that require a proper design, construction and maintenance in order to obtain a satisfactory treatment even for raw wastewater. The aerated lagoons or oxidation ponds are suitable in areas where cost of available large surface of the land is low (Suleaman, 2009). Lagoons remove biodegradable organic material and some of the nitrogen from wastewater (EPA, 2004).

Stabilization pods have an advantage that they are efficient and inexpensive (both in terms of capital investment and operation and maintenance). The disadvantages of waste stabilization are that it is land intensive and there are high water losses through evapotranspiration. Also wastewater from pond stabilization can only be used for restricted irrigation and this limits the type of crops which can be irrigated with the water (Hussain et al, 2002).

Tertiary treatment is designed to remove the nutrients, total N (comprising Kjeldahl-N, nitrate and nitrite) and total P (comprising particulate and soluble phosphorus) from the secondary effluents. Additional suspended solids removal and BOD reduction is achieved by these processes. The objective of tertiary treatment is mainly to reduce the potential occurrence of eutrophication in sensitive, surface water bodies. Advanced treatment processes are normally applied to industrial wastewater only, for removal of specific contaminants (Helmer and Hespanhol, 1997). Pollutant characteristics of the wastewater vary depending on the processes used in production and the quality of paper produced. However, in general, high organic material and suspended solid contents are considered as major pollutants of pulp and paper industry effluents. Major pollutant indicators biological oxygen demand (BOD) and suspended solid (SS) were chosen as design parameters (Buyukkamaci & Koke, 2010).

The Liquid Sanitation and National Wastewater Treatment Programme (SNP), was launched in 2005 jointly by the Department of Environment and the Ministry of Interior and sets specific targets for 2020 and following in 2030:

- Reach a level of global connecting to the network of 80 % on the horizon 2020 and 90 % on the horizon 2030;
- Reduce domestic pollution 80% by 2020 and 90% in 2030;
- Treat and use 100% of the wastewater collected in 2030.

The SNP opens the way to the mobilization of the treated water as a source of non-conventional water development.
The total cost of the investment program of around 50 billion dirhams by 2020.

- 70 % by operators.
- 30 % of state subsidies supplemented by contributions from local authorities and water agencies.

A Trust Account, National Sanitation Liquid and Wastewater Treatment (SLWTF) Fund was created to finance the SNP.
Five years after the implementation of the SNP, the situation of sewerage in urban areas experienced a net reflected through the following indicators improved:

- Rate network connection estimated at 72% against 70% in 2005;
- A rate of sewage treatment, which reached 21% (against 8% in 2005):
  - The number of wastewater treatment plants (WWTP) is carried past WWTP 49 against 21 in 2005.
  - The number of WWTP in progress is 33 WWTP.
  - The number of WWTP 2012 is programmed to WWTP 79.
  - The number of WWTP with tertiary level of treatment is 26 WWTP 9 which 17 completed and ongoing.

Table 4. Current status of wastewater treatment.

Total volume of wastewater	700 Mm^3/year	100 %
Treated volume in WWTP	150 Mm^3/year (54 % at the tertiary level)	21 %
WWTP volume current	116 Mm^3/year (26 % at the tertiary level)	17 %
Pretreatment volume and marine outfall completed	212 Mm^3/year	30 %
Pretreatment volume and marine outfall current	61 Mm^3/year	9 %
Untreated volume	161 Mm^3/year	23 %

Wastewater reuse in agriculture

Wastewater reuse is not a new practice, though there is no comprehensive global data onvwastewater reuse, it is estimated that about 7 % (or 20 million hectare) of irrigated land uses wastewater or polluted water (WHO, 2006). Of this 20 million ha only 10% uses treated wastewater.

Agriculture is the main consumer of water (consumes over 70 % of fresh water worldwide) and often competes with other uses for the scarce resource. Wastewater reuse in agriculture has many benefits which includes alleviating freshwater scarcity, providing a drought resistant source of water, provides nutrients (cuts on fertilizer costs) increase water productivity and confers environmental benefits. Wastewater is also more reliable than surface water and continual supply of wastewater from treatments plants and community sources enables the farmers to cultivate multiple crops throughout the year, raising cropping intensity and output.
Wastewater reuse and recycling of its nutrients in agriculture can contribute towards climate change adaptation and mitigation. Variability in composition of wastewater components causes the imbalance of components of wastewater and pause risk to the soil and ecosystems, plants, animals and human beings. The composition of the nonpathogenic components in wastewater vary over time and sites and regions, so it is necessary to monitor wastewater quality regularly and come up with maximize benefits while minimizing impact of these negative impacts to make wastewater irrigation sustainable (Grant et al, 2012; Hanjraa et al, 2012; Finea et al, 2006).

The effluent quality varied based on the wastewater treatment technology type as well as the target level of treatment. In the tertiary treatment process applied on the secondary treatment effluent to improve its characteristics in term of nutrients concentration. When using the wastewater effluent for irrigation, nutrient concentrations represent an added value to the agricultural system. Wastewater can meet 75 % of the fertilizer requirements of a typical farm in Jordan (Carr et al, in press). On the other hand, excess nutrients can also reduce crop productivity, so there is need for careful nutrient management is essential to reduce fertilizer costs and prevent a reduction in crop yield due to excess nutrients in wastewater (Hanjraa et al, 2012). From an economic viewpoint, wastewater irrigation of crops under proper agronomic and water management practices may provide the following benefits:

- higher yields,
- additional water for irrigation,
- value of fertilizer saved (Hussain et al, 2002).

Reuse of Treated Wastewater

On the reuse of treated wastewater, only 12% are currently recycled. This rate will increase to 22% in 2020 if the wastewater is discharged into the sea collect. It will reach about 100% by 2030 (target set by the strategy of development of the water sector).The use of these treated wastewater affects the agricultural sector (currently covering an area of approximately 550 hectares and will reach 4,000 hectares in 2020), watering golf courses and green areas, groundwater recharge and recycling in industry.

About the low level of use of wastewater in agriculture, it should be noted that despite interest early by the Department of Agriculture for the reuse of treated wastewater for agricultural purposes, efforts n 'have not been followed for a rapid transition from experimentation to scale the application to barn. This low speed can be attributed to several factors, including the difficulty of establishing an institutional and legal instruments accepted by all stakeholders as well as rules for sharing the costs of wastewater treatment between municipalities (producers) and users (farmers).

To overcome these constraints in order to promote the use of water in agriculture, taking into account economic, social, environmental, health reuse issues and the context of growing scarcity of water resources, the Ministry of Agriculture launched 2011 a study (turnaround time 15 months) to develop a master reuse of treated wastewater for irrigation in order to take stock of the state of the wastewater reuse in irrigation plan inventory potential resources treated wastewater could be used for irrigation, inventory irrigated and potentially irrigable land reuse and develop a toolkit to enable the services of the department to encourage and monitor the projects reuse of treated wastewater.

Regulatory and Policy Issues

Political aspects

- **National Water Strategy (NWS)**

National Water Strategy was approved by the government in 2010. It considers that the wastewater reuse is an important resource in unconventional water, and its valuation should be placed in the context of the integrated management of water resources at the national level.

- **The Green Morocco Plan**

The Green Morocco Plan adopted in 2008, highlighted the structural water deficits in most of the major agricultural production areas and considered the scarcity of water resources as a major constraint to agricultural development.
To address the challenge of water scarcity, the Green Morocco Plan and the National Water Strategy consider the management of water demand and water efficiency as a priority strategic scope for sectors water and agriculture.
In this context of increasing scarcity of conventional water resources, both water strategies and consider agriculture resource mobilization unconventional water including desalination of seawater and reuse of treated wastewater as an additional resource that can help alleviate local water deficits.

Regulatory aspects

- **The Water Act and its implementing regulations**

They are the main legislative and regulatory framework reuse in Morocco tool. Many provisions of the law designed to regulate and promote waste reuse. The main articles on reuse are:

- Article (84): Prohibits reuse in agriculture whenever the quality of the wastewater does not meet the standards set by regulation...

- Article (57): concerning the conditions of use of wastewater. It imposes an authorization to reuse and states that any user can benefit from financial assistance from the state and technical assistance where their use is in fact meet the conditions set by the administration and the effect of achieve water savings and preserve water resources against pollution.

- Article (51) on the establishment of standards of water quality for irrigation and other uses. These standards are developed by the Norms and Standards Committee, established by order and revised every ten years or whenever the need arises. The ABHS are required by the Water Act to take measures to ensure that water quality meets those standards.

- Article (54): Prohibits the discharge of wastewater into the receiving environment.

- Article (52) requires prior authorization for discharges of wastewater into receiving waters, issued by the Agency after an investigation Basin.

Economic and financial aspects

The financing of the projects concerning the construction of a treatment plant constitutes the main handicap for the realization of these projects. The majority of the projects of wastewater treatment are financed by communes through state credits. Other plants have been built by way of experiment, within the framework of partnership including water reuse and municipalities. The financial contribution of international organizations also helps in the construction of small plants in some cities and small communes of Morocco. Although the communes have proved to be willing to work, the initiation of treatment plant depends first on the establishment of a sewerage network. The cost of financing the latter makes future treatment plants seem illusory. The investment costs of wastewaters treatment plant varies considerably according to the adopted technology, the treatment process, and the specificities of the site, the pollutant load, and final disposal of treated wastewaters. For the treated wastewaters directed to reuse, the standards of health and environment protection impose a high quality requirement of the final effluent. Still, it is possible to compare the costs of investment of different projects and the reuse of wastewaters in Morocco per equivalent inhabitant.
Until now, there is no model for cost estimation of wastewater treatment in the Moroccan context.
As mentioned above, these costs vary according to a number of factors. However, leading experiences have shown that the cost of technologies appropriate for Morocco such as lagoon and filtration-percolation vary between 1,12 and 1,70 Dirham per m^3 of treated waters (1 Euro = 10 Dirham).

In the case of Drarga and Benslimane, the treated wastewaters are sold. In Benslimane, the treated wastewaters are sold to the golf course for 2 Dh/m^3 while the initial tariff for farmers in Drarga is 0,50 Dh/m^3. For mere comparison, the agricultural wastewaters distributed by the offices of Agricultural Development are sold for an average tariff of 0.5 Dh/m^3, while the price for potable water varies between 2 and 8 Dh/m^3. It is worth noting that in many places, farmers resort directly to underground waters and solely pay the fees of pumping. In some regions where the level of the ground water has witnessed a considerable decrease, especially in Souss Massa, the pumping cost have become very expensive and may raise up to 1.5 Dh/m^3.

The increase in the price of water has always been subjected to resistance. Nonetheless, due to the scarcity of resources and repetitive droughts, more and more farmers accept the principle of a more rational resource management, especially through a more adequate price setting policy. In the regions with more severe water scarcity, farmers are ready to pay the cost of water, provided they have a perennial source.

Within the framework of the law on water 10-95, the deduction charges are stipulated and the use of raw wastewaters are banned. It is therefore expected that once the application decrees of the law will be enforced, the demand for treated wastewaters, in addition to the willingness to pay for this water, will increase significantly.
The treated wastewaters contain fertilizing elements and allow the farmer to save fertilizes inputs.
The Table 5 is based on the performances obtained in Ouarzazate and Ben Sergao projects.

Table 5. Economic Gain from Treated Wastewaters Irrigation.

Cultivation	Net gain of water (Dh/year/inhab)	Benefit in fertilizers (Dh/year.inhab)	Total benefit (Dh/year.inhab)
Tender wheat	750	1.492	2.242
Unground corn	1.588	3.614	5.202
Fodder corn	1.568	3.572	5.140
Clover (Berseem)	774	1.539	2.313
Courgette	677	1.545	2.222
Marrow	611	1.216	1.827
Tomato	1.553	3.542	5.095
Potato	940	2.140	3.080

- Calculated on the basis of pumping water of Sous Massa (0.7 Dh/m^3) 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.

Health impact from wastewater irrigation

Wastewater contains pathogenic microorganisms such as viruses, bacteria and parasites which have the potential to cause disease and impact human health. Protozoa and helminth eggs are most virulent and they are most difficult to remove by treatment processes; they are often implicated in a number of infectious and gastrointestinal diseases in developing and even developed countries (Hanjraa, 2012). Improved wastewater irrigation is considered as the most effective factor in reducing the hazard of microbial exposure, especially when using relatively low quality wastewater effluent for irrigation. Improvement process depends on the implementation of suitable farm-level practices and post-harvest interventions, which are classified as non-treatment options and can be divided into the following major categories:

- Crop selection and diversification in terms of market value, irrigation requirements, and tolerance of ambient stresses;
- Irrigation management based on water quality, and irrigation methods, rates, and scheduling;
- Soil-based considerations such as soil characteristics, soil preparation practices, application of fertilizers and amendments if needed, and soil health aspects.

Flood irrigation is the lowest cost method, if the topography is favorable or farmers can afford a pump. However, water use efficiency is low, thus successful where water is not a limiting factor. Furrow irrigation provides a higher level of health protection, but requires favorable topography and land leveling. Irrigation with sprinklers and watering cans are not recommended as this spreads the water on the crop surface, although cans are usually the cheapest investment option and favored for fragile vegetable beds. Sprinklers require in addition a pump and hose, have medium to high cost, and medium water use efficiency.

Irrigating at night and not irrigating during windy conditions are important considerations when using sprinklers. Drip irrigation, especially with sub-surface drippers, can effectively protect farmers and consumers by minimizing crop and human exposure, but irrigation kits with appropriate planting density and pre-treatment of wastewater is needed to avoid clogging of emitters (Qadir et al, 2010). The WHO recommended a microbial guideline of not more than 1000 fecal coliforms (FCs) per 100 ml for unrestricted irrigation of all crops, with special emphasis on the removal of helminth eggs (Finea et al 2006).

There are many studies not only on farmers' exposure and risk of intestinal nematode infections, but also on actual and possible links between the consumption of crops irrigated with wastewater. Post-harvest contamination in markets can be an important factor affecting public health. Besides pathogens, chemical contaminants can be of concern especially in those countries where industrial development has started and industrial effluent enters domestic wastewater and natural streams (Qadir et al, 2010). This shaded cost of the public health impact can be evaluated based on the degree of risk might be affected the farmers or the consumers. Referring to different studies vulnerability factors are irrigation system, farmer behavior, crop types, wastewater quality, harvesting system, consumer behavior, and public awareness effectiveness. In this case, best cost will be at minimum risk (Finea et al, 2006). Argues zero-risk approach through the using of basic pathogen removal at the WWTP, followed by additional on farm protective means (or 'barriers' to pathogen infection) that are aimed to block pathogen transfer to the workers, to the consumers of the crop or to the general public.

In some cases of improving the vulnerability in a boundary area, extra cost should be added to the treated wastewater cost such as the cost of improving the irrigation system, the harvesting system or the costs of ensuring the safety of the consumer by providing 'barriers' against contamination of the agricultural product by enteric pathogens.

However there are some barriers to microbial contamination incur no additional cost: the air-gap between the drippers and the crop, components of the crop itself (peel or shell), and the manner in which the crop is marketed and processed (such as consumption only after proper cooking); these are natural barriers, which help to reduce the cost of effluent reuse (Qadir et al, 2010; Finea et al, 2006).

Environmental impact from wastewater irrigation

- **Soil**

Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible harmful impacts on soil health and crop yields. The leaching of these salts below the root zone may cause soil and groundwater pollution (Hussain et al, 2002).

Wastewater irrigation may lead to transport of heavy metals to fertile soils, affecting soil flora and fauna and may result in crop contamination. Some of these heavy metals may bioaccumulate in the soil while others such as Cd and Cu may be redistributed by soil fauna such as earthworms (Dikinya and Areola, 2010; Kruse and Barrett, 1985).

The impact of wastewater irrigation on soil may depend on a number of factors such as soil properties, plant characteristics and sources of wastewater. The impact of wastewater from industrial, commercial, domestic, and dairy farm sources are likely to differ widely Wastewater irrigation may have long-term economic impacts on the soil, which in turn may affect market prices and land values of saline and waterlogged soils (Hussain et al, 2002).

- **Groundwater**

Wastewater application has the potential to affect the quality of groundwater resources in the long run through excess nutrients and salts found in wastewater leaching below the plant root zone. Groundwater constitutes a major source of potable water for many developing country communities. Hence the potential of groundwater contamination needs to be evaluated before embarking on a major wastewater irrigation program. In addition to the accretion of salts and nitrates, under certain conditions, wastewater irrigation has the potential to translocate pathogenic bacteria and viruses to groundwater. However, the actual impact depends on a host of factors including depth of water table, quality of groundwater, soil drainage, and scale of wastewater irrigation (Hussain et al, 2002).

- **Ecological Impacts**

When drainage water from wastewater irrigation schemes drains particularly into small confined lakes and water bodies and surface water, and if phosphates in the orthophosphate form are present, the remains of nutrients may cause Eutrophication (non-point source pollution). This causes imbalances in plant microbiological communities of water bodies. Clearly, the impacts of wastewater irrigation on aquatic systems are largely similar to the impacts of direct disposal of effluent to receiving waters. Water-bodies located near densely built-up areas have a high recreation value. From other side, the likelihood of heavy metals from wastewater affecting the food chain is addressed under soil resources which usually acts as a filter and retains heavy metals in the soil matrix (Hussain et al, 2002; Hamilton et al, 2006). There are various factors may affect the relation between reused treated wastewater and ecosystem. The main factors are: soil properties, land use, geological formation, the distance to the near water body, wastewater quality, irrigation system and scale, and rainfall densities, hydraulic structures in the main watershed.

❖ Property Values

Depreciation of property values may sometimes be solely due to belief that risks persist. Thus both, actual and potential risk to property values due to wastewater irrigation should be evaluated in economic terms. attributes such as size, location, proximity to roads, markets and major population centers, productivity and fertility index, land rent and annual lease revenue, availability of canal/ groundwater, agroforestry, earthwork investments, greenhouse gas emissions and more importantly proximity to wastewater irrigation sites, should be valued in any economical evaluation of wastewater reuse system. Applying the hedonic pricing, the fall of property value due to negative impact caused by wastewater re use can be used as the shadow price of wastewater irrigation impact on the environment (Hussain et al, 2002; Hamilton et al, 2006).

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