Wastewater treatment and reuse in Morocco: situation and perspectives

Choukr-Allah R.

in

Hamdy A. (ed.), El Gamal F. (ed.), Lamaddalena N. (ed.), Bogliotti C. (ed.), Guelloubi R. (ed.).
Non-conventional water use: WASAMED project

Bari : CIHEAM / EU DG Research
Options Méditerranéennes : Série B. Etudes et Recherches; n. 53

2005
pages 271-287

WASTEWATER TREATMENT AND REUSE IN MOROCCO: SITUATION AND PERSPECTIVES

R. Choukr-Allah*
* IAV Hassan II BP 773, Agadir, Morocco, E-mail: choukrallah@iavcha.ac.ma

ABSTRACT – 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-re-use", obstacles still hinder the deployment of the re-use of treated wastewater. In the current state of affairs, no project integrating the three components has been realized. This paradoxical situation is due to several constraints.

Key words: Morocco, treated wastewater, treatment plants, effluent quality, technical, socio-economical and social aspects

INTRODUCTION

Located at the extreme North-West of the African continent and bordered in the south by the great Sahara, Morocco is affected by the Mediterranean climate that varies depending on the geography of the country, and characterized by more and more repetitive periods of drought leading to serious socio-economic problems.

Indeed, the Moroccan climate varies from sub-humid in the North, semi-arid to arid in the Centre, to Saharan in the South. The rainfall rate is irregular in time and space. The average annual rainfalls reaches more than 1000 mm in mountainous areas of the north (Riff and Tangiers basin and West Mediterranean Coast) and less than 300 mm in the Moulouya, Tensift, and Souss-Massa basins, South-Atlas areas and the Saharan area.

These conditions impose the choice of a politics of water saving. Otherwise, the repair of the unbalanced potential of demand and supply on water resources imposes sustainable management of these resources, aiming to more balance planning than the one practiced at the present time. The fast deterioration of the water quality, because of the absence of treatment of the discharged effluents, has a great effect on the degradation and depletion of water resources and therefore of their future availability. The present evaluations show that the discharge of large quantities of polluting effluent is responsible of the deterioration of the water quality generated in the hydrographic basins. In 1984, 20% of the water monitoring stations indicated bad quality waters; actually it reached 50%. The annual cost of water degradation is estimated to 4.3 billions Dirham (1 Euro = 10 Dirham), which correspond to 1.2% of the GIP. This percentage ranks the Kingdom of Morocco among the countries that the least equipped with systems to reduce pollution. If nothing is done to reduce this pollution, the volume of polluting effluents will triple by the year 2020.

With the rapid development of domestic, industrial, and agricultural water supplies, conventional water resources have been seriously depleted. The scarcity of natural water resources and the growing gap between demand and supply of potable water in most of the Kingdom of Morocco forced the government to face the water challenge with wise policies and decisions. The government realizes that the situation goes behind just a gap in water quantity and needs to be seen in the context of emerging environmental problems.

Moreover, there has been an increasing concern in the Kingdom of Morocco about the development of the water sectors and the efficient utilization of the water resources for sustainable water development.

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:
1) The limited water resources,
2) The potential of wastewater reuse, and
3) The institutional, socio-economical, legal, and environmental framework of wastewater reuse.

1. PRESENT CONTEXT AND SITUATION

1.1. 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 1000m^3/inhab/year. This rate is commonly considered as the critical threshold before the move to scarcity. At present, this rate varies between 180m^3/inhab/year for the areas known to be poor in terms of water resources (Souss-Massa, Atlas South, and Sahara) and 1850m^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 580m^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 500m^3/inhab/year.

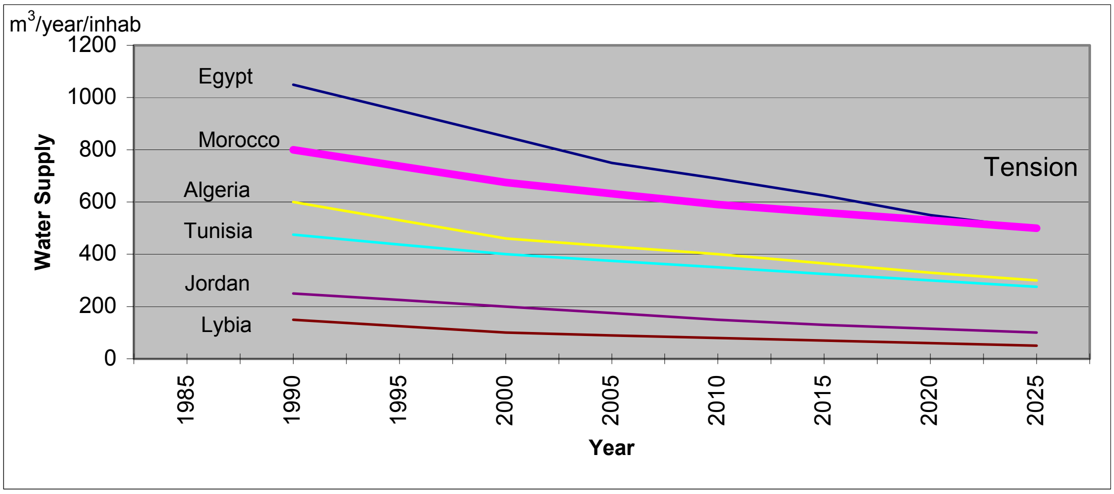

Figure1. Evolution of supply of available waters per inhabitant and per year in comparison with some countries of the Mediterranean (AGR/DDGI, 1999)

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, 2020 forecast

Basin	Population (Millions of inhabitants)	Water resources availability (m^3/inhab/year)			
		Average year	4 years over 5	Dry year after ten years	Dry year after one hundred years
Loukkos, Tangiers and coasts	3.645	1353	745	563	418
Moulouya	2.448	1065	795	696	541
Sebou	7.918	0996	605	509	395
Bou Regreg	9.076	0109	049	039	029
Oum Er-Rbia	6.171	1232	973	910	835
Tensift	3.131	0546	324	280	240
Souss-Massa	3.250	0362	207	180	156
Atlas South	2.606	0735	414	347	279
Sahara	0.625	0168	-	-	-

Source: AGR/DDGI (1999)

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.

1.2. The Potential of Wastewaters in Morocco

Since the 1960's, Morocco has largely contributed to the mobilization of its hydraulic capacities in order to face the demographic increase and sustain its social and economic development. Nonetheless, and in addition to the continuation of the efforts directed to mobilization, and the control of demand, the limited hydraulic potential requires Morocco to resort to unconventional resources (wastewaters and brackish waters). Due to the more and more pronounced hydraulic deficit, the use of treated wastewaters in irrigation is necessary for conservation of water resources. Moreover, the experience of Morocco in this domain has proved the feasibility of the reuse procedure.

In addition, farmers have already resorted to raw wastewaters in areas where these waters are available close to agricultural lands. This is supported by the increasing demand for food, which is easily sold due to the proximity of the urban areas.

At present, about 546 million m^3 of raw wastewaters are discharged in the receptor milieu. Around 60% are discharged to sea; the remaining quantity is divided between draining-off of surface waters that represent the major part and a reuse operation concerning more than 7000 ha.

The continuation of these discharges may lead to a deep degradation in the water resources and dangerous consequences on the potable water supply for many regions of the country. In parallel, continuing the reuse of raw wastewaters may have serious impacts on public health.

In the last three decades, the annual volume of wastewaters has almost tripled. It has increased from 48 in 1960 to 500 million m^3 in 1999. It is expected that this volume may reach about 900 million m^3 in 2020 (CSEC, 1994). The trend in urban wastes generated is presented in Fig. 2.

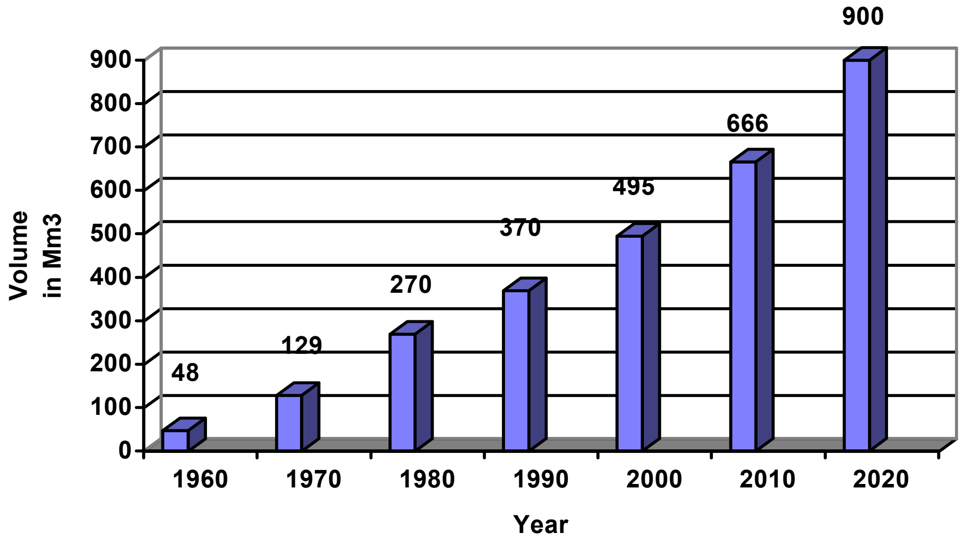

Figure2. Trend of urban waste volume in Morocco

The main factors that contribute to this increase are:

1) The increase in the urban population by a rate that varies from 4.4 to 5%;
2) 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;
3) The increase in the rate of sewerage network which has reached 75% in big cities in 1999, and;
4) 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.

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
Oueds (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. Classification of wastewaters 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

Source: ONEP-GTZ, 1998

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.

1.3. Reuse of Wastewaters

In Morocco, the use of raw wastewaters is a current and old practice. Raw wastewaters are used where they have most value in general. These practices are resorted to on the periphery of some big cities where agricultural lands are located downstream of effluent discharge, and also in small areas around the treatment networks. Climatic constraints push farmers to irrigate cultivations in places where these water resources are available.

In recent years, the reuse of wastewaters has also developed around some suburbs recently provided with a treatment network. A total of 7000 ha is directly irrigated with raw wastewater discharged by towns, i.e. about 70 million m^3 of wastewater is used every year in agriculture with no application of health control (WHO standards for example). Many crops are irrigated in this manner (fodder, market gardening, major crops, arboriculture…).

The irrigation of market garden crops with raw wastewaters is forbidden in Morocco, but this ban is not respected. This makes the consumer of agricultural products and the farmer face risks of bacteria and/or parasite disease.

Table 4. Main areas of raw wastewater reuse in Morocco

Area	Surface (ha)	Crops
Marrakech	2000	Cereals, fruit threes
Meknes	1400	Cereals, fruit threes
Oujda	1175	Cereals, fruit threes
Fès	800	Fruit threes
El Jadida	800	Fodder
Khouribga	360	Cereals
Agadir	310	Fruit threes, soybean, floriculture
Béni-Mellal	225	Cereals, cotton, beetroot
Ben guérir	95	Fodder, fruit threes
Tétouan	70	Fodder
Total	7235	

Source: CSEC, 1994

In general, the volume of wastewaters reused does not represent more than 0.5% of the water used in agriculture.

This situation tends to occur in all agglomerations that are provided with a treatment system or where wastewaters are discharged. Following an investigation carried out by SNAI (1998), a total of 70 areas, where raw wastewaters are used, are found in the country. This practice is not free of dangerous consequences for human health and for the environment. For example:

- Spread of water borne diseases (more than 4000 cases of Typhoid and more than 200 case of malaria have been noted in 1994, some cholera sources in the Sbou basin);
- Difficulty and high cost of treatment potable water;

- Many sections of water courses in the country contain low quantities of dissolved oxygen, and even a total deficit in oxygen when discharges are significant, and which causes massive fish mortality; and
- Many barrage waters are eutrophic, as a consequence of the significant phosphorus and nitrogen levels in the waste discharges.

For a decade, a number of multidisciplinary projects concerning the treatment and reuse of wastewaters in irrigation have been launched in Morocco. The aim was to answer the major agronomic, health and environmental concerns. The results of this research has meant that local collectivities and study offices benefit from reliable data necessary to plan and design the size of the wastewater treatment adapted to the local context and to the controlled use of treated wastewaters in agriculture.

2. TECHNICAL ASPECTS

2.1. Present Situation of Treatment Plants

In spite of the existence of numerous treatment plants, the quantity of treated wastewaters in Morocco is still low. There are wastewaters treatment plants in many of the large cities of Morocco, while some plants have been built in average cities (ex. Nador, Benslimane, Boujaâd), in small urban centers, in tourists medium size towns, tourist developments, in airports and in industrial units. Table 5 below describes the present situation of wastewater treatment plants.

Table 5. Situation of wastewater processing plants in Morocco

Treatment plant	Number	In function	Out of order	Non-connected	% functioning
Activated sludge	20	12	5	3	60
Percolating filter	11	5	6	0	45,5
Settling basin	17	2	13	2	11,8
Digester	3	0	3	0	0
Lagoon	13	7	5	1	53,8
Filtration-Percolation	2	2	0	0	100
Algal Channel	3	1	1	1	33,3
Total	69	29	33	7	42,0

Source: CSEC, 2001

The Table above shows that about:

i) 60% of activated sludge treatment plants are out of order, due to the expensive cost of electricity, the absence of equipment, maintenance and the lack of coordination between different contributors in the management of these plants. If we do not take into consideration the small activated sludge plants in hotels, airports, and industrial units, no more than two plants out of ten supplying the urban centers are operating, and

ii) 37% of the processing plants of other types are functional.

There are four projects, in Morocco, where the reuse of the treated effluents was considered right from the start: Ouarzazate (lagoon), Ben sergao (filtration-percolation), Benslimane (aerated lagoon) and Drarga (infiltration-percolation). Table 6 represents some identification elements concerning the main projects of processing and reuse of wastewaters. The table includes only studies subjected to a regular follow-up by multidisciplinary teams.

Table 6. Wastewater treatment and reuse projects in Morocco

Plant	Ouarzazate	Ben Sergao	Ben Slimane	Drarga
Processing system	Lagoon	Filtration-percolation	Aerated Lagoon	Filtration-percolation
Implementation	ORMVAO FAO-OMS-PNUD IAVHII	DGCL RAMSA	ONEP/ MILD Canadian Contribution Municipality of Ben Slimane	Project PREM/ USAID Department of Environment Commune of Drarga ERAC-Sud
Date of launch	1989	1990	1997	2000
Processing capacity	430 m³/d (5 l/s)	750 m^3/d	5.600 m^3/d	1.000 m³/d
Connected population (Eq-hab.)	4 300	15 000	37 000	8 000

2.2. The Added Value of the Projects

Ouarzazate and Ben Sergao treatment plants were realized at the end of experimental and research periods. In fact, the main objectives of these projects were to:

- Study the effects of using treated wastewaters on land, cultivations, and irrigation systems.
- Define the health criteria required for the use of treated wastewaters.
- Identify the most appropriate techniques for maximum exploitation rising treated wastewaters and the residual sludge.
- Study the efficiency of the wastewater treatment system per basin.
- Follow the effects of reuse process on the environment and especially on the quality of underground waters.
- Reinforce national capacities in reusing treated wastewaters for agricultural purposes.
- Exploit the results in extending the use of treated wastewaters at the national and regional level.
- Produce dimension standards for future plants.
- Calculate the direct or indirect costs that come within a financial and economic analysis.

The treatment plants of Benslimane and Drarga were conceived as pilot plants.

In Benslimane, the experience resulted in a treatment system adapted to the needs of the city. The project was launched to answer the following priority objectives:

i) reduce the nuisance impacts on the environment generated by the raw wastewaters, and
ii) conserve the underground water resources used to irrigate the golf course of Benslimane.

At present, the treated wastewaters are almost totally reused to irrigate the golf course of Benslimane. When necessary, the surplus of the plant is discharge outside the plant where it is reused seasonally and sporadically by farmers situated downstream of the discharge, especially in the commune of Ziaida.

The Drarga project was designed to maximize use exploitation of all treated wastewater products. The treated wastewaters are sold to farmers and reused in irrigation, the reeds of the wetland are cut and sold, the residual sludge is dried and then composted with the organic wastes of Drarga, and the biogas of anaerobic basins will be recovered and converted to energy.

Experiences conducted in Morocco are numerous and widespread. The results of these works showed that the reuse of processed wastewaters can contribute to water saving, improve agricultural products through the nutritional contribution of wastewaters and protect the health of the consumer and the environment.

2.3. Criteria Required for the Choice of the Projects Sites

The first criterion taken into consideration in the choice of a treatment plant location is generally the availability of land. Due to the absence of a long-term vision, some plants have been built on the limits of some cities, which threaten the future of these plants because of the extension of housing and of the nuisance of odors. The title deed of the land for construction of a treatment plant has often been a basic element in the choice of the site. The lands situated on the outskirts of the town are often agricultural lands of high commercial value. Though the expropriation procedure is a last resort solution, the treatment plants in Morocco are for the majority built on governmental lands. Until now, no project for building a treatment plant was stopped because of a lack of site.

2.4. Guidelines of Reuse of Wastewaters

The application Decree (N°2-97-875, dated February 4, 1998) acting as water law 10-95 related to the use of wastewaters stipulates that no wastewater can be used if it has not been beforehand recognized as treated wastewater. The use of raw wastewaters is thus banished.

The Norms and Standards Committee (NSC) that comes under the National Environment Council is setting objectives for the quality of receptor milieus (quality norms). The NSC is made up of representatives for all relevant ministerial departments. Among the different suggested norms comes a project of standards of the quality of wastewaters designed for irrigation, and which specifies the bacteriologic, parasitic, and physico-chemical parameters (Table 7).

Table 7. Quality standards of waters designed for irrigation

	Parmeters	Limit Values
	Bacteriological	
1	Fecal Coliform	5000/100ml *
2	Salmonella	Absence in 5 L
3	Cholera Vibrio	Absence in 450 ml
	Parasitological	
4	Pathogen	Absence
5	Eggs, Parasite cysts	Absence
6	Ancylostoma larva	Absence
7	Flurococercaires of Schistomosa hoematobium	Absence
	Physico-chemical	
8	Mercury Hg mg/l	0,001
9	Cadmium Cd mg/l	0,01
10	Arsenic As mg/l	0,1
11	Chrome Cr mg/l	0,1
12	Lead Pb mg/l	5
13	Copper Cu mg/l	0,2
14	Zinc Zn mg/l	2
15	Selenium Se mg/l	0,02
16	Fluorine F mg/l	1
17	Cyanide Cn mg/l	1
18	Phenol	3
19	Aluminium Al mg/l	5
20	Beryllium Be mg/l	0,1
21	Cobalt Co mg/l	0,05
22	Iron Fe mg/l	5
23	Lithium Li mg/l	2,5
24	Manganese Mn mg/l	0,2
25	Molybdenum Mo mg/l	0,01
26	Nickel Ni mg/l	0,2
27	Vanadium V mg/l	0,1

* 1000 CF/100 ml for crops consumed raw

These standards do not only apply to irrigation with treated wastewaters but to all types of irrigated water. The aim behind these standards for the reuse of wastewaters is to protect the environment and health.

2.5. Performance of the Treatment Dank in Moroccan Conditions

Concerning the treatment of wastewaters, Table 8 sums up the results of the treatment results of some experimental treatment plants.

Concerning the reuse in irrigation, the results obtained have shown that the reuse of treated wastewaters can contribute to saving water and fertilizers, increasing outputs, improving cultivation techniques and protecting the health of the consumer and the environment. The main cultivations tested are alfalfa, corn, wheat, zucchini, beans, cucumber, pea, tomato, and turnips.

Table 8. Treatment performance (in reduction percentage)

Plant	Ouarzazate		Ben Sergao	Drarga	Ben Slimane	Marrakech	Bouznika
Processing System	Lagoon	High Output Lagoon	Filtration - percolation		Aerated Lagoon	facultative Lagoon	Lagoon
Period of Stay (Days)	25	21.9	-	-	30 – 40	30	-
BOD_5 (mg/l)	81.7	65.3	98	98.5	78	97	75
COD (mg/l)	72	65.4	92	96	79	76	71
TTS (mg/l)	28	-	100	96.6	-	69	76
NTK (mg/l)	31.5	48	85	96.8	75	71	14
Pto t(mg/l)	48.5	54	36	95.9	41	85	-
CF /100ml	99.9	99.9	99.9	99.9	100	99.4	99.9
O. Helminthes/l	100	100	100	100	100	100	100

Source: ONEP-FAO, 2001

As other examples, in Nador and Khouribga, treated wastewaters from activated sludge plants are used for the irrigation of municipal tree nurseries. Furthermore, a tanker in Khouribga watering of trees in the town supplied by the treatment station ensures the irrigation of the trees of the city. In Boujaad, the treatment lagoon spontaneously allowed for a large sector irrigated by the treated effluents was spontaneously set. These effluents are characterized by a health quality that allows the production of market gardening cultivations. In Benslimane, the treated wastewaters produced by a lagoon system reinforced with slight ventilation are of quality A (intestinal nematoda ≤1 egg per liter; intestinal coliforms ≤ 100 par 100ml according the WHO standards (1989)). Almost all these treated wastewaters are reused to irrigate the golf course; the surplus is evacuated outside the plant to be reused seasonally and sporadically by farmers at the downstream.

2.6. Irrigation Techniques

Numerous irrigation methods have been tested in the pilot projects. These include flood, furrow, sprinkler, and drip irrigation. In Morocco, most of the problems encountered were not linked to the irrigation method but rather to the irrigation scheduling, which should take into consideration the quality of treated wastewaters generally loaded with salt (Ouarzazate) and with nitrogen (Case of BenSergao).

In Bensergao plant, it was proved that the choice of a good drip system might significantly improve the distribution of wastewaters at the level of the plot. Also, it is necessary to set up a double filtration system (sand and filter screen) to avoid the clogging of the drip system.

2.7. Valorization of the Residual Sludge

The experiences conducted in the reuse of residual sludge have been less developed than those conducted on the reuse of treated wastewaters. Meticulous tests have been carried out in Ouarzazate and Bensergao.

In Ouarzazate, the sludge emanating from the drying beds have given satisfactory results. In an agronomic experience concerning the cultivation of the Italian Ray Gras, the increase of dry products was by 200%. No heavy metal accumulation was found in neither the soil nor in the plants.

In the case of Ben Sergao, the sludge was composted and used for the organic enrichment of two grass species. The height and production parameters of the dry materials have been significantly improved. The composting operation allowed the total drainage of the sludge, and thus wiped out any risk of biological contamination.

3. INSTITUTIONAL ASPECTS

In Morocco, management of each type of water use is done by a private department or office or privately. Concerning the reuse of wastewaters, the administrative structures called to intervene directly or indirectly are multiple and different and include:

1) **The Superior Council of Water and Climate (CSEC):** It is in charge of formulating the general orientations of national policy in terms of water: planning, distribution, and management of resources. It examines and formulates its opinions on the plan of integrated development of water resources in hydraulic basins, especially the measures for more value, protection and conservation of water resources.
2) **Ministry of Interior:** Acting in its capacity of administration in charge of supervision of local collectivities, this department ensures the technical assistance, the implementation of works and the control and application of the state policy. The water autority also play a special role in managing wastewaters via the General Directorate of Local Collectivities (DGCL). Since the 1976 charter, the DGCL has been in charge of supplying populations with potable water through control departments and the liquid waste treatment.
3) **Ministry of Equipment:** Via the Hydraulics Administration (AH), this ministry is in charge of drawing and implementing the government policy in terms of water planning, mobilization, management, and conservation and in terms of large hydraulic works development, maintenance and management and minimizing their pollution effects. Amongst others, the Ministry of Equipment also supervises the National Office of Potable Water (ONEP), in charge of producing potable water, managing its distribution, providing the technical assistance, the liquid sanitation and the treatment of wastewaters for the communes who entrust these tasks to it. Furthermore, the office controls the pollution of waters that can be used in the supply for human consumption.
4) **Basins Agencies:** They are in charge of evaluating, planning, and managing the water resources at the level of the hydraulic basin. These agencies have the authorization for allowing reuse of wastewaters and to define the conditions required for using wastewaters.
5) **Ministry of Agriculture, Rural Development and Waters and Forests:** It is mainly in charge of elaborating and implementing the policy concerning the reuse of treated wastewaters in agriculture via the regional service (ORMVA and DPA) in addition to the management of these waters, the awareness and technical framing of Associations of Agricultural Waters Users (AUEA).
6) **Ministry of Health:** Is in charge of protecting public health, providing health-directed education, in addition to controlling and treating diseases and the sanitary quality of processed wastewaters.
7) **Ministry of Energy and Mines:** In charge of protecting the environment from the effects of pollution caused by mines and industries (cleanup of industrial waters).
8) **Environment Department:** Is in charge of animating, encouraging and coordinating with ministerial departments for environmental protection in order to reinforce the institutional and legal framework and to fight all forms of pollution and nuisances to receptor milieus. This department is in charge of coordinating all the actions linked to the protection of the environment and setting standards for the discharge of wastewaters. As for the National Council of Environment, its task is to set the national guidelines.

The reuse of wastewaters requires a close coordination between different departments concerned with the reuse operations at the regional level. In order to make this coordination efficient, an institutional partnership is to be developed in order to draw an agreement between the different partners specifying their respective roles.

4. 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.

Table 9. Comparison of the costs of different processing plants of wastewaters in Morocco

Plant	Investment cost (millions of dirham)	Functioning cost (dirham / year)	Cost per inhabitant / year (dirham)	Cost / m^3 (dirham)
Ouarzazate	5	108.500	643	1,43
Ben Sergao	5	307.500	250	1,12
Benslimane	96,44	935.000	1.928	1,45
Drarga	20,3	260.000	1.000	1,70

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 10 is based on the performances obtained in Ouarzazate and Ben Sergao projects.

Table 10. 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

(1) 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).
(2) Calculated on the basis of the total value of fertilizing elements in treated wastewaters.

5. LEGAL ASPECTS

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

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

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

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

This Law defines, in article 51, the quality standards that water shall satisfy, according to the usage that shall be made of it. These standards define the procedures, the operative mode of testing, sampling and analysis as the water scheme that defines the class of water quality that allows a standardization of quality evaluation (physico-chemical and bacteriological characteristics, particularly those of used water that is destined to such usage).

In articles 52 and 54, the Law specifies prohibits the discharge of wastewater or solid waste, or the spreading or hiding of any effluents likely to pollute underground water through infiltration or surface water through runoff, in a way that is likely to modify the physico-chemical or bacteriological characteristics without preliminary authorization, after investigation, by the Basin Agency. The Law also fixes penalty fee.

For the reuse of wastewater, this Law stipulates in its article 57, that the administration defines, in particular, the necessary conditions for wastewater reuse and to obtain the authorization for reuse. It also stipulates that every user of wastewater can benefit of the state's financial aid and of a technical aid from the Basin's Agency if the usage is in conformity with the conditions fixed by the administration and contribute to the saving of water and the preservation of water resources against pollution.

Law 10-95 stipulates in its article 84, that using wastewater for agricultural purposes is prohibited when the water does not respect the standards fixed by the law. These standards are currently being prepared at the national level by the Norms and Standards Committee (NSC).

This law formulates in its article 112, the infringements of the provisions of articles 12 and 57 relating to the conditions of wastewater use and article 84 relating to using wastewater for agricultural purposes.

Decree No. 2-97-224 of October 24, 1997 specifies, in its article 2, that the accumulation of raw wastewater shall not be allowed unless it is an integral part of a water treatment system that is approved by the appropriate hydraulic basin agency.

The implementation decree of Law 10-95 of 4 February 1998 (No. 2-97-875) relating to the use of wastewater specifies the necessary formalities to obtain the authorizations. The decree stipulates that wastewater shall not be used unless it is recognized as treated water beforehand. Using raw wastewater is thus prohibited. The authorization request shall comprise a file that includes a technical study indicating the quality of the treated wastewater to be used. The implementation decree provides that the Basin Agency might bring a financial contribution to the realization of the wastewater treatment investments and, if necessary, of its pumping and/or adduction, until it reaches the location where it shall be used, provided that water does not come directly from the natural environment. In order to benefit of the Basin Agency's financial contribution, the reprocessing of wastewater shall allow an economy of water and shall not cause damage to public hydraulic domain.

The implementation decree of Law 10-95 of February 4, 1998 (No. 2-97-787), sets the quality standards that water shall meet according to the planned use. These standards aim at defining the physico-chemical and bacteriological characteristics, in particular of wastewater to be used in irrigation. Moreover, the decree affirms the need to carry out an inventory of the degree of pollution surface water of groundwater.

6. ENVIRONMENT AND HEALTH

6.1. Impact on Environment

The treatment and the reuse of wastewater contribute to the protection of the milieu. Indeed, for every 900 m^3 of wastewater that will be discharged in 2020 in the country, it can be estimated that treatment allows a reduction of polluting in terms of BOD_5 from 270,000 tons to 27,000 ton per annum, and the nitrogenous polluting material will be reduced from 54,000 tons to less than 25,000 tons per annum. For instance, the system treatment that is currently adopted in the commune of Drarga allows a reduction in the nitrogenous material from 12.7 tons to 1.6 tons.

The reuse of wastewater allows exploiting the nutritive elements in this water in agriculture or in green areas. This makes it therefore possible to recycle the nutritive elements in the vegetable bio-mass and to reduce their pollution capacity that are particularly apparent when they infiltrate to groundwater or are found in particulate form or in solution in surface water.

However, it should be stressed that the reuse of treated wastewater aiming at preserving the environment should be based on good irrigation practices: types of irrigation, rotation mode, etc. In addition to the concern about the control of the health aspects, two parameters should be effectively managed: salinity and the pool of nutritive elements, particularly nitrogen that may exceed the usual needs for most agriculture types. The relation between treatment and reuse is also an important aspect that should be taken into account.

The nitrogenous assessment within the framework of wastewater reuse was measured in the experiments of Ben Sergao (filtration-percolation) and Ouarzazate (lagoon). In the case of Ben Sergao, irrigation with wastewater that was treated by the filtration-percolation system delivers large quantities of nitrate-nitrogen that largely exceed crop needs, and consequently, leads to nitrates reaching into groundwater. This is likely, in the long term, to lead to deterioration the quality of water resources. This concern is even more significant in areas with sandy ground where the transfer of nitrogen towards the water sources is fast. In the case of Ouarzazate, the average mineral nitrogen stock in the areas that were irrigated with treated wastewater varied between 350 and 450 kg per hectare, whereas the estimated need for the agriculture was of 175 kg/ha. However, in this particular case, a considerable part of the nitrogen stock is suddenly lost through volatilization, given the ground's basic nature.

Another environmental concern related to the reuse of treated wastewater is salinity. The soluble salt concentrations in used water effluents are generally higher than those in drinking water. Indeed, this water undergoes a mineral enrichment after domestic use. High concentrations of sodium and soluble salts in wastewater have harmful consequences on vegetable production and the physicochemical properties of the ground.

6.2. Impact on Health

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

The health risk related to wastewater can be measured according to the type of agriculture:

(i) Crops to be consumed raw: this risk is more serious when cleanliness and hygiene conditions are not respected. This is the case in the majority of diseases that are of an epidemic nature, and in particular in certain seasons of the year. Cholera is a good example. This disease existed in Morocco until 1994, and appears very frequent in the summer, in areas where consumer's agricultural products were irrigated with raw wastewater.
(ii) Agricultural products that can be consumed after cooking: the cooking temperature and the rules of kitchen hygiene determine the contamination risks.
(iii) Goods of animal origin as transmitters of pathogenic agents: this is often neglected or can act underestimated. Animals can accumulate in their bodies many pathogenic agents or toxic substances that they consume with fodder irrigated with of raw wastewater and which are transmitted later.

Given the complexity of the biology of the pathogenic agents and their mode of transmission, human beings can be contaminated through several means:

(i) Through direct contact with wastewater: this concerns farmers who cultivate the ground without taking the necessary precautions to protect themselves from the risk of contamination. Contamination can take place through simple direct contact with wastewater containing parasites of human or animal origin; these are able to cross the skin barrier and to penetrate in the organism.
(ii) The consumption of crops irrigated with wastewater also presents a frequent mode of human contamination. This risk is not limited to farmers who consume their own agricultural products; it also concerns the population that buys contaminated products. In certain cities of Morocco, the agricultural products irrigated with raw wastewater are often sold in big cities to escape mistrust from the local population. Therefore the whole country is at risk.

Human contamination often results from the combination of several factors that are not limited to pathogenic agents, but also include the anthropological activities in the area. The risk run by the population will depend on the epidemiological context of each disease. Concerning the use of raw wastewater in agriculture, the medical risk is higher than the regional norms due to the abovementioned reasons.

The risk inherent in the re-use of wastewater within a certain population is governed by the following factors:

- Consumption of products irrigated by wastewater or fertilized by sludge.
- Consumption of animal meat nourished by fodder that was irrigated by wastewater.

- Direct contact with wastewater (farm laborers.).
- Proximity to wastewater managing zones (children).

The risk of infection depends on the pathogenic agent and on the circumstances that encourage its transmission. The elements which are of a paramount importance are the concentration of the pathogenic agents in raw wastewater, their survival in the external medium, their infecting capacity, the biology of the causal agent and of the immunity induced in the human being. Except viral infections, no other pathogenic agent can confer a solid immunity that can protect human being against re-infection.

7. SOCIAL AND POLITICAL ASPECTS

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

For small farmers, raw wastewater that went through the ground or by a river before reaching the water source is perceived as water source to be used even if this water is polluted.

Within the framework of the project of Drarga, the PREM project carried out a survey among the populations of Drarga and Temsia to have their various views concerning the use of various types of water.

In Drarga the great majority of households are connected to the water network managed by an association. The population generally uses tap water (and sometimes only this source). Some families use water obtained from wells for washing, or housework, but also to water their gardens.

The local population is quite informed about and is aware of the questions of health and hygiene related to water. Water management associations play a significant role in the awareness disseminating effort among the local community and contribute to keeping it informed about all the questions relating to water. Historically, associations played a significant role in Drarga.

In the past, water management was assured by the communities (often through religious schools). The population paid fees in order to use water. Current associations only re-established this tradition. They are very close to the population and enjoy their trust. For the majority of the contacted people, reprocessing of wastewater is a new idea, but many locals affirmed that they would use treated water if the people in charge ask them to do so (e.g. irrigation, housework). Two visited regions in Drarga are provided with a wastewater network that was set up even before the drinkable water network. The Community participates actively in the management of water in certain parts of the Kingdom, particularly in the South, and its participation tends to be developed. Certain current projects tend to involve the beneficiaries in the choice of the technological options and the management of the systems of distribution of irrigation water. The Offices of Agricultural Development encourage the creation of associations for treated wastewater.

8. TEMPORARY SOLUTIONS

The assessment of leading experiments in terms of processing and re-using wastewater remains mitigated. With assistance from international organizations, Morocco launched several projects with significant results. The failure of certain processing projects because of the inadequacy of addressing the socio-economic context of the concerned regions made it possible to better understand the problem of wastewater.

In spite of the acquired experience, wastewater treatment projects achieve only little progress. The principal obstacle remains the financing, the awareness of the public authorities and the lack of a national policy in the field of management of the wastewater with the purpose to protect water resources.

Currently, certain stations treated wastewater by maintaining the treatment performances defined in their system. The follow-up of the physicochemical and microbiological parameters is regularly assured by scientific supervision teams (NODW -National Office of Drinking Water (ONEP), research establishments, PLSE -Public Laboratory of Studies and Experiments, etc…). Treated wastewater is currently used in agriculture only on an experimental basis or is limited in certain cases to the farmers on grounds located near the station when this water is discharge to nature. Except for Benslimane, re-use of treated water is not currently organized.

9. FUTURE CONSIDERATIONS

In spite of the progress that has been achieved in the last decade on technical, institutional, financial and legislative levels with regard to the development of the process "Sewerage network, Treatment, Reuse", obstacles still hinder the deployment of treated wastewater reuse. In the current state of affairs, no project integrating the three components has been realized. This paradoxical situation is due to several constraints. The principal constraints that have to be surmounted to obtain better performance can be presented within a general framework as follows:

- Institutional constraints:
    - Inadequate legislative texts.
    - Lack of co-ordination between the various steakholders (managers, operators, users).

A close dialogue between all partners involved in the water treatment and reuse chain is a necessity in order to co-ordinate and complete their respective efforts. Re-using treated wastewater requests close co-ordination between the organizations that are involved in the re-use process. Otherwise, this task should be delegated to an institution that ensures follow-up information and the implementation of legislative texts.

- Technical constraints:
    - Topography is an important reference guide in the planning phase of sewage networks.
    - The existence of various outlets in large cities, which limits the re-use of treated wastewater.
    - Insufficient infrastructure for the treatment of wastewater.

- Financial constraints:

These constraints result from the lack of financial equilibrium between the expenditure and the receipts due to:

- Recurrent delay in terms of treatment equipment.
- Lack of engagement on the part of the state in this sector.
- Insufficient financial resources of various population strata.
- Prohibitive cost of the necessary equipment to set up wastewater treatment stations. This cost largely exceeds the financial capacities of local communes.
- Costly mobilization or inter-seasonal storage of treated wastewater.

Faced with these limitations, local communes are obliged to approach their objectives in the following order of priority:

- Protecting health and improving the population's living conditions.
- Protecting the medium were re-used water is exploited.
- Re-using treated wastewater.

- Implementing the re-use process

The re-use of treated wastewater is practiced in several regions in the world, including the Mediterranean countries and the Middle East. Morocco, which irrigates a very small percentage of its agriculture with treated wastewater, should take advantage of these countries' experiences.
The success of programmes aimed at facilitating the implementation of a sustainable reuse of treated wastewater depends on the following factors:

- It is necessary to regulate and carry out studies on the environmental impact of every project to use wastewater in order to preserve the environment;
- Organizational capacity to manage resources, to select plans for effluent reuse and to implement them;

- The importance given to the health of the population's at the acceptable levels of risk;
- Choice of strategies to use treated wastewater; and
- The criteria to evaluate and adopt alternative re-use scenarios.

To create an institutional framework that encourages the re-use of treated wastewater, the government can adopt the following measures:

- The processing and reuse of treated wastewater has to be a component of the global strategy of water resources, on the level of the basins, with multidisciplinary links between the various sectors such as environment, health, agriculture, industry and the municipalities. For instance, municipalities, the first source of wastewater, should coordinate the re-use of treated wastewater with the department of agriculture, the largest user. The regional planning schemes should take into account the potentiality of re-using wastewater in industries that produce heavy metal waste and are situated in regions where treated wastewater is intended to be used in irrigation.
- The government should facilitate the participation of NGOs and the beneficiaries in all phases of the project, particularly at the levels of preparation, identification, planning, realization of different project components (the choice of site, the treatment system and the treated wastewater allocation) so as to ensure sustainable exploitation and management.
- Awareness campaigns on the danger of reusing raw wastewater and of the advantages in using treated wastewater should be undertaken. It is also necessary to relay up to date information on appropriate processing and crop protection technologies.
- To protect the environment and public health, the government should activate the preparation, approval and the setting up of implementation decrees for standards in relation to the reuse of treated wastewater.
- It is necessary to follow-up on of the quality of treated wastewater and of the reuse practices, public health, the quality of irrigation water, and to monitor the quality of soils and underground water.
- The processes of sanitation, treatment and the systematic reuse of treated wastewater particularly in irrigation can be combined. This will make it possible to reduce the cost of treatment and to make use of a significant water resource in the Moroccan climatic context, dominated by severe periodic droughts.
- In addition, a fundamental element for sustainable reuse is the payment of a fee to cover costs of mobilization. This fee would be substantial and regularly paid only if the practiced agriculture is able to generate a sufficient added value.
- Crops produced under shelter can produce significant added values, through the adoption of a localized irrigation system that leads to an absence of contact between water and the product in order to guarantee hygienic quality.