Water and wastewater management in Morocco: Biotechnologies application

This paper presents a review about water and wastewater management in Morocco with a special focus on the application of biotechnologies for wastewater treatment.

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Abstract

This paper presents an overview about water and waste water management in Morocco. The main problems related to the availability of water resources and their preservation from the pollution are described. Moreover, a detailed description of the different efforts done in Morocco in recent years to overcome the technical, economical and organizational problems of water and wastewater management and to catch up the considerable delay regarding sanitation and recovery of treated wastewaters has been reported too. Regarding sewage treatment, the stabilization ponds called also natural lagoons are considered as the most appropriate biotechnology to treat the increasing flows of domestic wastewater in Morocco. The treatment of sewage through natural stabilization ponds was recommended in early 2000 by the National Sanitation Master Plan (SDNAL), particularly because of its low investment and operating costs. However, other sophisticated biotechnologies such as aerated activated sludge have been chosen for big cities due to the large areas that would be required for.

Water resources

Morocco, located in the Northwest of Africa, has an area of 710,850 km² with two long coastlines of 3,500 km of which over 500 km of the Mediterranean and about 3,000 km over the Atlantic. Morocco has approximately a population of about 30 million inhabitants, and its climate is marked by sharp contrast in temperatures between the Mediterranean climate and desert. Like many countries in the world, Morocco is faced with the problem of the development and sustainable management of its water resources. These scarce resources, marked by wide geographical disparities and highly sensitive to vagaries of the weather, come under heavy pressure due to demand resulting from population growth, improved living conditions and the implications of economic development. To support this trend, there is a need for sustained development of water resources in quantity and quality in order to ensure widespread access to drinking water and reduce inequality between regions, notably between urban and rural areas (ADB, 2006). Insufficient rain and droughts are fairly frequent. In 1982, Morocco received less than 60% of the long-term mean rainfall. In 1994, on the other hand, 6 of 11 hydrological basins in Morocco had more than 50% deficit in their water balance (Doukkali, 2005). The average annual precipitation in Morocco is 150 billion m³, varying year by year between 50 billion m³ and 400 billion m³. Annual evaporation is, on average, 121 billion m³. Of the remaining 29 billion m³, about 22 billion m³ of water are technically and economically exploitable (Benbiba, 2010).

Water consumption and needs

The Moroccan exploitable resources are comprised of 18 billion m³ of surface water and 4 billion m³ of

Key messages:

- Preserving and protecting water resources, natural environment and sensitive areas
- Reducing vulnerability to the risks associated with water and adaptation to Climate Change
- Continuing regulatory and institutional reforms related to water resources management
- Biotechnologies such as stabilization ponds could be considered as efficient means for wastewater treatment relying on low cost technology with minimal maintenance
- Modernization of information systems and capacity building and skills is a necessity
- Making direct use of wastewater R&I for socio-economic development in the medium and long term

groundwater (Benbiba, 2010). In Morocco, the volume of water available per inhabitant per year, an indicator of a country's wealth in terms of water, is about 1000 m³/capita/year (Figure 1). Scarcity is often defined as starting from this point.

At present, the available water varies between 180 m³ per capita per year for the areas known to be poor in terms of water resources (Souss-Massa, Atlas South, and Sahara) and 1800 m³ per capita per year for areas of the basin of Loukkos, Tangier and Mediterranean Coast, known to be relatively rich (ADB, 2006). It is probable that the water resources per inhabitant will reach around 700 m³ per capita per year towards 2020 (Figure 2).

At this time, about 14 million inhabitants, i.e. almost 35% of the total population of the Kingdom will have less than 500 m³ per capita per year at their disposal. Water scarcity is thus becoming a permanent situation that can no longer be ignored when drawing up strategies and policies concerning water resources management in Morocco.

The water resource mobilization for the different social and economic uses is grossly done according to the following distribution (Figure 3).

Underground waters contribute for meadows of 32% to satisfy needs in drinkable water and about 31% for the agricultural needs. We have to mention that agriculture mobilizes the great part of water resources. It is a choice and strategy that Morocco took since the years 60 and concretely there was the construction of a great number of dams from this date. The vision was ensuring the food security and reducing the dependence with foreign countries.

The main producer of drinkable water in Morocco is the national office of drinkable water (ONEP) that was created in 1972. The production increases and the capacity of current production exceed 55 m³/s. This organism practices equally the distribution in the cities. For big cities, There are offices that do the distribution and some ones were privatized (Lydec in Casablanca, Amendis in Tangier, Redal in Rabat). The service rate in urban area exceeds currently 95%. In rural area, it exceeds now 91% while it was only about 14% in 1992 (Makhokh and Bourziza, 2011). For irrigation water and concerning the big hydraulic (irrigation from big dams), there are agricultural offices that sell water to the farmers. The big irrigated perimeters (Haouz,

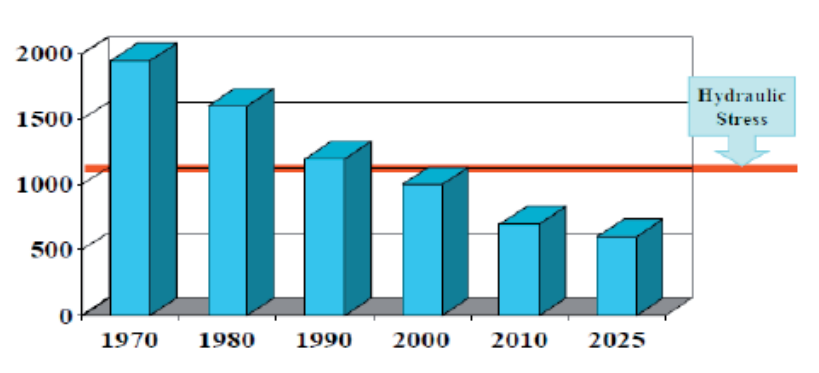

Figure 1: Water resources in Morocco in m³/year per inhabitant

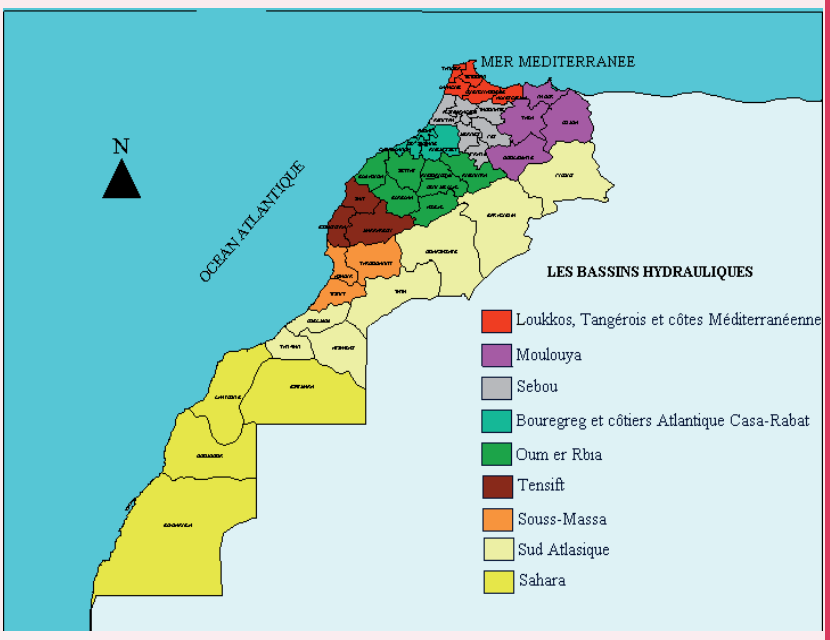

Figure 2: Geographical Distribution of River Basin in Morocco (Jemalli and Kefati, 2002)

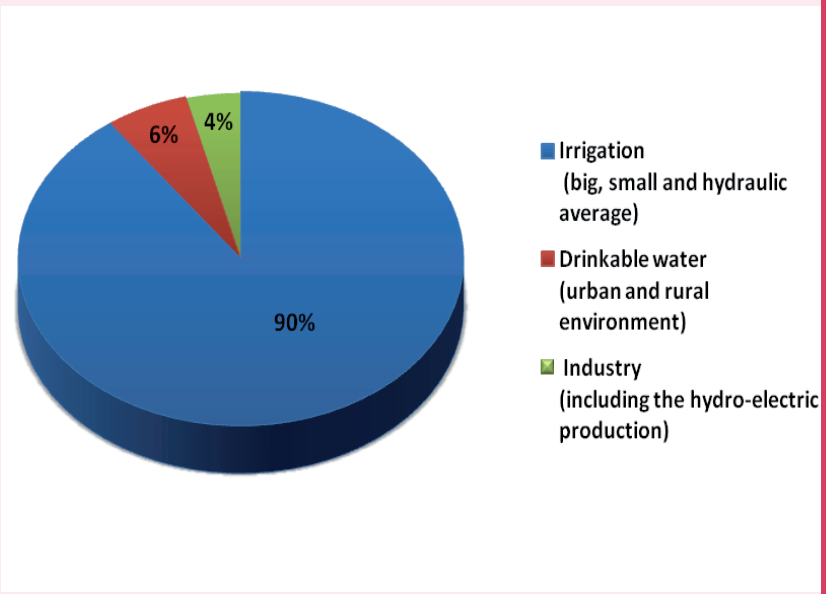

Figure 3: Water resources consumption in Morocco

Tadla, Gharb...) have fixed water allocations according to master plans and according to hydraulic state in dams. The other industrial uses of water concern mainly the industry food processing, sweets and the oilseeds. Regarding superficial waters mobilization, a sustained effort regarding construction of dams was undertaken since 1967 until our days. Up till now, the kingdom counts 128 large dams with a capacity of nearly 17 billion m³. The dam's edification continues currently with a rhythm of a 1 dam/year. From 1984 and considering the dry years that succeeded on the kingdom, a construction policy of hill dams (small dams) was adopted (Benbiba, 2010). Several infrastructures were realized to satisfy the local population's needs. Concerning balances between areas, 13 water transfer systems with a total length surpassing 1000 km were set up. The total mobilized flow is about 200 m³/s. For underground waters, a sustained effort about increasing resources is undertaken since a linear of 100 km/years including wells and drillings is realized. The park of well and drilling allows having 2.87 billion m³/ year.

Morocco is characterized by limited rainfall and strong geographical inequality of the rainfall. To address this situation a New National Water Strategy was launched in 2009 covering the period from 2010 to 2030.This policy is based on the main following strategic objectives (Benbiba, 2010):

- Management of water demand and water efficiency
- Management and supply development
- Preservation and protection of water resources, the natural environment and sensitive areas
- Reducing vulnerability to the risks associated with water and adaptation to Climate Change
- Modernization of information systems and capacity building and skills
- Improvement of the institutional, legal and financial framework

Legal framework

In 1982, the organizational aspect was marked by the establishment of the regional directions of hydraulic (DRH). The foundation of such act is the management and the water planning within watersheds. In fact, and before this date, prevailed the vision of a planning water resources by project. This date coincided with a drought cycle (1981-1986) that incited the authorities to review the old institutional aspect.

In 1995, and after the economic and social development of Morocco, the DRH structure and some old texts showed their limits and became not adapted to the general Moroccan context. It is the 10/95 law that entered in force and this with a new approach and concepts.

The federal principles of this law are as follows (Royaume du Maroc, 1995):

- The public domain of water: all water availability is part of the public domain of the state.
- The unity of water resources management: the domain and scale of study is the watershed.
- The recognition of the economic value of water: adoption of the principles operator payer and polluter payer.
- The creation of the basins agencies: spaces consultation between the different actors and water users. They are autonomous organisms taking care of the water management within the watershed.
- National and regional solidarity: among the objectives of basins agencies creation, the instauration of mechanisms of solidarities and notably about water transfers between basins.

The new structures coming from the 10/95 law are as follows:

- The higher water consul: for the elaboration of the general orientations regarding management and planning water at the national scale.
- The river basins agencies: for a rational and collective use of water integrating the different actors.
- The water provincial commissions: spaces consultation grouping together the local groups, the different provincial services and the professional associations.

The application Decree (No 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 recognized as treated wastewater. The use of raw wastewaters is thus prohibited and banished. The Norms and Standards Committee (NSC) that comes under the National Environment Council is setting objectives for the quality of receptor medium (quality norms). The NSC is made up of representatives from all relevant ministerial departments. Among the suggested norms, there is a project relating to quality standards of wastewaters designed for irrigation, which specifies the bacteriologic, parasitic, and physical-chemical parameters. These Standards for the reuse of wastewater apply to all types of irrigation water, including treated wastewaters. The aim of the standards is to protect environment and health.

Institutional organization

The institutional organization of water domain in Morocco is based on 3 levels, including the major stakeholders involved in the water domain (Figure 4).

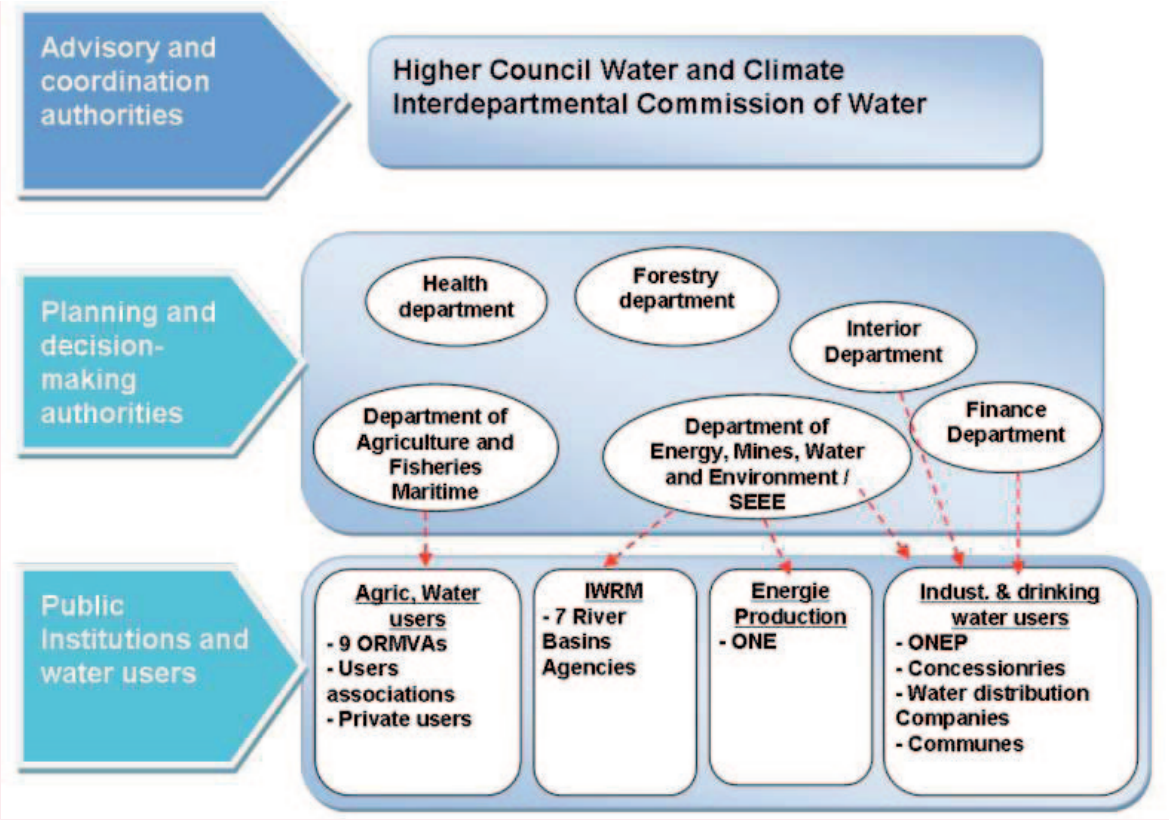

Figure 4: Main institutional stakeholders (Ouassou et al., 2005)

Among the inherent problems to the water management in Morocco, is the multiplicity of the stakeholders:

- River Basins Agencies: they are 9 throughout the country for managing the main hydraulic basins of the kingdom.
- ONEP (national office of drinkable water): principal producer of drinkable water in Morocco, it is equally distributor in small and average cities.
- Distribution offices: autonomous organisms taking care the drinkable water distribution in the big cities of the Kingdom.
- Municipalities: concerning the hydraulic aspect, they take care of watering gardens and green spaces.
- Rural Towns: drinkable water of the rural populations
- ORMVA (agricultural offices): responsible for the management of the big irrigated perimeters of the Kingdom.
- DPA (provincial delegations of agriculture): management of the small and average hydraulic.
- ONE (national office of electricity): principal producer of the electric energy including the hydraulic origin (merged actually with ONEP)
- Waters and forests administration: are taking care of the watersheds development.
- The provincial health delegations: health aspect, hygiene, Diseases including the ones from hydrous origin

The experience of the past showed that a lot of contentious situations in some areas occurred because of the insufficiency coordination between the different actors. In order to endow the country with a national strategy in water domain, the higher water consul was created in 1989 by his majesty the king Hassan II. This institution aims to coordinate the different departments intervening in the water sector. Thus, the big orientations concerning water policy are studied in this council. The studies of master plans are equally approved within this institution which is presided effectively by the King of Morocco (Mandi, 2012).

At a regional scale and in accordance with the 10/95 law promulgated in 1995, it is the river basin agency that plays the role motor since the water management is done in a collective way with the different actors and partners within this institution.

Wastewater treatment and reuse

The actual total volume of sewage discharged in Morocco is estimated at about 750 million m³ (Figure 5); 48% of these waters are discharged into the rivers or applied to land; the rest is discharged into the sea without any treatment. The pollutant load from wastewater is estimated at around 131,715 tons of organic load, 42,131 tons of nitrogen and 6,230 tons of phosphorus. Most of the wastewater produced by inland towns is reused, mainly as raw or insufficiently treated wastewater, to irrigate about 7500 hectares.

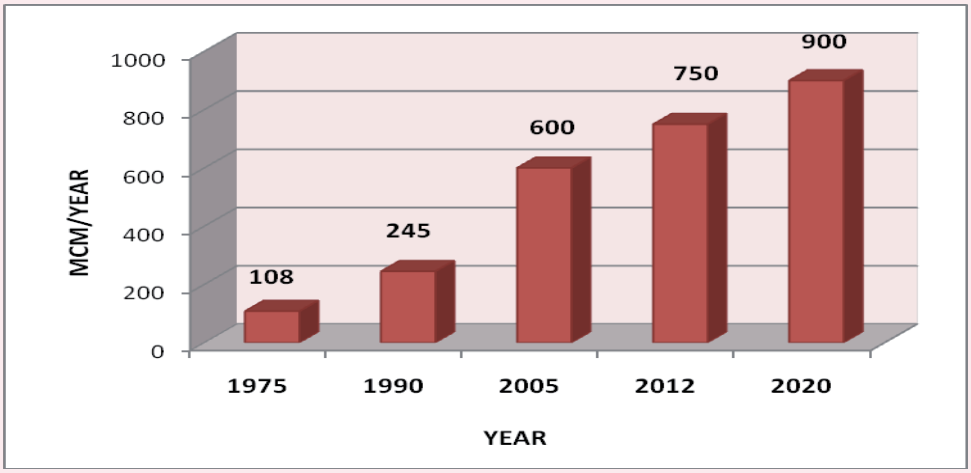

Figure 5: Evolution of total volume of sewage discharged in Morocco

The lack of wastewater treatment before reuse in inland cities was translated into the exposure of the local population to waterborne diseases and the degradation of superficial and ground water resources.

There is a considerable delay regarding liquid and solid sanitation in the construction of purification stations and recovery of treated wastewaters. In urban area, the global rate of connection to the sewer system is about 70% which means that about 4, 5 millions of urban populations are not connected to the network and are using autonomous purification systems (ADB, 2006). For the purification systems, Morocco has 100, of which more than half are not functional for many reasons: technical, financial and human (Mandi, 2012). Such situation shows not only delay that the country combined in this domain, but also contamination risks about receiver environment in general and water resources in particular. Therefore, to protect water resources and reduce the pollution, a national sanitation and sewage program is developed to improve sewerage collection, the treatment of both industrial and domestic wastewater, and increase the reuse.

In 2005, the National Sanitation Program was approved that aims at treating 60% of collected wastewater and connecting 80% of urban households to sewers by 2020 (Royaume du Maroc,2008). The main objectives of this program are:

- Achieve a rate of 80% as connection to sewerage.
- Improve sewerage collection,
- Reduce pollution caused by wastewater at least 60%.
- Catch up the delay in the sanitation domain.
- Treat both industrial and domestic wastewater,
- Increase the reuse.

The support of the EU in the national sanitation program of Morocco reaches € 90 million.

Application of water biotechnologies in Morocco

Since 1950s, Morocco has introduced Biotechnologies for urban wastewater treatment in some medium and small centres; these biotechnologies were: activated sludge, trickling filter and biodisc. Activated sludge plants were not operated regularly due to lack of maintenance and the high energy costs needed for continuous operation. The need to allocate necessary funds to sustain the operation of these plants was not properly understood by local governmental boards. Most of the new plants built in the 1990s employ extensive technologies, such as stabilization ponds or natural lagoons, high rate algal ponds and sand filter. Until 1993, there were 55 wastewater treatment plants serving small centres and medium-sized cities. Only 18 of them were operating normally while 31 plants were out of service and the remaining six were not connected to the sewerage network since pumping stations could not be financed for various reasons: inadequacy of the treatment system to local conditions, design defect structures, lack of maintenance, management issues (lack of budget, lack of competent technical staff), lack of planning short and long term (Mandi, 2000). The treatment of sewage through natural stabilization ponds was recommended in early 2000 by the National Sanitation Master Plan (SDNAL), particularly because of its low investment and operating costs. However, other treatment techniques such as activated sludge have been chosen for larger cities (Marrakech, Fez,) due to the large areas that would be required for using stabilization ponds. Actually Morocco has more than 100 wastewater treatment plants with more than 77% are natural lagoons (Figure 6).

The biotechnologies that are most known by the key actors acting in the field of sanitation in Morocco are natural lagoons (Figure 7). This biotechnology is considered as the most appropriate biotechnology to treat the increasing flows of domestic wastewater in Morocco.

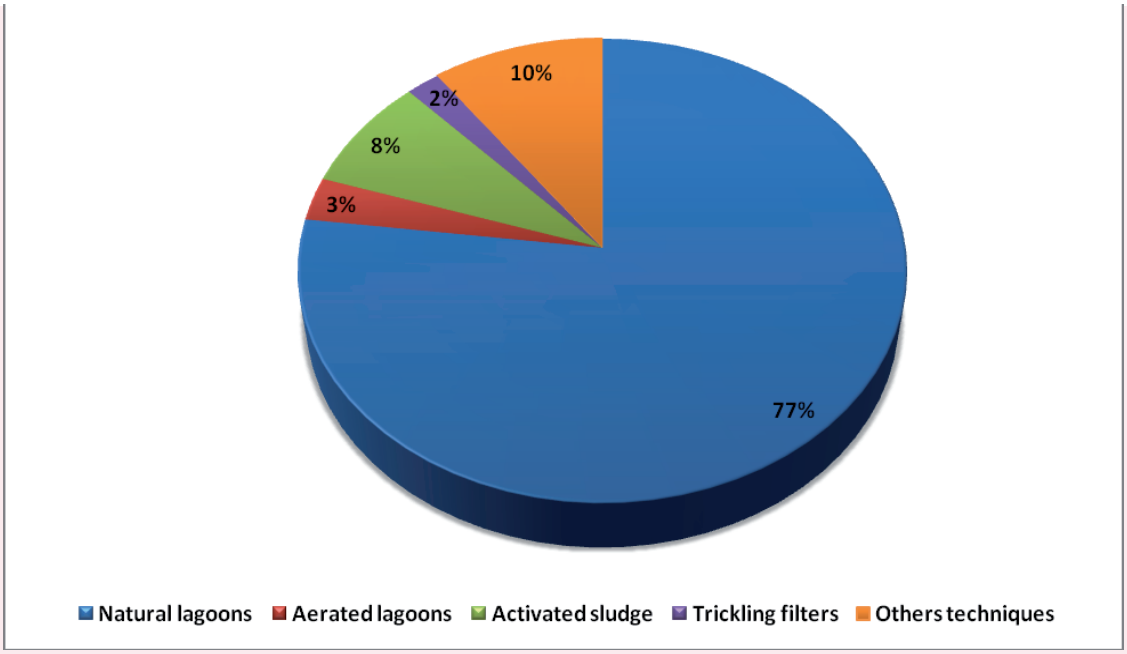

Figure 6: Distribution of different kind of wastewater treatment technologies existing in Morocco (Makhokh and Bourziza, 2011)

The natural lagoons or stabilization ponds have in general 1-4 m deep (sealed with plastic film) slowly traversed by sewage. Most installations consist of a chain of consecutive basins. Given that the total residence time of sewage in such a facility is several weeks, these systems required a relatively high surface area. The long-term retention of wastewater disposal promotes the effective inactivation of pathogens excreted with faeces. The mortality process is promoted by UV radiation and a net increase in pH caused by algae during active photosynthetic periods.

Examples

Over the past 20 years, the WSP systems have emerged and have proven their effectiveness as economic treatment process requiring little maintenance, especially in hot climates for both small as for large municipalities and cities (Ouazzani et al, 1995). This technology was developed by the ONEP in small and medium centres since 1970 and it represents now more than 80% of the biotechnologies used in Morocco (Picture 1). The ONEP have recommended the choice of Waste stabilization ponds in the majority of the directory schemes of sanitation realized for lot of small and medium cities in Morocco.

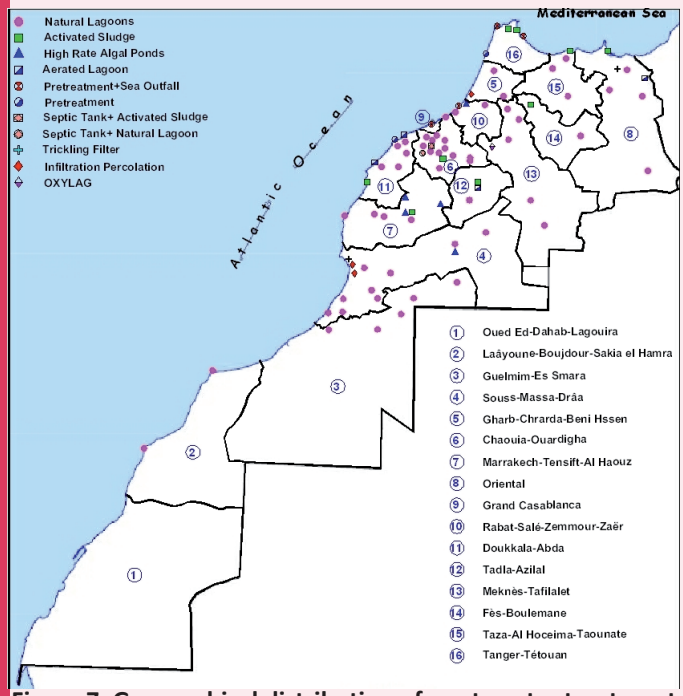

Figure 7: Geographical distribution of wastewater treatment Biotechnologies in Morocco

Picture 1: Natural lagoons for wastewater treatment plant of the Saada commune (Peri-urban area of Marrakech city)

Picture 2: Largest aerated lagoons in Morocco (Oujda city)

In Morocco, combined pond system that integrate aerated lagoons and storage reservoir have been successfully applied in Oujda city (Picture 2) and produces a high quality effluent meets the non-restricted irrigation WHO guidelines. The first important water reuse project in Morocco was implemented in 1997 in Ben Slimane city (Picture 3), where 5600 m³/day of wastewater is treated by anaerobic, aerated lagoons, facultative, and maturation ponds consecutively. The disinfected effluent (0 helminth eggs/l, <20 CF/100 ml) is used for golf course irrigation during the summer (for an average volume of reused water of 1000 m³/day).

The new Marrakesh wastewater treatment plant (WWTP), which started treating wastewater in 2011 (Picture 4), is considered as the first WWTP in North Africa to integrate wastewater treatment, biogas recovery from sludge, electricity &heat cogeneration, air treatment and water reuse. In this plant, about 120,000 m³/d of wastewater are treated in four stages: 1) pre-treatment 2) primary treatment in sedimentation tank 3) secondary treatment that employs activated sludge (i.e. aerobic sludge treatment) 4) tertiary treatment, which consists of microfiltration by sand filter and disinfection by ultraviolet lamp units. This last process raises the effluent quality of the wastewater before it is reused for irrigation of golf courses. The electricity consumed by the plant is around 30 GWh/year while the electricity generated by four cogeneration units with a power of 862 kW is in total about 10.5 GWh/year. About more than 70% of the treated water coming from this WWTP are re-used recreational purposes (golf course, palm grove, etc.). The treatment and re-use of Marrakech's wastewater is a milestone in sustainable development, which made significant progress towards attaining Morocco's national target of 60% effluent treatment by 2020.

Barriers for wastewater treatment biotechnologies

In spite of the progress achieved by Morocco in term of wastewater treatment, the majority of the biotechnologies for domestic wastewater treatment implemented in several small and medium communities still not functional for the following reasons (Mandi, 2012):

Financial

- Expensive cost of electricity.
- Absence of equipment and maintenance.
- Lack of an adequate budget for plant maintenance and operation.
- Lack of coordination between different contributors in the management of the plants.

Picture 3: Wastewater treatment and reuse project of Benslimane City (El Haite, 2010)

Picture 4: Marrakech Aerobic WWTP with sludge digestion and methane production for energy cogeneration

- The cost of further steps of treatment such as disinfection in order to have an effluent that meet the irrigation water standards.
- The need of additional cost for sludge treatment technologies in parallel to water treatment plants.

Social

- Some plants have been built on the limits of some cities which threaten the future of these plants because of extension of housing and the nuisance of odours.

Capacity building (experienced staff)

- The sewage treatment plants do not operate satisfactorily and, in most cases, treated wastewater discharges exceed the legal and/or hygienically acceptable maxima. This is attributed to the lack of adequately trained staff with the technical skills to operate these plants.
- Trained operators are a prerequisite for the control and monitoring of all treatment and reuse operations.

Regulation

- In several cases, the outflow of wastewater treatment systems does not meet specified quality standards, either because standard operating procedures are not followed or because technically qualified personnel to control and monitor plant operations is unavailable.
- Wastewater authorities are unable to monitor continuously operational parameters in the treatment plant.

Conclusion

Morocco is situated in arid area and has been faced to several water management problems. In addition of the aridity of climate, the heterogeneity of water resources distribution, repetition of drought related to climate change reduce the potential of water resources. In addition, the discharge of urban and industrial wastewater increases the threat of water pollution and reduces of the availability of water resources. In spite of big effort on water availability and water supply for the growing population in Morocco, and even though legislative, organizational upgrading of the management of water sector, a big delay has to be catch up in the sanitation and wastewater treatment. The high costs of conventional treatment processes have lead national authorities to search for creative, efficient and environmentally sound ways to control water pollution. The development of simple and cost effective water treatment biotechnologies such as Stabilization ponds and aerated lagoons is particularly interesting for Morocco. These processes that use relatively more land and are lower in energy and operational costs are becoming attractive alternatives for many wastewater treatment applications especially in Moroccan small communities. In the case of inland large cities where the land becomes extremely expensive and/or not available, the use of sophisticated biotechnologies such as activated sludge is recommended. Biotechnologies could be considered as useful tool to manage wastewater economically and effectively in Morocco as well as in other African countries. Moreover, the big challenge is to overcome all the socio-economic and institutional barriers that hindering their development.

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