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Artificial ecosystems for wastewaters treatment under Mediterranean conditions (Morocco)

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Abstract

The use of well-designed and high efficient extensive wastewater technologies can provide subsequent economic advantages (low-cost investment and cheaper operational costs) and can contribute to protecting the environment and ensuring safe water resources (reuse of treated wastewater). Following the progressive experimentations led under Mediterranean climate (MHEA® Experimental Centre in M'Diq, NW of Morocco), the methodological and technological process of Hierarchised Mosaics of Artificial Ecosystems (MHEA®) permitted to identify multi-ecosystemic plants for urban-wastewaters treatment, passing the traditional extensive-plants efficiencies. Results obtained during the optimization period permit to provide the structure of several MHEA® technologies adapted to the South Mediterranean socio-economic and environmental context, respecting a net treatment area of 2 m^2 PE^{-1}, a total load of 5 000 PE ha^{-1} and a retention time of 15 days. The valorisation possibilities of waters treated (23 m^3 PE^{-1} an^{-1}), sludge (57 kg of dry weight PE^{-1} $year^{-1}$) and aerial biomass of macrophytes under the Mediterranean climate constitute a significant economic input for these technologies.

Key words: Artificial ecosystem, wastewaters treatment, macrophytes, Morocco.

1. Introduction

Wastewaters reuse is an important mobilization way of non-conventional water resources, since about 50 % of Moroccan population would reach absolute water scarcity (500 m^3 $person^{-1}$ $year^{-1}$) in 2 020 (Anonymous, 2000). Besides, the quasi-totality of domestic and industrial wastewaters is evacuated in natural habitats without adequate treatment, and about 80 % of wastewaters treatment plants achieved by the local communities are out of use through, among others, lack of maintenance, managers training and specific allocations (Anonymous, 2000). The current urbanisation of Moroccan Mediterranean coast urbanisation is due to rural depopulation and development of tourist infrastructure (Anonymous, 2000). The wastewaters are evacuated in this area without treatment and often reused in market gardening.

Effective and cheaper systems of wastewater treatment constitute a fundamental aim for the local authorities. The use of well-designed and high efficient extensive wastewater technologies, especially for medium-sized conurbations and towns, can provide subsequent economic advantages (low-cost investment and cheaper operational costs) and can contribute to protecting the environment and ensuring safe water resources (re-use of treated wastewater). Nevertheless, experimental-data deficiency under the Mediterranean climate (North of Morocco) doesn't enable applications of these technologies. The MHEA® (Mosaic Hierarchised of Artificial Ecosystems) project has been achieved in M’Diq (NW of Morocco) through the channel of the Intergovernmental Agency of French-speaking countries (Walloon Region-Morocco) in order to develop wastewater-treatment systems adapted to the local climatic and socio-economic contexts.

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2. Material and method

The comparative experimental-protocol (1998/2000) and the optimization one (2001/2003) were carried out in order to assess the purification efficiency of the main types of ecosystems and to propose MHEA® systems for wastewaters treatment in tourist or agricultural areas. Comparison of treatment efficiency of different ecosystems categories (aquatic, semi-aquatic and terrestrial) aimed to research purification systems using percolation in third level. Treatment systems using percolation in second and third levels showed a particular interest in tertiary purification and disinfection (Ezzahri *et al.*, 2001; Radoux *et al.*, 2003; Ezzahri, 2005).

Eight treatment systems are experimented under the same circumstances of climate, load and flow, during the second experimental-protocol, permitted the design of efficient treatment-systems in order to protect the quality of coastal water (summer tourism and fishing) or to reuse wastewater after purification (agricultural areas). The two optimised treatment-systems, presented in this paper (Table 1), collect raw wastewater from the wastewater sewerage system in the city of M'Diq (hydraulic load = 1 183 L day^{-1}). The net treatment area is 2 m^2 Person $Equivalent^{-1}$ (0.8 m^2 PE^{-1} in level I, 0.6 m^2 PE^{-1} in level II and 0.6 m^2 PE^{-1} in level III). Monitoring of treatment efficiencies of tested systems is based on the analysis of physico-chemical (SS, COD, TN, TP) and biological (faecal coliforms, faecal streptococci, helminths) wastewater parameters of instantaneous or combined sampling every 14 days, i.e. 26 analysis campaigns per year.

The plant species used in this experimentation are selected for application in wastewater treatment, among other wetland species from the North of Morocco, based on studies of their ecology, development (biomass and macronutrients retention), regeneration and socio-economy (Ennabili *et al.*, 1996, 1998; Ennabili & Gharnit, 2003; Ennabili 2008).

Table 1. Characteristics of treatment systems for agricultural context (A) and tourist one (T).

Treatment	Level	Ecosystem	Macrophyte	Area (m^2)	Water circulation	Retention time (day)
System "A"	I	aquatic	-	18	translation	9
	II	terrestrial	-	2	percolation	3
	III	terrestrial	*Salix purpurea*	2	percolation	3
System "T"	I	aquatic	-	18	translation	9
	II	terrestrial	*Phragmites australis*	2	percolation	3
	III	terrestrial	*Phragmites australis*	2	percolation	3

3. Results

Considering the treatment net-area of 2 m^2 PE^{-1}, the global SS-retention by the treatment systems "A" and "B" reaches respectively 98 % and 100 %. Outflow SS-concentration averages 6 mg L^{-1} and 1 mg L^{-1} in the same order (Figure 1). Concerning COD-retention average (Figure 2), the treatment efficiency attains 95 % in the treatment system "A" with a mean concentration from 19 to 29 mg O_2 L^{-1}. These results are similar to those obtained by using the treatment system "T" (97 % and 19 mg O_2 L^{-1}).

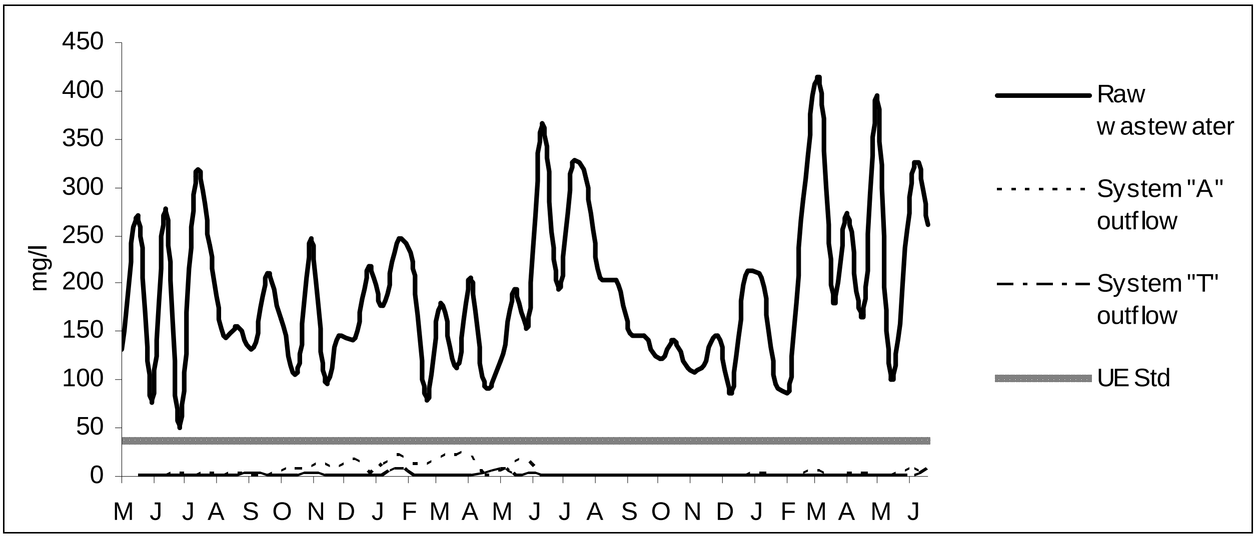

Figure 1. Concentration of suspended solids (SS).

The concentration of treatment-system "A" outflow means 12 mg N L^{-1}, corresponding to removal rate of 75 %. Nevertheless, N-concentration increases during the second year of experimentation and attains 26 mg N L^{-1}. While the mean N-retention obtained by the treatment system "T" gets to 88 % with an average of outflow N-concentration of 7 mg N L^{-1} (Figure 3). The treatment system "A", using percolation through soil at levels II and III, retains an average of 96 % of P-load and the outflow P-concentration not exceeds 1 mg P L^{-1}. Whereas mean P-removal by treatment system "T" reaches 98 % with an outflow concentration not passing 0.5 mg P L^{-1} (average = 0.2 mg P L^{-1}) (Figure 4).

The treatment system "A" guarantees removal ranges of 5.5 log_{10} units for FC and 5.2 log_{10} units for FS, with the mean concentrations of 50 CFU/100 ml for FC and 100 CFU/100 ml for FS (Figures 5 and 6), and <1 helminths egg/L. The disinfection rates obtained by the treatment system "T" are similar to those of previous system (5.8 log_{10} units for FC and 5.2 log_{10} units for FS) with an outflow mean-contamination of 18 CFU/100 ml for FC, 30 CFU/100 ml for FS and <1 helminths egg/L) (Figures 5 and 6).

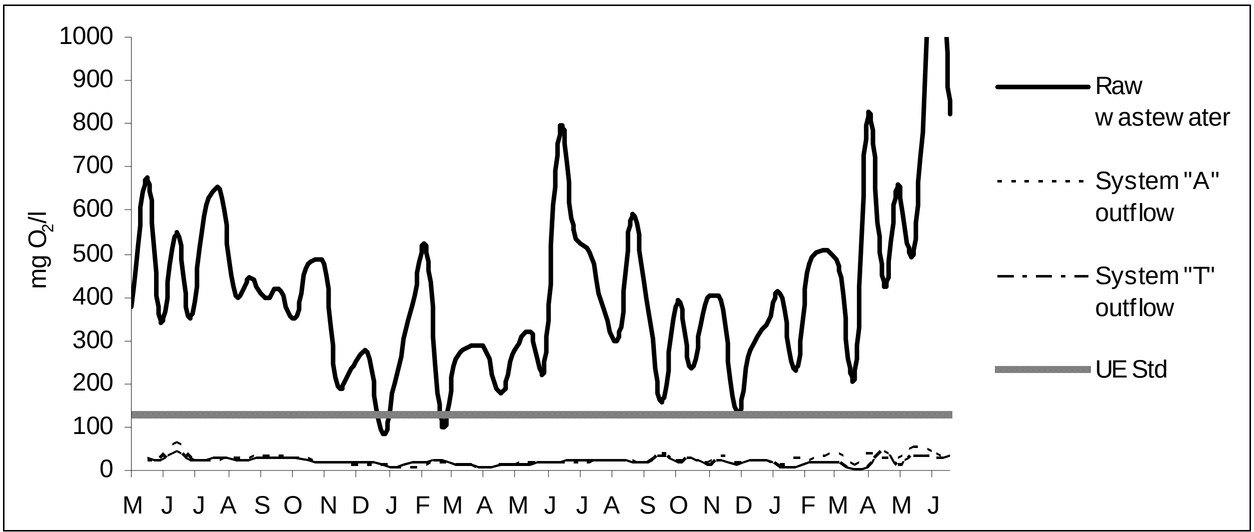

Figure 2. Concentration of COD (chemical oxygen demand).

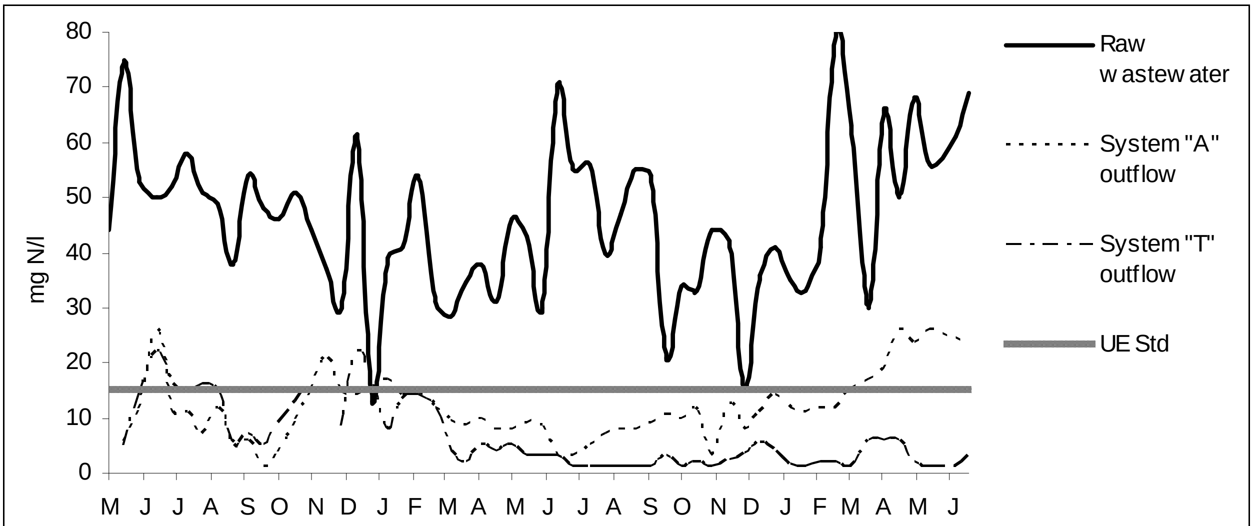

Figure 3. Concentration of total nitrogen (TN).

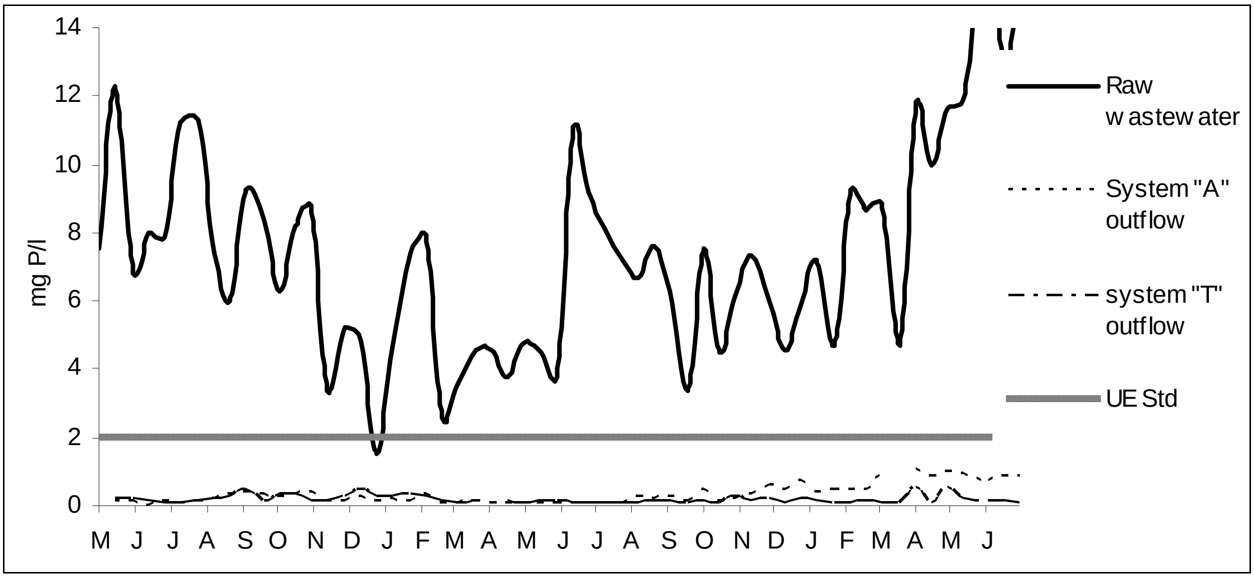

Figure 4. Concentration of total phosphorus (TP).

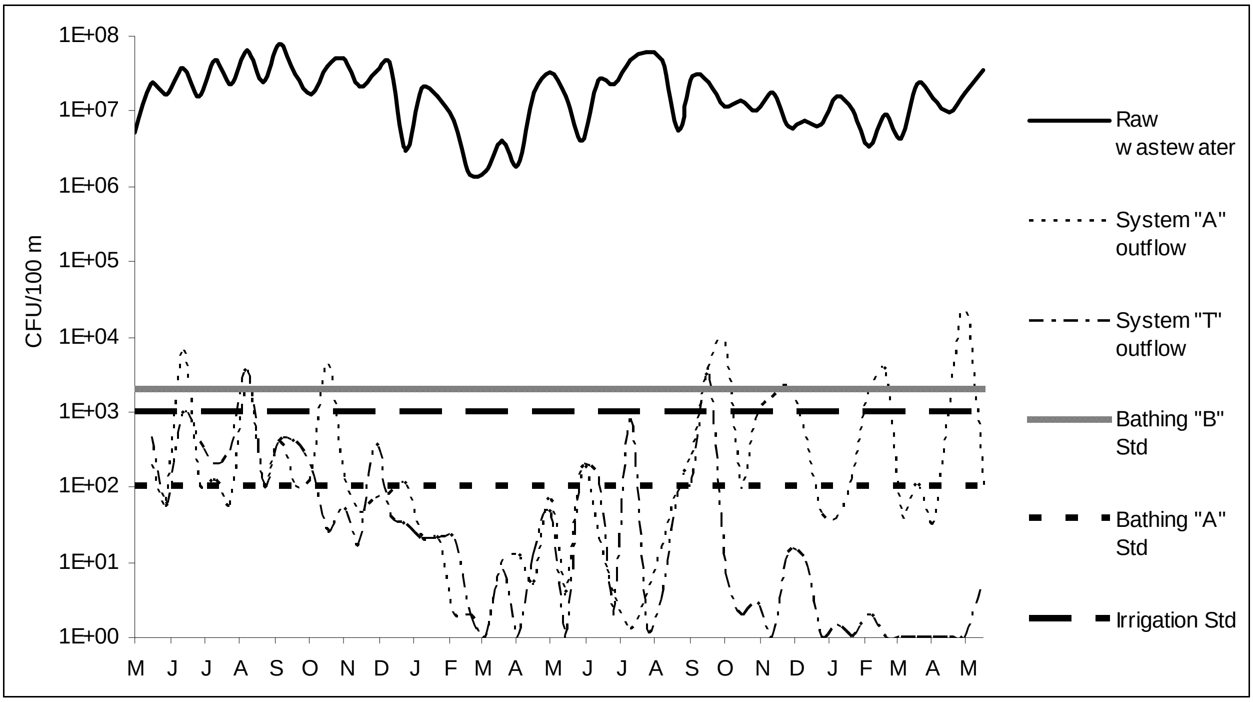

Figure 5. Number of faecal coliforms (FC).

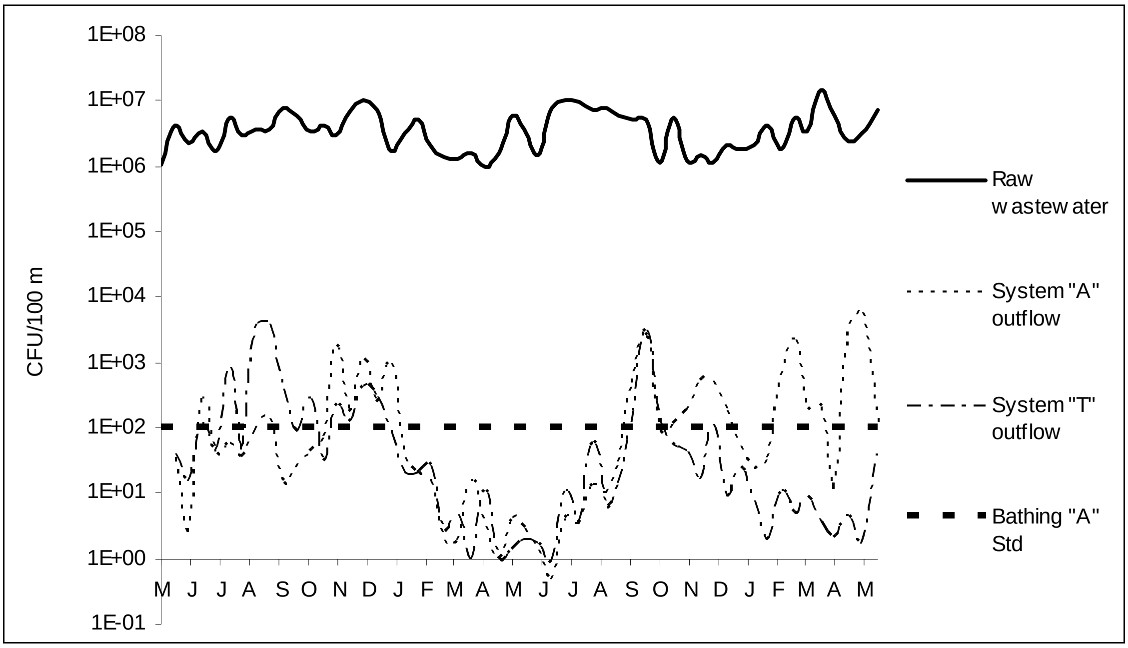

Figure 6. Number of faecal streptococci (FS).

The daily evapotranspiration in treatment system "A" averages 25 mm (80 % of treated flow, corresponding to 23 m^3 PE^{-1} $year^{-1}$), vs. 43 mm and a low outflow mean-volume of 50 % (not exceed 28 % and often without outflow from level III in summer) in treatment system "T".

4. Conclusions and discussion

Outflow SS-concentration averages respect the E.U. 91/271 standard of 35 mg L^{-1} and removal rate (90 %). The COD-retention efficiency guaranties also the E.U. standard of 125 mg O_2 L^{-1}. According to the tertiary treatment, N-concentration increases during the second year of experimentation in the system "A", which accords with advantage-reuse of treated wastewater in agriculture, and is distinctly less than the E.U. of 15 mg N L^{-1} in the system "T". The P-removal of both of experimented systems honours the E.U. standard of 2 mg P L^{-1}. The excellent results obtained by the treatment system "T" underline its particular interest in tourist areas.

The microbiological quality of treated wastewater from the system "A" agrees generally with the Moroccan standard allowing market-gardening irrigation (1 000 CFU/100 ml for FC). This treatment system is especially interesting for parasites retention and respect also the Moroccan standard sanctioning irrigation without restriction (<1 000 FC/100 ml and <1 helminths egg/L). The treatment system "T" guaranties for the most part the Moroccan standard bathing waters, range "A" (2 000 FC/100 ml and 100 FS/100 ml). In tourist areas (NO of Morocco), excellent results were underlined for all treatment parameters studied when using *Arundo donax* based treatment MHEA®-system. The obtained results will be published subsequently.

The treatment system "A" provides high volumes of treated wastewater and stills in keeping with agriculture requirements (high disinfection rates but low N and P removal rates). Whereas, the treatment system "T" is harmoniously recommended for seaside protection thanks to high average-daily-evapotranspiration and a low outflow mean-volume.

Experimental application of these MHEA® systems in wastewater treatment could generate annually 90 tons of dry matter ha^{-1} of macrophytes biomass, locally required for multiple uses. The financial product of macrophytes used in wastewater treatment is estimated in natural habitats to 80 341.00 MAD ha^{-1} $year^{-1}$(Ennabili 1999). It constitutes a significant economic input (17 MAD PE^{-1}) for their exploitation cost (about 8.50 MAD PE^{-1} for macrophytes harvesting and evacuation). Furthermore, the MEHA® treatment systems produce experimentally 57 kg of dry sludge PE^{-1} $year^{-1}$. Treated sludge could be advantageously used in agriculture sine its production (15 tons of dry sludge ha^{-1}) corresponds to fertilizing supply of 160 Kg N ha^{-1} and 60 Kg P ha^{-1}.

On an experimental scale, the main routine-measures concern (i) aerial-biomasses harvesting and evacuation, (ii) regular unclogging of unplanted terrestrial-ecosystems (4-6 times yearly), and/or (iii) sludge evacuation by pumping (1 time each 5 years). These operations would be validated on a pilot scale for any full-size application of treatment MHEA®-systems (Radoux, 1996), and are compatible with the socio-economic context of medium-sized conurbations and towns in N of Morocco.

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