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Influence of environmental parameters on reed beds in wastewater treatment in a small community in Morocco

K. Kabbaj, M. Mahi and A. Saoiabi

ABSTRACT

The Drarga treatment plant was chosen as a pilot site for treatment and reuse of domestic wastewater. It uses reed beds as a tertiary treatment, so this research was conducted to study the performance of the reeds over a period of 3 years (March 2006–March 2009), that is three growing seasons. The reeds were cut after 2 years. Knowing that the Drarga climate is semi arid, we studied the behaviour of purification by reeds over seasonal changes. The reeds were effective in removing pollution over the three growing seasons studied; the average removal of BOD_5 over 3 years was 71%. The maximum removal efficiency was in winter; this is associated with high oxygenation of the water mass caused by mixing and stirring induced by the movement of the long stems of the reeds.

Key words | Drarga, physicochemical parameters, reed bed filters, wastewater, water reuse

K. Kabbaj (corresponding author)
A. Saoiabi
Université Mohamed V Faculté des Sciences,
Avenue Ibn Battouta,
B.P 1014RP,
Rabat,
Morocco
E-mail: *kabbaj.khadija@gmail.com*

M. Mahi
Institut International de l'Eau et de l'Assainissement de l'ONEP,
BP-Rabat Chellah,
Morocco

INTRODUCTION

Morocco is a semi-arid country that will face water shortages in the future as a result of the increasing water demand from its growing population. The use of unconventional resources, such as wastewater and brackish water, has become a necessity to meet the demand for water. These resources require treatment before they can be used safely. For Morocco, a developing country, new alternative techniques, which are inexpensive, appropriate to the local socio-economic environment and are adequate to produce suitable quality effluent, will be useful. Among such techniques is treatment by reed bed filters (Kern & Idler 1999; Uggetti *et al.* 2011).

Reed bed filters are natural systems that are well suited to deal with pollutant removal in the Moroccan context. Various types of water pollution have been treated by natural techniques for a considerable number of years using several aquatic plant species. In this case study, a pilot treatment plant was established at Drarga in southern Morocco. BOD_5 (biological oxygen demand), COD (chemical oxygen demand) and other standard physicochemical control parameters were determined and are discussed taking into account the environmental conditions in the region. This treatment plant is one of the first trials in Morocco to use reed beds as tertiary treatment (Gumbricht 1992; Schönerklee *et al.* 1997).

This system is similar to those used in many other countries, where the main treatment of sewage is normally undertaken in a packaged wastewater treatment plant (WWTP), with the reed beds as a tertiary treatment module.

MATERIALS AND METHODS

Site description

The study was performed in Drarga, a small rural community, near Agadir, Morocco (30°25′01″ N; 9°36′00″ W). Agriculture is the dominant activity in the region. Drarga's water supply comes from surface water in the Souss basin and groundwater in the Souss aquifer. Drarga was chosen as the site of a pilot plant for treatment and reuse of domestic wastewater, as part of a project established in 2004 by the US Agency for International Development (USAID) and Moroccan partners. The National Office of Drinking Water (ONEP) is responsible for the operation and management of the WWTP.

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The pilot treatment plant is located in the southwestern part of the municipality of Drarga on land previously used for agricultural purposes and is designed to handle the total flow of wastewater discharged by the Municipality of Drarga (Table 1). The site is bordered on the west by the Wadi El Irhzer Arba, a dry river which flows into the Oued Souss. The aim of the treatment plant is to provide water for reuse in agriculture according to World Health Organization guidelines.

The treatment plant is at the bottom of the watershed of the city; rainwater is normally discharged into a trough near the WWTP, where flooding sometimes occurs during heavy rainfall. The Hydraulic Basin Agency of Souss Massa has constructed a 1.8-km dyke as protection against flooding.

The pilot treatment plant (Figure 1) consisted of a primary pond, where denitrification occurs, followed by secondary treatment using sand filters and, finally, tertiary treatment by reed beds. A pool to store treated water is provided (Li & Jiang 1995; Rousseau et al. 2004; Fabio & Martinuzzi 2007; Badalians et al. 2009; Bianchi et al. 2011). The effluent from the treatment plant will be stored and pumped to be provided to local farmers for irrigation. The reeds are also harvested to be sold, while the sludge removed from the WWTP is co-composted with solid domestic waste from the city.

Table 1 | Basic data used for the design of the pilot treatment plant

	Daily average	Peak
Flow m^3/day	607	1,090
BOD_5 (kg/day)	0.45	0.81
COD (kg/day)	0.87	1.57

Denitrification and nitrification in the treatment plant

Denitrification is the reduction of nitrate to molecular nitrogen (N_2). The denitrification ponds ensure the balance of nitrate needs between the reed beds (for their own development) and the needs of crops (downstream reuse). Heterotrophic bacteria operating in an anoxic environment

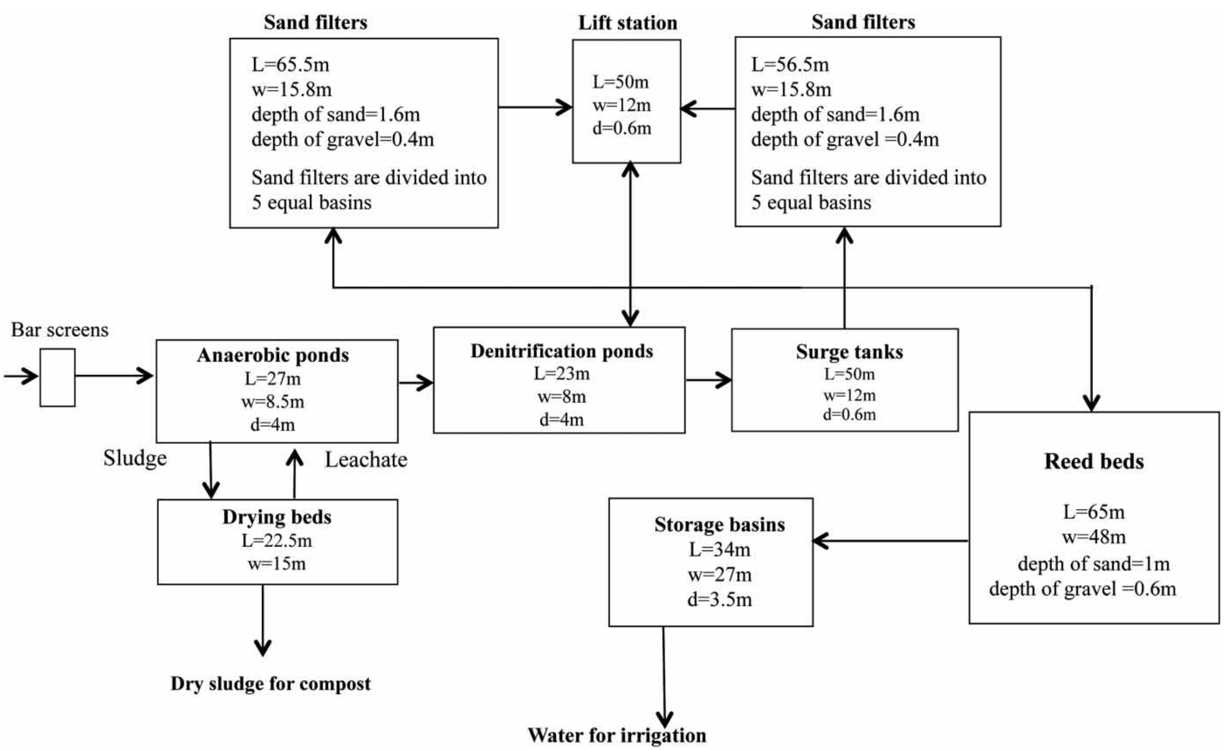

Figure 1 | Synoptic diagram of Drarga treatment plant (USAID 2002).

in the denitrification ponds remove the oxidized nitrogen (nitrate and nitrite). These bacteria require a carbon source to achieve the denitrification process. The carbon source for this process is the COD in effluent from anaerobic lagoons.

In anoxic conditions and in the presence of NO_3^- heterotrophic bacteria convert organic matter into dinitrogen according to the equation:

$$\text{organic matter} + \text{bacteria} + NO_3^- \Longrightarrow \text{new bacteria} + N_2 + H_2O + CO_2$$

Thus, aerobic heterotrophic bacteria and facultative bacteria can meet their energy needs from the nitrates through denitrification. It is estimated that half of the bacteria present in a WWTP can achieve denitrification.

In the sand filters, nitrification (a biological process by which aerobic autotrophic bacteria convert ammonia to nitrate) occurs. Denitrification may also occur in parts of sand filters that lack oxygen. A further reduction of BOD and some denitrification occurs also in the sand filter. The main source for oxygenation in the sand filter is the diffusion of oxygen from the surrounding air into the upper layers of sand.

Sampling

Sampling was carried out in strict aseptic conditions to prevent accidental contamination or change in quality or quantity of pollution. The sampling points were at the inlet and outlet of each basin (Figure 1).

The overall physical and chemical parameters (temperature, dissolved oxygen) were measured *in situ*. The measurements were made on grab samples taken three times a day. Physicochemical and biological parameters (BOD_5 and COD) were measured on composite samples made up in equal proportions of daily grab samples collected at the inlet and the output of each basin.

Analysis

Analysis of physicochemical parameters is based on grab samples and composite samples carried out regularly. The ONEP laboratories where the analyses are performed have two accreditations according to ISO 17025 by the Ministry of Industry and Trade of Morocco and the Ministry of Development Sustainability, Environment and Parks of Canada. The laboratory is accredited for the entire chain of water and wastewater analysis in accordance with ISO/IEC Guide 25 and the specific requirements of the Canadian accrediting body (Morocco Water Resources Sustainability Project 2004).

RESULTS AND DISCUSSION

Removal efficiency of BOD_5

Figure 2 shows the removal efficiency of BOD_5 according to days of rain and input of dissolved oxygen.

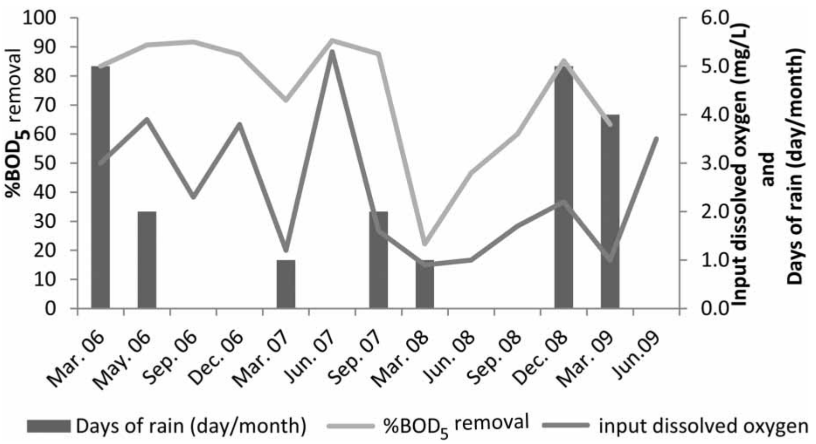

Figure 2 | Removal efficiency of BOD_5 as a function of days of rain (2006–2009) and input of dissolved oxygen.

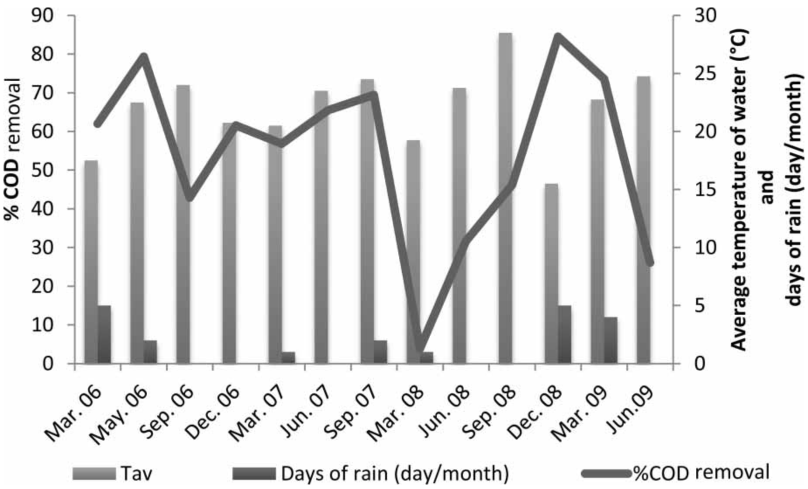

Figure 3 | Removal efficiency of COD as a function of days of rain (2006–2009) and average temperature.

The maximum removal of BOD_5 was in winter (80%). The average removal of BOD_5 during 3 years (from March 2006 to March 2009) was 71% indicating that the removal efficiencies in pollution load in BOD_5 are acceptable. The graph shows a marked decrease in removal efficiency in March 2008 (22% BOD_5; 0.9 mg/l input dissolved oxygen); we suggest this decrease is caused by lack of dissolved oxygen.

In fact this decrease in BOD_5 and associated low dissolved oxygen may be explained by regeneration of new roots, which consumes oxygen in the presence of old reeds.

Removal efficiency of COD

Figure 3 shows the efficiency of COD removal according to the average temperature of the water and days of rain.

As seen on the graph, the removal of COD decreased from the maximum level of 79.3% to a minimum value of 3.9% in March 2008. In general, the efficient removal of COD pollution load increases during winter. The average winter temperature is 21 °C (semi-arid climate); this temperature is optimal for the biological activity of reeds, so during this period, there is an increase in photosynthetic activity, biomass development and symbiosis-reed organic load. Oxygen positively influences the performance of filters. During the winter, there is probably high oxygenation of the water mass because of mixing and agitation induced by the movement of the stems of reeds: at this time the stems are over 2 m long (as shown in Figure 4), provide good wind resistance and the Drarga area is very windy. This movement of stems creates a stirring of the medium and a supply of oxygen to deeper layers. It is important to note, also, that the movement of reeds decreases the risk of clogging because the movement of roots facilitates the flow of water.

The presence of reed debris on the filter surface was also noted. This increases biological activity, and forms a 'crust', which acts as a protective layer for the reed

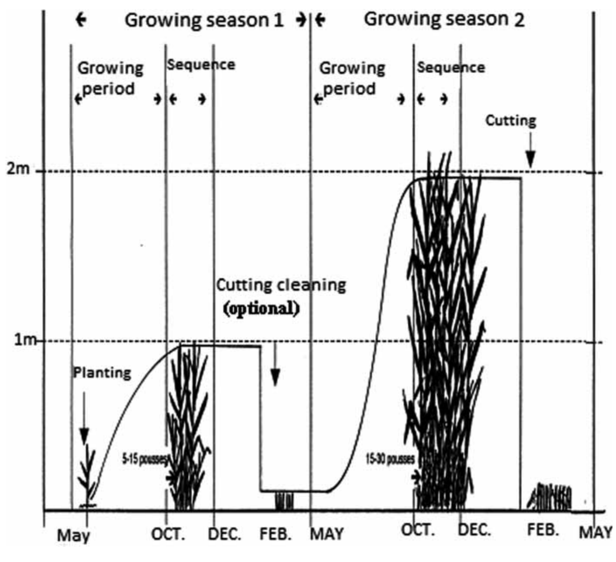

Figure 4 | Growing season for reeds (SRVA 1998).

plants during winter, and thus greatly influences the removal efficiency of BOD_5.

Figure 5 shows the association of BOD_5 and COD with the flow of wastewater. March 2008 marks an exception: the reduced removal of BOD_5 (22%), COD (3.9%) and the amount of flow (351 m^3/day) can be explained by cutting of the reeds in that month.

Study of biodegradability of effluents

Figure 6 expresses biodegradability measured as the ratio of COD/BOD_5 according to dissolved oxygen.

The ratio $0.2 < COD/BOD_5 < 1.2$ shows that the wastewater is readily biodegradable.

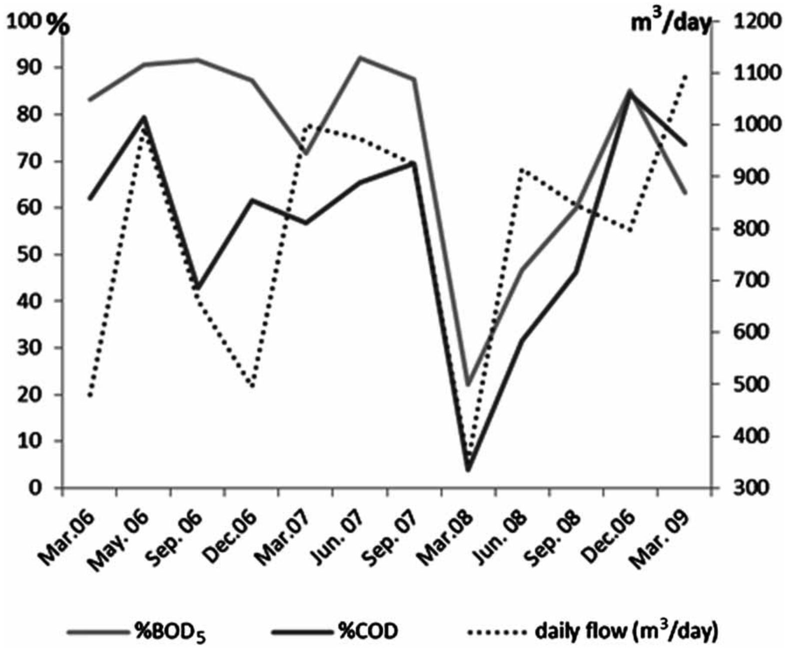

Figure 5 | Removal efficiency of BOD_5 and COD as a function of daily flow.

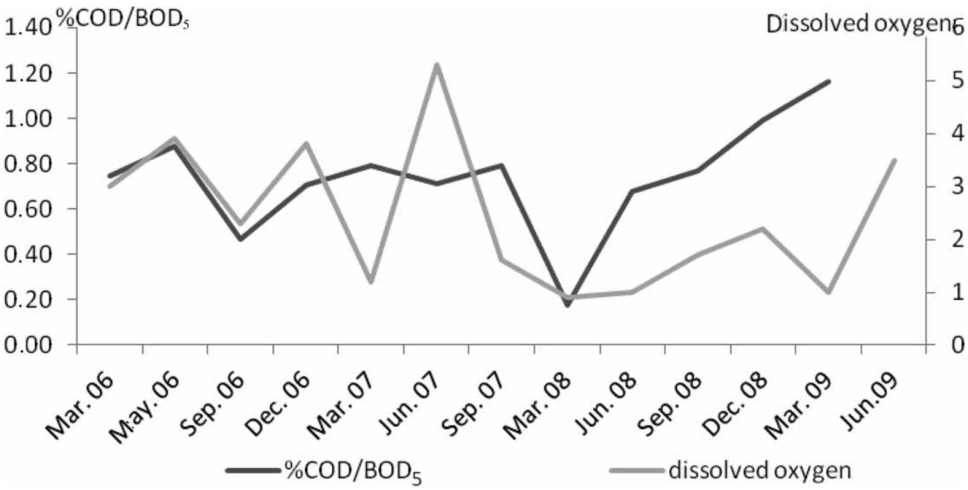

Figure 6 | Variation in performance COD/BOD_5 according to dissolved oxygen.

There is an absence of industrial effluent that could inhibit the biological activity of the filters; moreover, in Drarga, there is very little economic activity overall. The biodegradability is closely associated with the development of reeds: the roots easily assimilated organic matter and increased their own development (Figure 4).

CONCLUSION

This study confirmed the effects of changing seasons on the reed beds and the impact of this change on the reduction of BOD_5 and COD. Elimination of BOD_5 and COD depends mainly on three key factors: climate (sunshine all year round), type of hydraulic regime (continual flow) and concentration of oxygen dissolved in water. Also, it was noted that the presence of reed debris on the filter surface increases biological activity and creates a thermal protection by forming a 'crust'. The crust forms a protective layer for the growing reeds during winter, and thus greatly influences the removal efficiency of BOD_5.

In winter the average temperature at the Drarga pilot plant is between 17 and 22 °C. These temperatures are supportive of the biological activity of reeds; in this period the filters run effectively with accelerated photosynthetic activity, biomass development and symbiosis-reed organic load.

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