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Domestic wastewater treatment using tidal flow constructed wetland

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ABSTRACT

Wastewater treatment has become a large challenge. Constructed wetlands (CWs) are appropriate, sustainable and cost-effective technologies that had been successfully used as phytoremediation tool to remove pollutants from wastewater. They are able to produce effluent of a needed quality, they can be a valuable addition for wastewater reuse schemes, and consequently an important water management option to shore up conventional resources and to reduce the environmental impact of discharges. Tidal flow of engineered wetlands is a method developed to provide oxygen to wetland systems that not only improve treatment performance, but also can successfully compete with many conventional technologies. The ultimate goal of this study was to observe the performances of tidal flow wetlands throughout their operational period. A pilot experimental setup was conducted for treating domestic wastewater generated in campus wastewater outlet for 60 d. *Alpinia galanga* was chosen as vegetation in the constructed wetland. Various water quality parameters such as biological oxygen demand (BOD_5), chemical oxygen demand (COD) and Suspended solids (SS) were performed. The system was able to remove 70% of BOD, 80% of COD, 73% of SS, and the parameters values of treated water are within the permissible limits of domestic rejects according to National legislation of Morocco.

Keywords: Constructed wetland; Reuse; Tidal flow; Treatment; Wastewater

1. Introduction

Domestic wastewater faces several challenges, such as treatment, disposal, and reuse. The improper discharge of wastewater has a negative impact on the receiving aquatic environment and soil structure. Also, it could subject toxic effects on the groundwater after being discharged to the land. This necessitates prompt and adequate treatment of the wastewater before its disposal [1]. Wastewater are generally treated using biological methods such as activated sludge process, trickling filters, aerated and natural lagoons, bio-disc, and phytoremediation treatment [2]. The treatment of rural wastewater using traditional wastewater treatment plants is not feasible, as it will require high-energy rate to provide the required oxygen, requires more operation labor (administration, laboratory and unit process operation labor cost) and maintenance labor [3]. However, all these treatments need sewage collectors, which are difficult to construct in rural areas because of their low economic status and rugged terrain, and this

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is due to the fact that rural domestic wastewater has different characteristics to urban sewage; in particular, it has lower concentrations of pollutants [4]. Additionally, it is always widely distributed, with over 90% of untreated wastewater indiscriminately discharged directly onto nearby surfaces, groundwater becomes contaminated, which can endanger public sanitation and the health of rural residents [5]. Constructed wetlands (CWs) are considered to be an effective and low-cost treatment system reducing levels of chemicals and biological organisms in domestic wastewater, hospital wastewater, industrial effluents, agricultural drainage, mine drainage, stormwater runoff, and landfill leachate, through the use of organic materials and nutrients and could serve as a model for the rural environment [6–12]. Tidal flow wetland is a type of 4th generation or intensified wetland system for biological wastewater treatment. It operates by continually filling and draining the wetland cell with wastewater [13]. The cycle of filling and draining introduces additional oxygen into the wetland cell. Tidal wetland have been proven to remove both organic and inorganic contaminants from municipal wastewater. A large number of beneficial species can be used in constructed wetlands, depending on the type of filter, the mode of operation (continuous/discontinuous), the effluent flow and its characteristics, and the environmental conditions. The main characteristics of the selected species are fast growing, hyper-accumulation and high tolerance towards heavy metals toxicities. *Alpinia galanga* is a plant that meets these criteria [14]. It will be the subject of this study.

2. Materials and methods

2.1. Study area

The experimental device consisted of a physical microcosm model of raw wastewater treatment plant that was constructed within the domestic wastewater experimental pilot station, at upstream of the Bouregreg valley and downstream of the Sidi Mohamed Ben Abdallah, Northwest of Morocco (Between 4° 01′ 31″and 6° 50′ 10″), in Rabat City.

The experimental setup was conducted through a permeable bed of gravel from down upwards: 44 cm of 13/20 mm gravel to drain water passing through the filter means to an outlet point, and 25 cm of 2/4 mm gravel as filtration layer. The plastic tank measuring 1.14 m in length × 0.9 m

Fig. 1. Experimental setup.

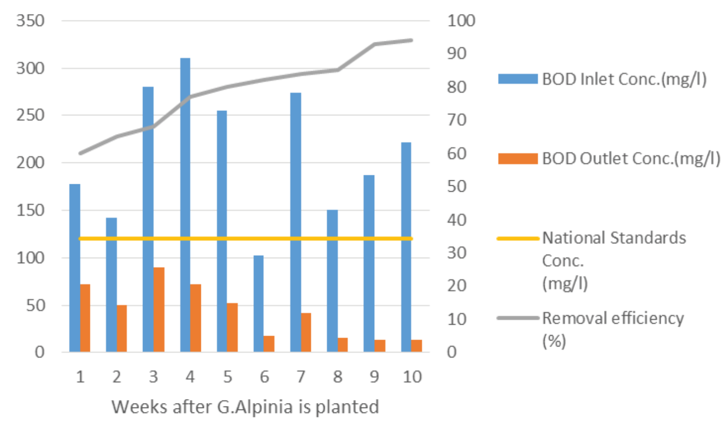

Fig. 2. Variation and percentage removal of BOD_5 before and after treatment.

in width × 0.64 m in depth. The root reaches depth of more than 3 m but in this case is limited to the optimal depth of the tank (Fig. 1). The experiment was carried out one month after the planting of the macrophytes and their adaptation period to the new environment.

The flow rate of raw wastewater into the tank was 0.5 m^3/d while the hydraulic retention time between the inlet point and outlet point was 5 h was selected as previously described by Merino-Solís et al. [15] and also approved by Khalifa et al. [16].

2.2. Sampling and analytical methods

The sampling was carried out by taking samples at two points of the tank (inlet, and outlet); collected almost at the same time, every week, using plastic bottles, these samples are carefully mixed to make a homogeneous and representative sample, transported to the laboratory, and stored at 4°C. These samples were placed at room temperature for 2 h before analyzed according to the standard methods NFXPT 90–210 [17].The experiment data consisted of 30 sampling.

Wastewater and treated water were analyzed for various parameters: BOD_5 was measured with a respirometer by the manometric method and the COD was determined using the method developed by Knetchel [18]. Suspended solids was executed by centrifugation and filtration on filtering records (disks) of Whatman GF/C 1.2 microns as stipulated in the French standard procedure [19].

2.3. Measurement of the purification performances

To evaluate the effectiveness of Tidal flow constructed wetland for the treatment of domestic wastewater, the following parameters were followed: Biological oxygen demand (BOD_5), Chemical oxygen demand (COD) and Suspended solids (SS).

The COD removal was calculated by analyzing the COD before and after the treatment of domestic wastewater. Eq. (1) was used to calculate the removal efficiency:

$$\text{COD removal}\left(\%\right)=\frac{C_{\text{inlet}}-C_{\text{outlet}}}{C_{\text{inlet}}}\times 100 \quad (1)$$

where C_{inlet} and C_{outlet} are the initial and final concentrations of COD of the wastewater, respectively. The same equation was applied for the determination of the % removal of BOD_5 and SS.

3. Results and discussion

3.1. Wastewater characterization

In order to study the effect of vertical system on purification, several samples were prepared and analyzed for various parameters quality. The average value of the parameters monitored for 60 d in the influent and effluent and their removal percentages obtained with the application of pilot system are presented in Table 1. The National effluent quality standards are also shown [20].

Constructed wetlands are ecological engineering systems designed to treat various types of effluents by reproducing the physical, chemical and biological purification mechanisms that exist in natural environments.

Suspended solids are removed by sedimentation and filtration according to Crites et al. [21]. Sedimentation as a physical process by which suspended particles stop moving and settle to form sediment. During filtration, the

Table 1
Influent and Effluent wastewater characterization

Parameter	Inlet conc. (mg/L)	Outlet conc. (mg/L)	Removal efficiency (%)	National Standards Conc. (mg/L)
BOD	170	40	70	120
COD	172	43	80	250
SS	254	59	73	150

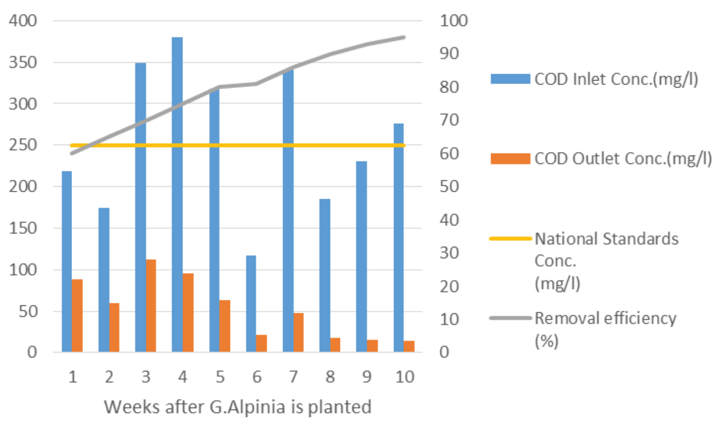

Fig. 3. Variation and percentage removal of COD before and after treatment.

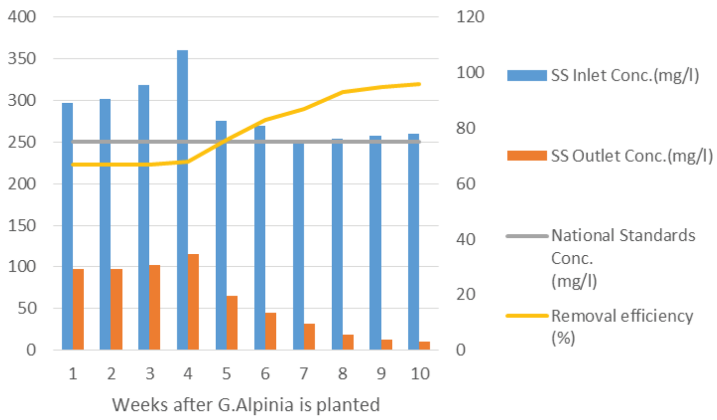

Fig. 4. Variation and percentage removal of SS before and after treatment.

particles in transport come into contact with the grains of the filter or with material already deposited on the filter and settle or by impaction of particles in the roots and stems of macrophytes. For the suspended solids, the removal efficiency in the tidal flow system was 73%. The SS content of the influent ranged from a maximum value of 360 to a minimum value of 250 mg/L. This content is reduced at the outlet to an average of 10 mg/L in accordance with Moroccan discharge standards (Fig. 4).

Organic substances within vegetated wetlands are removed due to aerobic biodegradation by microbes supported by macrophytes transferring oxygen to the water within the rhizosphere which allows to reduce the organic matter concentration [22–24]. The removal of organic matter was characterised in terms of BOD_5 and COD before and after wastewater treatment. The influent had a COD and BOD_5 concentrations of 172 and 170 mg/L, respectively (Figs. 2 and 3). In addition, the effluent had a BOD_5 and COD of 40 and 43 mg/L. The elimination efficiency of BOD_5 and COD were at 70% and 80 % respectively. The treatment with the herbaceous produces purified water that is well discharged in the Moroccan standards set at 120 mg/L for BOD_5 and 250 mg/L for COD.

4. Conclusions

The treatment of wastewater generated by the campus outlet of National Office for Electricity and Potable Water (ONEE) of Rabat using tidal system was carried out. The elimination efficiency of BOD_5, COD, and SS was at 70, 80 and 73% respectively. The results obtained are within the permissible limits for domestic rejects according to National legislation of Morocco. According to the results obtained, the tidal flow system is recommended because it achieves high yields in the elimination of pollutants present in domestic wastewater especially for small communities. The system is very efficient and low cost method for treatment of wastewater in rural area.

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