Effectiveness of vertical system planted with *Renealmia Alpinia* used in sub-humid climate to treat urban wastewater: a case study in the pilot site Bouregreg-ONEE RABAT

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Abstract. Wastewater treatment is a global environmental issue. In Morocco, 45% of wastewater is treated before its discharge. Their impact on the environment is further aggravated by the degradation or absence of the sewerage liquid system. The constructed wetlands are alternative systems for the treatment of wastewater. Therefore, the aim of this study was to evaluate period adaptation (60 days) of a substitute plant *Renealmia alpinia*, and its potential for treating wastewater generated by the campus of the National Office of Electricity and Drinking Water (ONEE) of Rabat. A pilot experimental setup (tank) was constructed. The pumping rate was adjusted to 0.7 m³ / h while the density of *R. alpinia* planting on the surface of the filter massif was 6 plants/m². At the end of monitoring, planting density was superior of 30, and *R.alpinia* plants have completed this phase clearly without any disease symptoms present. The treated water obtained from outlet and wastewater were analysed for various water quality parameters such as Biological oxygen demand (BOD), Chemical oxygen demand (COD) and Suspended solids (SS). The vertical system is able to remove 49 % of BOD, 80 % of COD, 88 % of SS. The results obtained are within the permissible limits for domestic rejects according to National legislation of Morocco. Overall results demonstrated that the selected plant posses a high potential for treating wastewater, it could represent a sustainable and inexpensive biotechnological strategy for untreated wastewater.

1 Introduction

Water is the most threatened resource worldwide because of its excessive use in several human activities and its inadequate disposal of wastewater [12]. Morocco developed a National Sanitation Program (NAP), to overcome the problem of liquid sanitation in rural areas or small communities. The (NPA), revealed a set of deficiencies, it has specified there are gaps in terms of processes and techniques adapted for wastewater treatment. In fact, conventional processes are expensive, inefficient, consume huge amounts of chemicals and could emit greenhouse gases [7]. The present trend is tending towards autonomous systems that allow the elimination of all forms of pollution while having minimal social, environmental and financial impacts. To guarantee the success of this program and strengthen capacities in innovative aspects of valuation of by-products, cost cutting and technologies, the faculty of sciences and techniques of Mohammedia in partnership with national office for electricity and drinking water (ONEE) of Rabat and the international institute of water and sanitation (IEA) was performed a pilot project of planting a wetland constructed with *Renealmia Alpinia* at the pilot site Bouregreg, to demonstrate that our project could serve as a model of purification for small

communities, in particular, the rural areas in Morocco. The constructed wetlands purifies domestic wastewater through a combination of physical and biological processes. Gravel and cobble material act as filter media and support for the bacteria and plants responsible for bioremediation and nutrient uptake [14,15,17]. A large number of 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, the environmental conditions. The main criteria for choosing plants must be their tolerance to the toxicity of the pollutants to be treated and their ability to reduce pollutants in water. *R.Alpinia* is a plant that meets these two criteria. *R.alpinia* is typically found in tropical moist lowland rainforests [13,16], belongs to the zingiberaceae family, it is a herbaceous plant of between 2 m and 6 m high, gregarious, simple leaves, alternating, without stipules, long-lanceolate leaves up to 110 cm long and 11 cm wide, parallel rib, open leaf sheath with ligule [2]. In addition to its functions, the ornamental plant is characterized by great pharmacological and nutritional importance.

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2 Material and Methods

2.1 Study area

The planting of a wetland constructed with *Renealmia Alpinia* was conducted at Bouregreg Pilot Wastewater Treatment Plant located at upstream of the Bouregreg valley and downstream of the Sidi Mohamed Ben Abdallah. Northwest of Morocco (4° 01' 31", 6° 50' 10"). Which is characterised by its pleasant warm and temperate climate with an average annual precipitation of ~523 mm, and an annual average temperature of 17.9 °C [18], which is of major importance for the development of the *Renealmia alpinia* species involved in purification. In addition to the climate, the site has the advantage of being in a good topographical position, making it easier to set up. With regard to hydrology, Oued Bouregreg at its source in the central plateau, it travels a distance of about 200 km before reaching the Atlantic Ocean. Freshwater supplies are limited to inputs from the Akkrach Oued enriched by discharges from the ONEE-Branch water treatment plant, the Sidi Mohamed Ben Abdallah restitutions, drainage basin between the barrage and the mouth of the river, and wastewater discharges from the Salé-Rabat Agglomeration.

2.2 Experimental device

As shown the (Fig.1), the experimental pilot was done into the ambient environment and consists of a permeable bed of gravel from down upwards : 15 cm of 13/20 mm gravel to drain water passing through the filter means to an outlet point, 15 cm of 5/8 mm gravel as a transition layer and 25 cm of 2/4 mm gravel as filtration layer. The constructed wetland is installed in a square tub made of polyethylene. The tank height, length, and width were adjusted to 65cm, 114 cm, and 90 cm respectively. The hydraulic load capacity to reach is 1 m³/m²/day. The pilot's wastewater supply is automatically pumped and programmed for 24 hours (every 2 hours) to achieve a flow of 100 l/day. An electrical control cabinet is provided to ensure the wastewater supply automations to be treated. Raw wastewaters were pre-treated at 0.91 m² using coarse screening. The tank was constructed using PVC piping with control valves and fittings which have an outlet as well as an inlet. *Renealmia Alpinia* is a local species. The plantation was carried out on 25 April 2019, with a density of 6 plants/m² (Fig.2).

Figure 1. Experimental Setup. 30 days after plantation

2.3 Monitoring protocol of adaptation period

The objective was to test the adaptation in the filter, before starting the experimental pilot. Each plant was placed with its clod in the filter, pierced in its lower part and was filled with gravel, a little compost that will mimic to some extent the organic deposit layer on the filter surface was applied [9]. For 2 months, the plants received the necessary water and were placed in quadrats. Regular monitoring (Tab.1) was carried out to identify plant density, stems height, leaves health (chlorosis, mottling, flowering, fungal attack, death, etc.).

Table 1. Evaluation of plant tissues during the adaptation period

Plant tissue	Parameters
Stem	<ul style="list-style-type: none"> ▪ Density: number of stems; ▪ Maximum height: The average of three high stems. The height is measured from the ground to the plant apex; ▪ State of health: observation of the symptoms (chlorosis, , death etc.); ▪ Development according to age: monitoring the height of the stems of different ages
Leaf	<ul style="list-style-type: none"> ▪ State of health: observation of symptoms (wilting, mottling, etc.).
Shoot	<ul style="list-style-type: none"> ▪ Appearance and growth. A shoot is considered as a plant when its stem exceeds 20 cm.

2.4 Wastewater sampling and analyses

The Alpinia plant used is a young stem. It is monitored for an adaptive period of two months. To monitor pilot effectiveness, the vertical system has been subjected to characterization campaigns that focus on the measurement of two-point physicochemical parameters (Inlet and Outlet). The protocol of physicochemical analysis used is based on the following methods: Solids suspended (SS) by centrifugation followed by a filtration on filtering records (disks) of Whatman GF/C 1.2 microns according to the standard AFNOR [1] the Biochemical demand in Oxygen (BOD) is determined by means of a measurement system OxiTop which

measures the consumption in oxygen by biological way; and the chemical oxygen demand (COD) is essentially made by oxidation with the dichromate of potassium $K_2Cr_2O_7$ for boiling in the presence of ions Ag^+ as catalysts of oxydation and having complexes ions Hg^{+2} as having complexes chlorides.

3 Results and discussion

3.1 Monitoring results

The simplified monitoring protocol is based on the use of quadras, within which the height and density of the plants are recorded. Regular observation of the plant's stage of development makes it possible, by coupling it with quadra data, to define the plant's vegetative cycle. Finally, the examination of the root parts of adult plants and the arrangement of the rejections make it possible to predict whether the plant will develop homogeneously or in clumps. The results are presented below.

Table 2.Summary of Renealmia alpinia satisfaction to the properties of a VFCW plants

Property	Renealmia Alpinia
Direct light	yes
Gravel support	yes
Perrenial / non-woody	yes
Rapid development	yes
Homogeneous development	yes
rhizomatous	yes
Height> 50 Cm, diam. stems 2 cm	yes
Rejections >30	yes
Vigour	yes
Wilting	No
Chlorosis	No
Fungal/microbial attack	No
Death	No
No water retention by aerial parts	yes
non-toxic plant (sap, leaves ...)	yes
unprotected species	yes
Non Invasive species	Yes

3.2Wastewater characterization

Samples are taken at the inlet and outlet of the system and have been characterized by measurements of physico-chemical parameters. The following table (Tab.3) shows the parameters for measuring the quality of raw and treated wastewater as well as their concentrations.

Table 3.Raw wastewater and treated water quality parameters

WEEKS	BOD(mgO2/l)		COD(mgO2/l)		SS(mg/l)	
	RW	TW	RW	TW	RW	TW
W₁	245	110	307.2	138	196	75
W₂	211	166	264	208	84	71
W₃	215	192	241	47	162	72
W₄	61	31	119	87	80	30
W₅	85	65	413	196	252	29.5
Moroccan standard of reject	120		250		150	

3.3 Measurement of the performance of the vertical system

The removal efficiency is determined as follows :

$$R_{\text{Efficiency}} = 100 \times (C_{\text{Inlet}} - C_{\text{Outlet}}) / C_{\text{Inlet}}$$

R_E = Removal efficiency;

C_{Inlet} = Concentration of the parameter considered for raw wastewater ;

C_{Outlet} = Concentration of the parameter considered after purification.

Figures 2, 3 and 4 show the pilot's content values (mg/l) and removal efficiencies (%) of BOD₅, COD and SS respectively.

Figure 2.Variation and percentage removal of BOD₅ before and after treatment

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

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

The main treatment mechanisms of constructed wetlands are based on the combination of several aerobic processes : the vertical flow filter is fed from the surface and the effluent percolates through the substrate. The effluent then undergoes a first filtration stage allowing a physical retention of suspended solids on the surface of the filter, thus allowing an accumulation of sludge on the surface. The biological degradation of the dissolved solids is carried out by the aerobic bacterial biomass fixed on the unsaturated support as well as on the deposit layer accumulated on the surface.

Organic matter is a term that encompasses a wide variety of molecules that degrade at different rates and, thus, the 5-day biochemical oxygen demand (BOD₅) is used as a standard method to estimate biodegradable organic matter [5]. Figure 2 shows the evolution of the BOD₅ during the test period, Note that the raw water at the pilot's inlet has a BOD₅ that varies between 245 and 85 mgO₂/L. In addition, the treated water has a BOD₅ value over the range (110 - 65 mg/L), this shows that treatment with the herbaceous "R.alpinia" produces purified water that is well discharged in the Moroccan standards set at 120 mgO₂/l for BOD₅. This phyto-purification process impacts the BOD₅ reduction which can reach 50%. This explains why the organic matter contained in the effluent is easily biodegradable by the phyto-purification process.

Unlike BOD₅, chemical oxygen demand (COD) is a measurement of the total amount of organic matter that can be chemically oxidized to inorganic products. Several studies report COD removal in CWs of between 85% and 95% [4,6, 8,11]. The COD content at the inlet was ranging from 119mg/L to 413mg/L. This content is greatly reduced during the treatment 47 mg/L at the pilot's outlet. This value remains within the Moroccan standards set at 250 mgO₂/L[19]. The purification efficiency of the COD has reached a very satisfactory level with a 80 % removal rate of oxidizable matters.

In turn, SS removal in constructed wetlands depends on physical and biochemical processes. Initially, solids are removed through sedimentation, given that wastewater flows slowly inside the constructed wetlands, and filtration by gravel and other porous solids close to the

inlet. Furthermore, microorganisms present in the CWS readily degrade retained TSS, thus increasing the amount of available organic matter [3,5]. Previous studies indicate that SS removal using this type of technology ranges between 61% and 88%. The SS content of the raw wastewater at the inlet of the pilot varies between a maximum value of 252 and a minimum value of 80 mg/L. This content is reduced at the outlet to an average of 29.5 mg/L in compliance with Moroccan discharge standards[19].

The rate of abatement of SS during the phyto-purification process is about 88%. This explains why the solids contained in the effluent are easily settled.

4 Conclusion

Except the perturbations observed during the first two weeks, the plant (R.alpinia) provides extra robustness to the system because it can adapt to a wide range of conditions (resistance to water stress, extreme climatic conditions: high temperature, long submerged periods in the filter, anoxic stress...) the plant achieved this period in a good health (absence of disease).

The treatment of wastewater generated by the campus outlet of National Office for Electricity and Potable Water (ONEE) of Rabat using R.alpinia system was carried out. The water quality parameters of raw water and the treated water were analysed and compared with the permissible limits (National legislation). From the results it is observed that most of the water quality parameters tested is within the permissible limits. The VS is able to remove 49 % of BOD, 80 % of COD, 88 % of SS. The information presented above demonstrates that the system are very efficient and low cost method for treatment of wastewater in rural area.

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