CASE STUDY: IMPLEMENTATION OF A REED BED PROTOTYPE ON A UNIVERSITY CAMPUS

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ABSTRACT

This study approaches a decentralized solution for wastewater treatment using constructed wetlands. Decentralized wastewater treatment systems favor water recycling and reuse of the water in the proximity of treatment location, thus transforming the nuisance into a resource that can be used for irrigation. The main advantage lies in the low cost and energy demand of constructed wetlands technology compared to conventional treatments[1]. In this case study, a reed bed prototype was used to deal with the effluent coming from the secondary treatment of the wastewater treatment plant at the University of Balamand (UOB). As the main campus spreads over 500,000 square meters of terrain forested with small oak trees and since the campus comprises over thirty buildings distributed across different areas and contains a growing number of staff and students; major concerns regarding the load capacity of influents going to the wastewater treatment plant might be faced with time[2]. This study aims to assess the efficiency of the reed bed prototype in providing clean water suitable for irrigation from secondary treatment effluent. After studying the suitable type of soils for the prototype, a search for a good environment to grow reed bed on campus was needed and hence the reed bed prototype was implemented. Water quality parameters, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), bacterial contamination, and coliform levels are checked in the influent and effluent of the reed bed prototype and compared with the Ministry of Environment (MoE) in Lebanon. Results indicate a decrease in chemical and microbial contamination with time, indicating the efficiency of the solution.

KEYWORDS

Decentralized wastewater treatment, constructed wetlands, reed bed, irrigation.

1. INTRODUCTION

Wetlands are alternative nature-based wastewater treatment solutions, relying on a biological process to remove nutrients, heavy metals, organic matter, sediments, and pathogens from wastewater, by providing a suitable environment for microorganisms. There are various types of constructed wetland technologies, the most common being horizontal flow systems and vertical flow systems, the latter being more efficient in nitrogen removal due to its higher concentrations of oxygen [3]. The low cost of implementation and operation and maintenance requirements promotes constructed wetlands to a considerable alternative for decentralized wastewater treatment in low-income countries, where rural and peri-urban areas might not be connected to a central sewer network. The main limitation of this technology is mainly land availability. At best, the required land area is linearly related to the population, which makes it only suitable in decentralized applications, where a small community is involved, whether it is a school, university, or a group of households, provided that the land is available. Conventional treatment plants require much less space and higher efficiency is observed given its capacity to treat large quantities of effluent. Another limitation is the temperature, wetlands operate effectively in warm climates since low temperatures limit bacterial growth. In Lebanon and the Mediterranean region, this is not a major issue since the climate conditions are favorable for the proper functioning of the system. Most of the third world countries fall in the warm regions where constructed wetlands can be used. Generally, constructed wetlands are also used in rich countries, where the high cost of energy and environmental impact is an issue. However, for lower-income countries, where the concept of production, use, and dispose is deeply rooted, and no significant change avoiding a tragedy could be done unless policies and regulations are implemented to turn the linear pattern of the economy into a circular one, protecting the resources of the countries. Until then, the cost of using would be lower than recycling and reusing, and no significant change could be made[4]. In Lebanon for example, a country once considered to be the richest in water resources, its water bill is independent of its volumetric consumption. As a result, the cost of wastewater treatment would be higher than the fixed fee for municipal water. Moreover, when municipal water shortages occur, people tend to pay for water trucks. As a result, only areas with high population density where water shortages are highly felt consider implementing water recycling solutions [15].

In this study, the efficiency of the reed bed prototype was a major concern, which is measured at the first stage with water quality parameters. Thus, economic and technical design considerations, such as the design hydraulic loading rate and retention time were not considered. In this study implemented at the University of Balamand, a vertical flow (VF) reed bed prototype is tested for tertiary treatment. The resulting water could be used for landscape and crop irrigation at the university. This would reduce the cost of tertiary treatment, without the need for large areas of land, while simultaneously providing recycled clean water for irrigation.

2. MATERIALS AND METHODS

The main components of the prototype are obtained locally at a very low cost. The common reeds were available on campus. Materials used are white clay, clay, sand, gravel, reeds, wooden planks, and a geotextile. The set up is shown in the following steps:

- Cleaning and preparing the site for excavation
- Excavate at a depth of 25cm length of 2m and width of 1m
- Setting boundaries with rocks to obtain two 1m x 1m x 25cm basins
- Placing a perforated plastic box at the bottom of the basin for water sampling
- Connecting tubes to the plastic box at the bottom of the reed bed, the tubes extend out of the reed beds so the effluent can be collected for testing
- Placing a cloth on the bottom to prevent large particles from clogging the system
- Placing wooden planks between the two reed beds to prevent soil erosion
- Placing a gravel layer of 5cm above the cloth, followed by another 5cm of soft gravel
- Mixing a 10cm layer of sand with clay and placing on top of the 10cm gravel layer
- Planting the reeds

This setup indicates clearly how the reed bed prototype was installed. The prototype acts as a VF system. The water discharge at the entry of the system percolates through the basin and is collected at the bottom through a perforated tube, directing the cleansed water to the plastic box, which in turn, once is filled, generates a flow out of the system. This flow would be the effluent from where the samples are taken for laboratory testing. The system is not constantly flooded and provides aerobic conditions for water treatment. This will be shown later in the results, where a significant reduction of nitrates highlights it.

3 WATER QUALITY TEST RESULTS

3.1 BOD and COD

Water quality parameters are tested before and after tertiary treatment and are compared simultaneously to the MoE (Ministry of the Environment) guidelines in Lebanon. BOD and COD values of the effluent were measured throughout a whole month on a weekly basis. Results are plotted in Figures 1 and 2.

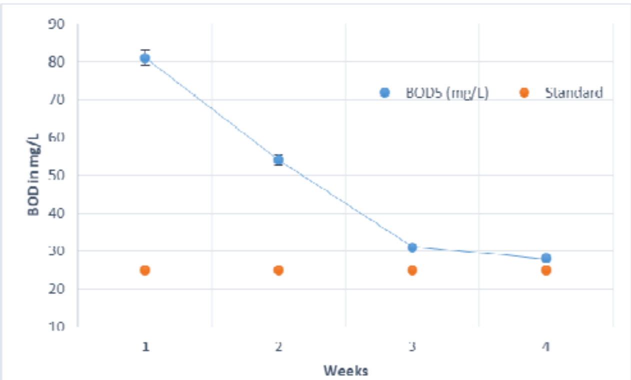

Figure 1. BOD Variations with Time.

A decreasing trend is observed in both COD and BOD values, with the BOD value approaching the standard limits provided by the guidelines of the Ministry of Environment. The continuous decrease in the BOD and COD levels is explained by the time required by the reeds and the microorganisms to absorb the pollutants and grow. Growing reeds would allow more oxygen into the soil and accelerate the growth of aerobic bacteria contributing to the digestion of organic matter

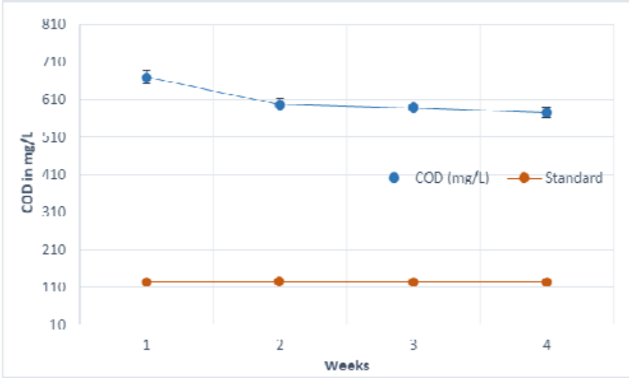

Figure 2. COD Variations with Time.

3.2 Test results on E.Coli and Coliform

Table 1 provides the results for the presence of harmful bacteria's such as E.Coli and Coliforms. It is well-known that after primary treatment, wastewater is delivered to the secondary wastewater treatment (biological treatment). In this part, the system contains biological organisms made to eliminate suspended solids and organic matter. In this process, microorganisms and bacteria play the role of dissolving the organic matter into gases and tissues[3]. As such, since the experimental setup uses the wastewater delivered from the secondary treatment plants to feed the reed beds whose main objective is to absorb these bacteria's to grow, table 1 indicates how the natural infiltration process was capable of absorbing these bacteria's with time and decrease the levels promptly as a sign of good operation.

Table 1. Prototype wastewater test results on E.Coli and Coliform values for the 4 weeks of March.

Week Number	E. coli (cfu/100 ml)	Coliform (cfu/100 ml)
1	>100	>100
2	>100	>100
3	>100	>100
4	35	0
Standard	20	50

4 RESULTS AND DISCUSSION

A water quality comparison was made between the wastewater coming out of the secondary treatment and the water quality retrieved from the reed beds (tertiary treatment). Results are shown in Table 2 below, where an evaluation was made every week for a month, by comparing the values taken from the effluent of the secondary treatment and the effluent of the reed bed. It was seen that, as the reed beds were performing as tertiary treatment, bacteria's such as E.Coli and Coliform were eliminated from the wastewater but caused an increase in turbidity and total suspended solids. This behaviour is quite expected since the water is mixed with soil during its retention in the reed beds. Reductions in BOD, COD, and harmful pathogens prove the efficiency of the reed beds for tertiary treatment.

Table 2. Physical Data sets obtained in comparison to the standard.

Tests	Secondary Treatment	Reed Bed Treatment	MoE Std
E.Coli (cfu/100 ml)	*21*	*35*	*20*
Coliform (cfu/100 ml	*1*	*0*	*50*
T (^{o} C)	*18.974*	*19.616*	*25*
TDS (mg/L)	*653*	*558*	*2,000*
Turbidity (NTU)	*11.19*	*14.854*	*-*
Conductivity (µs/m)	*975,000*	*846,000*	*100,000*
pH	*7.36*	*7.4*	*6<pH<9*
Salinity (%)	*0.484*	*0.413*	*0.7-3*
TSS(mg/L)	*43*	*58.4*	*60*
BOD (mg/L)	*59*	*48.4)*	*25*
COD (mg/L)	*661.3*	*606.84*	*125*

Table 3. Chemical Data sets obtained in comparison to the standard.

Tests	Secondary Treatment	Reed Bed Treatment	MoE Std
Ammonium (mg/l)	*0.31*	*<0.03*	*10*
Calcium (mg/l)	*93.6*	*110.4*	*0-400*
Magnesium (mg/l)	*6.7*	*5.8*	*60*
Potassium (mg/l)	*17.9*	*7.4*	*NA*
Sodium (mg/l)	*64.6*	*52.6*	*200*
Nitrite (mg/l)	*<0.03*	*<0.03*	*NA*
Nitrate (mg/l)	*188.4*	*116.4*	*90*
Chloride (mg/l)	*85.7*	*67.7*	*200*
Phosphate (mg/l)	*16.6*	*2.2*	*5*
Sulfate (mg/l)	*48.2*	*38.8*	*1000*

As for the anions and cations were studied: Chloride (Cl^-), Nitrate ($NO3^-$), Nitrite ($NO2$), phosphate ($PO4^{3-}$), sulfate ($SO4^{2-}$), sodium (Na^+), magnesium (Mg^{2+}), and ammonium ($NH4^+$) and presented in Table 3. It was observed that the Nitrate and Nitrite concentrations were less than the maximum contaminant levels. This is primarily due to the reed beds development that consumes bacteria and all chemicals available and therefore decreases the amount of nitrate and nitrite present in the effluent water tested. As noticed; cations and anions quantities determined in mg/l have decreased after treating the water coming from the secondary wastewater treatment plant at UOB. This shows that the reed bed prototype is functioning as expected. The only parameter that increased is calcium, Ca^{2+}, this is anticipated as the soil is rich in clay-based material.

5. CONCLUSIONS & RECOMMENDATIONS

The reed bed prototype was tested for its efficiency in tertiary treatment at the University of Balamand (UOB). Results indicated a positive performance in terms of reducing pathogens, chemicals, and organic matter. The experiment lasted one month due to time restrictions (COVID-19); but the trend observed is promising, and most of the water quality parameters comply with the guidelines set by the Lebanese Ministry of Environment. The major indicator of success is the removal capacity of nitrates in the reed beds. Due to the reliance of cleaning on detergents, the wastewater in the university's secondary wastewater treatment plant contains high concentrations of nitrates, which was significantly reduced by the prototype. This indicates that constructed wetlands can be effective in treating wastewater containing nitrates, which is mainly linked to agricultural wastewater. Hence, constructed wetlands can be implemented on farms, provided that land availability is not a limiting factor. Fortunately, farms are located in rural areas, where usually decentralized wastewater treatment is a good choice since the population density is low and land availability is not a major issue. In areas with no access or limited access to electricity, which is common in countries such as Lebanon, this technique is quite promising.

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