

Comparative study on different horizontal subsurface substrates in flow wetlands

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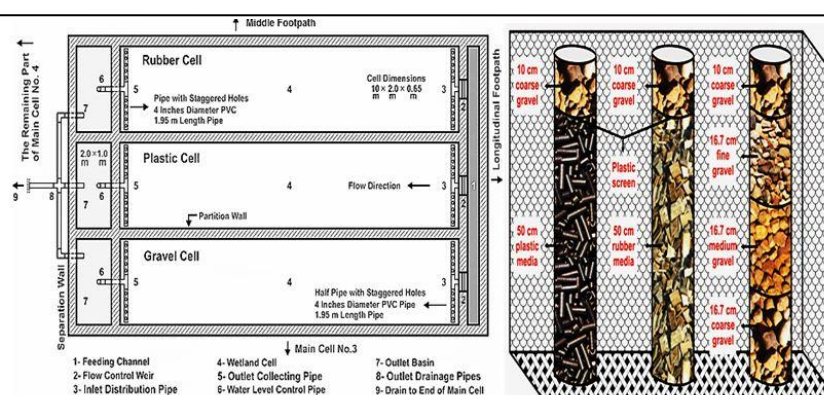
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GRAPHICAL ABSTRACT



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ABSTRACT

A greenhouse experiment has been conducted to study the effect of using different wetland substrates that have been compiled on the basis of effluent treatment efficiency. Wetland beds have been prepared with locally available plants, in particular (*Phragmites Australis*). The effectiveness of the treatment was evaluated on parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total suspended solids (TSS) and total phosphorus (TP). The results indicate that nutrient reduction corresponds to lower flow in wetland beds. At the lower flow rate of 2.34 m³/day, the system with plastic supports showed the highest removal efficiencies of BOD, COD, TKN, TSS and TP in percentages of 74.42, 74.9 %, 63.28, 87.49 and 71.29 %, correspondingly.

1. Introduction

Constructed wetlands (CWs) have long been proven to be an effective, low-cost, low-maintenance treatment system for municipal, industrial and agricultural wastewater in removing organic matter, nutrients and suspended solids. Constructed wetlands were designed to utilize natural processes involving wetland vegetation, soils and their associated microbial assemblages to assist in the treatment of wastewater. They are designed to take advantage of the many processes that occur in natural

wetlands, but in a more controlled environment [1]. CWs wastewater treatment technology with horizontal subsurface flow (HFCW) on research conducted by Kathe Seidel from the 1960s and by Reinhold Kickuth in the 1970s [2].

In these systems, the wastewater is introduced at the inlet and slowly flows through the porous medium beneath the surface of the bed in a more or less horizontal path until it reaches the outlet zone where it is collected before leaving via a level control arrangement at the

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outlet. During this passage, the wastewater will come into contact with a network of aerobic, anoxic and anaerobic zones. Aerobic zones are around the roots and rhizomes that release oxygen into the substrate [3, 4]. Due to the long retention time, HFCWs have been shown to provide a reliable secondary level of treatment for organic matter (OM) and total suspended solids (TSS) [5-7]. It is well documented that the effectiveness of OM and TSS in HFCWs ranged from 72.0 % to 95.0 % for suspended solids, from 71.2 to 94.1 % for BOD and 59.7 % to 89.0 % for COD [8].

The substrate can not only provide supports for the growth of plants and microbes, but it also directly removes pollutants by sedimentation, filtration and adsorption, etc. A large number of researches have explored the purification of the constructed wetland by choosing substrates, plant species and planting conditions such as the size of the wetland bed, the breadth proportion water operating conditions and temperature, etc. [9, 10]. This article investigated the effect of eliminating HSFW on pollutants with different substrates in order to find a scientific and efficient substrate. An appropriately constructed wetland substrate plays a vital role in optimizing the wastewater treatment technology of the constructed wetland. The experiments were carried out in a pilot scale wetland with (*Phragmites Australis*) at flow rates of 4.99, 3.39 and 2.34 m³/day.

2. Materials and Methods

All experiments were carried out on a field-scale, subsurface, subsurface wetland system at the Sherbeen Wastewater Treatment Plant in Sherbeen City, Sherbeen, Dakahlia Governorate, Egypt. Some modifications were conducted at Samaha Sewage Treatment Plant to serve different purposes in this research investigation.

A comparative study among the media used i.e. rubber, gravel and plastic to select the one that provides the best efficiency in the Horizontal Subsurface Flow (HSSF) wetlands treatment system. Experiments were conducted in three parallel, horizontally flowing wetlands below the field surface. All units have a rectangular shape with identical dimensions of 10 m × 2.0 m × 0.65 m (length × width × depth). Three selected types of media were chosen for this study (shredded tires as rubber media, graded gravel and small pieces of hollow electricity corrugated pipes as plastic media). Flow rates were maintained at 2.34, 3.39 and 4.99 m³ / day.

Samples were taken twice a week and analyzed immediately. Experimental determinations of biological oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen, total suspended solids (TSS) and total phosphorus (TP) were conducted using standard methods for examination of water and wastewater [11].

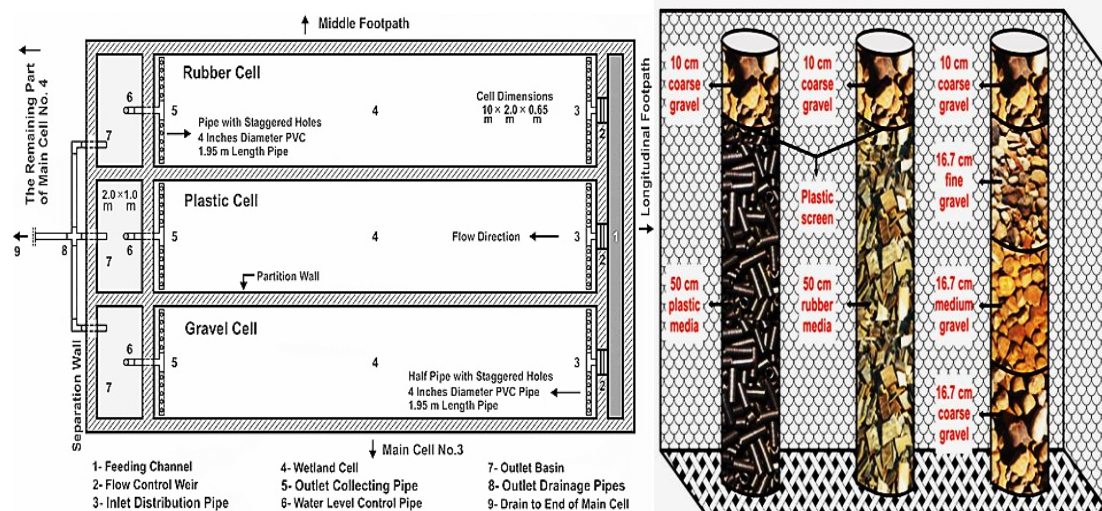


Fig. 1. Design of wetland treatment cells

3. Results and Discussion

3.1. Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) is removed by biological degradation and sedimentation processes.

Biological degradation of organic carbon in organic matter occurs in the wetland under aerobic conditions to produce CO₂ and, under anaerobic conditions, to produce methane. Figure 2 showed that plastic media have the highest removal efficiency at 74.43 % with the lowest flow rate

(2.34 m³/day), the removal of gravel was 68.16% and rubber was 61.2 % at the same flow rate.

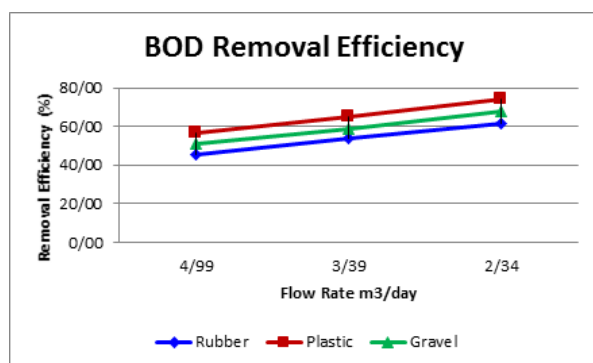


Fig. 2. Elimination of BOD using different types of media

3.2. Chemical Oxygen Demand (COD)

The removal of chemical oxygen demand (COD) from CWs relies mainly on the microbiological degradation of the matrix attached to the roots and roots of plants [12]. This mechanism responsible for COD reduction was probably a bacterial degradation in which oxygen synthetic photos produced by plant leaves were transferred to the root zones for bacteria to grow in the HSSF beds to biodegrade the organic compounds [13]. As shown in Figure 3, the plastic media showed the highest removal efficiency (74.9 %) to remove the COD from wetlands constructed at the lowest flow rate (2.34 m³/day), the gravel yield was 68.87% and the lowest value for removing COD was 63.72 % at the same rate.

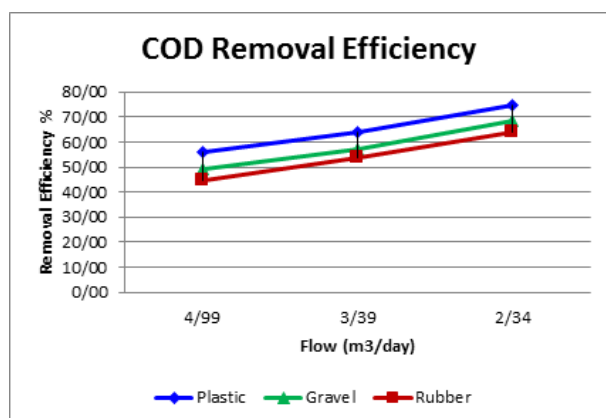


Fig. 3. Elimination of COD using different types of media

3.3. Total Kjeldahl Nitrogen (TKN)

The removal of nitrogen in the form of ammonia and organic nitrogen requires an oxygen supply for nitrification. This oxygen usually obtained from the roots of the plant. As the porosity of the medium increases, the transfer of oxygen through the medium also increases, so

the TKN decreases. Plastic and gravel substrates provide better microbial aeration sites than rubber, allowing for better mineralization of organic nitrogen and ammonium ion oxidation. As shown in Figure 4, the removal efficiency ranged from 53.33 % for rubber to 57.7 % for gravel and 63.28 % for plastic media.

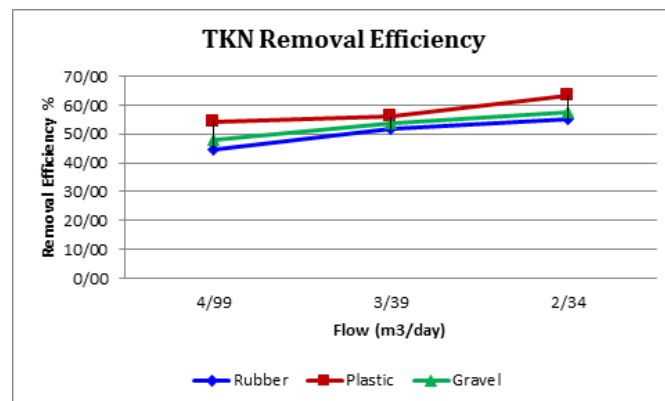


Fig. 4. Removing TKN using different types of media

3.4. Total Suspended Solids (TSS)

Total suspended solids (TSS) are solids in water that can be removed from the water sample by filtration to obtain an adequate filtration. The hydraulic conductivity of the bed must be large enough to allow the wastewater to contact the media. Suspended solids are removed by sedimentation, filtration and adsorption on the substrate. Figure 5 showed that TSS removal efficiency is 87.49 % for plastic, 73.66 % for gravel and 68.82% for rubber media at the lowest flow rate (2.34 m³/day).

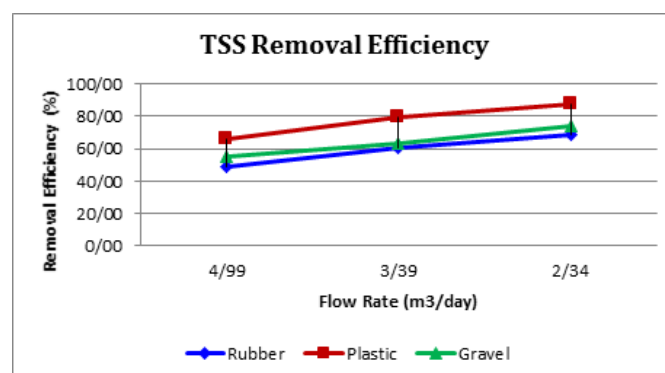


Fig. 5. Removing TSS using different types of media

3.5. Total Phosphorus (TP)

Phosphorus as the orthophosphate tends to accumulate in the system due to the lack of significant gaseous loss mechanism. Phosphorus retention by wetlands is regulated by physical mechanisms (sedimentation and entrainment) and biological (uptake

and release by vegetation, periphyton and microorganisms) [14, 15]. Figure 6 showed that the removal efficiency values are 71.29, 63.00 and 57.48 % for plastic, gravel and rubber media, respectively, at the lowest flow rate (2.34 m³ / day).

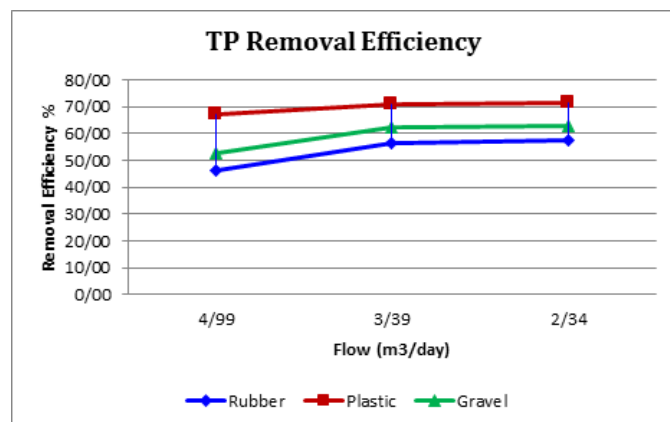


Fig. 6. Removing TP using different types of media

4. Conclusion

In the present work, the plastic supports showed the best results of the elimination rates of all the pollutants for the BOD, COD, TKN, TSS and TP in percentages of 74.42, 74.9, 63.28, 87.49 and 71.29 %, respectively. This can be attributed to the largest area and the largest layer of bacterial biofilms compared to other media. The gravel media took second place, followed by the third grade rubber. The properties of the effluent improved significantly as the effluents passed through the wetland cell and the quality of the effluent along the flow treatment path was improved.

Conflict of interest

The authors declare that they have no competing interests.

5. References

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