Selection of an Effective Substrate to Treat Gray Water in Horizontal Flow Constructed Wetlands

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Abstract: A study was carried out to compare the performances of different substrates used in a laboratory scale subsurface flow constructed wetland systems to treat gray water released from the university staff canteen. Three wooden boxes with the dimensions of 60cm x 25cm x 25cm were fabricated and 15mm rock aggregates, pebbles (15mm) and broken tiles (25mm) were used as substrates (which were selected considering the availability) in each of the boxes. Each horizontal subsurface flow bed was fed in a batch process with gray water with a flow rate of 20 litres per day. The retention time for each batch was maintained as 6 days. BOD, COD, pH, conductivity, NO_3^-, PO_4^{3-}, turbidity and temperature in the influent and the effluent were monitored for every batch of waste water passed through the systems and their removal efficiencies were determined. The highest removal efficiencies of COD and, BOD, and PO_4^{3-} were 80%-90% and 60% - 80%, respectively were recorded from broken tiles, while highest removal efficiency of NO_3^-, of 60% - 90%, was recorded from aggregates. Removal of turbidity in all three tanks was similar being between 60%- 90%. Hence, crushed aggregates and broken tiles are found to be the best substrates, considering the removal efficiencies to treat gray water.

Keywords: Batch process, Laboratory scale, Removal efficiency, Retention time

1. Introduction

Haphazard disposal of untreated wastewater from households as well as institutions are causing severe deterioration of water bodies in many urban areas in the developing world. Constructed wetlands for wastewater treatment is now a widely accepted and increasingly common treatment alternative. Substrates used in these constructed wetlands play an important role in the removal efficiencies of nutrients and other parameters. Substrate is used as a media where micro-organisms grow attached and they help in the degradation of organic matter in the gray water.

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The surface characteristics of the substrates also help in the removal. Media absorption, chemically enhanced settlement and degradation by the micro-organisms are some of the key removal mechanisms in wetlands (Zhi-Dan Nie et al., 2007).

The literature has shown that the effluent stability of subsurface flow wetland is better than that of free surface wetland (Huan Jing Ke Xue., 2007). Selection of a suitable substrate is critical since it facilitates the growth of micro- organisms and also acts as a filtering media.

Therefore, a study was conducted with the objective of selecting the most efficient substrate out of pebbles, aggregates, and broken tiles in treating gray water from the university staff canteen in a subsurface horizontal flow constructed wetland.

2. Methodology

2.1 Experimental setup

Three wooden boxes with the dimension of 60cm x 25cm x 25cm were fabricated. The boxes were completely lined with high grade polythene to prevent leakage. The outlet was fixed with a 12.5 mm PVC pipe as shown in the figures 1a and b.

Sieved and properly washed 15mm rock aggregates, pebbles (15mm) and broken tiles (25mm) were used as different substrates in the three boxes. The selection of the substrate types depended on the availability of the material.

2.2 Feed water

Gray water outlet of the staff canteen of the University of Moratuwa was tapped around the same time of the day (at around 9.30 a.m once in 6 days) to collect influent water to the treatment cells. Gray water was passed through the treatment cell in batches. The influent (feed water) stored in the overhead bucket entered the cell at a flow rate of 20 l/d and was retained in the system for 6 days (Figure 2). After the 6 day retention period, the effluent (treated water) were collected at the outlet, located 5 cm above the bottom level. The same cycle was repeated for seven times from 18.03.2009 to 08.05.2009.

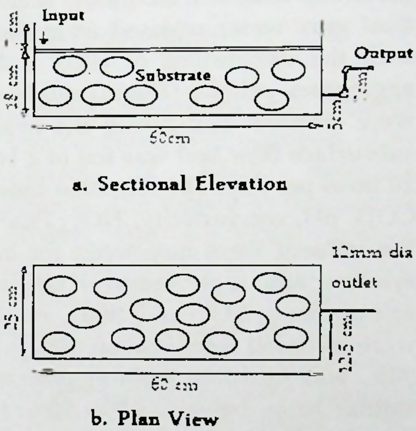

Figure 1. Typical arrangement of a treatment cell

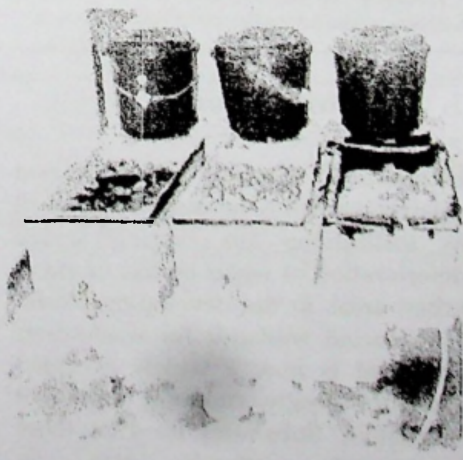

Figure 2. Experimental setup

2.3 Water quality analysis

Feed water as well as treated water was tested for pH (Hannah pH meter), conductivity (WP-84 conductivity-salinity), turbidity (TURB 350 IR), COD, BOD5, NO_3^- and PO_4^{3-} in the laboratory immediately after collection. Water samples were filtered through Millipore membrane filters (0.45µm) for P and N determinations. Chemical analysis was performed according to ASTM standards (1998).

Vanadomolybdophospheric acid colorimetric method was used for phosphorus determination and the amount of phosphorus in PO_4^{3-} form was measured. Nitrate was determined using the ultraviolet spectrophotometric (HACH, DR 2800) screening method.

COD was determined by the open reflux method (Selecta, SY 567) while BOD by the 5-day BOD tests (ASTM, 2002).

3. Results

Figures 3 to 6 show the COD, NO_3^-, PO_4^{3-} and turbidity values of influent and treated waste water with respect to the different substrates.

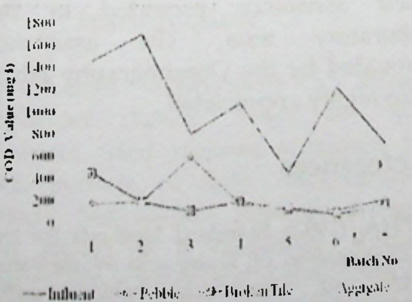

Figure 3. Values of COD of the influent and treated water for the three substrates

Broken tiles showed higher removal efficiency (around 80% - 90%) with respect to COD and BOD than the aggregates. The efficiency of pebbles was in the range of 40% - 80%.

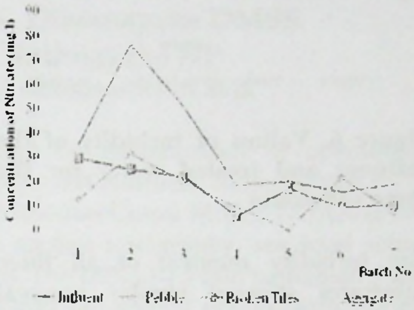

Figure 4. Nitrate concentrations for the influent and the treated water in all three substrates

Aggregates showed a higher nitrate removal efficiency (around 60% - 90%) compared to the pebbles and broken tile mediums. The nitrate removal efficiencies of the latter two mediums were in the range of 40% - 70%.

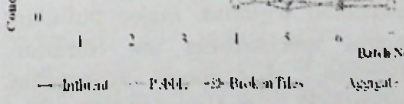

Figure 5. Phosphate concentrations for the influent and the treated water in all three substrates

Broken tiles showed slightly higher phosphate removal efficiency (around 60 - 80%) than pebbles, the efficiency being 50% - 70%.

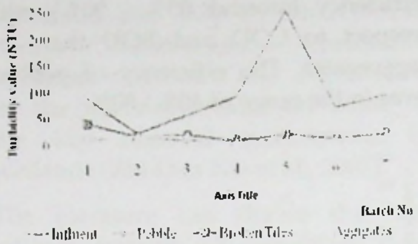

Figure 6. Values of turbidity of the influent and treated water for the three substrates

The turbidity removal of all three substrates showed similar removal efficiencies being around 60% - 80%, however aggregates outweigh them slightly showing around 90% removal efficiency.

The pH of the treated waste water was found to be in the range of 6.6 – 6.8 in all three substrates. However, aggregates showed a comparatively higher efficiency in the range of 20 % compared to pebbles and broken tiles in stabilising the pH.

4. Discussion

Once a wetland cell is commissioned, it takes above 4 – 6 months to attain the stabilised conditions. In a stabilised subsurface horizontal flow constructed wetland, major pollutant removal mechanisms are filtration, settlement, absorption, adsorption, nitrification and denitrification. However, in the present study, the age of the wetland cell is only 50 days. Hence, the higher removal efficiencies were displayed by broken tiles for BOD, COD and PO_4^{3-} removal and by aggregates for NO_3^- removal.

Due to the anaerobic conditions in the cell, denitrification helps the removal of nitrates whereas sorption occurs in the broken tile surface substituting the silicate molecules in the clay media with phosphate molecules.

If treated water is used for gardening /agricultural purposes broken tiles can be recommended as the most suitable substrate since it will maximise BOD/COD removal while retaining essential nitrates and phosphates for plant growth which will cut down the fertiliser costs in farming.

5. Conclusion

The overall removal efficiencies of the contaminants suggest that for the treatment of gray water released from domestic places, crushed aggregates or broken tiles are the best substrates depending on the final usage of the treated water. Therefore, broken tiles are more suitable if the treated water is used in agriculture and aggregates are preferred if they are discharged into surface water bodies.

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