Nutrients, Fe and Bacterial Removal in Sub Surface Flow Constructed Wetlands Treating Polluted Mine Water

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Abstract: A study was carried out to compare the performance of a pilot scale subsurface flow constructed wetland system to treat polluted water in Ragama prison quarry, an abandoned mine pit. Two cement sand tanks with the dimensions of 7.5 m × 0.75 m × 0.75 m were constructed. Both the tanks used a mixture of aggregates as the substrate, where 40-60 mm was used in the treatment zone and both 20-30 mm and 40-60 mm was mixed in the ratio of 1:1 in the inlet and outlet zones. *Typha Latifolia (T.Latifolia)* was planted in one tank, while the other was kept unplanted as the control. The initial plant biomass density was 1.7 kg/m². Each horizontal subsurface flow bed is fed continously with polluted water at 173 litres per day and the retention time was maintained as 8 days. Concentration of nitrate, nitrite, ammonia, total and ortho phosphate, Fe and faecal coliform in the influent and effluent of the wetland system were monitored daily and their removal rates were determined. Nitrites, nitrates, phosphorus and Fe removal.in planted tank varied between 45%-80% whereas it was between 40%-70% in the unplanted tank. Removal efficiency of free ammonia in planted system was 6 % less than that of unplanted tank .However, bacterial removal in both planted and unplanted tanks were similar being 51%.

Keywords: Abandoned mines, Environmental pollution, Removal efficiency, *Typha Latifolia*

1. Introduction

The construction of artificial wetlands for wastewater treatment is now a widely accepted and increasingly common treatment alternative. Constructed wetlands were initially utilized for nutrient removal in residential and municipal sewage, storm water and agricultural runoff displaying a wide range of removal efficiencies. Aquatic vegetation plays an important role in removing nutrients in wetlands. (Brix 1997; Koottatep and Polprasert 2002; Matheson et al. 2002). Plants take up nutrients such as N, P and transport oxygen to the root area to enable aerobic microbes to decompose the pollutants (Allen 1997) and aid in the settling of suspended material (Gopal, 1999).

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In recent times, degradation of water quality and ground water pollution has become a prominent adverse effect associated with abandoned mines. Therefore a study was conducted with the objectives of

1) Designing and constructing a pilot scale subsurface flow constructed wetland system to remove nutrients, Fe and bacteria from the polluted mine water in Mahara prison quarry
2) Estimating the removal efficiencies of the constructed wetland system.

2. Materials and Methods

2.1. Design of the pilot scale constructed wetland

Two tanks with the dimensions of 7.5m × 0.75m × 0.75m were constructed with cement+ sand+ aggregates and cured for 14 days. After the curing period properly washed aggregates (using 20 mm sieve) were packed in the inlet, and the outlet zones. Both the tanks were flushed with tap water for 3-4 times daily for a period of 5days.At the end of the 5 days one tank was planted with *T.Latifolia*. (Figures 1A & B). The height and the dry weight of the plants were in the range of 70-80 cm and 80-100g respectively. The initial biomass density was 1.73 kg/m^2. Planting was carried out in 2 plants per row and 3 plants per row alternatively. A constant interval of 25 cm was maintained between the rows. Plants were acclimatized for 60 days while adding the nutrients once in two weeks. (10 g/l each of nitrophoska 3000) before introducing the polluted water.

The influent entered the wetland through a PVC tube with an diameter of 25mm.The polluted water was transported once in every 4 days, stored in plastic barrels and transferred to the overhead tanks daily to maintain a constant head. Retention time was 8 days with plug flow conditions (length/width ratio of the tank is 10).

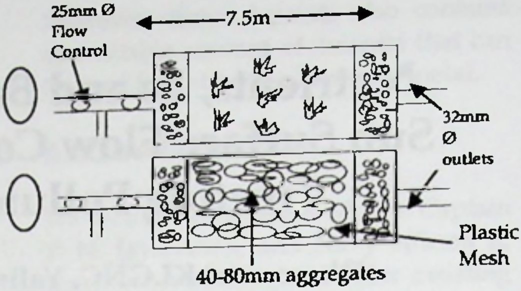

Figure 1A: Plan view of the constructed wetland constructed at the University of Moratuwa premises

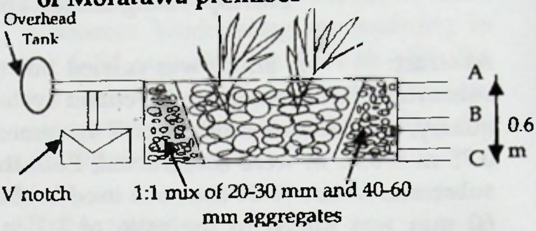

Figure 1B: Sectional elevation of the constructed wetland

2.2. Sample collection

Water samples were collected daily from 10.09.2007 to 30.09.2007. The samples were taken in triplicates at the inlet, center and the outlet of both tanks. The outlet samples were collected at the overflow (A) and at a height of 0.3m from the bottom (B).

2.3. Water analysis

Conductivity (33 model YSI conductimeter), dissolved O_2 (Hannah OM-14 portable meter) pH (Hannah pH-meter and the turbidity (20 model YSI turbidity meter) measured in the field. Water samples were filtered through Millipore membrane filters (0.45 μm) for P and N determinations. Chemical analysis was performed according to ASTM standards(1998); NO_2^- (coupling diazotation followed by a colorimetric technique), NO_3^- (potentiometry), free NH_3 (nesslerization), ortho phosphate (colorimetric molybdenum blue method) (Murphy and Riley, 1978) were measured in the laboratory using UV Spectrophotometer (model 1450 DE). Fe was determined by the atomic absorption spectrometer (AAS 500FG). COD was determined by the open reflux method (SY 567) and BOD by the 5-day BOD test (ASTM, 2002).

2.4. Statistical analysis

Statistical significance between 2 means were assessed using a paired- t test at $p<0.05$.

3. Results

Table 1 summarizes the efficiency of parameters measured at the inlet and outlet of the planted and the unplanted wetland system over 21 days. Comparison of the inlet and the outlet parameters showed a significant improvement of water quality ($p< 0.05$). Except for free NH_3 concentrations the other removal efficiencies in the planted cell are considerably higher than the unplanted (figures 2 to 4). COD was reduced by 60.3% and 49.5% at the planted and unplanted outlets, respectively, suggesting a large decomposition and metabolism of incoming organic matter. Nitrate and Ortho Phosphate were reduced by 81.1% and 79.6% in the planted and 71.8% & 56.2% in the unplanted (figures 2 and 3). The removal efficiency of Fe by the planted cell than the unplanted is significantly higher ($p<0.05$), the efficiencies being 73.9% and 58.2% respectively (figure 4)

4. Discussion

Planted cell displayed higher removal efficiencies than the unplanted cell in all most all parameters. However free NH_3 concentration was nearly lower in the planted than the unplanted cell. Organic mineralization represents an important source of ammonium, which is not nitrified most probably due to low O_2 concentration limiting nitrification. Given the observed, oxygen depletion it seems likely that denitrification is one of major removal processes.

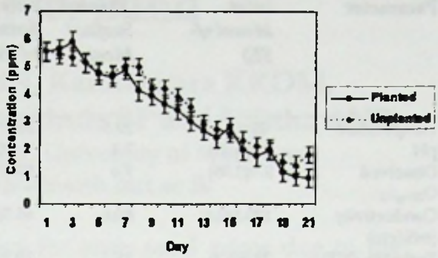

Figure 2. Variation Of Nitrate Concentration at a depth of 0.3m from the bottom (ppm +/- SE)

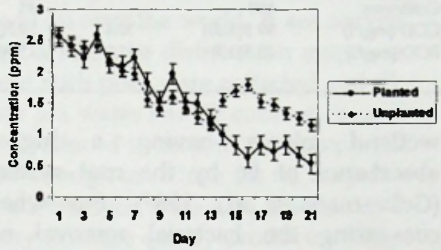

Figure 3. Variation Of Ortho Phosphate Concentration at a depth of 0.3m from the bottom (ppm +/- SE)

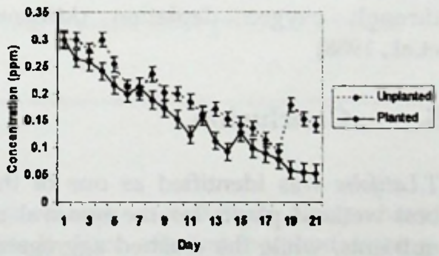

Figure 4. Variation Of Fe Concentration at a depth of 0.3 m from the bottom (ppm +/- SE)

D'Angelo and Reddy (1993) determined that most of the 15 N-nitrate (roughly 90%) applied to sediment-water cores was lost by denitrification. Organic matter mineralization increased CO_2 concentration in water, which, in turn decreased water pH to be 7.4 in the planted and 7.9 in the unplanted cell. The major removal mechanism for Fe is the plant uptake, since *T.Latifolia* has been identified as one of the major

Table 1: Removal efficiencies of measured parameters over a period of 21 days

Parameter	Inlet *Mean(+/- SE)*	Planted Outlet *Surface Mean*	Planted Outlet *Bottom Mean (+/- SE)*	Unplanted Outlet *Surface Mean Mean*	Unplanted Outlet *Bottom (+/- SE)*	Mean Removal % in Planted	Mean Removal % in Unplant
Temperature	29.5	29.5	29.5	29.5	29.5	9.75	3.65
pH	8.2(0.05)	7.1	7.4(0.05)	7.7	7.9(0.05)	-10.1	-7.8
Dissolved $O_{2(mg/L)}$	8.9(0.05)	7.8	8.0(0.05)	8.2	8.3(0.05)		
Conductivity (mS/cm)	120.5(0.4)	80.6	65.2(0.55)	91.2	72.5(0.05)	45.8	42.8
Turbidity (NTU)	23.5(0.3)	15.5	10.2(0.2)	19.4	12.2(0.2)	56.6	48.1
NO_2 (ppm)	0.005(0.0004)	0.001	0.0018(0.0005)	0.0022	0.0025(0.0005)	64	50
NO_3 (ppm)	5.5355(0.002)	0.9356	1.0462(0.005)	1.2525	1.5623(0.005)	81.1	71.8
Free NH_3 (ppm)	0.0865(0.002)	0.0512	0.0552(0.0025)	0.0462	0.0498(0.0036)	36.2	42.4
Ortho PO_4 (ppm)	2.5623(0.037)	0.4255	0.5236(0.011)	0.9865	1.1235(0.014)	79.6	56.15
Fe (ppm)	0.3(0.005)	0.0525	0.0782(0.0004)	0.1156	0.1254(0.0006)	73.9	58.2
Coliforms	100		48		51	52	49
COD (mg/l)	99.5(0.65)	30.4	39.5(0.3)	45.3	50.2(0.45)	60.3	49.5
BOD (mg/l)	25.5(0.3)	11.2	13.5(0.35)	15.9	18.9(0.5)	47.1	25.8

wetland plants having a higher absorbance of Fe by the root system (Golterman et al., 1988). But when comparing the bacterial removal no significant difference could be observed between the planted and the unplanted cell. The reason being the aggregates contribute much to the bacterial removal through oxygen depletion (Minzoni et.al., 1988)

5. Conclusion

T.Latifolia was identified as one of the best wetland plants for the removal of nutrients, while the crushed aggregates identified as one of the best substratum. The overall efficiencies of removal of contaminants removal efficiencies suggested, the current design for possible appropriateness of the use of similar systems in clean up and restoration of waste water and polluted water in abandoned mines and elsewhere

Acknowledgement

The authors would like to express their sincere gratitude to Dr.D.M.D.O.K. Dissanayake, the present Director of Geological Survey and Mines Bureau (GSMB) and Mrs.Siriwardene, chief chemist of GSMB for their kind co-operation & generosity. The assistance provided by Ms.Dilani de Seram is highly appreciated. This project was funded through a short term research grant awarded by the University Of Moratuwa and Lanka Quarries (Pvt) Ltd

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