Feasibility Studies of a Constructed Wetland to Treat Contaminated Water

Weerasooriya UK, Dilrukshi RAN, Adikari AMHV, Rajeeth A, Achchuthan P and *Karunarathne S
Department of Earth Resources Engineering, University of Moratuwa
*Corresponding author – shiromi@earth.mrt.ac.lk

Abstract: Among the vast number of methods that can be applied for the treatment of contaminated water, one of the best methods of treating of abandoned mine water was identified as the subsurface flow constructed wetlands through pytoextraction. Therefore further research was carried out to the applicability of constructed wetland to treat polluted water at abandoned quarry in Ragama (Prison Quarry). The main objective of the study was to measure the removal efficiencies of BOD, COD, NH_3, NO_3^-, PO_4^{3-} using *Thypha Latifolia* (Cattail). The hydraulic retention time was 8 days. The concentration of Nitrate, Orthophosphate and Ammonia was monitored twice a week and BOD and COD were monitored once a week in order to determine their removal rates. While monitoring the removal efficiencies, the mechanisms of N, P and COD removals were identified. The mechanisms are based on the principle of mass conservation. The main nitrogen removal mechanisms identified were plant uptake and denitrification. It is assumed that ammonia and nitrate removal from wetlands by macropytes depended on the biomass of the roots. Average Nitrate and Ammonia removal from the planted cell was 42.9% and 27.8%, respectively, whereas the removal efficiency of Ortho Phosphate was 17.5% in the planted tank. *Typha latifolia* was identified as a suitable wetland plant which can remove nitrogen compounds in contaminated water.

Keywords: Conceptual models, pyto-extraction, removal efficiency, *Typha Latifolia,*

1. Introduction

The constructed wetlands are considered as an environmental friendly, increasingly common treatment alternative for waste water treatment. These are complex and integrated systems in which water, plants, micro-organisms and the environment (sun, air) interact to improve water quality. Wetlands filter out pollutants and act as sinks for nutrients through physical, chemical and biochemical processes. The capacity of aquatic macropytes to control pollution and to treat municipal and industrial waste water has been exploited worldwide. Degradation of water quality has become a major problem associated with abandoned mines. These contaminated waters show relatively low concentrations of Nutrients which cannot be treated easily using other methods due to higher operational and maintenance costs. And the pollutants can be easily removed by advanced treatment such as Constructed Wetlands.

The overall goal of the study was to determine the feasibility of a Horizontal

Karunarathne S, B.Sc. Eng (Hons)(Moratuwa), M.Sc. (Saitama), PhD (Saitama), MASCE(USA), MIE(SL), Senior Lecture in Department of Earth Resources Engineering, University of Moratuwa.
***Weerasooriya UK, Dilrukshi RAN, Adikari AMHV, Rajeeth A, Achchuthan P,** Final year undergraduate students in the Department of Earth Resources Engineering, University of Moratuwa.*

Sub Surface Flow Constructed Wetland (HSSFCW) to remove contaminants such as Nitrogen, Phosphorous, BOD and COD from the polluted mine water in Mahara Prison Quarry and to formulate conceptual models for N and P removal.

2. Methodology

The pilot scale constructed wetland consists with both planted and unplanted tanks with the dimensions of 7.5mx0.75mx0.75m and crushed aggregates (20-30mm and 40-60mm) as substrate. The wetland plant chosen was *Typha Latifolia* (Cattail) because of its higher ability of uptake Ammonia, Nitrates and Phosphates.

During the study, we collected water quality data according the mechanisms described by the conceptual Nitrogen model (Figure 2) and Phosphorous Model (Figure 3).

2.1 Sample analysis

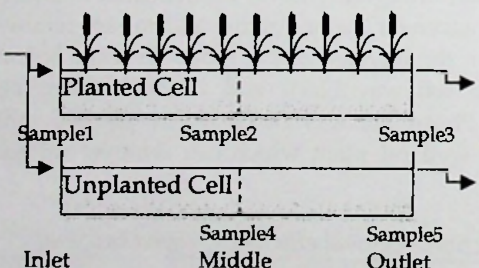

Figure 1 - Sampling locations of the pilot plant

Water samples were collected simultaneously at inlet, middle (through a perpetrated pipe) and outlet of both planted and unplanted tank and the samples were analysed for conductivity, DO, pH and the turbidity in the field. Chemical analysis was performed according to the ASTM standards(1992) for NO_3^--N (Ultraviolet Spectro-photometric Screening Method), NH_4^+-N (Nesslerization Method), Organic N (Macro Kjeldahl Method), Ortho phosphate (Vanadomolybdophosphoric Acid Colorimetric Method), Total Phosphorus (Sulphuric acid-Nitric acid Digestion), and total acid hydrolysable phosphate (H_2SO_4 hydrolysis) in the laboratory using UV Spectrophotometer. Sample analysis was done once a week for COD and BOD and twice a week for NO_3^--N, NH_4^+-N and Ortho phosphate.

The treatment mechanisms identified in the wetland was Pyto-extraction (plant uptake), Denitrification, and Substrate utilization. The removal efficiencies were evaluated using chemical analysis.

2.2 Conceptual model formulation

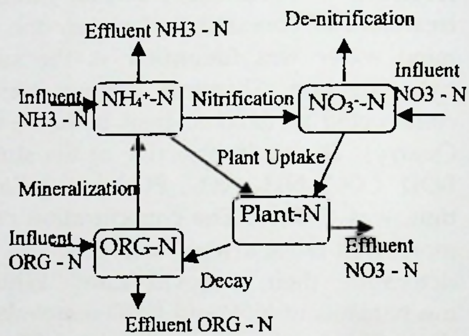

Figure 2 - Simplified conceptual model for nitrogen removal

The model of N removal processes includes nitrification, denitrification, mineralization, plant uptake and plant decay. In here, we assumed that the removal rate was constant along the wetland from inlet to outlet.

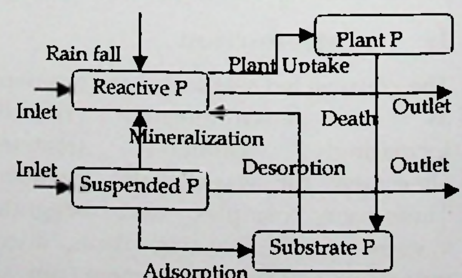

Figure 3 - Simplified conceptual model for phosphorous removal

In the P model, sediments on the substrate were accounted as additions from macrophyte death and adsorption of organic sediments. The reactive P (Ortho- phosphate) balance was accounted using mineralization from suspended P (Organic P), inflows, outflows, and desorption. Organic- P was accounted using inflow, outflow, adsorption and mineralization.

2.3 Statistical analysis

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

3. Results

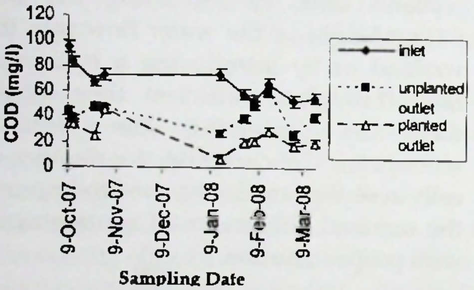

Figure 4 - Variation of COD in the constructed wetland (ppm +/- SE)

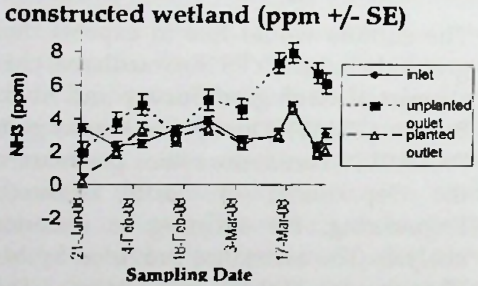

Figure 5 -Variation of NH_4^+-N in the constructed wetland (ppm +/- SE)

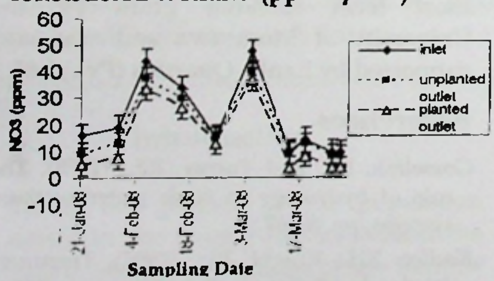

Figure 6 - Variation of NO_3^- -N in the constructed wetland (ppm +/- SE)

Comparison of the planted and the unplanted tank removal efficiencies of almost all parameters showed significant improvement of the water quality in the planted tank except for NH_4^+-N and ortho phosphate in the unplanted tank. Average removal efficiencies of COD ($p<0.05$) in planted tank and unplanted were 63.2% and 36.8% and for BOD, they were 43.8% and 37.7%, respectively. NH_4^+-N and NO_3^--N were reduced by 27.8% and 42.9%, respectively in the planted tank. Average removal efficiency of PO_4^--P in the planted tank was only 17.5%.

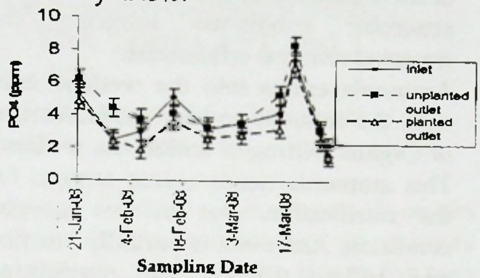

Figure 7 - Variation of PO_4^{3-} -P in the constructed wetland (ppm +/- SE)

3.1 Nitrogen Mass Balance

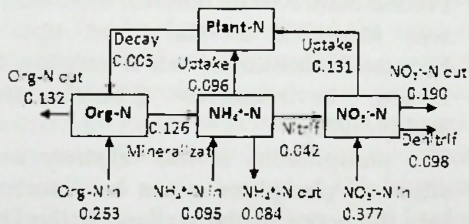

Figure 8 - Nitrogen transformation and removal in HSSFCW (g N/m²/d)

Plant uptake shows about 31% (0.227gN/m²/d) removal of the influent total N (0.725gN/m2/d).

4. Discussion

Planted cell displayed higher removal efficiencies than the unplanted cell in almost all parameters.

The DO level and the concentration of nutrients and COD can be decreased due to storing of contaminated water for about 2 weeks in an overhead tank while using in the pilot plant and then the available oxygen can be consumed by the available microorganisms for utilization of Nutrients/Foods before enters into the wetland cells. Also due to lack of mixing in the overhead tank, DO decreased with the time (DO in the influent varied between 7.4ppm and 3.5ppm). Therefore the water entering into the wetland had low concentration of oxygen. And also the wetland being subsurface flow type, there is very low contact between water and atmosphere, which also cause to decrease the oxygen concentration further. Therefore towards the outlet part of the wetland cell, this may lead to form anaerobic conditions lowering the expected removal efficiencies.

Ammonia enters into the wetland cells with the influent and by mineralization of Organic Nitrogen within the wetland. This ammonia needs excess oxygen for the nitrification. But in low oxygen condition, Ammonia is partially nitrified and bellow 0.3ppm, the nitrification stops (Patrick and Reddy, 1976). Therefore the predominant Ammonia removal process is plant uptake.

Predominant Nitrate removal mechanism was identified as the plant uptake because denitrification rate is very low in aerobic environments (Patrick and Reddy, 1976).

The phosphorous in the substrate and adsorbed phosphorous can be desorbed into the water in the wetland if the DO level in the wetland falls below 2.0ppm (Gosselink and Turner, 1978). The water in the wetland showed the DO around 2.1ppm. Therefore it is possible to increase the phosphorous concentration in the unplanted cell even higher than the inlet concentration. But plant uptake is predominant in the planted cell; hence the concentration of the effluent is low.

Mineralization is the biological transformation of organic matter through degradation. The main removal mechanism for COD and BOD was identified as mineralization.

5. Conclusion

According to the results, the removal efficiencies were low due to low DO concentrations. However, this wetland system can be used for effective treatment by improving the DO in the wetland water. Further more, *Typha latifolia* is a suitable wetland plant, which can remove nitrogen compounds in contaminated water.

The main removal mechanism for both Ammonia Nitrogen and Nitrate Nitrogen can be concluded as plant uptake. Therefore, by increasing the biomass density, the removal efficiencies of nutrients can be increased.

Aeration of the wastewater can be improved prior to entering into the wetland cells by increasing the free falling height of the water flow into the wetland or by introducing a horizontal flow through a sufficient flow length there by increasing the removal efficiencies. Concurrently the number of cells in series can also be used to improve the removal efficiencies of contaminants with proper aeration.

Acknowledgements

The authors would like to express their gratitude to Mrs. YPS Siriwardhane, chief chemist of Geological Survey and Mines Bureau (GSMB). Our special thanks go to Prof. WLW Fernando, senior professor in the Department of Earth Resources Engineering, for assisting in chemical analysis. The assistance provided by Ms. Thanuja is highly appreciated. This research project was funded through a short term research grant by the University of Moratuwa and was also supported by Lanka Quarries (Pvt.) Ltd.

References

Gosselink, JG., and Turner, RE., (1978). The role of hydrology in fresh water wetland systems, pp. 63-67.

Kadlec, RH., Knight, RL., (1996). Treatment Wetlands. CRC Press, Boca Raton, pp. 893.

Merete Bang Petersen., (2003). Nitrogen Removal from Domestic Wastewater by Indigenous Macrophytes in Horizontal Sub-surface Flow Constructed Wetlands in Tanzania, pp.72, 73, 115.

Patrick, WH., and Reddy, KR., (1976). Nitrification-denitrification in flooded soils and water bottoms: dependence on oxygen supply and ammonium diffusion, Journal of Environmental Quality, pp.469-472.