POLLUTION REDUCTION POTENTIAL OF SUBSURFACE FLOW CONSTRUCTED WETLAND SYSTEM

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ABSTRACT: Wetlands have been used as a potentially cost-effective secondary waste water treatment system to treat the waste water before discharge into the water bodies. The aim of this study was to compare the pollution reduction ability of plant species at various depths in a constructed wetland system. Two different grass species such as *Eleucine indica* (Goose grass), *Dactyloctenium aegyptium* (Crowfoot grass) and a sedge namely *Cyperus iria* (umbrella sedge) and the control without any plant species were introduced in the constructed wetland system. The system was operated continuously by inlet valve from tank filled with storm water. Physicochemical parameters such as pH, DO, BOD, TS, Nitrate and Phosphate contents were measured in one week interval using standard procedures. The results revealed that the pollution reduction ability was very high in *Cyperus iria* at one foot depth whereas the nitrate and phosphate reduction ability was comparatively high in *Cyperus iria* at their 1.5 feet depth.

Keywords: wetland, secondary treatment, sedge, pollution reduction

1. INTRODUCTION

Wetlands provide water quality improvement by providing effective free treatment for many types of water pollution. Large quantities of pollutants from point sources and non-point sources have been removed by the process of natural filtration, sedimentation and phytoremediation in a cost effective manner (Doku et.al, 1993). These benefits had created a global interest in constructing wetlands for the main purpose of wastewater treatment (Kadlec and Wallace 2009). Sherwood and Reed (1993) reported that the emergent plants found in wastewater wetlands include cattails, reeds, rushes, bulrushes and sedges. They absorb their nutrients form sediment or directly from the water and some of them have highly developed root systems in the sediment layer.

Vavuniya tank where the waste water from the Vavuniya town discharged without proper treatment causes pollution. It affects the crop productivity and the livelihood of fishermen who do fresh water fishing in this tank. Natural wetland system would be a most preferable secondary treatment system to treat the waste water before discharge into the water bodies. Mainly in dry zone area grasses are more suitable than the floating weeds. In dry season floating weeds are difficult to survive in considerably high temperature.

This proposed project aims to compare pollution reduction potential of a constructed artificial wetland system using naturally available plant species such as *Eleucine indica* (Goose grass), *Dactyloctenium aegyptium* (Crowfoot grass) and a sedge namely *Cyperus iria* (umbrella sedge) and the control without any plant species.

2. METHODOLOGY

The subsurface flow constructed wetland systems were constructed with three plant species and one control (figure 2). The dimension of each system was 1.2m length, 0.6m width and 0.8m height. The bottom and around of wetlands were built with brick and

plastered with concrete. The inlet part was directly connected with waste water tank whereas each system has three outlets (figure 1) separately. 1st outlet was in the 0.3m depth (1st depth) whereas the 2nd outlet in 0.5m (2nd depth) and 3rd outlet (3rd depth) in 0.6m depth installed in the constructed wetland system. The treatment and control systems were filled in the order of coarse gravels up to 0.1m height, then sand, fine gravel and fertile soil mixture (2:1:7) up to 0.4m height there after the fertile soil was filled up to 0.5m height. Then the storm water was filled up to 0.7m height.

Figure 2: outlets of the wetland system

Figure 1: Introduced plant species in wetland system

The waste water in the Vavuniya town area discharges to the Vavuniya tank. This waste water went through the grid to remove the large particle then reach to the oxidation pond which was not in working condition and directly discharge to the tank. For this research, the inlet waste water was collected in between the grid and oxidation pond. Two grass species such as *Eleucine indica* (Goose grass), *Dactyloctenium aegyptium* (Crowfoot grass) and a sedge namely *Cyperus iria* (umbrella sedge) were selected for the wetland system. Forty plants were planted in each treatment. The sample collection was started after three weeks of establishment of the plant species at each three depths. Three samples was collected in each outlets. The system was operated by inlet valve from tank filled with storm water while the retention time was three days. During this time, the invasive plants were removed and cut the wetland plants before the flowering time.

The physicochemical parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total solids (TS), concentration of phosphate and nitrate of water were measured (Reeta Kori, S. P., 2007) for the inlet wastewater and the outlet water after passing through the wetland system collected at three different depths in one week interval sstarting after three weeks of grass and sedge establishment from mid of August to end of November 2014.

The statistical analysis especially mean comparison was used to compare the pollution reduction ability of plant species at various depths in a constructed wetland system. Three replicates was used for each cases indicated by "N" whereas the grouping information showed by the letters explained the mean comparison.

3. RESULTS AND DISCUSSION

Analysis of physicochemical parameters

I. pH

The average pH level in inlet was 8. According to the Sri Lankan standard accepted pH level should be in between 6.5 – 8. Results revealed that plant species had the ability to reduce the pH within the acceptable limit. The pH reduction efficiencies of *Eleucine indica*, *Dactyloctenium aegyptium* and *Cyperus iria* were nearly 8%, 6% and 10% respectively at their first depth.

A. Tukey* Pairwise *Comparisons among the plant species

(Grouping Information Using the Tukey Method and 95% Confidence)

Table 4: Tukey Pairwise Comparisons for pH among plant species

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	0.708889	A
Eleucine indica	3	0.518889	B
Dactyloctenium aegyptium	3	0.425556	C
Control	3	0.156667	D

B. Tukey Pairwise Comparisons among the depths

(Grouping Information Using the Tukey Method and 95% Confidence)

Table 5: Tukey Pairwise Comparisons for pH among the depths

Depth	***N***	***Mean***	***Grouping***
1	4	0.5350	A
2	4	0.4375	B
3	4	0.3850	B

Mean comparison for every plant species and control showed that the mean of *Cyperus iria> Eleucine indica* > *Dactyloctenium aegyptium* > control for depths, mean of depth1 > depth2 = depth3. Hence *Cyperus iria* has high pH reduction ability at 1st depth.

II. Total Solids (TS)

The inlet water consisted nearly 1265ppm of total solids. The accepted level for TS in the waste water must be below 50ppm before discharge into the inland water bodies. In this study no plant species had the ability to reduce the TS level below the standard. The TS reduction efficiencies of *Eleucine indica*, *Dactyloctenium aegyptium* and *Cyperus iria* were nearly 84%, 75% and 92% respectively at 3rd depth. This may be due to the inadequate retention time and the depth

A. Tukey Pairwise Comparisons among plant species

(Grouping Information Using the Tukey Method and 95% Confidence)

Table3: *Tukey Pairwise Comparisons for TS among the plant species*

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	1098.56	A
Eleucine indica	3	994.00	B
Dactyloctenium aegyptium	3	855.67	C
Control	3	503.78	D

B. *Tukey* Pairwise Comparisons among the depths

(Grouping Information Using the Tukey Method and 95% Confidence)

Table4: Tukey Pairwise Comparisons for TS among the depths

Depth	***N***	***Mean***	***Grouping***
3	4	928.417	A
2	4	868.250	A
1	4	792.333	B

Mean comparison showed that the mean of *Cyperus iria* > *Eleucine indica* > *Dactyloctenium aegyptium* > control and according to mean comparison for depths, mean of depth3 = depth2 >depth1. Hence *Cyperus iria* had high TS reduction ability at 3rd and 2nd depth.

III. Dissolved Oxygen (DO)

DO of inlet waste water was around 1.2 ppm. Regarding the surface water bodies' standard for DO level must be above 5ppm. Here *Dactyloctenium aegyptium* did not have the ability to increase the DO level above 5ppm at their 2nd and 3rd depth. The ability of increasing DO level was gradually increasing with increasing depth. The DO increasing efficiencies of *Eleucine indica, Dactyloctenium aegyptium* and *Cyperus iria* were nearly 10, 6 and 13 times respectively at 1st depth.

A. Tukey Pairwise *Comparisons among plant species*

(Grouping Information Using the Tukey Method and 95% Confidence)

Table5: *Tukey Pairwise Comparisons for DO among the plant species*

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	11.0642	A
Eleucine indica	3	7.8597	A
Dactyloctenium aegyptium	3	4.0927	B
Control	3	3.1556	B

B. Tukey *Pairwise* Comparisons among the depths

(Grouping Information Using the Tukey Method and 95% Confidence)

Table6: Tukey Pairwise Comparisons for DO among the depths

Depth	***N***	***Mean***	***Grouping***
1	4	9.5925	A
2	4	6.0020	B
3	4	4.0346	B

The mean comparison for plant species and control revealed that mean of *Cyperus iria* = *Eleucine indica* > *Dactyloctenium aegyptium* = control and according to mean comparison for depths, mean of depth1> depth2 =depth1. Hence *Cyperus iria* has high DO improving ability at 1st depth.

IV. Biological Oxygen Demand (BOD)

BOD level of inlet waste water was nearly 15 ppm. *Cyperus iria* had the greater ability to reduce the BOD level whereas the BOD reduction was very less in *Dactyloctenium aegyptium*, but in all plant species BOD level was gradually increased with the increasing depth. BOD standard for surface water bodies are 30ppm. Here all three plant species reduce the BOD below standard in all depths. The BOD level decreasing efficiencies of *Eleucine indica, Dactyloctenium aegyptium* and *Cyperus iria* were nearly 66%, 64% and 69% respectively at first depth.

A. Tukey Pairwise *Comparisons among plant species*

(Grouping Information Using the Tukey Method and 95% Confidence)

Table7: *Tukey Pairwise Comparisons for BOD among the plant species*

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	9.896	A
Eleucine indica	3	9.379	A
Dactyloctenium aegyptium	3	9.060	A
Control	3	2.250	B

B. Tukey Pairwise Comparisons among the depths

(Grouping Information Using the Tukey Method and 95% Confidence)

Table8: Tukey Pairwise Comparisons for BOD among the depths

Depth	***N***	***Mean***	***Grouping***
1	4	7.83750	A
2	4	7.64625	A
3	4	7.45500	A

According to mean comparison for plant species and control explained that the mean of *Cyperus iria = Eleucine indica = Dactyloctenium aegyptium* > control and according to mean comparison for depths, mean of depth1 = depth2 = depth3. Hence all three grasses had BOD reduction ability for at any of three depths.

V. *Nitrate*

Nitrate concentration at inlet waste water was nearly 22.7ppm. Cyperus iria had greater ability to reduce the nitrate level whereas it was very less in Dactyloctenium aegyptium, but in the three plant species nitrate level was gradually reduced with the increasing depth up to second depth then the nitrate level suddenly increased in third depth. Acceptable nitrate level for inland water bodies is 5ppm.results showed that no plants had the ability to reduce the nitrate level below the acceptable limit at all depths. The nitrate reduction efficiency of Eleucine indica, Dactyloctenium aegyptium and Cyperus iria were nearly 47%, 39% and 64% respectively at 2nd depth.

A. Tukey Pairwise Comparisons among plant species

(Grouping Information Using the Tukey Method and 95% Confidence)

Table9: *Tukey Pairwise Comparisons for Nitrate among the plant species*

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	13.4809	A
Eleucine indica	3	9.6684	B
Dactyloctenium aegyptium	3	7.9314	C
Control	3	5.1731	D

B. Tukey Pairwise Comparisons among the depths

(Grouping Information Using the Tukey Method and 95% Confidence)

Table10: Tukey Pairwise Comparisons for Nitrate among the depths

Depth	***N***	***Mean***	***Grouping***
2	4	10.0027	A
1	4	8.9228	B
3	4	8.2648	C

Regarding to mean comparison for grass species and control showed that the mean of *Cyperus iria* > *Eleucine indica* > *Dactyloctenium aegyptium* > control and according to mean comparison for depths, mean of depth2 > depth1 > depth3. Nitrogen undergoes its various transformation and some are taken up by aquatic plants some is leached to the subsoil (Kadlec and Knight, 1996). Hence *Cyperus iria* had high pollution reduction ability at depth2.

VI. Phosphate

Phosphate concentration at inlet waste water was 7.4 ppm. The results indicated that Cyperus iria had the greater ability to reduce the phosphate level whereas it was very less in Dactyloctenium aegyptium, Acceptable phosphate level for inland water bodies is 5ppm. Eleucine indica, and Cyperus iria had the ability to reduce the phosphate level below the acceptable limit at all depths. The efficiency of phosphate level reduction of Eleucine indica, Cyperus iria and Dactyloctenium aegyptium were nearly 38%, 42% and

24% respectively. Phosphate level in outlet water was varied among plant species as well as depths.

A. Tukey Pairwise Comparisons among plant species
(Grouping Information Using the Tukey Method and 95% Confidence)

Table11: *Tukey Pairwise Comparisons for Phosphate among the plant species*

Plant_spp & control	***N***	***Mean***	***Grouping***
Cyperus iria	3	2.88600	A
Eleucine indica	3	2.60233	A
Dactyloctenium aegyptium	3	1.44300	B
Control	3	0.80783	C

B. Tukey Pairwise Comparisons among the depths
(Grouping Information Using the Tukey Method and 95% Confidence)

Table12: Tukey Pairwise Comparisons for Phosphate among the depths

Depth	***N***	***Mean***	***Grouping***
2	4	2.23850	A
1	4	2.01650	A
3	4	1.54938	B

According to mean comparison for plant species and control revealed that the mean of *Cyperus iria* = *Eleucine indica* > *Dactyloctenium aegyptium* > control and according to mean comparison for depths, mean of depth1 = depth2 > depth3. Hence both *Cyperus iria* and *Eleucine indica* had a significant high phosphate reduction ability at depth1 and depth2.

4. CONCLUSION

Results of the physicochemical parameters showed that the plant species reduced the pH, BOD, TS and the concentrations of Phosphate and Nitrate and increased the DO.

Further the results revealed that among the three species tested the sedge *Cyperus iria* was more effective in reducing the pollution level. The pollution reduction ability of pH, DO, BOD and TS were very high in *Cyperus iria at* 0.3m depth whereas the Nitrate and Phosphate reduction ability were comparatively high in *Cyperus iria at* 0.5m depth.

5. REFERENCES

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