Impact of Plant Density on the Sewage Treatment through selected Aquatic Macrophytes Using Angular Horizontal Subsurface Flow Constructed Wetland

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Abstract

Constructed wetland treatments are engineered systems that have been designed and constructed to utilize the wetland vegetation, soils and microbial populations to treat contaminants from surface water, ground water and wastewater. The use of constructed wetlands to treat wastewater is rapidly emerging as a feasible alternative at worldwide. A pilot scale study was conducted to examine the feasibility study and impact of plant density on the sewage treatment through selected wetland rooted plant species using Angular Horizontal Subsurface Flow (AHSSF) constructed wetland. In the present study 100 % sewage concentration and Cana indica, Pannicum maximum, Colocasia esculenta, Typha latifolia, Pennisetum purpureum Schumach and Eichhornia crassipes of plant species were used and planted in equal numbers in the media bed and examined its impact on the sewage treatment. In this investigation only plant growth and pollutants removal efficiency was studied in various seasons during sewage treatment. In this overall study the Pennisetum purpureum of emergent and Eichhornia crassipes of free floating plants removed greatest and maximum organic and inorganic pollutants from the sewage. The constructed wetland bed of all plants shows greenery, leafier and seems flowering and also most of the faunal species were attracted towards the experimental bed.

Key words

Constructed wetland, Plant Biomass, Sewage treatment, Angular Horizontal Subsurface Flow, Pennisetum purpureum, pollutants removal efficiency

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Introduction

The system of planting aquatic plants such as reeds or bulrushes in a wet (often gravel) substrate medium for gray water recycling is called a “Constructed Wetland” or “Artificial Wetland” or “Human Engineered Wetland”. Constructed wetlands with emergent vegetation have been used to treat various types of wastewaters (Wallace and Knight, 2006). They are efficient in removal of organics through microbial degradation and settling of colloidal particles. Suspended solids are effectively removed via settling
and filtration through the dense vegetation (Kadlec and Wallace, 2008). The use of constructed wetlands can be a cost-effective treatment alternative (Baltic Deal, 2011; Salomon and Sundberg, 2012; Hegazy et al., 2013). Subsurface flow wetland is considered to be advantageous as compared to the open surface wetlands and which are more commonly used for individual households. Constructed wetlands generally consist of one or more lined beds, or cells. Microorganisms and plants seem to work together symbiotically in constructed wetlands, as the population of microorganisms is much higher in the root areas of the plants than in the gravel alone. In comparison with conventional treatment systems, constructed wetlands have lower energy and chemical requirements. Another attraction of constructed wetlands is simplicity in operation, with less need for highly skilled manpower in day to day operations. They can be incorporated into the rural or urban landscape quite effectively, even in difficult terrain (Mayor and Sarana, 1950). Constructed wetlands are also appropriate for developing countries but they still have to become better known there (Mohamed, 2004; Heers, 2006; Kamau, 2009). Constructed wetlands have been used as an alternative option to treat wastewater.

The present study was conducted to assess the performance of AHSSF constructed wetland as a low cost facility to remediate (physically and biologically) pollution in wastewater phytoremediation treatment using planted macrophytes and study was conducted to examine the impact of plant density on the sewage treatment. The experiment was performed in the Department of Environmental Science, Solapur University Solapur (M.S) India. In experimental designing and fabrication of constructed wetlands there are three sets of buckets with different sizes and dimensions were used. The root zone bed set was prepared in three layers which were prepared with pebbles, sand and garden sieved soil. Selective healthy, small, young, locally available saplings of macrophytes were transplanted and which were arranged in rows and columns. The plant bed was provided 100 slopes and kept in the slanting position. Inlet and outlet flow rates were preset by using bucket and timer (Dhulap and Patil, 2014; Dhulap et al., 2014). In this study 100 % sewage concentration were tested using Cana indica, Pannicum maximum, Colocasia esculenta, Typha latifolia, Pennisetum purpureum Schumach and Eichhornia crassipes plant species. Each plant species of their densities and their treatment efficiencies were calculated.

**Result and Discussion**

*Cana indica* plant growth results shows that, plant biomass or number of *Cana* was increase 40 numbers at 0 day, 42 at 1st day, 45 at 2nd day, 48 at 3rd day, 53 at 4th day and 59 numbers at 5th day respectively (Fig. 1). On the same time studied sewage characteristics at 0 day to 5th day. The sewage result reveals pH values were changed by 6.83 at 0 day to 7.3 at 5th day. BOD (mg/L) was reduced by 51.44 at 0 day to 3.44 at 4th day. COD (mg/L) was reduced by 118 at 0 day to 8.9 at 4th day. Study showed the maximum pollutants removed at 4th day (Table 1).

*Pannicum maximum* shows that, plant biomass or number of *Pannicum* was increase 40 numbers at 0 day, 48 at 1st day, 66 at 2nd day, 74 at 3rd day, 79 at 4th day and
88 numbers at 5th day respectively (Fig. 2). The pH values were changed by 6.79 at 0 day to 7.29 at 5th day. BOD (mg/L) was reduced by 42.0 at 0 day to 3.50 at 4th day. COD (mg/L) was reduced by 118 at 0 day to 11.2 at 4th day. Study showed the maximum pollutants removed at 4th day (Table 2).

*Colocasia esculenta* shows that, plant biomass or number of *Colocasia* was increase 40 numbers at 0 day, 41 at 1st day, 46 at 2nd day, 54 at 3rd day, 63 at 4th day and 69 numbers at 5th day respectively (Fig. 3). The pH values were changed by 6.79 at 0 day to 7.91 at 5th day. BOD (mg/L) was reduced by 42.0 at 0 day to 3.82 at 4th day. COD (mg/L) was reduced by 121 at 0 day to 11.86 at 4th day respectively. Study showed the maximum pollutants removed at 4th day (Table 3).

### Table 1: Effect of plant growth of *Cana indica* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S.N. | Parameters            | 0 Day | 1st Day | 2nd Day | 3rd Day | 4th Day | 5th Day |
|------|-----------------------|-------|---------|---------|---------|---------|---------|
| 1.   | Plant Growth (Numbers)| 40    | 42      | 45      | 48      | 53      | 59      |
| 2.   | pH                    | 6.83  | 7.8     | 7.65    | 7.56    | 7.43    | 7.03    |
| 3.   | EC (µMoh/Cm)          | 2.56  | 1.12    | 0.92    | 0.88    | 0.82    | 0.84    |
| 4.   | TSS (mg / L)          | 394   | 223     | 203     | 109     | 100     | 102     |
| 5.   | TDS (mg / L)          | 1364  | 1129    | 961     | 612     | 458     | 462     |
| 6.   | TS (mg / L)           | 1758  | 1352    | 1164    | 721     | 558     | 564     |
| 7.   | BOD (mg / L)          | 51.44 | 37.04   | 12.36   | 7.27    | 3.44    | 3.48    |
| 8.   | COD (mg / L)          | 118   | 92.82   | 31.08   | 19.02   | 8.9     | 9.1     |
| 9.   | NO₃ (mg / L)          | 26.8  | 19.06   | 15.02   | 9.05    | 3.02    | 3.06    |
| 10.  | PO₄ (mg / L)          | 21.60 | 17.81   | 12.48   | 7.08    | 2.41    | 2.48    |
| 11.  | SO₄ (mg / L)          | 107   | 94.0    | 78.0    | 31.0    | 19.46   | 19.51   |

### Table 2: Effect of plant growth of *Panicum maximum* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S.N. | Parameters            | 0 Day | 1st Day | 2nd Day | 3rd Day | 4th Day | 5th Day |
|------|-----------------------|-------|---------|---------|---------|---------|---------|
| 1.   | Plant Growth (Numbers)| 40    | 48      | 66      | 74      | 79      | 88      |
| 2.   | pH                    | 6.79  | 6.96    | 7.86    | 7.52    | 7.21    | 7.29    |
| 3.   | EC (µMoh/Cm)          | 2.63  | 2.12    | 1.89    | 1.07    | 0.89    | 0.93    |
| 4.   | TSS (mg / L)          | 392   | 291     | 143     | 112     | 97      | 102     |
| 5.   | TDS (mg / L)          | 1360  | 1091    | 784     | 490     | 465     | 469     |
| 6.   | TS (mg / L)           | 1752  | 1382    | 927     | 602     | 562     | 571     |
| 7.   | BOD (mg / L)          | 42.0  | 34.8    | 21.6    | 9.26    | 3.50    | 3.54    |
| 8.   | COD (mg / L)          | 118   | 92.7    | 36.7    | 21.8    | 11.2    | 11.7    |
| 9.   | NO₃ (mg / L)          | 26.8  | 19.6    | 11.7    | 9.3     | 3.9     | 4.2     |
| 10.  | PO₄ (mg / L)          | 21.60 | 17.92   | 12.41   | 8.66    | 2.80    | 3.12    |
| 11.  | SO₄ (mg / L)          | 107.0 | 89.0    | 66.0    | 39.0    | 22.0    | 24.7    |
Table.3 Effect of plant growth of *Colocasia esculenta* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S.N. | Parameters                      | 0 Day | 1<sup>st</sup> Day | 2<sup>nd</sup> Day | 3<sup>rd</sup> Day | 4<sup>th</sup> Day | 5<sup>th</sup> Day |
|------|---------------------------------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 1    | Plant Growth (Numbers)          | 40    | 41                  | 46                  | 54                  | 63                  | 69                  |
| 2    | pH                              | 6.79  | 7.12                | 7.23                | 7.61                | 7.82                | 7.91                |
| 3    | EC (µMoh/Cm)                    | 2.63  | 2.17                | 1.72                | 1.02                | 0.98                | 0.99                |
| 4    | TSS (mg / L)                    | 402   | 339                 | 201                 | 115                 | 103                 | 111                 |
| 5    | TDS (mg / L)                    | 1360  | 1043                | 726                 | 502                 | 471                 | 481                 |
| 6    | TS (mg / L)                     | 1762  | 1382                | 927                 | 617                 | 574                 | 579                 |
| 7    | BOD (mg / L)                    | 42.0  | 36.04               | 21.05               | 9.86                | 3.82                | 4.2                 |
| 8    | COD (mg / L)                    | 121   | 93.7                | 37.9                | 24.3                | 11.86               | 12.87               |
| 9    | NO<sub>3</sub> (mg / L)         | 26.8  | 19.2                | 13.2                | 9.5                 | 4.3                 | 4.7                 |
| 10   | PO<sub>4</sub> (mg / L)         | 24.60 | 18.81               | 12.46               | 8.67                | 2.92                | 3.2                 |
| 11   | SO<sub>4</sub> (mg / L)         | 109.0 | 84.0                | 59.0                | 31.0                | 23.0                | 24.2                |

Table.4 Effect of plant growth of *Typha latifolia* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S.N. | Parameters                      | 0 Day | 1<sup>st</sup> Day | 2<sup>nd</sup> Day | 3<sup>rd</sup> Day | 4<sup>th</sup> Day | 5<sup>th</sup> Day |
|------|---------------------------------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 1    | Plant Growth (Numbers)          | 40    | 47                  | 59                  | 68                  | 77                  | 84                  |
| 2    | pH                              | 6.62  | 7.59                | 7.52                | 7.49                | 7.48                | 7.82                |
| 3    | EC (µmohs/cm)                   | 2.63  | 2.20                | 1.17                | 0.98                | 0.92                | 1.01                |
| 4    | TSS (mg/L)                      | 335   | 297                 | 210                 | 134                 | 96                  | 102                 |
| 5    | TDS (mg/L)                      | 1631  | 1371                | 1064                | 752                 | 548                 | 551                 |
| 6    | TS (mg/L)                       | 1966  | 1668                | 1274                | 886                 | 644                 | 653                 |
| 7    | BOD (mg/L)                      | 46.0  | 32.0                | 21.4                | 14.7                | 4.26                | 4.39                |
| 8    | COD (mg/L)                      | 111.0 | 76.2                | 26.8                | 12.4                | 9.2                 | 11.2                |
| 9    | NO<sub>3</sub> (mg/L)           | 21.0  | 17.6                | 13.1                | 9.2                 | 3.0                 | 3.6                 |
| 10   | PO<sub>4</sub> (mg/L)           | 17.0  | 12.5                | 9.3                 | 6.2                 | 1.82                | 2.9                 |
| 11   | SO<sub>4</sub> (mg/L)           | 96.0  | 88.0                | 67.0                | 58.0                | 46.0                | 54.0                |

Table.5 Effect of plant growth of *Pennisetum purpureum* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S.N. | Parameters                      | 0 Day | 1<sup>st</sup> Day | 2<sup>nd</sup> Day | 3<sup>rd</sup> Day | 4<sup>th</sup> Day | 5<sup>th</sup> Day |
|------|---------------------------------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 1    | Plant Growth (Numbers)          | 40    | 47                  | 53                  | 64                  | 72                  | 86                  |
| 2    | pH                              | 6.72  | 7.80                | 7.61                | 7.56                | 7.42                | 7.38                |
| 3    | EC (µmohs/cm)                   | 2.56  | 1.10                | 0.89                | 0.88                | 0.78                | 0.83                |
| 4    | TSS (mg/L)                      | 394   | 210                 | 144                 | 97                  | 88                  | 93                  |
| 5    | TDS (mg/L)                      | 1364  | 1038                | 920                 | 524                 | 451                 | 458                 |
| 6    | TS (mg/L)                       | 1758  | 1248                | 1064                | 621                 | 539                 | 551                 |
| 7    | BOD (mg/L)                      | 51.44 | 36.00               | 12.00               | 7.08                | 3.38                | 3.42                |
| 8    | COD (mg/L)                      | 118   | 90.16               | 29.80               | 18.20               | 8.07                | 8.09                |
| 9    | NO<sub>3</sub> (mg/L)           | 26.8  | 18.60               | 14.40               | 8.22                | 2.09                | 3.03                |
| 10   | PO<sub>4</sub> (mg/L)           | 21.60 | 16.40               | 11.58               | 6.50                | 2.32                | 2.40                |
| 11   | SO<sub>4</sub> (mg/L)           | 107   | 89.0                | 62.0                | 29.0                | 18.20               | 18.42               |
Table 6 Effect of plant growth of *Eichhornia crassipes* (Density) on wastewater treatment through various parameters at 100% concentration of sewage

| S. N. | Parameters            | 0 Day | 1st Day | 2nd Day | 3rd Day | 4th Day | 5th Day |
|-------|-----------------------|-------|---------|---------|---------|---------|---------|
| 1.    | Plant Growth (Numbers)| 40    | 49      | 57      | 66      | 78      | 91      |
| 2.    | pH                    | 6.81  | 7.97    | 7.86    | 7.57    | 7.42    | 7.34    |
| 3.    | EC (µmohs/cm)         | 0.6   | 1.3     | 1.9     | 2.2     | 3.2     | 3.7     |
| 4.    | TSS (mg/L)            | 1920  | 1773    | 1066    | 838     | 595     | 607     |
| 5.    | TDS (mg/L)            | 1240  | 1772    | 768     | 712     | 545     | 547     |
| 6.    | TS (mg/L)             | 3160  | 2945    | 1834    | 1550    | 1140    | 1154    |
| 7.    | BOD (mg/L)            | 230   | 220     | 200     | 165     | 118     | 120     |
| 8.    | COD (mg/L)            | 315   | 290     | 192     | 172     | 156     | 162     |
| 9.    | NO₃ (mg/L)            | 9.2   | 8.0     | 6.0     | 5.1     | 1.23    | 3.0     |
| 10.   | Chlorides mg/L        | 44.2  | 28.40   | 26.98   | 24.14   | 22.10   | 23.10   |

Fig.1 Growth of *Cana indica*

![Cana indica Plant Growth (Numbers)](image)

Fig.1 Growth of *Panicum maximum*

![Panicum maximum Plant Growth (Numbers)](image)
Fig. 3 Growth of *Colocasia esculenta*

![Graph of growth of Colocasia esculenta](image)

Fig. 4 Growth of *Typha latifolia*

![Graph of growth of Typha latifolia](image)

Fig. 5 Growth of *Pennisetum purpureum*

![Graph of growth of Pennisetum purpureum](image)

Fig. 6 Growth of *Eichhornia crassipes*

![Graph of growth of Eichhornia crassipes](image)
Typha latifolia shows that, plant biomass or number of Typha was increase 40 numbers at 0 day, 47 at 1st day, 59 at 2nd day, 68 at 3rd day, 77 at 4th day and 84 numbers at 5th day respectively (Fig. 4). The pH values were changed by 6.62 at 0 day to 7.82 at 5th day. BOD (mg/L) was reduced by 46.0 at 0 day to 4.26 at 4th day. COD (mg/L) was reduced by 111 at 0 day to 9.2 at 4th day respectively. Study showed the maximum pollutants removed at 4th day (Table 4).

Pennisetum purpureium shows that, plant biomass or number of Pennisetum was increase 40 numbers at 0 day, 47 at 1st day, 53 at 2nd day, 64 at 3rd day, 72 at 4th day and 86 numbers at 5th day respectively (Fig. 5). The pH values were changed by 6.72 at 0 day to 7.38 at 5th day. BOD (mg/L) was reduced by 51.44 at 0 day to 3.38 at 4th day. COD (mg/L) was reduced by 118 at 0 day to 8.07 at 4th day respectively. Study showed the maximum pollutants removed at 4th day (Table 5).

Eichhornia crassipes shows that, plant biomass or number of Eichhornia was increase 40 numbers at 0 day, 49 at 1st day, 57 at 2nd day, 66 at 3rd day, 78 at 4th day and 91 numbers at 5th day respectively (Fig. 6). The pH values were changed by 6.81 at 0 day to 7.34 at 5th day. DO (mg / L) was increased by 0.6 at 0 day to 3.7 at 5th day. BOD (mg/L) was reduced by 230 at 0 day to 118 at 4th day. COD (mg/L) was reduced by 315 at 0 day to 156 at 4th day respectively. Study showed the maximum pollutants removed at 4th day, but the plant growth was increases continuously and plant bed observed the greenery, leafier and seems flowering (Table 6).

In conclusion, this overall study the Pennisetum purpureium of emergent and Eichhornia crassipes of free floating macrophytes removed greatest and maximum organic, inorganic pollutants from the sewage. All plant beds observed greenery, leafier and seem flowering due to this most of the faunal species was attracted towards the experimental setup of pilot plant.

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