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Wastewater Treatment Using Vertical Flow Constructed Wetland

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Abstract
Water is one of the most important elements involved in the creation and development of healthy life. Disposal of untreated wastewater from households as well as institutions & industry is causing deterioration of water bodies in urban areas in the developing world. A high level of responsibility towards water usage is required, & it must be recycled according to its pollution content in order to maintain water quality and protect our environment.

One of the methods of the treatment is constructed wetland. Constructed wetland system for wastewater treatment has been proven to be effective & sustainable alternative for conventional wastewater treatment technologies. The removal of pollutants in this system relies on a combination of physical, chemical and biological processes that naturally occur in wetland & are associated with vegetation, and their microbial communities. The present study undertaken by fabricating the lab scale model of constructed wetland. The effluent of Amba Nala Amravati is treated with this system and wastewater characteristic like pH, DO, TS, BOD, COD with & without plant species studied. Using sandy soil as substrate, it was found that BOD, COD removal 61 % and 51 % for unplanted constructed wetland whereas for planted constructed wetland it was 74% and 61%.

Keywords: Alluvial soil, Constructed wetland, Sandy Soil, Typha, Wastewater.

1. INRODUCTION

Water is one of the most important elements involved in the creation and development of healthy life. The exponential growth of population and industrialization will cause a huge lack of water if we don't start to use it in a sustainable way. To achieve this, a high level of responsibility towards water usage is required, and it must be recycled according to its pollution content in order to maintain water quality and protect our environment. Many methods of water treatment have been researched and employed by responsible nations around the globe. There are various parameters that must be considered when a wastewater treatment choice is made, including level of pollution and the amount of water, to be recycled in a certain time. The use of plants for wastewater treatment is appropriate in smaller communities and agglomerations because they are easily constructed, inexpensive to maintain and very efficient. Constructed wetlands use plants which are able to cope with different concentrated pollutants in water and help bacteria's to break down these substances.

C. Smeal et.al have design Soil Based Reed Bed using surface flow systems and floating aquatics. A subsurface flow soil based reed bed is a combination of three interdependent elements the growing media, the plants and the micro-organisms. In this system the wastewater comes into contact with a wide range of microorganisms that occur in high densities on the surface of the growing media and around the plant roots. A plant was needed which thrives in water logged conditions, tolerates high level of pollutants, has a high capacity of absorbing these pollutants, particularly nitrogen and has also high biomass production under these extremely adverse conditions.

Giraldi and Iannelli have studied comparative analysis of planted and unplanted beds. They performed daily water content analyses in the interval between subsequent sludge loadings in a real scale reed bed system situated in Pisa (central Italy). A comparative analysis of planted and unplanted beds confirmed that the mechanical function of plants is essential in the winter, when the unplanted bed did not present any dewatering capability.

Bhushan Tuladhar, Prajwal Shrestha, and Rajendra Shrestha have shows the importance of small scale decentralized wastewater treatment using reed bed treatment systems (RBTS) in Nepal. The treatment plant has been constructed having the capacity to treat 50m3 of wastewater per day. The vertical flow and horizontal flow reed bed was constructed. A typical Vertical flow system can remove the BOD51 of up to 96%; the Horizontal flow system can remove only up to 65%. The system is found to be highly effective in removing pollutants such as suspended particles, ammonia-nitrogen, BOD, COD and pathogens. In general, the performance of the CWs has been excellent. Regular monitoring of the systems shows high pollutant removal efficiency achieving close to 100% removal of total coliforms and organic pollutants.

From the above literature review it can be said that the studies has been carried out for domestic sewage wastewater, industrial wastewater and other type of wastewater. The various type of combination of constructed wetland are also used. In this study, using the vertical flow system of constructed wetland the various characteristics such as BOD, COD, TS, pH, DO are studied for the municipal wastewater.

The aim of this paper is to study the wastewater characteristics of Amba Nala like BOD, COD, DO, pH and TS using constructed wetland with and without plant species.

2. THEORETICAL BACKGROUND

2.1 Constructed Wetlands (CW)

Constructed Wetlands (CW) is a biological wastewater treatment technology designed to mimic processes found in natural wetland ecosystems. These systems use wetland plants, soils and their associated micro-organisms to remove contaminants from wastewater (Okuda and Higa, 1990). Application of constructed wetlands for the treatment of municipal, industrial and agricultural wastewater as well as storm water started in the 1950s and they have been used in different configurations, scales and designs. The plant within the constructed wetland is the major component for the treatment process. The type of macrophyte chosen will vastly influence the efficiency and quality of wastewater. Plants provide an environment for microbes to live, they oxygenate the wastewater, providing nutrients for the microbes to survive, they stabilize the soil and they also partake in the reduction of nutrients.

2.2 Types and classification of Constructed Wetlands

2.2.1 Surface flow treatment wetlands

Surface flow or free-water-surface wetland systems show, as the name suggests, a water flow primarily conducted aboveground and exposed to the atmosphere (free water body). Re-aeration at the Surface is the major oxygen source in this wetland type. Below the free water body, the bed contains a soil layer which serves as a rooting media for the emergent vegetation. At the bottom of the wetland system, an impermeable barrier (liner or native soil) is required to avoid infiltration, and thus, contamination of groundwater.

2.2.2 Subsurface flow treatment wetlands

Subsurface flow treatment wetlands can be divided into soil and gravel based wetlands on the one hand, and into horizontal and vertical flow systems on the other hand.

2.2.2.1 Horizontal flow systems

Main feature of horizontal flow systems is that the water level remains underneath the ground surface. The wastewater flows horizontally through a porous soil medium where the emergent plant vegetation is rooted, and is purified during the contact with the surface areas of the soil particles and the roots of the plants. This system includes an impermeable liner or native soil material at the bottom to prevent possible contamination of the groundwater.

3. MATERIALS AND METHODS

3.1 Experimental set up and operation conditions of wetlands

Vertical flow systems are characterized by an intermittent charging including filling and resting periods where wastewater percolates vertically through a soil layer that consists of sand, gravel or soil. The plant species primarily used in vertical flow wetlands is common reed (Phragmites australis) due to its deeply penetrating, dense root and rhizome system. Key advantage of vertical flow systems is an improved oxygen transfer into the soil layer (Melidis et al, 2010).Beside oxygen input by the plants and diffusion processes that both occur also in horizontal subsurface flow wetlands, vertical flow filter show a significant oxygen input into the soil through convection caused by the intermittent charging and drainage.

Compared to horizontal subsurface flow systems, the additional aeration of the soil by convective processes allows higher nitrification capacities as well as removal of organic matter. However, denitrification that requires anoxic conditions is usually lower in vertical flow beds compared to horizontal subsurface flow beds. They are also less effective for removal of suspended solids than horizontal surface flow and subsurface flow beds.

Vertical flow constructed wetland system similar to vertical subsurface flow wetland systems were constructed and located at the Institute Environmental Engineering Laboratory. The constructed wetland systems, including *Typha orientalis* without vegetation and with vegetation, were operated in continuous flow mode alternately. The raw wastewater was sampled from the local Amba nala. The constructed wetland lab model made up of plastic. The raw wastewater and treated wastewater container have dimension of 23cm × 20cm × 38 cm and bed assembly is in cylindrical shape having diameter 23 cm and height 45 cm. The inlet unit is provided with a PVC pipe along with a calibration knob. The calibration knob has been such adjusted that it will work for different detention period. The inlet chamber is there with a scale and it shows a marking of one litre so that the volume of waste water in the inlet and outlet chamber can be measured. The water which will percolate through the bed assembly will come out from the PVC pipe attached at the bottom and from there it will be collected in the outlet chamber. The required plant species, *Typha orientalis* is collected from a local stream. The schematic of the wetland modules with out *Typha orientalis* is shown in

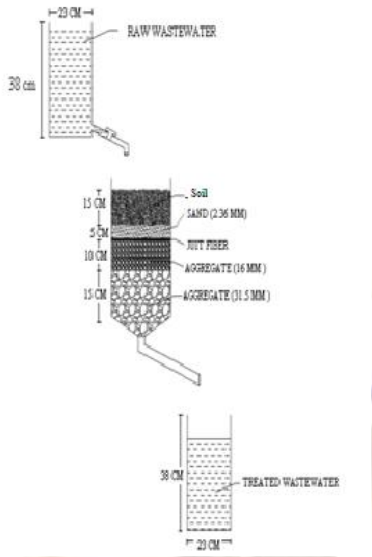

Figure.3.1 and with *Typha orientalis* is shown in figure3.2.

Figure 3.1. Laboratory setup for constructed wetland without Typha orientalis.

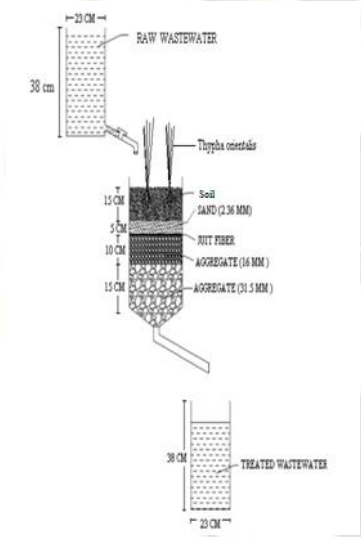

Figure 3.2. Laboratory setup for constructed wetland with Typha orientalis.

3.2 Preparation of Bed

The constructed wetland having narrow bottom with the height of 45cm.Top layer consist of substrate (soil media), the Sandy soil & Alluvial soil use as the substrate for different wetland bed conditions. Before placing the soil in the bed, it was be cleaned and was ensured to free from the impurity. The soil media have the depth of 15 cm, below the soil layer the sand is placed, the depth of sand layer is 5cm.The mean grain size of sand is 2.36 mm, below the sand the jute fibers are placed. Before placing the sand, it was cleaned and washed with the clean water, so as to remove the dust over it. The bottom of wetland unit is filled aggregate having size 16 mm & 31.5 mm respectively. The 16 mm aggregate have the depth of 10 cm and the 31.5 mm aggregate have the depth 15 cm. Aggregate must be wash with the clean water and dried so as to remove the impurity over the surface of it. The unplanted and planted wetland system has the same assembly, the only difference in case of planted wetland system is that it has the macrophyte plant also in the assembly. Constructed wetland technology is based upon the treatment power of three main mechanisms: microorganisms colonizing the system, the physical and chemical properties of the bed media, and finally the plants themselves. The laboratory scale model calibrated for the various discharge like 3days, 5days, 7daysand 9days.

3.3 Starting of Experiment

After the preparation of the bed for the constructed wetland the actual performance of the bed was started. The raw wastewater from the local Amba nala is collected and screened through fine mesh, before putting the wastewater in the influent container. The raw wastewater characteristics like pH, DO, BOD, COD, and TS were determined using procedure mentioned in standard methods. The screened wastewater was put into the influent container; the container provided with the calibration knob, the knob calibrated for the varying detention time i.e for 3, 5, 7 and 9 days. After the calibration the wastewater was allowed to pass over the surface of the bed, as the time progress the percolation of wastewater start into the bed.

Percolated water from the bed collected in the outlet tank. The purified wastewater characteristics also studied by using standard methods. The same procedure was adopted for

the planted constructed wetland. The comparative study between the unplanted and planted wetland was done.

4. Results and Discussion

4.1 Raw Wastewater Characteristics

The raw wastewater collected from different location of Amba Nala was studied in the

The various tests were conducted on the raw wastewater like pH, DO, BOD, COD, T.S, Phosphorus, Chloride, Nitrate, Sulphate and hardness, as per procedure laid down in standard methods. The results are enlisted in Table.1. From the table it is observed that the waste is moderate in strength and needs the treatment before discharging into stream.

Table 1: Raw wastewater characteristics of Amba Nala

Parameter	Rukhamini Nagar	Asiad Colony	Prashant Nagar	H.V.P.M.
pH	7.54	7.56	7.62	7.63
Conductivity (ds/m)	146	149	148	148
Calcium (mg/l)	26	28	27	26
Magnesium (mg/l)	34	37	36	36
Chloride (mg/l)	64	67	65	67
Sulphate (mg/l)	19	17	19	19
Nitrate (mg/l)	4.4	4.8	4.7	4.5
Phosphate (mg/l)	0.14	0.136	0.138	0.135

4.2 Sandy soil as a substrate

The bed was studied for the two main conditions i.e. for planted and unplanted wetland. Considering the general performance of treatment system, looking at the inlet and outlet concentration have been satisfactory. The constructed wetland bed studied for the black cotton soil, the bed studied for the different detention period i.e for the 3, 5, 7, and 9 days.

4.2.1 For the detention period of 3 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet was studied for the detention time of 3 days. In case of the unplanted constructed wetland it was observed that the percentage removal for the total solids was 71 %, whereas in case of the planted constructed wetland it was increases from 73%.Figure 4.1 shows percentage removal of total solids for detention time 3 days using Sandy soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was varying from 31% for first day and 27% for third day, and for planted constructed wetland it was in the range of 34%. Figure 4.2 percentage removal of B.O.D. for detention time 3 days using Sandy soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal of 16% to 18%, whereas for the planted constructed wetland shows the percentage removal of 17% to 19%. Figure 4.3 shows the percentage removal of C.O.D. for detention time 3 days using Sandy soil for the unplanted and planted wetland.

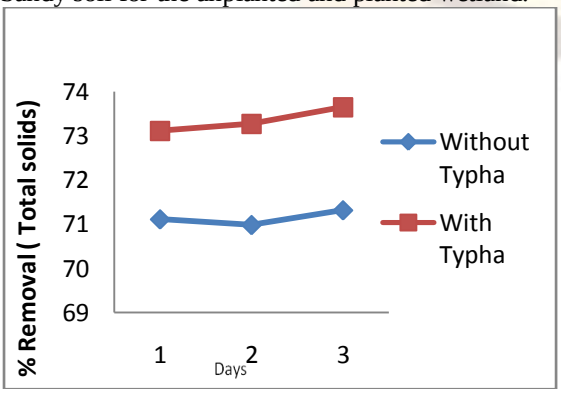

Figure 4.1 % Removal of Total solids for Detention Time 3 days using Sandy soil

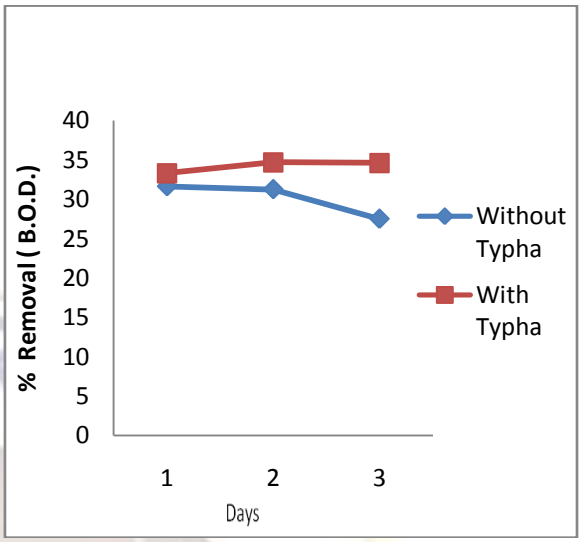

Figure 4.2 % Removal of B.O.D. for Detention Time 3 days using Sandy soil

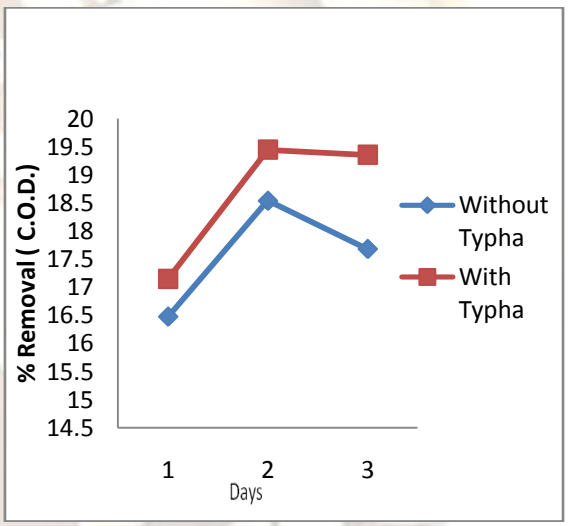

Figure 4.3 % Removal of C.O.D. for Detention Time 3 days using Sandy soil

4.2.2 For the detention period of 5 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 5 days. For the 5 day detention time it was found that, for unplanted constructed wetland the percentage removal for the total solids was 71 % and for planted constructed wetland percentage removal for the total solids was in the range of 74%.Figure 4.4 shows percentage removal of total solids for detention time 5 days using sandy soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was 36 to 39 %, and for planted constructed wetland it was 44%. Figure 4.5 percentage removal of B.O.D. for detention time 5 days using sandy soil for the unplanted and planted wetland. For the

C.O.D the unplanted constructed wetland shows the percentage removal of 29 %, whereas for the planted constructed wetland shows the percentage removal of 34%. Figure 4.6 shows the percentage removal of C.O.D. for detention time 5 days using sandy soil for the unplanted and planted wetland.

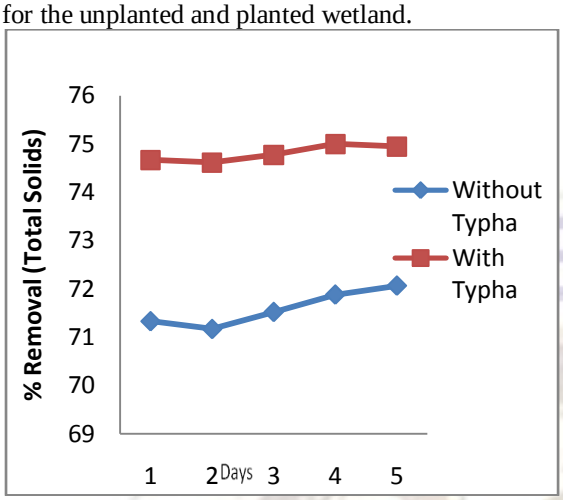

Figure 4.4% Removal of Total solids for Detention Time 5 days using Sandy soil

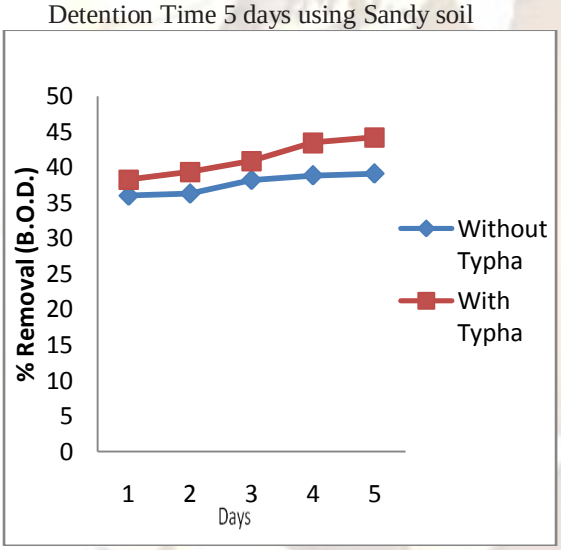

Figure 4.5 % Removal of B.O.D. for Detention Time 5 days using Sandy soil

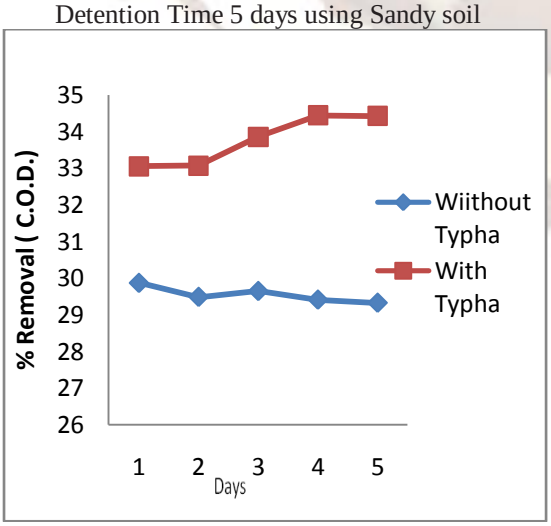

Figure 4.6 % Removal of C.O.D. for Detention Time 5 days using Sandy soil

4.2.3 For the detention period of 7 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 7 days. For the 7 day detention time it was found that, for unplanted constructed wetland the percentage removal for the total solids was 73 % and for planted constructed wetland percentage removal for the total solids was in the range of 74%.Figure 4.7 shows percentage removal of total solids for detention time 7 days using sandy soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was 45 %, and for planted constructed wetland it was 56%. Figure 4.8 percentage removal of B.O.D. for detention time 7 days using sandy soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal in the range of42% - 45%, whereas for the planted constructed wetland shows the percentage removal of 51%. Figure 4.9 shows the percentage removal of C.O.D. for detention time 7 days using sandy soil for the unplanted and planted wetland.

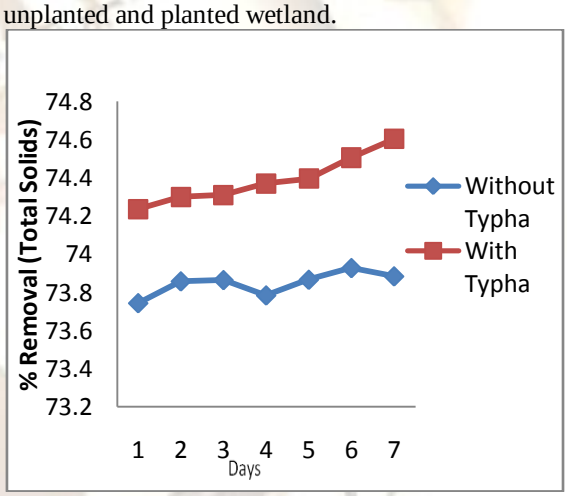

Figure 4.7 % Removal of Total solids for Detention Time 7 days using Sandy soil

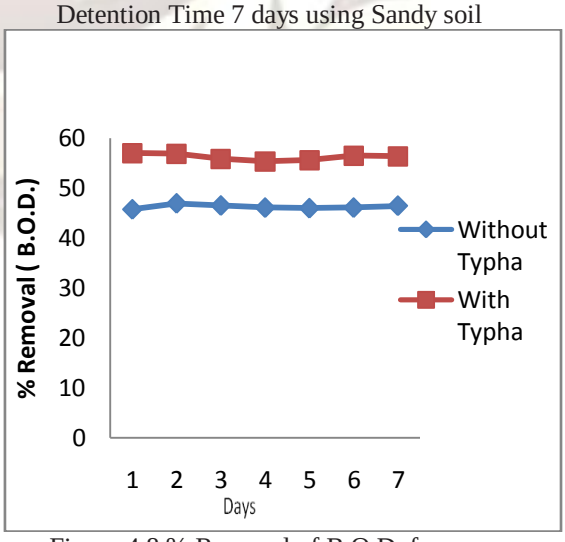

Figure 4.8 % Removal of B.O.D. for Detention Time 7 days using Sandy soil

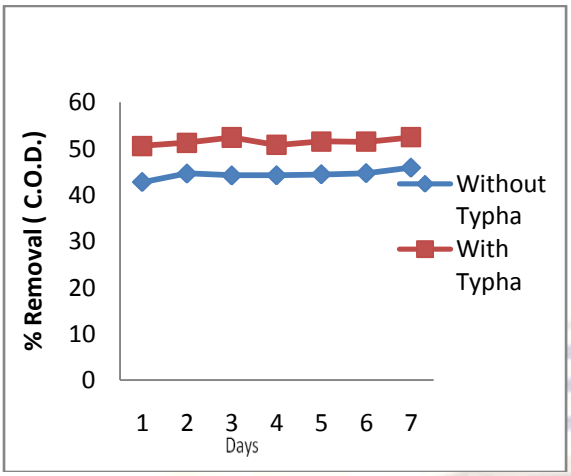

Figure 4.9 % Removal of C.O.D. for Detention Time 7 days using Sandy soil

4.2.4 For the detention period of 9 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 9 days. For the 9 day detention time it was found that, for unplanted constructed wetland and for planted constructed wetland percentage removal for the total solids was in the range of 75%.Figure 4.10 shows percentage removal of total solids for detention time 9 days using sandy soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was in the range of 59 % to 61 %, and for planted constructed wetland it was 71% to 74 %. Figure 4.11 percentage removal of B.O.D. for detention time 9 days using sandy soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal in the range of 52%, whereas for the planted constructed wetland shows the percentage removal of 61%. Figure 4.12 shows the percentage removal of C.O.D. for detention time 9 days using sandy soil for the unplanted and planted wetland

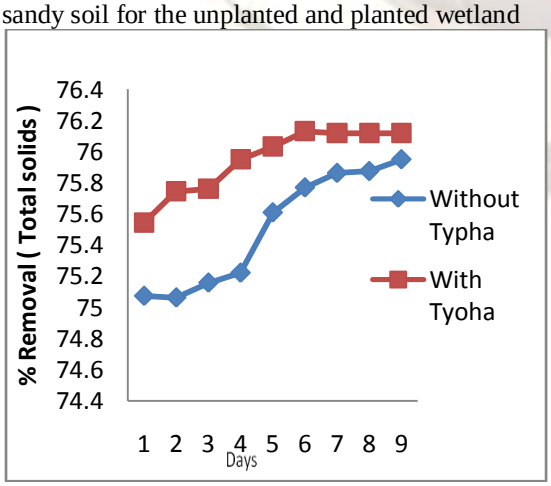

Figure 4.10 % Removal of Total Solidsfor Detention Time 9 days using Sandy soil

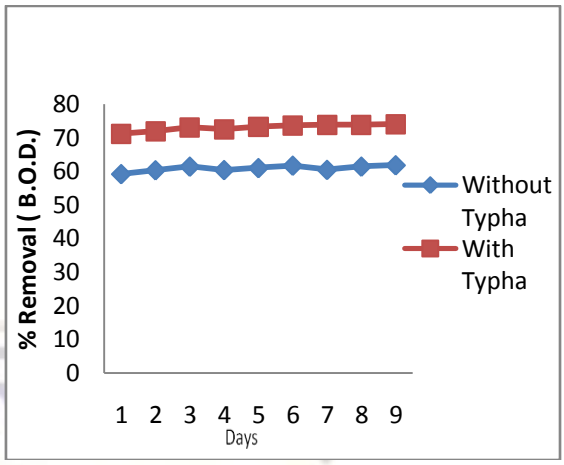

Figure 4.11 % Removal of B.O.D. for Detention Time 9 days using Sandy soil

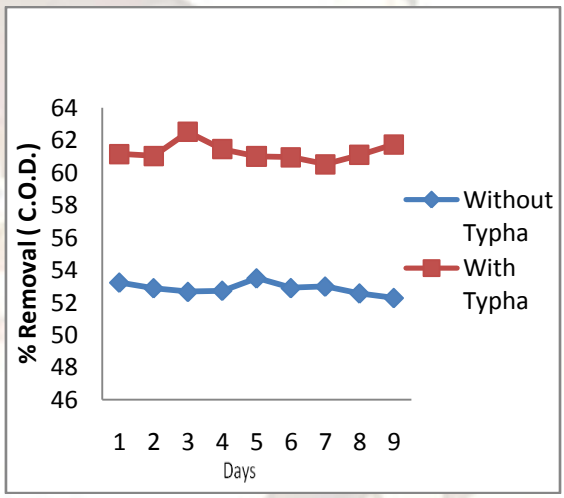

Figure 4.12 % Removal of COD for Detention Time 9 days using Sandy soil

4.3 Alluvial soil as a substrate

After the completion of the various testing over the sandy soil the substrate layer change to the Alluvial soil the bed with Alluvial soil was prepared as explain earlier. The bed was studied for the two main conditions i.e. for planted and unplanted wetland. Considering the general performance of treatment system, looking at the inlet and outlet concentration have been satisfactory. The constructed wetland bed studied for alluvial soil, the bed studied for the different detention period i.e for the 3, 5, 7, and 9 days.

4.3.1 For the detention period of 3 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet was studied for the detention time of 3 days. In case of the unplanted and planted constructed wetland it was observed that the percentage removal for the total solids was 72 %,.Figure 4.13 shows percentage removal of total solids for detention time 3 days using alluvial soil

for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was varying from 34% for first day and 37 % for third day, and for planted constructed wetland it was in the range of 41%. Figure 4.14 shows percentage removal of B.O.D. for detention time 3 days using alluvial soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal in the range 18%, whereas for the planted constructed wetland shows the percentage removal of 26 %. Figure 4.15 shows the percentage removal of C.O.D. for detention time 3 days using alluvial soil for the unplanted and planted wetland.

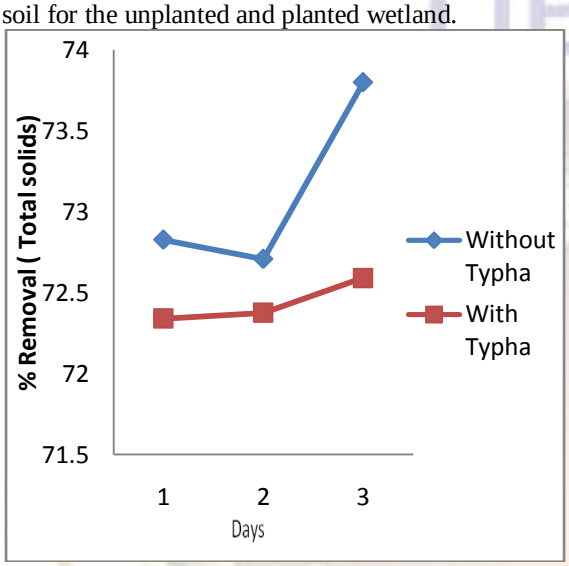

Figure 4.13 % Removal of Total solids for Detention Time 3 days using alluvial soil

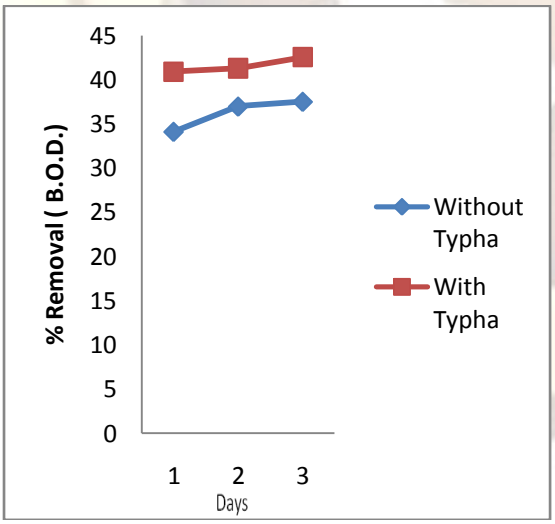

Figure 4.14 % Removal of B.O.D. for Detention Time 3 days using alluvial soil

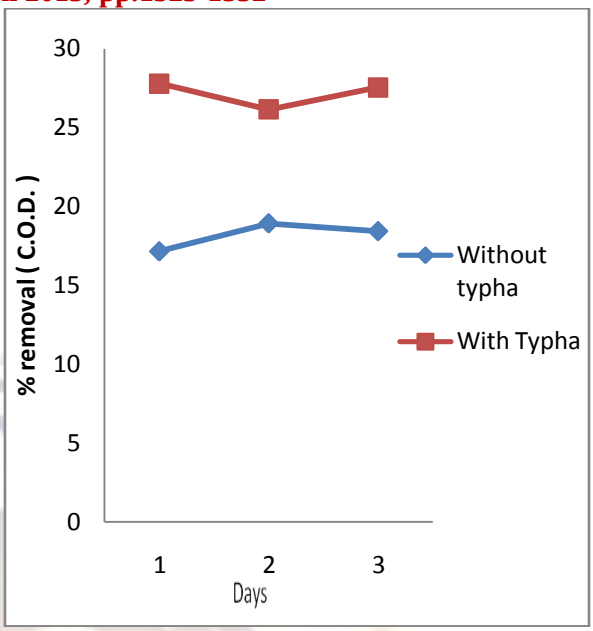

Figure 4.15 % Removal of C.O.D. for Detention Time 3 days using alluvial soil

4.3.2 For the detention period of 5 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 5 days. For the 5 day detention time it was found that, for unplanted constructed wetland the percentage removal for the total solids was 72 % and for planted constructed wetland percentage removal for the total solids was in the range of 74 %.Figure 4.16 shows percentage removal of total solids for detention time 5 days using alluvial soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was 43 %, and for planted constructed wetland it was 45 %. Figure 4.17 percentage removal of B.O.D. for detention time 5 days using alluvial soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal of 37 %, whereas for the planted constructed wetland percentage removal of C.O.D. increases from 39 % to 42 %. Figure 4.18 shows the percentage removal of C.O.D. for detention time 5 days using sandy soil for the unplanted and planted wetland.

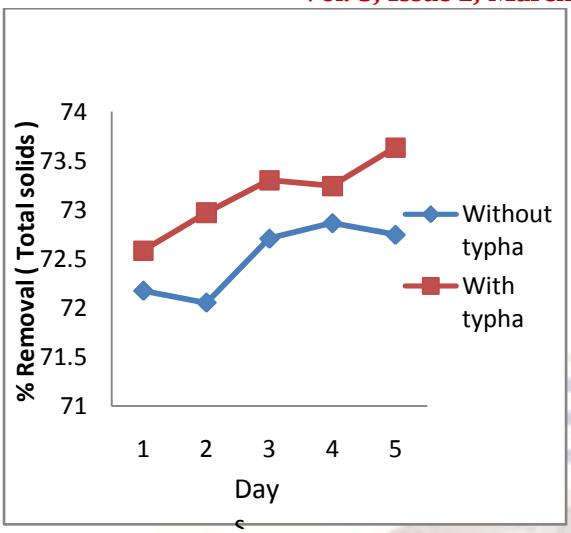

Figure 4.16 % Removal of Total solids for Detention Time 5 days using alluvial soil

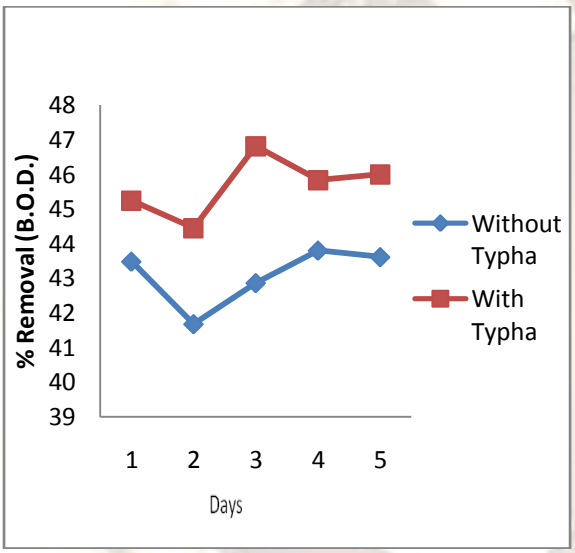

Figure 4.17 % Removal of B.O.D. for Detention Time 5 days using alluvial soil

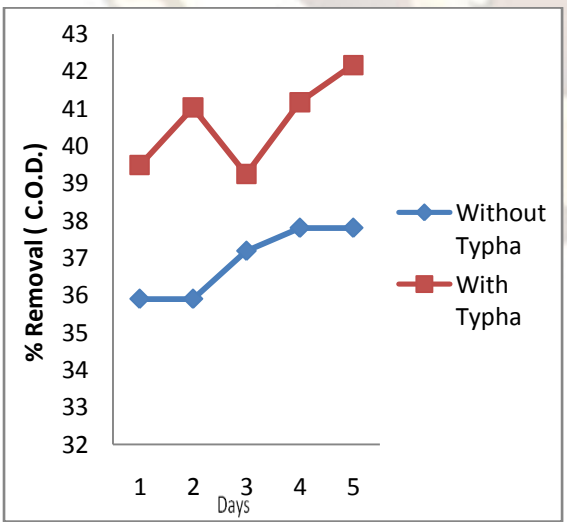

Figure 4.18 % Removal of C.O.D. for Detention Time 5 days using alluvial soil

4.3.3 For the detention period of 9 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 7 days. For the 7 day detention time it was found that, for unplanted constructed wetland the percentage removal for the total solids was 73 % and for planted constructed wetland percentage removal for the total solids was in the range of 74%. Figure 4.19 shows percentage removal of total solids for detention time 7 days using alluvial soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland increases from 47 % to 53 %, and for planted constructed wetland it was in the range 56%. Figure 4.20 percentage removal of B.O.D. for detention time 7 days using sandy alluvial soil for the unplanted and planted wetland. For the C.O.D the unplanted constructed wetland shows the percentage removal in the range of 43 %, whereas for the planted constructed wetland shows the percentage removal of 52 %. Figure 4.21 shows the percentage removal of C.O.D. for detention time 7 days using alluvial soil for the unplanted and planted wetland

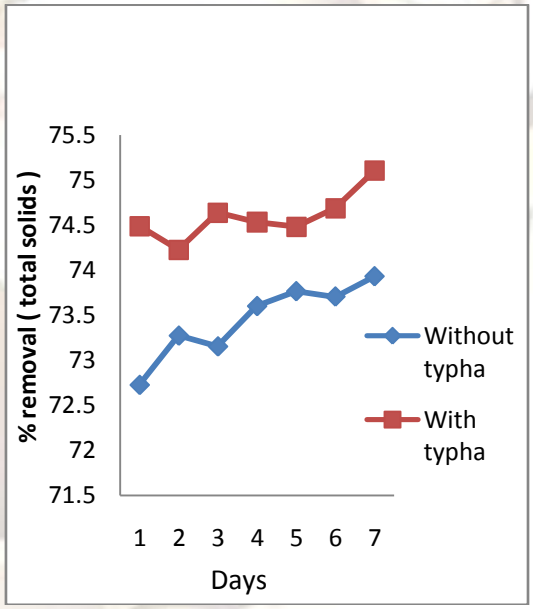

Figure 4.19 % Removal of Total solids for Detention Time 7 days using alluvial soil

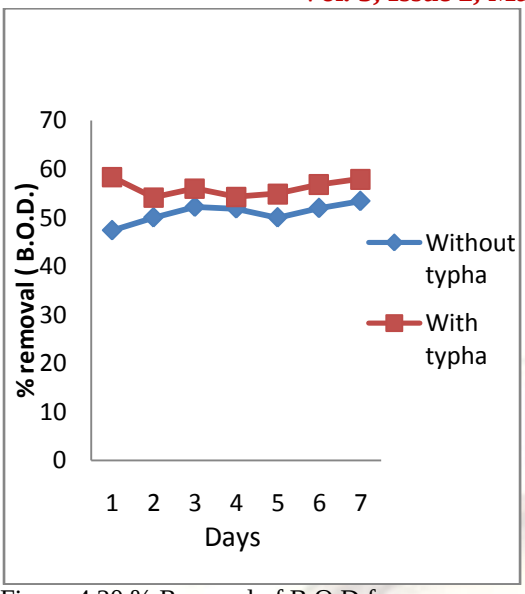

Figure 4.20 % Removal of B.O.D for Detention Time 7 days using alluvial soil

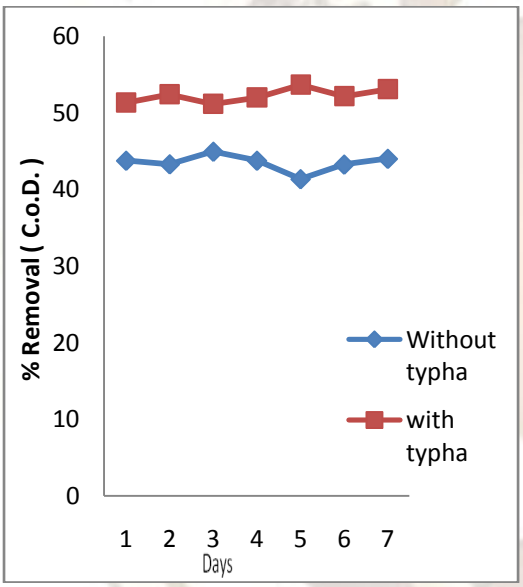

Figure 4.21 % Removal of C.O.D. for Detention Time 7 days using alluvial soil

4.4.4 For the detention period of 9 days

The characteristics of the raw wastewater in the inlet and the characteristics of treated wastewater at the outlet were studied for the detention time of 9 days. For the 9 day detention time it was found that, for unplanted constructed wetland and for planted constructed wetland percentage removal for the total solids was in the range of 75%. Figure 4.22 shows percentage removal of total solids for detention time 9 days using alluvial soil for the unplanted and planted wetland. The percentage removal of B.O.D. for the unplanted constructed wetland was in the range of 63 %, and for planted constructed wetland it was 78 % to 79 %. Figure 4.23 percentage removal of B.O.D. for detention time 9 days using alluvial soil for the unplanted and planted wetland.

For the C.O.D the unplanted constructed wetland shows the percentage removal in the range of 54%, whereas for the planted constructed wetland shows the percentage removal of 63%. Figure 4.24 shows the percentage removal of C.O.D. for detention time 9 days using alluvial soil for the unplanted and planted wetland.

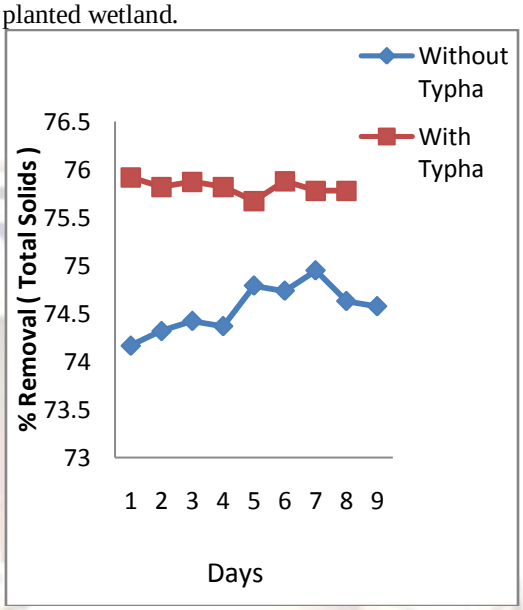

Figure 4.22 % Removal of Total solids for Detention Time 9 days using alluvial soil

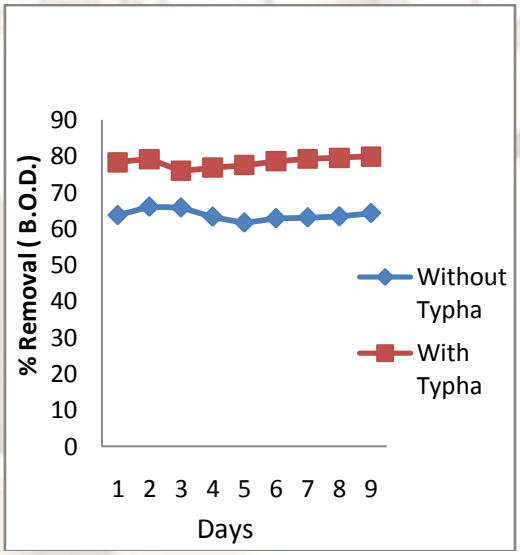

Figure 4.23 % Removal of B.O.D. for Detention Time 9 days using alluvial soil

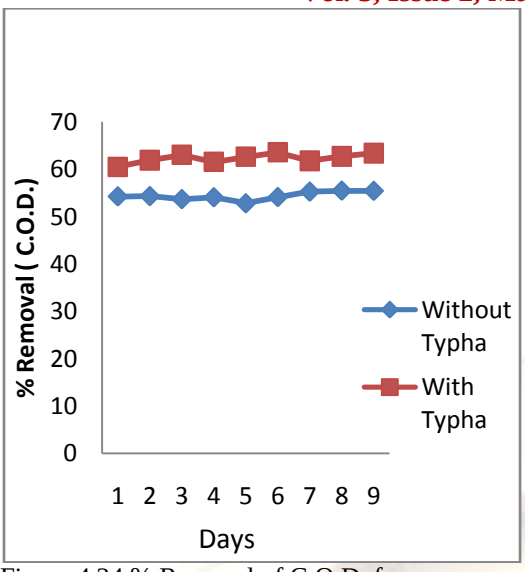

Figure 4.24 % Removal of C.O.D. for Detention Time 9 days using alluvial soil

5. Discussion

In case of sandy soil the percentage removal of pollutant was more as compare to the alluvial soil as the sandy soil has the more water holding capacity than the alluvial soil. It was found that the percentage removal of pollutant in case of the planted wetland was more than the unplanted constructed wetland it is because of the oxygen diffusion from roots of the typha and the nutrient uptake and insulation of the bed surface. It is also observed that increases in the detention time increase the % removal of the pollutant. The % removal for increasing detention time was not linear but for the detention time of 7 days it was found that the overall percentage removal of all pollutant was best.

6. Conclusions

Following conclusion are drawn by using laboratory scale model on different soil substrate Condition and using with and without plant species for different detention time.

1. The raw wastewater characteristics of Amba Nala was determined and found that waste is moderate in strength and needs treatment.
2. Using sandy soil as substrate, it is found that BOD, COD removal 61 % and 51 % for unplanted constructed wetland whereas for planted constructed wetland it was 74% and 61%.
3. It was found that the overall percentage removal of all pollutants were better for the detention time of 7 days as compare to the other detention time.
4. During hydraulic retention study, it was found that the BOD, COD was best removed in planted wetland than unplanted wetland. It is because of the oxygen diffusion from roots of the typha and the nutrient uptake and insulation of the bed surface.
5. It was found that there is an increase in the pH of the treated wastewater for each case which is because of the presences of the jute fiber in the bed assembly.
6. At both soil substrate conditions, it was found that that percentage removal for planted was 76% and for unplanted constructed wetland in the average range of 74%, which shows slightly improvement of total solids using planted condition.
7. The planted wetland system shows the better performance than the unplanted system. It is also found that the increases in the detention period of the wastewater the removal rate also increases.

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