ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.11 pp 87-95, 2016

# Study of Constructed Wetland for Treatment of Landfill Leachate

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**Abstract :** Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving plants, soils, and their associated microbial assemblages to assist in treating wastewater. The main purpose of this study was to treat organic pollution, nitrates and phosphates present in landfill leachate by the use of constructed wetland systems by studying the effect of retention time and plant species variation. A lab-scale study was conducted on horizontal mode subsurface flow constructed wetland systems using gravel, sand and garden soil as media. Retention time was varied from 1 hour, 2 hours, 3 hours, 4 hours, 8 hours, 12 hours and 24 hours to study the variation in efficiency of treatment of two locally available plants species namely; Cattail (Typha Latifolia) and Bulrush (Scirpus Californicus). Maximum removal efficiencies of Turbidity, COD, Total Solids, Nitrates and Phosphates achieved were 84%, 82%, 91%, 65% and 89%, respectively with the retention time of 8 hours. The plant species Cattail (Typha Latifolia) showed better results as compared to Bulrush (Scirpus Californicus).
**Keywords**: Constructed Wetland; Landfill Leachate; Organic Pollution; Nitrates ; Phosphates.

## Introduction

One of the major methods of disposing municipal solid wastes in the world today is landfill disposal. The main purpose of landfill disposal of solid wastes is to stabilize the waste and to make it hygienic through the use of natural decomposition. Landfill leachate is an important pollution factor resulting from municipal landfill sites. Leachate produced from municipal landfill sites contains concentrated toxic chemicals. Leachate is produced as a result of rainfall and surface runoff or groundwater entry into the landfill site[1]. Water that percolates into landfill takes up the soluble constituents from the wastes and may enter either the ground water or the surface water and thus act as a vehicle, carrying potentially toxic matter from the landfill to the water sources[2].

There has been an increased concerned caused to ground water and public health due to the presence of large quantity of hazardous chemicals in solid waste disposal sites close to residential areas[3].Leachates are classified as problematic wastewaters and a dangerous source of pollution and cannot be treated along with conventional municipal wastewater because of its variable characteristics such organics with low biodegradability, toxic components such as heavy metals, inorganic constituents such as ammonia, sulfate and cationic metals and low pH[4]. In order to achieve environmental friendly criteria for landfill leachate, the pollutants levels in leachate should be minimized to discharge standards. Hence, landfill leachate must be collected and treated[5]. It is difficult to be treat leachate to satisfy the discharge standards due to variable composition and high proportion of refractory materials[6].Advanced leachate treatment systems are being used by many developed municipal corporations. But biological and chemical treatment methods require high investment and operating costs, hence limiting their application to a very great extent [7]. For small communities with small scale landfills in particular, this cost represents a higher percentage of the budget[8]. Hence, many communities of the developing countries cannot afford the construction and operation of conventional treatment systems. For these communities, alternative natural treatment systems, which are simple in the construction and operation, yet inexpensive and environmentally friendly, seem to be appropriate. Natural based treatment systems such as constructed wetland would to be more appropriate and practical for their treatment as these systems have the attractive advantages of low cost and efficient removal mechanisms.

Constructed Wetlands (CWs) are a natural, eco-technological biological wastewater treatment technology designed to mimic processes found in natural wetland ecosystems, which is now standing as the potential alternative or supplementary systems for the treatment of wastewater[9]. Treatment of wastewater in constructed wetland systems includes biological and biochemical processes[10]. Constructed Wetland takes treatment systems use rooted wetland plants and shallow flooded or saturated soil for wastewater treatment. Constructed wetlands takes are designed to take advantage of the chemical and biological processes of natural wetlands for removing contaminants from wastewater[11]. Various factors play an important role in the treatment includes the availability and accessibility of contaminants for Rhizomes microorganism, the extent of soil contamination and uptake into roots. The main advantage of constructed wetlands is that it is extremely easy and cost effective to build, operate and maintain. Since all process involved in the treatment are natural, there are no chemicals used which in turn help keeping secondary pollution limited. Constructed wetlands are of two types, namely, surface flow and subsurface flow wetlands. Subsurface flow is again classified as horizontal flow and vertical flow. Extensive studies have been carried out on many types of constructed wetland with various media, plant species and other variations. The main objective of this work was to construct a lab scale horizontal sub surface flow constructed wetland, and hence study the effect of two plant species, Bulrush (Scirpus Californicus) and Cattail (TyphaLatifolia) on the removal efficiency of organic and inorganic contaminants of synthetic landfill leachate and to study the variation of retention time and the efficiency of the constructed wetland.

## Experimental Methodology

Two trays of dimensions 0.45X0.30X0.125m were taken and pipes of diameter 1.75cms were attached to both the sides of the tray as the inlet and outlet. The inlet was above the outlet with respect to the distance from the bottom of the tray. The plants chosen are aquatic plants and depend on their adaptability to the climate. The plants used for the lab scale model are Cattail (TyphaLatifolia) and Bulrush (Scirpus Californicus) which are locally available. Extensive studies have been carried out on both these plants by Gallardo-Williamsa, M.T.[13]and Al-Baldawia, I.A. [14]These aquatic plants have the characteristic ability of transporting air (oxygen) from the atmosphere to the roots from where a part diffuses into the liquid substrate. They have relatively deep routes and rhizosomes which create a large volume of active rhizosomes per unit surface area. They supply oxygen to the microorganisms in the substrate and help stabilize the organic matter applied [15]. There were three layers of purification, namely gravel, sand (sieved with 1.18mm sieve) and garden soil in the tray setup so as to explicably recreate a soil stratum. Garden soil growing a variety of plants was taken, preferably loamy, containing silt and clay. Each of these layers had specific roles to play in the purification process of a constructed wetland. Technical Specifications of the setup have been given in Table 1. The ability of gravel to make biofilms, the efficiency of sand to remove phosphates and nitrates from the water and adsorptive properties of the garden soil because of binding sites on the organic soil particles which allow cation exchange, are some of the mechanisms kept in mind while selecting constructed wetland media.

**Table1: Technical Specifications of Lab Scale Model**

| Operational Specifications | Value |
|---|---|
| CW Type | Subsurface Flow |
| CW Configuration | Horizontal Flow (HF) |
| CW Substrate | Garden Soil, Sand, Gravel |
| Type of Influent | Synthetic Leachate |
| Tray Dimensions | 45cm*30cm*12.5cm |
| Saturation Volume of tray | 5.5 Litres |
| Dilution Factor | 6 |
| Type of feeding | Intermittent |
| Plant Species | Cattail (TyphaLatifolia) |
| | Bulrush (ScirpusCalifornicus) |
| Depth of Gravel | 7 cms |
| Depth of Sand | 9 cms |
| Sand Sieve size | 1.18 mm |
| Depth of Garden Soil | 9 cms |
| Slope of Setup | 2% |
| Plant spacing | 20cm |

## Leachate Characteristics

Leachate was prepared in the laboratory and was tested for various characteristics. locally available waste such as fruit peels, dry food waste, wet food waste, garden waste, paper waste, plastics and some wood waste was collected, and mixed well with water. It was kept to decompose for 7 days and only the leachate was collected by sieving out the solid particles. This leachate was diluted using water to maintain a COD of 4000-5000 mg/l because of leading constraints on the constructed wetland. Then this fresh leachate was immediately tested for parameters such as pH, turbidity, Total Solids, Fixed Solids, Total Dissolved Solids, Chemical Oxygen Demand, Total Nitrates and Total Phosphates. All the analyses were performed according to standard methods [16]for the examination of water and wastewater. The characteristics of the influent leachate are presented in the Table 2.

**Table 3: Leachate Influent Characteristics**

| | |
|---|---|
| **pH** | 4.50 |
| **Turbidity** | 197 NTU |
| **COD** | 4480 mg/l |
| **Phosphates** | 23.67 mg/l |
| **Nitrates** | 9.75 mg/l |
| **TS** | 9650 mg/l |
| **TDS** | 9200 mg/l |
| **TSS** | 450 mg/l |
| **FS** | 3350 mg/l |

## Retention time

Diluted synthetic leachate was fed into the inlet and allowed to flow slowly because of the slope through the porous medium under the bed horizontally until it reached the outlet zone. Water was allowed to flow into the setup and kept for different Retention Times of 1hr, 2hrs, 3hrs, 4hrs, 8hrs, 12hrs and 24hrs. This water when passed through soil stratum, witnessed breaking down of the particles due to the microbial action of the plants and also the collective action of soil layers. The treated water was then collected from the outlet pipe. Each of the given samples obtained were tested for pH, turbidity, Total Solids, Fixed Solids, Total Dissolved Solids, Chemical Oxygen Demand, Total Nitrates and Total Phosphates.

## Results and Discussion

The treatment efficiency of the horizontal subsurface constructed wetland unit was examined by wastewater quality parameters such as pH, turbidity, Total Solids, Fixed Solids, Total Dissolved Solids, Chemical Oxygen Demand, Total Nitrates and Total Phosphates, in the outlet of wastewater at intermittent flow of retention times of 1hr, 2hrs, 3hrs, 4hrs, 8hrs, 12hrs and 24hrs.

The maximum change in pH values were obtained in Cattail (Typha Latifolia) ranging from 4.5 to 6.88 at a retention time of 24 hours and 4.5 to 6.71for Bulrush (Scirpus Californicus) at a retention time of 24 hours for the inlet and outlet respectively as seen in Figure 1. This increase of pH value may be due to formation of some acidic components in the bioremediation process[17].

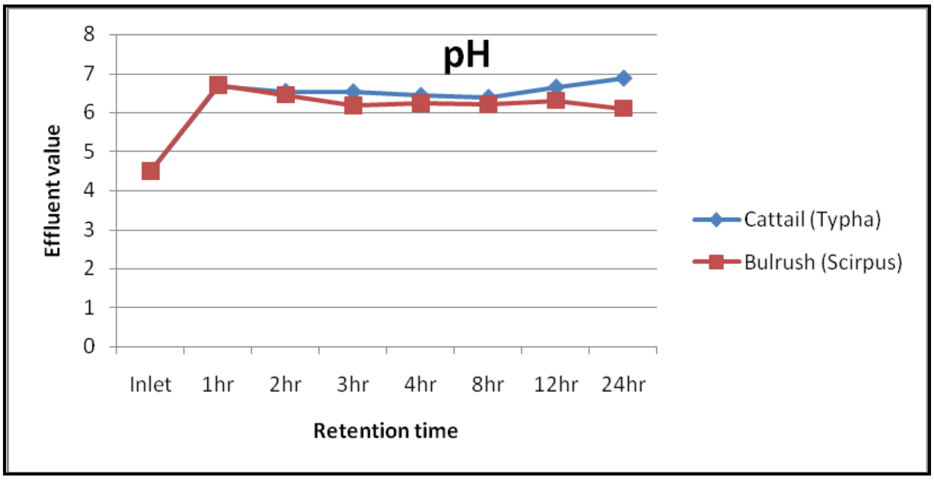


**Figure 1: Change in pH obtained for Typha Latifolia and Scirpus Californicus**

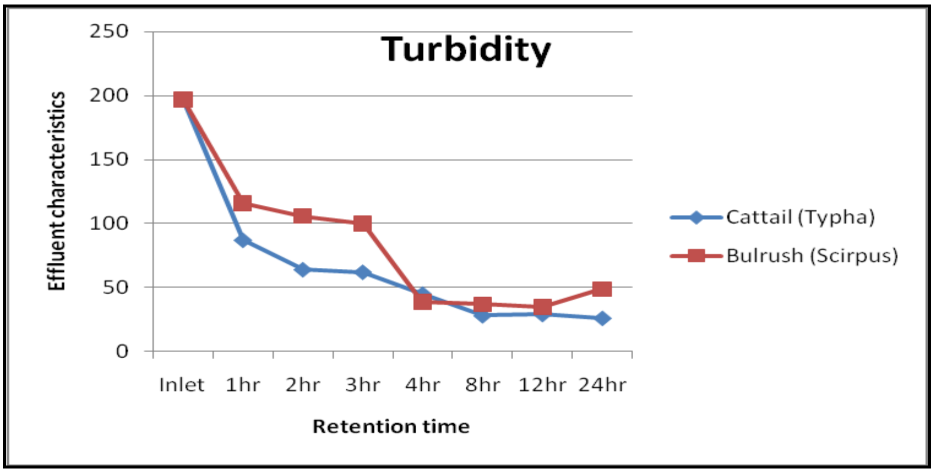


**Figure 2: Change in Turbidity value obtained for Typha Latifolia and Scirpus Californicus**

As seen in Figure 2, the turbidity of the outlet showed significant reductions from that of the inlet. The reduction efficiency at the retention time of 8 hours for Cattail was 85.7% and that for Bulrush (Scirpus Californicus) was 81%.

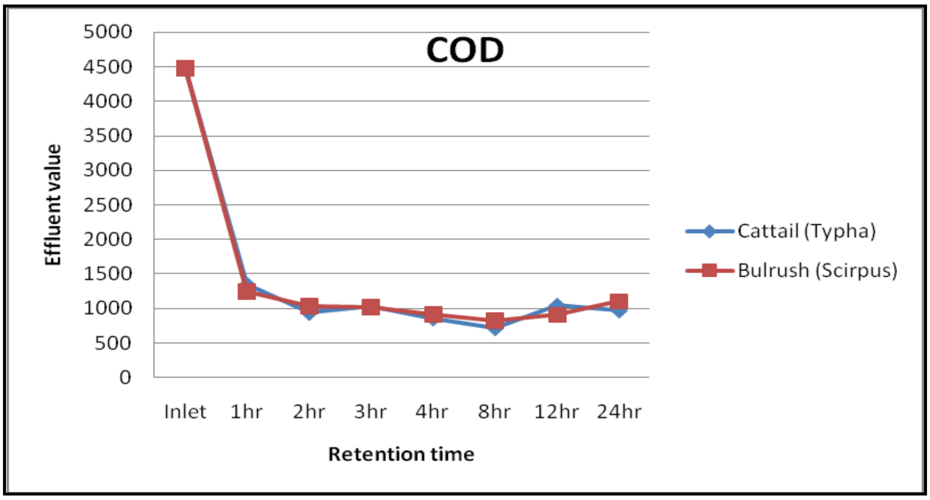


**Figure 3: Change in COD value obtained for Typha Latifolia and Scirpus Californicus**

The maximum COD removal was seen at the retention time of 8 hours for Cattail. It was reduced significantly from 4480mg/l to 716 mg/l providing a removal efficiency of 84% as seen in Figure 3. The removal efficiency of Bulrush (Scirpus Californicus) at the same retention time was observed to be 81.5%. The COD removal is believed to occur rapidly through settling and entrapment of particulate organic matter in the void spaces of the substrate. The substrate is the main supporting material for plants and microbial growth. Fine gravel promotes higher growth of plants and therefore increases the quantity of contaminant removal.

The constructed wetland showed significant reductions in the phosphate levels as seen in Figure 4. The level of phosphate fell from 23.6mg/l to 2.55mg/l during which it attained maximum efficiency of 89.9% in the setup with Cattail and 81% while using Bulrush (Scirpus Californicus). The soil contains low concentrations of minerals with reactive Fe or Al hydroxide or Ca which can promote phosphate precipitation.

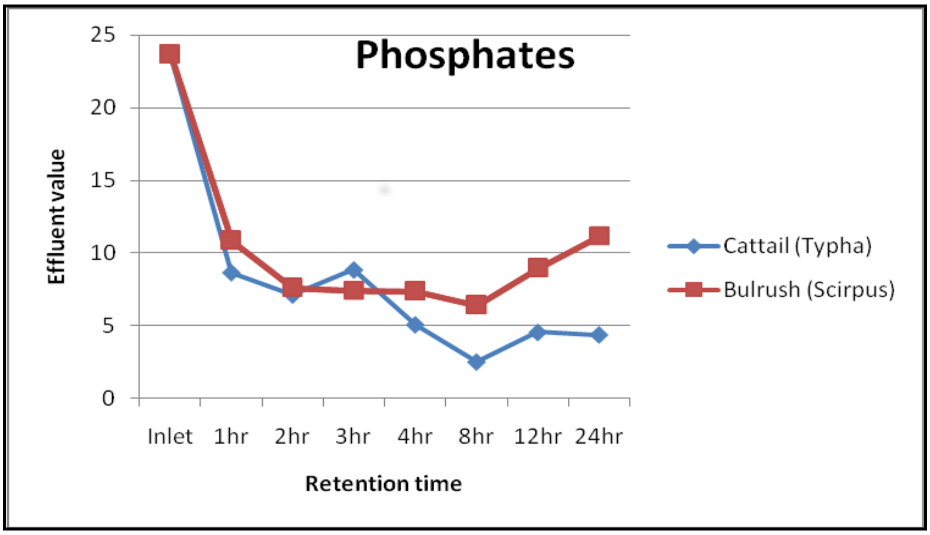


**Figure 4: Change in Phosphate value obtained for Typha Latifolia and Scirpus Californicus**

The maximum nitrate removal was obtained in Cattail changing from an inlet value of 9.35mg/l to 3.37mg/l with a removal efficiency of 65% in comparison with 63% efficiency for Bulrush (Scirpus Californicus) at a retention time of 8 hours as seen in Figure 5.

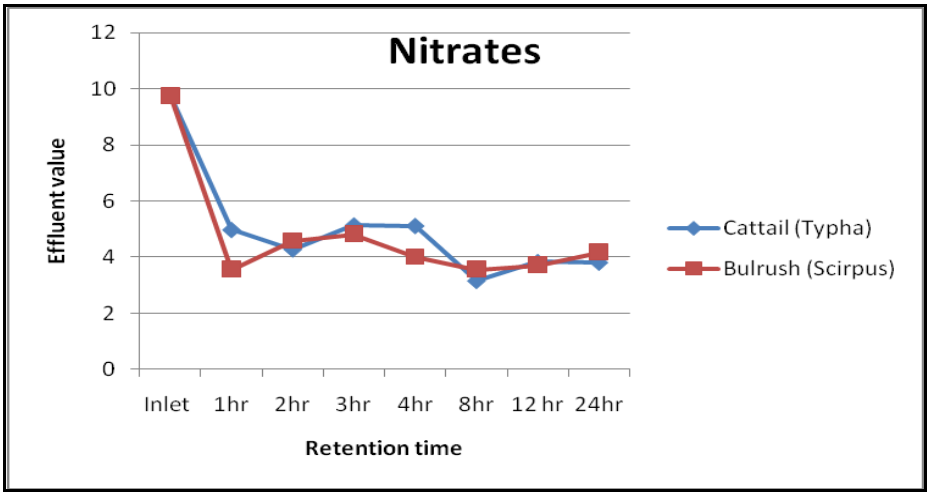


**Figure 5: Change in Nitrate value obtained for Typha Latifolia and Scirpus Californicus**

Macrophytic plants encourage the assimilation and breakdown of nutrients within a wetland system. They have the ability not only to bind high amounts of nutrients within their system, but also to create an environment conducive to decreasing nutrients [18]. Nitrification of ammonia–nitrogen can occur in the oxidized root zone of the Typha Latifolia and denitrification occurs into reduced environments in water column or in the sediments[19].

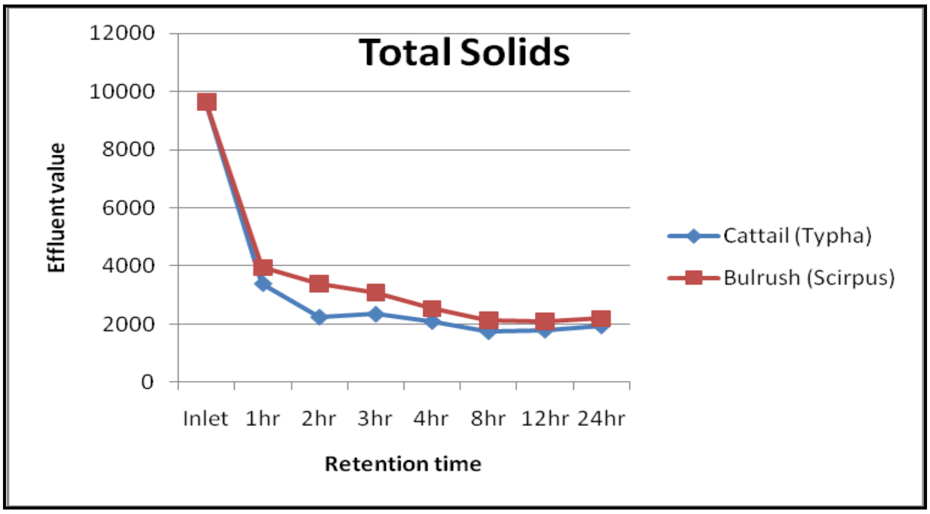


**Figure 6: Change intotal solids value obtained for Typha Latifolia and Scirpus Californicus**

The maximum removal was seen during the retention time of 8 hours for Cattail. It was reduced significantly from 9650mg/l to 1750 mg/l providing a removal efficiency of 81.7% as seen in Figure 6. The removal efficiency of Bulrush (Scirpus Californicus) at the same retention time was observed to be 77%.

The reduction in Fixed Solids obtained in Cattail changed from an inlet value of 3350mg/l to 350mg/l with a highly efficient removal efficiency of 91% in comparison with 88% efficiency for Bulrush (Scirpus Californicus) at a retention time of 8 hours as seen in Figure 7.The microorganisms within the leachate quickly adhere to the bead surface thereby lowering the drainable porosity and hence causing more leachate to stick to the film/bead surface [20].

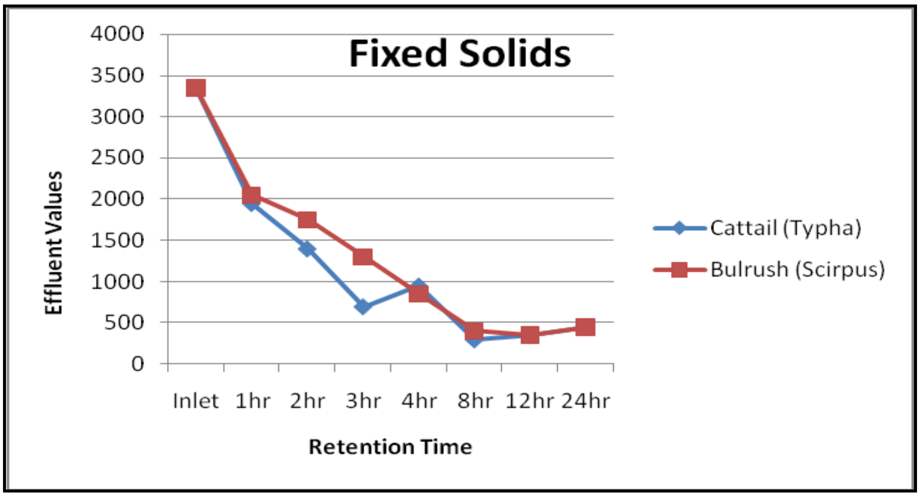


**Figure 7: Change infixed solids value obtained for TyphaLatifolia and ScirpusCalifornicus**

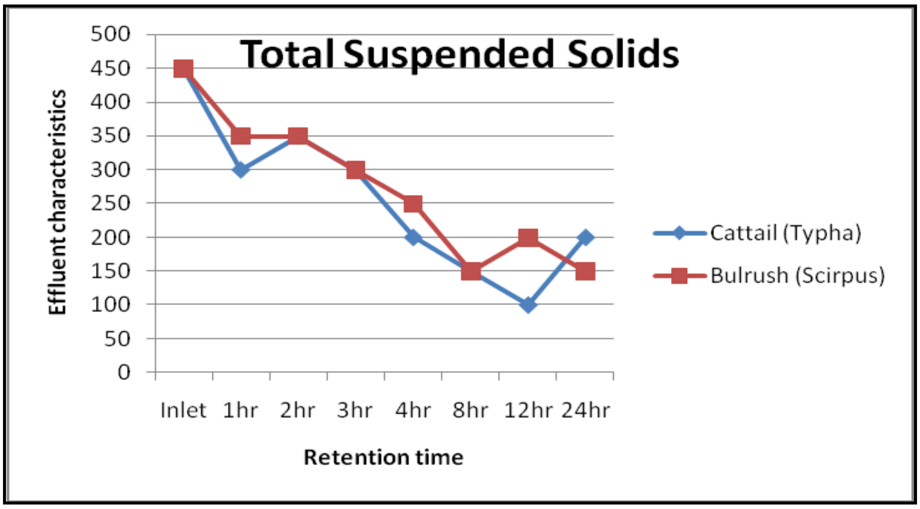


**Figure 8: Change intotal suspended solids value obtained for TyphaLatifolia and ScirpusCalifornicus**

The reduction in Total Suspended Solids ranged from 450mg/l to 100mg/l at a retention time of 12 hours and to 150mg/l for a retention time of 8 hours for Cattail as seen in Figure 8. The maximum reduction efficiency was seen in Bulrush (ScirpusCalifornicus) (from 450mg/l to 150mg/l) at a retention time of 8 hours.

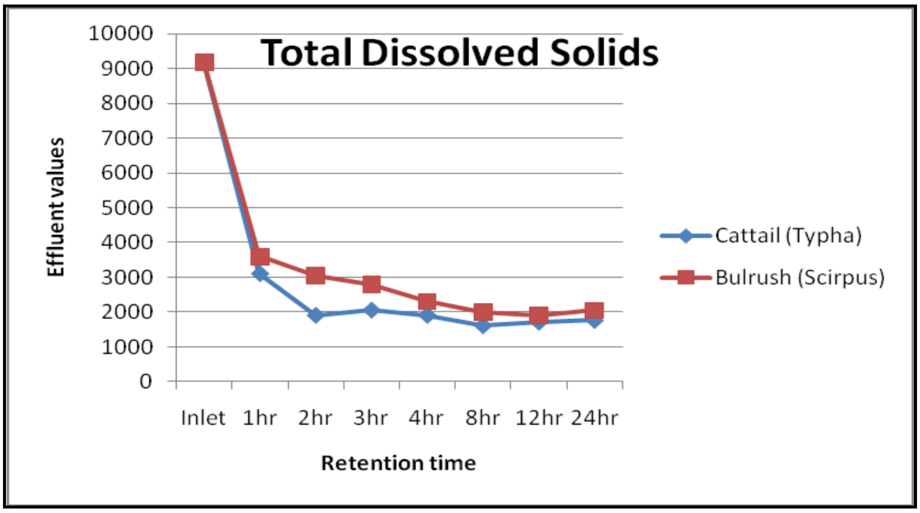


**Figure 9: Change inTDS value obtained for TyphaLatifolia and ScirpusCalifornicus**

As shown in Figure 9, the TDS values of the outlet showed significant reductions from that of the inlet. The reduction efficiency at the retention time of 8 hours for Cattail was 82.6% and that for Bulrush (Scirpus Californicus) was 78.26%.

These pollutants may be reduced due to trickling process and biofilm of aerobic and an anaerobic microorganism. The difference in the efficiency of each parameter in both plant species indicates that the use of Cattail at a Retention Time of 8 hourswill be helpful for better treatment of leachate.

## Conclusion

In this study, subsurface horizontal flow constructed wetland was applied for the treatment of synthetic waste leachate. Results from the study show that Cattail (Typha Latifolia) and Bulrush (Scirpus Californicus) can be used effectively for treatment of landfill leachates. However, Typha Latifolia showed better contaminant removal as compared to Scirpus Californicus. It was observed that retention time of 8 hrs showed better results for both the species. Maximum removal efficiencies of Turbidity, COD, Total Solids, Nitrates and Phosphates achieved were 84%, 82%, 91%, 65% and 89%, respectively with the retention time of 8 hours.

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