Research article **Available online www.ijsrr.org** **ISSN: 2279–0543**

International Journal of Scientific Research and Reviews

Treatment of Domestic Wastewater by Typha Angustifolia based vertical sub-surface flow constructed wetland with hydric and sandy loam substrates

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ABSTRACT

Though several investigations were done on constructed wetlands, the role of soil media in the process of treatment has not been much focused. This work was done to find the role of two different soil media hydric and sandy loam (rhizobium rich) soil planted with locally available Typha Angustifolia, under Vertical Subsurface Constructed wetland conditions for treatment of wastewater. A model of dimensions 0.75m x 0.4m x 0.30m was employed for the study at different Hydraulic Retention Times (HRT) of 24, 48, 72, 96 and 120 hours, for the discharge rates of 75, 37.5, 25, 18.75, and 15 L/day respectively. Various parameters such as BOD, COD, Organic Nitrogen, Ammonia Nitrogen, Kjeldhal Nitrogen, Total Nitrogen, Ortho Phosphates, Nitrates, and Nitrites were investigated for their removal. At the end of 5^{th} day retention time, the removal was found to be 84.88% and 89.92% of BOD, 80.12% and 86.75% of COD, Organic nitrogen removal was found to be 48.97% and 52.37%, Ammonia Nitrogen 49.43% and 56.27%, Kjeldhal Nitrogen 42.54% and 54.77%, Nitrites 63.59% and 92.7%, Nitrates 41.28% and 35.78% Total Nitrogen 42.57% & 54.07% and Ortho Phosphates 42.52% and 77.84% respectively for hydric and sandy loam soils. Hence, this study demonstrates that soil substrate plays a significant role in constructed wetland for wastewater treatment. The model with Sandy loam (rhizobium rich) soil as substrate exhibited better in the removal of all selected parameters except Nitrates.

KEY WORDS: Constructed Wetlands, Hydraulic Retention Time, Hydric Soil, Sandy loam soil, Typha Angustifolia.

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INTRODUCTION

The conventional treatment of wastewater is very expensive, requires highly trained operators onsite at all times and does not work well on a small scale. It consists of preliminary, primary, secondary and tertiary treatments that are based on biological, physical and chemical processes. The most common biological process of wastewater treatment is a treatment with activated sludge process, trickling filter, rotating biological filters, oxidation ponds. Constructed wetlands (CWs) are capable of reducing the treatment cost and the complexity of operation with much control over degree of pollution [1]. Subsurface flow constructed wetlands (SSFCW) have proved to be consistent to remove organic C and particulate matter from wastewater but have been less successful in the removal of N and P. The high purification efficiency of constructed wetlands can be accomplished by choosing suitable growth media [2]. The results with sand[3] is more efficient treatment than gravel. It is determined through a study, that the CW with media containing a soil and sand mixture yields the highest removal efficiencies of the pollutants[4]. Several researchers use different types of media (e.g. vermiculite, zeolite, and lime) to remove certain compound from the wastewater.

OBJECTIVE OF THE PRESENTSTUDY

The Present Study is intended to construct and develop a pilot-scale Vertical Sub-Surface Flow Constructed Wetland (VSSFCW) model and to find efficacy of two different substrates (Hydric/Sandy loam) for treatment of various parameters such as BOD, COD, Nitrate, Nitrite, Ammonia Nitrogen, Organic Nitrogen, Kjeldhal Nitrogen, Total Nitrogen, Ortho-Phosphates, to study the potential of TyphaAngustifolia (a locally available aquatic plant).It is also aimed to examine the plant nutrient uptake above-ground (leaves, shoots) as well as the below-ground biomass (roots).

MATERIALS ANDMETHODOLOGY

Source of Domestic Wastewater: Grab sampling was adopted for the collection of pretreated wastewater from Municipal Sewage Treatment Plant near Renigunta, in Chittoor District of Andhrapradesh, India.

Construction of the Vertical Sub-Surface Flow Constructed Wetland (VSSFCW): In the Vertical subsurface flow constructed wetland, the wastewater flows vertically from planted layer through the substrate. In this study the models used were constructed with plastic-fiber for better visibility of filter media and flow of wastewater.

The wetland cell is of 0.75m long, 0.4m wide and 0.3m deep. A vertical freeboard of 0.05m (5cms) was provided and a working volume of the reactor was 0.075 m^3 is provided. The cell is divided into three layers, the top and bottom layers consists of coarse aggregate (20 mm) with a depth 0.03m (3 cms) and 0.02 (2 cms) and middle layer was filled with Hydric soil/sandy loam with depth of 0.2m (20 cms) respectively as in one instant and sandy loam soil with depth of 0.2m (20cm) in another instant. Line diagram comprising different layers is shown in the following Fig.1 and 2 respectively.

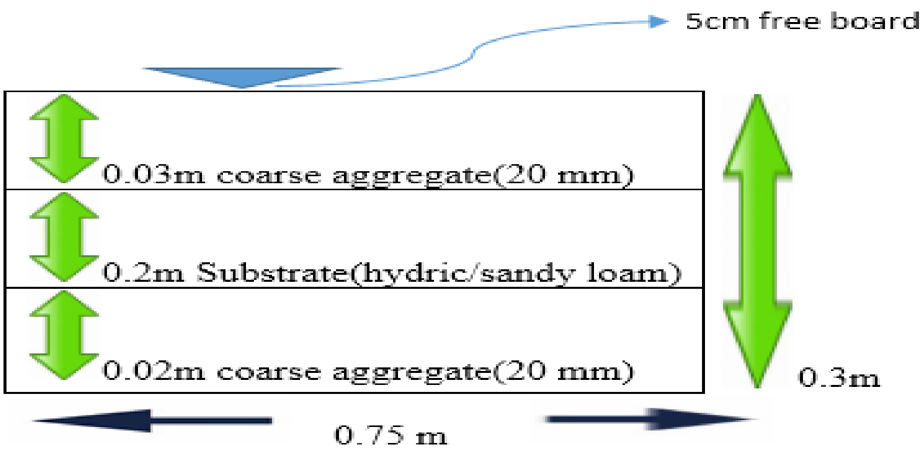

Figure -1: Line diagram of model showing different layers

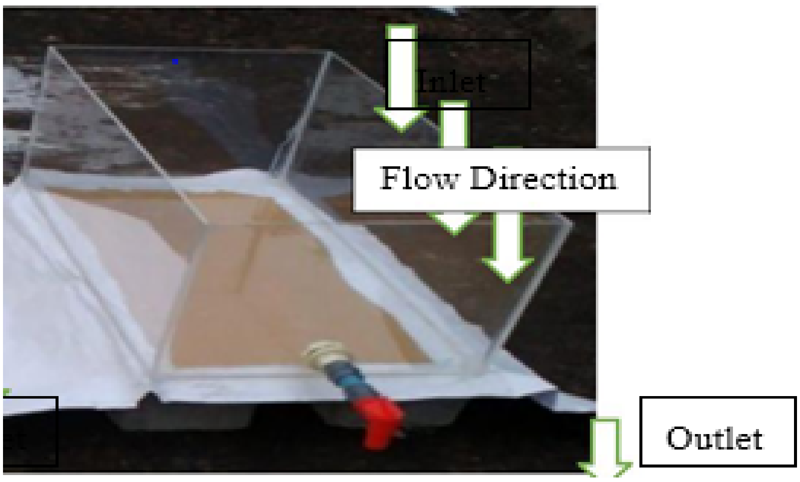

Figure -2: VSSFCW model without filling

"TyphaAngustifolia" is planted in both the soil media in vertical flow constructed wetland model. The unit planted with 6 *TyphaAngustifolia* plant species arranged in 2 rows and 3 columns based on root zone spreading is shown in Fig.3 and 4 respectively.

Width of root zone was 0.1m, plants spacing was 0.12m along length and 0.1m along the width. Depth of roots was 0.15m and plant density of each wetland cell was 20 plants/m^2.

Figure -3: VSSFCW (model and blank) with *TyphaAngustifolia*in Hydric soil substrate

Figure -4: VSSFCW (model and blank) with *Typha Angustifolia* in Sandy loam soil substrate

Methodology

Domestic wastewater collected from sewage treatment plant, was made to pass vertically down the constructed wetland model filled with Hydric/Sandy loam soil, with rate of discharges as mentioned in Table 1. The wastewater passed through the constructed wetland model and samples were collected at an intervals of 1, 2, 3, 4 and 5 days and investigated for BOD, COD, Organic-N, Ammonia-N, TKN, Total-N, Nitrate-N, Nitrite-N, Ortho-Phosphates. In between each interval of reaction 24 hours gap was provided to enable free circulation of air.

A blank was run using tap water instead of wastewater for making comparisons. The same process was repeated with sandy loam soil.

Wastewater flow rate was adjusted at the inlet valve. As the volume is known, required time was calculated according to the formula given in following equation: T=V/Q.

Table: 1 Details of HRT at different flow rates (Q)

Volume of the wetland model	Discharge rates	Hydraulic Retention Times
LXBXH=0.75X0.4X0.25 =0.075 cu. m	Q=100ml/115 sec=75lit/day	T=24 Hours
	Q=100ml/230 sec= 37.5lit/day	T=48 Hours
	Q=100ml/345sec=25lit/day	T=72 Hours
	Q=100ml/460 sec=18.75lit/day	T=96 Hours
	Q=100ml/576sec=15lit/day	T=120 Hours

METHOD OF ANALYSES

Analysis of wastewater: Samples of the sewage influents and effluents were collected. The samples were analyzed for BOD using Wrinkler's method, COD using the Block Digester method, ammonium nitrogen, total kjeldhal nitrogen using titrimetric method of macro kjeldhal process, Nitrate nitrogen at 410 nm with the ultraviolet spectrophotometer, nitrite nitrogen at 543 nm with the ultraviolet spectrophotometer, ortho phosphate at 450 nm using the vanadomolybdophosphoric acid colorimetric method (as specified in APHA Standards).

Analysis of soil (Microbial analysis): In order to quantify the microorganisms in the respective soils the total bacterial count and amount of nitrifying bacteria present in the two substrates were found out using nutrient agar and modified winogradsky's medium process.(as specified in hand book of laboratory culture media, reagents, stains and buffers, by N. Kannan, panima publishers, New Delhi).

Analysis of plant: The percentage nitrogen, phosphorous in plant leaf, shoot, roots are found out using Kelplus Apparatus and %N is determined titrimetrically and %P is as color metrically.(as specified in Laboratory manual on advances in agro-technologies for improving soil, plant, and atmosphere systems).

RESULTS AND DISCUSSION

Initial studies were conducted to estimate total bacterial and nitrifying bacterial count for two distinct substrates Hydric/Sandy loam soil. Experiments were carried using the vertical flow constructed wetland model to assess the removal efficiencies of wastewater pollutants such as BOD, COD, Nitrates, Nitrites, Ammonia Nitrogen, Organic Nitrogen, Kjeldhal Nitrogen, Total Nitrogen and Ortho Phosphates. Plant analysis were done to estimate height, percentage N and percentage P in roots, shoots and leaf planted in Hydric/Sandy loam soil.

Estimation of total bacterial count in Hydric soil and Sandy loam soil: The Bacterial count were estimated using nutrient agar as the medium and the results obtained are given in this section. The picture of hydric soil sample and the colonies of bacteria from hydric soil sample on nutrient agar medium is shown in Fig.5.

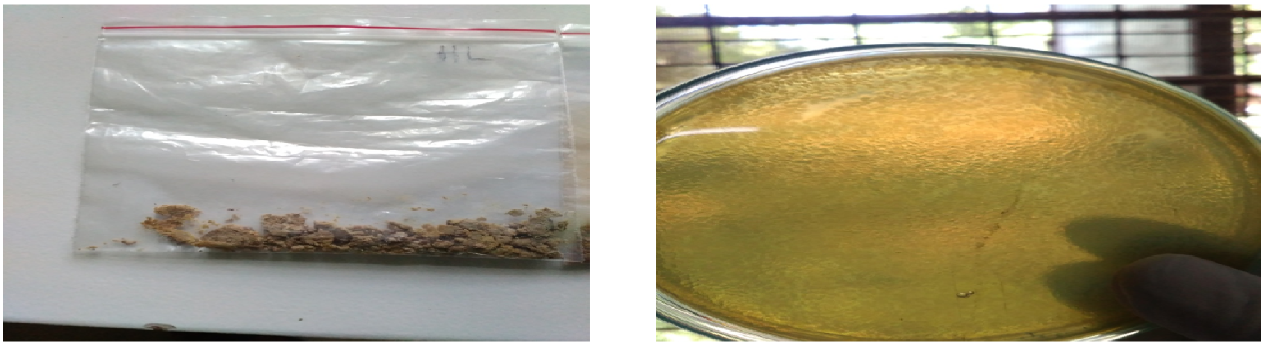

Figure -5: Hydric soil sample with Bacterial colonies of Hydric soil on Nutrient Agar

Similarly the pictures of sandy loam soil sample and the colonies of bacteria from sandy loam soil sample on nutrient agar medium is presented in Fig. 6.

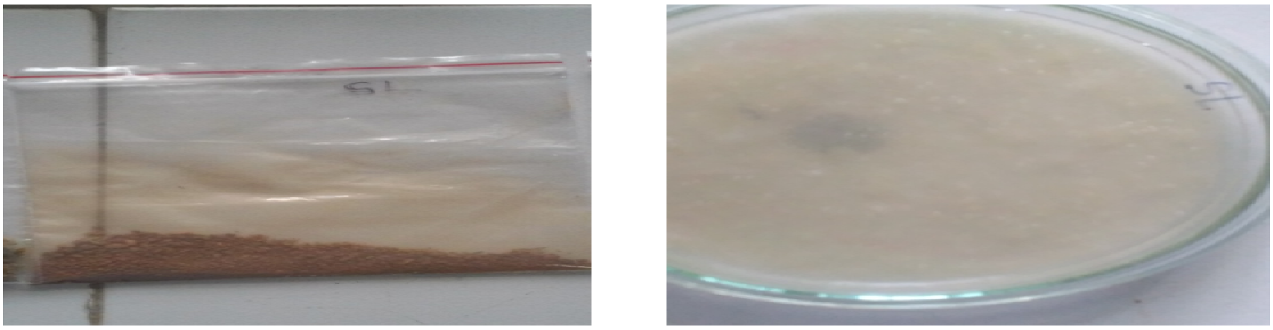

Figure -6: Sandy loam soil sample with colonies of Bacteria of Sandy loam soil on Nutrient Agar

The Bacterial Count in Hydric Soil was observed to be 920 x 10^{15}cfu/ml, where as in Sandy loam Soil was observed to be 12 x 10^{15}cfu/ml.

Estimation of nitrifying bacterial count in hydric soil and Sandy loam soil: Nitrifying bacteria was counted using Winogradesky's medium. The pictures of the colonies formed with sandy loam and hydric soil were presented in Fig.7. The Nitrifying Bacterial Count in Hydric Soil was observed to be 4 x 10^{16}cfu/ml, where as in Sandy loam Soil is observed as 17 x 10^{16}cfu/ml.

Figure -7:Colonies of Nitrifying Bacteria with Sandy loam soil and Hydric soil

Performance of Vertical Flow Constructed Wetland model with Typaangustifolia plants: The vertical sub-surface flow constructed wetland were planted with *Typha Angustifolia*and supplied with wastewater at five different Hydraulic Retention Time and analysed for wastewater characteristics such as BOD, COD, Nitrates, Nitrites, Ammonia Nitrogen, Organic Nitrogen, Kjeldhal Nitrogen, Total Nitrogen and Ortho Phosphates. Characteristics of pretreated Domestic Wastewater are presented in the Table 2.

Table: 2 Characteristics of Pretreated Domestic Wastewater

Sl no	Parameters	Concentration (mg/l)
1	Biochemical Oxygen Demand(5 day 20^0c)	397
2	Chemical Oxygen Demand	483.21
3	Nitrate-Nitrogen	2.18
4	Nitrite-Nitrogen	0.206
5	Ammonia-Nitrogen	29.34
6	Organic-Nitrogen	16.46
7	Total Kjeldhal Nitrogen	45.81
8	Total Nitrogen	48.19
9	Ortho-Phosphates	12.91

Biochemical Oxygen Demand (BOD): The removal efficiencies of BOD in percentage are shown in Fig.8 by bar diagram.

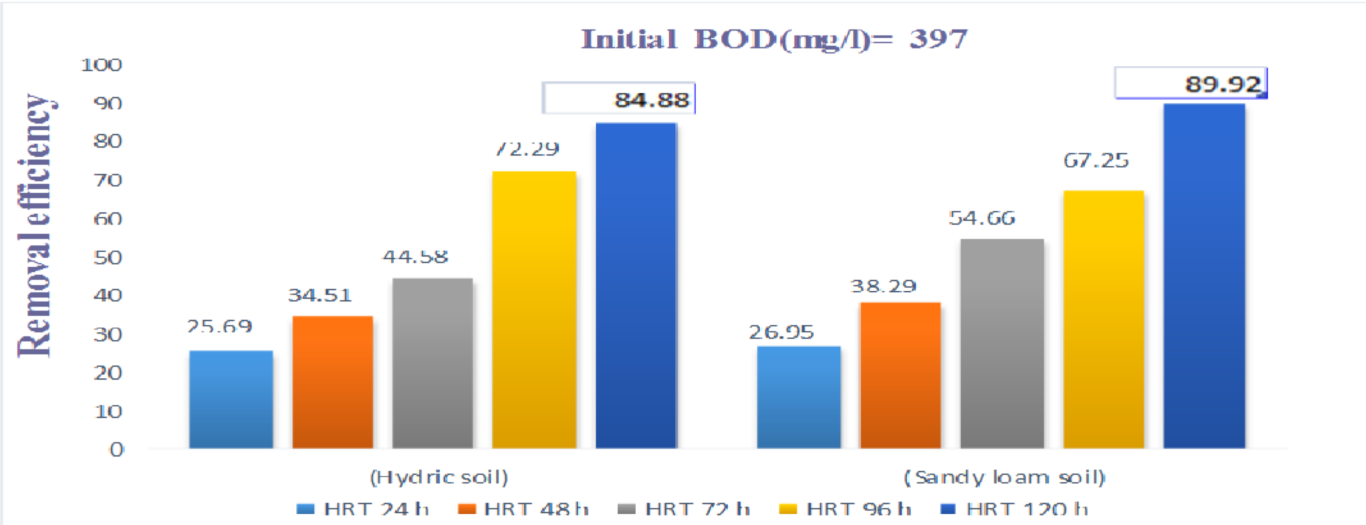

Figure -8: Removal efficiencies of BOD by VSSFCW Model at various HRT

It is observed that maximum removal efficiency (89.92%) of BOD was found at HRT of 120 h in Sandy loam Soil. The removal at the end of 1 day HRT is more than 25% in both cases, and rapid at 4 day HRT and 5 day HRT in Hydric and sandy loam soil respectively. It is found the average percent removal of BOD by the planted beds (PhragmitesAustralis) was 84%, in media type (gravel or vermiculite) treating domestic wastewater compared to 37% of BOD removal in unplanted model in an eight months study[5]. The reasons behind the removal of BOD (Organic compounds) are biological degradation both aerobically as well as anaerobically in the wetland system depending on the oxygen concentration in the bed. The removal efficiencies from the present study (89.92%) is better than that of the studies by respective author. A study on "Effect of hydraulic retention time on temperature of secondary effluent in a subsurface constructed wetlands" found[6] that for influent concentration of BOD is 160.83 mg/l the average removal of BOD in effluent wastewater varied greatly between 1-3 days HRT but no further removal at 4 days HRT is seen i.e. 81.41%, whereas 1 day HRT is 16.17%, for 2 day HRT 47.04% and for 3 day HRT is 64.54%, observed in Typha Angustifolia planted in layers of gravel but no such removal is comparable with phragamities. The results obtained from the studies (89.92%) are better when compared to studies made by this author. A two years study [7]on "Municipal wastewater treatment using vertical flow constructed wetland planted with Canna, Phragmities and Cyprus" indicated 90% of removal is observed at every 7.7 days HRT. This study is made in gravel planted in divided sections of the model. The removal percentage obtained is nearly equal to that of our investigations. The result shows better removal of Biochemical Oxygen Demand in Sandy loam soil than hydric soil.

Chemical Oxygen Demand (COD): The removal efficiencies of COD in percentage are shown in Fig.9 by bar chart.

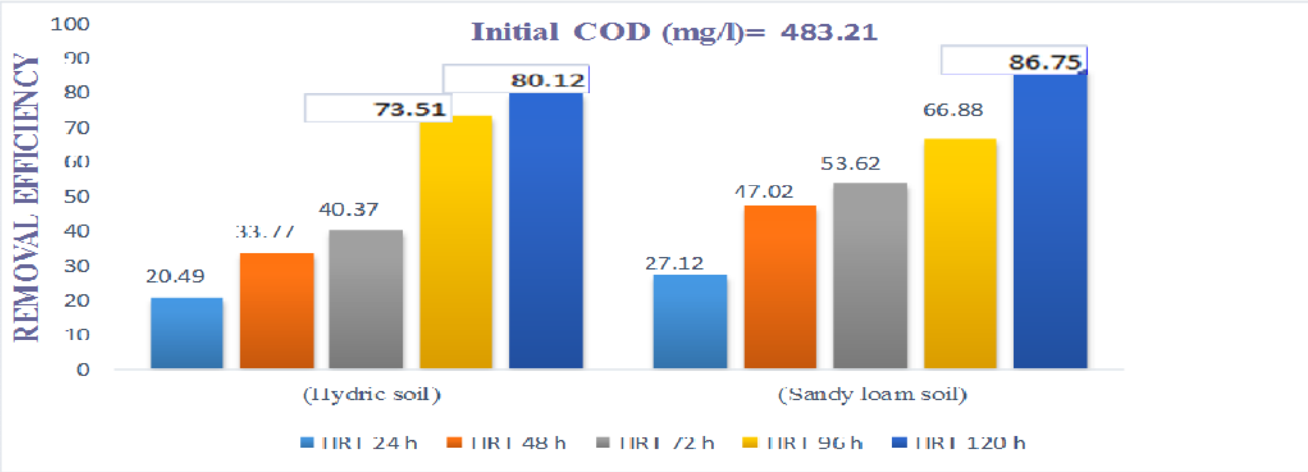

Figure -9: Removal efficiencies of COD by VSSFCW Model at various HRT

It is observed that maximum removal efficiency (86.75%) of COD was at HRT 120 h in Sandy loam Soil. The removal efficiencies are found to be rapid at 4 day HRT in the case of hydric soil, whereas the 4 day removal is low in sandy loam soil. But the 5 day efficiency in sandy loam soil is 86.75% which is higher than that of hydric soil. This variation in trends of the plot could be due to climatic factors such as variations in day and night and subsequent variation in temperature, availability of sunlight for photosynthesis and cloudiness in the sky etc. It is found the average percent removal of COD by the planted beds (PhragmitesAustralis) was 75%, in media type (gravel or vermiculite) treating domestic wastewater[5]. The reasons behind the removal of COD (Organic compounds) are biological degradation both aerobically as well as anaerobically in the wetland system depending on the oxygen concentration in the bed. The removal percentage (86.75%) obtained from our studies are better than the studies by the authors.A study[8] on "Vertical subsurface flow constructed wetland for polishing secondary kaduna refinery wastewater in Nigeria " found that 65% of COD is removed using c Alternifolius and 63% removal is observed in Dactylon, in entire work the plants are planted in cylindrical containers and employing gravel mixed with coarse sand as media. The results (86.75%) from our investigations are better when compared to that of the studies done by the researchers, might be due to the model they used was cylindrical, as our study is carried in rectangular in plan. Sandy loam soil exhibited greater removal of Chemical Oxygen Demand when compared to hydric soil.

Nitrate nitrogen: The removal efficiencies of Nitrate nitrogen in percentage are shown in Fig.10 by bar chart.

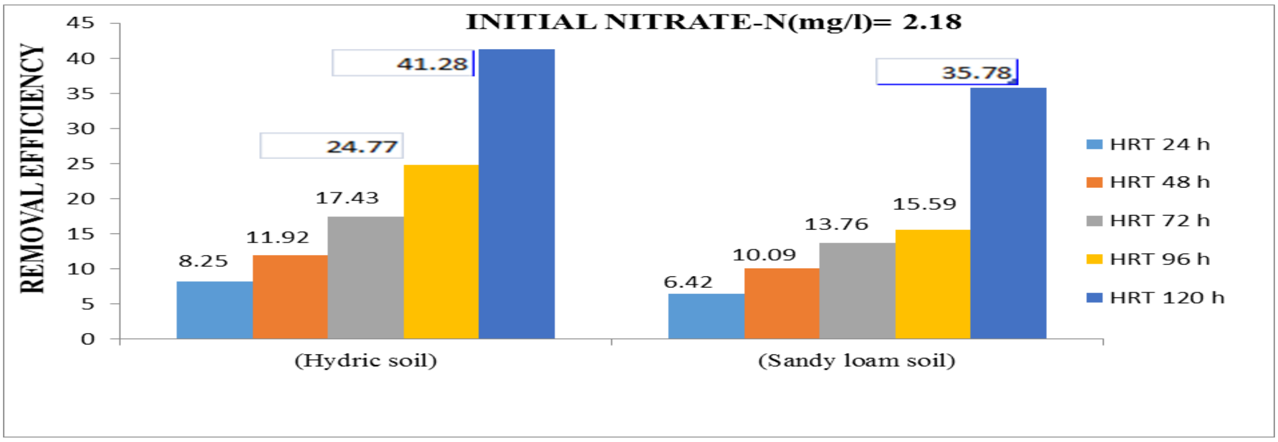

Figure -10: Removal efficiencies of Nitrate Nitrogen by VSSFCW Model at various HRT

It can be observed that maximum removal efficiency (41.28%) of Nitrate-N was at HRT 120h in hydric Soil. There is a marginal removal of nitrates in both the models up to 3 days in hydric soil and 4 days in sandy loam soil but the rise in removal is seen afterwards in both cases. The reason behind this might be more anaerobic situations arrived in hydric soil in comparison to sandy loam soil. It is found that NO3 concentration in the effluent of the planted beds (PhragmitesAustralis) increased by 16% over that of the influent, in media type (gravel or vermiculite) treating domestic wastewater[5]. The reason behind the removal of nitrate is the reduction of nitrate to molecular nitrogen or nitrogen gases, which is called de-nitrification. A study[9]summarized the environmental factors known to influence de-nitrification rate including the absence of oxygen, redox potential, soil moisture, temperature, pH value, the presence of de-nitrifiers, soil type, organic matter and the presence of overlying water. The result of the authors were contrary to our studies, it might be due to de-nitrification did not occur in their experimental setup. The percentage removal (41.28%) obtained from our studies are better than the result by the researchers. Studies[6] on "Effect of hydraulic retention time on temperature of secondary effluent in a subsurface constructed wetlands" found that influent concentration of Nitrate-N is 2.72 mg/l and effluent concentration of Nitrate-N is 0.94 mg/l. The removal is seems to be more at 4 days HRT of 96.78%,whereas the removals at the end of 3 days, 2 days, 1 day is 92.15%, 74.46%, 27.25% respectively when planted in TyphaAngustifolia, which indicates the removal of nitrates depends on retention time. The results by the authors are comparable to our work but better removal were arrived in their studies than our investigations. The above results indicates better removal of Nitrates in Hydric soil than Sandy loam soil.

Nitrite Nitrogen: The removal efficiencies of Nitrite nitrogen in percentage are shown in Fig.11 by bar chart.

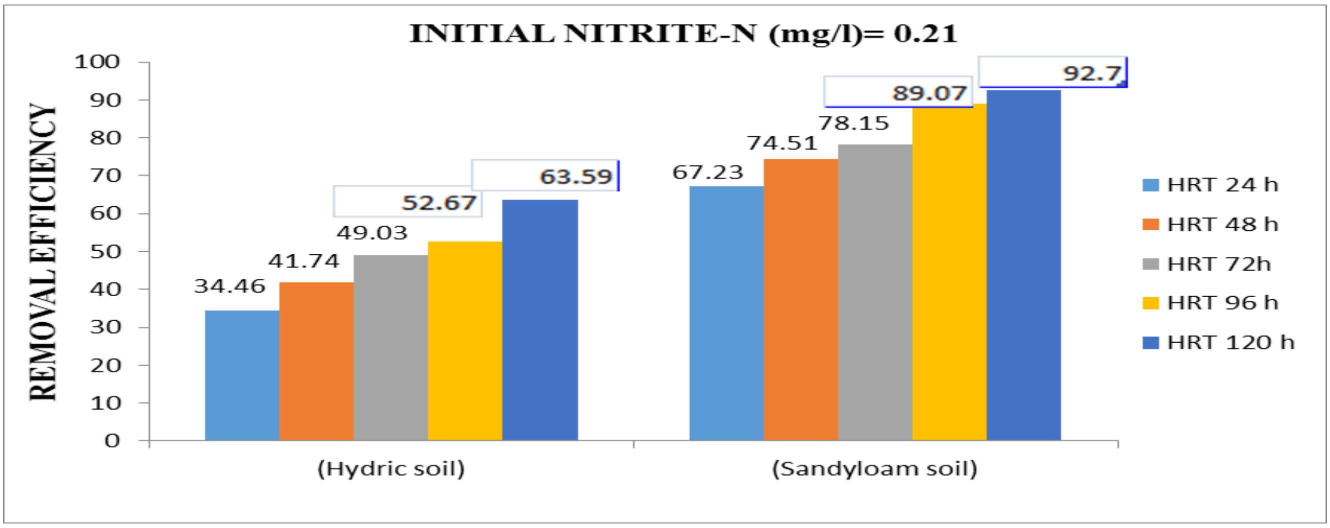

Figure -11: Removal efficiencies of Nitrite Nitrogen by VSSFCW Model at various HRT

It is observed that maximum removal efficiency (92.7%) of Nitrite- N was at HRT 120 h in Sandy loam Soil. This might be due to conversion of nitrites to nitrates with huge amount of oxygen present in the upper layers and then into nitrogen gas due to de-nitrification. The reason behind the removal of nitrites is conversion of nitrite to nitrate and then to nitrogen gas by nitrifier and de-nitrifiers. The above observations yields greater removal of Nitrites in Sandy loam soil than hydric soil.

O-Phosphates: The removal efficiencies of O-Phosphates in percentage are shown in Fig.12 by bar chart.

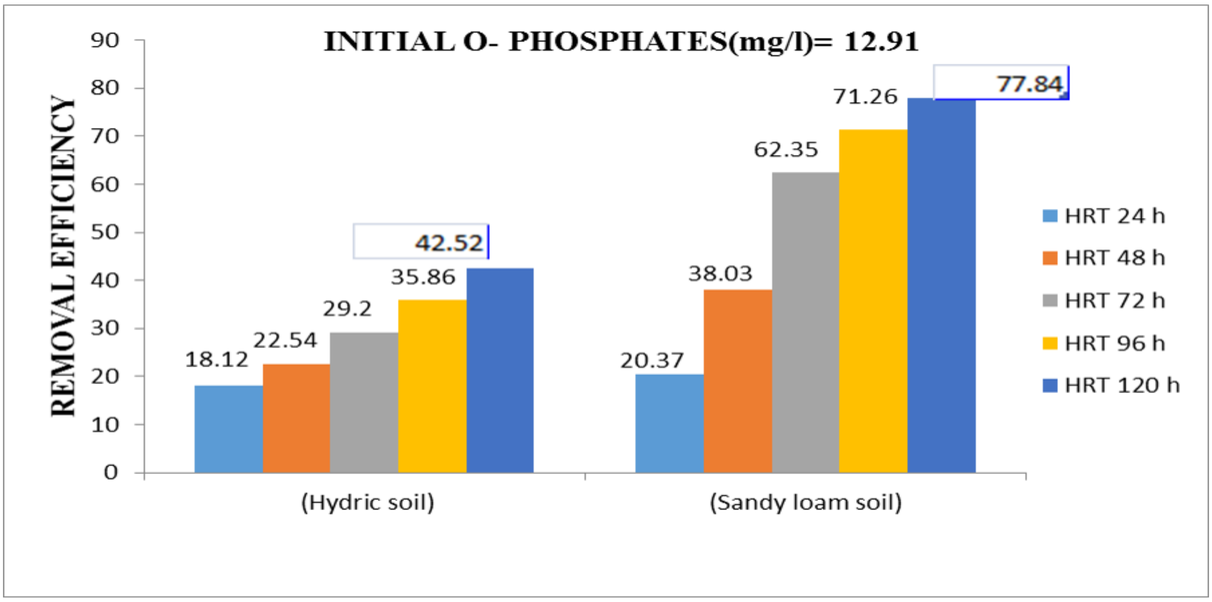

Figure -12: Removal efficiencies of O-Phosphates by VSSFCW Model at various HRT

- It is observed that, maximum removal efficiency (77.84%) of O-PHOSPHATES was at HRT 120 h in Sandy loam Soil. It suggests that removal of ortho-phosphates are limited to 42.5% at the end of 5 day HRT, but it crossed 62% at the end of 3 day itself in sandy loam soil. A two years study[7] on “Municipal wastewater treatment using vertical flow constructed wetland planted with Canna, Phragmities and Cyprus” found that average O-phosphates removal is 62% with three sections planted as canna, phragmites and cyprius in gravel. The results obtained from our studies are better (77.84%) than the studies by the author.Study on “Vertical subsurface flow constructed wetland for polishing secondary Kaduna refinery wastewater in Nigeria[8] ” found that 43% of O-phosphates is removed using C Alternifolius and 42% removal is observed in c. Dactylon, in entire work the plants are planted in cylindrical containers and employing gravel mixed with coarse sand as media. Better results (77.84%) were obtained from our investigations when compared to the studies by this author. The results indicates that in Sandy Loam soil is better in removing O-Phosphates than Hydric soil.

Ammonia Nitrogen: The removal efficiencies of Ammonia Nitrogen in percentage are shown in Fig.13 by bar chart.

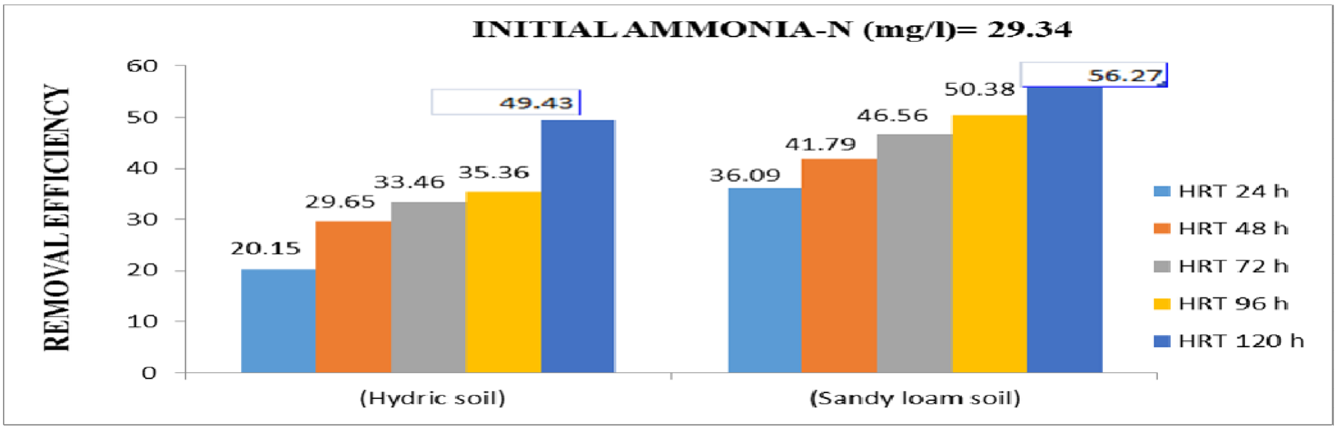

Figure -13: Removal efficiencies of Ammonia Nitrogen by VSSFCW Model at Various HRT

It is observed that maximum removal efficiency (56.27%) of Ammonia-N was at HRT 120 h in Sandy loam Soil. The rapid removal is observed at 1 day HRT in both cases but in the case of sandy loam soil the removal efficiency afterwards overbeat the removals in hydric soil. A research[5] found that Ammonia-N planted in vermiculite media (33%), gravel as media (25%) treating domestic wastewater. The reason behind the removal is conversion of ammonia to nitrite then to nitrates and at last to nitrogen gas. Observations (56.27%) made in our study were better than the obtained values of the authors. A Study[6] on “Effect of hydraulic retention time on temperature of secondary effluent in a subsurface constructed wetlands” found that the removal is seems to be more at 4 days HRT of 99.96%, whereas the removals at the end of 3days, 2 days, 1 day is 98.87%, 87.12%, 77.58% respectively when planted in TyphaAngustifolia, which indicates the removal of Ammonia-N depends on retention time. The results of these researchers were better than that of our study, might be due to rapid nitrification occurred in their experimental set up. The study proves the ability of Sandy Loam soil in removing Ammonia-N when compared to hydric soil.

Total Kjeldhal Nitrogen (TKN): The removal efficiencies of TKN in percentage are shown in Fig.14 by bar chart.

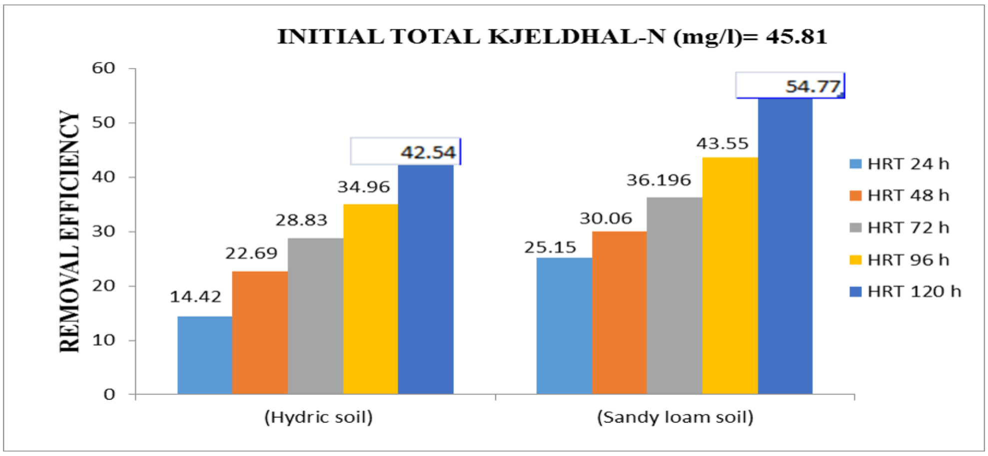

Figure -14: Removal efficiencies of Total Kjeldhal Nitrogen at various HRT

It can be observed that maximum removal efficiency (54.77%) of TKN was at HRT 120 h in Sandy loam Soil. The removal of TKN is gradual in both the cases but the sandy loam soil exhibits more removal at every corresponding HRT.Studies[6] on “Effect of hydraulic retention time on temperature of secondary effluent in a subsurface constructed wetlands” found that the removal is seems to be more at 4 days HRT of 83.99%, whereas the removals at the end of 3 days, 2 days, 1 day is 72.03%, 63.66%, 21.86% respectively when planted in typha angustifolia, which indicates the removal of nitrates depends on retention time. The results of these researchers were better than our work, might be due to rapid ammonification and nitrification occurred in their model. A two years study[7]on “Municipal wastewater treatment using vertical flow constructed wetland planted with Canna, Phragmities and Cyprus” found that average TKN removal is 53% with three sections planted as canna, phragmites and cyprius in gravel. More removal is observed at 7.7 days HRT. The removal percentage (54.77%) obtained from our work is better than by the authors investigations. The result demonstrate the better removal of Total Kjeldhal Nitrogen in Sandy loam soil when compared to hydric soil.

Organic Nitrogen: The removal efficiencies of Organic Nitrogen in percentage are shown in Fig.15 by bar diagram.

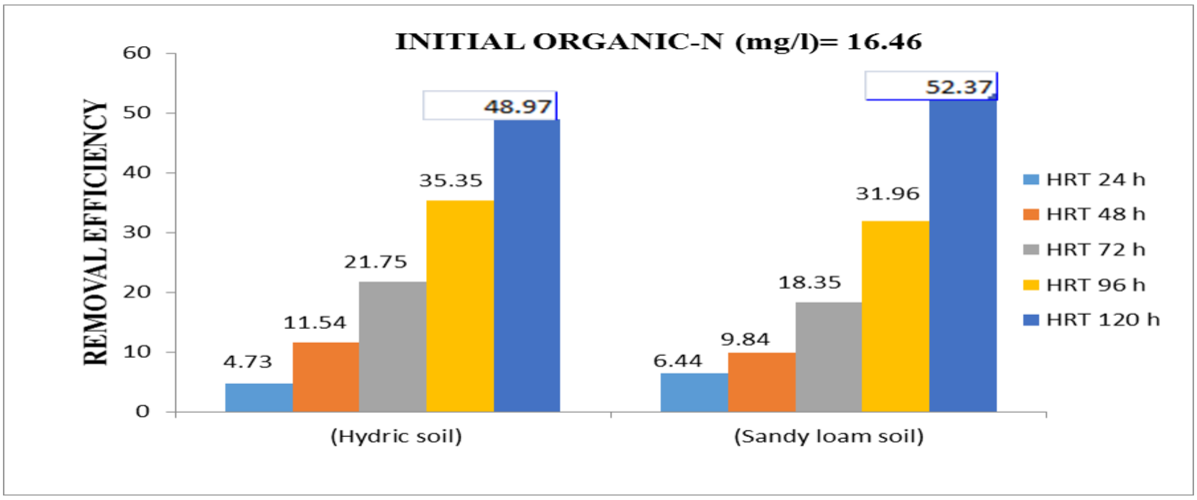

Figure -15: Removal efficiencies of Organic Nitrogen by VSSFCW Model at various HRT

It is observed that maximum removal efficiency (52.37%) of Organic nitrogen was at HRT 120 h in Sandy loam Soil. The removal is marginal up to 2 days in both instants of soil. This may be due to very less conversion of organic-N, to ammonia. After then the removal is considerable in nature in both soils.

A study[10]"Comparative Study of Three Two-Stage Hybrid Ecological Wastewater Treatment Systems for Producing High Nutrient, Reclaimed Water for Irrigation Reuse in Developing Countries" states that Horizontal flow constructed wetland itself removes 60.6%, vertical flow constructed wetland itself removes 80.3%, HF-VF Removes 77.5%, VF-HF Removes 83.1% of organic nitrogen .The result of these researchers are better than our work, might be due the model they used were of hybrid type. The above results shows efficacy of Sandy loam soil than hydric soil in removing Organic Nitrogen.

Total Nitrogen: The removal efficiencies of Total Nitrogen in percentage are shown in Fig.16 by bar diagram.

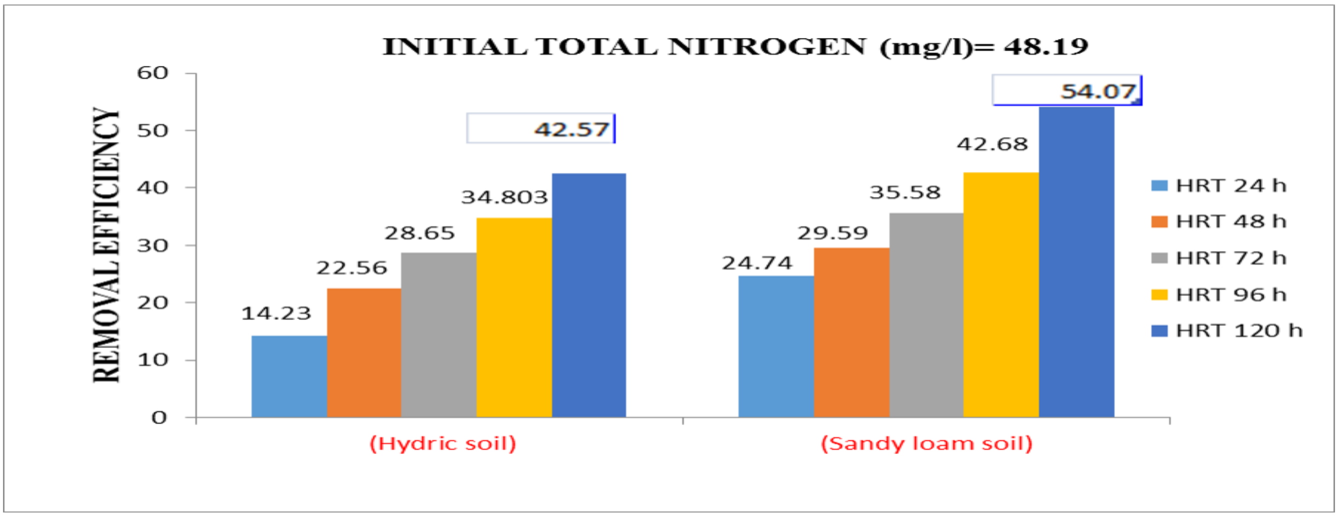

Figure -16: Removal efficiencies of Total Nitrogen by VSSFCW Model at various HRTs

It can be observed, that maximum removal efficiency (54.07%) of Total Nitrogen was at HRT 120 h in Sandy loam Soil. The removal of total –N was gradual in the case of Typha planted in hydric soil, but there is sudden rise in the case of sandy loam soil. This might be due to nitrification and de-nitrification rapid in sandy loam soil. The reason behind the removal is volatilization, ammonification, nitrification/de-nitrification, plant uptake and matrix adsorption. A study[11] on "Wastewater Treatment Using Vertical Subsurface Flow Constructed Wetland in Indonesia" found that 71.70% of total nitrogen is removed from farm house wastewater when *Phragmiteskarka* planted in river sand. During the study period (August 2009-January 2010). The results of these authors were better than our work, might be due to difference in plant and media type used in our study. A study[12] on "Nitrogen removal from domestic wastewater using constructed wetland having different water levels" obtained that removal efficiency of Total Nitrogen in sands of different porosities used in Phragmites as 38.8%, 32.3%, 25.5% respectively at 7cm, 14 cm, 21cm depths of wastewater in the buckets and also 27.1%, 30.5%, 25.6% respectively at 7 cm, 14 cm, 21 cm depths of wastewater in the buckets, it was observed at the end of 6 days. The obtained results (54.07%) from our study were better than that of the author's investigation. The result shows the efficacy of Sandy loam soil in removing Total Nitrogen than Hydric soil.

Plant Analyses: Plant Analysis is carried out for the reference plant as well as plants in the model the results are (as shown in Fig.17 & 18 and Tables 3& 4) as follows:

Figure -17: Measuring heights of *TyphaAngustifolia* in wetland model and in blank under Hydric Soil Substrate

The initial height of *TyphaAngustifolia*is 60 centimeter. Average height of *TyphaAngustifolia*in the model is 88 centimeter against 63 centimeter in the blank, possibly due to nutrient uptake from supplied wastewater at the end of all discharges.

Table: 3 %N and %P in plant Leaf, Root, Shoots planted in Hydric Soil

Nutrient	Plant part	Plants in the model	Reference plant
N%	LEAF	1.62	1.28
P%	LEAF	0.59	0.23
N%	ROOT	1.28	0.88
P%	ROOT	0.48	0.12
N%	SHOOT	1.46	1.06
P%	SHOOT	0.51	0.16

From the Table 3 it can be observed that %N is at its maximum in the leaf zone, whereas in the shoots it is lesser and the least at the root zone. This shows that the absorption of nitrogen is good by the plant both in the model as well as in the blank. The similar observations are seen at % P transfer from roots to leaf. The model acquired more phosphorous % in all parts when compared to the blank.

Figure -18: Measuring heights of *TyphaAngustifolia* in wetland model and in blank under Sandy loam Soil Substrate

The initial height of *TyphaAngustifolia* is 60 centimeter. Average height of *TyphaAngustifolia*in the model is 106 centimeter against 71centimeter in the blank, possibly due to nutrient uptake from supplied wastewater at the end of all discharges.

Table: 4 %N and %P in plant Leaf, Root, Shoots planted in Sandy Loam Soil

Nutrient	Plant part	Plants in the model	Reference plant
N%	LEAF	1.76	1.32
P%	LEAF	0.91	0.14
N%	ROOT	1.31	0.96
P%	ROOT	0.46	0.22
N%	SHOOT	1.52	1.19
P%	SHOOT	0.57	0.18

From the Table 4, it can be observed that %N is at its maximum in the leaf zone, whereas in the shoots, it is lesser and the least at the root zone. This shows that the absorption of nitrogen is good by the plant both in the model as well as in the reference or blank.

However, in the case of phosphorous, the model showed a good absorption, whereas the blank reactor showed a poor absorption. This could be probably due to greater absorption of phosphorous by the soil than that of the plant.

CONCLUSION

Vertical sub-surface flow constructed wetland was established with hydric/sandy loam (rhizobium soil) soils and planted with TyphaAngustifolia (a locally available aquatic macrophyte) and employed for domestic wastewater treatment. Based on the experimental results, the following conclusions are made.

- The maximum removal of BOD 84.88%, COD 80.12%, Nitrate-N 41.28%, Nitrite-N 63.59%, O-Phosphates 42.52%, Ammonia-N 49.43%, Total Kjeldhal Nitrogen 42.54%, Organic Nitrogen 48.97% and Total Nitrogen 42.57% was observed in hydric soil.
- The maximum removal of BOD 89.92%, COD 86.75%, Nitrate-N 35.78%, Nitrite-N 92.70%, O-Phosphates 77.84%, Ammonia-N 56.27%, Total Kjeldhal Nitrogen 54.77%, Organic Nitrogen 52.37%, and Total Nitrogen 54.07% was noticed in Sandy loam soil.
- Increasing HRT (from 1 day to 5 days) resulted in considerable increase in BOD, COD, Nitrate, Nitrite, Organic-N, Ammonia-N,TKN, Total-N and O-phosphates removal efficiencies in both soil substrates.
- In all the treatment studies Sandy loam soil (rhizobium rich) exhibited better removal.
- The percentage nitrogen and phosphorous in plant roots (1.28%, 0.48%), shoots (1.46%, 0.51%) and leaves (1.62%, 0.59%) of TyphaAngustifolia planted in Hydric soil.
- The percentage nitrogen and phosphorous in plant roots (1.31%, 0.46), shoots (1.52%, 0.57%) and leaves (1.76%, 0.91%) of TyphaAngustifolia planted in Sandy loam soil.
- More uptake of %N and %P was observed in TyphaAngustifolia planted in Sandy loam soil. Study demonstrate that locally available aquatic macrophyteTyphaAngustifolia is potential to be used in wastewater treatment.

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