STUDY ON POLLUTANT REMOVAL EFFICIENCY BY SUBSURFACE FLOW CONSTRUCTED WETLAND WITH MANGROVE PLANTS AND VETIVER PLANTS

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Abstract

The Water pollution is one of the major environmental issues that we are facing today. The rapid urbanization, industrialization and increase in population are the main reasons for it. So the need of wastewater treatment is very essential due to the lack of purified water for drinking and domestic purposes. Of all sources; food sector is major sources of pollution, because it produces large volume of wastewater, for example dairy industry. There are many conventional wastewater treatment facilities are available. The Constructed wetland is a type of wastewater treatment technology which is cost effective and eco-friendly. They are man-made wetlands constructed to remove pollutants from the wastewater. In this study an attempt is made to find the effectiveness of vetiver plants (vetiveria zizanioides) and mangrove plants (Aegicirus cornicultum) in horizontal subsurface flow constructed wetland for the pollutant removal from dairy wastewater. Various characteristics of water before and after treatment has been checked to study the comparative effectiveness of mangrove plants and vetiver plants. Removal efficiencies of parameters like BOD, COD, Ammoniacal nitrogen, Phosphate and Nitrate were greater than other parameters. After phytoremediation the water obtained was good quality, so it can be reused and recycled. This study proven that constructed wetland using vetiver plants and mangrove plants are reliable, low cost, coefficient method for treating dairy wastewater.

Index Term- ***Phytoremediation, Dairy wastewater, Constructed Wetland, Wastewater Treatment***

I.INTRODUCTION

In recent years, due to high necessity and less availability, water is to be conserved better. Increased population and Industrialization is considered main causes of the pollution. Many industries requires a large volume of water for its production.the used and polluted water need to be treated for further usage. Somany eco-friendly treatment were introduced with low construction and maintenance cost.

Constructed wetland is one of the better alternative methods to treat urban as well as industrial wastewater. They are found to be effective for removal of nutrients from wastewater. The effectiveness to treat the pollutants are mainly depend on the types of wetland plants,soil and area used. They are constructed to mimic the processes that found in the natural wetland ecosystem through engineering designs. It removes pollutants and nutrients from the waste water and storm water. Constructed wetland is an accepted method worldwide, they are low cost,with less energy consumption and low maintenance. The main advantage is its feasiblity in any adverse climatic conditions.

There are mainly three types of constructed wetland; Free water surface constructed wetland (FWS CW), subsurface horizontal flow constructed wetland (SSHF CW) and sub-surface

vertical flow constructed wetland (SSVF CW). In FWS CW wastewater flows in a shallow water layer over soil surface. In SSHF CW water flows horizontally through the soil substrate. In SSVF CW the water is dosed intermittently onto the surface of the soil filters and gradually drains and is collected through the drains provided at the base. Constructed wetlands can reduce the contaminants such as total suspended solids (TSS), biochemical oxygen demand (BOD), organic and other inorganic components (Singh et al, 2003).

Phytoremediation strategy is used in the construction of wetland technology. Phytoremediation is defined as the application of plants and microorganisms to remove harmlful pollutants from contaminated sites. The selection of constructed wetland plants is important, because different species have different pollutant removal efficiency. In this project the comparison to removal efficiency when mangrove plant and vetiver plant are used for the dairy wastewater treatment. The Dairy wastewater is considered for the treatment. It is already found out that the mangrove plants are able to tolerate the toxic pollutants such as heavy metals and toxic persistent pollutants.The vetiver plants have the ability to control eutrophication, they are very tolerant to soil acidity, alkalinity, heavy metals etc.Vetiver system is found highly efficient to treat the sediment bound chemicals.

The main objectives of this project were To analyze the parameters like pH, turbidity, TDS, TSS, BOD, COD, chlorides, nitrate,electrical conductivity and Phosphate influent and effluent. To design and develop constructed wetlands with mangrove plant (Aegicirus Corniculatum) and vetiver plant (Vetiveria Zezanioides) to treat dairy wastewater. To investigate the removal efficiency of pollutants by using mangrove and vetiver plants. To compare the efficiency of mangrove plants and vetiver plants with the constructed wetlands over dairy wastewater for the pollutant removal and its behavior.

II.MATERIALS AND METHODS

1. MATERIALS

In this project the experiment is carrying out by using mangrove plant species Agecirus Corniculatum and Vetiver plants of species Vetiveria Zizanioides. The mangrove plant saplings are collected from Kannur Kandal Project and Vetiver plants are collected from local gardening nursery.

2 SAMPLE COLLECTION

The dairy wastewater is using for the experiment. It is collected from Kannur Milma. The collected effluent sample were tested by Indian standard procedures. Parameters like pH, BOD, COD, DO, Ammoiacal Nitrogen, NO_3, PO_4, Turbidity, TSS, TDS, Chloride and Electrical Conductivity were tested.

Fig no.1 Sample Collection

3 EXPERIMENTAL SETUP

3.1 Inlet zone

The inlet zones having feed buckets were used to hold the wastewater samples. The bucket has a capacity of 15 liters. The rate of flow is controlled by the half inch pvc taps connected in the bottom of the feed buckets followed by the pipe and elbow of suitable length without any leaks and losses.

3.2 Constructed wetland unit

The constructed wetland unit is constructed with glass in rectangular shaped basin/tank / channel of a thickness 5mm. The size of the wetland unit tank is depends on the quantity of wastewater to be treated. the size of the tank was 70x50x40 cm. 1 to 2% slope is providing at the bottom of the tank so that the flow will occur through gravity. This basin or channel is filling with suitable depth of porous media/substrate media as bed.

Fig no.2 Glass basin with slope provided

The substrates that are mainly used are gravel particles of sizes 4.75mm to 6.3mm. the gravels are collected and sieved through 10mm. the gravels which are retained on 6.3mm and 4.75mm is taken and filled it near the inlet and outlet portal, thereby removing any particulate matter that are present in the wastewater. Before filling gravel particles a screen net was provided near the effluent outlet in order to avoid scouring of substrate medium.

The sand particles of sizes 2.36mm, 600µm and 300µm were used for the bed. The sand bed is the region where the wetland plants are grown. The sieved, washed and dried sand particles are filled at the center portion about 50cm in length of the tank. The sand layer is filled about 20cm in height of the tank of suitable thickness.

Fig no.3 Bed preparation

The filter bed is provided with the dimension of 50 x 50 x 20 cm wih suitable plant species for the pollutant removal.

The filter bed is designed as:

- 9cm thick 2.36mm at the bottom
- Again 9cm thickness of 600 micron above the 2.36mm
- A thickness of about 2 cm of 300 micron is provided at the top

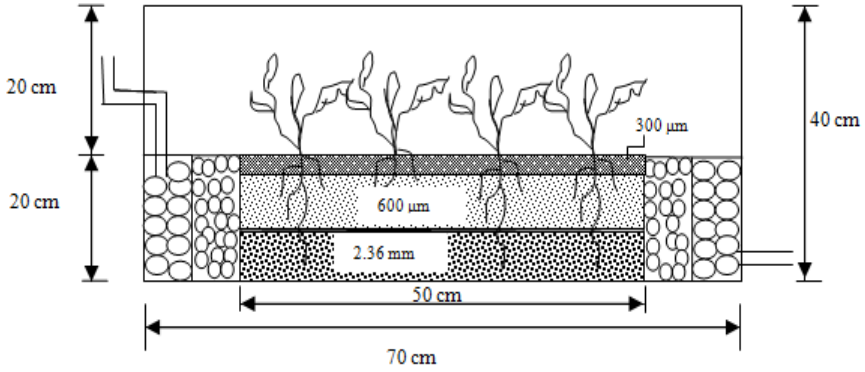

Fig no.4 Schematic diagram of the designed constructed wetland unit

Fig no.5 the constructed wetland unit which is filled with water for plant growth

3.3 Outlet zone

Outlet zone consists of outlet pipe of half inch was fixed above 3cm from the bottom of constructed wetland unit tank. A net screen was provided inside to avoid scouring of substrate media. A tap was connected to the hole for effluent collection without any leak.

4 QUALITATIVE ANALYSIS

The effluent samples of about 2L were collected from the outlet points of the constructed wetlands units in every 3 days gap to determine the following: pH,TSS, TDS, Turbidity, Chlorides, Electrical conductivity, BOD ,COD, Nitrate , Ammoniacal Nitrogen, Phosphate were determined using APHA , 2017.

Table No 1- Test methods and initial characteristics of sample

PARAMETRES	TEST METHODS	RESULTS
pH	PART 4500 H^+	7.21
TSS	PART 2540	168
TDS	PART 2540	1050
TURBIDITY	PART 2130	156
CHLORIDES	PART 4500 Cl^-	79.12
ELECTRICAL CONDUCTIVITY	PART 2510	1486
BOD	PART 5210	576.15
COD	PART 5220	787.20
NITRATE	PART 4500 NO_3^-	14.19
AMMONIACAL NITROGEN	PART 5000	42
PHOSPHATE	PART 4500-P	3.40

5 REMOVAL EFFICIENCY CALCULATION

The removal percentage of nutrients and pollutants is calculating based on the formula:
Removal percentage =

$$\frac{\textit{Influent conc.} - \textit{Effluent conc.}}{\textit{Influent conc.}} \text{X100}$$

III RESULTS AND DISCUSSIONS

1 CONSTRUCTED WETLAND UNIT USING MANGROVE PLANTS

The effluent was passed through the constructed wetland unit which is planted with mangrove plants of species A.corniculatum. The pollutant concentration after 1day, 3days, 6days and 9 days with iitial pollutant concentration were found out and are given in the table

Table No 2- Effluent characteristics on various detention time when passed through filter bed with Aegiceras Corniculatum

PARAMETERS	DETENTION TIME (DAYS)			
	DAY 1	DAY 3	DAY 6	DAY 9
pH	7.23	7.40	7.98	8.28
TSS	1.86	6	18	20
TDS	1700	1750	1510	132
TURBIDITY	0.50	BDL	2.20	2.7
CHLORIDE	260	712	672	637
EC	3600	2400	2130	1867
BOD	111.9	14.4	11.0	9.74
COD	520	39.3	31.4	29.3
NITRATE	6.78	3.59	1.34	0.98
AMMONIACAL NITROGEN	10	0.2	BDL	BDL
PHOSPHATE	1.57	0.01	BDL	BDL

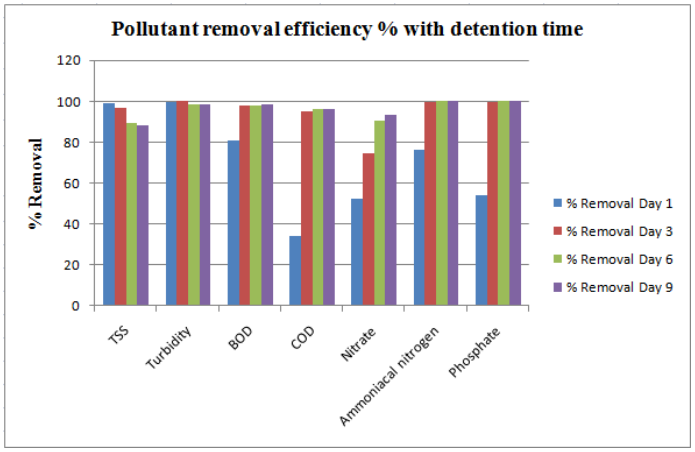

Fig no.6 Evaluation of % removal efficiency in Aegiceras corniculatum CW unit

Considerable removal efficiencies were observed in mangrove plants CWs after 9 days detention period for all tested parameters except pH, TDS, Chloride, and electrical conductivity. 100 % removal was observed in the system at day 3. The removal efficiencies of TSS and Turbidity goes on drecresing as the detention time increases. It is due to the presence of dissolved organic loading like fats and oils present in the wastewater. The pH values increases (from 7.23 to 8.28)

The BOD and COD reduction after treatment was 98.30 % and 96.26 % respectively. 93.09 % removal observed for nitrate at the end of treatment. Ammoiacal nitrogen and phosphate shows 100% reduction from 6 days detention time. The graphical representation of pollutant removal efficiencies percentage with detention time in mangrove plant CW unit.

2 CONSTRUCTED WETLAND UNIT USING VETIVER PLANTS

Table No 3- Effluent characteristics on treatment by vetiver plant constructed wetland at various detention time

PARAMETERS	DETENTION TIME (DAYS)			
	DAY 1	DAY 3	DAY 6	DAY 9
pH	7.24	7.59	7.67	7.72
TSS	1.53	8	15	29.85
TDS	2000	2300	1960	1640
TURBIDITY	BDL	0.70	3.50	5.45
CHLORIDE	140	870.3	949.4	928.3
EC	4100	3250	2790	2460
BOD	91.8	17.72	7.75	6.50
COD	384	94.96	55.10	30.45
NITRATE	7.65	5.24	1.90	1.54
AMMONIACAL NITROGEN	13	0.3	BDL	BDL
PHOSPHATE	1.86	BDL	BDL	BDL

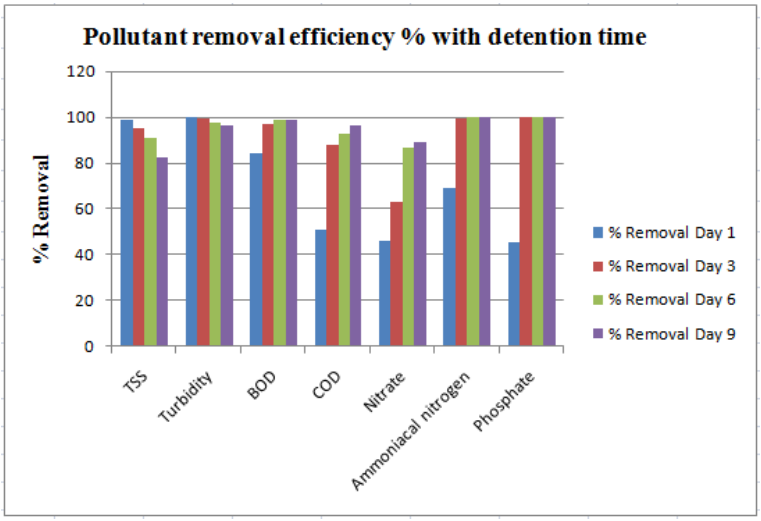

Fig no.7 Evaluation of % removal efficiency of Vetiveria Zizanioides CW unit

The BOD and COD reduction after treatment was 98.87% and 96.13% respectively.the percentage reduction of nitrate at the end of the treatment was 89.14%.

Ammoniacal nitrogen and phosphate shows higher reduction compared to other parameters. Percentage reduction of ammoniacal nitrogen was 99.28 % at day 3 and it again reduced and attained 100% removal efficiency after 6 days of treatment. In the case of phosphate the percentage reduction became 100% after 3 days detention time. The graphical representation of pollutants removal efficiencies percentage with detention time for vetiver plants CW unit as follows.

3 COMPARATIVE STUDY

3.1 Colour and odour

Initially the colour of the dairy wastewater was white thick and was highly turbid in nature which is gradually changed to clear. It became colourless, odourless effluent after phytoremediation. The influent which is collected from the dairy industry had pungent smell sng it got highly reduced after three days of treatment. And that smell is completely removed after 6 days. Clour less and odour less effluents aere collected after 9 days of detention period.

3.2 pH

During the treatment process in both constructed wetland unit the pH got increased into 8.28 while using Aegiceras corniculatum, and 7.72 by the Vetiveria Zizanioides. Even though the pH increased, they were with in the limits, that is in between 7-9.

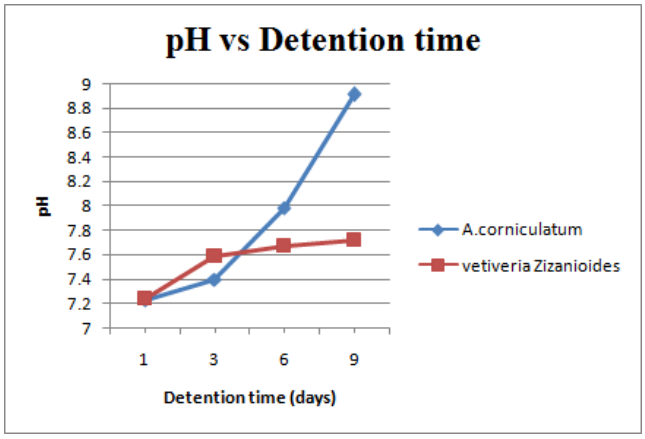

Fig no.8 Comparative study graph of pH Vs Detention time

3.3 TSS

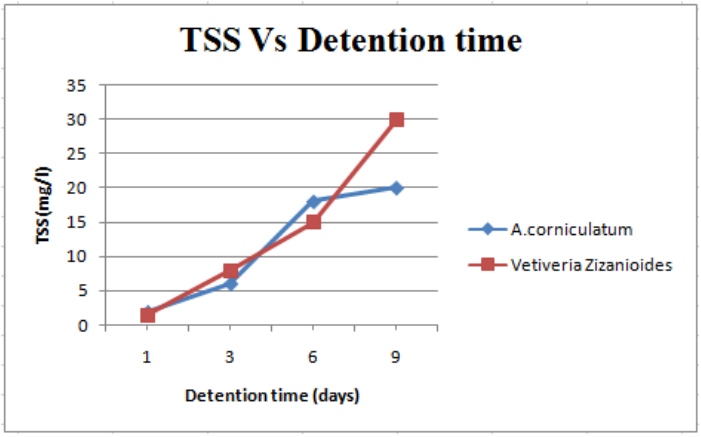

Fig no.9 Comparative study graph of TSS Vs Detention time

The most of the suspended solids are mainly occur mainly due to the presence of inorganic materials, the presence of algae and bacteria can also contribute to total suspended solids. The TSS concentration in the constructed wetland unit with A.corniculatum shows increasing throughout the treatment from 1.86 mg/l to 20 mg/l. and in the case of constructed wetland unit using vetiveria Zizanioides were increased from 1.53 mg/l to 29.85 mg/l. Even though they lies with in the permissible limit 100 mg/l.

3.4 TDS

In the case of Total dissolved Solids it shows a rise and fall in the concentration throughout the treatment. The concentration were reduced from 1700 mg/l to 1325 mg/l in the case of A.Corniculatum. TDS concentration in the case of Vetiveria Zizanioides was decreased from 2000 mg/l at day 1 to 1640 mg/l at day 9.

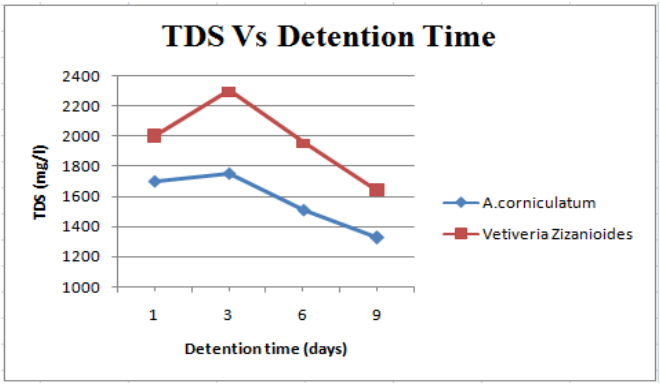

Fig no.10 Comparative study graph of TDS Vs Detention time

3.5 TURBIDITY

The turbidity depends on the concentration of TDS and TSS of the effluent. Therefore the concentration of Turbidity shows rise and fall during the treatment. At the end of treatment at day 9 the constructed wetland using A.Corniculatum the concentration become 2.7 NTU and on Day 3 it got reduced in to BDL. And in the case of Vetiveria Zizanioides the concentration become 5.45 NTU at 9 days, before that the concentration got reduced to BDL on 1 day treatment.

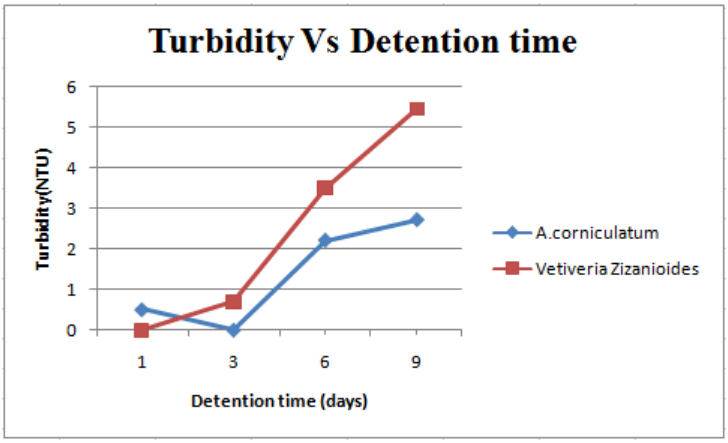

Fig no.11 Comparative study graph of Turbidity Vs Detention time

3.6 CHLORIDE

The chloride concentration in both constructed wetland shows gradual increment through the treatment. For A.corniculatum it increased from 260 mg/l to 637.2 mg/l from day 1 to day 9. For Vetiveria Zizanioides increased from 140 mg/l to 928.35 mg/l from day 1 to day 9 respectively.

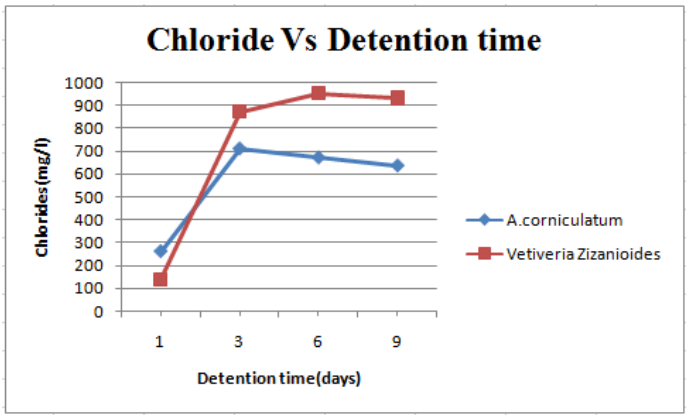

Fig no.12 Comparative study graph of Chloride Vs Detention time

3.7 ELETRICAL CONDUCTIVITY

The concetration in the constructed wetland with Aegecirus corniculatum reduced from 3600 µs/cm to 1867 µs/cm and in the case of Vetiveria Zizanioides was from 4100 µs/cm to 2460 µs/cm.

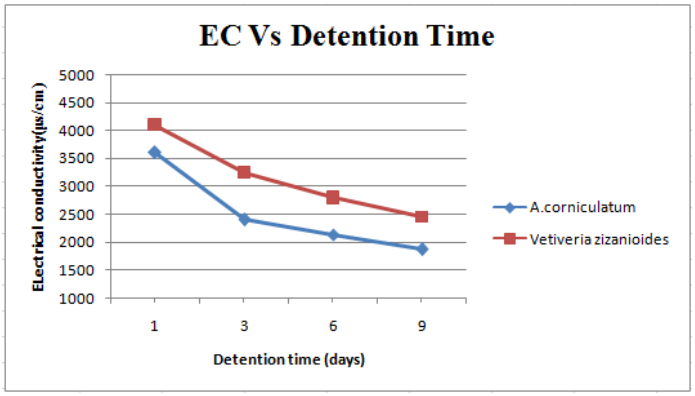

Fig no.13 Comparative study graph of Electrical conductivity Vs Detention time

3.8 BOD

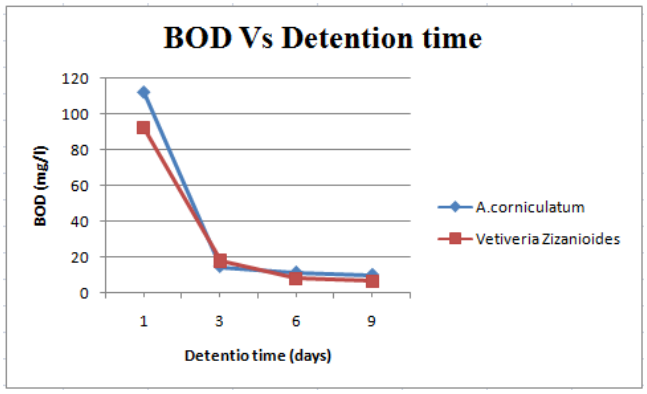

Fig no.14 Comparative study graph of BOD Vs Detention time

The BOD was reduced significantly in both constructed wetland unit. The initial to final concentration for the constructed wetland unit with A.Corniculatum was 111.9 mg/l to 9.74 mg/l. Similarly the initial and final concentration of the constructed wetland unit with vetiveria zizniodes was 91.8 mg/l to 6.50 mg/l. the 9 days detention period helps to reduce the BOD concentration in to below permissible level.

3.9 COD

Similar to BOD the COD concentration also got reduced significantly through out the treatment. The COD initial and final concentration was decreased from 520 mg/l to 29.38 mg/l in the case of wetland system with A.Corniculatum. while in wetland system with vetiveria zizanioides the reduction was initially from 384 mg/l to 30.45 mg/l finaly. In the both constructed wetland system the removal efficiency become 96.16% by using Aegecirus Corniculatum and 96.26 % by using Vetiveria Zizanioides when 9 days detention period reaches.

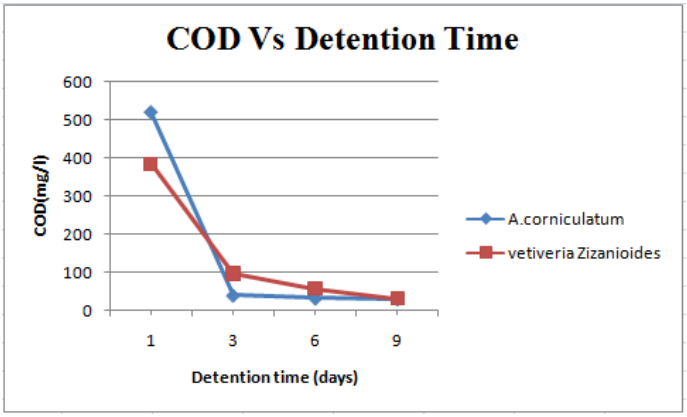

Fig no.15 Comparative study graph of COD Vs Detention time

3.10 NITRATE

It is found that the constructed wetland system which uses Aegecirus corniculatum species shows the decrease in the concentration from 6.78 mg/l to 0.98 mg/l which has 93.26 % removal efficiency. and in the case of wetland system which uses Vetiveria Zizanioides also reduces the nitrate concentration from 7.65 mg/l to 1.54 mg/l which has 89.14 % removal efficiency.

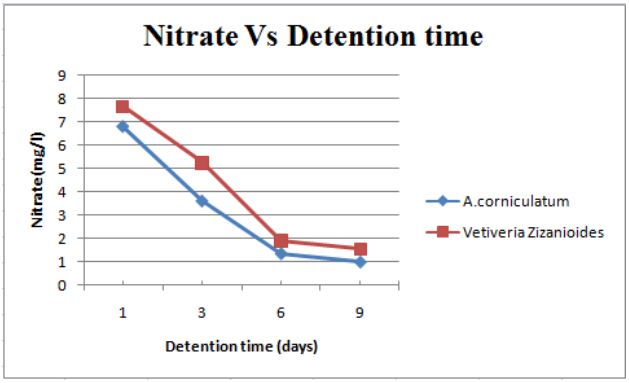

Fig no.16 Comparative study graph of Nitrate Vs Detention time

3.11 AMMONIACAL NITROGEN

A measurable reduction in concentration of Ammoniacal Nitrogen were obtained at the end of the treatment. The concentration of ammoniacal nitrogen got completely reduced for both systems when the treatment reaches at the day 6, that is the concentration became BDL. For the wetland unit with A.coriculatum thae concentration got reduced to 0.2 mg/l at day 3 from 10mg/l at day 1. Also in the case of other unit the concentration is reduced to 0.3 mg/l when the treatment reaches day 3. That is both system shows 100% removal efficiency.

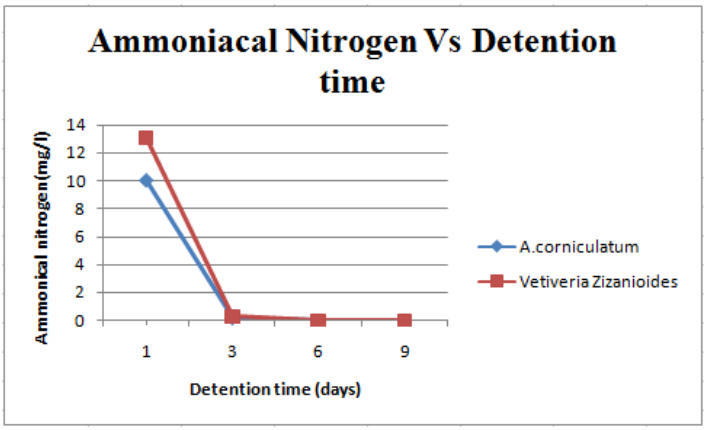

Fig no.17 Comparative study graph of Ammoniacal nitrogen Vs Detention time

3.9 PHOSPHATE

The treatment gave a complete reduction of phosphate concentration in both constructed wetland system. For the wetland unit with A.corniculatum the concentration reduced from 1.57 mg/l to 0.01 mg/l at day 3 and from 6 dys onwards it got reduced into BDL. Similarly in the case of constructed wetland system planted with Vetiveria Zizanioides the concentration phosphate reduced to BDL from 1.86 mg/l when the detention period reached 3 days. So both system shows complete removal efficiency in the removal of phosphate by using this treatment method.

III CONCLUSION

The experiment were conducted to evaluate the performance efficiency of horizontal subsurface flow constructed wetlands with Aegiceras Corniculatum and Vetiveria Zizanioides for treating Dairy wastewater. The parameters which were analyzed includes pH, TSS, TDS, Turbidity, Electrical Conductivity, Chloride, BOD, COD, Nitrate, Ammoniacal Nitrogen and Phosphate. The result obtained from the experiments proved that both constructed wetland system had the potential to treat the dairy wastewater.

Table No 4- Comparison of results after treatment and permissible limit

PARAMETERS	PERMISSIBLE LIMITS	USING CW WITH AEGECIRAS CORNICULATUM	USING CW WITH VETIVERIA ZIZANIOIDES
PH	6-8.5	8.28	7.72
TDS (mg/l)	2100	1325	1640
EC (µs/cm)	2250	1867	2460
BOD (mg/l)	30	9.74	6.50
COD(mg/l)	250	29.38	30.45
TSS (mg/l)	100	20	29.85
NITRATE (mg/l)	10	0.98	1.54
AMMONIACAL NITROGEN (mg/l)	50	BDL	BDL
PHOSPHATE (mg/l)	5	BDL	BDL
TURBIDITY (NTU)	5	2.7	5.45

Hence it is concluded that the method of treating dairy wastewater through constructed wetlands are cheaper and advicable for further use to irrigation purpose.

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