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Original Research Article

Efficiency of *Cyperus esculentus* as a biofilter in treatment of domestic waste water

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Abstract: This study presents treatment of domestic wastewater collected from the Harmony Lodge Ifite Awka, Anambra state using laboratory scale constructed wetland vegetated with Cyperus esculentus(tiger nut)plant as biofilter.to determine the removal of pollutants. The study was conducted from August 19th 2016 to September 2016, at Nnamdi Azikiwe University laboratory, Awka. Result of laboratory analysis on samples of wastewater collected showed reduction in pollutant of nitrate 50%, phosphorus 42%, ammonia 36%, COD 59%, BOD 70%, pH range was changed from 6.59 to7.15. Analysis of Variance (ANOVA) was used to analyse data obtained. Differences in parameter concentration between the influent and effluent parameters and also between effluents for three detension periods were considered significant at 5% level of significance (i.e $p \leq 0.05$). The concentration of these parameters decreased significantly as a result of the treatment. This shows that the cyperus plant is effective in pollutant removal from domestic wastewater.
Keywords: biofilter, Cyperus esculentus, Constructed Wetland, efficiency, treatment.

INTRODUCTION

Constructed Wetland can be used for the treatment of different types of wastewaters, that is, domestic, municipal, industrial, leachate, acid mine drainage, surface runoff, and so forth [10]. The emerging technology for the treatment of a variety of wastewaters is constructed wetlands (CWs) [11]. The natural wetland system uses mostly natural energy, requires low construction and operational costs, and so is energetically sustainable [12–14]. However, this assumption is not true for constructed wetlands where some energy input from human source is also required.

The constructed wetlands are classified into two type, that is, free water surface (FWS) and subsurface flow (SSF) systems. In case of FWS systems, plants are rooted in the sediment layer, and water flow is above ground (surface flow). In SSF systems, plants are rooted in a porous media such as gravels or aggregates through which water flows and treatment are accomplished. SSF systems are further divided into two types: horizontal flow SSF (HSSF) and vertical flow SSF (VSSF). Compared to HSSF, the subsurface vertical flow constructed wetland (SVFCW) system is more effective for the mineralization of biodegradable organic matter and has greater oxygen transport ability [15]. For the removal of suspended solids carbon and nitrification process vertical flow CW is more efficient, because of aerobic conditions and denitrification is poor. In VSSF CWs, feeding is intermittent (discontinuous), and the flow of wastewater is vertically administered through a substrate layer which mainly consists of sand, gravel, or a mixture of all these components [16]. Constructed wetlands can be used as an accepted ecotechnology, in small towns or industries that cannot afford conventional treatment systems [17]. In the free water surface (FWS) type of wetland, the water is filtered through a dense stand of aquatic plants as it flows over the bed surface Another constructed wetland system, known as the subsurface flow wetland consists of a lined shallow basin with a gravel media and emergent aquatic plants. Worldwide, now thousands of constructed wetlands are in use which are receiving and treating a variety of municipal, industrial, and other wastewaters.

The technology which uses plants for the removal of contaminants from a specified area is known as green technology and the process is known as phytoremediation. Phytoextraction, phytovolatilization, rhizospheric degradation, phytodegradation, and hydraulic control are the five mechanisms involved in the phytoremediation for the removal of pollutants. The most common plants used in constructed wetlands are bulrushes *(Scirpus)*, spikerush *(Efeocharis)*, and other sedges (Cyperus). Rushes *(Juncus)*, common reed *(Phragrnites)*, and cattails *(Typha)*.Different types of pollutants can be removed by phytoremediation such as heavy metals, pesticides, petroleum hydrocarbons, explosives, radionuclides, and CVOCs [18]. Sedimentation/coagulation, filtration, plant uptake/removal efficiency, adsorption (binding to sand particles and root), formation of solid compounds, cation exchange, and microbial-mediated reactions, especially oxidation, are the different processes through which different pollutants can be removed in the constructed wetlands [19].

The objective

The objective of this study is to analyse the relationship between the input and output variables generated by comparing the effect of individual detention time on effluent parameter concentration to determine the presence or absence of any difference between them.

Hypothesis testing

H_{O1}: There is no significant difference between the effluent parameter concentrations from 5days, 10days and 15days.

$H_{O2:}$ There is no significant difference between the influent and overall effluent parameter concentrations

$H1_1$: There is a significant difference between the effluent parameter concentration from the 5days, 10days and 15days

$H1_2$: There is a significant different between the influent and overall effluent parameter concentration.

Under the four general hypotheses stated above, the following hypotheses for various parameters underlisted were tested:

pH

$Ho_{1_{pH}}$: There is no significant difference between pH concentration from the aerator, coagulation/ flocculation/ sedimentation and filtration units.

$H1_{1_{pH}}$: There is a significant difference between pH concentration from the aerator, coagulation/ flocculation/ sedimentation and filtration units.

$Ho_{2_{pH}}$: There is no significant different between pH of influent and overall effluent pH concentration.

$H1_{2_{pH}}$: There is a significant different between pH of influent and overall effluent pH concentration.

This procedure was also applied in the testing of other parameter viz :, BOD, COD, nitrate,, aammonia, phosphorus, and pH.

MATERIAL AND METHOD

(i) Laboratory- scale constructed wetland

(ii) Tiger nut (*Cyperus esculentus*)

Description of Laboratory-Scale Constructed Wetland

A laboratory-scale construction wetland was designed and fabricated to treat domestic wastewater through the process of physical, chemical and biological processes. Feed domestic wastewater from collection tank to sedimentation tank by means of 0.5Hp pump at a flow rate of 0.00023m^3/s through a 12mm (P.V.C)pipe and was controlled by a manual control valve at a height of 450mm from the ground. The water flow into the wetland which consists of tiger nut plant (*cyperus esculentus*). This plant was collected from Uturu in Abia state Nigeria by uprooting from its root and transferred to the wetland. The plant treated the wastewater through the process of adsorption, nitrification\dentrification and plant uptake at different detention periods of 5, 10, and 15 days and collected in the clear water tank. The sedimentation tank was fabricated with galvanized metal sheet of 24mmgauge while the collection tank, wetland and clear water tank are fabricated with plastic materials.

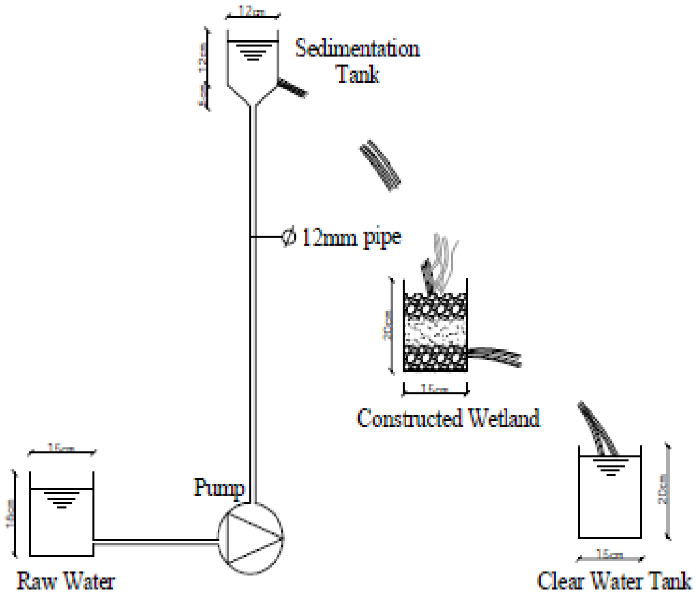

Figure 1. Experimental Setup

Plate 1. Pictorial diagram of the treatment plant

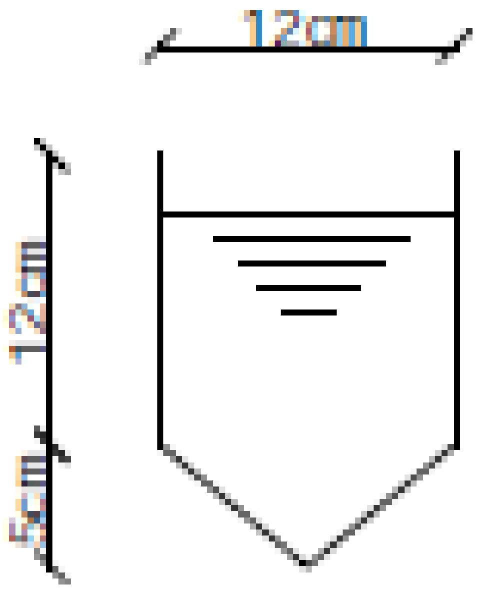

Figure 2a: Sedimentation tank

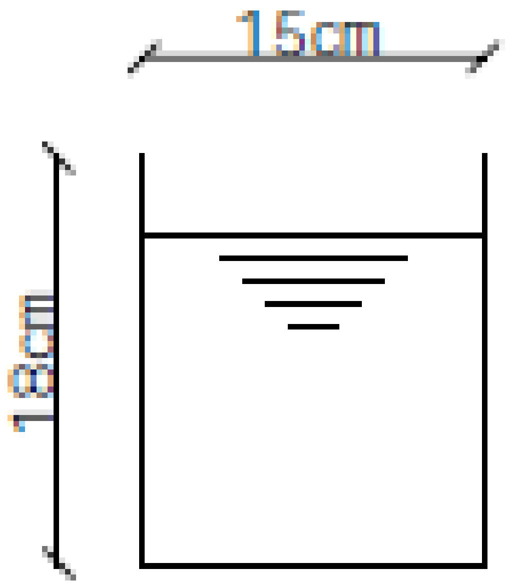

Figure 2b: Clear water

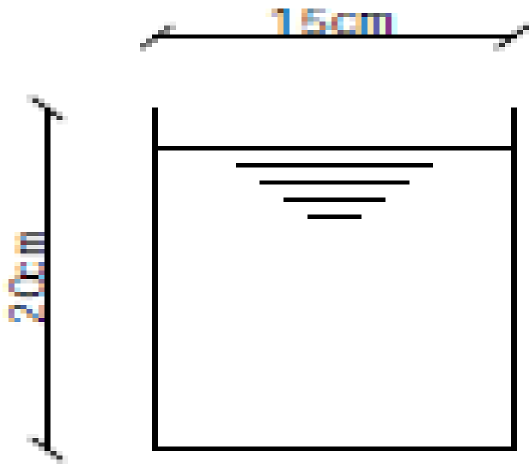

Figure 2c: Collection tank

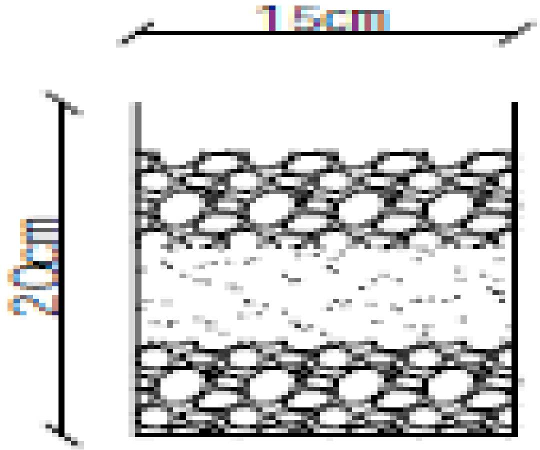

Figure 2d. Artificial wetland

Sample Collection

Five sample was collected for five days from Harmony Lodge Hostel Ifite-Awka. The samples was collected by simply placing a 15 liters plastic container below the discharging point of the hostel's kitchen and bathroom.

Method

Domestic wastewater from collection tank was pumped into the sedimentation tank at a flow rate of 0.00028m^3/s. The flow was regulated using a control value. The wastewater was allowed to settle for 2 hours in the sedimentation tank before it was gradually released into the wetland at a flow rate of 0.000016m^3/s. The wastewater was detained for a maximum of 15 days in the constructed wetland for treatment by the roots of the plant (*Cyperus esculentus*). The treated water was finally discharged into a clear water tank and samples of treated water were collected from the clear water tank at interval of 5 days (i.e. for 5 days, 10 days and 15 days retention time) for physiochemical analysis.

Treatment processes in Batch System

In this study, the treatment was carried out in a batch system basis. Water samples were taken at the inlet and outlet processes. The systematic processes are shown in figure 8.

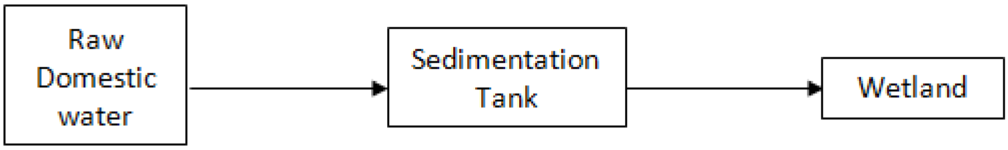

Figure 3: Schematic Flow Diagram for Domestic Water Treatment Process.

Sedimentation Processes

The treatment of the domestic water was carried out in an intermittent tank with a hopper at the bottom where sludge was deposited and removed. This tank was designed as a single of cylindrical shape and with a conical bottom so it combines function of sedimentation and sludge removal.

Treatment Processes in Wetland

Constructed artificial wetland system imitates the treatment that occur in natural wetland by relying on plants and a combination of natural occurring of physical , biological and chemical processes to remove pollutants from wastewater. The constructed wetland system was designed as a vertical flow wetland. The constructed wetland consists of a bed that is rectangular in shape and is planted with a common wetland plant *cyperus esculentus* in a plastic container. Pollutant removal occurs in different processes in wetlands; suspended solid removal is by filtration while soluble organic compounds and pathogens are removed by absorption and precipitation, sedimentation by adsorption and metallic removal is by these processes including cation exchange.

The filter media is placed in layers inside a plastic container. The first layer from the bottom consists of 20mm gravel at a depth of 2cm.

The second layer is filled with sand of effective size of 0.19 at a depth of 2cm. The third layer have the same characteristics as the first layer but have different size of 10mm gravel filled at a depth of 1cm. The total depth of the media inside the plastic container is 5cm.

DISCUSSION OF RESULTS

A one-way analysis of variance is used to show the presence of statistical significant differences in the percentage reduction of parameter concentrations between three different detention periods and also between influent and overall effluent.

Table 1: One-way analysis of variance for comparing effects of 5days, 10days and 15days on pH

Source of Variance	SS	df	MS	F	P-value	F crit
Between G	2.918093	2	1.457547	157.3595	2.37E-09	3.775294
Within Gro	0.1105	12	0.008217			
Total	3.028593	14				

The analysis in Table 1 indicates that the pH values of effluents between 5days,10days and 15days are significantly different. (F = 157.3 > F critical = 3.7; 2.37E-09 < p<0.05). This confirms that there is a variation in the pH value of the effluents from the three detention time although the value lies within the acceptable limit.

Summary

There is a significant difference in the pH values between effluents from the three different detention days. Therefore reject $Ho_{1_{pH}}$.

Table 2: One-way analysis of variance for comparing effects of 5days, 10days and 15days on nitrate

Source of Variance	SS	df	MS	F	P -value	Fcrit
Between G	87092.8	2	43041.4	2362.401	3.42E-16	3.775294
Within Gro	233.6	12	17.46667			
Total	87326.4	14				

The ANOVA for nitrate shown in Table 2 below, reveals that nitrate values of effluents between the three days are significantly affected. (F = 2362.4 > F critical 3.7; 3.42E-16 < p <0.05).

Summary

There is a significant difference in nitrate values . Therefore reject $Ho_{nitrate}$.

Table 3: One-way analysis of variance for comparing effects of 5days, 10days and 15days on ammonia

Source of Variance	*SS*	*df*	*MS*	*F*	*P -value*	*F crit*
Between G	84713.73	2	803.4247	236.7843	2.28E-13	3.775294
Within Gro	468	12	39			
Total	85181.73	14				

The result in the Table 3 reveals that there is a significant variation in ammonia between effluent from the three detention time (F = 236.8 > F critical 3.7); 2.28E-10 < p<0.05).

Summary

There is a significant difference in ammonia between effluents from the three detention time. Therefore reject $Ho_{1_{ammonia}}$.

Table 4: One-way analysis of variance for comparing effects of 5days, 10days and 15days on phosphorus

Source of Variance	*SS*	*df*	*MS*	*F*	*P -value*	*Fcrit*
Between G	68515.	2	29257.6	4369.849	6.65E-18	3.775294
Within Gro	80.344	12	6.695333			
Total	68595.344	14				

In Table 4, one-way analysis shows that phosphorus varied significantly between. (F = 4369.8 > F critical 3.7; 6.65E-18 < p<0.05).

Summary

There is a significant difference in phosphorus values between effluents from the three detention. Therefore reject $Ho_{1_{phosphorus}}$.

Table 5: One-way analysis of variance for comparing effects of 5days, 10days and 15 days on BOD

Source of Variance	*SS*	*df*	*MS*	*F*	*P - value*	*F crit*
Between G	45366.53	2	22683.27	803.4215	1.66E-13	3.775294
Within Gro	468	12	39			
Total	45834.53	14				

Table 5 shows that BOD values between effluents from the three detention time (F = 803.4 > F critical 3.7; 1.66E-13< p<0.05).

Summary

There is a significant difference in BOD between effluents from the three detention time. Therefore reject $Ho_{1_{BOD}}$.

Table 6: One-way analysis of variance for comparing effects of 5days, 10days and 15days on COD

Source of Variance	*SS*	*df*	*MS*	*F*	*P – value*	*F crit*
Between G	49591.6	2	24795.8	635.7897	635.E-13	3.775294
Within Gro	468	12	39			
Total	50059.6	14				

In Table 6, it can be seen that there is a variation in COD values between the three detention time (F = 4369.8 > F critical 3.7; 6.65E-18 <p<0.05).

Summary
There is a significant difference in the COD values between the three detention times. Therefore reject $Ho_{1_{COD}}$.

Table 7: One-way analysis of variance for differences between influent and mean effluent pH values

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between G	3.89376	1	3.89376	2225.006	4.51E-1	5.317655
Within Gro	0.014	8	0.00175			
Total	3.90776	9				

The analysis in Table 7 indicates that the pH values between influent and effluent are significantly affected. (F = 2225.0 > F critical 5.3; 4.51E-11 <p<0.05)

Summary
There is a significant difference in the pH values between the influent and overall effluent. Therefore reject $Ho_{2_{PH}}$.

Table 8: One-way analysis of variance for differences between influent and mean effluent nitrate values

Source of Variance	*SS*	*df*	*MS*	*F*	*P –value*	*Fcrit*
Between G	91202.5	1	91202.5	11400.31	6.61E-14	5.317655
Within Gro	64	8	8			
Total	91266.5	9				

The ANOVA for total hardness shown in Table 8 reveals that the nitrate values between the influent and overall effluent are significantly affected. (F = 11400.3 > F critical 5.3; 6.61E-11 < p<0.05).

Summary
There is a significant difference in nitrate values between the influent and overall effluent. Therefore reject $Ho_{2_{nitrate}}$.

Table 9: One-way analysis of variance for differences between influent and mean effluent ammonia values

Source of Variance	*SS*	*df*	*MS*	*F*	*P – value*	*F crit*
Between G	69105.9	1	69105.97	20138.71	6.8E-15	5.317655
Within Gro	27.452	8	3.4315			
Total	69133.42	9				

Significant difference is shown in the variance analysis table (Table 9) for ammonia. The one-way analysis shows that ammonia varied significantly between the influent and overall effluent. (F = 20138.7 > F critical 5.3; 6.8E-15 <p<0.05).

Summary
There is a significant difference in ammonia values between the influent and overall effluent. Therefore reject $Ho_{2_{ammonia}}$.

Table 10: One-way analysis of variance for differences between influent and mean effluent phosphorus values

Source of Variance	*SS*	*df*	*MS*	*F*	*P –value*	*F crit*
Between G	67240	1	67240	8150.303	2.53E-1	5.317655
Within Gro	66	8	8.25			
Total	67306	9				

In Table 10, it can be seen that there is a variation in phosphorus values between the influent and overall effluent (F = 8150.3 > F critical 5.3; 2.53E-13 <p<0.05).

Summary

There is a significant difference in phosphorus values between the influent and overall effluent. Therefore reject $Ho_{2_{phosphorus}}$

Table 11: One-way analysis of variance for differences between influent and mean effluent BOD values

Source of Variance	*SS*	*df*	*MS*	*F*	*P value*	*F crit*
Between G	69388.9	1	69388.9	9570.883	1.33E-13	5.317655
Within Gro	58	8	7.25			
Total	69446.9	9				

Table 11 shows that BOD values between the influent and overall effluents are significantly affected (F = 9570.9 > F critical 5.3; 1.33E-13 <p<0.05).

Summary

There is a significant difference in BOD values between the influent and overall effluent. Therefore reject $Ho_{2_{BOD}}$.

Table12: One-way analysis of variance for differences between influent and mean effluent COD values

Source of Variance	*SS*	*df*	*MS*	*F*	*P value*	*F crit*
Between G	313290	1	313290	46759.7	2.34E-16	5.317655
Within Gro	53.6	8	6.7			
Total	313343.6	9				

Lastly, analysis of variance shown in Table 12 reveals that there is a significant variation in COD between the influent and overall effluent. (F = 46759.7 > F critical 5.3; 2.34E-16 < p<0.05).

Summary

There is a significant difference in COD values between the influent and overall effluent. Therefore reject $Ho_{2_{COD}}$.

The implication of the above one-way anova for differences between influent and overall effluent parameter concentrations is that the system is efficient in reduction of parameter concentrations in the mean effluent.

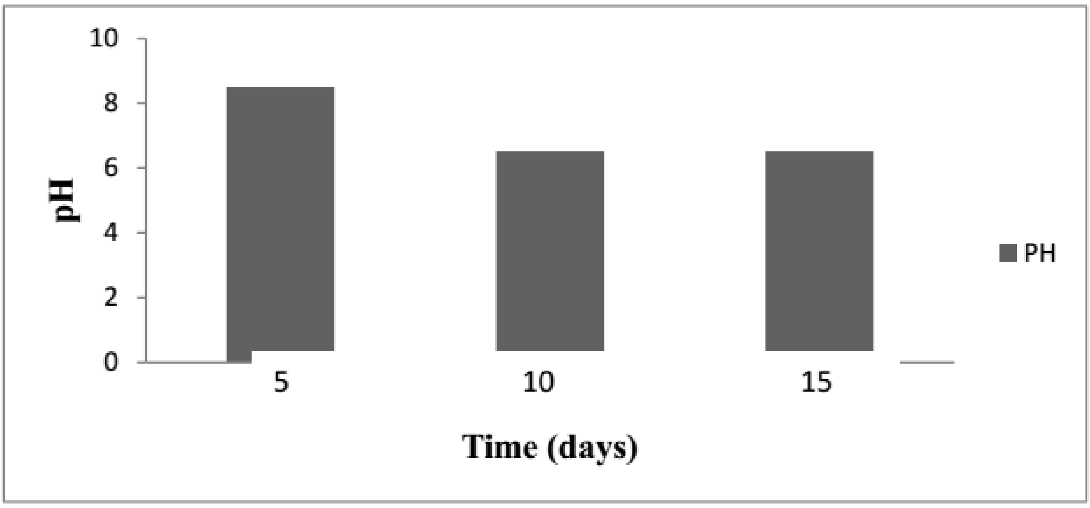

Fig- 4: pH measurement in the three detention periods

From figure 4; The pH value of the effluent sample for the detention periods are within 8.5 - 6.5 and *cyperus esculentus* plant has shown to neutralize the pH of the waste water when the initial pH is lowered by 8.5 to 6.5.

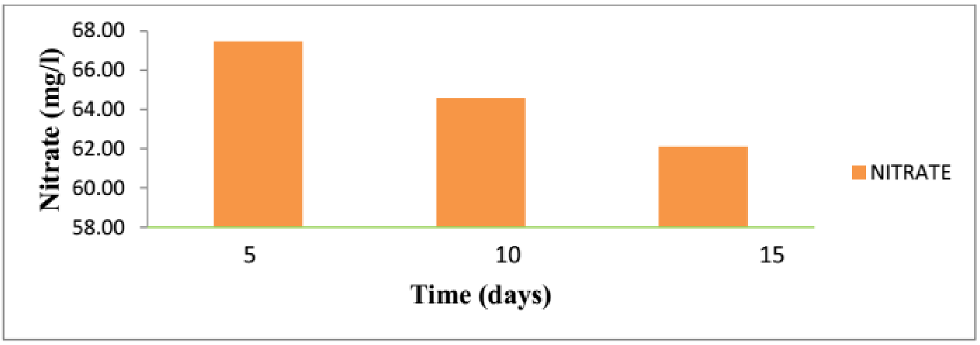

Fig- 5 : Nitrate measurement in the three detention periods

80% of nitrate removal was observed (Figure 5) in constructed wetland in the presence of DO (dissolved oxygen), microbes in the wastewater column converts ammonia to nitrate.

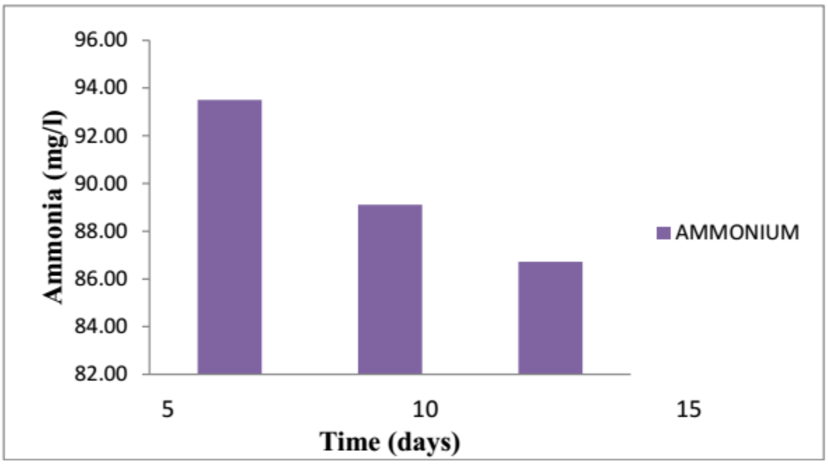

Fig- 6: Ammonium measurement in the three detention periods

Figure 6 indicates that ammonia reduction of 37% was observed due to higher plant density, increased nutrient uptake and development of biofilms in plant roots.

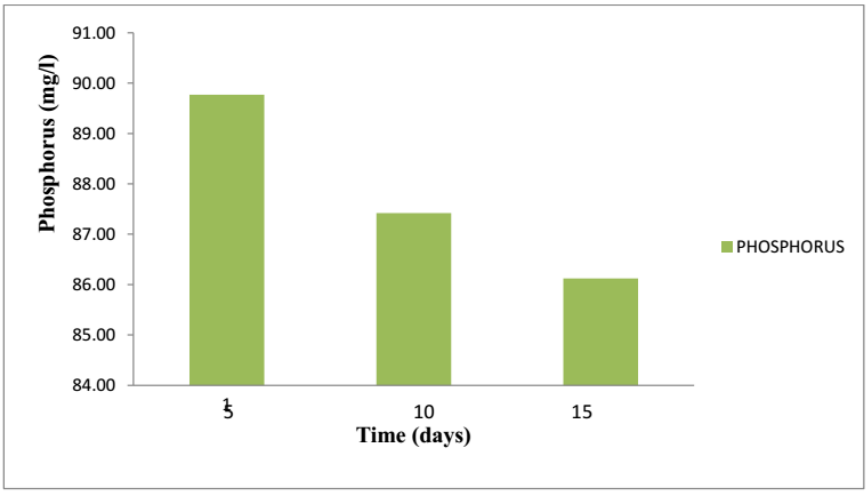

Fig-7 : Phosphorus measurement in the three detention periods

From Figure 7, phosphorus was reduced by 42% due to the increase in plant density, plant uptake which is an important mechanism of phosphorus removal.

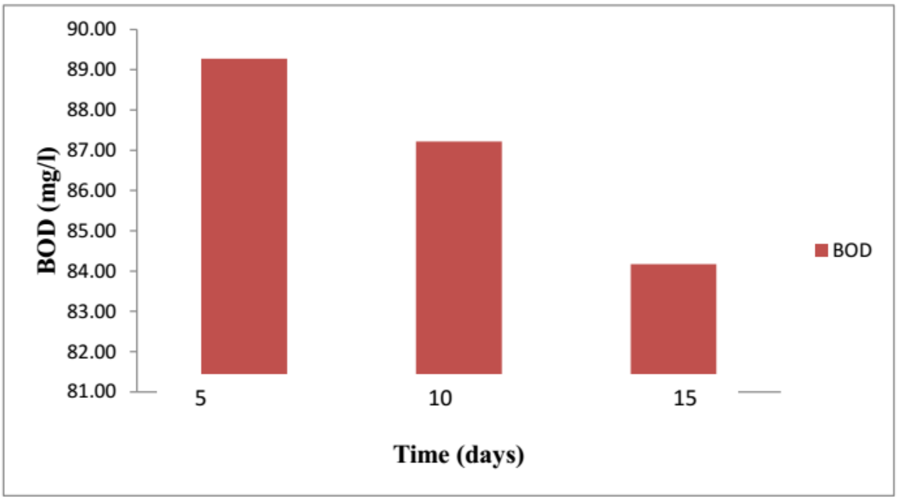

Fig-8: BOD measurement in the three detention periods

Figure 8 shows that 70% removal of BOD from the domestic wastewater in the constructed wetland occurs when the material causing BOD is completely converted by anaerobic biological processes to gaseous and products.

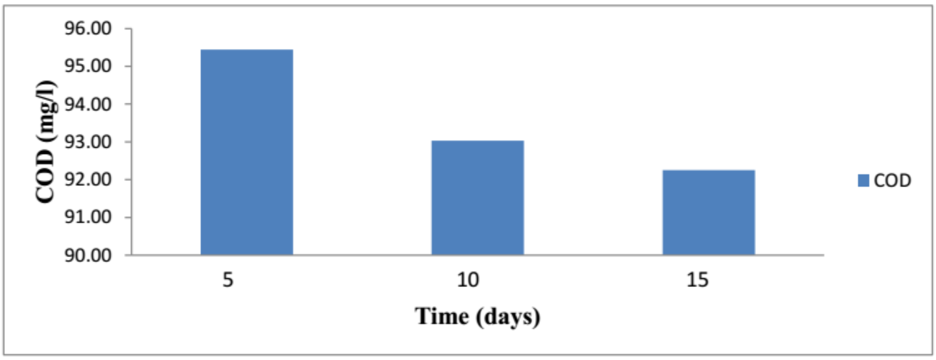

Fig-9: COD measurement in the three detention periods

From Figure 9, (COD) Chemical Oxygen Demand; Removal of 59% was accomplished by good cooperation between physical and microbial mechanisms. It was due to overall physical microbial plant, surface area and being characterized with anaerobic conditions.

CONCLUSION

From the research, the following conclusion was made:

(i) *Cyperus Esculentus* plant (tiger nut) is effective in removal of pollutant in terms of Chemical Oxygen Demand (COD), pH, nitrate, phosphorus, Biological Oxygen Demand (BOD), and ammonia respectively.

(ii) Constructed wetland is more economical comparing to other wastewater treatment processes because the materials are readily available and characterized with low investment and maintenance cost.

(ii) Reduction of pollutant in domestic wastewater using constructed wetland by native plant (*cyperus esculentus*) is a great achievement in water purification system and therefore the current study includes that *cyperus esculentus* plant specie be conserved and be utilized for pollution assessments in water system.

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