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CONSTRUCTED WETLAND SYSTEMS VEGETATED WITH DIFFERENT MACROPHYTES IN THE TREATMENT OF INDUSTRIAL WASTE WATER EFFLUENT

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ABSTRACT

Wastewater effluents generated from the soft drink industry contain pollutants which are higher than what is acceptable for the discharge in the water bodies in Nigeria. This result in environmental unbalance which causes adverse health issues. In this study, the performance of two macrophytes (*Phragmites karkaa and Typha domingensis*) in a sub-surface vertical flow constructed wetland was investigated. One hundred litres of wastewater effluent obtained from an Industry (Seven Up Bottling company in Ibadan, Nigeria) was applied to the systems and the properties of the waste water effluent as well as the performance of the treatment tanks with respect to parameters such as; pH; TDS; TSS; DO; BOD_5; turbidity; nitrate and phosphate were evaluated. The treatment performance of the systems was evaluated for a retention period of 6, 12 and 18 days. It was observed that parameters such as pH, BOD_5; and TSS did not conform to the acceptable limits; they had values greater than those prescribed in the standards for discharge. The value for BOD_5 was 652 mg/l and after six days retention in the vegetated tanks had reduced by at least 98%. The unvegetated control setup only reduced the BOD_5 by 40.18% after the first six days of treatment. The performance of the *Phragmites karka* and the *Typha domingensis* in the removal of organic substances and solid pollutants were similar with both plants effectively removing the pollutants. However, *Typha domingensis* performed better than *Phragmites karaka* in removing organic pollutants and *Phragmites karka* gives clearer water than *Typha domingensis* in terms of turbidity.

Keywords: *Typhadomingensis, phragmiteskarka, wetlands, soft drink and macrophytes*

INTRODUCTION

Wetlands refer to a wide range of wet areas surrounded by land that are saturated with water (Brix, 1994). A great variety of ecosystems around the world are considered wetlands, including saltmarshes, tidal freshwater marshes, inland marshes, riverine marshes, forested wetlands, mangrove swamps, and peat lands (Taylor, 2009). Natural wetlands typically have the ability to treat wastewater and its sludge; they act as bio-filters and remove heavy metals, sediments and other pollutants (EPA, 2009). Natural wetland systems have often been described as the "earth's kidneys", because they filter pollutants from water that flows through it, discharging into various water course.

Wetlands have a tendency to form anywhere the land terrain directs surface water to shallow basins and where a relatively impermeable subsurface layer prevents the surface water from seeping into the ground. These conditions can be artificially created to form a constructed wetland. This is done in order to be used as treatment systems to treat a vast array of wastewater effluent.

Vymazal, (2008) opined that it was difficult for scientists to understand how plants are required for the effective treatment of wastewater because it was common practice to eliminate all vegetation when it comes to sewage treatment. This greatly hindered the development of constructed wetland in Germany. Constructed wetlands primarily designed for wastewater treatment take advantage of cleansing procedures found in natural wetlands. They offer an energy efficient, low cost of operation and maintenance compared to mechanical means of wastewater treatment. (Ayaz *et al.,* 2001).

Constructed wetlands (CWs) can be used to treat municipal or domestic wastewaters, storm-water, agricultural and industrial wastewaters such as landfill leachate, petrochemicals, food wastes, pulp and paper and mining, usually combined with an adequate pre-treatment process (Kadlec *et al.,* 2000).wetlands have a common feature, which is the presence of surface or near surface water. Wetlands have three main features which are the macrophyte, the substrate - also known in the literature as filter beds and an impermeable membrane. The substrate in wetlands are usually saturated which lead to their poor reception of oxygen. An impermeable membrane is required to prevent the wastewater being treated to infiltrate and percolate downwards in the soil (EPA, 1995).

Nigeria is among those with the highest soft drink consumption rates according to Mazariegos *et al.,* which may be inferred that Nigerians are among the countries of the world generating the most soft-drink waste water effluent. There is therefore the need to find a cost effective way of treating these large amounts of wastewater before discharging them into our communities. The objective of this study was to compare the purification effects of different macrophytes used in constructed wetland in treating wastewater effluent from the soft-drink industry

MATERIALS AND METHODS

Three Pilot Scale CW tanks to serve as impermeable membranes/basin were used for the experiment. The macrophytes were *Typha domingensis* and *Phragmites karaka*. Soft drink industry wastewater effluent obtained from an industry in Lagos was used. Washed gravel granite and Sand bed (sharp sand) was used as the substrate.

The two different plants that were used are *Typha domingensis* and *Phragmites karkaa* planted on a pilot scale constructed wetland. The flow path was vertical by gravity, the plastic unit served as the impermeable membrane mounted on block units for stability of the CW for the first sixteen (17) weeks transplanted rhizomes of each of the plants were grown in a vegetated submerged bed CW until they were well established before introducing the soft drink industry wastewater effluent into the system.

The CW units contain three identical beds thathave a surface area of 1 x 1 m and depth of 1 m. Two beds were planted with *Phragmates karka* and *Typha domingensis* separately while one was left unplanted to serve as control to the research. The tanks were layered with gravel and sharp stone. The base of the units were layered with gravel to a depth of 400 mm, while the subsequent layer was made of sharp sand to a depth of 200 mm in order to aid the growth of the macrophytes to be planted. Freeboard of 400mm was left in order to facilitate sludge accumulation. The CW was conditioned by planting nine macrophytes in each planted constructed wetland. A drainage pipe was connected for easy discharge of drained water from the bed.100 litres of wastewater was applied to the each bed after maturation of the macrophytes. The bed had a retention period of 6, 12 and 18-days, treated wastewater was withdrawn from the beds by the use of sampling bottles. The surface loading of the CW was 216 kg/m^2.

Grab samples of the treated wastewater were taken from the pilot tanks for day 6, 12, and 18. PVC bottles (100ml) were obtained to this effect. The wastewater was then collected in the bottles in a manner such that it leaves no space for air bubbles, and is completely filled. After collection, the wastewater was kept in a refrigerator in order to render the microorganisms in the wastewater inactive. The samples were taken to a laboratory in LASEPA (Lagos State Environmental Protection Agency) for accurate testing of parameters.

RESULTS AND DISCUSSION

Soft-drink Wastewater Characteristics

The characteristics of the effluent from the beverage industry obtained in the laboratory are shown in table 1

Table 1: Characteristics of the wastewater effluent from the soft drink industry

Parameter	Soft Drink industry Effluent	FEPA standard (Discharge)	FEPA standard (Land application)
Temperature (°C)	26.8	< 40	< 40
PH	10.68	6 – 9	6 – 9
EC (µs)	1344	-	-
TDS (ppm)	920	2000	2000
TSS (ppm)	48	30	-
Turbidity	50	-	-
DO (mg/l)	1.18	-	-
COD (mg/l)	559	-	-
BOD_5; (mg/l)	652	50	500
PO_4^{3-} (ppm)	42	5	10
NH_3 (ppm)	3.53	-	-

PERFORMANCE OF THE CONSTRUCTED WETLANDS (CWs)

The performance of both planted tanks showed similar results after the specified retention times adopted for the research. The performances are represented in the tables 2-4.

PERFORMANCE EVALUATION OF TANK VEGETATED WITH *PhragmitesKarkaa*

The performance of the tank vegetated with *Phragmites Karkaa* with respect to temperature, pH, EC, TDS, TSS, Turbidity, DO, COD, BOD_5;.PO_4^{3-}, NH_3 was evaluated and the results tabulated in the table 2 below.

Table 2: Performance evaluation of the tank vegetated with Phragmites karkaa

Retention Period (Days)	Temperature (°C)	pH	EC (µs)	TDS (ppm)	TSS (ppm)	Turbidity FTU	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	PO_4^{3-} (ppm)	NH3 (ppm)
0d (influent)	26.8	10.66	1344	920	48	50	1.18	559	652	42	3.53
6-d	28.1	7.13	646	450	6	24	2.78	29	10.4	NIL	0.12
12-d	28	7.3	634	460	3	18	2.75	12	2.5	2.5	NIL
18-d	28	7.4	650	460	NIL	1.35	2.38	56	16.6	NIL	NIL

PERFORMANCE EVALUATION OF THE TANK VEGETATED WITH *Typha domingensis*

The performance of the tank vegetated with *TyphaDomingensis*with respect to temperature, pH, EC, TDS, TSS, Turbidity, DO, COD, BOD_5;. PO_4^{3-} , NH3 was evaluated and the results tabulated in table 3.

Table 3: Performance of the tank vegetated with *Typha domingensis*

Retention Period (Days)	Temperature (°C)	pH	EC (µs)	TDS (ppm)	TSS (ppm)	Turbidity FTU	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	PO_4^{3-} (ppm)	NH3 (ppm)
0d (influent)	26.8	10.66	1344	920	48	50	1.18	559	652	42	3.53
6-d	27.9	6.93	549	420	6	65	3.25	29	12.5	NIL	2.39
12-d	27.5	7.12	552	380	16	73.4	3.08	6	1.3	NIL	0.72
18-d	27.6	6.85	528	370	4	21.4	1.75	6	0.84	NIL	NIL

PERFORMANCE EVALUATION OF THE CONTROL TANK

The performance of the control tank with respect to temperature, pH, EC, TDS, TSS, Turbidity, DO, COD, BOD_5; PO_4^{3-}, NH_3 was evaluated and the results tabulated below in table 4.

Table 4: Performance of the control tank

Retention Period (Days)	Temperature (°C)	pH	EC (µs)	TDS (ppm)	TSS (ppm)	Turbidity FTU	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	PO_4^{3-} (ppm)	NH3 (ppm)
0d (influent)	26.8	10.66	1344	920	48	50	1.18	559	652	42	3.53
6-d	28	7.64	975	690	4	28	1.67	500	390	NIL	0.23
12-d	27.2	7.1	894	620	43	18	5.18	324	225	NIL	1.32
18-d	27.5	7.94	816	550	102	217.81	2.58	56	25.8	NIL	NIL

VARIATION IN PARAMETERS

The pH was reduced across the three pilot tanks, however the tank vegetated with macrophytes experienced their largest reduction after six days of retention time, while the control tank reached its lowest pH value in a retention time of 12 days. All the treatment tanks effectively reduced pH to the acceptable levels of 6-9 according to FEPA standard of discharge into streams and land application. The range of pH was neutral ranging from 6.85 to 7.94. This average neutral pH range agrees with results obtained from a previous study carried out using a surface flow CWs by Yadav *et al.,*(Year????)

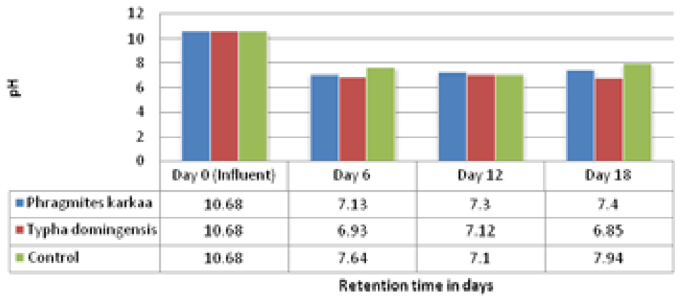


Figure 3.1 pH variation

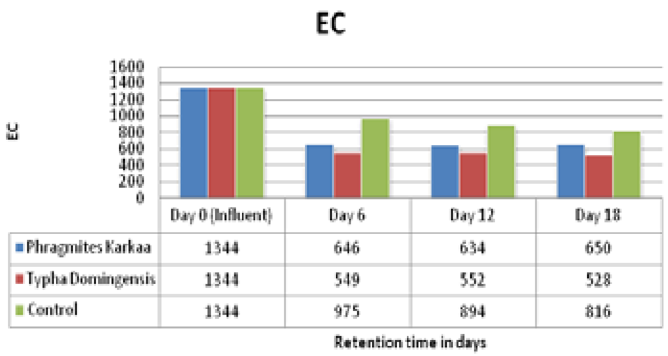


Fig 3.7: Electrical Conductivity variation

Electrical conductivity is seen to have reduced in the three CW units after 18 day retention period (Figure 3.7). Electrical conductivity is an indicator of the total amount of Total Dissolved Solids present in a water sample; therefore a general reduction in EC indicates a fall in the volume of TDS present after 18 days retention time across the tanks.

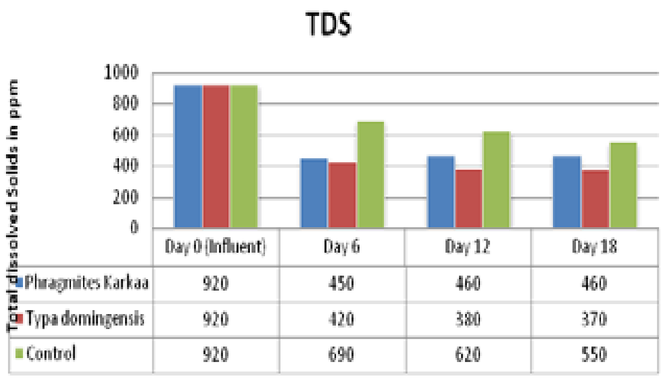


Fig 3.8: Variation in quantity of Total dissolved solids

Total dissolved solids was reduced from 920 ppm to 450 ppm and 920 ppm to 420 ppm in the tanks vegetated with *Phragmites karkaa* and *Typha domingensis* respectively, while it only reduced from 920 ppm to 690 ppm in the control tank after a retention time of 6 days (figure 4.3) . By day 12, the tank with *Phragmites karkaa* had increased its TDS concentration by 1% (450 ppm to 460 ppm), while the tank with Typha domingensis further reduced its TDS concentration by another 4 %(420 ppm to 380 ppm) . The control tank also continued to drop its TDS concentration by 7.6 % (from 690 ppm to 620 ppm). By day 18, the TDS concentration in the vegetated tanks remains relatively stable while the control tank dropped by another 7.6%, but still did not reduce as much as the vegetated tanks. This shows that plants play a significant role in the removal of TDS in CWs. This result showing a reduction in the amount of TDS after treatment in a CW agrees with research findings carried out by Brix *et al.*

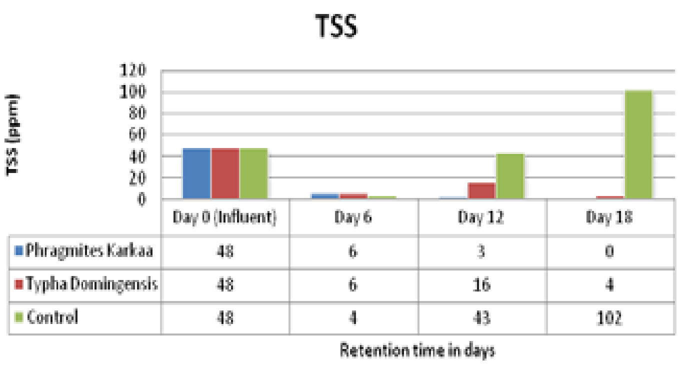


Fig 3.9: Variation in quantity of Total suspended solids

It was observed that TSS was reduced significantly from 48ppm to 6ppm in the vegetated tanks and even reduced a little more from 48ppm to 4ppm in the control tank after a retention period of 6 days (figure 3.9) . After 12 days retention time, it reduces further by another 6.25% in the tank vegetated with Phragmites karkaa but begins to increase in the tanks vegetated with Typha domingensis and the control tank by 20.83% and 81.25% respectively. This implies that the optimal retention time for the removal of TSS in the tank with Typha domingensis and the control tank is 6 days. At day 18, the tank vegetated with Phragmites karkaa showed no signs of TSS, while the tank vegetated with Typha domingensis further reduced its TSS concentration by 25%. The control tank however was observed to have increased its TSS concentration by 122.9%. This also shows that vegetation plays a vital role in the effective removal of TSS in a CW. The general reduction trend in the Total Suspended solids agrees with results obtained from previous studies carried out by Brix *et al.,* (Year)and Vidales *et al.(*????year)

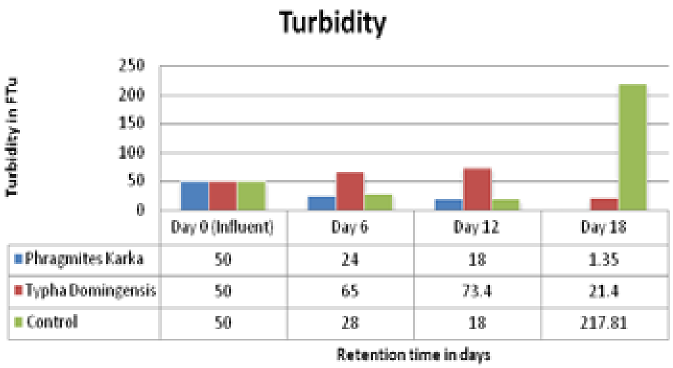


Fig 3.10: Variation in quantity of Turbidity

It was observed that turbidity in the tanks vegetated with Phragmites karkaa and the control tank reduced progressively after 12 days retention time, while the tank vegetated with Typha domingensis increased in turbidity by 46.8% after 12 days retention time (figure 3.10). This implies that the activities in the tank vegetated with Typha domingensis are such that it increases the turbidity of the influent wastewater. After a retention time of 18 days, the tank vegetated with Phragmites karkaa had reduced its turbidity by another 33.3%, however a swing occurs in the tank vegetated with Typha domingensisas it begins to reduce in turbidity while the control tank increases the turbidity of water by a staggering 399.2%. This also implies that CW s require vegetation in order to reduce turbidity effectively.

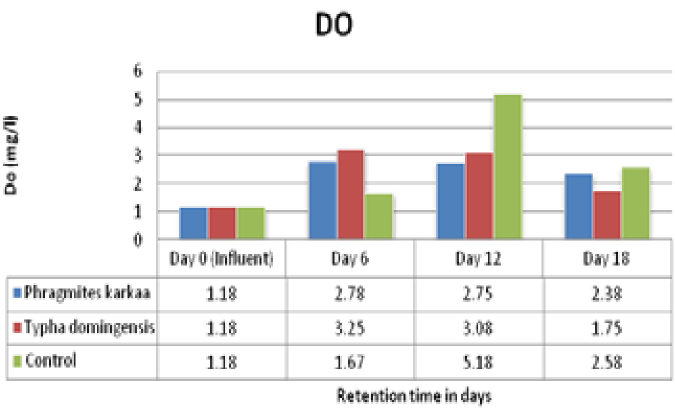


Fig 3.11: Variation in DO

A significant increase in the concentration of DO was observed across all platforms. This is resulting from the supply of oxygen to the systems through the atmosphere and the photosynthetic activities of the plants. However, after day 6, the vegetated systems had started to reduce in their DO concentration while the control system continued to rise in DO concentration (figure 4.6). At day 18, the DO reduced across the three tanks, with the control tank still having the highest concentration of DO. This results from the fact that oxygen is being used up in the vegetated systems as the plants grow, whereas in the control system, there are no plants to make use of its oxygen. Also, at day 18, a general reduction is recorded across all platforms which shows that oxygen has been used by bacteria in breaking down the organic compounds. However, on the average, there was a rise in DO concentration across all platforms when comparing the results from day 0 until day 18, which conforms to results obtained from a previous study carried out using CWs by Yadav *et al.*

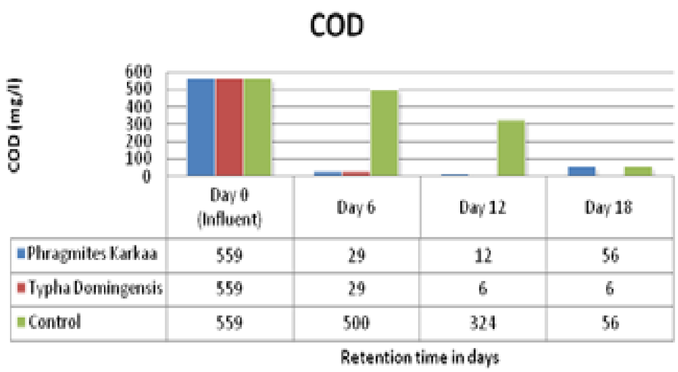
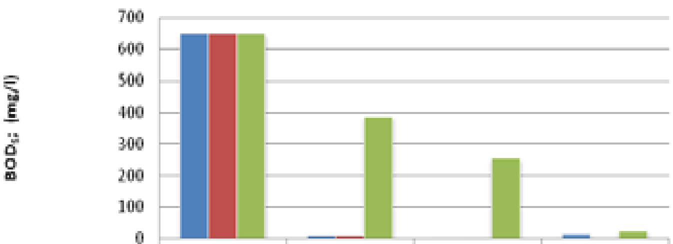


Fig 3.12: Variation in COD

The COD of the effluent was significantly reduced by 94.8 % within the first six days of treatment in the vegetated systems (figure 4.7), whereas it only reduced by 10.55% in the control system. After 12 days retention time, the COD had undergone a further reduction of 3.04% and 4.11 % in the tanks vegetated with *Phragmites karkaa* and *Typha domingensis* respectively. Also the control system further reduced the COD concentration by 31.48%. After a retention time of 18 days, the tank vegetated with common reed begins to increase by 7.87%. The tank vegetated with cattails remained stable, while the control tank experienced its largest reduction in COD, it reduced by 47.9% (324 mg/l to 56 mg/l). It can be seen that the vegetated systems performed far better than the control systems, therefore plants play a vital role in the removal of COD in a CW. Plants provide attachment sites for bacteria which speed up the process of removal of COD.

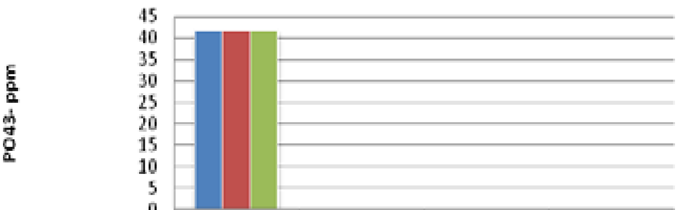


	Day 0 (Influent)	Day 6	Day 12	Day 18
Phragmites Karkaa	652	10.4	2.5	16.6
Typha Domingensis	652	12.5	1.3	0.84
Control	652	390	255	25.8

Retention time in days

Fig 3.12: Variation in BOD_5

The BOD_5; of the influent wastewater was reduced by over 98% in the first 6 days in the vegetated tanks, while it only reduced by 40.18% in the control tank after 6 days retention time. At 12 days, the BOD_5 had been reduced to 2.5 mg/l and 1.3 mg/l in the tanks vegetated with Phragmites karkaa and Typha domingensis respectively (Figure 4.8). According to (FEPA 2007), the allowable BOD_5 concentration level for discharge into streams is 50mg/l and the vegetated tanks have reduced the value of BOD_5 to far less than that. The result also agrees with the required standard of 95% removal of BOD5required for discharge into streams (Brix *et al.,* 2003). It is observed that the vegetated tanks performed far better than the control tank in reducing BOD_5. This result also indicates that plants speed up the removal of BOD from wastewater.

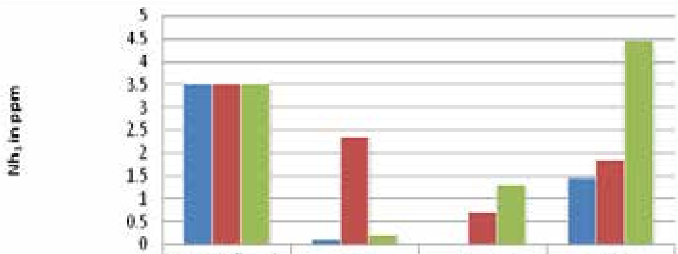


	Day 0 (Influent)	Day 6	Day 12	Day 18
Phragmites Karkaa	42	0	0	0
Typha Domingensis	42	0	0	0
Control	42	0	0	0

Retention time in days

Fig 3.12: Variation in Phosphates - PO_4^{3-}

It is observed that phosphate is reduced to zero after 6 days retention time and continues till day 18 across the three tanks. The reduction in phosphate content agrees with results obtained from Brix *et al.*year, and Arias *et al.,* year??



	Day 0 (Influent)	Day 6	Day 12	Day 18
Phragmites Karkaa	3.53	0.12	0	1.47
Typha Domingensis	3.53	2.39	0.72	1.87
Control	3.53	0.23	1.32	4.47

Retention time in days

Fig 3.13: Variation in NH_3

It can also be observed that nitrate concentration is reduced generally in the vegetated tanks and the control tank after a retention time of 6 days. After which it reduced further in the vegetated tanks but begins to increase in the control tank. After day 12, a general increase is recorded across all tanks. This result signifies that in terms of reduction of NH3, the control tank reaches its optimum efficiency at day 6, while the vegetated tanks reach their optimum treatment efficiency at day 12. The general reduction in NH_3 content conforms to results obtained from studies carried out by Brix *et al.,* (2003).

CONCLUSION

From the analysis of the wastewater effluent from the soft drink industry, it was observed that the effluent has a high level of organic content; a BOD_5 concentration of 652 mg/l and a COD content of 559 mg/l. It also had a high pH value of 10.68, a high volume of dissolved and suspended solids. These values were high when compared to the criteria for the discharge into water bodies. The performances of the two vegetated units in respect to treatment of wastewater was highly effective with Typha domingensis performing slightly better than *Phragmites karkaa* in treating organics by a small margin. Both macrophytes, reduced the concentrations of organic content and solids in the wastewater to acceptable standards. They had both decreased the BOD_5; of the wastewater by at least 98% after the first six days. The two vegetated units also had reduced the pH of wastewater to acceptable standards after the first six days of treatment. It was however observed that the tank vegetated with *Phragmites karkaa* was adjudged as being better in terms of reducing the turbidity level of the waste water effluent drastically when compared with the tank vegetated with *Typha domingensis* where the turbidity had increased after treatment. The reeds/

macrophytes have been found from this study to play a vital role in the treatment of waste water effluent using a CW.

Based on the analysis carried out, CWs serve as alternative means of treating wastewater effluents from a soft drink industry. The two reeds, *Phragmites karkaa* and *Typha Domingensis* are equally adequate in treatment of wastewater but it is highly recommended that mixed plantation be adopted in order to check the inadequacy of each type of reed used. This will help increase the efficiency of the CWs in treating wastewater generated from municipal and industrial sources.

Furthermore, locations of considerably low power supplies should adopt this particular treatment method as it requires virtually no power in accomplishment of greater treatment efficiency as required of wastewater effluents before discharge into various water courses.

REFERENCES

Akratos C.S and V. A. Tsihrintzis, 2007. Effect of temperature, HRT, vegetation andporous media on removal efficiency of pilot-scale horizontal subsurface constructed wetlands. *Ecological Engineering 29*:173191.

Arias C.A, Cabello A, Brix H, Johansen N.H, 2003b. Removal of indicator bacteria from municipal wastewater in an experimental two-stage vertical flow constructed wetland system. *Water Sci. Technol. 48* (5), 35- 41

Ayaz SC, Akca L (2001). Treatment of wastewater by natural systems. *Environ. Int. 26*:189-195.

Brix, H., 1994. Functions of macrophytes in constructed wetlands. *Water. Sci. Tech. 29*(4),71-78.

Brix, H., 2003b, Plants used in constructed wetlands and their functions. In: Dias, V., Vymazal, J. (Eds.), Proceedings of the First International Seminar on the Use of AquaticMacrophytes for Wastewater Treatment in Constructed Wetlands. Ministerio das Cidades, Ordenamento do Territorio E Ambiente, Lisboa, Portugal, 8-10 May, pp. 81-109.

Corcoran E., Nellemann C, Baker E, Bos R, Osborn D, Savelli H (eds) (2010) "Sick Water"?The central role of wastewater management in sustainable development.A Rapid Response Assessment.UNEP/UN HABITAT, GRID-ARENDAL. 2010

Cristina S.C. Calheiros, Anto´nioO.S.S. Rangel, Paula M.L. Castro (2006) Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. Incomplete reference

De Sousa J.T., Haandel A. van, Lima E.P.C and Guimarães A.V.A, (2003). Performance of Constructed Wetland Systems Treating Anaerobic Effluents. *Water Science and Technology: 48*. p295-299.

Environmental Protection Agency (2004).Constructed Treatment Wetlands (PDF), August, 2004. (EPA) 843-F-03 013). Available online at: http://www.epa.gov/agriculture/awet.html

Environmental Protection Agency (2004).Constructed Treatment Wetlands (PDF), August, 2004, (EPA) 843-F 03-013). Available online at: http://www.epa.gov/agriculture/awet.htmlfor wastewater treatment. Bio-echnol. Adv. 22, 93–117.

FEPA – Federal Environmental Protection Agency (2007): Guidelines and standards for Environmental Pollution Control in Nigeria.

Gopal, B. (1999). Natural and constructed wetlands for wastewater treatment: potentials and problems. *Water Science and Technology, Vol. 40, No. 3.*

Hiley P. D, (1995) The reality of sewage treatment using wetlands. Water Sci. Tech. Joana de C.Baptista, Russell J.Davenport, Thomas P.Curtis (2008) The microbial diversity of laboratory scale wetlands appears to be randomly assembled. Incomplete reference

Kadlec R. H., and R. L. Knight. 1996. Treatment Wetlands. Lewis Publishers, Boca Raton, FL. Kadlec, R.H., Knight, R.L., Vymazal, J., Brix, H., Cooper, P., Haberl, R., 2000. Constructed wetlands for pollution control—processes, performance, design and operation. IWA Scientific and Technical Report No. 8.IWA Publishing, London, UK.

Knight, R.L., Payne, V.W.E., Borer, R.E., Clarke, R.A. and Pries, J.H. (2000).Constructed Wetlands for livestock wastewater management. *Ecol. Eng. 15*, 41:55.

MacIntyre, M.E., B.G. Warner and R.M. Slawson, 2006. Escherichia coli control in a surface flow treatment wetland. *J. Water Health, 4: 211-214. PMID:* 16813013

Mazanegos Ramos (1995) Consumption pattern of soft drinks, International *Journal on FoodandNutrition* 32:12-17

Mihret DU, Ermias AD, Mekonene AG, AdungaEB (2013). Environmental Impacts of SmallScale Irrigation Schemes: Evidence from Ethiopian Rift Valley Lake Basins, *Scientific J. Environ. Res. Engine. Manage.*

ISSN 1392-1649, ISSN (online) 2029-2139. www.erem.ktu.lt. 63:1.

Mitsch, W. J., &Gossenlink, J. G. (2000).Wetlands. New York: Wiley and Sons.

Nor Idzwana Mohd Idris (2015) Constructed Wetland as Natural Waste Water Treatment and Public Park in Urban Area – An Overview.

Rodrigo *et al ,* 2013 Influence of Constructed Wetland and Soil Filter Systems in theDynamics of Phytoplankton Functional Groups of Two Subtropical Fish Farm Wastewaters

Seidel K. (1953) pflanzugenzwischeGewassern and land.Mitteilungen.Max-Planck.Gesselschaftpp ,17-20.

Stottmeister, U., Wießner, A., Kuschk, P., Kappelmeyer, U., Ka¨ stner, M., Bederski, O., Mu¨ ller, R.A., Moormann, H., 2003.Effects of plants and microorganisms in constructed wetlands???????

Straka, R.P., Stokes, J.L., 1959. Metabolic injury to bacteria at low temperatures. *Journal of Bacteriology, 78* (2), 181-185.

Sugumar, G., Mariappan, S., 2003.Survival of Salmonella sp. in freshwater and seawater microcosms under starvation. *Asian Fisheries Science, 16*, 247-255.

Tanner, C.C., 2001. Plants as ecosystem engineers in subsurface flow treatment wetlands.*Water Sci. Technol.* 44(11–12), 9–17.

Taylor C (2009) . Selecting plant species to optimize waste water treatment in constructed wetlands U.S. EPA (1995) A handbook on constructed wetlands (5 volumes, (region III with USDANRCS ISBN 0-16 052999-9)

U.S. EPA (2000) Design Manual Constructed Wetlands for Municipal Wastewater Treatment, US EPACERI,Cincinnati, Ohio (in press.)

U.S. EPA (2000) Design Manual Constructed Wetlands for MunicipalWastewaterTreatment,USEPACERI, Cincinnati, Ohio (in press.)

UNEP (2004).Integrated watershed management -EcohydrologyandPhytotechnology Manual. Online at: www.unep.or.jp/ietc/publications/freshwater/watershed_manual/index.asp

UN-Water (2015) Water security & the global water agenda.A UN-Water analytical brief.

US.EPA (1993) Subsurface Flow Constructed Wetlands for Wastewater Treatment A Technology Assessment, EPA 832-R-93-008, US EPAOWM, Washington, DC.

US.EPA (1993) Subsurface Flow Constructed Wetlands for Wastewater Treatment. A Technology Assessment, EPA832-R-93-008, US EPAOWM,Washington, DC.

Vacca, G., Wand, H., Nikolausz, M., Kuschk, P., Kastner, M., 2005. Effect of plants and filter materials on bacteria removal in pilot-scale constructed wetlands. Water Res. 39 (7),1361–1373.

Venus ,G.C., (1987) Wetland wastewater treatment : A review . Whangarei, New Zealand

Vidales-Contreras1 J. A., Gerba C. P., Karpisack M. M., Rodríguez-Fuentes H., Chaidez- C Quiroz, E., Olivares-Sáenz., 2011. Tropical and Subtropical Agroecosystems, 14 (2011): 375-384

Vymazal J (2011). Plants used in constructed wetlands with horizontal subsurface flow.

Vymazal J (2005). Horizontal sub-surface flow and hybrid constructed wetlands systems for wastewater treatment

Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands.Scienceof the Total Environment Vymazal, J.; Kröpfelová, L.

Vymazal, J. (2008). Constructed wetlands for wastewater treatment : A review. Sengupta, M. And Dalwani, R. (Editors). Proceedings of Taal2007: The 12th World Lake Conference : 965 – 980.

Vymazal, J.; Kröpfelová, L. Is Concentration of Dissolved Oxygen a Good Indicator ofProcesses in Filtration Beds of Horizontal-flow Constructed Wetlands?In Wastewater Treatment, Plant Dynamics and Management; Vymazal, J., Ed.; Springer: Dordrecht, The Netherlands, 2008; pp. 311-317.

Watson J.T., Reed S.T., KadlecR.H., Knight R.L. and Whitehouse A.E. (1989): Performance expectations and loading rates for constructed wetlands. In: HAMMER D.A. (ed.): Constructed wetlands for wastewater treatment, Lewis Publishers, Chelsea, USA.

Werker, A.G., Dougherty, J.M., McHenry, J.L., Van Loon, W.A., 2002. Treatment variability for wetland wastewater treatment design in cold climates. *Ecological Engineering, 19* (1), 1- 11.

WHO (2000). Global water supply and sanitation assessment, 2000 report. World Health Organisation, Geneva, Switzerland.