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Treatment of Industrial Wastewater in Sand-based Surface flow Constructed wetland using Typha Orientalis as Macrophyte

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Abstract-

A laboratory-scale free water surface-flow constructed wetland was set up at the Department of Civil Engineering, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Nigeria in May 2013 to demonstrate the performance of sand- based constructed wetland, using Typha Orientalis as a viable low-cost efficient treatment option for Industrial wastewater from Pharmaceutical Company. The nutrient removal and performance evaluation of the constructed wetland in treatment of kitchen wastewater against retention period of ten days was investigated. During the 10-day retention period, the sand- based constructed wetland set up with Typha Orientalis had improved the wastewater quality significantly as it had reduced the concentrations of BOD5, Nitrate, Sulfite, Magnesium, Turbidity and Oxygen Reduction Potential (ORP) by 46.96%, 50%, 63.63%, 42.96%, 31.03%, 63.63%, respectively on the average, respectively and the initial offensive odour of the raw water was no more noticeable. The final effluent was found to be suitable for non-drinking purposes like crop irrigation and keeping aquatic animals. However, it was noted that a 7- day detention time was optimal for the treatment of domestic wastewater from kitchen. The treatment system was found to be economical, as the cost of construction only was involved and maintenance cost very minimal. It was environmentally friendly as it was free from offensive odour and insect invasion. The prototype scale is recommended for in-situ use, especially for wastewater from kitchen.

Keywords: Constructed wetland, Indusrial wastewater, Laboratory scale, Nutrient removal, Pharmaceutical Company, Retention period, Typha Orientalis

1. INTRODUCTION

The water bodies in developing countries are the worst victim of industrial wastewater sewage, basically because of the widening gap between the increasing wastewater generation and unavailability of commensurating economical resources to address the issue through conventional technologies. The problem is expected to increase due to rapid pace of urban growth, unless measures are taken to control and treat effluents.

By definition Constructed wetlands are artificial wastewater treatment systems consisting of shallow (usually less than 1 m deep) ponds or channels which have been planted with aquatic plants, and which rely upon natural microbial, biological, physical and chemical processes to treat wastewater. They typically have impervious clay or synthetic liners, and engineered structures to control the flow direction, liquid detention time and water level. Depending on the type of system, they may or may not contain an inert porous media such as rock, gravel or sand. Constructed wetlands have been classified by the literature and practitioners into two types.

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Free water surface (FWS) wetlands (also known as surface flow wetlands) closely resemble natural wetlands in appearance because they contain aquatic plants that are rooted in a soil layer on the bottom of the wetland and water flows through the leaves and stems of plants. Vegetated sub- merged bed (VSB) systems (also known as subsurface flow wetlands) do not resemble natural wetlands because they have no standing water. They contain a bed of media (such as crushed rock, small stones, gravel, sand or soil) which has been planted with aquatic plants. When properly designed and operated, wastewater stays beneath the surface of the media, flows in contact with the roots and rhizomes of the plants, and is not visible or available to wildly.

Furthermore, wetland water treatment systems have been found to lower concentrations and mass loads of biochemical oxygen demand (BOD), total suspended solids (TSS), and total nitrogen concentrations to 10 to 30 percent of the concentrations entering the systems (70 to 90 percent reduction). For total phosphorus, metals, and organic compounds, removal efficiencies vary more widely, typically from about 20 to 90 percent. Therefore, the use of constructed wetland technique (root zone technology) is a good alternative to the conventional wastewater treatment system, since it is suitable for small to medium size communities, rural areas,

so also developing countries. Vegetation is the principal component of a wetland system. The ability of the plants to stay healthy and therefore to continue to grow is an important factor in the choice of plants for phytoremediation. Reed bed is one of the natural and cheap methods of treating domestic, industrial and agricultural liquid wastes. Reed bed is considered as an effective and reliable secondary and tertiary treatment method where land area is not a major constraint [1] . The pollutant removal mechanisms in a constructed wetland plant comprise several physical, chemical, biological and biochemical processes [2]; [3], and this include; sedimentation, filtration, aerobic and anaerobic microbial degradation, plant uptake, soil sorption, precipitation and so on.

Furthermore, these treatment systems have been widely employed in the treatment of wastewater, and a brief summary of few of such studies include; [4] study on constructed wetland with and without *Typha Orientalis* plant for a detention time of 3,5,7 and 9 days indicated that the beds with *Typha Orientalis* produced effluents of better quality than the bed without *Typha Orientalis,* as the result shows a reduction of 75% in total solids, 86 % in BOD, 63% in COD using *Typha Orientalis* compared to that without *Typha Orientalis* with 70% reduction in total soilids, 62% in BOD and 53% in COD. [5] study on Two pilot-scale integrated vertical-flow constructed wetlands (IVCWs) in parallel at a loading rate of 250 mm/d, and each planted with two different plant species (*Typha orientalis* and *Arundo donax var. versicolor* (Plot 1), *and Canna indica* and *Pontederia cordata* (Plot 2)) showed that the mean removal efficiencies associated with Plot 1 and Plot 2 were 59.9% vs. 62.8% for COD, 15.0% vs. 12.8% for TN, and 52.0% vs. 51.1% for TP, respectively.

The aim of this study is to evaluate the treatment performance of a laboratory scale free water surface flow constructed wetland using *typha orientalis* for the treatment of domestic wastewater while the objectives are to; analyze the wastewater generated and evaluate the suitability of treating wastewater by root zone technology, determine the effect of detention period on treatment efficiency and recommend a low-cost and environmentally friendly techniques for wastewater treatment.

2. Material and Methods

2.1 Study Site

The laboratory scale free water surface flow constructed wetland was set-up at the department of civil engineering Ladoke Akintola University of Technology which was established in September 1990 and located in the agrarian town of Ogbomoso in Oyo state which lies between latitude 8^{o} 08′ 01′′N and longitude 4^{o} 14′ 48′′E. The town is characterized by an average daily temperature of between 25^{o} and 35^{o} almost throughout the year.

2.2 Experimental Setup

The wetland cell which was made of a transparent plastic was 0.9 m deep, 0.6 m long and 0.6 m wide to give a total volume of 0.324 m^3 (Fig. 1). The outlet is a plastic tap fitted to the bottom side of the basin while the inlet is excluded as water will be fed into the wetland system manually. The basin was lined to prevent leakages, and encased with a wooden frame to give it the required rigidity and support to prevent outburst of the plastic basin (Fig. 2). Furthermore, the inlet of the tap was covered with screen during substrate filling to prevent the passage of sand with the water, the substrates were properly washed to eliminate the undesired particles and dust, and sieved to obtain the desired grain size (granite 13.5 mm and 8mm, gutter sand and humus < 2mm), and the basin was filled as follow:

The first layer of 100mm depth consisted of granite of 13.5 mm size.

The second layer of 150mm depth consisted of granite of 8mm size.

The third layer of 200mm depth consisted of washed gutter sand.

The fourth layer of 150mm depth consisted of humus soil to support plant growth.

300mm free board was provided.

2.3 Planting of the Vegetation

Live plant transplant was employed for this setup, the planting density was nine plants (six of 62cm height and three of 38cm height) per 0.54 m^2, the depth of planting was 10 cm below the surface of the humus soil and the plant was cultured in the setup with tap water by wetting it manually every day . After a period of seven months (19th of August 2013 to 17th of March 2014), the nine *Typha Orientalis* plants that were planted initially have multiply to cover the entire setup forming a thick vegetation with profuse roots (Fig. 3). The plant growth was also monitored and the plant was found to have a rapid rate of growth with an average growth rate of 0.31 meter per week.

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Figure 1: Wetland Unit

Figure 2: Wetland Unit with Lining

2.4 Wetland Operation

Draining of the Setup: All the water present in the setup was drained two days before the introduction of the wastewater by keeping the outlet widely open. This is necessary to avoid the dilution of the wastewater by the fresh water used in nurturing the plant and therefore eliminate error during analysis.

Wastewater Collection: The wastewater used for this research work was collected from an eatery located in Aroje area of Ogbomoso along Ilorin road with the aid of six 25 liters kegs to make the total volume of the waste water collected 150 liters.

Figure 3: Setup Before and After Seven Months

Pretreatment and Introduction of the Wastewater into the Setup: A total volume of 75 liters of wastewater was screened using a 75µm sieve and introduce into the setup manually from the open roof at top of the basin on 17th of March 2014.

Sample Collection and Qualitative analysis:

The influent samples that were collected from Sofak Pharmaceutical Company, Aroje Ogbomoso. ware analyzed to determine the quality of influent, variation in quality over a detention period of Ten (10) days.

75cl sample each was collected from the setup for detention time of 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 days respectively including that of the raw waste water, and qualitative analysis carried out according to [6] standard on each of the sample collected to determine the effect of detention period on the wastewater.

The parameters tested for are; Colour, pH and odour, Temperature, Turbidity, Conductivity, Dissolved Oxygen (DO), Biochemical Oxygen Demand ($BOD_{5,20}$), Magnesium (Mg), Chloride (Cl^-), Sulphide (SO_4) and Nitrate (NO_3).

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3. Results and Discussion

The results of the Physico-chemical analyses carried out on the samples daily for a retention time of ten (10) days were presented as shown in Table 1, Table 2 showed Parameters with Percentage Reduction and Increase

Table 1: Results of the Physico-chemical analyses carried out on the samples daily for a retention time of ten (10) days

PARAMETERS	DETENTION PERIOD										
	Raw	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Temperature (^{0}C)	26.1	27.1	25.2	26.4	31.4	25.8	27.1	25.9	27.2	28.6	26.5
PH Value	4.94	6.96	6.97	6.67	6.67	6.81	6.69	6.79	6.81	6.69	6.67
Oxygen Reduction Potential (mV)	0.150	0.065	0.062	0.059	0.059	0.054	0.061	0.051	0.049	0.047	0.044
Turbidity (FTU)	143.7	132.9	119	113	107	101	98	97	86	72	65
Colour	550	550	440	550	450	550	550	550	550	550	550
Iron (mg/l)	1	2	2	2	5	5	5	5	5	5	5
Nitrate (mg/l)	30	30	20	10	10	10	10	10	10	10	10
Magnesium (mg/l)	155.5	132.1	121.2	112.6	96.2	83.1	78.5	66.4	54.2	47.8	45.2
Sulfite (mg/l)	38	29	26	24	21	20	17	16	15	15	14
Conductivity µS/cm	680	850	620	700	960	640	860	670	860	910	710
Dissolved Oxygen (mg/l)	354.0	255.5	248.0	198.4	181.7	155.6	172.5	166.5	162.4	160.3	152.2
BOD_5 @ 20^{o}C in (mg/l)	250.6	149.5	146.2	131.3	129.4	125.5	125.1	119.6	117.5	117.2	116.3

Table 2: Parameters showing Percentage Reduction and Increase

PARAMETERS	DETENTION PERIOD											Range of Percentage Removal
	Raw	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day7	Day 8	Day 9	Day 10	
Oxygen Reduction Potential (%)	0.15	56.60	58.66	60.66	60.66	64.00	59.33	66.00	67.33	68.66	70.66	56.6 - 70.66
Turbidity (%)	143.7	7.51	17.18	21.36	25.53	29.71	31.80	32.49	40.15	49.89	54.76	7.51 -54.76
Nitrate (%)	30	0	33.33	66.66	66.66	66.66	66.66	66.66	66.66	66.66	66.66	33.33 - 66.66
Magnesium (%)	155.5	15.00	22.00	27.58	38.13	46.55	49.51	57.29	64.92	69.26	70.93	15 - 70.93
Sulfite (%)	38.0	23.68	31.57	36.84	44.73	47.36	55.26	57.89	60.52	60.52	63.15	56.6 - 70.66
BOD_5 @ 20°C in (%)	250.8	40.34	41.66	47.60	48.36	49.92	50.07	52.27	53.11	53.23	53.59	40.34 – 53.59
*PH Value (%)	4.94	40.89	41.09	35.02	35.02	37.85	35.42	37.44	37.85	35.42	35.02	35.02 - 41.09
*Iron (%)	1.0	100	0	0	400	300	400	400	400	400	400	100 – 400

3.1 pH
The pH of the treated water ranged from 6.67 to 6.97. Generally, the obtained pH values fall within 6.5 to 8.5 of the [7] Standards for drinking water. There was an improvement in the ph values from acidic range to neutral.

3.2 Temperature
The temperature profiles of the treated water samples varied significantly and ranged from 25.2 to 31.4 °C. 40°C is the limit given by [7] while 20-35°C is the recommended limit for no risk according to the NER standard for discharge effluent into water bodies. Based on these guidelines, the temperature of the effluent does not appear to pose any threat to the homeostatic balance of the receiving water bodies. It will however reduce solubility of oxygen and amplified odour due to anaerobic reaction.

3.3 Turbidity
The turbidity profile varies significantly throughout the study period and reduced from 132.9 to 65 FTU. The turbidity values obtained from the treated water is higher than [7] standard of 5 NTU [7]. These values are grossly exceeded in the water samples and it disqualifies the water from direct domestic use. But it meets the National Environment (discharge of effluent into water or land) Regulations of 300NTU. Also, the excessive turbidity in water can cause clogging problem with water purification processes such as flocculation and filtration, which may increase treatment cost. The percentage reduction however, is approximately, 8 – 55%.

3.4 Dissolved Oxygen
The concentration of total dissolved oxygen decreased from 255.5– 152.2 mg/l which is much lesser than the maximum permissible limit of 500mg/l of [7]. This could be attributed to the presence of aerobic bacteria degrading organic matters which resulted in the absorption of dissolved oxygen. The DO values from this study fell in the range of the recommended standard.

3.5 Electrical Conductivity
The electrical conductivities of the water samples generally varied significantly and ranged from 620 to 960 µs/cm throughout the period of study. Higher conductivities were observed in the treated sample. Electrical conductivity is a useful indicator of mineralization and salinity or total salt in a water sample. The FEPA acceptable limit for electrical conductivity in domestic water supply is 70µs/cm. Thus, the treated water is saline and not suitable for direct domestic use.

3.6 Sulphite
The concentrations of Sulphite in the treated industrial water was reduced from 29- 14 mg/l; with removal percentage ranged from 57- 71%. In industrial applications, a sulfite concentration of approximately 20 mg/L must be maintained to prevent pitting and oxidation of metal components as in boiler feed and effluent waters. A high level of sulfite results in a lowered pH, thus promoting corrosion. The monitoring of sulfite is important in environmental control. Sulfite ions are toxic to aquatic life forms and their ability to remove dissolved oxygen in water

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will destroy the delicate balance of ecology of lakes, rivers and ponds.

3.7 Oxygen Reduction Potential

Reduction potential is measured in volts (V), or millivolts (mV). Each water sample has its own intrinsic reduction potential; the more positive the potential, the greater the waters' affinity for electrons and tendency to be reduced. In aqueous solutions, the reduction potential is a measure of the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. This was reflected in the concentration of the dissolved oxygen. Oxygen reduction potential ranged between 57- 71%.

3.8 Magnesium

In concentration greater than 125 mg/L, magnesium can cause diuretic effects. Magnesium is also an important contributor to the hardness of water: when heated, magnesium salts break down forming incrustation in boilers. Moreover magnesium is necessary to plant metabolism since it is an essential constituent of organic molecules such as chlorophyll. In the analysis carried out, the value of magnesium decreased from 132.1 – 45.2mg/l which falls lower than the NER standards for discharge of effluent into water. Percentage removal of Magnesium is of the range 15- 71%.

3.9 Nitrate

In this study, the nitrate-N concentrations reduced from 30-10 mg/l and changed significantly. It is important to note that nitrate level in the stream could be a source of eutrophication for receiving water as the obtained values falls within the range recommended limit for FEPA. Excessive amounts can contribute to blue baby syndrome that affects the oxygen carrying capacity of infant's blood, also known as methaemoglobinemia and also causes adult illness. The percentage reduction is 33-66%.

3.10 Biological Oxygen Demand

Biological Oxygen Demand (BOD) is the measure of the oxygen required by microorganisms whilst breaking down organic matter. From the analysis carried out there was gradual reduction in BOD from 149.5- 116.3 mg/l. The percentage removal is above 50%..

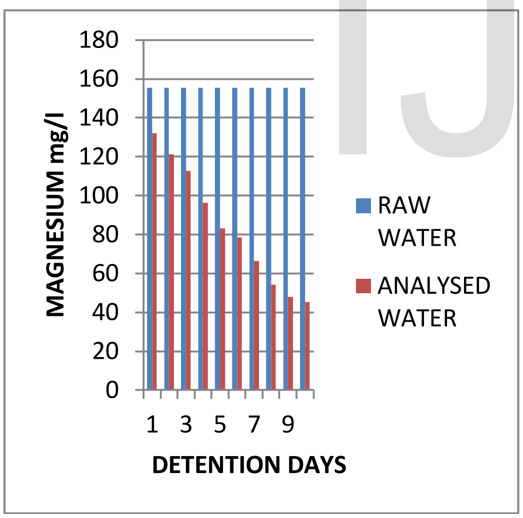

Figure 5: Chart Illustrating Magnesium Values

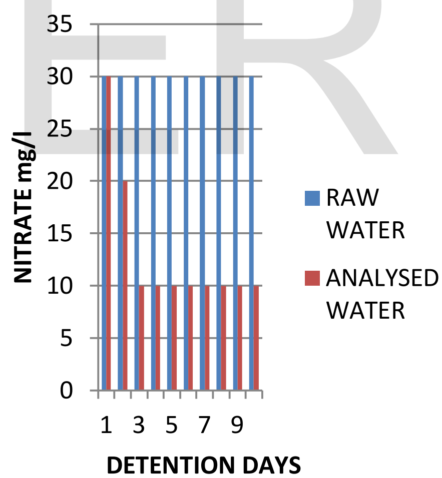

Figure 6: Chart illustrating Nitrate

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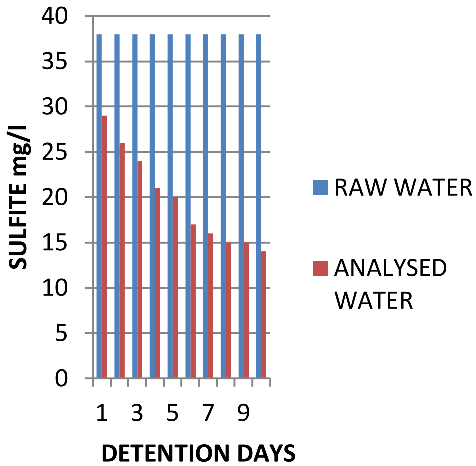

Figure 6: Chart Illustrating Sulfite Values

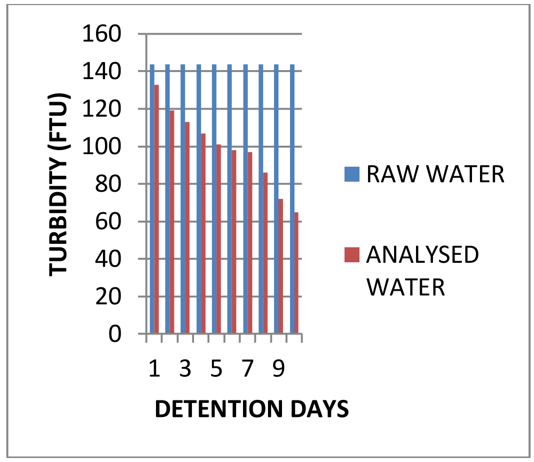

Figure 7: Chart illustrating Turbidity Values

Figure 4: Sample before and after treatment

4 CONCLUSION

The waste water discharged from Sofak Pharmaceutical Industry was analyzed to determine its characteristics. pH, Oxygen Reduction Potential (ORP), Nitrite (NO_2), Iron, Sulfite, BOD_5 particularly show large variations. This study established the ability of Typha Orientalis to remove pollutants from wastewater. The final effluent after the 10-day experiment did not meet WHO's standard for potable water supply. The setup was able to achieved over 50% efficiency in BOD_5, Sulfite, Nitrate, ORP, Magnesium, and turbidity during the later end of the detention period precisely from day 6-10 while the pH value increase as expected.

The free water Surface flow constructed wetland using *Typha Orientalis* is effective and suitable for treating domestic wastewater. The treatment system is a low cost and environmental friendly technique. The treated water may be suitable for non-drinking purpose, but may be discharged on water bodies or land.

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REFERENCES

[1] Wood and Hensman. (1988): Experimental Study on Waste Water Treatment Using Large Scale Reed. International Journal of Enviromental Sciences.

[2] Brix Hans (1993). Waste water treatment in constructed wetlands; system design, removal processes and treatment performance. Lewis publisher.

[3] UN-HABITAT, 2008. Constructed Wetlands Manual. UN-HABITAT Water for Asian Cities Programme Nepal, Kathmandu.United Nations. 3-12

[4] Borkar, R.P. and Mahatme, P.S. (2011). Waste water treatment with vertical flow constructed wetland. International Journal of Environmental Sciences Volume 2.

[5] Jun-Jun Chang, Su-ging Wu, Yan-ran Dai, Wei Liang and Zhen-bin Wu. (2012). Treatment performance of integrated vertical-flow constructed wetland plots for domestic waste water. Ecological Engineering, 44 (2012,) 152– 159.

[6] American Public Health Association (APHA, 1998). Standard Methods for the Examination of Water and Wastewater (20th Edition). American Public Health Association, New York, U.S.A. p.4-173.

[7] WHO. 2008. Guideline for Drinking water Quality, vol. 1 Third Edition. 215-219, 490.