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Sequential Treatment of Brewery Effluent using Vegetated Subsurface and Surface Flow Constructed Wetland

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Abstract: This study investigated the efficiency of a sequential system involving surface flow and vegetated sub-surface flow constructed wetland (CW) in the treatment of Brewery Wastewater. Six experimental CW (2 surface and 4 subsurface flow) and control (1 surface and 2 vegetated subsurface flow) with 200 mm depth of 19.05 mm diameter granite and 100 mm depth of sharp sand as substrate were used for the experiment. The CWs were planted with locally available macrophytes: water hyacinth (*Eichhornia crassipes),* Cattail (*Typha latifolia)* and Vetiver grass (*Vetiveria nigritana*). The microcosms were irrigated using wastewater from Brewery Effluent (BE), pollution parameters were measured and treatment efficiency was monitored. The pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD_5) of the BE studied were 6.84, 1189 µs/m, 2998 mg/l, 9.4 mg/l and 1244 mg/l, respectively. Average reductions of 92.53, 48.30 and 67.16 % were observed in the TDS, BOD and Nitrate after treatment. The BOD_5 percentage removal was higher in the Subsurface CW than in the Surface flow CW (30.11 and 49.04 % for surface and subsurface flow, respectively). The study showed that CW using surface and subsurface flow constructed wetland with locally available macrophytes is efficient in Brewery wastewater treatment.

Keywords: Brewery effluent, Cattail, vetiver grass, water hyacinth, constructed wetland.

I. Introduction

Since rapid industrial development began, the release of industrial effluent into natural water bodies has been a major source of pollution and has become an environmental issue for many countries, especially developing nations like Nigeria [1]. One of the industrial effluents available in large quantities in Nigeria is Brewery effluent (BE) due to the high quantity of water required in the production process. BE contains organic and inorganic compounds and nutrients [2]. The treated effluent could be recycled as a water source and the nutrient (Nitrogen and Phosphorus) for plant growth [3]. However, untreated or partially treated BE discharged into streams constitutes severe environmental risk and the need for adequate treatment cannot be over-emphasized [4, 5]. Studies have shown that BE used for irrigation inhibits seed germination and plant yield; the high COD content of BE results in low soil quality; the nutrients in BE also cause eutrophication in receiving rivers and microbial community imbalance [6, 7, 8].

Several methods have been used for treating BE, some are solely aerobic or anaerobic, while others involve a combination of anaerobic and aerobic treatment [9, 10]. Upflow anaerobic sludge blanket reactors have been used for BE

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with high COD [11]; Membrane bioreactors have also been used in BE treatment to produce high-quality effluent [12]; Nanofiltration or Reverse osmosis membranes have been incorporated in BE treatment required for reuse purposes [13]. Microbial Fuel Cells are also being researched to ensure proper treatment of BE [14]. However, a promising treatment method that is non-mechanized requires minimal maintenance and uses locally available macrophytes is found in Constructed Wetland (CW).

Constructed Wetland is a low-cost wastewater treatment alternative with minimal cost of construction and low maintenance/operation cost. It has been used with success severally in the treatment of municipal, agricultural and industrial wastewater [15, 16, 17, 18]. CWs are a combination of aerobic and aerobic treatment zones made of shallow ponds planted with tolerant aquatic plants. CWs act as bio-filters by removing nutrients and organic pollutants; they rely on natural microbial, biological, physical and chemical processes to treat wastewater. Contaminants in wastewaters are removed in CWs by various mechanisms such as sedimentation, filtration, microbial degradation, and plant uptake [19].

Constructed Wetlands are grouped based on water flow regime (surface flow, sub-surface, vertical or horizontal flow) or the type of macrophytic growth (emergent, submerged, free-floating and rooted with floating leaves) [20]. They have three major components, namely, macrophyte, substrate and impermeable membrane. Sub-surface CW consists of substrate, microorganisms and macrophytes while Surface CW has only microorganisms and macrophytes as the wastewater flows through the CW Bed [21, 22, 23].

Locally available macrophytes always adapt to their local weather; *Eichhornia crassipes, Typha latifolia* and *Vetiveria nigritana* are readily available in Nigeria. In this study, a pilot scale sequential CW consisting of Surface and Vegetated Sub-surface flow CW was constructed and used to assess the treatment of BE using locally available macrophytes.

II. Materials and Methods

The study was carried out at the Civil Engineering Department in the Engineering Campus of Olabisi Onabanjo University (6.8047^0N, 3.0129^0E). Nine 0.1 m^3 plastic basins of 0.45 m height and 0.6 m diameter pilot scale Constructed Wetlands (consisting of 2 surface and 4 subsurface flow reactors with 3 reactors as control) were used for the experiment. Two experimental setups with one control were used, each setup consisted of 3 CWs, one surface and 2 subsurface s (SFCW, $VSCW_1$ and $VSCW_2$) arranged in sequential order at different heights to allow flow under gravity. The CWs were connected by pipes with valves and taps to control and collect effluent samples (Fig. 1). Washed granite and sharp sand of 0.25 and 0.1 m depth respectively were used as substrate. Locally available *Eichhornia crassipes, Typha latifolia* and *Vetiveria nigritana* obtained from River Ogun, Ogun-Oshun River Basin, Alabata, Ogun State and Olodo, Ibadan Oyo State, respectively were used as macrophytes.

The industrial effluent used was collected from a Brewery in Sango-Ota, Ogun State. The plastic basin served as the impermeable membrane, transplanted rhizomes of the plants were grown in the CW until they were well established before introducing BE into the system. Wastewater was retained for 3, 6, 9, 12 and 15 days after which grab samples of the treated wastewater were collected. Determination of physicochemical parameters such as pH, Electrical Conductivity (EC), nitrate, Total Dissolved Solids (TDS), Dissolved Oxygen and Biological Oxygen Demand (BOD_5) were carried out using standard methods [24]. The physicochemical analysis was carried out at Covenant University, Ota and

Olabisi Onabanjo University (Civil Engineering Laboratory); and a total number of 135 samples were analyzed. Three replicate samples were taken for each of the sampling points and the mean values were used in the analyses. The experimental tests were repeated in some cases to control errors.

III. Results and Discussion

A. Characterization of Brewery Effluent

The characteristics of the raw brewery wastewater, mean, range and standard deviation of the wastewater samples during the study are shown in Table 1. Physico-chemical parameters analyzed were observed to display variable concentrations throughout the study period which is consistent with studies on wastewater [25]. The BOD_5 obtained showed a high-strength wastewater. This is due to the fermented characteristics of the product from the industry. The high BOD_5 content has a tendency of depleting the oxygen in receiving stream if not treated and this may affect the aquatic ecosystem.

B. Treatment Efficiency

The pH varied throughout the study period, with an average of 6.98±0.3. The resulting pH after 15 weeks retention period was relatively neutral, between 7.04 and 7.14 [26]. This lies within the Federal Environmental Regulation [27] tolerant limit for Wastewater Discharge into the stream.

The E_C was observed to reduce from 1189 to 350 mg/l after treatment. The E_C increased by 18.50% after 9 days of retention in the SFCW. A percentage reduction of 33.86 and 19.17 % was observed in the $VSCW_1$ and $VSCW_2$ respectively. A removal efficiency of 70.56% was obtained after 15 days of treatment (Fig. 2 and 3). A reduction of 60.64% was observed in the control, indicating that the vegetation also contributed to the reduction in E_C.

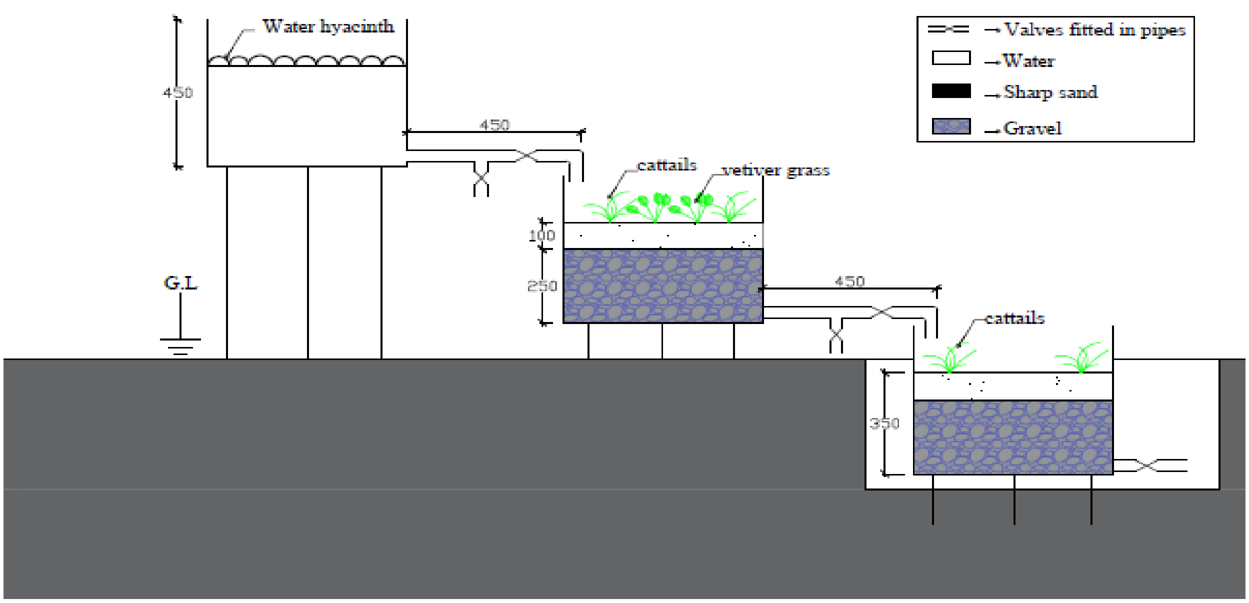

Figure 1: A schematic diagram of the Constructed Wetland connected in series

Table 1: Characteristics of Brewery Effluent During the Study Period

Parameters	Range	Mean	Standard Deviation	Raw
pH	6.01 – 7.34	6.98	0.3	6.84
EC (µs/m)	350 – 2010	1029.93	419.8	1189
TDS (mg/l)	2998 – 178	626.26	685.6	2998
DO (mg/l)	2.2 – 9.4	5.6	2.1	9.4
BOD (mg/l)	643.1 – 2059.5	1174.6	444.6	1244
Nitrate (mg/l)	0.66 – 3.56	1.806	0.95	2.036

Nitrate can have serious health effects when consumed or mixed with drinking water sources. Water quality degradation through eutrophication is always associated with excessive accumulation of nitrogen in surface water. A combination of Surface and Vegetated subsurface CW removed 67.16% of nitrate from BE. The concentration of nitrate initially increased in the surface flow CW during the first 9 days after which a reduction was observed as shown in Figures 2 and 3. This is due to an increase in the relative amount of carbon sources in the surface flow CW system as the retention time increases [28]. In the Vegetated Submerged CW, the nitrate was reduced by 42.02 and 62.19% in CW_2 and CW_3 respectively. This is similar to the observation by Bigambo and Mayo [29].

The plants in the sequential flow CW were observed to contribute to the BE treatment as only 3.43% reduction was observed in the control [30, 31].

The total solid and BOD_5 are the major parameters taken into consideration in the design of CW. The TDS was observed to reduce by 76.42, 49.79 and 79.66 % in the SFCW, $VSCW_1$ and $VSCW_2$ respectively. A treatment efficiency of 94.06% was observed in the sequential treatment plant after 15 days retention period.

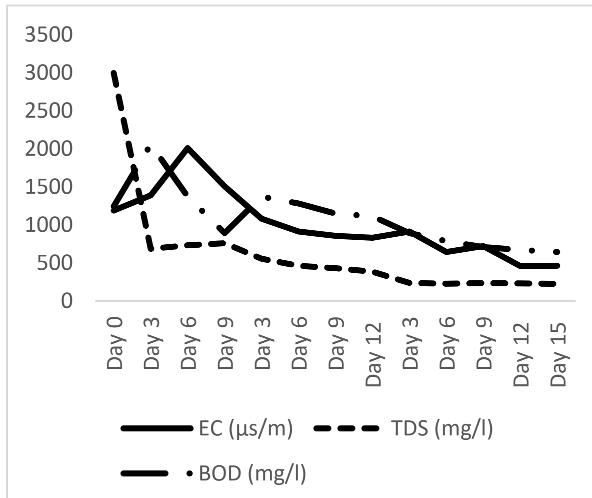

Figure 2: Variation in EC, TDS and BOD_5 in the SFCW, $VSCW_1$ and $VSCW_2$ (Setup 1)

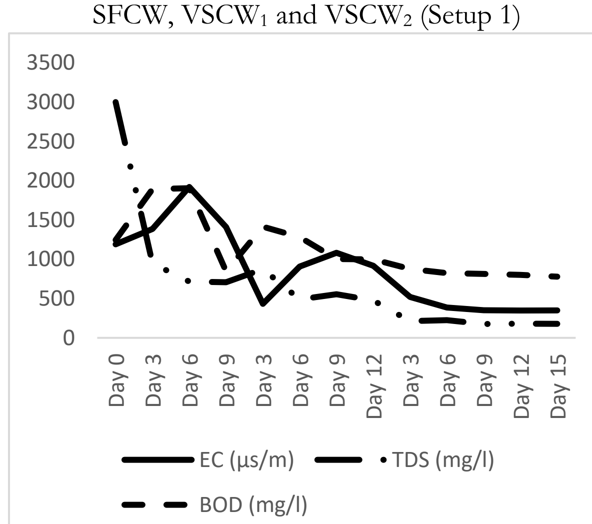

Figure 3: Variation in EC, TDS and BOD_5 in the SFCW, $VSCW_1$ and $VSCW_2$ (Setup 2)

IV. Conclusion

The result of this study showed that a combination of Surface Flow Constructed wetland using *Eichhornia crassipes* and Vegetated Sub-Surface Flow Constructed Wetland planted with *Typha latifolia* and *Vetiveria nigritana* is a viable wastewater management alternative. A sequential Surface and Vegetated Sub-surface flow Constructed Wetland can be used solely or in combination with available conventional Brewery effluent treatment methods for efficient wastewater treatment. The materials required for the construction of the constructed wetland are locally available and problem of unstable power supply is eliminated based on the non-mechanized nature of the process.

The sequential treatment using Surface and Vegetated Sub-Surface flow Constructed wetland is sustainable, it requires minimal maintenance and eliminates environmental risks associated with lack/inadequate treatment of Brewery effluent.

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