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Utilization of *Lemna paucicostata* for Low-cost Removal of Contaminants from Beverage Factory Effluent

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ABSTRACT: Biological treatment using aquatic plants have been investigated as an alternative process for treatment of beverage factory effluent. In this study, *Lemna paucicostata* Hegelm was exposed to different concentrations (0%, 5%, 10%, 20% and 25%) of beverage factory effluent. The experiment was set up in triplicates for each concentration and observed for fourteen days. From the results obtained, fast growth and turnover of *L. paucicostata* was observed and the relative growth rate was found to be concentration dependent. *L. paucicostata* successfully lowered the sulphate and nitrate content and also reduced the biological oxygen demand (BOD), total dissolved solids (TDS) and electrical conductivity of the effluents after exposure. Statistical analysis showed significant difference in TDS, Nitrate and BOD between the different concentrations before and after exposure. This study further provides an insight to the phytoremediating potential of this plant. It can be concluded that *L. paucicostata* will be an effective candidate for the reduction of nitrate, sulphate, BOD and TDS in beverage factory effluent before disposal.

Keywords: *Lemna paucicostata*, Beverage, Nutrients, Treatment.

Introduction

Wastewaters are generated by many industries as a consequence of their operations and processes. The beverage industry is one of the largest and most complicated industrial chains in manufacturing. It includes manufacturers and distributors of carbonated soft drinks, bottled water, energy drinks, sport drinks, milk products, coffee, tea based products, and nutritional products. Vast volume of freshwater is required for beverage industry so it generates significant quantity of wastewater (Fillaudeau *et al*., 2006), from different production processes including drink production, washing bottles, plant washdown as well as washing the floors and the general work area. Bottle washing uses also a lot of water and generates about 50% of the total wastewater generated by this industry (Abdel-Fatah *et al*., 2017; Abrha and Chen, 2017). Wastewater discharged from beverage industries are usually polluted by suspended solid, organic substances, high pH, and turbidity, COD, BOD, (Abdel-Fatah *et al*., 2017) chlorides, sulphate, nitrates, phosphates, sodium and potassium contaminants capable of disrupting the aquatic ecosystem if not well treated before discharge into the receiving water bodies.(Imoobe and Okoye, 2011; Edjere *et al*., 2016). The use of plants for treatment of wastewaters has gained acceptance as a cost effective and eco-friendly method (Priya and Selvan, 2017; Kore *et al*., 2017).

Aquatic macrophytes treatment system is recognized as an environmental protective technique for pollutants removal. Some freshwater macrophytes including *Eichhornia crassipes, Pistia stratiotes, Lemna* spp*, Azolla*

pinnata, Myriophyllum spicatum, Ipomoea aquatica and *Ceratophyllum demersum* have been well investigated by different research groups for phytoremediation of organic and inorganic pollutants (Eribo and Kadiri, 2016; Yapoga *et al*., 2013). This study was aimed at identifying the potential of *Lemna paucicostata* to remove contaminants from a beverage factory wastewater.

Materials and methods

The study was conducted in the screen house of the Department of Plant Biology and Biotechnology, University of Benin, Benin City, Edo State Nigeria

Materials: The plant used for this study is a locally available aquatic plant *Lemma paucicostata*, which was collected from a wetland area by Nigeria Brewery factory along Agbor Road, Benin City. The beverage factory wastewater was collected directly from the tunnel of discharge behind Seven-up Bottling Company, Benin – Lagos expressway for the phytoremediation experiments.

Experimental set up: The initial and final physical, biological and chemical parameters of the collected beverage wastewater were analyzed and recorded on termination of the experiment. Selected *L. paucicostata* of uniform size were carefully placed in plastic bowls having capacity of 4 litres containing 1 litre wastewater of 0%, 5%, 10%, 15%, 20% and 25% concentration. The experiment was set up in triplicates for each concentration. The plant number was counted, recorded at every two days interval and harvested after fourteen (14) days.

Parameters analyses were done by following the guidelines of APHA (1998). pH meter (Hanna Instrument Model S358236), Digital Total Dissolved Solids meter (HACH Co 150) were used for the analysis study. All the experimental materials were placed under the same environmental conditions, to ensure completeness and accuracy of data.

The pollutant removal efficiency of *L. paucicostata* was determined as reduction percentage. The initial and final concentrations of the physico-chemical parameter of the wastewater analysed was used to determine the removal efficiency (%) on day 10 using the formula below (Terfie and Asfaw, 2015).

$$RE = \left(\frac{WC - C}{WC}\right) * 100$$

where RE = removal efficiency (%)
WC = initial value of water quality parameter
C = value of water quality parameter on termination.

Relative growth rate of plants was estimated after the experiment and compared with the plants initial weight and was calculated using the equation below (Saha *et al.,* 2017)

Relative growth rate $$\mu = \frac{ln\, W_2 - ln\, W_1}{t_2 - t_1}$$

where W_1 and W_2 are initial fresh biomass and final fresh biomass at harvest, respectively, and (t_2- t_1) is the time change of the experiment in days

Statistical Analysis: Data obtained were graphically represented using bar charts, line graph. Data were presented as mean value ± standard error. Comparison of mean values was made by Paired t- test at a significance level of $p<0.05$. The statistical package used was SPSS version 16.

Results and discussion

Relative growth rate is one of the most widely used methods for estimating plant growth. In the present study, the effects of different concentrations of beverage effluent on relative growth of *L. paucicostata* were studied and the result was presented in Figure 1. The relative growth rate increased with 5 – 25 % of beverage factory effluent but decreased with 0 %. It appears that high concentration of beverage effluent stimulated the plant growth. This can be attributed to the presence of dissolved solutes, nutrients and organic and inorganic compounds.. While studying the

primary productivity of *Lemna* spp, Bergmann *et al*. (2000); Cheng *et al*. (2002) and Mkandawire *et al,* (2004) reported that *Lemna* spp removed excess nutrient from medium to fuel fast growth and primary production. The fast growth and turnover of *L. paucicostata* is fuelled by its ability to rapidly take up high amount of nutrients from the medium as recorded in 25% concentration. Thus the value of nutrient elimination potential is a direct result of rapid growth rate and high turnover. A study by Mkandawire and Dudel (2007) and Dixit *et al*. (2011) showed that *Lemna* spp grow rapidly in nutrient rich environments, having high rate of absorption and uptake of nutrients properties that can be exploited to remove surplus nutrients from effluents in wastewater.

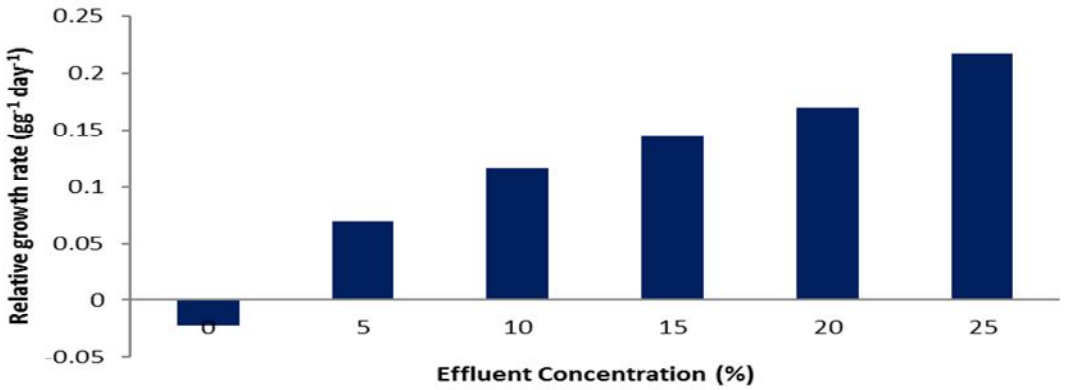

Figure1: Growth rate of *L. paucicostata* in concentrations of beverage factory effluent

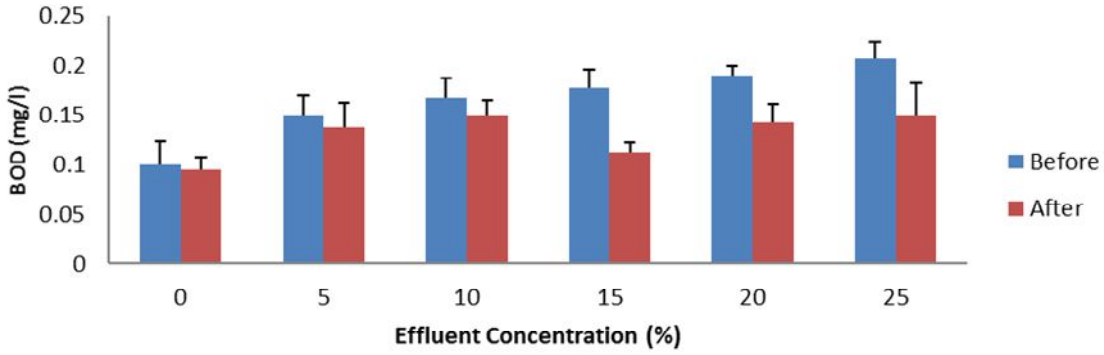

Figure 2: Effect of *L. paucicostata* treatment on biochemical oxygen demand of beverage factory effluent

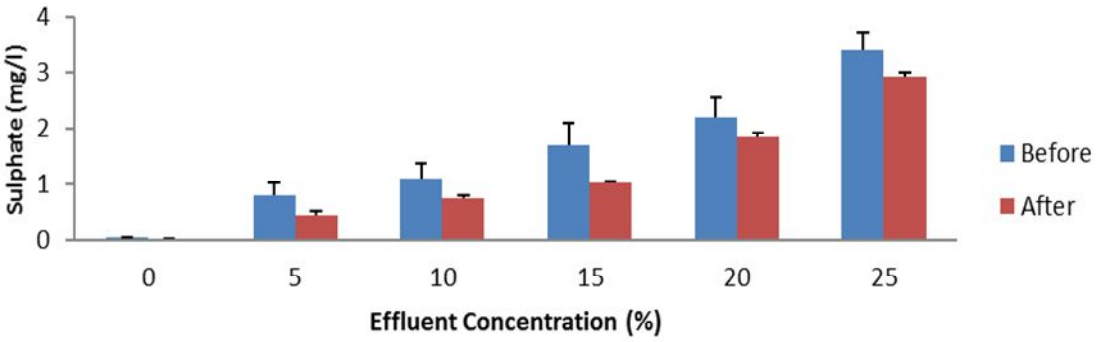

Figure 3: Effect of *L. paucicostata* treatment on sulphate of beverage factory effluent

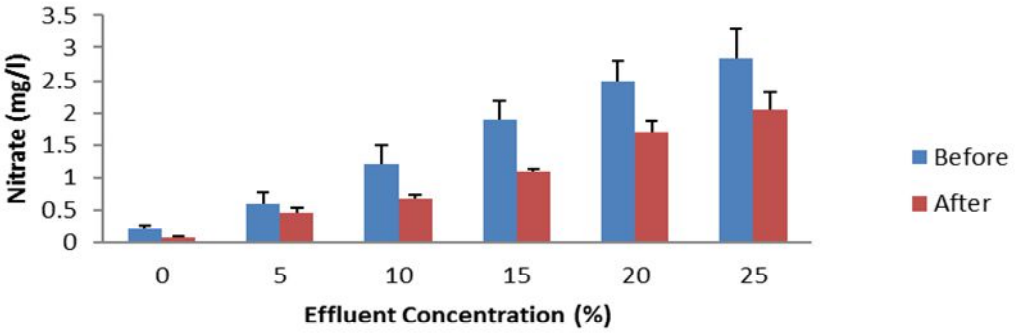

Figure 4: Effect of *L. paucicostata* treatment on nitrate of beverage factory effluent

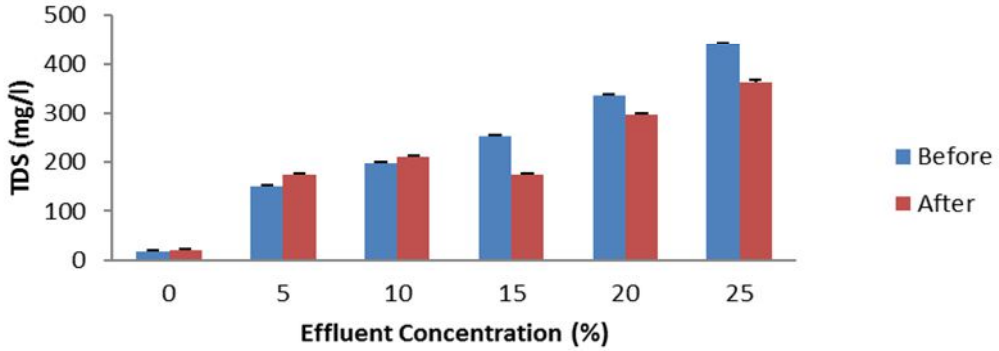

Figure 5: Effect of *L. paucicostata* treatment on total dissolved solids of beverage factory effluent

Table 1: Removal efficiency of physico-chemical parameters from beverage factory effluent by *L. paucicostata*

Parameters	**Removal Efficiency (%)**					
	Effluent Concentration					
	0	**5**	**10**	**15**	**20**	**25**
BOD (mg/l)	05	13.3	10.1	37	25	27.7
Sulphate (mg/l)	9.3	12.5	31.8	40	15.9	13.5
Nitrate (mg/l)	07	25	44.16	42.6	31.7	27.8
TDS (mg/l)	-11	-17	-6.06	31.1	11.3	17.23

Marked reduction in BOD was observed in the beverage effluent treated with *L. paucicostata* (Figure 2). Statistical analysis showed significant difference before and exposure to the test plant 15% concentration with a removal efficiency of 37% (Table 1). According to Reddy (1981) and Ugya (2015), the presence of plants in wastewater decreased dissolved CO_2 during the period of high photosynthetic activity. This photosynthetic activity increases dissolved oxygen in wastewater which favour the aerobic bacterial activity to reduce the BOD. The aquatic macrophyte used in the present study reduced the sulphate content of the effluent by reducing the acidic content of waste water although no significant difference was observed. However the highest removal efficiency occurred at 40% in 15% effluent concentration (Figure 3). Progressive reduction in nitrate with increasing concentration was recorded at all concentrations (Figure 4). The interaction of treatment concentrations with test macrophyte revealed

that the highest nitrate removal was recorded at 10 % treatment concentrations (Table 1). Significant difference was observed at 15% after treatment with the test macrophyte. Nitrate is among the vital nutrients required for the synthesis of nucleic acids, proteins and many secondary metabolites which play a significant role in the overall growth of the plants. Similar result was recorded by Patel and Kanungo (2010). The TDS values recorded in absence of *L. paucicostata* were brought to the minimum in the presence of the plant (Figure 5). The comparison of concentrations at final stage revealed that with increasing concentration TDS values were decreased progressively although no significant difference was observed. This is similar to the result obtained by Ugya (2015).

Conclusion

The percentage removal efficiency and relative growth rate indicates that this plant is a potential tool in the reduction of nitrate, sulphate, TDS and BOD from contaminated wastewater. From the above results, it has been concluded that the *L. paucicostata* can be used effectively in the treatment of beverage factory effluent on a large scale since it is able to remove pollutants present in the wastewater.

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