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Research Article

Municipal Runoff Remediation Using *Typha orientalis* and *Sorghum arundinaceum*

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Abstract

Background and Objective: The use of floating macrophytes in stabilization ponds for the secondary treatment of effluent has become popular in recent years. In this study the performance of two macrophytes: *Typha orientalis* and *Sorghum arundinaceum* in the phytoremediation of municipal runoff wastewater was investigated in constructed wetland ponds. **Materials and Methods:** The runoff wastewater was characterized using standard methods. The wetlands were continuously fed with municipal runoff wastewater while the treated effluents were collected and analyzed at 5 days interval for a period of 29 days. **Results:** Overall, the results of the usage of the two macrophytes revealed that *Typha orientalis* showed higher efficiency in the removal of parameters including turbidity (73.3%), sodium was reduced from (74.68%), iron was reduced (98.12%), phosphate was reduced (94.11%) and BOD reduced (97.62%) while *Sorghum arundinaceum* was more efficient in the removal of calcium (12.3%), magnesium reduced (18.1%), potassium reduced (30%), nitrate reduced (98.02%) and lead reduced (95.24%). Worthy of note were iron, nitrate, phosphate, lead and BOD which achieved between 94 and 98% removal efficiency. A close examination of the roots of the two macrophytes at the expiration of the experiment revealed that most metals were accumulated to the organ unlike other organs such as the leaves and stem which is mostly due to the possession of root air as the absorption organelle in the roots. **Conclusion:** This study further indicated that *Typha orientalis* and *Sorghum arundinaceum* both have the potential to be used in the phytoremediation of municipal runoff waste waters and their further usage is encouraged.

Key words: Aquatic plants, *Typha orientalis*, macrophytes, *Sorghum arundinaceum*, phytoremediation, treatment, runoff wastewater

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Macrophytes are a group of aquatic plants usually dominating wetlands, streams and shallow lakes where they take different growth positions ranging from being floating, emergentor submerged. These plants are the primary producers of oxygen in the ecosystem through photosynthesis thereby providing a substrate for algae and shelter for fish and other invertebrates[1]. They help in nutrient recycling in water and sediment besides serving as food and habitats for wildlife[1]. Due to the enormous natural features of macrophytes, they have huge potentials for use in the treatment of waste waters and runoffs[2]. They are also very efficient in the removal of nutrients, heavy metals, dyes and radioactive substances from wastewaters. Most macrophytes grow on waters containing high concentrations of minerals such as nitrogen, phosphorus and potassium[1] and play important roles during the biological, chemical and physical treatment of water in constructed wetlands[3].

Currently, researches on the use of macrophytes for nutrient removal from waste waters and runoffs has been ongoing the world over for the last two decades[4]. One of such studies in India investigated the efficiency of nitrate removal from synthetic medium and groundwater in different areas using water hyacinth, water lettuce and *Salvinia*[5]. The highest removal efficiency (83%) was achieved by using water hyacinth in synthetic medium with an initial nitrate concentration of 300 mg L^{-1}. However, lower removal efficiencies were shown by water lettuce and *Salvinia* in the same medium. This lower efficiency shown by water hyacinth was influenced by the presence of other nutrients which includes sulfate and phosphate among others. In another study, *Spirodela oligorrhiza* (Duckweed) was able to remove 83.7 and 89.4% of total nitrogen and total phosphorus, respectively from swine lagoon water over a period of 62 days in which harvesting was done twice a week[6].

In a similar study involving nutrient removal in vertical free surface flow constructed wetlands using 21 different aquatic plants, maximum nutrient removal was achieved with floating macrophytes including water hyacinth, water lettuce and water chestnut on the basis of the plant weight calculation whereas most emergent macrophytes achieved maximum removal rates based on planted area calculation. From this study, it was clear that the plant species is a major factor in determining the nutrient removal efficiencies and also there is a paucity of information parameters and nutrients like turbidity, total suspended solids, chemical oxygen demand, nitrate, phosphate and ammonia concentration in terms of water quality[7].

The floating treatment wetlands (FTWs) carrying different types of plants, provide a sustainable solution for the remediation of wastewater due to their low cost and energy requirements[8,9]. These wetlands can be natural or artificial but in either case, they combine the properties of natural ponds and hydroponic floating vegetation[10]. Plant roots hanging down into the water column not only act as a natural filter for contaminant removal but also provide surface area for enhanced growth of micro-organisms and bio-films formation[11,12]. While bacteria growing within or on roots are involved in the breakdown of organic matter, aerial parts of the plant provide habitat for wildlife and are aesthetically pleasant[13,14]. Municipal runoff wastewaters are very abundant in developing nations majorly due to lack of appropriate technology/facilities for rain water harvesting. These runoff are however dangerous as they become the medium for conveying solid and liquid wastes in the environment thereby transmitting pathogens within the population. This phenomenon calls for adequate treatment of these waters for reuse in agriculture and other economic activities, hence this study. Although FTWs have been successfully applied for nutrient and organic matter removal from municipal and industrial effluents[14,15], such have not yet been applied to municipal run-offs which are very common in developing countries. Therefore, this study aimed at filling this inadequacy by assessing the nutrients uptake ability from municipal run-off using constructed artificial wetland ponds using *Typha orientalis* and *Sorghum arundinaceum*.

MATERIALS AND METHODS

Experimental site and vegetation description: The pilot sub-surface flow constructed wetland used in this study was designed to be 1800×900×900 mm diameter and 900 mm high and vertical in shape using substrates such as washed granite (12 mm in diameter and covering a total area of 200 mm), washed sand (Covering an area of 400 mm), humus soil (Covering an area of 150 mm) and another 150 mm of freeboard which were all properly filled from bottom to the top so as to support the growth of the macrophytes. The treatment units were constructed within the Civil Engineering Department of the Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria while the experiment was carried out between February, 2017 and March, 2018. Runoff wastewater collected from Ogbomoso municipality was fed to each wetland unit from elevated reservoirs and circulated to the wetland units via PVC pipes.

The plants used in this investigation i.e., *Typha Orientalis* and *Sorghum arundinaceum* was homogeneous in their weight and height. They were initially cultivated in tap water for a month to allow development of an extensive root-system after which they were transplanted into the constructed wetlands fed with the wastewater samples[16]. Four experimental designs were used as shown below:

T1 : Municipal runoff with *Typha orientalis*
T2 : Municipal runoff with *Sorghum arundinaceum*
T3 : Municipal runoff without vegetation (Un-vegetated)
T4 : Tap water with *Typha orientalis* and *Sorghum arundinaceum* (Vegetated)

Three replicates were maintained per treatment. All experiments were set up at ambient temperature and light[16].

Effluent sampling: Collection of water samples were done after 0, 7, 14, 21 and 28 days of transplanting the macrophytes and this was followed by analysis for determination of the various physicochemical parameters in the plant materials and wastewater including pH, Nitrate, Phosphate, Turbidity and biochemical oxygen demand (BOD) which were determined using standard methods of the American Public Health Association[17-22]. Determination of others (Calcium, Magnesium, Sodium, Potassium, Manganese and Iron) was done with the aid of the atomic absorption spectrophotometer BOD, Na, K and heavy metals as described earlier[23-26]. Statistical analysis of all analyzed samples were carried out accordingly in triplicate values.

The percentage removal for each nutrient was calculated using the formula below:

$$\text{Nutrient removal (NR) (\%)} = \frac{P-F}{P} \times 100$$

Where:
P = Initial concentration
F = Final concentration

In all the experiments, alkaline pH was maintained throughout.

Determination of fresh weight of biomass: Fresh biomass of *Typha orientalis* and *Sorghum arundinaceum* were carefully dried by blotting them with a clean cloth before weighing.

Total carbohydrate determination: The colorimetric method was used for the determination of the carbohydrate. The blending of dried samples of *Typha orientalis* and *Sorghum arundinaceum* biomass was done prior to extraction via acid hydrolysis. The hydrolysis was carried out by mixing 0.1 g of the fine powder sample with 1.25 mL of 72% (w/w) sulphuric acid in the vial[27]. Determination of carbohydrate content was done with reference to a standard curve constructed through a series of dilution, using sucrose as standard[28].

Total protein determination: The test tube procedure of BCA as clearly spelled out in Thermo Scientific™ Pierce™ BCA protein Assay Kit was employed in the determination of protein using the supernatant obtained from the samples before carbohydrate determination. Protein determination was done with reference to a standard curve constructed through a series of dilution, in which bovine serum albumin (BSA) was used as a standard[28].

Statistical analysis: The mean value and standard error (Mean±SD) were calculated for all analyzed parameters.

RESULTS AND DISCUSSION

Physicochemical characteristics of macrophytes used in phytoremediation: The results in Table 1 showed the physicochemical parameter analysis of *Typha orientalis* before and after the phytoremediation regime. There was an increase in the value of all parameters after remediation except for potassium, iron and lead which recorded lower values after the remediation. The same trend was observed for *Sorghum arundinaceum* in which all parameters were increased in values after remediation except for total phosphorus, iron and lead (Table 1). This agreed with the submissions of earlier researchers on wastewater remediation[29,30].

Characteristics of run off before phytoremediation: As shown in Table 2, the run off wastewater used in this study was of neutral pH with a value of 7.2 and a high turbidity value of 13.5 NTU. The organic loading of the wastewater was quantified by the concentration of Nitrate and Biochemical Oxygen Demand (BOD) which gave the values of 4.05 and 185 mg L^{-1}, respectively. The water was heavily contaminated with heavy metal with the values 0.02 mg L^{-1} for Manganese, 5.33 mg L^{-1} for Iron, 0.63 mg L^{-1} for Lead while Phosphate recorded a concentration of 0.17 mg L^{-1}. For the cations, the value recorded for Magnesium, Potassium and Sodium were 16.85, 20.1 and 8.73 mg L^{-1}, respectively while Calcium recorded the highest concentration of 332.5 mg L^{-1}.

Characteristics of run off after phytoremediation: Data in Table 2 showed the physicochemical characteristics of the

Table 1: Physicochemical composition of *Typha orientalis* and *Sorghum arundinaceum*

Parameters	Initial concentration	Final concentration	Nutrient uptake (%)
Typha orientalis			
Total nitrogen (mg L^{-1})	0.883±0.02	1.777±0.01	50.30
Total phosphorus (mg L^{-1})	0.14±0.01	0.163±0.01	8.58
Calcium (mg L^{-1})	2.345±0.02	3.075±0.00	23.73
Magnesium (mg L^{-1})	0.224±0.02	0.437±0.01	48.74
Potassium (mg L^{-1})	1.52±0.01	1.365±0.02	-0.01
Sodium (mg L^{-1})	2.18±0.02	2.842±0.05	23.29
Iron (mg L^{-1})	5500±0.05	1695±0.010	-224.48
Manganese (mg L^{-1})	2950±0.03	890±0.020	45.50
Lead (mg L^{-1})	37.40±1.02	17.35±1.050	-115.56
Total carbohydrate (g g^{-1} biomass)	0.3012±0.02	0.3816±0.01	27% increase
Total protein (g g^{-1} biomass)	0.3244±0.03	0.3488±0.02	8% increase
Weight (g)	473.450±0.01	1482.35±0.030	212% increase
Typha orientalis and Sorghum arundinaceum			
Total nitrogen	0.834±0.02	1.835±0.01	54.55
Total phosphorus	0.137±0.05	0.124±0.01	-10.48
Calcium	0.154±0.01	0.400±0.02	61.50
Magnesium	0.158±0.02	0.176±0.01	10.22
Potassium	1.533±0.01	1.538±0.03	65.34
Sodium	1.230±0.01	2.236±0.02	44.99
Iron	5705±0.05	3350±0.02	-70.29
Manganese	146±0.02	300±0.05	51.33
Lead	35.35±0.02	12.600±0.01	-180.55
Total carbohydrate (g g^{-1} biomass)	0.2938±0.01	0.3324±0.02	19% increase
Total protein (g g^{-1} biomass)	0.3492±0.02	0.3772±0.01	13% increase
Weight (g)	441.4900±3.01	1123.9200±9.02	155% increase

run off wastewater after the four different treatments that were applied over the 29 days retention time in each case. The final concentration of turbidity decreased at the end of the experiment with removal efficiency 73.3% and achieved in experiment T_1 where *Typha orientalis* was used as remediation agent. Similarly, reduction in the initial values of turbidity was recorded in all experiments. Calcium was considerably reduced in the final effluent with the highest efficiency of 12.3% found in experiment T_2 using *Sorghum arundinaceum* for remediation. The duo of Magnesium and Potassium were not efficiently removed in experiment T_1 but in T_2 with the highest efficiencies of 18.1 and 30%, respectively. Sodium was maximally reduced with highest efficiency of 74.68% removal in experiment T_1. These results are similar to the earlier reports[31,32].

There was no removal of Manganese in any of the experiments as increased values were observed at the end of the experiments with the highest negative value in T_3. Iron was effectively removed in T_1 with efficiency of 98.12% while the final values increased in the remaining experiments except for T_4. Nitrates and lead were effectively removed by experiment T_2 with highest efficiencies of 98.02 and 95.23% while different levels of removal were also observed in other treatments. For Phosphate and BOD, the most efficient removal was recorded in experiment T_1 with 94.11 and 97.62% efficiencies while different removal levels were also recorded in other experiments.

Overall, the results of the usage of the two macrophytes revealed that *Typha orientalis* showed higher efficiency in the remediation of parameters like turbidity, sodium, iron, phosphate and BOD while *Sorghum arundinaceum* was more efficient in the removal of calcium, magnesium, potassium, nitrate and lead. A close examination of the roots of the two macrophytes at the expiration of the experiment revealed that most metals were accumulated to the organ unlike other organs such as the leaves and stem which is mostly due to the possession of root air as the absorption organelle in the roots. This result agreed with earlier submissions[33-37]. This nutrient uptake method can actually help to stabilize treated municipal run off and other waste waters before being released to the environment, thus mitigating the occurrence of eutrophication. After the phytoremediation experiments, the municipal run off quality was improved so much that it is suitable for discharge into the environment without risks to life forms.

Morphological characteristics: The survival and tolerance of plants/macrophytes to contaminants in their medium of survival are very important factor in the selection of suitable plant species for remediation purpose. As shown in this

Table 2: Physicochemical characteristics of Runoff using *Typha orientalis* (T$_1$), *Sorghum arundinaceum* (T$_2$), phytoremediation without vegetation (T$_3$) and tap water with *Typha orientalis* and *Sorghum arundinaceum* (T$_4$)

Parameters	Raw runoff before phytoremediation	After phytoremediation (days) 1	8	15	22	29	Nutrient uptake (%)
***Typha orientalis* (T$_1$)**							
pH	7.20±0.01	7.40±0.01	7.50±0.01	7.30±0.02	7.45±0.01	7.20±0.01	-
Turbidity (NTU)	13.50±0.01	1.50±0.01	5.50±0.01	3.80±0.01	3.60±0.01	3.60±0.02	73.33
Calcium (mg L^{-1})	332.50±3.01	439.50±2.02	311.50±3.05	339.50±0.01	309.10±4.02	302.20±2.11	9.11
Magnesium (mg L^{-1})	16.85±0.01	26.10±0.01	27.30±0.01	31.70±0.05	29.20±0.01	26.60±0.01	-57.86
Potassium (mg L^{-1})	20.10±0.02	25.30±0.01	27.30±0.01	31.70±0.01	27.70±1.01	25.10±0.01	-24.87
Sodium (mg L^{-1})	8.73±0.01	2.81±0.03	2.90±0.05	2.64±0.01	2.22±0.01	2.21±0.01	74.68
Manganese (mg L^{-1})	0.02±0.02	0.01±0.01	1.00±0.01	10.20±0.01	10.10±0.01	10.10±0.01	-50.40
Iron (mg L^{-1})	5.33±0.01	0.02±0.01	0.20±0.05	0.17±0.01	0.11±0.02	0.10±0.01	98.12
Nitrate (mg L^{-1})	4.05±0.01	3.69±0.01	3.63±0.01	3.54±0.02	3.41±0.01	3.33±0.11	17.77
Phosphate (mg L^{-1})	0.17±0.02	0.08±0.01	0.02±0.01	0.02±0.01	0.01±0.01	0.01±0.01	94.11
Lead (mg L^{-1})	0.63±0.02	0.66±0.11	0.06±0.01	0.19±0.01	0.10±0.01	0.07±0.01	88.88
BOD (mg O$_2$ L^{-1})	185.10±1.11	4.10±0.01	6.20±0.01	5.10±0.01	4.60±0.01	4.40±0.02	97.62
***Sorghum arundinaceum* (T$_2$)**							
pH	7.20±0.01	7.30±0.01	7.20±0.01	6.90±0.02	7.00±0.01	7.10±0.01	-
Turbidity (NTU)	13.50±0.01	5.00±0.02	6.60±0.01	5.00±0.01	4.90±0.02	4.90±0.05	63.70
Calcium (mg L^{-1})	332.50±3.01	343.50±2.02	308.50±3.05	296.50±5.01	295.50±4.02	291.60±2.11	12.30
Magnesium (mg L^{-1})	16.85±0.01	33.75±0.01	14.50±0.04	14.60±0.05	14.20±0.01	13.80±0.01	18.10
Potassium (mg L^{-1})	20.10±0.02	3.10±0.01	14.50±0.01	14.60±0.21	14.40±1.01	14.10±0.01	29.85
Sodium (mg L^{-1})	8.73±0.01	4.10±0.03	3.95±0.05	3.82±0.01	3.83±0.03	3.80±0.01	56.47
Manganese (mg L^{-1})	0.02±0.02	0.98±0.01	1.60±0.01	4.79±0.01	4.78±0.01	4.71±0.02	-23.45
Iron (mg L^{-1})	5.33±0.01	1.43±0.02	8.81±0.05	0.71±0.01	0.72±0.02	0.70±0.01	86.86
Nitrate (mg L^{-1})	4.05±0.01	0.23±0.01	0.58±0.01	0.12±0.02	0.11±0.01	0.08±0.11	98.02
Phosphate (mg L^{-1})	0.17±0.02	0.02±0.01	0.02±0.01	0.06±0.01	0.03±0.01	0.02±0.01	88.23
Lead (mg L^{-1})	0.63±0.02	0.74±0.01	0.46±0.01	0.07±0.01	0.05±0.01	0.03±0.01	95.23
BOD (mg O$_2$ L^{-1})	185.10±1.11	4.14±0.11	8.50±0.05	7.70±0.01	7.50±0.01	7.30±0.05	96.05
Phytoremediation without vegetation (T$_3$)							
pH	7.20±0.01	7.10±0.01	7.20±0.01	6.90±0.02	6.90±0.01	7.00±0.01	-
Turbidity (NTU)	13.50±0.01	6.50±0.02	11.00±0.01	11.50±0.01	11.10±0.02	11.00±0.05	18.52
Calcium (mg L^{-1})	332.50±3.01	378.10±2.02	293.00±3.05	288.50±5.01	282.40±4.02	278.40±2.11	16.27
Magnesium (mg L^{-1})	16.85±0.01	36.50±0.01	19.00±0.04	7.97±0.05	7.75±0.01	7.44±0.01	55.84
Potassium (mg L^{-1})	20.10±0.02	9.93±0.01	10.18±0.01	7.97±0.21	7.59±1.01	7.52±0.01	62.58
Sodium (mg L^{-1})	8.73±0.01	3.58±0.03	3.10±0.05	2.96±0.01	2.97±0.03	2.97±0.01	65.83
Manganese (mg L^{-1})	0.02±0.02	1.64±0.01	18.20±0.01	18.30±0.01	18.30±0.01	18.10±0.02	-90.40
Iron (mg L^{-1})	5.33±0.01	5.63±0.02	29.20±0.05	4.22±0.01	4.19±0.02	4.11±0.01	22.88
Nitrate (mg L^{-1})	4.05±0.01	1.33±0.01	0.96±0.01	0.58±0.02	0.55±0.01	0.26±0.11	93.58
Phosphate (mg L^{-1})	0.17±0.02	0.16±0.01	0.03±0.01	0.02±0.01	0.01±0.01	0.01±0.01	94.12
Lead (mg L^{-1})	0.63±0.02	0.71±0.01	0.19±0.01	0.15±0.01	0.12±0.01	0.09±0.01	85.71
BOD (mg O$_2$ L^{-1})	185.10±1.11	65.00±0.11	63.50±0.05	57.80±0.01	57.00±0.01	56.30±0.05	69.58
***Sorghum arundinaceum* (T$_4$)**							
pH	6.80±0.01	7.10±0.01	7.10±0.01	7.00±0.02	6.90±0.01	7.00±0.01	-
Turbidity (NTU)	1.12±0.01	1.03±0.02	1.03±0.01	1.02±0.01	1.01±0.02	0.90±0.01	91.96
Calcium (mg L^{-1})	120.50±3.01	152.10±2.02	163.00±1.05	152.50±2.01	139.00±3.02	133.50±1.15	-10.79
Magnesium (mg L^{-1})	9.20±0.01	9.60±0.01	9.80±0.02	8.90±0.05	9.70±0.01	9.40±0.01	-2.17
Potassium (mg L^{-1})	7.60±0.02	7.93±0.01	7.98±0.01	7.98±0.02	7.89±1.01	7.82±0.01	-2.89
Sodium (mg L^{-1})	3.30±0.01	3.45±0.02	3.50±0.05	3.61±0.01	3.70±0.03	3.70±0.01	-12.12
Manganese (mg L^{-1})	0.10±0.02	0.14±0.01	0.21±0.01	0.13±0.01	0.13±0.01	0.11±0.02	-10.00
Iron (mg L^{-1})	0.17±0.01	0.13±0.02	0.12±0.02	0.14±0.01	0.19±0.02	0.16±0.01	5.88
Nitrate (mg L^{-1})	0.38±0.01	0.35±0.01	0.36±0.01	0.38±0.02	0.25±0.01	0.29±0.11	23.68
Phosphate (mg L^{-1})	0.01±0.02	0.02±0.01	0.02±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.00
Lead (mg L^{-1})	0.01±0.02	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.00
BOD (mg O$_2$ L^{-1})	1.75±1.11	1.71±0.11	1.55±0.03	1.48±0.01	1.40±0.01	1.13±0.01	35.43

Removal (%): Initial concentration-Final concentration/Initial concentration×100

study, the fresh *Typha orientalis* and *Sorghum arundinaceum* both had initial weights of 473.45 and 441.49 g at the commencement of the experiments but the final weights were 1482.35 and 1123.92 g for both macrophytes, respectively (Table 1). The implication of this is that *Typha orientalis* and *Sorghum arundinaceum* displayed positive growth after being for the phytoremediation of the municipal run off wastewater. This result disagreed with previous studies[38-40] which reported the inhibition in the growth of macrophytes especially *Suphisellus grossus* after remediation due to the toxic effects of the waste waters used in such studies.

The methodologies for the determination of total carbohydrate and protein contents of the macrophytes in this study are well reported[41]. At the end of the remediation in this study, the total carbohydrate content of *Typha orientalis* increased from 0.3012- 0.3816 g g^{-1} biomass i.e., 27% while that of *Sorghum arundinaceum* increased from 0.2938-0.3492 g g^{-1} biomass i.e., 19% increase which is a reflection of build-up of mono and polysaccharides in the plant which ultimately indicate the presence of more energy storage molecules in the biomass. As for total protein content for *Typha orientalis*, there was an increase from the initial 0.3244-0.3488 g g^{-1} biomass showing a total of 8% increase while that of *Sorghum arundinaceum* showed increase from 0.3324-0.3772 g g^{-1} biomass which is equal to 13% increase. Similar to the carbohydrate accumulation, the biomass also showed evidence of peptides accumulation from the nitrate and ammonia contents of the municipal run off. These results showed that the municipal run off used in this study provided the necessary nutrient required for the growth and well being of both *Typha orientalis* and *Sorghum arundinaceum.* Similar results have been obtained in a previous study[42]. The possibility is high that the biomass of *Typha orientalis* and *Sorghum arundinaceum* after remediation could be useful as fish feed in aquaculture 43 or as a suitable substrate for biofuel generation due to the possession of enormous nutrients[43].

CONCLUSION

The result obtained in this study showed that both *Typha orientalis* and *Sorghum arundinaceum* macrophytes are capable in remediating municipal run off. Worthy of note are iron, nitrate, phosphate, lead and BOD which achieved between 94 and 98% removal efficiency. In the same vein, turbidity and sodium were removed to the tune of over 70% which further confirmed the efficiency of the two macrophytes in phytoremediation as against the results obtained from the controls. However, further field studies are recommended to evaluate the full potential of the macrophytes in remediation using wastewaters from different sources.

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SIGNIFICANCE STATEMENT

This study has advanced research in the area of wastewater bioremediation as it establishes the potentials of two macrophytes: *Typha orientalis* and *Sorghum arundinaceum* for adequate treatment of municipal run off waters for reuse in agriculture and other economic activities. It has also established the usability of FTWs in municipal run off treatment.

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