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SUSTAINABLE METHOD OF WASTE WATER TREATMENT USING MICROALGAE: A CASE STUDY OF KANO METROPOLIS

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ABSTRACT

The present study investigates the sustainable treatment of wastewater using microalgae in Kano Metropolis, Nigeria, using changes in the physicochemical condition of the water and algal species distribution across three sampling sites: Sallari (A), Hauren shanu (B), and BUK old site pond (C). Water analysis and algal species identification, culture and isolation for bioremediation potential were carried out for 14 days using standard procedures. The results revealed the mean physicochemical condition of the water temperature of 24.6 ± 0.65°C., Bioremediation potential revealed the dominant algal species of *Scenedesmus quadricauda* and *Chlorella vulgaris*)on key water quality parameters including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), pH, Electrical Conductivity (EC), Nitrate-Nitrogen, Phosphate-Phosphorus, Alkalinity, and Total Hardness. Results demonstrated significant reductions in DO (from 3.45±0.13 to 2.45±0.10 mg/L), EC (from 897.33±0.90 to 714±4.10 µS/cm), Phosphate-Phosphorus (from 9.56±1.01 to 5.34±0.18 mg/L), and Total Hardness (from 320.00±2.64 to 210.33±3.78 mg/L), alongside increases in pH (from 8.2±0.7 to 9.93±0.31) and Nitrate-Nitrogen (from 26.8±1.13 to 35.8±0.19 mg/L). Pearson correlation analysis revealed strong positive relationships between total hardness, pH, and algal composition ($P<0.01$), while negative correlations were observed between total hardness and BOD, TDS, and alkalinity ($p<0.05$). The findings confirm that microalgae-mediated treatment offers a viable and environmentally sustainable approach for wastewater remediation, with *S. quadricauda* and *C. vulgaris* demonstrating significant ($p<0.05$) efficiency in nutrient removal and physicochemical modulation under tropical conditions. Microalgal species were effective as it removes 78-99% of Nitrogen and Phosphorus. The treatment system also succeeds to remove 40-65% of COD and BOD.

Keywords: Microalgae; Wastewater Treatment; Nutrient Removal; Bioremediation; *Scenedesmus quadricauda; Chlorella vulgaris*

Introduction

Microalgae play an important role in the secondary/tertiary treatment of municipal wastewater. They enhance the removal of nutrients, heavy metals, and pathogens (Okereke et al. 2016). Due to industrialization and development, there is increase in population which is the most critical environmental problem in developing country like Nigeria. Due to this rapid industrialization and urbanization, the amount of wastewater generated every day is very huge (Chen et al. 2015). For this reason, water pollution is one of the most critical environmental problems. For the treatment of waste water various conventional methods are used but they are not so economical and have negative impact on the surrounding environment (Aguilar et al. 2013). Due to rapid advancement in technology, some green technical methods are introduced for the treatment of waste water to solve the problems domestic waste water treatment (Kumar et al. 2021).

The ecological importance of microalgae is emphasized by their extraordinary photosynthetic efficiency, surpassing terrestrial plants by 40–50% (Aguilar et al. 2013). Their notable carbon sequestration capacity significantly contributes to global CO_2 sequestration, with 1 kg of microalgae absorbing 1.83 kg of CO_2 (Okereke et al. 2016). Additionally, they play a vital role in producing around 50% of Earth's atmospheric oxygen. There are some unconventional biological methods that are very helpful in treating the water pollution just like the bioremediation technology that has been used for treating the toxic and hazardous waste. It is ecologically reliable and economic as compared to the other technology that used some chemicals, many countries successfully used these ancient technologies. In bioremediation technology or biological treatments, different types of microorganisms are capable of utilizing organic waste and reducing the pollutant content of waste water. These microorganisms utilize organic content as a food source and takes energy from them by releasing soil nutrients as a reaming substance with lots of oxygen content.

Treatment through Microalgae is very efficient as it removes nutrients very effectively from wastewater. Algae are small photosynthetic plants that perform photosynthesis process for own needs and release back O_2 after utilizing CO_2. In this way, microalgae-based treatment plants require less energy resources and deduct the use of electromechanical blowers that consumed large amount of energy (Green et al., 1995). These microalgae do not require anaerobic digestion and hydrothermal liquefaction (Chakraborty et al. 2012). There are number of benefits of growing algae in wastewater as it absorbs nutrient thus reducing the treatment cost of wastewater. The growing Environmental problem such as Global warming, the increase of Ozone hole and climate changed can be solved by using Microalgae treatment system as it has ability to consume high amount of carbon dioxide in Photosynthesis process to produce oxygen and glucose. Microalgae has ability to remove nutrients, heavy metals, organic and inorganic toxics substance and other impurities which is present in the wastewater.

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, and industrial and or agricultural wastes, and can encompass a wide range of potential contaminants and concentrations (Nielsen et al. 2004). Waste water that contains urine, faeces, kitchen and laundry waste is referred to as sewage. At the beginning of the 20th Century, septic tank was introduced as a means of treating domestic sewage from individual households both in suburban and rural areas. Then a few cities and industries recognized that the discharge of sewage directly into streams caused health problems and this led to the development of sewage treatment facilities referred to as waste water treatment plants

(Ikupolati, 2005). Wastewater Treatment Plants (WWTPs) are complex systems which include a large number of biological, physicochemical, and biochemical processes (Sotomayor et al. 2001). The activated sludge process is the most widely applied biological treatment of liquid waste, treating both municipal sewage and a variety of industrial wastewaters (Aguilar-López et al. 2013 & Slater, 2006). The microbiological quality of effluent consumable water is a concern to consumers, water suppliers, regulatory and public health authorities alike. Most recent gastrointestinal outbreaks that have been reported throughout the world demonstrated that transmission of pathogens by effluent consumable water remains a significant cause of illness (Hunter and Syed, 2001).

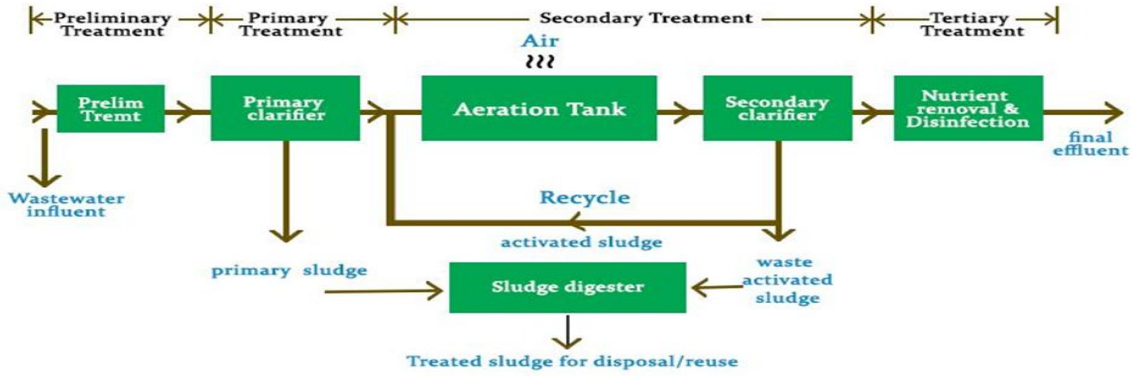


Figure 1. Flow of Biological Wastewater Treatment

Statement of the Research Problem

Kano metropolis generates large volumes of domestic wastewater due to rapid population growth and urbanization. This wastewater contains high levels of organic matter, nutrients, and pathogenic microorganisms. Due to inadequate treatment infrastructure and reliance on inefficient septic tanks and soak-away systems, much of the wastewater is discharged untreated or partially treated into open drains and nearby water bodies, causing environmental pollution, groundwater contamination and public health risks. Conventional domestic wastewater treatment methods in the metropolis are constrained by poor maintenance, high operational costs and limited nutrient removal efficiency, making them unsustainable. Microalgae-based biological wastewater treatment offers an environmentally friendly and cost-effective alternative for nutrient and organic pollutant removal. However, its feasibility for wastewater treatment in Kano metropolis remains understudied locally.

Materials and Methods

Description of the Study Area

The study area is Kano metropolis, the capital city of Kano, it is the second largest industrial and commercial centre in Nigeria after Lagos and lies between latitude 12.0022^0N to longitude 8.5920^0E. It experienced rapid population growth rate of almost 4.4million in 2023 (UN, 2023). The area covers almost 499square kilometers.

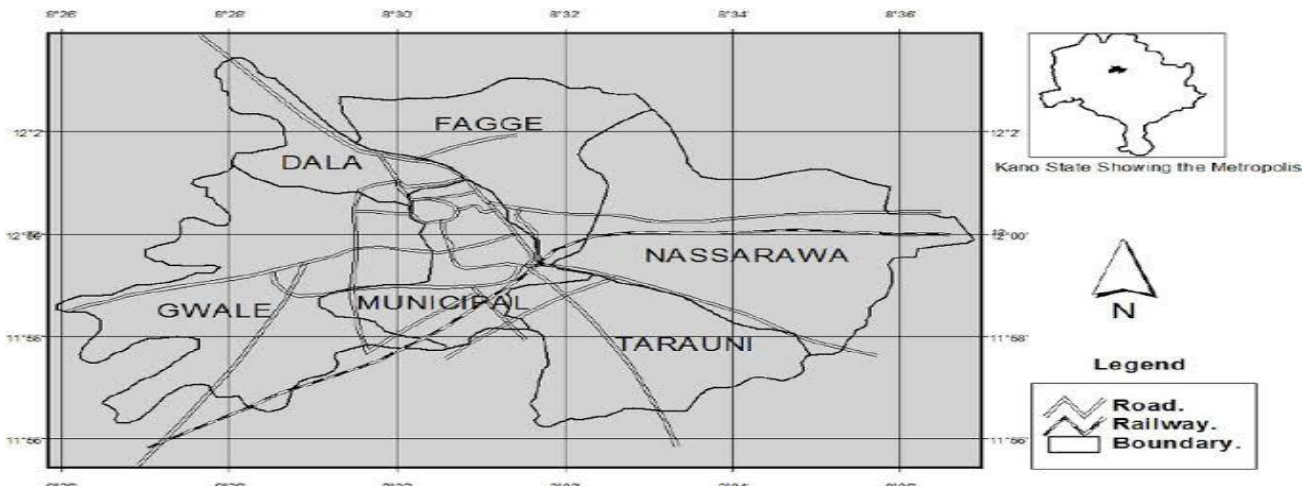


Figure 2: Kano Metropolis Showing Sampling Sites

Sampling sites

Three sampling sites were selected for algal and wastewater collection sampling.

SITE A- Sallari Borrow pit, located in Tarauni Local Government along court road off Karkasara way by School of Nursing Kano. It receives mainly domestic input in addition to block laying industries operating near by the pit.

SITE B- Hauren Shanu located at Gwale Local Government along BUK opposite Zone 1 Police headquarters. It receives mainly anthropogenic discharge and cow dung form the nearby annual cattle market.

SITE C- Water samples from a mini water pond located at Biological Science Department, BUK Gwale Local Government. It receives input solely from falling leaves, dust from wind among other sources.

Determination of Physico-chemical Parameters of the Water Sample

The water samples were collected at depth of 20cm between 7:00am to 7:30am into three separate pre-cleaned plastic containers sliding over the surface of the water with their mouth against the water current to permit undisturbed passage of the water into the bottle as described by Adamu *et al*. (2016).

Water quality parameters such as Dissolved Oxygen, Electrical Conductivity, Ph, Water Temperature, Total Dissolved Solids and Turbidity were determined every 48hours during the toxicity test using multifunction water testing kit (Model no. EZ-9909-SP) as adopted by Akinwande *et al*. (2018).

Nitrate-nitrogen and Phosphate-Phosphorus Concentration were determined using phenol disulphuric acid and ammonium molybdate method as described by APHA (1985). **Total Hardness and Alkalinity was determined using** acid-base titrimetric method using the protocols described by WHO (2021).

Collection and Identification of Algal Samples

Algal samples were collected using plankton net of 15cm diameter and mesh size 70µm. They were collected between 7:00am-7:30am. The samples were maintained at 4°C in ice box and immediately transported to aquarium laboratory Biological Sciences Department, Bayero University, Kano for further analysis. The samples were condensed to10mI and 1ml

of the algal subsample was withdrawn for sorting and counting using camera microscope. Identification of the algal to species level was done using keys described by Suther and Rissik, (2009).

Isolation, Identification and Culturing Algal Species

Isolation of Algal cells was done using Capillary Pipette Isolation method as adopted by Ibrahim and Raneen (2018).

Experimental Design for Algal Biosorption

The three wastewater samples were autoclaved for 30 minutes, and 1,000 mL of each sample was inoculated with the dominant algal species, *Chlorella vulgaris* and *Scenedesmus quadricauda*, individually and in combination. The experiments were conducted for 14 days at 24.3 ± 0.66°C under continuous illumination of (100 µE/m2/sec). After treatment, samples were analysed to assess changes in physicochemical parameters and nutrient removal efficiency, following WHO (2021) guidelines.

Statistical Analysis

Analysis of variance (ANOVA) was used to determine whether there is significant difference in physico chemical and algal composition between sites in three borrow pits. LSD was used to separate the mean difference between sites, algae and physicochemical parameters. Pearson product moment's correlation was used to determine the degree of association between the algal species and physicochemical parameters.

Results Analysis and Discussion

Table 1, indicates the mean and range of physicochemical parameters obtained before and after treatment. DO, BOD, pH, EC, Nitrate- Nitrogen, Phosphate-phosphorus, Alkalinity, and total hardness before experiment ranged from 2.74 - 3.86mg/L, 3.10-3.64mg/L, 7.70 - 8.50, 938.67-1356.36 µS/cm, 22.7-34.87mg/L, 7.56 – 12.24mg/L, 28.5-31.8mg/L and 386.67±10.50mg/L. Moreover, after the experiment DO, EC, Nitrate- Nitrogen, Phosphate-phosphorus, Alkalinity, and total hardness in the water samples. A corresponding increase in BOD and pH was recorded respectively.

Table 1: Mean Values Physicochemical Parameters of Water Before and After the Experiment (14 days)

	Before		**After**		
Parameters	Range	Mean	Range	Mean	WHO (2021)
DO (mg/L)	2.74 - 3.86	3.45±0.13	2.20 - 3.14	2.45±0.10	5.0-9.0mg/L
Electrical Conductivity (µS/cm)	938.67-1356.36	897.33±0.90	758.13 - 964.64	714±4.10	<1000µS/cm
pH	7.70 - 8.50	8.2±0.71	9.22 - 10.74	9.93±0.31	6.0-9.0
Phosphate-Phosphorus (mg/L)	7.56 – 12.24	9.56±1.01	6.34 -7.97	5.34±0.18	
Nitrate-Nitrogen (mg/L)	22.7-34.87	26.8±1.13	25.1-41.71	35.8±0.19	
Alkalinity	28.5-31.8	29.4±0.31	33.1-34.6	34.0±0.54	< 1.00
Total hardness (mg/L)	386.67±10.50	320.00±2.64	210.33±3.78		
BOD (mg/L)	3.10-3.64	3.25±0.31	2.56-3.45	2.87±0.61	3.0-6.0mg/L

Key: RPL= Recommended Permissible Range (WHO, 2021)

Table 2: Mean Variation of Physicochemical Parameters Before the Experiment

Sampling Sites	A	B	C
Parameters			
pH	8.00±0.55[a]	7.93±0.15[b]	8.26±0.35[a]
DO (mg/L)	3.50±0.30[a]	3.25±0.61[a]	2.41±0.11[b]
BOD (mg/L)	2.26±0.15[a]	1.96±0.20[b]	2.66±0.15[a]
Total hardness (mg/L)	454.66±2.08[a]	301.67±2.08[b]	264.33±4.04[a]
Electrical Conductivity (µS/cm)	1003.3±18.77[a]	1081.66±5.34[b]	1030.00±0.35[a]
Phosphate - phosphorus (mg/L)	28.46±0.50[b]	16.73±0.20[a]	19.00±0.20[b]
Nitrate - nitrogen (mg/L)	25.67±0.52[a]	25.00±2.54[a]	35.00±3.00[b]
Total alkalinity (mg/L)	214.00±3.60[a]	352.00±3.46[a]	241.00±0.73[a]

Table 3: Mean Variation of Physicochemical Parameters After the Experiment

Sampling Sites	A	B	C
pH	8.00±0.55[a]	7.93±0.15[b]	8.26±0.35[a]
DO (mg/L)	2.20±0.07[a]	2.57±0.07[b]	2.55±0.10[a]
BOD (mg/L)	3.54±0.11[a]	3.14±0.05[b]	3.36±0.54[a]
Total hardness (mg/L)	386.67±10.50[a]	320.00±2.64[b]	210.33±3.78[a]
Electrical Conductivity (µS/cm)	938.67±15.36[a]	877.33±10.00[b]	858.33±14.64[a]
Phosphate - phosphorus (mg/L)	7.06±1.47[a]	5.62±0.90[b]	5.31±0.61[a]
Nitrate - nitrogen (mg/L)	6.65±1.00[a]	8.60±0.90[a]	11.29±1.92[b]
Total alkalinity (mg/L)	214.00±3.60[a]	352.00±3.46[a]	241.00±0.73[a]

Key: A= Sallari, B= Hauren shanu, C =BUK old site pond

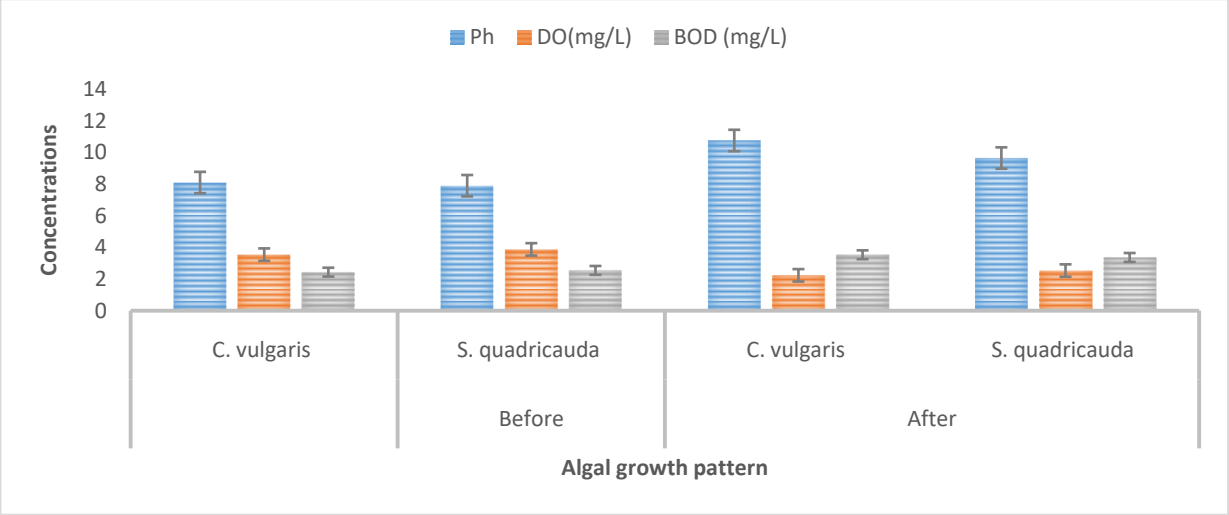


Figure 3: Reduction or Enhancement of pH, Dissolved Oxygen and Biochemical Oxygen Demand Physico-chemical Conditions along with Algal Growth Pattern

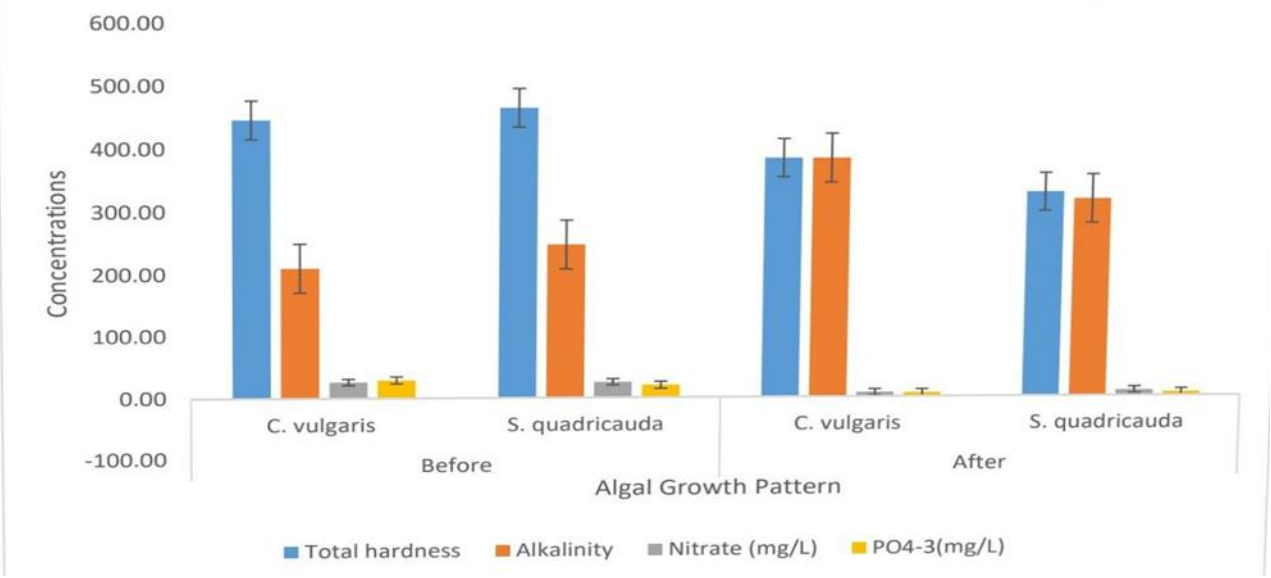


Figure 4: Reduction or Enhancement of some Physico-chemical Conditions along with Algal Growth Pattern

Table 4: Algal Species Distribution Identified from the Sampling Sites

Algal taxa	A	B	C	Total	% frequency
Cyanophyta					
Microcystis aeruginosa	7	8	17	22	7
Nostoc sp.	4	5	7	16	2.2
Anabaena flosaquae	3	7	24	34	6.3
Phormidium uncinatum	25	6	8	39	7.6
Chlorophyta					
Spirulins platensis	12	0	14	26	3.8
Spirogyra communis	56	89	73	19	14.4
Pediastrum simplex	4	4	21	29	4.6
Cosmarium connatum	9	27	46	46	2.7
Scenedesmus quadricauda	9	14	23	82	8
Chlorellavulgaris	3	7	9	218	4.4
Bacillariophyta					
Gyrosigma sp.	3	7	11	21	4.8
Navicula radiosa	34	18	12	64	11.4
Cyclotella sp.	6	4	2	12	8.4
Euglenophyta					
Phacus sp.	2	5	13	20	3.3
Euglena acus	6	8	14	28	7.1
Total no. of individuals/site					

A= Sallari, B= Hauren shanu, C =BUK old site pond

Table 5, illustrates the values for Pearson Correlation Coefficient of different physicochemical conditions and algal composition. Total hardness showed strong positive correlation with pH, algal composition and Electrical Conductivity (P<0.01). Strong positive correlation was recorded between pH and algal species (P<0.01). Alkalinity and TDS also had strong positive correlation with Dissolved Oxygen (P<0.05). Electrical conductivity had positive correlation with Alkalinity. Total hardness had negative correlation with BOD, TDS and alkalinity (p<0.05). Negative correlation was also reported between BOD and algal species.

Table 5: Pearson Correlation Coefficient Showing Relationship between Algal Composition and Physico-chemical Conditions of the Water Samples

Parameters	Thardness	pH	DO	BOD	TDS	EC	Alkalinity	PO_3^{-4}	N03	Algal composition
Thardness	1.000									
pH	0.400	1.000								
DO	0.736*	-0.467	1.000							
BOD	-0.523	-0.355	0.967	1.000						
TDS	0.442	-0.092	0.863*	0.748	1.000					
EC	0.853*	0.417	-0.574	0.689	0.559	1.000				
Alkalinity	-0.773	0.595	0.890*	0.469	-0.217	0.647	1.000			
PO_3^{-4}	0.458	-0.090	-0.458	0.261	0.801	0.276	-0.202	1.000		
No3	-0.565	-0.904	0.130	0.219	0.398	0.384	-0.934	0.389	1.000	
Algal composition	-0.209	-0.150	0.481	0.474	-0.839	0.240	0.231	-0.4534	0.565*	1.000

Discussion

There are number of benefits of growing algae in wastewater as it absorbs nutrient thus reducing the treatment cost of wastewater (Pires *et al.*., 2013). It also digests large amount of organic carbon to produce its biomass which can further processed to the production of biodiesel (Pires *et al.*., 2013). Microalgae have ability to remove nutrients, heavy metals, organic and inorganic toxics substance and other impurities which is present in the wastewater. In the present findings, the two algal induced the pH increase in all the sampling points. Hydrogen ion concentration (pH) maintains the mobility, solubility and availability of ions in water bodies (Reddy, 2018). The pH range of 7.9 to 10.0 provides protection for life of fresh phytoplankton and other bottom dwelling biota (Shahid *et al.*., 2017). The pH value recorded ranged from during the study period indicates that the waste water was hampered by decomposition of impurities in the water bodies as results of photoautotrophic growth of the algal species. Algal species consumed more CO2 in the waste water produced by some bacteria during the natural decomposition, leading to an increase in the pH level in the waste water. Similar observation was recorded by Tanimu *et al.*. (2012). Increase in pH could be due to the phosphate-phosphorus precipitation by the formation of hydroxyapatite. According to Sekaran *et al.*. (2013) increased pH helps the flocculation process of sludge in biological

treatment. *Scenedesmus quadricauda* and *Chlorella vulgaris* were the dominant species identified in the waste water at normal room temperature at 24.6±0.65°C which showed a remarkable reduction in DO, EC, N, P, Alkalinity and Total hardness. In the present study the reduction or increase in the physiochemical parameters was variable in all the three sites as presented in figure 1 and 2. The reduction in DO after the experiment is either by the rate of uptake during respiration by the algal species or due to oxidative breakdown of the inorganic c compounds in the water. The mean DO recorded after the experiment was below the recommended limit of 5.0mg/L by FAO/WHO (2018) for freshwater bodies. The decrease of BOD concentration in all the samples could be due to the oxygenation of sample during the aeration process by which aerobic bacteria use more oxygen produced by the photosynthetic activities of the algae as reported by Mahapatra *et al.*. (2013). In the present study hardness of all the three samples was significantly reduced which could be attribute to the presence of some contaminants usually metallic compounds so that the two test algal species do not utilize or precipitate them. According to the Lu *et al.*. (2017) the calcium ions present in the raw waste water form precipitate with CO2 as Calcium carbonate which are the contributing components to water hardness. Pirez *et al.*. (2013) reported that many algal species absorb solar radiation in the form of energy in its chloroplast cell and absorbs CO_2 along with nutrients from the wastewater to synthesis their biomass and produce oxygen. Algal photosynthetic activities consume more CO_2 enabling the calcium ions to precipitate as calcium carbonate thereby lowering the hardness of the water (Darmaki *et al.*., 2012).

It is evident from the figure 2 that alkalinity reduced significantly with both algal in all three sites. The amount of alkalinity depends on the inorganic and organic compounds dissolved in the water with suspended amount of organic matter. For the good growth of beneficial algae and bacteria‟s there should be required amount of alkalinity so that all the biological species optimize the decomposition process. Decrease in alkalinity means proper utilization of organic compounds by the algae by neutralization with acid present in water samples as reported by Miranda *et al.*. (2017). Ng *et al.*. (2017) reported the majority part of the acidic environment reduced by some acidophilic or acid tolerant algae as they utilize them by metabolic process. In the present study both algal species reacted differently according to the concentration of alkalinity.

Conclusion

Algal treatment of wastewater is a traditional technique that has been used for decades due to environment friendly alternative for removing inorganic and organic nutrients and some heavy metals. Several algal species have been identified and utilized for such studies. *Scenedesmus quadricauda* and *Chlorella vulgaris* were capable of reducing EC, BOD, DO, total Hardness, Alkalinity and increase pH to certain level. The two algal species are abundantly present and can easily be harness for waste water treatment. The observed reductions in dissolved oxygen, electrical conductivity, phosphate-phosphorus, and total hardness reflect the active metabolic uptake of nutrients and inorganic compounds by the algal species. These reductions are particularly significant given the role of phosphorus and nitrogen in eutrophication and the adverse effects of elevated hardness and conductivity on aquatic ecosystems. The concurrent increase in pH and nitrate-nitrogen can be attributed to photoautotrophic consumption of CO_2 and the mineralization of organic nitrogen, respectively.

Recommendations

The following recommendations were made:

1. Algal removal facilities should be introduced into our treatment plants with a view to reduce the negative impacts of untreated wastewater in the environments and to improve the removal efficiency of Total Dissolved Solids
2. Efforts should be geared towards full utilization of available wastewater plant capacity so as to maximize its full potentials.
3. There must be continuous monitoring of the efficiency of the wastewater treatment plant so as to enhance biological treatment of wastewater and ensure sustained adherence to permissible standards.

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