Journal of Applied Sciences, Information and Computing
Vol. 3, No. 1 (June, 2022)
School of Mathematics and Computing, Kampala International University

ISSN: 1813-3509 https://jasic.kiu.ac.ug

CHEMICAL OXYGEN DEMAND AND METAL (CHROMIUM AND IRON) CONCENTRATIONS AS KEY DRIVERS CONTROLLING THE PHYTOPLANKTON COMPOSITION OF FISH PONDS IN OSOGBO, NIGERIA

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Abstract

There is an alarming increase in industrialization and anthropogenic activities in many parts of the world, which raises concern as to the roles they play in the aquatic ecosystems. The study was conducted to investigate chemical oxygen demand (COD) and metal concentrations as key drivers of the phytoplankton community of selected fish ponds in Osogbo, Nigeria, from February 2021 to July 2021. Water samples were collected monthly and analysed for physicochemical parameters, phytoplankton composition and abundance. Analysis of variance (ANOVA) was performed on linear regression models to assess their prediction of phytoplankton community diversity. Mean water temperature was 27.57±0.14 °C, pH 6.91±0.16, Biological Oxygen Demand (BOD) 1.30±0.13 mg/l, Chemical Oxygen Demand (COD) 345.1±75.0 mg/l, phosphate-phosphorus 7.518±1.75 mg/l, electrical conductivity 594.9±97.75 µs/cm, DO 2.37±0.29 mg/l and alkalinity 129.0±47.25 mg/l in the investigated ponds. The dominant phytoplankton group was Chlorophyceae (74%), followed by Bacillariophyceae (11%), Cyanobacteria (9%) and Euglenophyceae (6%). Canonical correspondence analysis (CCA) revealed that COD, chromium (Cr) and iron (Fe) were the key parameters controlling the phytoplankton composition of the investigated ponds. Analysis of variance performed on the CCA model revealed that the most significant environmental determinants controlling the occurrence and abundance of phytoplankton in the investigated ponds were COD ($p = 0.009$), Fe ($p = 0.023$) and Cr ($p = 0.024$). Results of the phytoplankton composition in the ponds indicated that physicochemical parameters play a very important role in their distribution and abundance.

Keywords: Physicochemical parameters, Phytoplankton, Ponds, Analysis, Metals

1. Introduction

Phytoplankton comes from the Greek words φυτόν (*phyton*) which means 'plant' and πλαγκτός (*planktos*) which means 'wanderer' or 'drifter' (Karlusich *et al*., 2020). They live in the well-lit surface layers (euphotic zone) of aquatic ecosystems and use sunlight through the process of photosynthesis to obtain their energy (Karlusich *et al*., 2020). Phytoplankton serve as important source of food for zooplankton and fishes which also serve as food for other animals and humans (Yisa, 2006). They play key role in the transfer of energy to higher organisms (Saifullah *et al*., 2014).

A pond is a body of water that can be natural or artificial. Artificial ponds are often created for different purposes such as aquaculture, research and conservation of certain species of organisms. Ponds can be created naturally (through volcanic or tectonic activities) or as depressions filled by groundwater, precipitation or runoff (Clegg, 1989). They serve as habitats for a variety of living organisms such as phytoplankton, plants, fishes and reptiles (Johnson *et al*., 2013). The quality of an aquatic ecosystem and its suitability for aquatic organisms can be evaluated by measuring the physicochemical variables of water (Patil *et al*., 2012). Physico-chemical parameters refer to the physical and chemical characteristics of water. The physical variables include pH, temperature, turbidity, color and total dissolved solids while the chemical parameters include chemical oxygen demand, biological oxygen demand, dissolved oxygen, hardness, alkalinity and various nutrients (Patil *et al*., 2012).

Wetzel (2001) stated that physicochemical parameters such as chemical oxygen demand (COD) influence the phytoplankton community in aquatic ecosystems. Chemical oxygen demand refers to the amount of dissolved oxygen that is required for the oxidation of organic matter. It is a parameter used to determine the presence of organic pollutants in water (Li and Liu, 2019). Ifigenia *et al.,* (2003) stated that organic load of water which is expressed as COD is an indication of phytoplankton abundance especially in eutrophic lakes. According to Hassan *et al.,* (2017), water bodies with COD > 40 mg/l are considered as polluted waters; however, those with COD > 120 mg/l are extremely polluted.

Iron (Fe) and Chromium (Cr) are important metals required by phytoplankton species in trace amounts (Wetzel, 2001). Iron is required for photosynthesis and respiration in plants (Briat *et al*., 2015). It is utilized in the reduction of carbon dioxide, nitrates and sulphates during the production of organic compounds via photosynthesis. Liu *et al*., (2018) reported in their studies that iron was the main limiting factor for the growth of microalgae most especially *Anabaena flos-aquae* and *Scenedesmus quadricauda*. According to Javed (2003) who evaluated the relationship between plankton and heavy metals (Fe, Zn, Mn and Pb), metal uptake and bioaccumulation depends on physicochemical parameters of water and influences plankton biomass. Chromium plays a role in cell density, cell size, pigment concentration and photosynthetic activities of certain species of plants according to Samantaray *et al.,* (1998). Hussain *et al.,* (2021) posited that photosynthetic oxygen evolution in *Chlorella vulgaris* was considerably inhibited by chromium. The effects of heavy metals on phytoplankton community depends on factors such as specific concentration of metals, the phytoplankton species, nutrient availability and physicochemical variables of the water body. Wang and Dei (2001) reported that the ability of algae to accumulate metals depends on nutrient availability especially nitrates. Rauf *et al.,* (2018) studied the relationship between plankton and heavy metals (Chromium, Cadmium Copper, Cobalt) and reported a low abundance of certain phytoplankton species such as *Chlorella* spp. and *Synedra* spp. with increasing metal pollution. However, there was an higher abundance of *Amphora* spp., *Chroococcus* spp., *Cymbella* spp., *Pediastrum* spp. and *Spirulina* spp. in heavy metal polluted sites.

Anthropogenic activities such as discharge of domestic wastes and industrial effluents have been identified as the major causes of pollution in aquatic ecosystems (Chua *et al.,* 2000). Heavy metals are constantly released into various water bodies as a result of increasing industrialization in many parts of the world. The accumulation of heavy metals has a traceable impact on phytoplankton composition and thus affects the subsequent trophic levels in the food chain as stated by Robin *et al.,* (2012). Metallic pollution of water bodies have a relationship with the abundance of phytoplankton which plays a role in aquaculture and human health since the accumulation of metals moves up the food chain (Javed, 2006). Roy *et al.,* (2010) stated that phytoplankton species have an increased tendency to concentrate heavy metals and thus can be utilized as indicators of metal pollution.

There is a gap in knowledge as regards the influence of specific physicochemical parameters on phytoplankton composition. Physicochemical characteristics such as chemical oxygen demand (COD) and metal concentrations are key parameters controlling the distribution of phytoplankton, unfortunately how these function in tropical aquaculture communities have been poorly reported. The present study aimed to evaluate the relationship between chemical oxygen demand, metal concentrations and phytoplankton composition of selected fish ponds in Osogbo, Osun State, Nigeria.

2. Materials and methods

2.1. Study area

Osogbo is the capital city of Osun state. Osun state is in the Southwestern geopolitical zone of Nigeria. It is about 88 kilometres by road, northeast of Ibadan. Osogbo shares boundary with Ede, Ikirun, Ilesha and Iragbiji and is accessible from any part of Osun state because of its central nature. Osogbo is located at latitude 7°46°N and longitude 4°34°E. In Osogbo, temperature varies from 65 °F to 93 °F and is rarely below 60 ° F or above 98 °F. The rainy season of the study area begins from March to October while the dry season commences from November to February. Five ponds (A, B, C, D, and E) with coordinates 7.77458, 4.59433; 7.774352, 4.594356; 7.774186, 4.594445; 7.774293, 4594905 and 7.77480, 4.595354 respectively were selected for the study (Fig. 1).

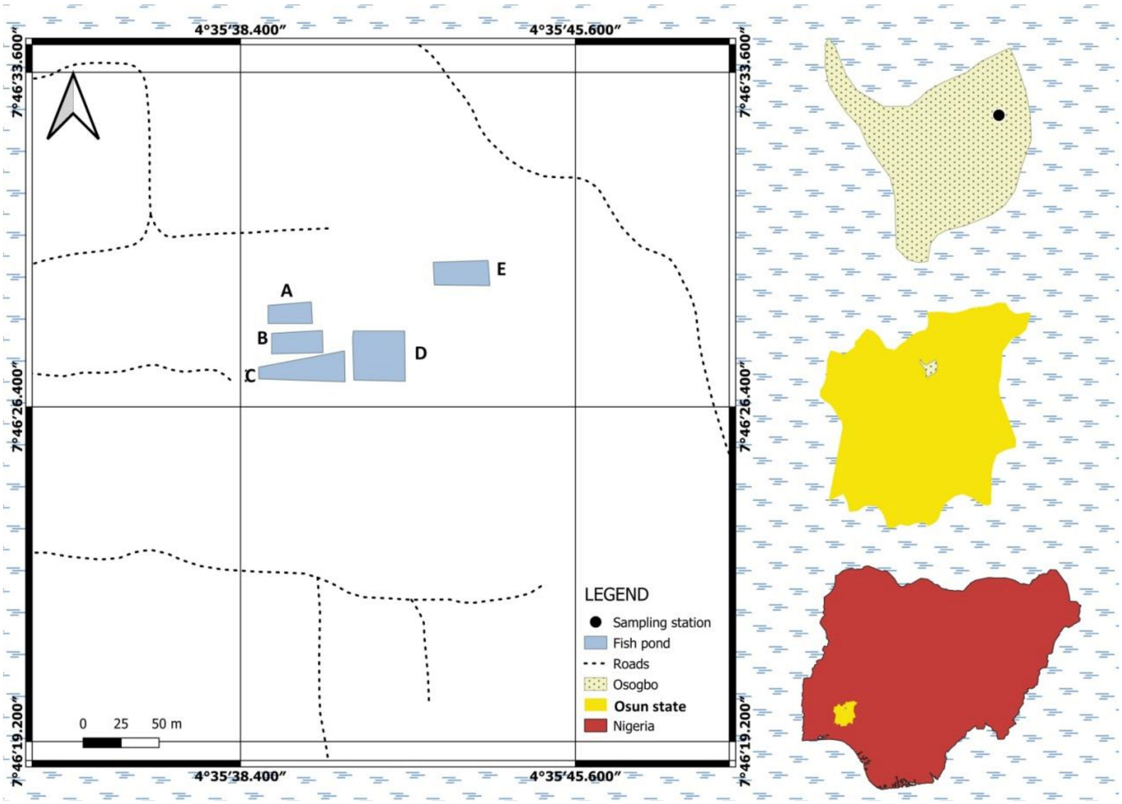

Figure 1 Map of the sampled ponds (represented as A, B, C, D, E) located in Osogbo, Osun State, Nigeria

The ponds are about 5 feet deep and are fed by underground springs as well as flowing streams. Plants nearby the ponds include *Nymphaea odorata*, *Pistia stratiotes* and *Cyperus rotundus*. The ponds receive waste loads from surrounding farmlands. Human activities around the ponds include livestock farming and arable farming. In addition, surface run-off and slums wash also entered the ponds from neighboring households.

2.2. Collection of Water Samples

All the sample bottles (500ml) were thoroughly washed, dried and rinsed with the same water to be collected in the pond. Sampling was done at monthly intervals from February 2021 to July 2021. Water samples were collected monthly using two different sample bottles from each pond; one for the analysis of physicochemical parameters and another for qualitative and quantitative analysis of phytoplankton. The sample bottles were labeled with date and collection sites. Temperature and pH were measured at the sites of collection. Temperature was recorded using a mercury thermometer and pH was recorded using an electronic pH meter (Jenway 3020, Germany). Water samples for other physicochemical parameters (Conductivity, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Alkalinity, Phosphate, Nitrate, Chloride, Magnesium hardness, Calcium hardness, Iron, Silica, Chromium, Potassium, Copper, Zinc, Aluminum, Manganese, Carbonate and Bicarbonate) were held in iceboxes and immediately transported to the laboratory for analysis following common protocols. Nitrate-nitrogen and phosphate-phosphorus were measured using a HACH Kit (DR/2010, a direct reading spectrophotometer) with high range chemicals (Nitraver 5 Nitrate Reagent Powder Pillows for No_3- N, and Phosver 3 Phosphate Reagent Powder Pillows for Po_4-P analysis). Total alkalinity, magnesium hardness and calcium hardness were measured with Hach's Model FF-2 Aquaculture test kit. Dissolved oxygen and BOD were measured by Winkler's method (Welch, 1952). The electrical conductivity was determined using a conductivity meter (Lovibond US meter, type CM-21). COD was measured using open condensation and digestion by titration (Dinesh *et al*., 2017). The level of potassium was measured using a colorimetric method (Mustapha, 2017). The concentration of manganese, chromium, zinc, copper, iron and aluminium were measured using a Flame Atomic absorption spectrophotometer (FAAS.210VGP). Chloride was determined using a titration method as described in APHA (2005). A known volume of water sample was titrated with standardized silver nitrate solution using potassium chromate solution in water or eosin/fluorescence in alcohol as an indicator. Carbonate was measured by titration with standardized hydrochloric acid using phenolphthalein as an indicator. Bicarbonate was determined by titration with standardized hydrochloric acid using methyl orange as an indicator. A spectrophotometric method was used in the determination of the silica concentration of the pond waters.

2.3. Phytoplankton analysis

Phytoplankton of all the ponds were collected by the filtration of ten liters of water through a plankton net. Filtered water samples from the fish ponds were transferred to well-labeled 500ml clean sample bottles and fixed in 4% formalin for qualitative and quantitative examination. The drop count method was employed in phytoplankton microscopy. The relative abundance method was applied for individual numbers of phytoplankton and expressed as % organism. For species identification, samples were gently shaken to resuspend all materials and allowed to settle down for one minute. Then 2 – 3 drops were removed from the middle of the sample and placed on a glass slide. Identifications of the phytoplankton samples were done microscopically by Digital Compound Optical Microscope with HD camera and identified with standard taxonomic keys (Desikachary, 1959).

2.4. Data analysis

Linear regression models were used to evaluate the association between pond type and sampling time with the community diversity indices used in this study. The segregation of phytoplankton into environmental gradients was explored using canonical correspondence analysis. Also, analysis of variance (ANOVA) was performed on the models to assess their prediction of phytoplankton community diversity. Species richness was defined as the total number of phytoplankton species sampled; the Shannon-Weiner index was employed to measure the species diversity weighted by relative abundance (Magurran, 2004) and rarefied species richness was used to account for differences in abundance of phytoplankton between the ponds (Heck *et al.,* 1975).

Community structure analysis and ordination methods used in the present study were done using the 'vegan' R package (Oksanen *et al*., 2015). Canonical correspondence analysis was performed to establish the relationship between physical and chemical variables and the phytoplankton of the investigated ponds. The abiotic variables that made independent and significant contributions to the variations of phytoplankton composition dynamics and abundance of the ponds were identified using permutation tests and then selected by a variance inflation factor (VIF). Only variables with a VIF of less than 20 were used in performing CCA.

Physicochemical characteristics data were evaluated for normality and homogeneity of variance with Shapiro Wilk and Levene's tests respectively. Differences in the mean of water quality parameters were determined using a two-way analysis of variance. Separation of significantly different means was done using the LSD.test function of the 'agricolae' R package. All statistical analyses were done using R version 4.1.0 GUI 1.76 High Sierra build for macOS at a 5% significance level.

3. Results

3.1. Physicochemical parameters

The mean values of the physicochemical parameters of fish ponds A to E are presented in fig. 2-4. There was a statistically significant difference at $p<0.05$ in the concentrations of Iron for the five ponds in this study. However, there was no statistically significant difference at $p<0.05$ in the levels of pH, temperature, DO, BOD, COD, phosphate, Nitrate 0.525, chloride, magnesium hardness, magnesium hardness, alkalinity, conductivity, silica, chromium, potassium, copper, zinc, aluminium, manganese, carbonate and bicarbonate.

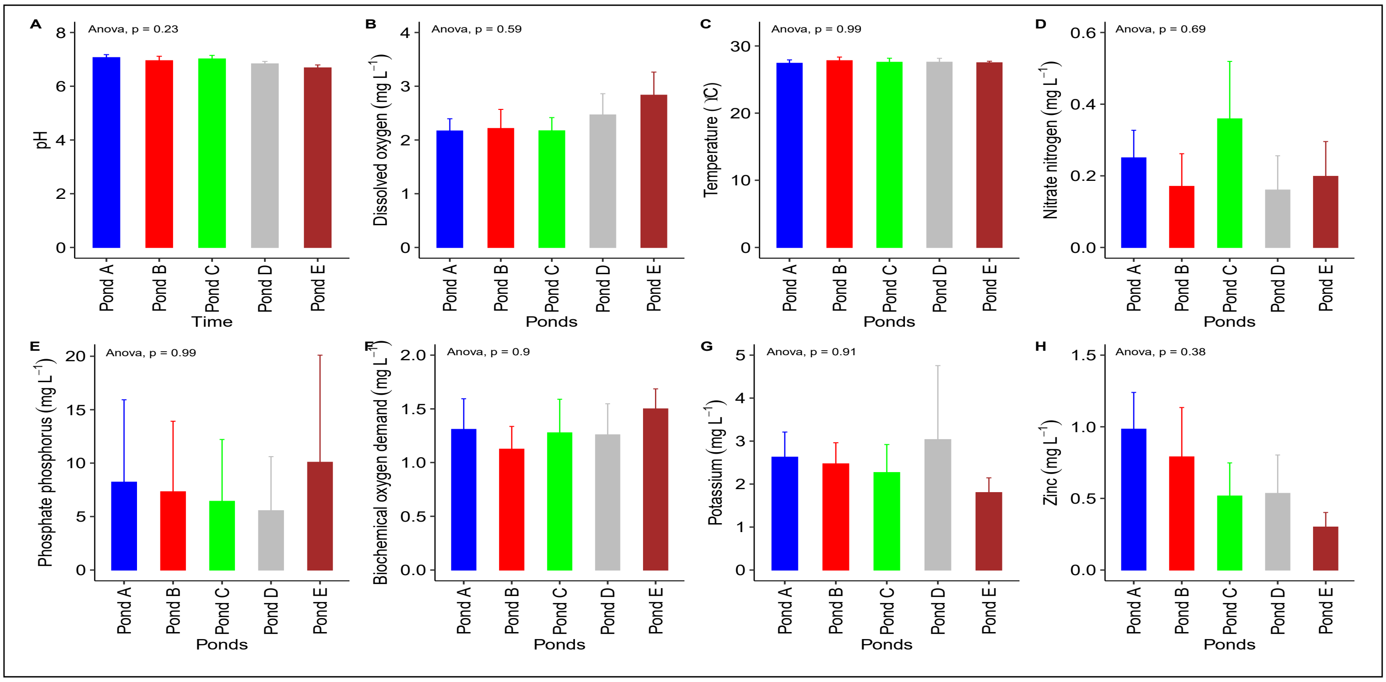

Figure 2 Variation of (a) pH (b) dissolved oxygen (DO) (c) temperature (d) nitrate (NO_3-N) (e) phosphate (PO_4-P) (f) biochemical oxygen demand (BOD) (g) potassium (h) zinc of the investigated ponds

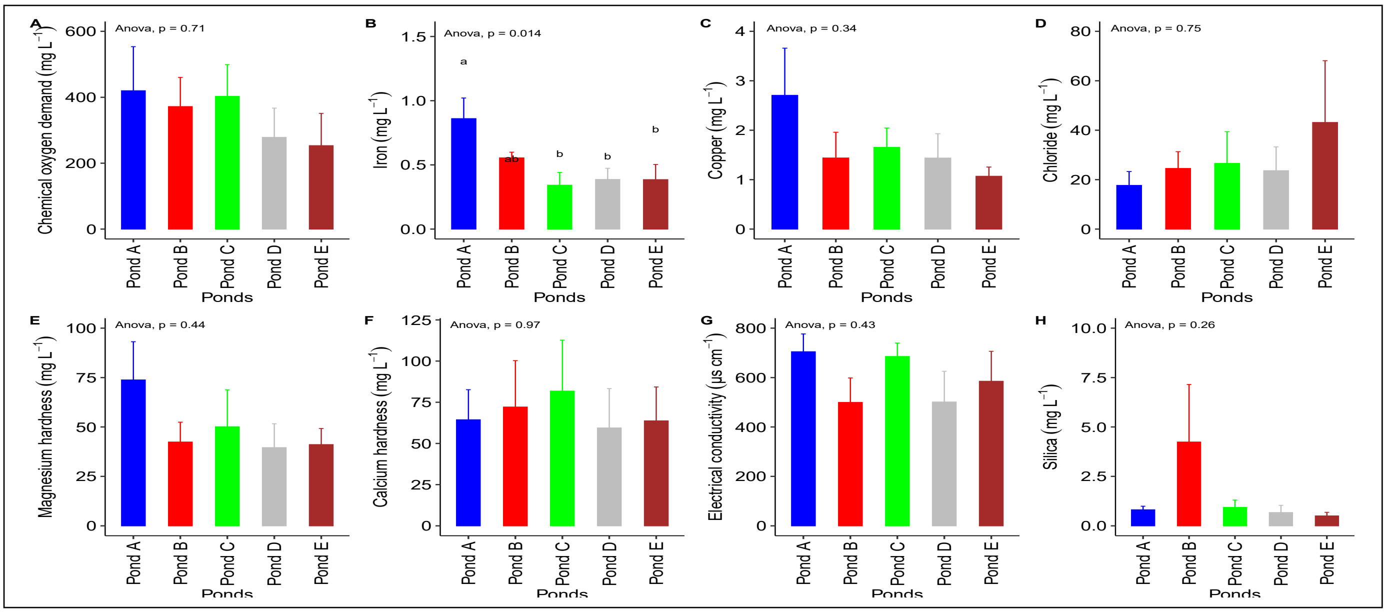

Figure 3 Variation of (a) chemical oxygen demand (COD) (b) Iron (Fe) (c) Copper (Cu) (d) Chloride (Cl) (e) Magnesium hardness (Mag-H) (f) Calcium hardness (Cal-H) (g) Electrical conductivity (EC) (h) Silica (Si) of the examined ponds

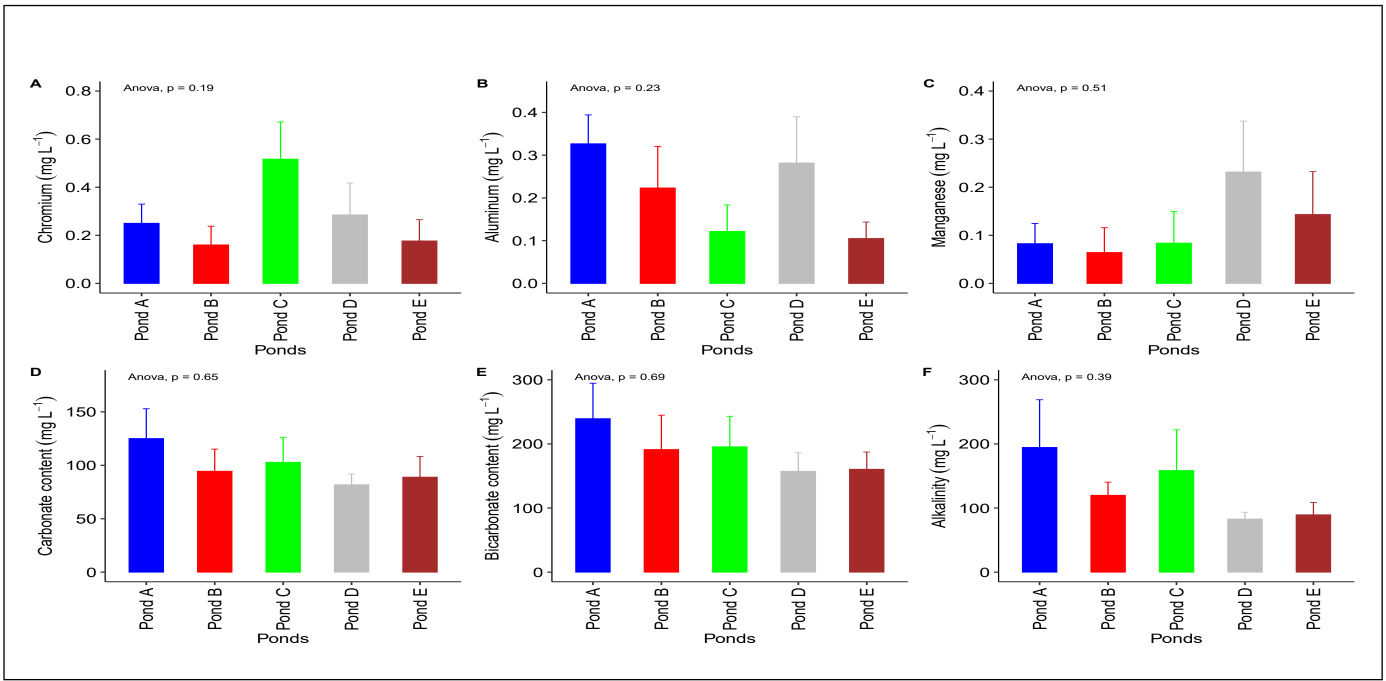

Figure 4 Variation of (a) Chromium (Cr) (b) Aluminium (Al) (c) Manganese (Mn) (d) Carbonate (e) Bicarbonate (f) Alkalinity of the studied ponds

Water temperature fluctuated within the 6 months (27.42±1.26 to 27.80±1.34 ^{0}C) in all five ponds. Pond C had the lowest temperature of 25 °C in April, while Pond D recorded the maximum temperature of 29.8 °C in March. The pH mean ranged from 6.68±0.27 to 7.07±0.27 in the five ponds. Pond B had the lowest pH of 6.2 in February, while Pond A and B recorded the maximum pH of 7.4 in April and May respectively. Pond B had the lowest DO value of 0.8 mg/l while Pond E recorded the highest DO value of 4.8 mg/l in February. The biochemical oxygen demand (BOD) mean for the five ponds varied between 1.13±0.52 to 1.50±0.46 mg/l. Pond D had the highest BOD of 2.2 mg/l in July and Pond C recorded the lowest (0.1 mg/l) in March. COD ranged from 253.20±240.04 mg/l to 419.67±327.84 mg/l in all five ponds. Pond C had the lowest COD of 9.0 mg/l in March, while Pond A recorded the maximum COD of 920 mg/l in May. Phosphate concentrations ranged from 5.55±12.39 mg/l to 10.08±24.56 mg/l in all five ponds. Pond A and D had the lowest Phosphate of 0.01 mg/l in July, while Pond E recorded the maximum Phosphate of 62.2 mg/l in February. Nitrate (0.525) mean fluctuated from 0.16±0.23 mg/l to 0.36±0.39 mg/l in all five ponds. Pond B had the lowest Nitrate 0.525 of 0.01 mg/l in July, while Pond B recorded the maximum Nitrate of 0.525 ± 0.96 mg/l in May. The chloride content varied from 17.65±13.80 mg/l to 43.12±61.27 mg/l in all five ponds. Pond D had the lowest Chloride of 4.5 mg/l in April, while Pond E recorded the maximum Chloride of 168 mg/l in March.

Magnesium Hardness concentrations fluctuated from 39.57±29.58 to 73.77±47.42 mg/l in all five ponds. Pond B had the lowest Magnesium hardness of 10 mg/l in April, while Pond C recorded the maximum Magnesium hardness of 142 mg/l in February. Calcium hardness ranged from 59.40±58.59 to 81.80±75.71 mg/l in all five ponds. Pond B had the lowest Calcium hardness of 10 mg/l in April, while Pond B recorded the maximum Calcium hardness of 204 mg/l in February. Alkalinity ranged from 82.83±25.95 to 194.43±182.33 mg/l in all five ponds. Pond B and D had the lowest Alkalinity of 54 mg/l in April, while Pond A recorded the maximum Alkalinity of 560 mg/l in March. The conductivity of the ponds ranged from 499.1±243.9 to 704.4±176.5 µscm^{-1}. Pond D had the lowest conductivity of 2.34 µscm^{-1} in February, while Pond A recorded the maximum Conductivity of 912.1 µscm^{-1} in March. Iron content ranged from 0.34±0.24 to 0.86±0.39 mg/l in all five ponds. Pond C had the lowest Iron of 0.05 mg/l in February, while Pond D recorded the maximum Iron of 1.44 mg/l in April. Silica mean ranged from 0.50±0.44 to 4.2±7.1 mg/l in all five ponds. Pond D had the lowest Silica of 0.05 mg/l in June, while Pond B recorded the maximum Silica of 18.5 mg/l in April.

Chromium concentrations ranged from 0.16±0.19 to 0.52±0.38 mg/l in all five ponds. Pond C had the lowest Chromium of 0.01 mg/l in March, while Pond C recorded the maximum Chromium of 1 mg/l in June. The potassium content ranged from

1.8±0.84 to 3.0±4.2 mg/l in all five ponds. Pond E had the lowest Potassium of 0.6 mg/l in July, while Pond E recorded the maximum Potassium of 11.5 mg/l in February. Copper means ranged from 1.1±0.46 to 2.7±2.3 mg/l in all five ponds. Pond A had the lowest Copper of 0.8 mg/l in March, while Pond A recorded the maximum Copper of 5.7 mg/l in April. Zinc ranged from 0.30±0.25 to 0.98±0.63 mg/l in all five ponds. Ponds A and D had the lowest Zinc of 0.01 mg/l in June and March respectively, while Pond A recorded the maximum Zinc of 1.95 mg/l in February. Values of Zinc in the five ponds were lower which indicates the same trend as the observation made regarding copper. Aluminium concentrations ranged from 0.11±0.095 to 0.33±0.17 mg/l in all five ponds. Ponds C, D, and E had the lowest Aluminum of 0.01 mg/l in June, May, and March respectively, while Pond D recorded the maximum Aluminum of 0.72 mg/l in March. Manganese mean ranged from 0.064±0.13 mg/l to 0.23±0.26 mg/l in all five ponds. Pond C had the lowest Manganese of 0.001 mg/l in March, while Pond D recorded the maximum Manganese of 0.62 mg/l in April.

Carbonate fluctuated from 82±25 mg/l to 125±68 mg/l in all five ponds. Pond B had the lowest Carbonate of 20 mg/l in April, while Pond A recorded the maximum Carbonate of 232 mg/l in March. Bicarbonate mean ranged from 157±71 mg/l to 239±135 mg/l in all five ponds. Pond C had the lowest Bicarbonate of 73.5 mg/l in February, while Pond A recorded the maximum Bicarbonate of 390.4 mg/l in March.

In the present study higher nutrient concentrations were recorded during the rainy season. Generally, the concentration of the nutrients in the examined pond varied from month to month during the study period. Similarly, maximum values of pH, biochemical oxygen demand, chemical oxygen demand and nitrate were recorded during the rainy season. The maximum peaks of temperature, alkalinity, magnesium hardness, calcium hardness, conductivity, dissolved oxygen, phosphate, chloride, carbonate and bicarbonate were recorded during the dry season. As for heavy metal contents in the pond, the maximum values of iron, silica, chromium, copper and manganese were recorded during the rainy season while potassium, zinc, and aluminium had their highest values in the dry season.

3.2. Phytoplankton Composition and Abundance

Four divisions comprising Chlorophyta (74%), Bacillariophyta (11%), Cyanophyta (9%) and Euglenophyta (6%) were recorded, implying that the phytoplankton populations of the five ponds were dominated by the green algae Chlorophyta was represented by *Scenedesmus dimorphus, S. quadricauda, Pediastrum* spp*, Chlorella* spp*, Oedogonium* sp*, Coelastrum* sp*, Closterium* spp, *Spirogyra* sp, *Cosmarium* spp, and *Ulothrix* sp. Bacillariophyta was represented by *Amphora ovalis, Cocconeis placentula, Cyclotella meneghiniana, Cymbella* spp, *Diploneis ovalis*, *Gomphonema parvulum, Hentzschia amphioxi*, *Navicula* spp, *Pinnularia* spp and *Synedra* spp. Cyanophyta was represented by *Oscillatoria* spp, *Chlorococcus turgidus, Microcystis aeruginosa* and *Spirulina* spp. *Euglenophyta* was represented by *Euglena acus* and *Phacus* spp. (Fig. 5). Fig. 5 indicated that Pond B contained the most phytoplankton with 490 organisms/ml, followed by Pond D with 460 organisms/ml, Pond A with 434 organisms/ml, Pond E with 428 organisms/ml and Pond C with 233 organisms /ml.

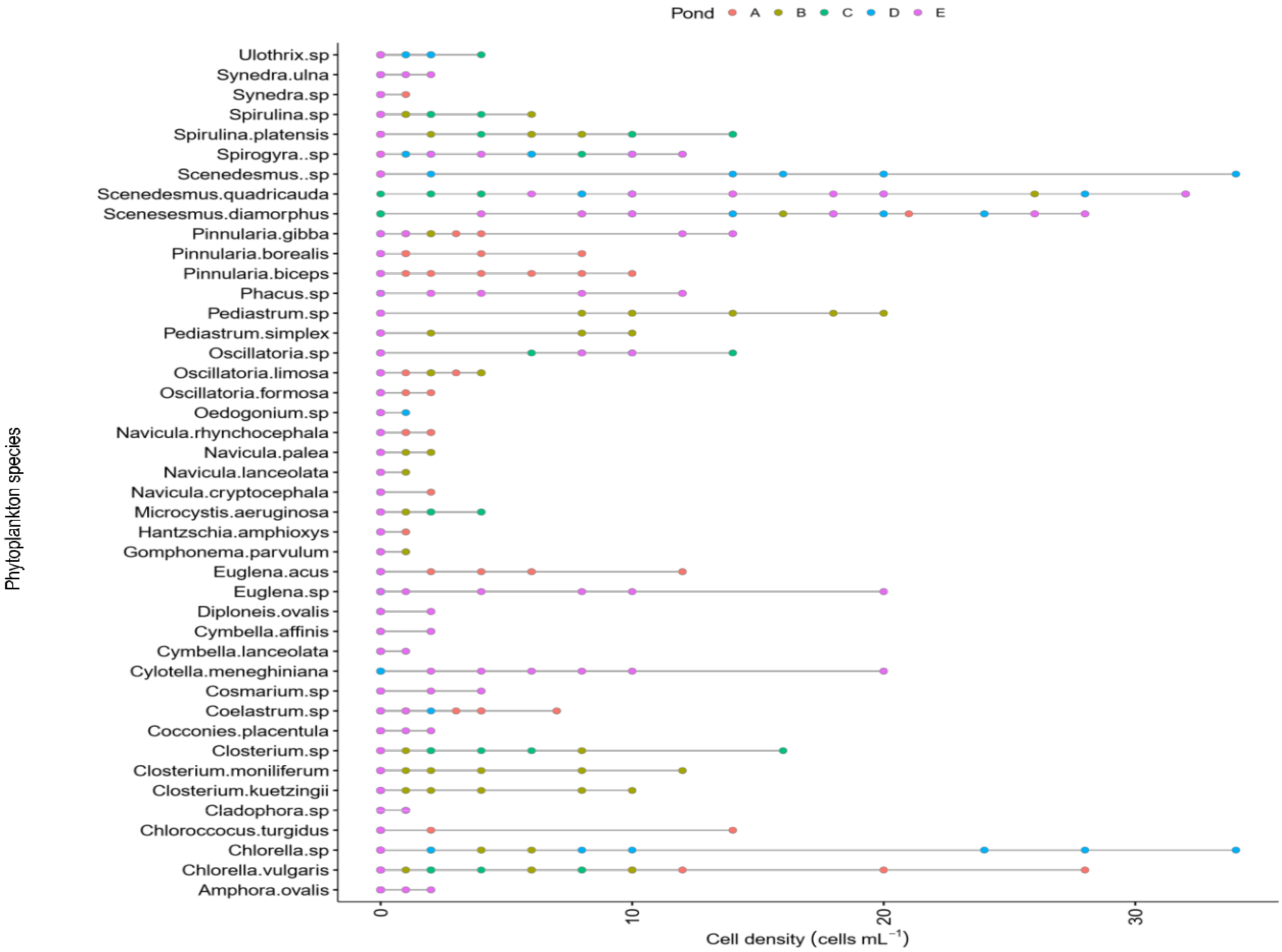

Figure 5 Cell density of phytoplankton in the five ponds

3.3. Community Structure and Dynamics

The diversity and abundance of phytoplankton in the fish ponds show spatial variations. The percentage abundance of the phytoplankton groups were in the order : Chlorophyceae (74%) > Bacillariophyceae (11%) > Cyanophyceae (9%) > Euglenophyceae (6%).

The Shannon value was found to be highest in Pond B (2.53) followed by Pond E (2.18), Pond A (2.16), Pond C (2.07) and Pond D (1.76) had the least (Fig. 6). The Dominance index in the present study indicates that Pond B had the highest dominance (9.92) of phytoplankton species followed by Pond C (7.23), Pond E (6.94), Pond A (6.56) and Pond D (5.24) had the least.

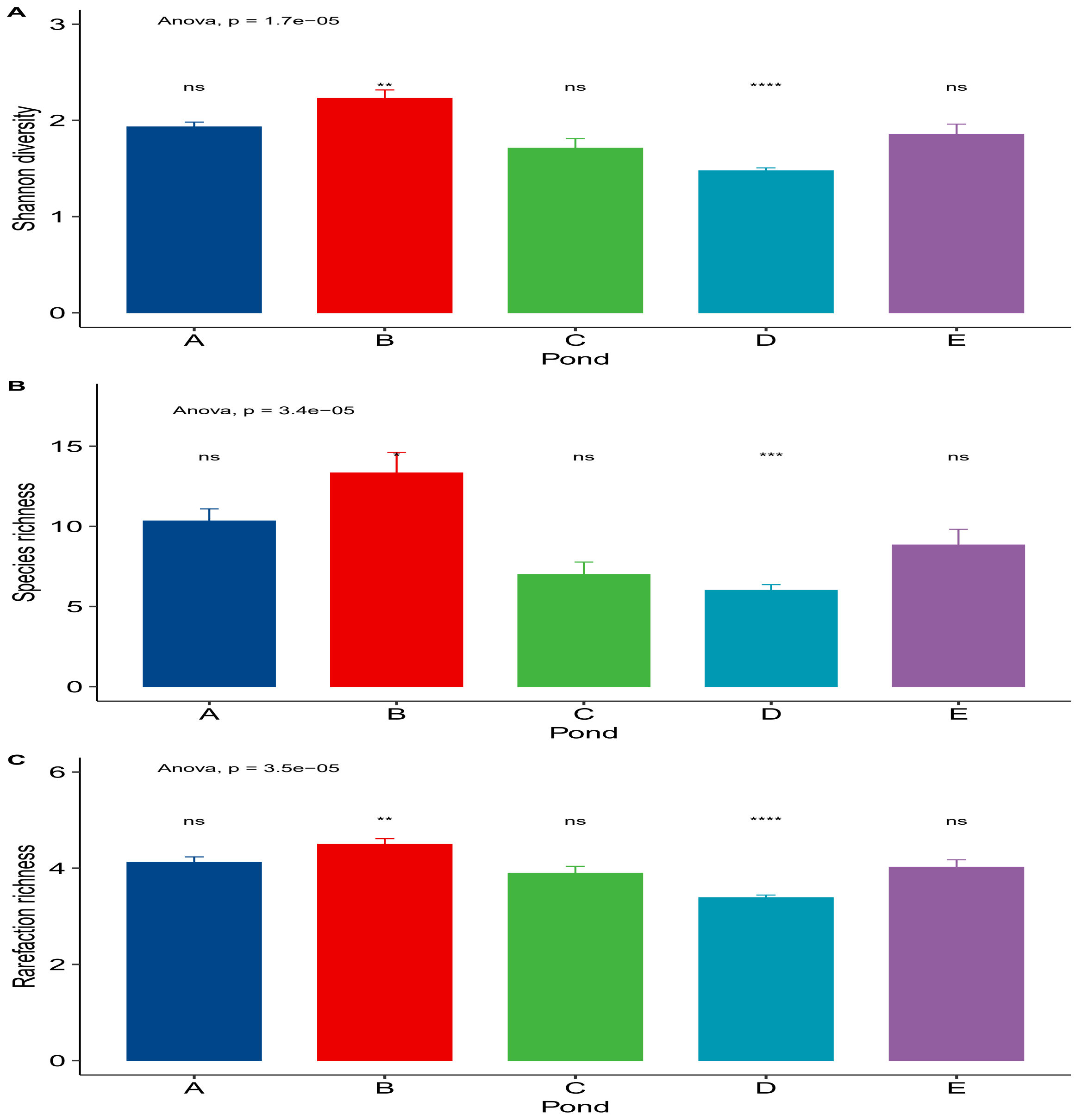

Figure 6 H' (Shannon Weiner Index), D (Simpson Index) and Rarefaction richness

3.4. Association between physicochemical parameters and phytoplankton community structure and dynamics

Fig. 7 shows the relationship between species abundance and environmental variables following canonical correspondence analysis (CCA). The first two components of the CCA accounted for 71% of the total variation. Analysis of variances performed on the CCA model revealed that the most significant environmental determinants controlling the occurrence and abundance of phytoplankton in the investigated ponds were COD ($p = 0.009$), Fe ($p = 0.023$), and Cr ($p = 0.024$). Specifically, the levels of Fe were positively associated with the presence of *Euglena acus, Pinnularia borealis, Chlorella vulgaris* and *Navicula cryptocephala.* Contrarily, *Oscillatoria* sp, *Cladophora* sp, *Closterium* sp and *Ulothrix* sp were negatively related to the increasing levels of Fe in the fish ponds. Also, the increasing presence of species such as *Closterium* spp., *Pediastrium,* and *Oscillatoria limosa* correlated with high levels of COD in the ponds. A significant negative relationship occurred between *Cymbella affinis, Cosmarium* sp., *Amphora ovalis* and *Cyclotella meneghiniana* and rising levels of COD in the pond. It is important to note changing levels of bicarbonate and zinc had a similar impact like COD on phytoplankton occurrence. The concentration of Cr in the ponds had a positive relationship with the population dynamics of *Scenedesmus* sp., *Closterium* sp., *Chlorella* sp., *Microcystis aeruginosa* and *Ulothrix* sp. Additionally, *C. vulgaris, P. borealis* and *N. cryptocephala* were adversely sensitive to high levels of Cr in the ponds.

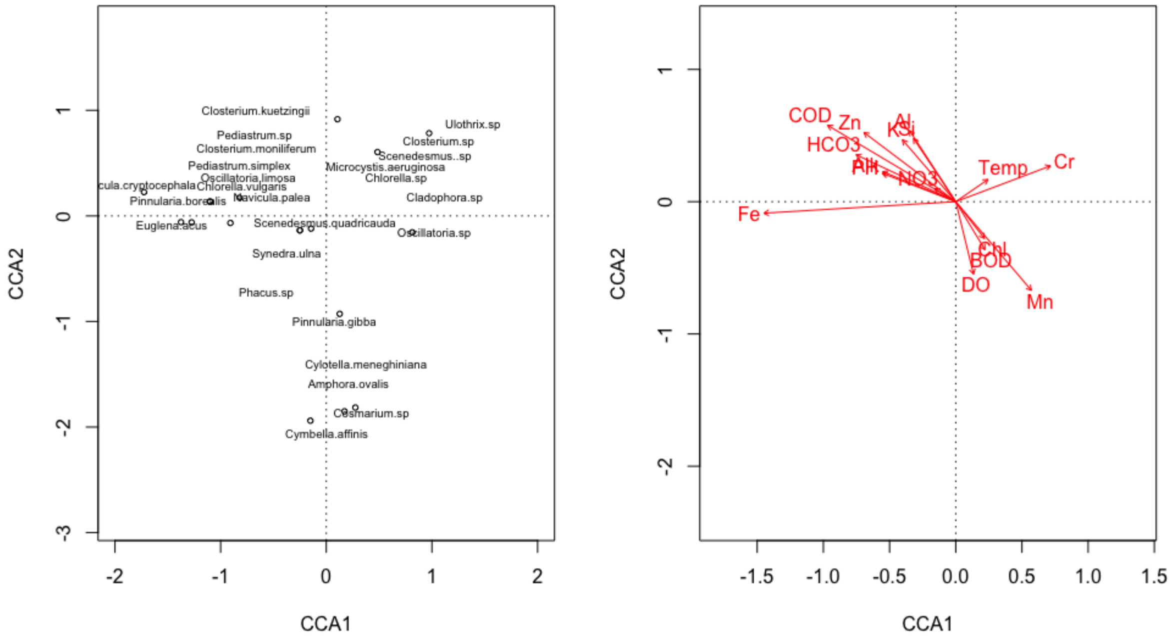

Figure 7 Canonical Correspondence Analysis (CCA) ordination, the group environmental bi-plot

4. Discussion

4.1. Key drivers of phytoplankton composition of Osogbo ponds

The results of the present study revealed positive relationship between certain phytoplankton species and physicochemical parameters such as COD, Iron and Chromium. Our findings suggest that COD controls phytoplankton growth in the studied ponds. Lv *et al.,* (2011) carried out a study on phytoplankton composition of subtropical lakes in China and documented phytoplankton groups (Cyanophyta, Bacillariophyta, Chlorophyta and Euglenophyta) similar to the results of this study. The study reported a positive correlation between the predominant species (*Microcystis aeruginosa, Euglena caudate, Chlorella vulgaris, Chroococcus minor* and *Phacus longicauda*) and increased COD levels. Hassan *et al*., (2017) opined that a higher value of COD indicated pollution due to oxidized organic matter and may have been due to the discharge of domestic wastewater from nearby settlements. According to Sheila (2007) as cited by Danba *et al.,* (2015), phytoplankton is favoured by enrichment due to the presence of organic load in water.

According to Rani and Sivakumar (2012), the deficiency or sufficiency of heavy metals depends on the requirement of a given phytoplankton species. The concentrations of heavy metals in the investigated ponds may be due to human activities around the ponds. Stanley *et al.,* (2003) and Meesukko *et al.,* (2007) opined that high nutrient concentrations in rainy season could be due to the surface water inflow that brought nutrients from the surrounding agricultural areas and leachates of municipal wastes from waste disposal areas. Aladesanmi *et al.,* (2014) stated that the presence of heavy metals in water is a result of atmospheric deposition, industrialization and other human activities around water bodies. In the present study, Canonical correlation analysis established that iron (Fe) and chromium (Cr) affected the growth of phytoplankton. The species identified to show a positive correlation with Fe and Chromium in this study can serve as useful instruments for monitoring water quality (Lacerda *et al.,* 2004). Phytoplankton can provide information on the toxic effect of a pollutant on their metabolic processes and in monitoring the response of the aquatic ecosystem to heavy metal contamination. Rachlin and Grosso (1993) submitted that heavy metals can react with biological active group of biomolecules and thus disrupt cell processing.

Rauf *et al.,* (2018) studied the accumulation of heavy metals (Chromium, Copper, Cobalt, Cadmium) and plankton biomass of river Ravi in Pakistan. Bacillariophyceae and Chloropyceae made up the dominant groups in the river. Phytoplankton species such as *Chlorella, Synedra, Scenedesmus* were sensitive to heavy metal pollution and therefore had a lower abundance . *Oedogonium, Frustulia, Pinnularia, Ulothrix* and *Closterium* had relatively low density or almost absent at heavy metal concentrations. *Amphora, Chrococcus, Cymbella, Pediastrum, Spirulina, Staurastrum* , *Cyclotella* and *Navicula* had good tolerance against heavy metal pollution and were more abundant. Javed (2006) reported that *Cladophora, Scenedesmus, Oscillatoria* and *Pandorina* showed low tolerance against metal pollution. Javed (2003) studied the relationships among plankton and accumulation of metals (Iron, Zinc, Manganese, Lead) and reported that bioaccumulation depended on physicochemical parameters of water.

4.2. The impact of other physicochemical conditions on water quality and phyplankton abundance

The temperature range in this study was within the recommended temperature range for optimum performance of aquatic organisms. Begum *et al.,* (2003) posited that an optimal temperature range of 18.3 to 37.8 ºC is suitable for the production of phytoplankton in tropical ponds. According to Afzal *et al.,* (2007), a temperature range between 25 °C and 32 °C is recommended for the good performance of aquatic biota. The result agreed with a previous report that the temperature in the tropics ranged between 21 ºC and 32 ºC (Atobatele and Ugwumba, 2008). This implies that the temperature range in the present study is suitable for aquatic organisms. The pH range in the examined ponds fell within the recommended pH range of 6.5-8.5 (WHO, 2009). Keremah *et al.,* (2014) opined that pH plays a significant role in the biological process of all aquatic organisms. The DO values recorded in this study were low. According to Rao (2005), DO concentration below 5 mg/l adversely affects aquatic life. Weber (2002) stated that BOD is a fair measure of the purity of any body of water on the basis that values of less than 2mg/1 are clean, 3-5mg/l fairly clean and 10mg/1 is seriously polluted. The results of this study showed that BOD values were within the WHO guidelines.

Amutha and Srisudha (2008) stated that phosphorous and nitrogen are the major elements for pond productivity. Ude *et al.,* (2011) submitted that high values of phosphate and nitrate support phytoplankton growth and hence good biomass. Phosphate concentrations in the present study were higher during the rainy season while nitrate levels were significantly lower. According to Kolo *et al.,* (2010), phosphate and nitrate levels determine the level of eutrophication in water bodies.

The result of this chloride concentration in this present study disagreed with the findings of Trivery and Khatavker (1986) who reported chloride concentration of 7.1 ± 28.4 mg/1. Kaul *et al.,* (1978) posited that the water bodies rich in calcium and magnesium ions support massive growth of algae. Fazio and O’Farelle (2005) reported that biodiversity diminished with increasing conductivity in Loss Coipos Lake. The acceptable limit for conductivity in aquaculture is between 20 and 1500 ųs/cm (DWAF, 1996). Temperature, dissolved oxygen, nutrient enrichment and other water characteristics may be related to variable changes in the phytoplankton distribution in the ponds. The variation observed in physicochemical characteristics in the examined ponds tallied with the observations of Chia *et al.,* (2009a, b).

Ansari e*t al.,* (2015), Mahor and Singh (2010), Rout and Birah (2009) and Devi and Singara (2007) have reported phytoplankton groups in their studies. The dominance of Chlorophyta in the present investigation is typical of most African waters as posited by Kadiri (1996). Hossain *et al.,* (2007) in their investigation on earthen fish ponds discovered that Chlorophyceae (34.48%) formed the dominant group. A high number of green algae (Chlorophytes) could be due to an increase in the nutrient content of water bodies leading to their abundance as observed by Kilham and Hecky (1988). Other phytoplankton groups were poorly represented. Edward and Ugwumba (2010) posited that the distribution of phytoplankton is mainly determined by various environmental factors such as temperature, pH, dissolved oxygen and nutrients like nitrate, phosphate, silicate and calcium. In the ponds, Chlorophyta (represented by *Scenedesmus dimorphus* and *S. quadricauda*) were the dominant algae and they had their best growth in the rainy season. According to Boumann *et al.,* (2005), temperature and light are the most effective factors in the seasonal development of algae. The observation made regarding the relationship between water temperature of the ponds and phytoplankton growth in the present study collaborated with Boumann's observation since increasing water temperature supported the growth of algae. Bacillariophyta was another important group in the ponds. The diatoms were rich in species composition during the rainy season. *Pinnularia gibba* was the most dominant species.

Euglena acus was the most important species among the euglenoids. Palmer (1980) pointed out that the existence of Euglenoids in waters is an indication of the richness of water with organic compounds. The observation was in line with the present study since *Euglena acus* showed better growth in the rainy season when the concentration of organic matter was in higher concentrations. *Spirulina platensis* was the richest blue-green algal species in terms of composition.

The diversity indices in phytoplankton studies is useful in the evaluation of pollutants in water bodies. Ganai and Parveen (2013) stated that the Shannon Weiner diversity index is greater than 4 for clean water, between 3 and 4 for mildly polluted water and less than 2 for heavily polluted water. The Shannon Weiner diversity index for the ponds in this study ranged between 1 and 3 which indicates they are moderately polluted. The study recorded the presence of *Oscillatoria* spp., *Microcystis* spp., *Navicula* spp. and *Synedra* spp. which are indicators of pollution in aquatic ecosystems. The organic pollution may be a result of human activities and discharge of industrial effluents around the sites of study. Tas and Gonulol (2007) reported that high density of Cyanophyceae is an indication of high pollution load.

Simpson index (1949) describes the diversity of habitat with reference to the number of species present as well as the abundance of species. The greater the Simpson index, the greater the diversity. In this study, the greatest diversity was obtained in pond B. The outcome of the examined ponds indicated that phytoplankton composition and their abundance varied during the study period.

5. Conclusion

The concentrations of heavy metals reported in this study are indicators of the anthropogenic activities around the ponds.The present findings revealed that COD, Fe and Cr had greater impacts on phytoplankton composition and abundance in the selected fish ponds as compared to other physicochemical parameters. The ponds had a diversified group of phytoplankton dominated by the division Chlorophyta followed by Bacillariophyta, Cyanophyta and Euglenophyta. There is need for environmental agencies to have an action plan that regulates the community activities as they adversely affect the aquatic biota and humans. More studies can be carried out to selectively evaluate the impact of individual parameters on phytoplankton using a mesocosm approach.

ACKNOWLEDGEMENT

Authors are thankful to the management of the Osun Water Cooperation and Osogbo fish ponds for their kind collaboration to conduct the research work.

REFERENCES

Afzal, M., Rab, A., Akhtar, N., Khan, M. F., Barlas, A. and Qayyum, M. (2007). Effect of organic and inorganic fertilizers on the growth performance of bighead Carp Aristichthys nobilis) in polyculture system. *International Journal of Agriculture and Biology*, **9** (6): 931-933.

Aladesanmi, O.T., Adeniyi, F. and Adesiyan, I.M. (2014). Comparative Assessment and Source Identification of Heavy Metals in Selected Fishpond Water, Sediment and Fish Tissues/Organs in Osun State, Nigeria. *Journal of Health and Pollution.* **4**(7): 42-53. https://doi.org/10.5696/2156-9614-4-7.42

Amutha, V. and Srisudha, S. (2008). A comparison on the algal diversity and physico-chemical profile of selected contaminated water bodies of Madurai, India *J. Ecol. Env. & Cons.* **14**(2-3): 375-378.

Ansari, E., Gadhia, M. and Ujjania, N.C. (2015). Phytoplankton diversity and water quality assessment of ONGC pond, Hazira. *Internatioinal Journal of Research in Environmental Sciences* **1**(1) : 1-5

APHA (2005). American Public Health Association, Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC, pp. 1–1368.

Atobatele, O.E. and Ugwumba, O.A. (2008). Seasonal variation in the physico-chemistry of a small Tropical Reservoir, (Aiba Reservior, Iwo, Osun, Nigeria). *Afr. J. Biotech.* **7** (12): 62-171. https://doi.org/10.5897/AJB2008.000-5043

Begum, M., Hossain, M.Y., Wahab, M.A. and Kohinoor, A.H.M. (2003). Effects of Iso-phosphorus fertilizers on water quality parameters and biological productivity in fish pond. *Journal of Aquaculture in the Tropics,* **18**(1): 1-12.

Bouman, H., Platt, T., Sathyendranath, S. and Stuart, V. (2005). Dependence of light-saturated photosynthesis on temperature and community structure. *Deep Sea Research Part I Oceanographic Research Papers*, **52**(7), 1284-1299. https://doi.org/10.1016/j.dsr.2005.01.008

Briat, J., Dubos, C. and Gaymard, F. (2015). Iron nutrition, biomass production and plant product quality. *Trends Plant Sci.* **20**(1): 33–40. https://doi.org/10.1016/j.tplants.2014.07.005

Chia, A.M., Abolude, D.S., Ladan, Z., Akanbi, O. and Kalaboms, A. (2009a). The presence of microcystins in aquatic ecosystems in Northern Nigeria: Zaria as a case study. *Research Journal of Environmental Toxicology,* **3**(4), 170-178. https://doi.org/10.3923/rjet.2009.170.178

Chia, A.M., Oniye, S.J., Ladan, Z., Lado, Z., Pila, E.A., Inekwe, V.U. and Mmerole, J.U. (2009b). A survey for the presence of microcystins in aquaculture ponds in Zaria, Northern Nigeria: possible public health implication. *African journal of Biotechnology*, **8**(22), 6282-6289. https://doi.org/10.5897/AJB09.1263

Chua, T.E., Gorre, I.R.I., Ross, G.A., Bernad, S.R., Gervacio, B. and Ebarvia, B.C. (2000). The Malacca straits. *Marine Pollution Bulletin*, **41** (1-6) 160-178.

Clegg, J. (1989). Observer's Book of Pond Life (The New Observer’s Series). 192pp.

Danba, E.P., David, D.L., Wahedi, J.A., Buba, U.N., Usman, D., Bingari, M.S. and Tukur, K.U. (2015). Physicochemical analysis and fish pond conservation in Kano State, Nigeria. *Archives of Applied Science Research.***7**(6):28-34.

Department of Water Affairs and Forestry (1996). South African Water Quality Guidelines. Domestic Water Use. 2nd (ed). Pretoria, **1**. 214pp.

Desikachary, T.V. (1959). Cyanophyta. *Indian Council of Agricultural Research Monograph* on Algae, New Delhi, 1-686.

Devi, A.V. and Singara, C.M.A. (2007). Phytoplankton in lower manair dam and kakatica canal, karimnager, *Nat. enviro poll. Tech* **6**(4): 643-648.

Edward, J.B. and Ugwumba, A.A.A. (2010). Physicochemical Parameters and Plankton Community of Egbe Reservoir, Ekiti State, Nigeria. *Research Journal of Biological Sciences* **5** (5): 356-367. https://doi.org/10.3923/rjbsci.2010.356.367

Fazio, A. and O’ Farewell, I. (2005). Phytoplankton and water quality in a shallow lake: A response to secondary salinization (Argentina). *Wetlands* **25**(3) : 531 – 541.

Ganai, A.H. and Parveen, S. (2013). Effect of physicochemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir, India. *International Journal of Biodiversity and Conservation.* **6**(1):71-84. https://doi.org/10.5897/IJBC2013.0597

Hassan, M., Khalil, T., El-halim, A., Saad, A. and Gamal, M.E.S. (2017). Zooplankton Community Structure of Lake Edku, Egypt. *Egyptian Journal of Aquatic Biology And Fisheries.* **21**(3): 55–79. https://doi.org/10.21608/EJABF.2017.4129

Heck, K. L., Van Belle, G., and Simberloff, D. (1975). Explicit Calculation of the Rarefaction Diversity Measurement and the Determination of Sufficient Sample Size. *Ecology*, **56**(6), 1459–1461. https://doi.org/10.2307/1934716

Hossain, M.Y., Jasmin, S., Ibrahim, A.H.M., Ahmed, Z.F., Ohtomi, J., Fulanda, B., Begum, M., Mamun, A., El-kady, M.A.H. and Wahab, M.A. (2007). A preliminary observation on water quality and plankton of an earthen fish pond in Bangladesh: Recommendations for Future Studies. *Pakistan Journal of Biological Sciences,* **10**(6): 868-873. https://doi.org/10.3923/pjbs.2007.868.873

Hussain, F., Rom, H., Toor, U.A., Lee, C.S. and Oh Sang-Eun (2021). Rapid assessment of heavy metal-induced toxicity in water using micro-algal bioassay based on photosynthetic oxygen evolution. *Environmental Engineering Research* **26**(6): 200391

Ifigenia, K., Dimitris, P. and George, T. (2003). Seasonal Variation of Water Quality Parameters and Plankton in a Shallow Greek Lake, *Journal of Freshwater Ecology,* **18**(2): 199-206. https://doi.org/10.1080/02705060.2003.9664485

Javed, M. (2003). Relationships among water, sediments and plankton for uptake and accumulation of metals in the river Ravi. *Indus Journal of Plant Sciences,* 2, 326-331.

Javed, M. (2006). Studies on metal contamination levels in plankton and their role as biological indicator of water pollution in the river Ravi. *Pakistan Journal of Biological Sciences,* **9**(2): 313-317.

Johnson, P.T.., Preston, D.L., Hoverman, J.T., Richgels and Katherine, L.D. (2013). Biodiversity decreases disease through predictable changes in host community competence. *Nature*. **494**(7436): 230–233. https://doi.org/10.1038/nature11883.

Kadiri, M.O. (1996). More desmids from the Ikpoba reservoir, Nigeria: Comparison with other Africa records. Algol. Stud. 80: 87-98.

Karlusich, J.J.P., Ibarbalz, F.M. and Bowler, C. (2020). "Phytoplankton in the Tara Ocean". *Annual Review of Marine Science*. **12** (1): 233–265. doi:10.1146/annurev-marine-010419-010706

Kaul, V., Trisal, C.L. and Handoo, J.K. (1978). Distribution and production of macrophytes in some water bodies of Kashmir. In Glimpse of Ecology, Eds. J.S. Singh and B. Gopal. *Praksh Publ. Jaipur.* 592 pp.

Keremah, R.I., Davies, O.A. and Abezi, I.D. (2014). Physico-Chemical Analysis of Fish Pond Water in Freshwater Areas of Bayelsa State, Nigeria. *Greener Journal of Biological Sciences* . **4** (2):033-038. https://doi.org/10.15580/GJBS.2014.2.042313583

Kilham, P. and Hecky, R.E. (1988). Comparative ecology of marine and freshwater phytoplankton. *Limnology and Oceanography*. **33**(4part2)776-795. https://doi.org/10.4319/lo.1988.33.4part2.0776

Kolo, R.J., Ojutiku, R.O. and Musulmi, D.T. (2010). Plankton Communities of Tagwai Dam Minna, Nigeria. *Continental J. Fisheries and Aquatic Science* 4: 1-7.

Kumar, D.G., Karthik, M. and Rajakumar, R.(2017). Study of seasonal water quality assessment and fish pond conservation in Thanjavur, Tamil Nadu,, India. *Journal of Entomology and Zoology Studies*. **5**(4): 1232-1238.

Lacerda, S.R., Koening, M.L., Neumann-Leitao, S. and Flores-Montes, M.J. (2004). Phytoplankton nyctemeral variation at a tropical river estuary (Itamaraca Pernambuco-Brazil). *Brazilian Journal of Biology* 64(1):81-94. https://doi.org/10.1590/s1519-69842004000100010

Li, D. and Liu, S. (2019). Water Quality Monitoring and Management, Academic Press. Chapter 12. 303 - 328.

Liu, J., Tan, K., He, L., Qiu, Y., Tan, W., Guo, Y., Wang, Z. and Sun, W. (2018). Effect of limitation of iron and manganese on microalgae growth in fresh water. *Microbiology.* **164**(12) :1514-1521. https://doi.org/10.1099/mic.0.000735.

Lv, J., Wu, H. and Chen, M. (2011). Effects of nitrogen and phosphorus on phytoplankton composition and biomass in 15 subtropical, urban shallow lakes in Wuhan, China. *Limnologica*. **41**(1) : 48-56. https://doi.org/10.1016/j.limno.2010.03.003

Magurran, A.E. (2004). Measuring Biological Diversity. *African Journal of Aquatic Science* **29**(2). https://doi.org/10.2307/4126959

Mahor, R.K. and Singh, B. (2010). Diversity and seasonal fluctuation of phytoplankton in fresh water reservoir, Igra Gwalior (M.P). *Int. Res. J.,* **1**(10): 51-52.

Meesukko, C. Gajaseni, C., Ppeeraponpisal, Y. and Voinava, A. (2007). Relationship b/w seasonal vaviaxen an plytop location dynamics in Karakachan reservoir, Phetchaburi Provaince, Tharland, *nat. hist J*. (7) 131-143.

Mustapha, M.K. (2017). Comparative assessment of the water clarity of four types of aquaculture ponds under different culture systems. *Advanced Research in Life Sciences* **1**(1); 104-110. https://doi.org/10.1515/arls-2017-0017

Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., Simpson, G.C., Solymos, P., Stevens, M.H.H. and Wagner, H.H. (2015). Vegan: Community Ecology Package. R Package Vegan, Version 2.2-1.

Palmer, C.M. (1980). Algae and water pollution. Castle House publications. 235pp.

Patil. P.N, Sawant. D.V. and Deshmukh. R.N (2012). Physico-chemical parameters for testing of water – A Review. *International Journal Of Environmental Sciences*. 3(3) 1194 - 1207

Rachlin, J.W. and Grosso, A. (1993). The growth response of the green alga *Chlorella vulgaris* to combined divalent cation exposure. *Arch. Environ. Contam. Toxicol.* **24**(1): 16–20. https://doi.org/10.1007/BF01061084.

Rani, R. and Sivakumar, K. (2012). Physicochemical parameters and phytoplankton richness In certain ponds of Chidambaram, Cuddalore District of Tami Nadu. *International Journal Of Research in Environmental Science and Technology,* **2**(2):35-44.

Rao, P.V. (2005). Textbook of environmental engineering. Eastern Economy Ed., Prentice-Hall of India Private Limited, New Delhi, Chapter 3, 280.

Rauf, A., Javed, M. and Jabeen, G. (2018). Uptake and Accumulation of Heavy Metals in Water and Planktonic Biomass of the River Ravi, Pakistan. *Turkish Journal of Fisheries & Aquatic Sciences.* **19**(10), 857-864. https://doi.org/10.4194/1303-2712-v19_10_05

Robin, R.S., Mudulli, P.R., Vardhan, K.V., Ganguly, D., Abhilash, K.R. and Balasubramanian, T. (2012). Heavy metal contamination and risk assessment in the marine environment of Arabian Sea along the Southwest Coast of India, *American Journal of Chemistry,* **2**(4):191- 208. https://doi.org/10.5923/j.chemistry.20120204.03

Rout, J. and Birah, D. (2009). Algal diversity in Chatla Wetland in Cachar District (Southern Assam). *Assam University Journal of Science & Technology: Biological Sci*ences **4**(1) 46-55.

Roy, U., Shaha, B.K., Mazhabuddin, K., Haque, M.F. and Sarower, M.G. (2010). Study on the diversity and seasonal variation of zooplankton in a brood pond, Bangladesh. *Marine Research of Aquaculture*, **1**(1):30 - 37.

Saifullah A.S.M., Hena, M.K.A., Idris, M.H., Halimah, A.R. and Johan, I. (2014). Diversity of phytoplankton from mangrove Estuaries of Sarawak, Malaysia. *World Appl. Sci. J.*, 31 , pp. 915-924.

Samantaray, S., Rout, G.R. and Das, P. (1998). Role of chromium on plant growth and metabolism. *Acta Physiologiae Plantarum* **20,** 201–212. https://doi.org/10.1007/s11738-998-0015-3

Sheila, M. (2007). General Information on Solids. BASINS. City of Boulder/USGS *Water Quality Monitoring*. pp.223 -245.

Simpson, E.H. (1949). Measurement of diversity. Nature 163, 688. https://doi.org/10.1038/163688a0

Stanley, C.D., Clerk, R.A., Moneal, B.L., and Macleod, B.W. (2003). Impact of agricultural land use to nitrate levels in leke manatee, Florida. Soil and water science departed, florida coignative extrusion service.

Tas, B. and Gonulol, A. (2007). An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey. *Journal of Environmental Biology* 28(2): 439 - 445.

Trivery, R.K. and Khatavker, S.D. (1986) . Phytoplankton ecology of the river Krishna in Maharashtra with reference to bio-indicators of pollution. *Asian Environ.* pp.31 – 42.

Ude, E.F., Ugwu, L.L. and Mgbenka, B.O. (2011). Evaluation of Zooplankton Diversity in Echara River, Nigeria, *Continental J. Biological Sciences*.**4**(1): 1-5.

Wang, W. and Dei, R.C.H. (2001). Effects of major nutrient additions on metal uptake in phytoplankton. *Environmental pollution* **111**(2):233-240. https://doi.org/10.1016/S0269-7491(00)00071-3

Weber, T.J. (2002). Wastewater Treatment. *Met. Finish.* 100, 781–797.

Welch, P.S. (1952). Limnology, 2nd edition. McGraw-Hill Book co., New York. Pp 538.

Wetzel, R.G. (2001). Limnology: Lake and River Ecosystems. Third Edition, Academic Press, San Diego, 1006 p.

World Health Organization (2009). Guideline for Drinking Water Quality. Geneva.

Yisa, M. (2006). Physical and chemical water quality parameter in fishpond management: A review. *Best Journal* **4**(1):142-147.