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Green algal interactions with physicochemical parameters of some manmade ponds in Zaria, northern Nigeria

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ABSTRACT – (Green algal interactions with physicochemical parameters of some manmade ponds in Zaria, northern Nigeria). Green algal species and their association with physicochemical parameters in some manmade ponds in Zaria, Nigeria were studied from November 2005 to August 2006. Phytoplankton and water samples were collected, preserved and analyzed using standard methods. A total of 27 green algal species divided into 16 families were recorded. Shannon diversity indices ranged from 1.75 to 2.39 in all ponds, dominance index from 0.14 to 0.23 and species evenness 0.56 to 0.64. *Closterium* sp. and *Rhizoclonium hookeri* Kuetz. were positively associated with the concentration of Fe, however they were negatively correlated (sensitive) to alkalinity, total dissolved solids and electrical conductivity. *Stichococcus bacillaris* Naegeli, *Staurastrum rotula* Nordst. and *Sphaeroplea* sp. had significant positive relationship with biochemical oxygen demand (BOD), Mn, and Mo levels in the water. *Pseudouvella americana* (Snow) Wille. and *Scenedesmus quadricauda* (Turp.) de Bréb. showed a close positive association with alkalinity but were sensitive to Fe, BOD, Mn and Mo. The species reported here showed closed association with physicochemical factors in these ponds.

Key words - Chlorophyta, diversity, ecology, lenthic water bodies, trace metals

RESUMO – (Interação de algas verdes com parâmetros físico-químicos em lagoas artificiais em Zaria, Norte da Nigéria). As espécies de algas verdes e sua associação com parâmetros físico-químicos em lagoas artificiais de Zaria, Nigéria foram estudados entre novembro de 2005 e agosto de 2006. As amostras de fitoplâncton e de água foram coletadas, preservadas e analisadas usando métodos padrões. Foram registradas um total de 27 espécies de algas verdes divididas em 16 famílias. Os indices de diversidade de Shannon variaram de 1,75 a 2,39 em todas as lagoas; índice de dominância de 0,14 a 0,23 e a eqüidade de espécies de 0,56 a 0,64. *Closterium sp*. e *Rhizoclonium hookeri* Kuetz. foram associados positivamente com a concentração de Fe, porém eles foram correlacionados negativamente (sensíveis) à alcalinidade, condutividade elétrica e sólidos totais dissolvidos. As espécies *Stichococcus bacillaris* Naegeli, *Staurastrum rotula* Nordst. e *Sphaeroplea* sp. tiveram relação positiva e significativa com a demanda bioquímica de oxigênio, e com os níveis de Mn e Mo na água. *Pseudouvella americana* (Snow) Wille. e *Scenedesmus quadricauda* (Turp.) de Bréb. mostraram estreita associação positiva com a alcalinidade, mas foram sensíveis ao Fe, DBO, Mn e Mo. As espécies relatadas aqui apresentaram associação próxima com fatores físico-químicos nessas lagoas.

Palavras-chave - Chlorophyta, diversidade, ecologia, corpos d'água lênticos, metais-traço

Introduction

Ponds constitute an ecosystem that supports a wide array of organisms ranging from lower plants to higher plants. In some developing countries they are a contributing source of water for domestic use such as washing of cloths, bathing and sometimes as a source of drinking water (Chia *et al.* 2009a). The distribution and abundance of microalgae in this system are controlled by a wide range of physical, chemical and biological factors. Trace elements are essential for metabolic processes in phytoplankton (Monastersky 1995) and constitute part of the sediment or bedrock materials of aquatic systems. They are not degradable but can be bioaccumulated along the food chain, transformed or complexed from one form to another in aquatic systems (Rai *et al.* 1981, Sunda *et al.* 2005). Human activities around the catchment affect the concentration of trace elements in ponds, thereby rising the levels sometimes beyond tolerable for some aquatic organisms. The extent to which microalgal species can tolerate trace metals makes them potential indicators for the presence and levels of these metals. Trace elements act as micronutrients at low concentrations, while at high concentrations they become toxic. *Chlorococcum* sp. is sensitive to zinc and mercury (Palmer 1969), *Hormidium* sp. is sensitive to copper (Hargreaves & Whitton 1976), and *Stigeoclonium* sp. to zinc and cobalt (Pawlik-Skowronska *et al.*, 1999).

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Other physicochemical factors like pH, alkalinity, water hardness and macronutrient concentration determine which species or group thrives in a pond ecosystem (Sipaúba-Tavares *et al.* 2010).

On a general note, studies focusing on algae from small static water bodies are less reported compared to larger lenthic water bodies. Published works on green algae and other phytoplankton groups from artificial ponds from northern Nigeria are very scarce. A few generalized studies on the pond ecosystems in Nigeria include: Ado *et al.* (2004) on phytoplankton from burrow pit ponds in Kano; Mustapha & Omotosho (2002) on a temporary pond in Ilorin; Bwala & Omoregie (2009) on fish ponds in Jos; Adeogun *et al.* (2005) on fish ponds in Ibadan; and Chia *et al.* (2009a, b, 2011a, b) on other phytoplanktonic groups in ponds in Zaria.

This study attempts to provide more insight into the green algae and their relationship to physicochemical parameters in artificial ponds in Zaria, northern Nigeria.

Material and method

Study area – Four manmade ponds in Zaria (11°04’50” N and 7°42’58” E) Nigeria were investigated. Some characteristics of these ponds are: Danmika Pond with 1.59 hectares area, 11°05’39.35’ N and 7°41’28.99’ E, and 648 m elevation; Mairabo Pond with 3.69 hectares area, of 11°05’40.73’ N and 7°41’32.33’ E, and 647 m elevation; Kabama Pond with 3.65 hectares area, 11°05’57.56’ N and 7°41’23.55’ E, and 642 m elevation; and Aviation Quarry pond with 0.52 hectare area, 11°08’24.38’ N and 7°40’55.86’ E, and 670 m elevation. The first three ponds are located at Dan Magaji along Zaria-Kano express way and lying within 2.5 km of each other. The Aviation Quarry Pond is located opposite the Nigerian College of Aviation Technology. These ponds are seasonal in nature, usually containing water for about 8-9 months per year *i.e.* from May of each year on. Danmika, Mairabo and Kabama ponds were formed from the excavations of top soils for use in road construction. The third pond was formed as a result of mining activities. The location of the pond is ravaged by stone mining for construction purposes. All the four ponds serve as important sources of water for drinking (to animals and man), washing, bathing and irrigating farmlands. Farmlands surround the first three ponds Aviation Quarry Pond is surrounded by domestic and small scale industrial structures.

Sampling and analysis of green algal samples – Samples were collected from four sampling stations in each pond from November 2005 to January 2006 (dry months), and from June to August 2006 (wet months). Water samples were collected at about 30 cm depth and one meter away from the shore at each sampling station (APHA 1998). Glass jars (100 mL) were used to collect samples for algal analysis and dark brown glass bottles (250 mL) for pH, dissolved oxygen (DO) and electrical conductivity (EC) analyses. Polyethylene bottles were used for collection and storage of water samples for other chemical analyses. All samples for chemical analysis were either analyzed immediately or stored at -20 °C. Samples for green algae analysis were collected using a cone shaped, silk bolting cloth net of 20 µm mesh size, a mouth radius of 20 cm and a 50 mL concentration bottle. The 50 mL concentrates were transferred to separately labeled 100 mL glass jars and fixed immediately with Lugol solution to preserve green algal cells (APHA 1998). Treatment and analysis of algal samples were done according to the procedures of Prescott (1977) and APHA (1998). Direct microscopic cell counts using the drop count technique (Bartram & Rees 2000) was used to determine the green algal cell density (nº of cells per mL). Briefly, a drop of the concentrate was placed on a glass slide and the total number of individuals in that drop counted. Prior to these counts, the glass dropper used was calibrated to determine the number of drops that gave one milliliter.

Analyses of physicochemical parameters – Water temperature (°C) readings were taken *in situ* using a mercury thermometer. Total dissolved solids (TDS), pH and EC (eletrical conductivity) were measured using a portable Hanna pH/EC/TDS/temperature meter (model nº H1991300). The modified Winkler azide method (Lind 1979, APHA 1998) was used to determine DO and biochemical oxygen demand (BOD). Total hardness and phenolphthalein alkalinity were determined using the procedure of Lind (1979) and APHA (1998). Nutrient concentrations (phosphate-phosphorus, PO_4-P; and nitrate-nitrogen, NO_3-N) were determined spectrophotometrically using a HACH DR/2000 direct reading spectrophotometer. Specific nutrient concentrations were read from calibration curves (Mackereth 1963, Lind 1979, APHA 1998).

Elemental analysis – Total trace metal composition and concentration of the water samples were determined using energy dispersive x-ray fluorescence (EDXRF) spectrometry at the Center for Energy Research and Technology (CERT), Ahmadu Bello University, Zaria, Nigeria. Measurements were performed using an annular 25 mCi ^{109}Cd as the excitation source, that emits Ag-K X-rays [22.1 KeV] in which case all elements with lower characteristics excitation energies were accessible for detection in the samples (Funtua 1999a, b). The system is further equipped with a Si (Li) detector having a resolution of 170 eV for the 5.90 KeV line, coupled to a computer controlled ADCcard. Quantitative processing of the samples was done by the emission transmission (E-T) method (Bernasconi *et al.* 1996, Kump 1996, Leroux & Mahmoud 1996). Thick pure metal foils were used for sensitivity calibration of the system (Ti, Fe, Co, Ni, Cu, Zn, Zr, Nb, Mo, Sn, Ta, Pb) and stable chemical compounds (K_2CO_3, $CaCO_3$, Ce_2O_3, WO_3, ThO_2, U_3O_8). Sample spectra were collected for 3000 s with the ^{109}Cd source and their evaluation done with the AXIL-QXAS program (Bernasconi 1996).

Data analysis – Diversity indices were calculated using PAST for windows statistical software (Hammer *et al.* 2001). These involved Shannon diversity index (Shannon 1948); Simpson's dominance index (Simpson 1949); and Pielou's species evenness index (Pielou 1966).

Multivariate analyses were used (1) to identify environmental parameters that were most strongly associated with each other, and (2) to define environmental factors to phytoplankton species associations. Principal component analysis (PCA) (Ter Braak 1986) was used to identify trends between highly correlating physicochemical parameters. Afterwards, the possible relationship between physicochemical parameters and green algae from the ponds were subjected to canonical correlation analysis (CCorA). A CCorA finds two sets of basis vectors, one for x and the other for y, such that the correlation between the projections of the variables onto these basis vectors are mutually maximized (Hotelling 1936). Ordination analyses (PCA and CCorA) were carried out using XLSTAT-ADA software for windows.

Temporal and spatial difference of mean physicochemical parameters and metal concentrations were determined using a two analysis of variance (ANOVA) at 5% significance level.

Results

Eletrical conductivity (EC) of the ponds increased gradually in the dry months with the highest value of 429.5 µS cm $^{-1}$ in January for Aviation Quarry Pond. From June 2006, EC declined to the lowest value of 60 µS cm^{-1} for Kabama Pond in August (figure 1). Changes in EC observed were significantly different ($P < 0.05$) between the study ponds (table 1). Variations in TDS were similar to those observed for EC. Aviation Pond also had the highest amount of dissolved solids. The highest TDS (209 mg L^{-1}) was recorded in January for Aviation Quarry Pond. However, higher values were recorded in the wet months when compared to the dry months (figure 1). Values of pH in these ponds fell within a range of 5.9-8.3 (figure 1). Throughout this study, the water temperature values ranged from 26.9 - 28.7 °C in all ponds. The lowest value (25.9 °C) was recorded in November 2005 for Danmika Pond (figure 1). The highest DO concentration recorded (5.35 mg L^{-1}) was for Danmika Pond in December. Lower dissolved oxygen values were observed in the dry months than the wet months (figure 1). Although, the highest BOD concentration (1.70 mg L^{-1}) was observed in August 2006 for Kabama Pond, higher values were recorded in the dry months (figure 1). Alkalinity and water hardness significantly differed between the studied ponds. However, only water hardness showed significant monthly variation throughout this study (table 1). There was a general increase in alkalinity from November to December and then a decrease observed in Mairabo and Kabama ponds in January. In Aviation Quarry Pond, the highest value (17.0 mg L^{-1}) for the whole study was recorded in January (figure 1). Water hardness on the other hand had higher values during the wet months than in the dry months. The highest value of 5.0 mg L^{-1} was recorded in Aviation Quarry Pond in June (figure 1). Analysis of variance showed that there was significant difference between ponds and months for nitrate concentration (table 1). Higher nitrate concentrations were recorded in the dry months than in the wet months, while higher phosphate concentrations were observed in the wet months (figure 1).

The concentration and distribution of trace elements over time in the different ponds are shown in figure 2. All the trace elements except cobalt analyzed had higher concentrations in the dry months. Cobalt concentration increased and decreased over time without having a defined pattern. The concentrations of copper, arsenic and zinc significantly ($P < 0.05$) varied from month to month, while those of nickel and

Table 1. Results of ANOVA analyses for physicochemical parameters and metals analyzed in the selected ponds. (TDS = total dissolved solids; EC = electrical conductivity; DO = dissolved oxygen; Water Temp = water temperature; BOD = biochemical oxygen demand; PO_4-P = phosphate phosphorus; NO_3-N = nitrate nitrogen).

	Ponds		Months	
	F value	P value	F value	P value
BOD	2.01	0.16	1.69	0.20
Alkalinity	5.24*	0.01	1.66	0.20
Water hardness	3.96*	0.03	6.91*	0.00
PO_4-P	0.73	0.55	1.75	0.18
NO_3-N	3.09	0.06	2.90*	0.05
DO	1.86	0.18	0.36	0.87
Water temp	1.13	0.37	0.69	0.64
EC	6.19*	0.01	0.98	0.46
pH	1.96	0.16	1.83	0.17
TDS	2.00	0.16	0.18	0.97
Mn	1.02	0.41	2.06	0.13
Co	1.85	0.18	1.60	0.22
Ni	1.95	0.17	3.72*	0.02
Cu	1.50	0.26	4.17*	0.01
Zn	1.31	0.31	4.25*	0.01
As	1.47	0.26	6.88*	0.00
Pb	1.41	0.28	6.23*	0.00
Fe	1.91	0.17	1.07	0.41

* Significant at $P < 0.05$.

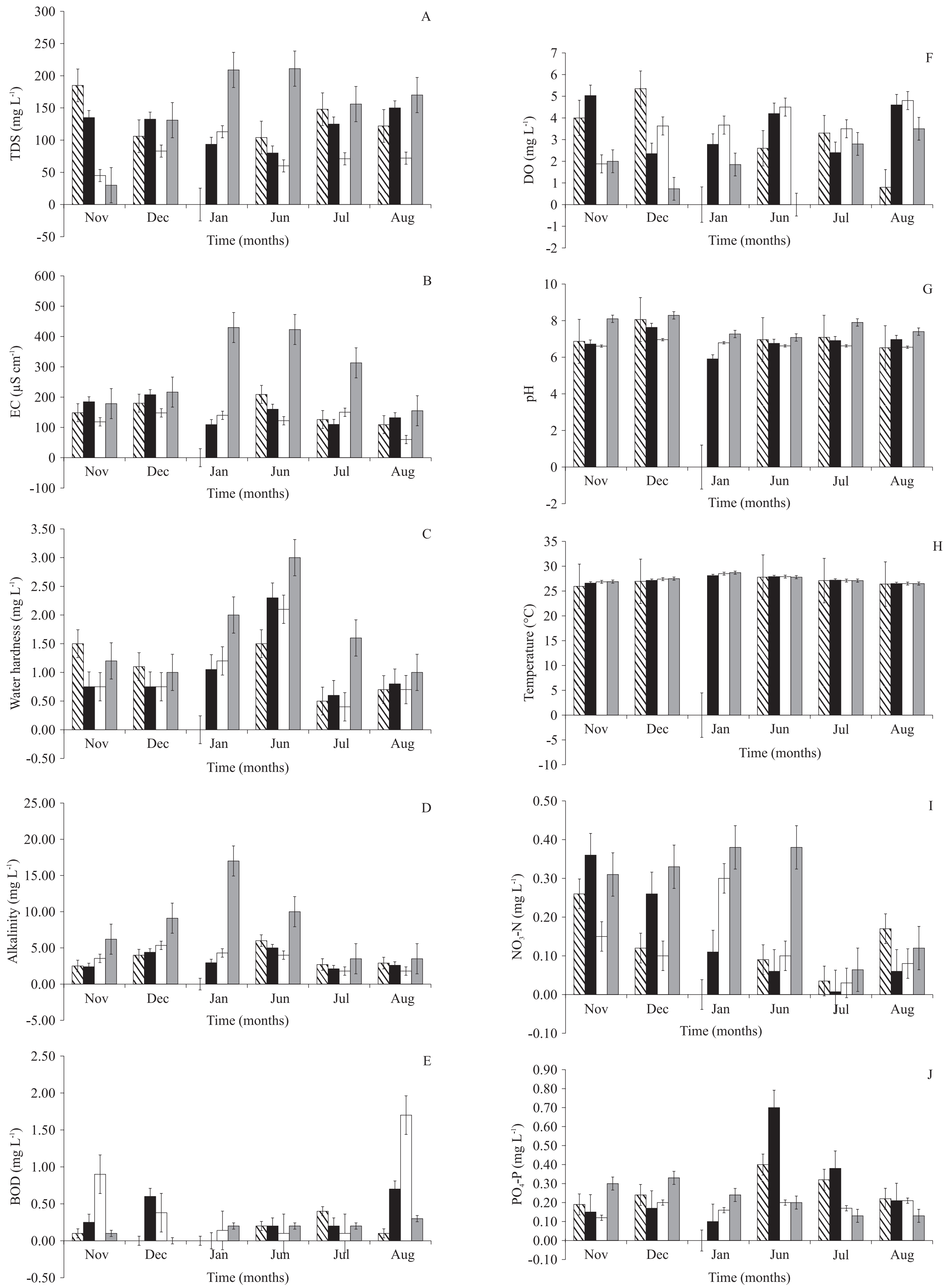

Figure 1. Temporal and spatial variation of (a) total dissolved solids (TDS); (b) electrical conductivity (EC); (c) water hardness; (d) alkalinity; (e) biochemical oxygen demand (BOD); (f) dissolved oxygen (DO); (g) pH; (h) temperature; (i) nitrate (NO_3-N); (j) phosphate (PO_4-P) of the studied ponds in Zaria, Nigeria. Bars represent standard error for $n = 4$. (▧ = Danmika pond; ■ = Mairabo pond; □ = Kabama pond; ▒ = Aviation quarry pond).

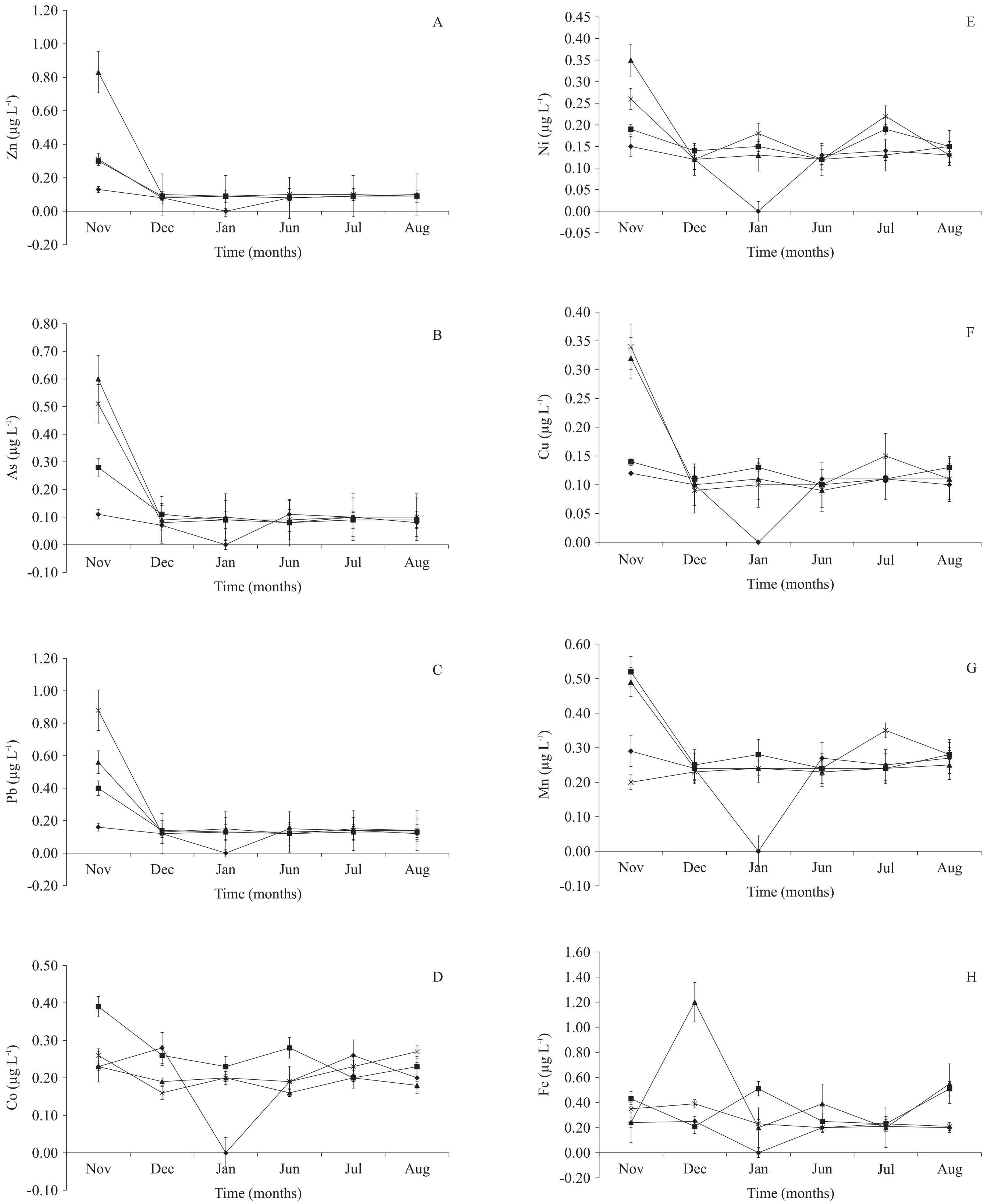

Figure 2. Changes in (a) Zinc (ZN); (b) Arsenic (As); (c) Lead (Pb); (d) Cobalt (Co); (e) Nickel (Ni); (f) Copper (Cu); (g) Manganese (Mn); (h) Iron (Fe) concentrations of the studied ponds. Bars represent standard error for $n = 4$. (–◆– = Danmika pond; –■– = Mairabo pond; –▲– = Kabama pond; –x– = Aviation quarry pond).

lead significantly varied both temporally and spatially (table 1). The relationship between trace elements and physicochemical parameters using PCA showed that the contributions of most trace elements were distinct from those of the physicochemical parameters (figure 3). The highest eigen values recorded were for Mn (0.33), Ni (0.35) and Mo (0.36) to the first (F1) axis and Zn (-0.26) to the second (F2) axis. For physicochemical parameters, the highest contributions to the F1 axis in terms of eigen values were by pH (0.30), temperature (0.30), alkalinity (0.11) and nitrate nitrogen (0.19), while to the F2 axis TDS (0.38), EC (0.41), alkalinity (0.38), water hardness (0.36) and nitrate nitrogen (0.24) had the highest contributions (figure 3). The first and second axis of the PCA contributed to 56% of the total variation observed throughout the study.

A total of 27 green algal species divided into 16 families were recorded (table 2). *Stichococcus bacillaris* was found to have the highest relative abundance (65%) in all the ponds. With 50%, *Haematococcus lacustris* was next to *Stichococcus bacillaris* in abundance. The abundance of the remaining species was within the range of 12.5 to 37.5% in all the ponds. Diversity indices analyses of green algae from these ponds showed that Kabama Pond had the highest dominance index of 0.23, while Danmika Pond had the lowest dominance index of 0.14. Shannon diversity index analysis showed that Danmika Pond had the highest value of 2.39 while in Kabama Pond the least value of 1.75 was observed. Species evenness values ranged from 0.56 to 0.64 in all the ponds (table 3). Canonical correlation analysis of all the parameters analyzed showed that *Closterium* sp. and *Rhizoclonium hookeri* were closely positively associated with the concentration of Fe and sensitive to alkalinity, TDS and EC (figure 4). *Stichococcus bacillaris, Staurastrum rotula* and *Sphaeroplea* sp. had close positive association with BOD, Mn, and Mo levels in the water. These species were however sensitive to alkalinity and phosphate phosphorus concentration. Sensitivity here means that as the concentration or levels

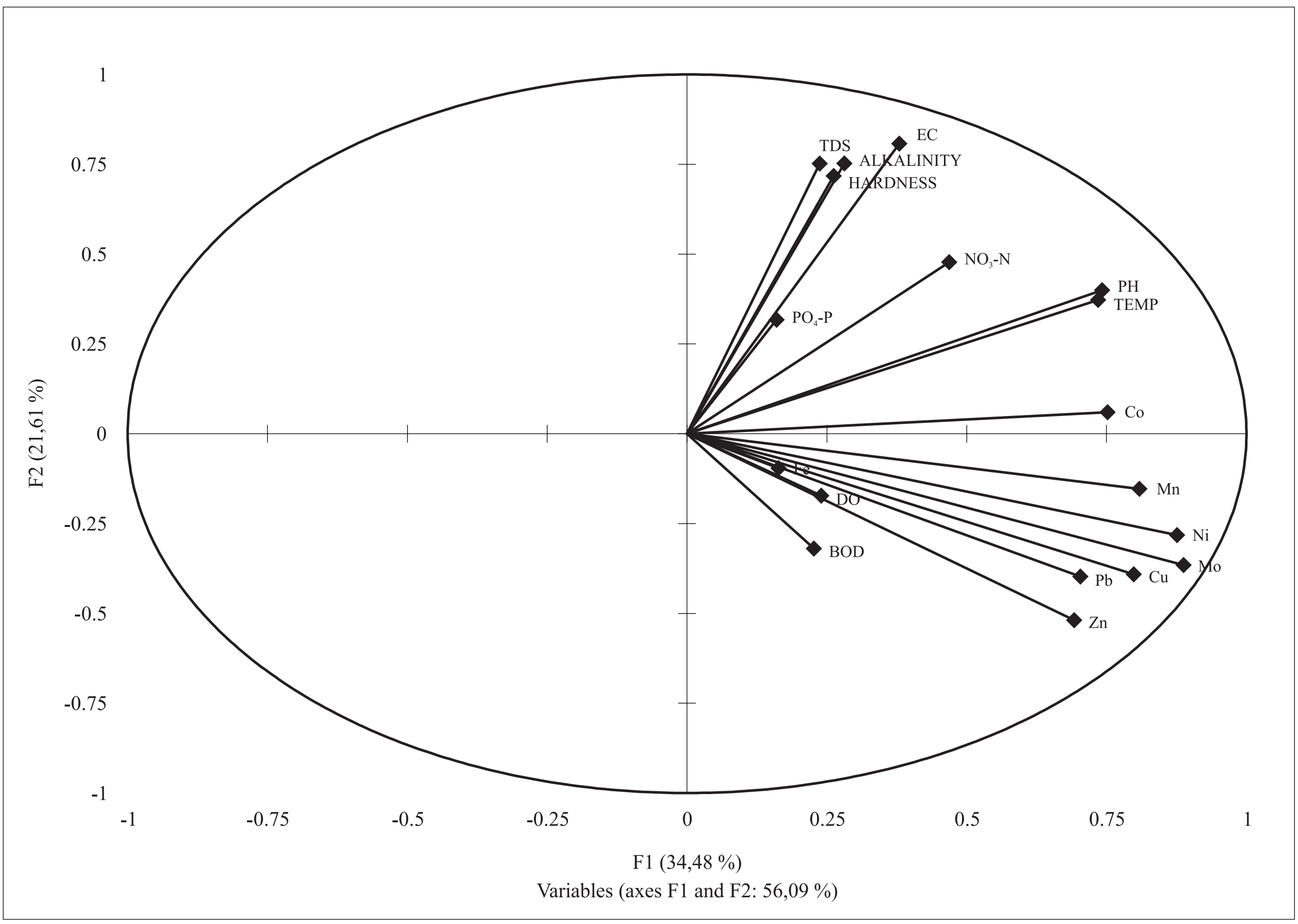

Figure 3. PCA analysis of the ten physicochemical parameters and eight metals analyzed for the selected ponds in Zaria, Nigeria.

Table 2. Occurrence of green algal species in selected ponds in Zaria, northern Nigeria. (– = absent; + = sparse; ++ = abundant; +++ = dominant; RA = relative abundance in percentage).

	Dry months				Wet months				
	Danmika	Mairabo	Kabama	Aviation quarry	Danmika	Mairabo	Kabama	Aviation quarry	RA (%)
Chaetophoraceae	+	–	–	–	–	–	–	–	12.5
Draparnaldia glamerata (Vauch.) Ag.	++	–	–	–	–	–	–	–	12.5
Pseudouvella americana (Snow) Wille.									
Chloroangiaceae	+	+	–	–	–	–	–	–	25.0
Chlorangium stentorinum (Her.) Stein									
Cladophoraceae	+	–	–	–	–	–	–	–	12.5
Dermatophyton radians Peter.	+	–	–	–	–	–	–	–	12.5
Pithophora oedogonia (Mont.) Wittr.	++	+	–	–	–	–	–	–	25.0
Rhizoclonium hookeri Kuetz.									
Desmidiaceae	–	–	++	–	+	–	+	–	37.5
Closterium sp.	++	+	–	–	–	–	–	–	25.0
Cosmarium panamense Presc.	–	+++	–	–	–	–	–	–	12.5
Micrasterias radiata Hass.	–	+	–	–	–	–	+	–	25.0
Staurastrum rotula Nordst.	–	–	–	++	–	+++	+	–	37.5
Xanthidium cristatum Hass.									
Endosphaeraceae	–	–	–	–	+	–	–	–	12.5
Rhodochytrium spilanthidis Lagerheim									
Eremosphaeraceae	–	–	–	–	+++	–	–	–	12.5
Eremosphaera sp.									
Gloeocystaceae	+	–	–	–	–	–	–	+++	25.0
Palmellopsis gelatinosa Korsch									
Haematococcaceae	–	–	+++	–	++	+	–	++	50.0
Haematococcuslacustris (Girod.) Rostaf.									
Hydrodictyaceae	–	+	–	+	–	–	–	–	25.0
Hydrodictyon reticulatum (L.) Lagerheim									
Oocystaceae	–	–	–	++	–	–	–	–	12.5
Ankistrodesmusbraunii (Naegeli)	–	–	–	+	–	–	–	–	12.5
Brunn.	+++	+	–	–	–	–	–	–	25.0
Cerasterias irregulare G. M. Smith	–	–	+	–	–	–	–	–	12.5
Chlorella parasitica Brandt.									
Selenastrum gracile Reinsch.									
Phacotaceae	–	–	+	–	–	–	–	–	12.5
Pedinopera sp.									
Polyblepharidaceae	+	–	–	–	–	–	–	–	12.5
Polyblepharides sp.									
Scenedesmaceae	++	–	–	–	–	–	–	–	12.5
Coelastrum microporum Naegeli.	–	–	–	++	–	+	–	+++	37.5
Scenedesmus quadricauda (Turp.) Bréb.									
Sphaeropleaceae	+	–	–	–	–	–	++	+	37.5
Sphaeroplea sp.									
Ulotrichaceae	+	+++	+	++	–	–	+++	–	65.5
Stichococcus bacillaris Naegeli									
Volvocaceae	–	–	++	+	–	–	+	–	37.5
Volvox tertius Meyen.									

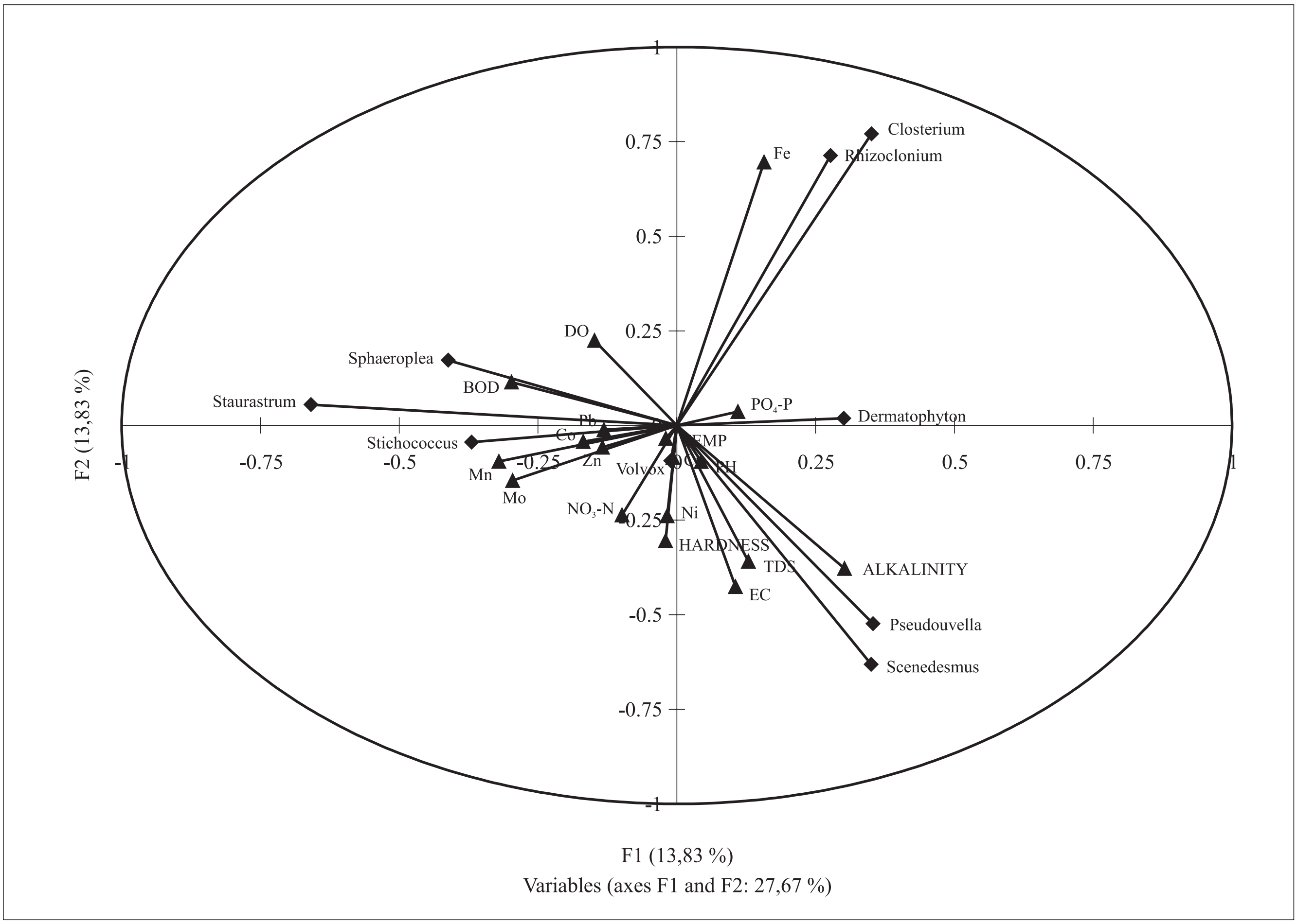

Figure 4. Canonical correlation analysis for the ten physicochemical parameters, eight metals and green algal species analyzed in the different ponds.

of the parameters increased or decreased, the number of individuals decreased or increased in the opposite direction to this variation. *Pseudouvella americana* and *Scenedesmus quadricauda* showed a positive association with alkalinity but were sensitive to Fe, BOD, Mn and Mo. The variations in the first two axis (cumulative eigen percentage) amounted to the 27.67% of the total variation observed for all parameters analyzed.

Table 3: Chlorophyta community structure indices for the different ponds studied

Water body	Indices		
	Dominance	Shannon	Evenness
Danmika pond	0.14	2.39	0.61
Mairabo Pond	0.22	1.90	0.56
Kabama Pond	0.23	1.75	0.64
Aviation Quarry Pond	0.21	1.92	0.62

Discussion

Variations in TDS and EC in the ponds are common to other lenthic water bodies found in Zaria and northern Nigeria (Chia *et al.* 2009a, b, 2010). These changes may be linked to climatic conditions, and human activities around the catchment which range from surface runoff of fertilizers from neighboring farms and other substances from the catchment area. The pH values were mostly maintained between the optimum range (6.5-8.5) for most biological activities. The only shift from this trend was observed in January in Mairabo pond where the pond was slightly acidic, which may have harmful effect on non tolerant algal species. According to Stumn & Morgan (1981) and Sunda *et al.* (2005), the correlation of pH and temperature with chromium, manganese, cobalt, nickel and copper could be attributed to the fact that the solubility and speciation of these metals in water are affected by them. Lower temperature values in the dry months are characteristic of the Harmattan season in northern Nigeria (Balarabe 2001), while resultant lower water volume in the ponds could be implicated for the increase temperatures in January. This is because most ponds were almost totally dried up at the end of this month. However, the values in the wet months did not significantly vary from those of the dry months. This finding agrees with those of Gobo (1988) and Chindah & Pudo (1991) for equatorial tropical areas. The absence of rains and high rates of evaporation are factors that best explain the high alkalinity values in the dry months in all four ponds studied. Kabama and Aviation Quarry ponds had high alkalinity values and also hardness mainly due to the anthropogenic activities around the catchment and the nature of the bed rock material (Balarabe 2001). The concentrations of DO and BOD of these pond fall within the range reported from other ponds and standing water bodies in Zaria (Chia *et al.* 2009a). Differences in the amount of nutrients (phosphate-phosphorus and nitrate-nitrogen) in these ponds may be from differential rates of nutrients entering them throughout the year. The sources of these materials are mainly feces from grazing animals, mining activities, untreated sewage and fertilizers from surrounding farmlands.

The growth of microalgae is not dependent only on a sufficient provision of essential macronutrient elements but also on a number of micronutrient metals (Sunda *et al.* 2005). Among these micronutrients are iron, copper, molybdenum, manganese and zinc of which their total concentrations were determined. Their concentrations varied from month to month between the wet and dry months. This variation may be controlled by the volume of water present in these ponds per time, which controls the dilution rate. As water levels decrease from evaporation and lack of rainfall, the concentrations of these metals also increase. This is supported by the fact that in the dry months, the highest concentrations of these metals were recorded. Other researchers have also reported higher trace element concentrations in periods of low or no rainfall than the wet months (Olaifa *et al.* 2004, Nguyen *et al.* 2005, Igbal *et al.* 2006). The sufficiency or deficiency of these metals for algal cells depends on the requirement of a given algal species, cellular metal concentration and the aqueous form in which they are present (Peterson 1982, Bates *et al.* 1982, 1983, Parent & Campbell 1994).

The changes in green algal populations in these ponds are as a result of their interactions with their physical, chemical and biological environment. The species that showed close association with the physicochemical conditions of the ponds may be useful tools for ecological water quality index analysis (Lacerda *et al.* 2004). Community analysis indices showed that species dominance was relatively low throughout this study in all the ponds. This is because the highest value recorded in this study was 0.23 in Kabama Pond, which means that no single species consistently had higher abundance than that the rest species. In addition, this is supported by the Shannon diversity index having an average value of two. The distribution of species in these ponds was relatively even. The values obtained in this study were on the high side. The community indices analysis of the green algal community structure shows that environmental conditions within these ponds were generally favorable to them (Rueda *et al.* 2002). Canonical correlation analysis implicated the trace elements as having the most significant association with some green algae species recorded in this study. Our results show that while some species could tolerate and thrive at certain levels of some physicochemical parameters, others showed sensitivity to the same parameters at these levels. The environmental requirements of different species differ, hence defining how they respond to variations in these factors. Le Jeune *et al.* (2006) reported that copper concentration in natural phytoplankton showed community structure and composition effects that were depended on season in which they were applied. They showed marked differential effects between spring and summer. These metals serve important metabolic purposes ranging from photosynthetic electron transport, respiratory electron transport, nitrate and nitrite reduction, sulfate reduction, dinitrogen fixation and detoxification of reactive oxygen species (Rueter & Ades 1987, Boyd *et al.* 2000, Sunda 2001, He *et al.* 2010).

Our study has shown that the occurrence and abundance of green algae species in these ponds are closely linked to their physicochemical characteristics. In addition, most parameters analyzed showed specific temporary and/or spatial variation.

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