Taxonomic Composition and Diversity of Phytoplankton Community in Kpassa Reservoir (Northern Benin)

Ousmane T. Boukari¹*, Youssouf Abou², Moctar L. Bawa³ and Daouda Mama¹

¹Laboratory of Applied Hydrology, Department of Hydrology and Integrated Management of Water Resources, National Institute of Water, University of Abomey-Calavi, Abomey-Calavi, P.O.Box 526, Cotonou, Benin.

²Laboratory of Ecology and Aquatic Ecosystem Management, Department of Zoology, Faculty of Sciences and Technics, University of Abomey-Calavi, Abomey-Calavi, P.O.Box 526, Cotonou, Benin.

³Laboratory of Water Chemistry, Department of Chemistry, Faculty of Sciences, University of Lomé, P.O.Box 1515 Lomé, Togo.

Authors’ contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
(2) Fábio Henrique Portella Corrêa de Oliveira, Universidade Federal Rural de Pernambuco, Brazil.
(2) Ibrahim M. Magami, Usmanu Danfodiyo, Nigeria.

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ABSTRACT

Aims: The present study was conducted to determine the taxonomic composition and the diversity of phytoplankton community in Kpassa reservoir.

Place and Duration of Study: The investigation occurred in Kpassa reservoir at 6 stations from August 2014 to May 2016.

Methodology: Microscopic observations and identification keys allowed to index phytoplankton taxa. Diversity was evaluated using species richness index (d), Shannon-Weiner index (Hs) and species equitability index (J). Means ± standard deviation, ANOVA, Kruskal-Wallis, Kolmogorov-Smirnov and Levene test were performed using SPSS 16.0.

Results: Current study recorded 52 phytoplankton taxa grouped as Conjugatophyceae (18 taxa), Diatomophyceae (16 taxa), Euglenophyceae (8 taxa), Cyanophyceae (5 taxa), Chlorophyceae (3 taxa).

*Corresponding author: E-mail: oboukari3@gmail.com;
1. INTRODUCTION

Anthropogenic activities exerce pressures resulting in numerous impacts on the aquatic ecosystems. Governed by complex interactions, these impacts can not be studied only on the basis of the chemical knowledge of water. The health of an ecosystem is better reflected by the characteristics of the biological communities [1].

The phytoplankton made up by the whole vegetal plankton, is a key component of the trophic networks [2,3]. At annual scale, phytoplankton community structure variations are observed in response to environmental conditions changes [4]. Phytoplankton blooms are evident indicator of eutrophication of aquatic systems, which arouses the interest of aquatic environment managers [5,6].

In Benin, there are four reservoir used to supply Parakou, Savaou, Djoougou and Savê cities in drinking water. Because of its eutrophication since 2000, Kpassa reservoir built on Okpara river to supply Parakou city in drinking water, were the subject of several studies on its physico-chemical and biological characteristics. [7] assessed the level of heavy metals pollution of water and sediments in Kpassa reservoir. [8] recorded flora and fauna of Benin ecosystem infested by the watery plants. [9] work concerned the development of a treatment process able to remove iron and manganese overloading from Kpassa reservoir water. [10] worked on iron and manganese speciation in sediments of Kpassa reservoir. [11] carried out a study on phosphorus speciation and trophic state in the sediments of Kpassa reservoir. [12] evaluated the degree of organochlorinated pesticides pollution in fish and water of Kpassa reservoir. To finish, [13] provided recent data on the physico-chemical characteristics of the reservoir. Of all this work, besides the eighteen phytoplankton species listed by [9] in water samples taken punctually, any study of abundance, specific richness, diversity and equitability of the phytoplankton community was carried out. However, it is to achieve such study that the present work aim at analyzing the taxonomic composition and the diversity of phytoplankton community in Kpassa reservoir.

2. MATERIALS AND METHODS

2.1 Study Area

Kpassa reservoir located at 13.5 km at East of Parakou city is used for drinking water production (Fig. 1). The Benin Company of Water and Energy (current National Company of Benin Water) started to supply Parakou city in drinking water since 1975 with raw water pumped from Kpassa reservoir. The dyke of the reservoir is built in laterite over a length of 480 m and a height of 10 m. Two overfall located on the Southern part of the reservoir are used to control

Keywords: Phytoplankton; taxonomic composition; diversity; Kpassa reservoir; Parakou; Benin.
the water level. The pumping station, equipped with two pumps of 350 m3/h each one, is installed on the reservoir at 105 m from the Western shoreline. A first treatment of the raw water is made \textit{insitu} before aspirated towards the treatment plant located at Banikani district in Parakou.

The basin of Kpassa reservoir covers the district of Bembérékè, Nikki, N’Dalí, Pèrèrè, Parakou and Tchaourou [14]. The portion of Okpara river delimited by the basin and its tributaries, Niessi, Nióré and Sabha with a length respectively of 41.5 km, 32 km and 18 km supply water to Kpassa reservoir [15]. The basin is under the influence of the Soudanian wet tropical climate. The wet season go from May to October and the dry season from November to April. The area is also under the influence of the wind called harmattan. The low temperatures recorded during the dry season are related to the occurrence of this wind.

Agriculture is the main activity of the study area. Breeding and fishing are also very practised. Breeding is developed and varied with bovines, sheep, caprine, porcine and poultry. Physical characteristics of Kpassa reservoir and its basin are shown in Table 1.

2.2 Sampling Procedure

Ten investigations were conducted at six sampling stations (Table 2) between August 2014 and May 2016 (Table 3). At each sampling station, samples were collected with conic phytoplankton net SDMO QUINIOU model F131P20 (mesh 20 μm, diameter 30 cm, length 90 cm) drag on 5 m in water sub-surface. The retained materials (250 ml) were preserved with 5% lugol solution and 4% formaldehyde. All samples were stored in ice containers during their transport to the laboratory.

### Table 1. Physical characteristics of the studied area [14,15]

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Kpassa reservoir</th>
<th>Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>N 9°17'034</td>
<td>N 9°16’ - N 9°58’</td>
</tr>
<tr>
<td>Longitude</td>
<td>E 2°43’975</td>
<td>E 2°35’ - E 3°04’</td>
</tr>
<tr>
<td>Lenght (km)</td>
<td>15</td>
<td>117</td>
</tr>
<tr>
<td>Lenght of Shoreline (km)</td>
<td>-</td>
<td>217</td>
</tr>
<tr>
<td>area (ha)</td>
<td>190</td>
<td>207,000</td>
</tr>
<tr>
<td>depth (m)</td>
<td>4.5 - 9</td>
<td>-</td>
</tr>
<tr>
<td>Volume (m$^3$)</td>
<td>5.750,000</td>
<td>269.000,000</td>
</tr>
<tr>
<td>Discharge (m$^3$/s)</td>
<td>0.001 - 150</td>
<td>-</td>
</tr>
<tr>
<td>Overflow-discharge (m$^3$/s)</td>
<td>400</td>
<td>-</td>
</tr>
<tr>
<td>Interannual average pluviometry (mm)</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>

### Table 2. Description of the sampling stations established in Kpassa reservoir [13]

<table>
<thead>
<tr>
<th>Sampling stations</th>
<th>Characteristics</th>
<th>Reason of sampling stations choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 1 (St1)</td>
<td>closer to the raw water pumping point of the national water company</td>
<td>- their accessibility;</td>
</tr>
<tr>
<td>Station 2 (St2)</td>
<td>closer to the East shore of the reservoir where cultural practices was made</td>
<td>- the localization of potential sources of pollution;</td>
</tr>
<tr>
<td>Station 3 (St3)</td>
<td>along the West shore of the reservoir near Kpassa village</td>
<td>- the phytoplankton ecology.</td>
</tr>
<tr>
<td>Station 4 (St4)</td>
<td>Kpassa village</td>
<td></td>
</tr>
<tr>
<td>Station 5 (St5)</td>
<td>in the middle of the dam</td>
<td></td>
</tr>
<tr>
<td>Station 6 (St6)</td>
<td>in upstream of the dam</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Description of the sampling months and corresponding seasons

<table>
<thead>
<tr>
<th>Months</th>
<th>Seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-14</td>
<td>rainy</td>
</tr>
<tr>
<td>Oct-14</td>
<td>rainy</td>
</tr>
<tr>
<td>Dec-14</td>
<td>dry</td>
</tr>
<tr>
<td>Febr-15</td>
<td>dry</td>
</tr>
<tr>
<td>April-15</td>
<td>dry</td>
</tr>
<tr>
<td>Sept-15</td>
<td>dry</td>
</tr>
<tr>
<td>Nov-15</td>
<td>rainy</td>
</tr>
<tr>
<td>Jan-16</td>
<td>dry</td>
</tr>
<tr>
<td>March-16</td>
<td>dry</td>
</tr>
<tr>
<td>May-16</td>
<td>rainy</td>
</tr>
</tbody>
</table>

2.3 Phytoplankton Analysis

Each subsample (250ml) was homogenized carefully before enumeration and identification procedure.

For qualitative analysis, one drop between slide and slip cover were observed three times using microscope Zeiss Axio Imager.M2 (magnification ×100) equipped with an image acquisition system. Identification was made at the possible taxonomic level using the keys of [16-18]. Some additional monographs and papers were also used for taxonomic identification [19-24].

Phytoplankton sampled was enumerated using standard operational procedures [25]. A subsample of 1 ml was placed in the Sedgwick-Rafter counting slide. Phytoplankton taxa were counted in the entire counting slide using

Fig. 1. Map of the location of monitoring stations in Kpassa reservoir [13]
microscope Labomed Lx 400 (magnification ×100). Colonies and filaments were counted as individuals. Because of the richness of some samples in particles and organisms, dilution has been necessary.

2.4 Data Analysis

Phytoplankton abundance was assessed using [25] formula as follows:

\[ N = \frac{n \times V_2}{V_1} \]

N = abundance in number of phytoplankton individuals per milliliter of water filtered by the net.  
\( n \) = average number of phytoplankton individuals counted in 1 ml of sample observed in microscope.  
\( V_1 \) = volume of total water filtered by the net in liter.  
\( V_2 \) = volume of plankton concentrated in milliliter.

The three indexes below were used to assess the diversity of the phytoplankton community:

1. Species richness index (d) evaluated using [26] function as follows:

\[ d = \frac{(S-1)}{\log_2 n} \]

\( S \) = number of species in the sample and \( n \) is the total number of individuals in the \( S \) species.

2. Diversity index (Hs) calculated using [27] formula as follows:

\[ Hs = -\sum_{i=1}^{S}(P_i \log_2 P_i) \]

\( i \) = count denoting the ith species ranging from 1 to \( S \), \( S \) is the number of species in the sample.  
\( P_i \) = ratio between the number of individuals of the ith species and the total number of individuals in the sample.

3. Equitability index (J) evaluated according to [28] formula as follows:

\[ J = \frac{Hs}{\log_2 S} \]

\( Hs = \) Shannon-Weaver index and \( S \) is the number of species in the sample.

Statistical analysis was carried out using SPSS (Statistical Package for the Social Sciences) software version 16.0. Total abundance was expressed as means ± standard deviation for each month. ANOVA and Kruskal-Wallis test was used to analyse the variance of phytoplankton abundance and diversity between sampling locations and seasons. ANOVA was used after verify the normality (One-Sample Kolmogorov-Smirnov test) and the homogeneity of variables (Levene test). When these conditions are not verified, the Kruskal-Wallis test was used.

3. RESULTS AND DISCUSSION

3.1 Phytoplankton Community Composition

The results of phytoplankton analysis in Kpassa reservoir showed the presence of 52 taxa distributed in 7 classes (Table 4). The images of some taxa recorded are shown in Fig. 2. [9] reported 18 taxa in the same reservoir. The 34 additional taxa recorded is due to the sampling frequency in the present study. The number of taxa in Kpassa reservoir is low but higher than those reported for some reservoirs of tropical and temperate area. 22 species were identified in Sidi Saâd reservoir in Tunisia [29] and 47 species in Rewalsar lake in India [30]. Conjugatophyceae and Diatomophyceae have the greatest number of taxa (respectively 18 taxa and 16 taxa), followed by Euglenophyceae (8 taxa), Cyanophyceae (5 taxa) and Chlorophyceae (3 taxa) (Table 4). Dinophyceae and Xanthophyceae are represented by only one species each one (Table 4). Similar conditions of Conjugatophyceae and Diatomophyceae prevalence were observed in south of Benin [31] and Côte-d’Ivoire [32]. Diatomophyceae are more representative in Lake Ahémé with 24 taxa [31]. Conjugatophyceae are richest in taxa in Fresco lagoon, with 23 taxa [32]. Phytoplankton composition reflects the overall ‘health’ status of an aquatic system and its suitability for different uses [33]. Among the two predominant taxa in the present study, Diatomophyceae are recognized to be a good indicator of the level of rivers eutrophication because of their sensitivity to nutrients and organic matter [34]. They are especially adapted to cold and turbulent water [35]. Their predominance in Kpassa reservoir could thus indicates organic pollution and high enriched water. The high enrichment of the
reservoir was confirmed by [9] and [36] who respectively classified the reservoir as eutrophic and hypertrophic. The organic pollution could be due to organic matter produced by aquatic plants covering the reservoir on about 90% of its surface [37].

Fig. 2. Images of some taxa of phytoplankton community in Kpassa reservoir. (a) Phacus longicauda; (b) Peridinium sp.; (c) Micrasterias radiosa; (d) Micrasterias sp.; (e) Staurodesmus sp.; (f) Euglena oxyuris; (g) Eudorina sp.; (h) Anabaena sp.
Table 4. Taxonomic composition of phytoplankton in Kpassa reservoir

<table>
<thead>
<tr>
<th>Classes</th>
<th>Number of taxa</th>
<th>Names of taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyceae</td>
<td>5 taxa</td>
<td>Anabaena Bory de Saint-Vincent ex Bornet &amp; Flahaut (WoRMS), Chroococcus turgidus (Kützing) Nägeli (ab), Coelosphaerium sp., Microcystis aeruginosa (Kützing) kützing, Nostoc sp.</td>
</tr>
<tr>
<td>Chlorophyceae</td>
<td>3 taxa</td>
<td>Eudorina sp., Pediastrum duplex Meyen (ab), Spirogyra sp.</td>
</tr>
<tr>
<td>Dinophyceae</td>
<td>1 taxa</td>
<td>Peridinium sp.</td>
</tr>
<tr>
<td>Xanthophyceae</td>
<td>1 taxa</td>
<td>Goniochloris fallax Fott.</td>
</tr>
</tbody>
</table>

3.2 Total Abundance of Phytoplankton

Fig. 3 shows the variation of total abundance of phytoplankton in Kpassa reservoir. It ranged between 706 ± 140 individuals/mL (October 2014) and 25828 ± 4642 individuals/mL (January 2016). The total abundance presents its maximum values during dry season (December 2014 and January 2016). It decreases then in rainy season where it reaches its minimal values in August and October 2014. According to [38] and [39], the tropical lakes and reservoirs do not experience marked seasonal fluctuations and thus do not exhibit variations in stocks of phytoplankton species composition. These notices are not confirm in Kpassa reservoir because the monthly distribution of the total abundance of phytoplankton reveals a clear seasonal variation so that minimum abundances are recorded in rainy season (August 2014, October 2014, September 2015 and May 2016) and the maximum in dry season (December 2014 to April 2015 and November 2015 to March 2016). This is testify by the Kruskal-Wallis test which revealed that the total abundance showed significant differences ($P = .00$) between seasons (Table 5). There were no significant differences ($P = .76$) between sampling sites (Table 5). The peak of phytoplankton abundance recorded in December 2014 and January 2016 coincides with the arrival of Harmattan. Indeed, this wind appear in December and January inducing a significant decrease of temperature. Generally, water temperature, nutrients, light availability and hydrologic regime are the primary variables influencing phytoplankton growth [40-42]. The cold temperatures which occur in December and January could explain the phytoplankton bloom observed during this month. Phytoplankton also need nutrients like nitrogen, phosphorus and
silica to grow [35]. These nutrients come from grounds leaching or urban waste water. One of the geochemical particularities of our study area is the presence of silica in high proportions (57 to 74%) [9]. High values of total phytoplankton abundance recorded could be thus due to silica but further work should be done to confirm the link. Under favourable conditions, diatoms may form blooms [43]. [44] stated that the growth of diatoms is highly dependent on the presence of dissolved silica in water. Several works also presented silica like a necessary element to the growth of Diatoms [45,46]. It is therefore likely that total phytoplankton abundance is directly dependent of Diatomophyceae abundance. Low values of total abundance could be attributed to the grazing pressure of zooplankton on phytoplankton. According to [47], zooplankton contributes significantly to the clarification of water in lakes and reservoir by the chattering of phytoplankton. On the other hand, this could also due to the presence of large number of aquatic plants which lack phytoplankton get sufficient light quantity to do the photosynthesis process.

3.3 Phytoplankton Diversity

3.1.1 Species richness index (d)

Fig. 4 presents the spatio-temporal variation of species richness expressed by [26] index. Highest values of species richness are recorded in August and October 2014 (rainy season), ranging from 1.71 at station St2 to 2.67 at station St1. The lowest values (0.64 to 1.03) were detected in December 2014 and November 2015 (dry season). This seasonal variability is corroborated by the Kruskal-Wallis test which revealed a significant variation (P = .00) of the specific richness between the seasons (Table 5). The spatial variation is less (P = .98) during months (Table 5). According to [48], the increase of cellular density generally coincides with the decrease of species richness and vice versa. High increase of abundance observed during December 2014 and January 2016 (Fig. 3) could justify the low values of species richness detected during this month. During the other months, the specific richness fluctuated between 0.91 at station St5 and 1.62 at station St3. Phytoplankton diversity is widely used as biological determinates of water quality in lakes and reservoirs. A high diversity suggests a healthy ecosystem; the reverse of this indicates a degraded environment [49]. High values of species richness recorded in the present study thus indicate clean water of Kpassa reservoir. Low values reflect a degraded water quality of the reservoir.

3.1.2 Diversity (Hs) and equitability (J) index

Diversity index is often accompanied by equitability index to the fact that it is necessary to taking into account the two indexes to appreciate the state of an environment [50]. Figs. 5 and 6 represent the spatio-temporal variations of diversity and equitability index in Kpassa reservoir. These figures reveal a similar evolution of the two indexes in time and space. ANOVA test showed that there were no significant differences of these index (P = .97; P = .96) between sampling stations but the difference between seasons is very significant (P = .00; P = .00) (Table 5). The greatest diversity index are obtained in rainy season (August 2014, October 2014, September 2015 and May 2016) with values ranging from 2.16 bits/individuals at station St6 to 2.98 bits/individuals at station St1. Equitability follows the same evolution than diversity but the high values of equitability index ranged from 0.50 to 0.64 at station St1 and St5. The station St1 which recorded the greatest Shannon index (2.98 bits/individuals) appears being the most stable site. This stability is corroborated by its higher equitability index (0.64) but the standard value of 0.80 retained by [51] as a stable community index is not reached. Minimum values of diversity and equitability (Hs = 0.30; J = 0.09) are observed at station St4 during December (dry season) because of the high abundance obtained during this month (Fig. 3). During the other months, the diversity and equitability index values fluctuated respectively between 0.50 at station St1 and 2 bits/individuals at station St2, and 0.13 at station St1 and 0.49 at station St2. Species diversity index and evenness index could be considered as explanatory variables of eutrophication levels, which to some degree are interrelated [49]. High diversity and evenness index noted in Kpassa reservoir could be a reflection of a stable trophic status. Low values may reveal a eutrophic reservoir. Fertilizers and pesticides used in agricultural and pastoral activities undertaken in the reservoir basin added to soaps used in washing and crockery activities along the reservoir river may be the principal cause of the deterioration of the reservoir water quality. The aquatic plants which cover the reservoir on about 90% of its surface [37] were also found to induce organic pollution.
Fig. 3. Monthly variation of total phytoplankton abundance (mean ± standard deviation) in Kpasa reservoir.

Fig. 4. Monthly and spatial variation of phytoplankton species richness index (d) in Kpasa reservoir.

Table 5. p-probability (Sig.) of One-Sample Kolmogorov-Smirnov test, Levene test, ANOVA test and Kruskal-Wallis test.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Kolmogorov-Smirnov test Sig.</th>
<th>Levene test Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total abundance (individuals/mL)</td>
<td>0,01</td>
<td>0,04</td>
</tr>
<tr>
<td>Species richness index (d)</td>
<td>0,11</td>
<td>0,01</td>
</tr>
<tr>
<td>Diversity index Hs (bits/individuals)</td>
<td>0,82</td>
<td>0,85</td>
</tr>
<tr>
<td>Equitability index (J)</td>
<td>0,34</td>
<td>0,89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
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<th>ANOVA test Sig.</th>
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<tbody>
<tr>
<td>Diversity index Hs (bits/individuals)</td>
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<td>0,00</td>
</tr>
<tr>
<td>Equitability index (J)</td>
<td>0,96</td>
<td>0,00</td>
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</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Kruskal-Wallis test Sig.</th>
<th>Kruskal-Wallis test Sig.</th>
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</thead>
<tbody>
<tr>
<td>Total abundance (individuals/mL)</td>
<td>0,76</td>
<td>0,00</td>
</tr>
<tr>
<td>Species richness index (d)</td>
<td>0,98</td>
<td>0,00</td>
</tr>
</tbody>
</table>
Fig. 5. Monthly and spatial variation of phytoplankton diversity index (Hs) in Kpassa reservoir

Fig. 6. Monthly and spatial variation of phytoplankton equitability index (J) in Kpassa reservoir

4. CONCLUSION

The study contributed to the knownledge of the taxonomic composition and diversity of phytoplankton in Kpassa reservoir. The results revealed the presence of 52 phytoplankton taxa distributed in 7 classes. Conjugatophyceae and Diatomophyceae have the greatest number of taxa. Diatomophyceae occurrence suggests organic pollution and high enriched water. The total abundance of phytoplankton reveals seasonal variation. The prevalence of harmattan in December and January could be responsible of the phytoplankton bloom observed during these months. Silica could also be on the basis of high total phytoplankton abundance recorded during the study. Total phytoplankton abundance is likely directly dependent of Diatomophyceae abundance. The species richness, diversity and equitability showed that August and October (rainy season) represent the stability periods of the phytoplankton community in Kpassa reservoir. Station St1 close to raw water pumping point of the National Company of Benin Water is most stable. Low values of species richness indicate a degraded water quality of Kpassa reservoir. Low values of diversity and evenness reveal a eutrophic state of the reservoir. Agricultural, pastorals, washing and crockery activities undertaken in the reservoir basin may be the principal cause of the deterioration of the reservoir water quality. The presence of aquatic plants was also found to induce organic pollution. The three indexes and total abundance did not
show significant differences between sampling sites but the difference between seasons is very significant.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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