RESEARCH ARTICLE   **OPEN ACCESS**

MICROBIOLOGICAL AND PHYSICO-CHEMICAL QUALITY OF THE ZIGA DAM LAKE IN BURKINA FASO

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ARTICLE INFO

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ABSTRACT

The practice of activities on the shores of the Ziga Dam Lake involves the use of products that can affect the quality of its water, thus upsetting the ecological balance of the environment. In order to prevent this damage, it is necessary to regularly monitor the quality of the lake's water, because without this, no decision can be taken to protect it. The objective of this study is to evaluate the microbiological and physico-chemical quality of the dam lake. For this purpose, we evaluated in 16 water samples taken from the lake, the concentrations of coliforms, fecal streptococci, *Escherichia coli*, suspended solids, ammonium, nitrite, nitrate, and orthophosphorus. Electrical conductivity, pH and temperature were measured during the collection of the 16 samples. The results of the analyses show that the micro-organism load varied between 10,000 UFC/100 ml and 60,000 CFU/100 ml for coliforms, 1,500 CFU/100 ml and 20,000 CFU/100 ml for faecal streptococci and 100 CFU/100 ml and 1,300 CFU/100 ml for *E. coli*. The mean values of the physico-chemical parameters measured were 1.63 ± 0.28 mg/l for ammonium, 14.13 ± 4.62 mg/l for suspended solids, 95 ± 29.12 µS/cm for electrical conductivity, 1.37 ± 1.43 mg/l for nitrates, 0.06 ± 0.01 mg/l for nitrites, 0.22 ± 0.03 mg/l for ortho phosphates, 7.72 ± 0.12 for pH and $21.74\pm0.93°C$ for temperature. It appears from this study that parameters such as conductivity, nitrates, nitrites, pH, phosphorus and temperature are favorable to maintain its quality. On the other hand, parameters such as ammonium and suspended solids show values that exceed the standards set by the state of Burkina Faso. Given the importance of this dam lake in the region, the use of the banks and even the water from the dam must be monitored more closely. Indeed, these punctual measurements carried out give an idea of the degradation of the water quality. In addition, the concentrations of the less acceptable microorganisms (coliforms, streptococci and *E. coli*) can quickly change and endanger the lives of consumers.

INTRODUCTION

In sub-Saharan African countries, more than a priority, the problem of access to water is a question of survival (Ba, 2009). In Burkina Faso, we note the existence of significant local disparities likely to create an imbalance between the locally available resource and demand. This is particularly the case for the considerable punctual (urban) needs in crystalline basement areas that cannot be met from groundwater (Cecchi et al., 2005). The country continues to move resolutely towards the continued creation of water reservoirs such as the Ziga dam in the center of the country. Dependent on surface water (DGRE, 2001), this dam is intended to supply drinking water thanks to the installation of a treatment plant.

The populations located near the dam go there to withdraw water for consumption and domestic activities (Ouattara et al., 2012). Today, the sustainability of water from the Ziga Dam faces many challenges given its multiple uses. Agricultural inputs and animal dejecta are a potential source of pollution of the lake water. Indeed, for Leight et al (2010) and Sass et al (2010), agricultural intensification is the main cause of degradation of aquatic ecosystems. Bouloud et al. (2001) found that the degradation of the raw water quality of the lake can lead to an excessive proliferation of microscopic algae leading to visual and olfactory nuisances and a disruption of the ecological balance of the environment. In view of these potential risks, the objective of our study was to evaluate the

microbiological and physico-chemical quality of the Ziga dam lake.

METHODOLOGY

Study area : The study was carried out at the Ziga dam located in the Nakambé (White Volta) watershed and is situated between latitude 12°29'21.44"North and longitude 1°7'25.84"West. The dam is located in the rural commune of Nagreongo in the southeastern part of the Oubritenga province, which is itself located in the Central Plateau region (Map 1). The capital of the commune is 18 km from Ziniaré and 38 km from Ouagadougou. The commune of Nagréongo is bordered to the northeast by the rural commune of Absouya, to the southwest by the commune of Koubri (Kadiogo province), to the east by the commune of Zam (Ganzourgou province), to the west by the commune of Saaba (Kadiogo province), and to the northwest by the commune of Ziniaré.

Characteristics and purpose of the Ziga Dam: With a surface area of 8,872.5 hectares, the Ziga dam mobilizes an estimated 208 million m3 of water during flood periods. The dam is 18.80 m high and 3,154 m long. The length of the spillway is 120 m. All these characteristics give it a drinking water production capacity of 3,000 m³/h with the possibility of extension to 4,500 m³/h and 9,000 m³/h. The main objective of the Ziga dam is to supply the city of Ouagadougou with drinking water. It has been in operation since 2004 and supplies 70% of the city and the communes of Ziniaré, Loumbila and Donsin with drinking water (ONEA, 2002).

Collecting water samples: The samples were taken downstream of the dam at about 1000 meters from the dyke. Sixteen (16) sampling points were identified using GPS (map 2). This area is easily accessible and is the place where the animals drink and is distant from the market garden plots by about 500 m. The sampling points are about 200 m apart from each other. Before any sampling was carried out between 7 am and 9 am, pH, temperature and conductivity were measured at each point using a multi-parameter meter. Each sample was taken by hand, using sterile 1000 ml plastic bottles. The sampling depth was 15 centimeters. After sampling, the vials were labelled and transported immediately to the laboratory for analysis within 24 hours.

Analysis of water samples

Dosing parameters : In the laboratory, the parameters measured are coliforms, fecal streptococci, Escherichia coli colonies, ammonium, suspended solids, nitrates (NO_3^-), nitrites (NO_2^-), ortho phosphates (PO_4^{3-}). The samples are placed in graduated glass tubes. The measurement of each parameter was made on a given volume of sample (Table 1). The analyses were done in accordance with ISO standards (Afnor, 2005), in particular the NF EN ISO/CEI 17025 standard which is specific to the analysis laboratory. Its field of application is extended to sampling. Methodologies, quality control, reliability of results and the guarantee of competence and independence are taken into account in this standard (Zoundi, 2008).

Research and enumeration of coliforms and faecal streptococci

Operating procedure

The method used to search for fecal coliforms and streptococci is that of Rodier et al. (2009). This method is done by inoculation as follows:préparer un milieu de culture (m *Enterococcus*) ;

- Pour 15 ml of the culture medium into 16 different Petri dishes;
- add 1 ml of one of the samples to the contents of each of the Petri dishes using a sterile pipette ;
- then carefully invert the plates to mix the medium and sample;
- finally, place the Petri dishes in an oven at 37.5°C for 24 hours.

All manipulations were done under aseptic conditions, especially in the presence of a Bunsen burner.Colonies appear under a blue color for coliforms and pink or dark red for fecal streptococci. The count of colonies present on each Petri dish was made with the naked eye based on these indicator colors. In case of very large number of colonies, the surface of the Petri dish is subdivided into four equal parts and the total number of colonies on the dish is obtained by multiplying the number of colonies in one part by 4.The results are expressed in Colony Forming Units per 100 ml of water (CFU/100 ml). For each Petri dish, the total number of microorganisms was found by applying the formula below used by Gandji Mgbatou (2015) :

$$N \frac{n}{dv} 100$$

N (log10/100ml) = N (CFU/100 ml) * log10
N : number of bacteria required per 100 ml of sample
n : Number of characteristic colonies counted on the Petri dish
d : Dilution rate of the inoculated sample (1/4 for well water and 1/1000 for sump water)
v : Test volume (ml).
Since dam water is similar to well water, the dilution rate we used is 1/4.

Research and enumeration of *E.coli*

To search for E. coli colonies, we used the method of Rodier et al. (2009). The microorganisms were inoculated as follows:

- Prepare the culture medium(*Chromocult Coliform Agar ES*) ;
- Place 1 ml of one of the 16 samples in each of the Petri dishes containing 15 ml of culture medium ;
- Then carefully mix the culture medium and the sample;
- Finally, turn the plates over and place them in an oven at 44.5°C for 48 hours.

For each petri dish, we counted with the naked eye the number of colonies of *Escherichia coli* that appeared under a purple color. In case of a very large number of colonies, the surface of the Petri dish is subdivided into four equal parts and the total number of colonies on the Petri dish is obtained by multiplying the number of colonies in one part by 4.The results are expressed in Colony Forming Units per 100 ml of water (CFU/100 mm). For each Petri dish, the total number of microorganisms was found by applying the formula previously used to enumerate fecal coliforms and streptococci.

Ammonium : The measurements were performed with a DR/3800 spectrophotometer following the method of Hach (2009). They consisted of :

- Switch on the instrument and enter the number 380 for ammonium as specified in the analysis program ;
- Put 20 ml of each sample in different tubes;
- pipette and add 3 drops of each of the following reagents: "mineral stabiliser", "polyvinyl alcool" and"nessler" ;
- Shake for about 30 seconds or turn the tubes over several times to mix well;
- Then put 20 ml of distilled water in another tube only for "the blank" (sample without control reagent) ;
- After validating the spectrophotometer timer which lasts 1 min, carefully wipe the control tube with absorbent lotus ;
- Then place the control tube in the spectrophotometer and press "zero" ;
- Remove the control tube, now place the control tube of the sample to be read and proceed with the reading.

Suspended Solids (SS)

The SS concentrations were obtained by filtering through Whatman filters previously washed and dried at 105°C. The method for determining the mass of SS is that of Rodier et al (2009) described as follows:Bien homogénéiser les échantillons au préalable;

- Wash and dry the filters in the oven in the presence of a desiccator at 115°C for 1 hour and 30 minutes; weigh it to obtain a mass M1 (virgin filter in milligram)
- After filtering, the filters are recovered, dried in an oven at 115°C for 1 hour and 30 minutes and weighed using an electronic balance: the result is a mass M2 (filter + solid in milligram).

The volume of each filtered sample (Vp) being 100 ml, the concentrations (in milligram per liter) (CMES) in SS are obtained by the formula :

$$C_{MES} = \frac{(M2 - M1) \times 1000}{Vp}$$

Nitrates (NO_3^-) : The cadmium in the capsule reduces the nitrate in the sample. The nitrite ion reacts with sulfanic acid to form an intermediate diazonium salt. This salt reacts with Gentile acid to form an amber-colored complex. The reading is obtained at 500 nm (nanometers). Measurements are performed with a spectrophotometer type DR/3800 according to the method of Hach (2009). This method consists of:

- Switch on the unit and enter the number 355 for nitrate ;
- Put 10 ml of each of the 16 samples in 16 different tubes;
- Add one sachet of « nitraver » reagent to each tube;
- Shake the mixture for one (01) minute and let it stand for five (05) minutes.
- Then put 20 ml of distilled water in another tube only for "the blank".

The nitrate concentration value in milligram/liter (mg/l) is read immediately after the blank (sample without reagent) by inserting the cell into the meter. The "blank" reading measures a value of 0.00 mg/l when empty.

Nitrites (NO_2^-)

Nitrites are reduced to nitrogen oxide by iron sulfate in an acidic medium. The ferrous ions react with the nitrogen oxides

to form a greenish complex. The intensity of the color developed is proportional to the nitrite concentration. The reading is taken at 507 nanometers (nm). The measurements were made using a spectrophotometer type DR/3800 following the method of the company Hach (2009) whose steps are:

- Switch on the unit and enter the number 371 for nitrite ;
- Then put 10 ml of each of the 16 samples in 16 different tubes;
- Add one packet of nitriver reagent to each tube;
- Shake and let stand for twenty (20) minutes.
- Then put 20 ml of distilled water in another tube only for "the blank".

The nitrite concentration value (mg/l) is displayed immediately after the blank (sample without reagent) by inserting the cell into the meter. The "blank" reading measures a value of 0.00mg/l when empty. The tubes are cleaned thoroughly before measuring.

Ortho phosphates (PO_4^{3-}) : The determination of ortho phosphates by spectrometry is based on the formation, in an acid medium and in the presence of ammonium molybdate, of a phosphomolybdic complex that envelops a blue coloration when reduced by ascorbic acid. The reading is obtained at 880 nm.

The measurements were performed by the method of Rodier et al (2009), using a spectrophotometer of the DR/3800 type as follows:

- Switch on the unit and enter the number 490 ;
- Take and place 10 milliliters (ml) of each sample into the tubes;
- Add one sachet of the "phosphaver" reagent for each tube;
- Shake and allow to stand for two (02) minutes to allow the reagent to dissolve completely in the tubes.
- Then put 20 ml of distilled water in another tube only for "the blank".

The value for the phosphate concentration (mg/l) is read immediately after the value for the "blank" (sample without reagent). The "blank" readout measures a value of 0.00 mg/l when empty.

Data analysis and interpretation : The average values of the various parameters were compared to those of decree 2001-185 on standards for pollutant discharges into the air, water and soil in Burkina Faso, taken as a reference (Présidence du Faso).

RESULTS

Microbiological characteristics of the water of the Ziga dam lake. Microbiological analysis of the lake water have focused on the search for the indicator germs of fecal pollution, which are coliforms, fecal streptococci and E. coli colonies. The microorganisms (coliforms and fecal streptococci) in the Ziga dam lake vary from 3000 to 60,000 UFC/100 ml with an average of 28125±10117 UFC/100 ml for coliforms and from 1200 to 20,000 CFU/100 ml with an average of 6956.25 ±3045.34 CFU/100 ml for faecal streptococci (Figure 1). E. coli colonies ranged from a minimum of 100 CFU/100 ml

found at point 14 to a maximum of 1,300 CFU/100 ml found at point 3 with an average of 575±178.86 CFU/100 ml (Figure 2). A comparison of the averages of these three microorganisms shows a strong predominance of fecal coliforms (Figure 3).

Physico-chemical characteristics of the water of the Ziga dam lake : Table 2 summarizes the physico-chemical parameters obtained after measurement or dosage at the level of the dam lake.

Electrical conductivity, pH and temperature: With averages of 7.72±0.12 and 21.74±0.93°C respectively, the pH and temperature values did not vary too much at the sampling points. This is not the case for conductivity whose values went from a minimum of 70 250μS/cm and a maximum of 250μS/cm with an average of 95±29,12 250μS/cm (Table 2).

Suspended solids (SS): The suspended solids loading of Lake Ziga water varied widely from one sampling point to another (Table 2). It ranged from 3 mg/l to 32 mg/l. The mean value was of the order of 14.13±4.62 mg/l.

Ammonium, Nitrates, Nitrites et Orthophosphate: The mean values for ammonium, nitrate, nitrite and orthophosphate are 1.63±0.28 mg/l, 1.37±1.43 mg/l, 0.06±0.01 mg/l and 0.22±0.03 mg/l respectively (Table 2). There is no statistical difference between the averages of ammonium and nitrate contents (Figure 4). On the other hand, the averages of the nitrite and orthophosphate concentrations are different from each other, and different from the other averages (ammonium and nitrate).

Correlation between the different parameters : The principal component analysis shows a strong correlation between suspended solids (SS), nitrite and orthophosphorus, also between ammonium and pH and finally between faecal coliforms and streptococci (Figure 5). The latter (coliforms and streptococci) are opposed to an increase in temperature. An opposition is also observed between conductivity and ammonium.

DISCUSSION

Microbiological quality of dam water : Fecal coliforms and streptococci are mainly of animal origin (Ouhsassi, 2018). At the level of the Ziga dam, Sanogo et al. (2020) highlighted the risks of contamination linked to the direct watering of livestock. These microorganisms were studied by Ouédraogo (2016) at the Ouagadougou dams. He had found average coliform and E. coli colonies close to ours, respectively 21,000 CFU/100 ml and 600 CFU/100 ml. But the average of streptococcus colonies he found (12,000 CFU/100 ml) was higher than the average we found at Ziga.

Physico-chemical quality of the water of the Ziga dam lake
Electrical conductivity : The values measured in this study are higher than those found by Ouattara et al (2012) at the same dam. Indeed the values of this author varied between 60 μS/cm and 77 μS/cm. Nevertheless, our values are largely below the standards set at the level of the country which is 1000 μS/cm (Présidence du Faso, 2001).

However, Ouédraogo (2016) had found conductivities fluctuating between 1185 μS/cm and 1294 μS/cm at the dam n°1 of Ouagadougou.

Suspended Solids (SS) : Measured SS concentrations differ considerably from one point to another at the Ziga Dam. They are made up of fine dust particles varying around 14.13±4.62 mg/l. Two points showed values exceeding the national standard. This parameter therefore contributes to the degradation of the lake water quality. Our results are lower than those of Ouattara et al (2012) and Tapsoba et al (2016) who found mean values of 100 mg/l and 18 mg/l respectively in Ziga and Ouagadougou.

Hydrogen potential (pH) : With an average of 7.72±0.12, the pH values of the Ziga dam lake conform to the standards set (Presidency of Faso, 2001). Our results are very close to those of Neya (2011) who found values between 7.73 and 7.83 in the same dam lake. These basic values could be explained by the use of NPK around the dam (Sanogo et al., 2020).

Temperature : Previous studies at the level of the dam lake have given temperature values close to ours. Indeed, Botny-Capel (2015) had measured 23°C. However, our values ranged from 20.3°C to 24.45°C with an average of 21.74±0.93°C.

Ammonium, nitrates, nitrites and orthophosphate : Among these chemical elements, only the average ammonium concentrations exceed the country's standards (Presidency of Faso, 2001). Indeed, the standards set for ammonium, nitrate, nitrite, and orthophosphate are 1.5 mg/l, 50 mg/l, 0.2 mg/l, and 3.4 mg/l, respectively. Tapsoba et al (2016) found an average ammonium level of 0.26 mg/l at Ouagadougou Dam No. 3. As for nitrate, Ouattara et al. (2012) had a higher value than ours, which is of the order of 2 mg/l in the same dam. For nitrite, our results are slightly higher than those of Neya (2011) who found values close to 0.043 mg/l at Ziga. However, they are much lower than those of Tapsoba et al (2016) who found 0.13 mg/l at Ouagadougou Dam No. 3. Nitrite levels observed at Ziga below 0.1 mg/l would indicate that self-purification is functioning normally in this lake (Zongo, 2007). For orthophosphorus, Ouédraogo (2016) obtained values similar to ours in the order of 0.2 mg/l at Ouagadougou Dam No. 2 and Tapsoba et al. (2016) found higher values (0.678 mg/l) at Ouagadougou Dam No. 3.

Correlation between physicochemical parameters : The presence of microorganisms in this environment is a consequence of the exploitation of the banks of this body of water. Nevertheless, the optimum of their development is often dependent on temperatures around 50°C for streptococci (Bautista et al., 1966). In addition, studies by the Centre d'Expertise en Analyse due l'Environnement du Québec (2014) confirm that thermotolerant (fecal) coliforms belong to the species E. coli. These results confirm our findings on the negative correlation between these microorganisms and temperatures varying around 21.74°C. Nitrites, orthophosphate and suspended solids are exogenous in origin. Indeed, the banks of the Ziga dam are exploited by farmers. Hébert and Légaré (2000) had indicated that these elements were found in watercourses. Hence, there is a strong correlation between these elements of the same origin. In this study, it was found that there is a negative correlation between pH and conductivity. However, there is no direct correlation between them;
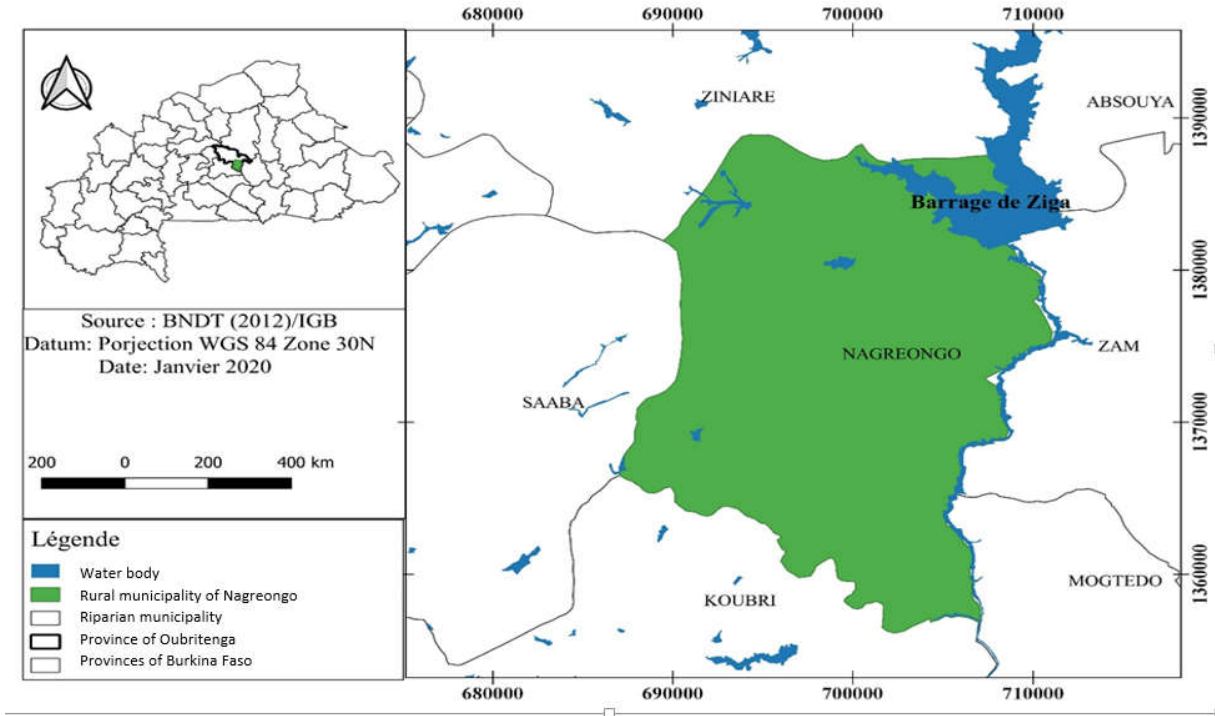
Map 1. Location of the Ziga Dam
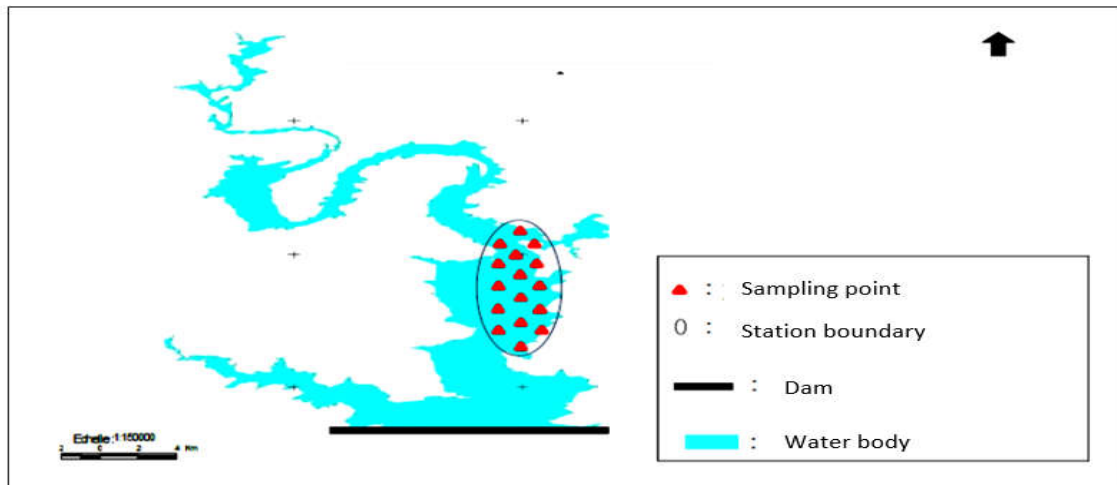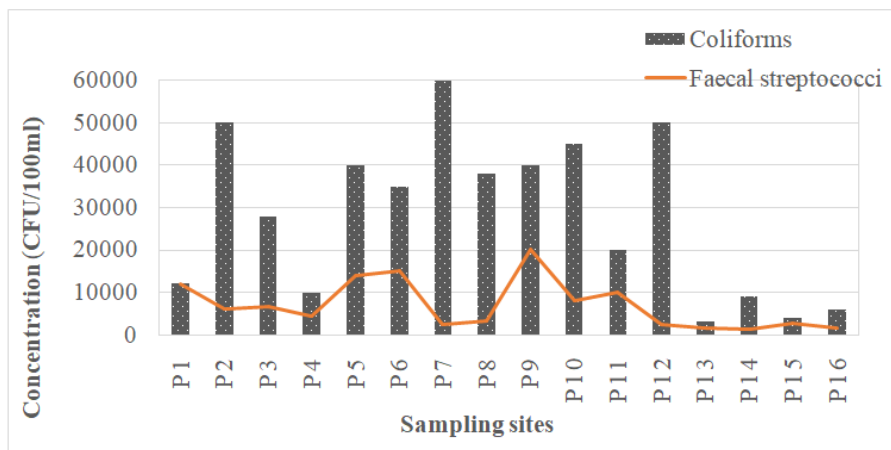

Map 2. Location plan of sampling points

Figure 1: Faecal Coliform and Streptococcal Loading at Sampling Points
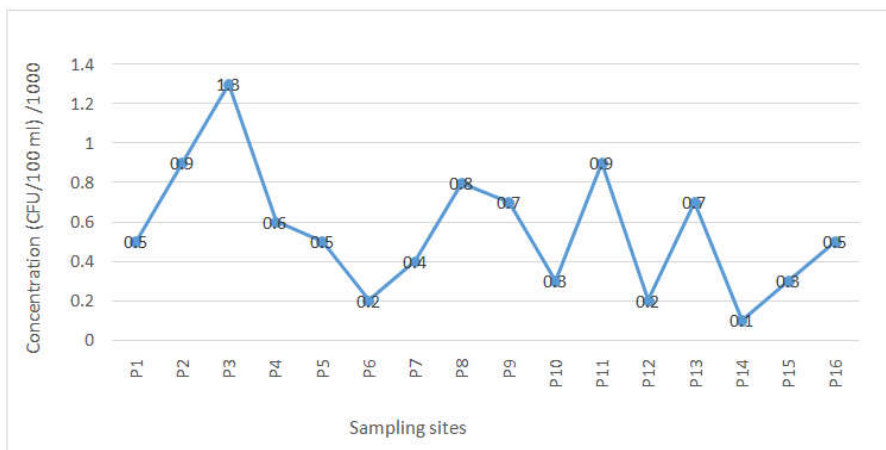
Figure 2. Concentration of *E.coli* on sampling sites
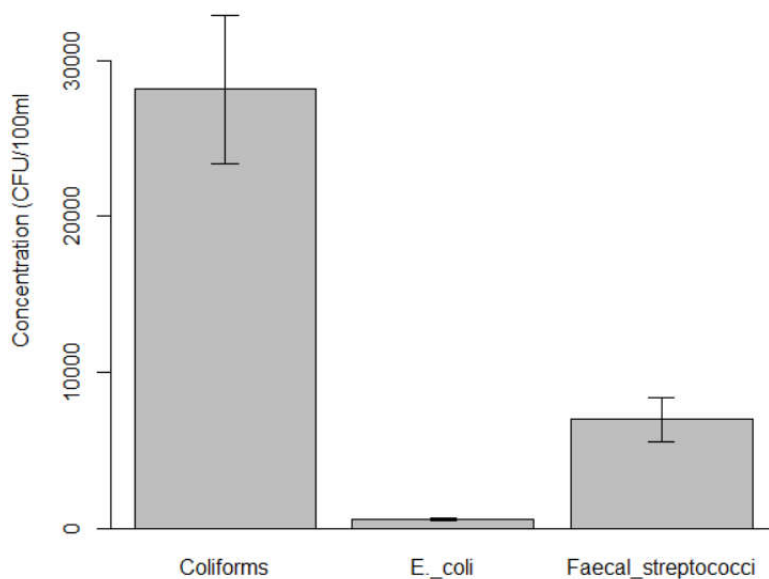

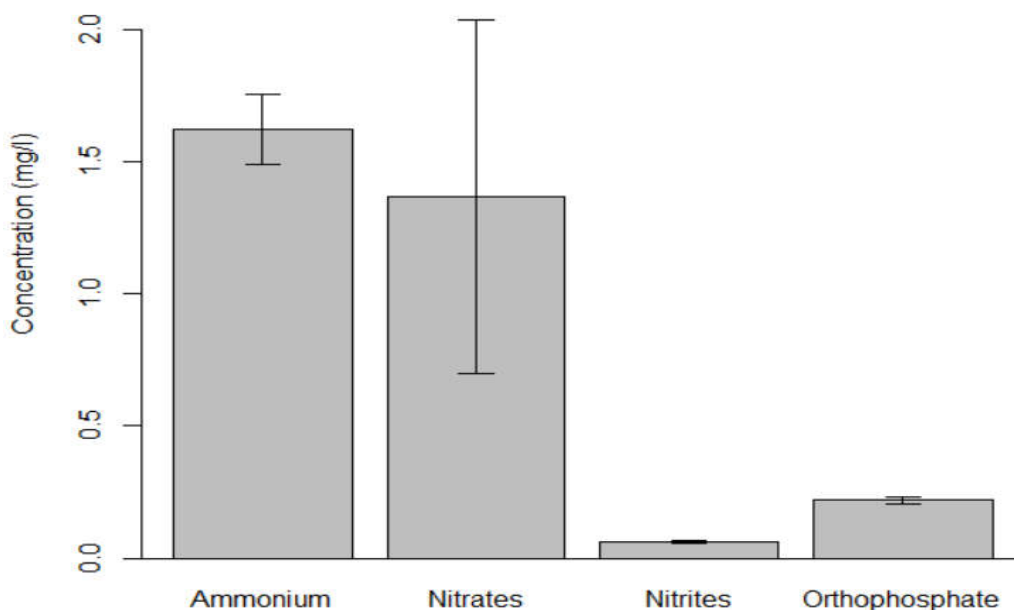**Figure 3. Comparison of colony averages of microorganisms (Coliforms, E. coli and fecal streptococci) at the Ziga Dam**

Figure 4: Comparison of ammonium, nitrate, nitrite and orthophosphate concentrations at the level of the Ziga dam lake
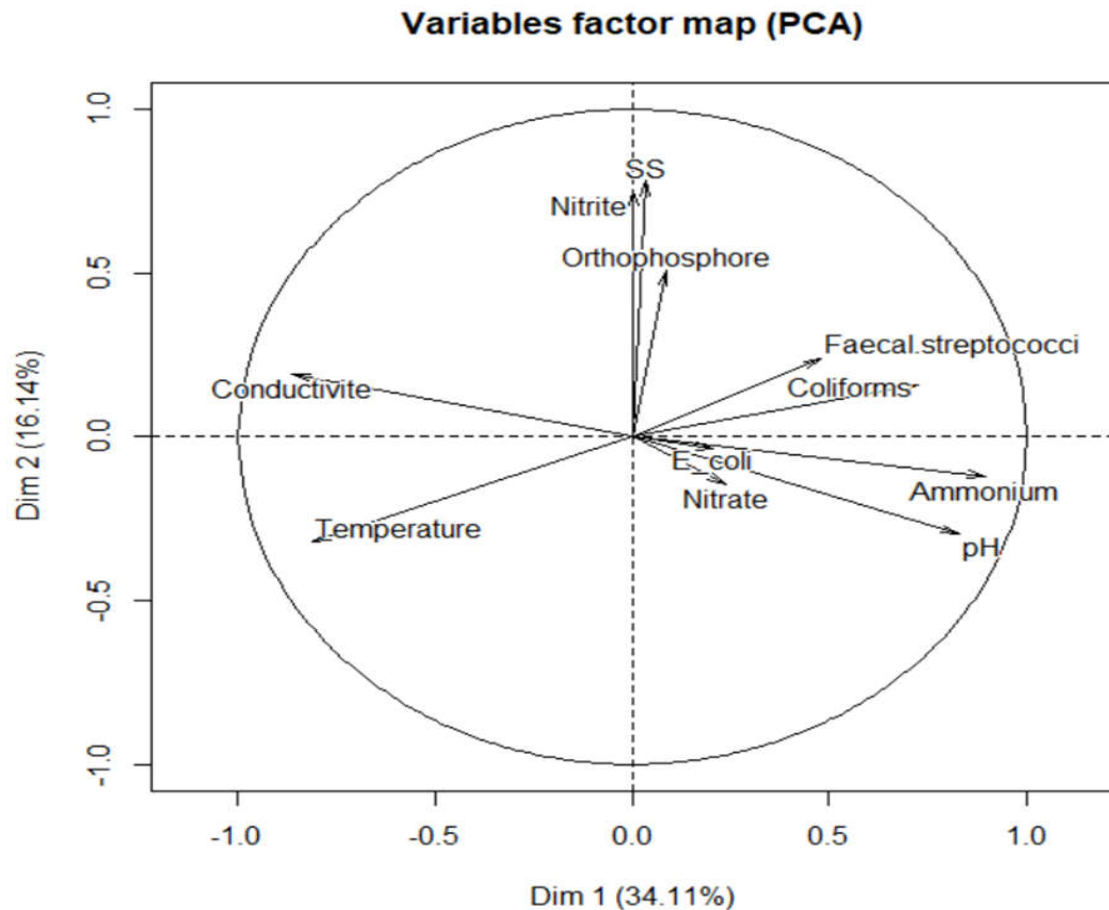
Variables factor map (PCA)

Figure 5. Analysis of the main components of the different variables measured at the Ziga dam lake.

Table 1: Bottles used in the analyses

Parameters	Type of bottle	Volume	Preservative
Coliforms	Plastic pipettes	1 ml	
Faecal streptococci			
Escherichia coli			
Ammonium	Glass bottles	10 ml	Thiosulfate
Nitrates			
Nitrites			
Ortho phosphates			
Suspended solids (SS)		100 ml	

Table 2. Physico-chemical parameters of the water of the Ziga dam lake

Stations	Ammonium (mg/l)	Electrical conductivity (µS/cm)	suspended solids (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	orthophosphates (mg/l)	pH	Temperature (°C)
P1	1.64	70	19	0	0.051	0.3	7.72	20.4
P2	1.68	70	8	10.3	0.052	0.25	7.73	20.4
P3	1.65	70	30	0	0.043	0.25	7.74	20,4
P4	1.7	80	10	0	0.055	0.28	7.76	20.4
P5	1.68	70	20	0	0.087	0.27	7.74	20.4
P6	1.72	70	8	0	0.063	0.18	7.71	20.3
P7	2.07	120	19	1.3	0.084	0.19	8.16	20.4
P8	2	70	7	0	0.065	0.2	8.03	20.5
P9	1.91	70	9	0	0.07	0.2	7.86	20.6
P10	1.93	70	32	3.5	0.079	0.2	7.74	20.7
P11	1.86	80	3	0	0.073	0.17	7.83	23.7
P12	1.94	70	12	3.1	0.06	0.15	7.66	23.5
P13	1.75	80	11	1.1	0.049	0.16	7.63	23.3
P14	1.84	70	8	2.6	0.043	0.32	7.64	24
P15	0.29	210	7	0	0.016	0.12	7.56	24.39
P16	0.34	250	23	0	0.118	0.26	7.05	24.45
Averages	1.63±0.28	95±29.12	14.13±4.62	1.37±1.43	0.06±0.01	0.22±0.03	7.72±0.12	21.74±0.93

pH corresponds to the concentration of a single species, H+ ions (N'Diaye, 2013), while conductivity is influenced more or less by all ions. Our results are different from those of Aw et al, (2011). Indeed, the latter had found a null correlation between conductivity and pH in the lakes of Yamoussoukro (Côte d'Ivoire).

Conclusion

The physico-chemical analysis of the water of the Ziga dam lake indicates that parameters such as conductivity, nitrates, nitrites, pH, phosphorus and temperature are favourable for maintaining its quality. On the other hand, parameters such as ammonium and suspended solids show values that exceed the standards set by the state of Burkina Faso. Given the importance of this dam lake in the region, the use of the banks and even the water from the dam must be monitored more closely. Indeed, these punctual measurements carried out give an idea of the degradation of the water quality. In addition, the concentrations of the less acceptable microorganisms (coliforms, streptococci and E. coli) can quickly change and endanger the lives of consumers.

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