BirEx JOURNAL
Budapest International Research in Exact Sciences
Medical, Biological, Argiculture, Engineering
Science and other related areas
e-ISSN : 2655-7827
p-ISSN : 2655-7835
http://www.bircu-journal.com/index.php/birex

Physico-chemical Characterization of the Waters of Balobo, Tributary of the Ngiri River, Middle Basin of the Congo River, Democratic Republic of the Congo

Bedi Ngalanza Benjamin[1], Nyongombe Utshudienyema[2], Monzambe Mapunzu Paul[3], Kitambala Kaboka Achille[4], Inkoto Liyongo Clément[5], Koto-Te-Nyiwa Ngbolua[6]

[1]*Institut Supérieur d'Etudes Agronomiques de Bokonzi, B.P. 67 Gemena, Sud-Ubangi, République démocratique du Congo*

[2,3]*Faculté des Sciences Agronomiques, Université Pédagogique Nationale, B.P. 8815 Kinshasa-Ngaliema, République démocratique du Congo*

[4,5,6]*Faculté des Sciences, Université de Kinshasa, B.P. 190 Kinshasa XI, République démocratique du Congo*

Abstract: *A study was conducted between December 2021 and July 2022, to contribute to the physico-chemical characterization of the waters of Balobo, a tributary of the Ngiri River, Middle Congo River Basin in Democratic Republic of the Congo. These waters have particular physico-chemical characteristics: brown waters known to be acidic, with a sour taste, with low light penetration, which raises questions in relation to the diversity and abundance of fish. Some physico-chemical parameters of the water (velocity, flow rate, temperature, pH, Secchi transparency, turbidity, dissolved oxygen, total dissolved solids, ammonium and nitrate) were determined in situ and in the laboratory of the Faculty of Sciences of the University of Kinshasa. The results obtained show that the average morphometric values of the stream are: width (8.10±1.03 m), depth (0.81±0.023 m), velocity (0.094±0.04 m/s) as well as flow (0.59±0.4 m3/s). The water temperature of Balobo varies between 23.9°C and 29.8°C, with an average of 27±1.04°C. The waters of Balobo are brown with low Secchi transparency oscillating between 23 cm and 67 cm, with an average of 46.1±14.6 cm and turbidity especially in the dry season characterized in May by a minimum Secchi of 20 cm and a maximum of 30 cm, with an average of 25.6 cm. Turbidity ranges from 63.4 to 109.8 NTU, with an average of 92.5±14.4 NTU. The waters of Balobo are highly acidic, with pH ranging from 3.1 to 4 with an average of 3.4. Their dissolved oxygen content is very low and varies between 1.03 and 2.7 with an average of 1.62±0.5 mg/L. Total dissolved solids in the Balobo water ranged from 57.1 to 101.3 mg/L with an average of 83.8±15.23 mg/L. Ammonium content in Balobo water ranged from 0.150 to 1.097 mg/L, or an average of 0.613±0.5 mg/L. Nitrate content ranged from 1.02 to 2.06 mg/L with an average of 1.35±0.4 mg/L.*

Keywords: *Congo basin; fresh water; physico-chemical quality; Ngiri River; Democratic Republic of the Congo*

I. Introduction

Aquatic environments and water management represent one of the major challenges for the coming decades. In these environments, the fish that live there are a source of good quality protein for human consumption, but also a significant source of income for societies in developing and developed countries. However, demography, urban development, watercourse development, industrialization, climate change, deforestation... have irreversible consequences on the environment, on aquatic biodiversity and therefore on the people living along the river. Numerous researches for the determination of the physico-chemical characteristics of fresh and brackish waters are conducted in all corners of the globe (De Villers et a.l, 2004; S.E.E., 2007; Anonymous, 2012; Bernier, 2015; Paugy et al., (sd); Youkanaba, 2011; Fermon, 2006; Lacroix, 2004; FAO, 2020; Gnagne et a.l, 2015; Hasni et

al., 2018; Karima and Semrani, 2016; Mehounou et al., 2016; Merah, 2019; N'Diaye et al., 2009; WHO, 2017; Ravenga et al., 2000; Evrard, 1996; Tourab, 2013; Tremblay and Pienitz, 2015; Vissin et al., 2016; Youkanaba, 2011; Safiatou et al., 2019; Soude et al., 2018).

Furthermore, it should be noted that aquatic organisms depend for their growth and reproduction on the quality of the waters in which they live or their surrounding environment. This quality is not only conditioned by abiotic parameters (pH, salinity, oxygen content, metals, toxic substances, nutrients) but also by biotic parameters (substrate, natural environment, other organisms, currents, etc. (Anonymous 2004; S.E.E.E., 2007).

In general, according to Fermon (2006), water quality is determined on the basis of quantitative criteria such as the presence in sufficient quantities of certain nutrients, pH, oxygen content, salinity or the presence of substances known to be toxic (metals, pesticides, phenols, etc.).

According to the claims of the Balobo population in the Bangala sector, Makanza territory in the Equateur province, their waters, otherwise known as "Mai ya Ndobo", have very specific physico-chemical characteristics (acidic brown water, with a sour taste, low light penetration, medicinal properties that heal wounds and scabs, and that can keep freshly slaughtered game immersed in it without decomposing for three days, etc.)

It is in this context that this investigation took place on the waterways of Balobo, in order to analyze some physico-chemical parameters of these waters.

The present study was carried out on the basis of the following hypothesis: the physico-chemical parameters of the waters of Balobo would favor the life of living organisms.

The objective of the present study is the analysis of some physico-chemical characteristics of the waters of Balobo. This study was conducted in the Bondoko grouping, between December 2021 and July 2022, given the accessibility of the area. Bondoko is located in the Makanza territory, as indicated by the geographical coordinates below: 1° 36' North and 19° 09' east.

II. Materials

To carry out our study, we used the following technical materials for our study:

- Water samples kept in plastic jars hermetically sealed and quickly transported to the laboratory by air
- Notebook, pen;
- HP computer;
- Statistical calculator;
- pH meter type Universal Test Paper
- Multi-parameter brand HACH connected with an electrode and/or Multi-parameter PCTesterTM35, OAKION EUTECH of the laboratory of the Faculty of Sciences of the University of Kinshasa;
- Thermometer with probe called DIGITAL THERMOMETER;
- UV and visible spectrophotometer brand HACH 2400 S1;
- Motorcycle and paddle boat for the circulation;
- A float (plastic bottle hermetically sealed) and a stopwatch to measure the speed of the river;
- A tape measure (pulling meter).

III. Research Methods

- Measurements of hydrometric parameters of the Balobo channel
- The float method was used to measure the stream velocity and deduce the discharge.

3.1 Measurement of Physico-Chemical Parameters

Many works on the study of physico-chemical characteristics were consulted, to choose the parameters to be analyzed for this preliminary research on Balobo waters (Anonymous, 2004; Anonymous, 2007; De Villers J. et al., 2004; Safiatou et al, 2019; Merah, 2019; Bernier, 2015, Youkanaba, 2011; Anonymous 2012; Tourab, 2013; Vissin et al, 2016; Tremblay and Pienitz, 2015; Soude, 2018; N'diaye. et al., 2009; Mehounou et al., 2016; Gouaidia, 2008; Karima and Semrani, 2016; Gnagne et al., 2015; Amadou et al, 2014, Razafindraibe, 2019).

For water sampling required for physicochemical analysis, we used 500 mL bottles with a string. At the time of sampling, the flask is opened and inserted into the water at a depth of 30cm. Then, the bottle filled with water is removed. The string is detached and the bottle is closed again until the time of the analysis.

The most studied physico-chemical parameters of the water are: temperature, turbidity, transparency, pH, conductivity, total dissolved solids, dissolved oxygen, ammonium ion, and nitrates.

3.2 Temperature

To take the temperature, the thermometer with a rod of 20 cm length is placed in the water at 6 o'clock, at noon, at 6 o'clock and at midnight, in order to follow the possible variations. To take a temperature reading, the thermometer is turned on and the probe is immersed in the water for at least 15 seconds according to the instructions on the label of the device, until the temperature stabilizes. The reading is taken while holding the thermometer in the water.

a. Transparency

Transparency is measured with a paddle canoe, using the Secchi disk with a string graduated in centimeters attached to its center; the disk is immersed in the middle of the watercourse. The graduation allows the reading of the depth from which the disc is not visible anymore.

b. pH, Total Dissolved Solids, dissolved oxygen, ammonium NH4+ and nitrate

The pH was measured in the laboratory of the Faculty of Sciences of UNIKIN (University of Kinshasa, DRC) by the potentiometric method using a HACH Multi-parameter connected to an electrode and/or Multi-parameter PCTestrTM35, OAKION EUTECH. Turbidity was measured with a Hach turbidimeter. Dissolved oxygen was measured using a spectrophotometer.

c. The Procedures for Measuring these Parameters are Described as Follows:

- **pH measurements:**
  - Calibrate the multi-parameter with KCl at 25 °C
  - Take 25 mL of the sample in a test tube;
  - Immerse the electrode of the multi-parameter;
  - Read on the digital display the value stuck to its unit;
  - Switch from one parameter to another as required with the mode key;
  - The value is °C for temperature, in Siemens micron per centimeter for Electrical Conductivity.

- **Mesure of turbidity:**
    - Take 25 mL of the sample in a rinsed bottle;
    - Immerse the electrode;
    - Read the value on the digital display;
    - The value is displayed in PtCo (expression of the color of the water using the platinum/cobalt color scale (Pt/Co scale);
    - Note the value.

- **Dissolved oxygen measurement:**
    - Take a 25 mL volume of the sample in the Vac tube;
    - Take 25 mL of distilled water (blank);
    - Add Oxydisdolved reagent 1 and 2 to the two accu vac tubes;
    - Mix or blend each tube;
    - Wait for a reaction period of 5 minutes;
    - Wipe the tubes with a soft blotting paper;
    - Read with the spectrophotometer with the blank;

The concentration is displayed on the screen in mg O_2/L

IV. Discussion

4.1 Results

The different results of the hydrometric characteristics of the stream and the physico-chemical parameters of the water are presented in this section.

a. Hydrometric Characteristics of the Watercourse

The hydrometric characteristics of the river were measured in May 2022, a period marking the end of the dry season and the return of rains. They are summarized in Table 1 below.

Table 1. Hydromorphic characteristics of the Balobo/Bondoko River

Parameters	N	Minimum	Maximum	Mean±SD
Width (m)	10	6,98	9,84	8,10±1,03
Depth (m)	10	0,60	0,90	0,81±0,02
Speed (m/s)	10	0,053	0,18	0,9±0,04
Flow (m^3/s^2)	10	0,343	1,01	0,59±0,39

Legend: N: number of repetitions; SD: standard deviation

It appears from this table that in May 2022, the width of the minor bed varies between a minimum of 6.98 m and a maximum of 9.84 m with an average of 8.1±1.03 m ; the depth in this period presents a range between a minimum of 0.60 m and a maximum of 0.90 m, with an average of 0.81±0.02 m; the average speed of the water is slow, 0.08±0.04 m per second with a minimum of 0.053 m/s and a maximum of 0.175 m/s. Stream flow varies from a minimum of 0.343m3/s and a maximum of 1.01 (m^3/s), averaging 0.585±0.39 m^3/s. Omasombo et al., (2016) consider the streams in Balobo as a set of channels. It should be noted that in navigating these channels, one encounters buffer zones where water is stagnant, but runs off to either side (sometimes it is upstream, sometimes downstream as it progresses).

b. Physico-chemical Parameters Bondoko/Balobo channel water

The different physico-chemical characteristics determined are recorded in Table 2.

Table 2. Physico-chemical Parameters of Balobo Water at Different Times

Parameters	N	Minimum	Maximum	Mean±SD
Temperature (°C)	4*	23,9	29,8	27±1,04
Transparency Secchi (cm)	10	23	67	46,1±14,62
pH	6	3,1	4,0	3,4±0,30
Dissolved Oxygen (mg/L)	6	1,03	2,22	1,62±0,50
TDS (mg/L)	6	57,1	101,3	83,8±15,23
Turbidity (NTU)	6	63,4	109,8	92,5±14,43
Ammonium (mg/L)	6	0,150	1,103	0,613±0,50
Nitrate (mg/L)	6	1,02	2,06	1,35±0,41

*Legend: * means the general averages; pH= Hydrogen Potential; TDS= total dissolved solids; NTU= Nephelometric Turbidity Unit*

c. Temperature

The results in Table 2 show that the temperature of the Balobo water oscillates between a minimum of 23.9 °C and a maximum of 29.8°C, with an overall average of 27±1.04 °C. This temperature range is consistent with the body temperature of tropical ichthyological species that require the water to be maintained between 15 and 25°C. It is understandable why Clarias are abundant in Balobo streams: they can survive easily at temperatures above 30 °C.

d. Turbidity, Secchi transparency and Total Dissolved Solids (TDS)

From the results in Table 2, it is clear that the turbidity values oscillate between a minimum of 63.4 NTU and 109.8 NTU at the maximum, with an average of 92.5±14.43 NTU. The Secchi transparency varies with the season, i.e. depending on whether the river is flooded or not. It averages 46.1±14.62 cm, with a range between 23 cm and 67 cm. It is very low in May 2022, around 25.6 cm, corresponding to the return of the rains, compared to 58.7 in December 2021, which marks the beginning of the dry season, and 53.9 in July 2022, which is normally the full rainy season, despite the climatic disturbances that characterized the period of our study.

It should be understood that in the dry season, the water level drops significantly and the TDS has a minimum of 57.1 mg/L and a maximum of 101.3 mg/L. This reflects the presence of minerals in the water. Our own observation shows that the Balobo stream has neither a rocky nor a sandy bottom. It is essentially characterized by a muddy bottom, resulting from the decomposition of abundant organic matter from a hydromorphic forest. This would justify the brown coloring of the water which persists even after a strong boiling.

e. The pH of the Bondoko/Balobo Water

Still in light of the results in Table 2a above, it is clear that the Balobo water is highly acidic: the pH varies between a minimum of 3.1 and a maximum of 4, with an average of 3.4±0.3. We can think of an organic acidity that is justified by the presence of a muddy bottom.

f. Dissolved Oxygen

The average value of the dissolved oxygen content varies between 1.03 and 2.7, i.e. an average of 1.62±0.5 mg/L (Table 2a). The water in Balobo is therefore poorly oxygenated.

g. Ammonium and Nitrate Content

The ammonium content ranges from 0.150 to 1.097 mg/L, with an average of 0.613±0.5 mg/L (Table 2a). Nitrate content ranged from 1.02 to 2.06 mg/L with an average of 1.35±0.4 mg/L.

Note that the acceptable concentration for water with a pH below 8.5 is 0.20 mg/L. However, ammonia in solution in water is eventually transformed into less and less toxic molecules (into nitrites and then into nitrates).

There are two forms of ammonia in water: the non-ionized form (NH_3 called ammonia) and the ionized form (NH_4^+ called ammonium). The transition from one to the other of these two forms depends mainly on the pH of the water (and the temperature). The reaction is as follows: NH_3 and H_2O are in equilibrium with NH_4^+ and OH^-. The non-ionized part (NH_3) is by far the most toxic form, and its share increases with increasing water pH. However, both forms are toxic to fish even at very low doses.

4.2 Discussion

a. Hydromorphic Characteristics of the Balobo River

The average values of the stream obtained are: for width (8.10±1.03 m), depth (0.81±0.023 m), velocity (0.094±0.04 m/s) as well as discharge (0.59±0.4m/s2. The depth is significantly lower than that found by Klossa, (2012) for the SÔ River, 1.8-6 m.

b. Physico-chemical Parameters of the Balobo Water

The water temperature of Balobo ranges from 23.9°C to 29.8°C, averaging 27±1.04°C. Klossa (2012) found an average temperature that ranges from 25.1 to 28.8°C for the SÔ River.

Nyongombe (1993) points out that temperature has a dual importance, both chemical (by affecting equilibrium constants and reaction kinetics) and biological by influencing the metabolism and distribution of animal and plant species in flowing waters. According to Boika et al, (2021), warm waters are those with temperatures between 26.68±0.96 °C and 24.64±0.59 °C.

The water temperature values of Balobo are therefore within the ranges favorable to the biological activities of the fish identified in this stream, as stated by Dépasse (1956): 23 °C to 29 °C; Gosse (1963): 20.9 °C to 27.9 °C, Golama and Symoens (1990): 24°C to 28.5 °C, all cited by Nyongombe (1993). This temperature range can be explained by the fact that the Balobo stream is generally under vegetation cover where variations are small. The waters of Balobo are brown with low Secchi transparency oscillating between 23 cm and 67 cm, with an average of 46.1±14.6 cm, and turbid especially in the dry season characterized in May by a Secchi minimum of 20 cm and a maximum of 30 cm, with an average of 25.6 cm. It should be noted that the dry season usually begins in December until the return of heavy rains in May. The turbidity of these waters' ranges from 63.4 to 109.8 NTU, with an average of 92.5±14.4 NTU. Klossa, (2012) noted a transparency that varies from 3.2 to 39 cm for the SÔ River.

Also, Boika et al, (sd) point out that less turbid waters have turbidity ranging from 4.54±0.68 NTU to 5.04±1.69 NTU). The brown color of Balobo water, although not always synonymous with low transparency according to Lacroix (2004), is the result of the continuous decomposition of plant products in tropical environments where the decomposition releases phenol and other compounds. Also, according to Nyongombe (1993), studies conducted by Matthes (1964) affirm that the waters of the central basin in which Bondoko/Balobo is located are brown and called "black equatorial waters. Our own observations of the water boiled for our bath confirm the statements of Marlier (1957) quoted by Nyongombe (1993) that "the brown coloration of the water remains unchanged after a long period of boiling.

The waters of Balobo are strongly acidic, with pH ranging from 3.1 to 4 with an average of 3.4±0.30. These data are similar to those found by Nyongombe (1993) for the waters of Masendula: a strongly acidic pH between 3 and 6, an acidity that would result from the origin of the waters, the geological and pedological nature of the land crossed, and the activities of the thermostable humic matter, whether dissolved or not. Several studies mentioned by Nyongombe (op. cit.), particularly in the lower reaches of the Bohamba and Lola rivers (minimum pH values of 3.7 and 3.8 and maximum values of 4.8 and 6.2; the average pH values of between 3.6 and 4 found in the watercourses around Yangambi attest to the strongly acidic waters encountered in the marshes that characterize Balobo, with its predominantly silty bottom. Indeed, it is difficult to observe in Balobo a sandy or rocky bottom, even in the dry season when the brown water disappears almost completely, leaving in some areas a clear water that foams and smells of oil. These pH values differ from those of the SÔ River pH 5.6 to 6.7 (Klossa, 2012).

We confirm that the impact of this acidity results in low phytoplankton development and ipso facto low production joined with low ichthyological specific diversity of Balobo waters. According to Nyongombe (1993), Love-MC Connel (1987) established the link between water color and pH; he noted that rivers with black water are very acidic (pH: 3.8 - 4.9), poor in inorganic ions, which translates into low plankton development and low dissolved oxygen content due to the decomposition of plant products.

The average value of dissolved oxygen in Balobo water ranged from 1.03 to 2.7, with an average of 1.62±0.5 mg/L. This is sufficient evidence that this water is less oxygenated. Dissolved oxygen values of 3.9 to 10.9 mg/L were, however, found by Klossa (2012) for the SÔ River in Burkina Faso. Certainly, oxygen requirements vary among species and resistance to hypoxia, as studied by many authors cited by Nyongombe (1993). Trying to compare our dissolved oxygen values to those found by Nyongombe (1993): 4.6 mg/L; Gosse (1963): 4.6 mg/L; Golama & Symoens (1990): 1.4 mg/L; Gosse (1963): 2.3 mg/L; Musala (1989): 2.7 mg/L and Kimpe (1964): 2.8 mg/L all cited by Nyongombe (1993), we can conclude that Balobo's waters are low in oxygen.

Dissolved oxygen (DO) in water is essential for the respiration of most living organisms. Oxygen is also necessary for the breakdown of dead organic matter during the process called decomposition. According to (Hasni et al., (2018), oxygen level is among the good indicators for the presence of aquatic life, it measures the concentration of dissolved oxygen in water. Dissolved oxygen participates in the majority of chemical and biological processes in the aquatic environment and its average content in unpolluted surface waters is about 8 mg/L (Abboudi et al., 2014; Djemai, 2008) cited by (Hasni et al., op. cit.). This parameter measures the amount of organic and inorganic ions dissolved in the water. Total dissolved solids in Balobo water range from 57.1 to 101.3 mg/L or an average of 83.8±15.23 mg/L. Our values are lower, comparing them with those found by Hasni et al, (2018) where the lowest TDS values are found in Tough (100mg/L), the highest values are 358 mg/L in Ejar. In the warm season, the lowest TDS values are encountered at Tally (188mg/L), the highest values are recorded at Dendare (590 mg/L). The author goes on to cite measurements in surface waters of the Ouémé delta in Benin that yielded TDS values between 28 and 119.5 mg/L, much lower than those he recorded; he goes on to say that analysis of fresh waters from 28 water points in Congo showed TDS variations between 40.4 mg/L and 229.8 mg/L, the range in which our values are included.

Studies conducted in Mali state that TDS levels measured in freshwater show seasonal variations Hasni et al., (2018). As our studies were conducted in the intermediate period between the dry and rainy seasons due to climatic disturbances, further studies can be conducted later throughout the year to draw definitive conclusions on this parameter in Balobo. Nitrate is the end product of aerobic stabilization of organic nitrogen; its presence in

water is indicative of organic enrichment of agricultural or industrial origin. It is often used as fertilizer in pond culture (Fermon, 2006). Nitrates are only a problem at very high concentrations (in the order of several hundred mg/L). At moderate concentrations (above 50 mg/L), effects on fish such as reduced growth, reproduction, vitality, and increased susceptibility to disease can be noted. The ammonium content in Balobo waters ranges from 0.150 to 1.097 mg/L, with an average of 0.613±0.5 mg/L. Nitrate levels range from 1.02 to 2.06 mg/L with an average of 1.35±0.4 mg/L. Nyongombe (1993) found for the Masendula River values between 0 and 9 mg/L for nitrate and 0 to 0.5 mg/L for ammonium. Our values are much higher and within the range found by Nyongombe (op. cit.). Based on the results of Berg 1961 in Burgis & Symoens, (1987) cited by Nyongombe (1993) who reports nitrate levels (10, 13 and 80 mg/L) and 6, 6 and 6 mg/L for ammonium in the Central Cuvette, respectively in acidic humic waters (pH : 3.6 to 4.8), partially neutralized humic waters -pH: 5 to 7) and completely neutralized humic waters (pH: 6 to 8), we can place the Balobo waters in the acidic humic water category.

V. Conclusion

The objective of our study was to find out the physico-chemical characteristics of Balobo waters. After analysis of the physico-chemical parameters, the following was found: The width of the stream varies between a minimum of 6.98 m and a maximum of 9.84 m with an average of the stream is 8.1±1.03 m; the depth has an interval between the minimum of 0.60 m and the maximum of 0.90 m, an average of 0.81±0.02 m; the average speed of the water is 0.08±0.04 m per second with the minimum of 0.053 m/s and the maximum of 0.175 m/s. The stream flow varies from 0.343 m^3/s minimum and the maximum of 1.01 (m^3/s), with an average of 0.585±0.39 m^3/s. The water temperature of Balobo ranges from a minimum of 23.9 °C to a maximum of 29.8 °C, with an overall average of 27±1.04 °C. The transparency of the water in Balobo varies with the season, i.e. depending on whether the river is flooding or receding. It averages 46.1±14.62 cm, with a range between 23 cm and 67 cm. Very low in May 2022 of about 25.6 cm, compared to 58.7 in December 2021 and 53.9 in July 2022; turbidity values range from a minimum of 63.4 NTU to a maximum of 109.8 NTU, with an average of 92.5±14.43 NTU. Balobo water is highly acidic; the pH varies from a minimum of 3.1 to a maximum of 4, with an average of 3.4±0.3 by laboratory analysis. The average value of dissolved oxygen content varies between 1.03 and 2.7 with an average of 1.62±0.5 mg/L. Total dissolved solids ranged from 57.1 to 101.3 with an average of 83.8±15.23 mg/L. The ammonium content ranges from 0.150 to 1.097 mg/L, with an average of 0.613±0.5 mg/L. The nitrate content varies from 1.02 to 2.06 mg/L with an average of 1.35±0.4 mg/L. Thus, the results of the physico-chemical analyses of Balobo water show that the hypothesis that the variations of the physico-chemical parameters of Balobo water would favor the life of living organisms is confirmed.

References

Amadou H., Laouali M.S., Manzola A., 2014. Analyses Physico-Chimiques et bactériologiques des eaux de trois aquifères de la région de Tillabery : Application des méthodes d'analyses statistiques multi-variées. Université Abdou Moumouni de Niamey. Faculté des sciences et Techniques. Niamey-NIGER. Larhyss Journal, n°20, pp. 25-41.

Anonyme, 2004. Qualité des eaux piscicoles Institut Bruxellois pour la Gestion de l'Environnement/Observatoire des Données de l'Environnement. Les données de l'IBGE : "L'eau à Bruxelles" Septembre 2004. Qualité des eaux piscicoles.pdf).

Bernier A., 2015. Caractérisation de la matière organique des eaux naturelles et traitées par spectroscopie par fluorescence 3D. Mémoire. Université Laval. Québec, Canada.

DE Villers J., Dutrieux S., Onclincx F., Squilbin M., 2004. Qualité des eaux piscicoles. Institut Bruxellois pour la Gestion de l'Environnement/Observatoire des Données de l'Environnement.

Evrard M., 1996. Utilisation des exuvies nymphales de Chironomidae (Diptera) en tant qu'indicateurs biologiques de la qualité des eaux de surface wallonnes. Thèse de Doctorat, Facultés Universitaires Notre Dame de la Paix Namur, Belgique.

Gnagne Y. A., Yapo B.O., Meite L., Kouame V.K., Gadji A.A., Mambo V. ET Houenou P., 2015. Caractérisation physico-chimique et Bactériologique des eaux usées brutes du réseau d'égout de la ville d'Abidjan. International Journal of Biological and Chemical Sciences 9(2): 1082-1093.

Hasni T., Mahfoudh M., Baba A.M., Ahmed A., Lemhaba Y., ET Abdellahi M. V.H., 2018. Caractérisation physico-chimique des eaux de surface et étude de la diversité ichtyologique de quelques zones humides continentales en Mauritanie. European Scientific Journal 14(6) : 83. https://doi.org/10.19044/esj.2018.v14n6p83.

Karima B., Semrani S.O., 2016. Analyse physico-chimique et bactériologique des eaux brutes d'oued Fedjana (W. Tipaza). Mémoire de fin d'études en vue de l'obtention de Diplôme de Master en Biologie. https://www.researchgate.net/publication/305280745.

Mehounou J. P., Josse R. G., Dossou-Yovo P., Senou S. F., Toklo R. M., 2016. Caractérisation physico-chimique et microbiologique des eaux souterraines et superficielles dans la zone de production cotonnière d'Aplahoué. Journal of Applied Biosciences 103 : 9841 – 9853.

Merah A., 2019. Etude De La Qualité Physico-Chimique Et Microbiologique de l'eau des puits de la région El Hassiane (W. Mostaganem). Mémoire de Master Université Abdelhamid Ibn Badis-Mostaganem.

Morin R., 2012. Qualité de l'eau requise pour l'élevage des salmonidés ». Document d'information DADD-14. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation. 25 p. http://www.mapaq.gouv.qc.ca/Fr/Peche

N'diaye A. D., Kankou M.O.S.O., Sarr A. D. ET Baidy L.O., 2009. Caractérisation Physico - Chimique des eaux usées brutes de la ville de Nouakchott (Mauritanie). Measurement Science and Technology 14 (1813-3290): 97-109.

OMS, 2017. Directives de qualité pour l'eau de boisson. Quatrième édition. Organisation mondiale de la Santé.

Paugy D. & Leveque C., 2017. Impacts of human activities. In: Paugy D, Leveque C. & Otero O. (Eds). The inland water fishes of Africa: Diversity, Ecology and Human use, Institut de Recherche pour le Développement (IRD), Royal Museum for Central Africa (RMCA), pp. 459–478.

Safiatou C., N'Goran V.K., Boua A.C., 2019. Etude comparative de la qualité des eaux des étangs et du Barrage d'une ferme piscicole en étang au Sud-Est de la Côte d'Ivoire. Centre de Recherches Océanologiques, Abidjan, Côte d'Ivoire. European Scientific Journal 15(24): 42. https://doi.org/10.19044/esj.2019.v15n24p42.

S.E.E.E, 2007. Normes de qualité eaux piscicoles. Secrétariat d'Etat auprès du Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, chargé de l'Eau et de l'Environnement. www.water.gov.ma. Consulté le 30/5/2021.

Soude M.K., Bothon F.T.D., Deguenon H. E. J., Koudoro Y.A., Agbangnan D.C.P., Mama D. et Wotto D.V., 2018: Analyses physico-chimique et bactériologique des eaux usées de quelques hôtels de Cotonou. International Journal of Innovation and Applied Studies Vol. 23 No. pp. 227-234.

Tourab M. H., 2013. Contribution à l'étude de la qualité physicochimique et bactériologique des eaux souterraines dans la plaine du Haouz. Mémoire de fin d'études. Université Cadi Ayyad. Faculté des Sciences et Techniques. Département des Sciences de la Terre.

Tremblay R. et Pienitz R., 2015. *Caractéristiques limnologiques de 56 lacs du Québec Méridionale lien avec l'état trophique*. *Limnological characteristics of 56 lakes in southern Quebec in relation to their trophic sta*te. Revue des sciences de l'eau Journal of Water Science. Volume 28, numéro 2,

Vissin W., Aimade H. S. S., Dougnon L.D., SOhounou M., Atiye E.Y., Atchade G.A.A., 2016. *Qualité de l'eau et maladies hydriques dans la commune de Toffo (Bénin, Afrique de l'ouest)*. Journal of Applied Biosciences 106:10300 –10308.

Youkanaba Y., 2011. Usages de l'eau et leurs conséquences dans le district de Bamako et environs. Quantification des caractéristiques physico-chimiques, biologiques et microbiologiques des eaux de robinets, de puits et forages du district de Bamako et environs. Thèse Université de Bamako. République du Mali.