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WATER QUALITY IN BATRAN, KARAKOUDAROU, NAWARI AND TISSAROU DAM RESERVOIRS IN THE DEPARTMENT OF ALIBORI IN THE NORTHERN BENIN

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ABSTRACT

Dams have been playing very important socioeconomic role for people living in underdeveloped countries. This study evaluates the water quality of four dams (Batran, KarakouDarou, Nawari and Tissarou) in the department of Alibori in northern Benin through physical, chemical and biological parameters. Physical properties including pH, conductivity, temperature, and turbidity were evaluated in situ; and chemical analyzes such as ammonium, bicarbonates, calcium, chlorides, fluorides, magnesium, nitrites, nitrates, phosphates were performed in the laboratory from water samples taken in January. The results indicate that the four dam's waters did not meet the physical, chemical or biological standards. The water quality indices (WQI) were greater than 50 in most of the dams except Batran; however, we identified four water quality classes: good (>25 – 50), bad(>50 – 75), very bad(>75 – 100) and out of use (> 100). An out of use water was observed in the Karakou Darou dam (IQE > 100), and poor quality water (50 ≤ IQE ≤ 75) occurred in Batran, Nawari and Tissarou. Abundant fecal coliforms were found in all the dams, but only *Escherichia coli* occupied water from Tissarou dam. This information can be important for the proper management of the water from Batran, KarakouDarou, Nawari and Tissarou dams; and to preserve health of neighboring populations of the dams.

Keywords: Dam water, feacal coliforms, Water quality index, North Benin.

INTRODUCTION

The sustainable management of natural resources, and particularly water resources, has been taken into account in the process of combating poverty, since the United Nations conference on environment and development held in 1992 in Rio de Janeiro. Water is a natural resource essential for life in any ecosystem (Tampo et al., 2015). The water quality gives a global view of the risks in order to ensure the protection of resources and to determine the possible sources of water quality deterioration (Myers, 2015, Normatov et al., 2015). However, water quality can be a major concern for a society that has to meet increasing water needs (Foto et al., 2011), because water plays a very important role in socio-economic development at local, regional and national level. Thus, water resources are a major concern in countries with arid or semi-arid climates; but, despite this great importance water is not always available in quantity and quality everywhere.

Several studies have investigated the current level of waters contamination in the cotton basin of Benin, and highlighted the water and sediments pollution with various types of chemical compounds (OCDE 2015). The department of Alibori in north Benin is not an exception, since water here is increasingly scarce in the dry season either because of its availability or its quality. The main sources of water (water reservoirs/dams) are gradually degrading with even drying up when the dry season is prolonged/pronounced (OCDE 2015) The largest water dams/reservoirs in Alibori are Batran, Karakou Darou, Nawari and Tissarou, which face pollution and degradation issues due to climatic variations aggravated by increasing human activities around these structures. Knowing the water quality of these dam reservoirs can help to bring out the determinants of their pollution for better management.

Water quality have been an important criterion for meeting the demand and supply of water, to ensure freshwater quality suitable to human and ecological needs is therefore an important aspect of integrated environmental management and sustainable development (Bekri et al., 2020). The physicochemical and bacteriological properties of water appear as dominant parameters to assess water quality, to highlight essential parameters of water quality, and to characterize the water environment (Ghazali and Zaid, 2013). However, the use of physicochemical and bacteriological properties to assess water quality is complex, because these properties are made up of several individual variables that are difficult to combine without prior treatment. Several water quality indices are highlighted to assess the quality of surface water, which can vary over time and from one place to another even in the absence of pollution (Hebert and Legare, 2000). The water quality index overcomes this problem since it represents water quality through a single value. The water quality index is therefore a synthesized tool and a mean of communication that can facilitate the assessment of the water quality (Hébert, 1997).

The aim of this study is to assess the water quality of four reservoirs in the Alibori department through the determination of physicochemical parameters and the evaluation of microbial activity. We used WQI based on physicochemical parameters, as well as microbial activity in the dam waters to assess of their quality.

MATERIALS AND METHODS

Characteristics of the study area

The department of Alibori is located between 11°19′ North latitude and 2°55′ East longitude. Figure 1 shows the area covered by the department and the four dams considered in this study. The department is characterized by a Sudanese-type climate in the southern part towards the Sudano-Sahelian type in the northern part (Karimama-Malanville) with an average rainfall spread over 70 to 80 days between April and October, and is estimated between 700 mm and 1000 mm (Government of the Republic of Benin, 2011). The dry season is characterized by the drying up of ponds and water reservoirs according to the 3rd generation Communal Development Plan (PDC) of the Commune of Gogounou (2017). The annual average temperature is around 26 °C with a maximum of 32 °C in March to drop to around 23 °C in December-January (Harmattan period) according to the third National Communication of Benin to the United Nations Framework Convention on Climate Change (Ministry of the Living Environment and Sustainable Development, 2019). The average potential evapotranspiration (ETP) varies from 817 mm for the period 1955-1972 to 794 mm for 1973-1992 (Vissin, 2007) but significantly increased later to 1422 mm in 2001 pastoral and agricultural hydraulics project (PHPA 2001).The region is crossed by many rivers with the most important ones being the Alibori (427 km long) and the sota (254 km long), which are tributaries of the Niger River (Fig.1). These important rivers have favored the construction of more than 70 water reservoirs and dams in this department, including excavations which are subject to intense human activity. The relief is dominated by plateaus sometimes modeled in a sedimentary series of Cretaceous or of plateaus crowned with armored mounds which descend towards the Niger river and hills of ferruginous sandstone (RGP H-4, 2013). The dams water and reservoirs dry up between March and May.

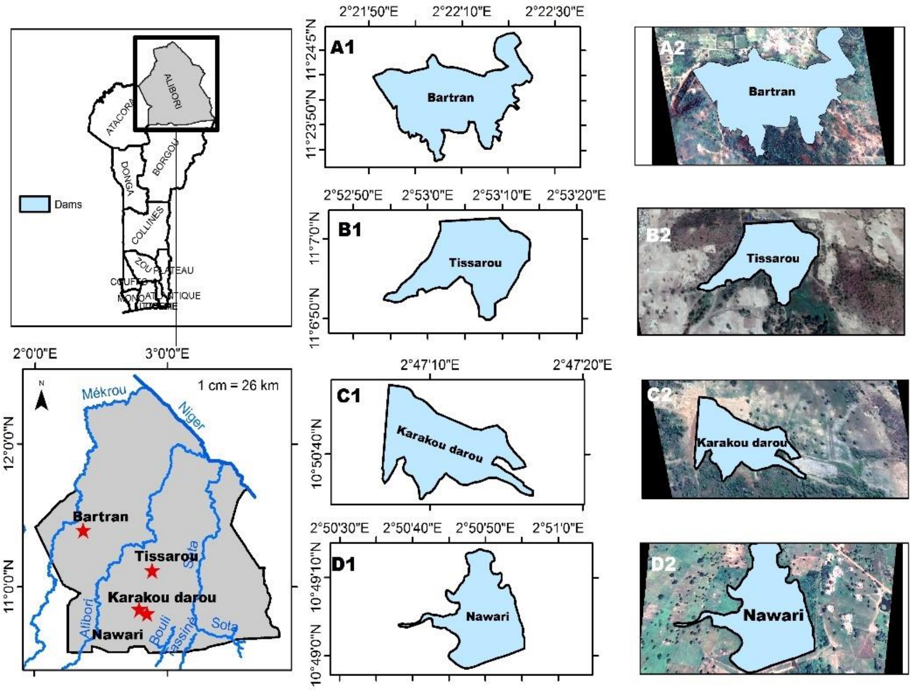


Figure 1: Sites of water reservoirs monitored for water quality in the Alibori department.

Characteristics of the water reservoirs

Batran, Nawari, and Tissarou are larger reservoirs, characterized by their respective capacities of 192 075 m^3, 500 000 m^3 and 348000 m^3 for an average height of the dikes which varies from 2.39 m to 7 m. Nawari has the longest dike length (717.79 m) against 216.5 m at Batran. The weirs of these water reservoirs are lateral except Nawari which has a central weir. The conical shape of the Tissarou weir makes its particularity with its small dimension of 8 m. As for the Karakou Darou dam, rehabilitated more than twice, it dries up even faster than the other three. The main characteristics of the studied water reservoirs are presented in Table 1.

Table 1: Main characteristics of the studied water reservoirs

Characteristics	Dam			
	Batran	**Karakou Darou**	**Nawari**	**Tissarou**
Geography position	11°23’59.7’’ 2°21’50.3’’ -272	10°50’44.4’’ 2°47’07.3’’ -328m	10°49’00.2’’ 2°50’53.1’’ -290m	11°07’03.3’’ 2°53’02.2’’ 295m
Year of construction	2004	2004	2001	1996
Dike height (m)	5	2.39	6.35	7
Dike length) (m)	216.5	247.46	717.79	338.08
Weir length(m)	39.4	35.5	35.5	8
Capacity (m3)	348000	55099	192075	500000

Determination of physico-chemical and biological water parameters

The evaluation of water quality was based on the measurement of physical and chemical parameters and of the biological activity of the water which contribute to the determination of the water quality index. The physical parameters were assessed in situ and water samples were taken for the determination of chemical and biological parameters in the laboratory. Three Points P_1, P_2, and P_3 in the basin were considered at each reservoir. The physical parameters and samples were taken near the dike and the dam at distance between 1 to 20 m from the edges of the water surface, depending on the condition of the shore and the depth of the dam water. The sampling was performed in the morning between 7 a.m. and 10 a.m. in undisturbed water.

Determination of water physical parameters

The physical parameters were measured in-situ and consisted of pH, temperature, conductivity, turbidity and dissolved oxygen of the waters of the Batran, Karakou Darou, Nawari and Tissarou dam waters. Fifteen measurements points were considered in the basin for these parameters, with three measurement points per observation zone (P1) in the basin, (P_2) close to the dike and (P_3) close to the dam. The measurements at (P_1), (P_2), and (P_3) were performed in equidistant points at the level of the basin, but varied according to the state of the water reservoir while avoiding human activities. In all cases, the the physical parameters were measured as a function of the turbidity observation depths. The depths of the measurements varied from 0.18 to 1.80 m from the water surface depending on the dam waters (Figure 2). The hydrogen potential, the temperature, the dissolved oxygen and the conductivity were measured in situ using a pH-meter (pH, EP of HANNA), and the color and the turbidity were determined using a colorimeter (DR890/HACH DR 2400/HI99300/EC/TD3 by colorimetric assay).

Determination of water chemical and biological parameters

Water samples from the Batran, Karakou Darou, Nawari, and Tissarou dam waters were taken during January 2021 to determine the chemical and biological parameters. Three samples were taken in 50 ml polyethylene bottles (P1) in the cuvette, (P2) close to the dike and (P3) close to the dam, with one sample per point. The water samples were then transported to the laboratory under a cold regime for further measurements.

The water samples subject to ion analysis were first filtered through 0.45 µm cellulose acetate membranes. The samples for the determination of cations were first acidified with ultra-pure nitric acid (HNO_3). We determined ions including nitrites (NO^{2-}), ammonium (NH^{4+}), nitrates (NO^{3-}), fluorides (F^-), phosphates ($PO4^{3-}$), sulphates ($SO4^{2-}$), bicarbonatos (HCO^{3-}), chlorides (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}) in the laboratory of the Departmental Water Directorate of Borgou and Alibori, according to the standardized methods of the American Public Health Association [APHA-AWWA - WPCF, 1994]. In short, this method consists of quantitative analysis using volumetry. Calcium and magnesium contents were determined by complexometry, with titration using Ethylene-Diamine Tetra Acetic acid (EDTA). Chloride content was analyzed by argentometry with titration using silver nitrate. The bicarbonate content was measured with acid-base assay using sulfuric acid titration. The quantitative analysis of nitrates, nitrites, ammonium, phosphates and fluorides was carried out by spectrophotometry (HACH DR 2400), with operational wavelengths ranged between 400 and 800 nm. The procedure and reagents were obtained from HACH.

The total feacal coliforms and *Escherichia coli* were determined at 37 °C in the laboratory of the Departmental Directorate of Water of Borgou-Alibori. Per Adjagodo et al., (2016) the total feacal coliforms (TC) and *Escherichia coli* were measured in the water samples through germs of faecal contamination by type of Seed filtration of 100 ml of water on a 0.45 µm membrane in Agar-violet culture media at 37° C.

Determination of Water Quality Index (WQI)

The Water Quality Index (WQI) is a simplified method applied in the analysis of the overall water quality based on a set of parameters which allow to determine a single indicator, usually dimensionless and which can be reproduced. The different quality indices (of water, organic pollution, etc.) can be grouped into different categories according to the objective of their applications or structures, namely: general water quality, specific quality for a use, planning, statistical, biological or trophic state approach (Bekri et al., 2020). The characterization of a quality index is determined by its goal pursued (Cluis et al., 1986). Thus, the formula for calculating the WQI takes into account almost all of the parameters necessary for determining water quality and which corresponds to the composite influence of various parameters important for the evaluation and management of water quality (Zekri and Mansouri, 2020). Previous studies have used this index to assess the physicochemical changes capable of occurring in the year and their impact on the quality of drinking water (House et al., 1990). We selected different groups of parameters for the calculation of the IQE: sixteen (16) parameters namely pH, temperature, turbidity, conductivity, color, hardness, nitrites, ammonium, nitrates, fluorides, phosphates, sulfates, bicarbonates, chlorides, calcium, and magnesium; and nine parameters (pH, temperature, turbidity, conductivity, nitrites, ammonium, nitrates, phosphates and sulfates. The WQI helps to summarize large amounts of data on water quality in simple terms (Excellent, Good, Poor, Very Poor, etc.). The water quality parameters were also compared with international or national standards in Benin (Table 2). In this study, the WQI was calculated using the weighted arithmetic index method (Brown and Horton 1970). In this approach, a numerical value called relative weight (Wi), specific to each physicochemical parameter, is calculated according to the following formula (1):

$$W = \frac{K}{S_i} \tag{1}$$

Where *K* is the constant of proportionality and can also be calculated using the following formula (2):

$$K = \frac{1}{\sum_{i=1}^{i=n}\left(\frac{1}{S_i}\right)} \tag{2}$$

Within the number of parameters and S_i the maximum value of Benin standard for ground water of each parameter in mg/L.

Table 2: Variables used to calculate the WQI

Variables WQI **16**[a]	**Variable** WQI **9**[b]	**S_i (Standard, Benin)**
pH		**7**
Color (U.C)	Color (U.C)	14
Conductivity (µS/cm)	Conductivity (µS/cm)	400
Temperature (°C)	Temperature (°C)	30
Turbidity(UTN)	Turbidity (UTN)	5
Dissolved oxygen (mg/L)	Dissolved oxygen (mg/L)	5
Hardness (mg/L)	Hardness (mg/L)	200
Calcium (mg/L)	-	100
Magnesium (mg/L)	Magnésium (mg/L)	50
Chlorides (mg/L)	Chlorides (mg/L)	250
Nitrates (mg/L)	-	45
Nitrites (mg/L)	-	3.2
Ammonium (mg/L)	-	0,5
Fluorides (mg/L)	-	1.5
Phosphates (mg/L)	-	5
Bicarbonates (mg/L)		
	Sulfates (mg/L)	100

[a] 16 parameters used to determine the WQI, and [b] 9 parameters used to determine the WQI

Next, we calculated the water quality (Qi) rating scale for each parameter using the formula (3):

$$Q_i = 100\left(\frac{C_i}{S_i}\right) \quad (3)$$

With Qi the quality rating scale for each parameter, Ci the concentration of each parameter in mg/L. Finally, the WQI water quality index was obtained by the following formula (4):

$$WQI = \frac{\sum_{i=1}^{i=n} Q_i W_i}{\sum_{i=1}^{i=n} W_i} \quad (4)$$

Then, the water quality classes will be identified by considering the calculated values (Table 3).

Table 3: Classification and possible use of water according to the WQI **(Brown et Horton 1970)**

WQI Class	Water quality	Possible use
0 - 25	Excellent quality	Drinking water, irrigation and industry
>25 - 50	Good quality	Drinking water, irrigation and industry
>50 - 75	Bad quality	Irrigation and industry
>75 - 100	Really bad quality	Irrigation
> 100	Waste water	Appropriate treatment required before any use

Statistical analysis

The physico-chemical and bacteriological parameters were evaluated using descriptive statistical analysis with Excel spreadsheet (Microsoft Excel 2019). The statistics parameters (averages, standard errors, standard deviations) were used to produce graphs and tables presenting the results, and to calculate IQE and perform the classes of water quality.

RESULTS

Physical parameters

Physical parameters such as pH, temperature, conductivity, dissolved oxygen and turbidity were determined in the four dams studied. The pH of the water was almost neutral with an average value (standard deviation) of 7.37 ± 0.36. The temperature varied between 22.05 ± 0.66 and 26.49 ± 0.39 ° C, with the minimum value observed at Karakou Darou and the maximum at Tissarou. The mineralization of the water was relatively low with an electrical conductivity which varied between 65.97 ± 0.71 and 259 ± 1µS/cm.

The dissolved oxygen concentration ranged from 11.68 ± 2.99 (mg/L) for Tissarou to 23.44 ± 1.41 (mg/L) at Karakou Darou with an average value of 18.46 ± 5.89 (mg/L). For drinking water, the maximum acceptable color is 15 CU, from which the consumer can perceive the color of the water in a glass of water. The Batran and Tissarou dams had a high color index which varied between 35 CU and 40 CU. The lowest value recorded near Nawari with 12 CU. It is still in the same dam that the lowest turbidity value was observed (55 NTU), while the highest values of turbidity (195 ± 21.21NTU - 206.6 ± 37.85 NTU) was found in Karakou Darou and Tissarou, which explains a strong variation in color making the water cloudier (colored) in these two dams (Table 4)

Table 4: Physical parameters of the four dam waters

Dam waters	Conductivity (µS/cm)	Conductivity (µS/cm)	pH	Depth (m)	Temperature (°C)	Turbidity (NTU)
BATRAN	65.97 ±0.71	21.87 ±4.47	7.28 ±0.14	1.03 ±0.48	23.67 ±1,81	96.6 ±42.52
KARAKOU DAROU	259 ±1	23.44 ±1.41	7.73 ±0.30	0.42 ±0.19	22.05 ±0,66	195 ±21.21
NAWARI	77,86 ±2.55	18.53 ±4.90	7.25 ±0.13	0.79 ± 0.51	24.57 ±0.45	63.33 ±18.92
TISSAROU	190.96 ±.35	11.68 ±2.99	7.35 ±0.54	0.45 ±0.23	26.49 ±0,39	206.6 ±37.85
Overall average	148.45 ±76.53	18.46 ±5.89	7.37 ±0.36	0.7 ±0.46	24.39 ±1.84	140.41 ±71.23

Chemical Parameters

The diagrams in figure 2b illustrate the variations of the investigated chemical parameters. Total hardness is the total concentration of calcium, magnesium and other divalent and trivalent ions in that water. Here, the water hardness varied between 24 and 160 mg/L. The highest average value (152 mg/L) was recorded at point (P_2) of Karakou Darou and the lowest average value (42 mg/L) at point (P_2) of Batran.

Nitrites are considered to be intermediate ions between nitrates and ammoniacal nitrogen, which explains the low concentrations encountered in the aquatic environment. The high mean value of nitrites was recorded at Batran with 0.018 mg/L. Nitrates, with higher average value of 7 mg/L in the Tisarou dam water, generally originated from the decomposition of organic matter by bacterial oxidation of nitrites, thus constitute the ultimate product of nitrification. The nitrate contents were between the 3 mg/L (minimum value) recorded at point (P_2) of Karakou Darou and 7.5 mg/L (maximum value) at point (P_3) of Tissarou.

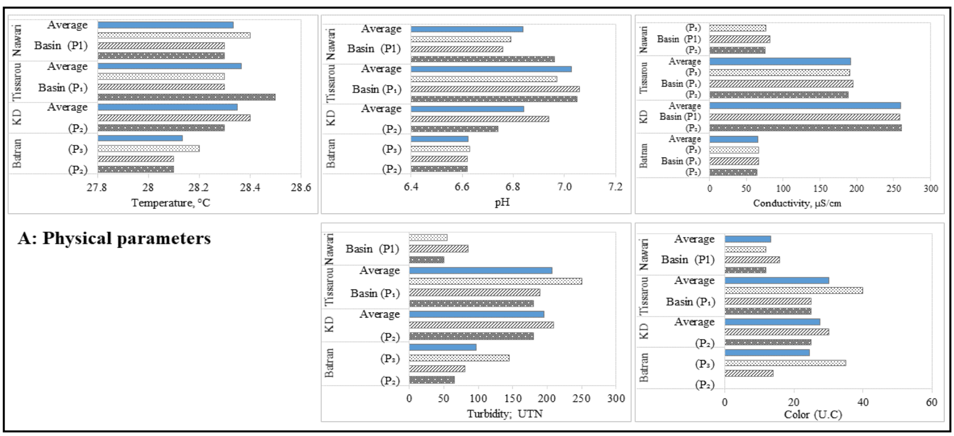
Ammonium is the final reduction product of nitrogenous organic substances and inorganic matter in water and soil. It also comes from the excretion of living organisms and the reduction and biological degradation of waste, without however neglecting inputs from domestic and agricultural sources. The ammonium ion concentrations at the four studied water reservoirs were less than 0.5 mg/L, except the Karakou Darou water reservoir which recorded a concentration of 1 mg/L at Points (P_1) and (P_3).

The fluoride concentration was low (0-0.33 mg/L) in the four water reservoirs, and was less than 1.5 mg/L which is the Benin standard. This low concentration could mean that the fluoride ions do not constitute a danger for the use the four dams water as drinking water.

The phosphate concentrations of the water reservoirs were between 0 and 2.7 mg/L. The highest average value was 1.7 mg/L recorded at Batran. However, it was clearly below the admissible limit for phosphates, i.e. 5 mg/L. Consequently, this parameter may not constitute a major risk.

Biological parameters

The water points were mostly contaminated with fecal feacal coliforms (Table 5, figure 3). Only the Tissarou cuvette was contaminated by E. Coli (6400 (CFU/100 mL). The general average of the feacal coliforms was 178 472.727 CFU/100 mL. The maximum value was obtained in areas near the Tissarou dam with a value of 1011200 UFC/100 mL. The minimum value of 1600 CFU/100 mL was recorded in the zones (P_3) near the Batran dam.



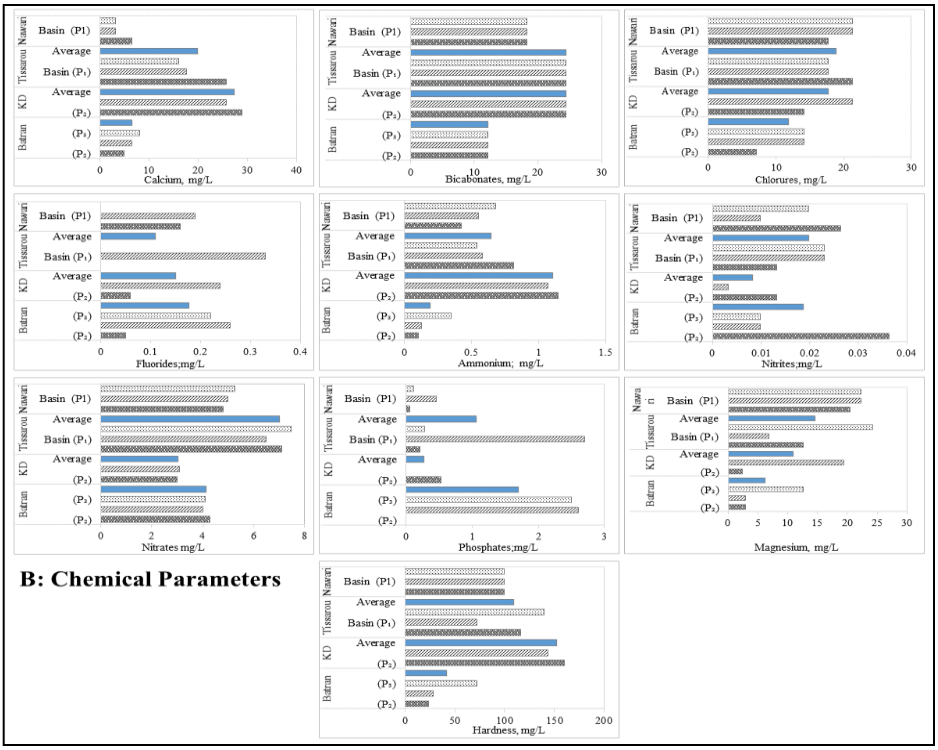


Figure 2: Variation of physico-chemical parameters in the dam waters of Batran, Karakoudarou, Nawari and Tissarou (January, 2021)

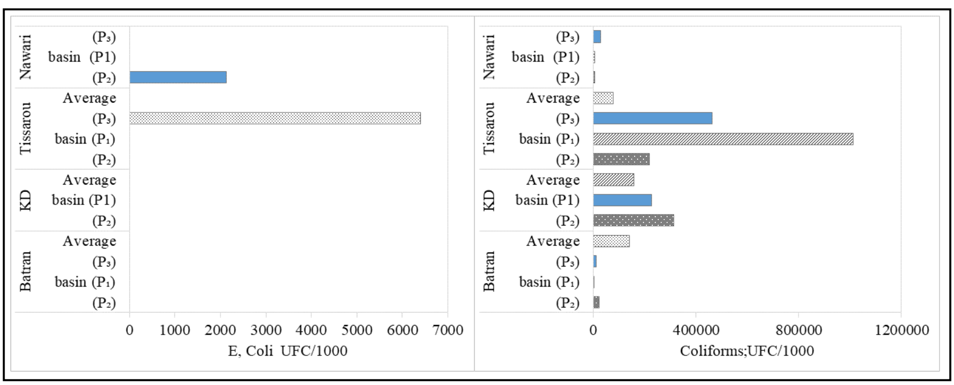


Figure 3: Variation of biological parameters in the water reservoirs.

Table 5: Total coliform and E. Col in the water reservoirs

Identification	Feacal coliforms (UFC/100 mL)	E. Coli (UFC/100 mL). Coli (UFC/100 mL)
Batran (P_1)	22400	0
Batran (P_2)	11200	0
Batran (P_3)	1600	0
Karakou Darou P_1)	312000	0
Karakou Darou (P_2)	140800	0
Tissarou (P_1)	219200	6400
Tissarou Digue (P_2)	156800	0
Tissarou (P_3)	1011200	0
Nawari (P_1)	4800	0
Nawari (P_2)	78400	0
Nawari (P_3)	4800	0
Average	**178472.7**	**581.8**

Spatial variation of physicochemical parameters in the water reservoirs

Table 6 shows the mean concentrations of the physicochemical parameters of the dam waters and reservoirs which favored the calculations of the WQI. Among the 16 parameters, temperature remained constant with an average value of 28°C. The highest conductivity was 259 (µS/cm) at Karakou Darou. In the four dam waters, except Karakou Darou, the average ammonium was higher than Benin standard which is 0.5 mg/L, whereas the average nitrites value was lower than Benin standard in all the dam waters/water reservoirs. The total absence of E. Coli (UFC /100) in all the water reservoirs was remarkable except in Tissarou which registered an average of 2133.33 (3695 CFU/100). However, the presence of high levels of Feacal coliforms (CFU/100 mL) was noted in all the water reservoirs with a high average of 462.400 CFU/100 mL) in Tissarou.

Determination of WQI and evaluation of the water quality

Using the maximum values of the Benin standard for surface water physicochemical parameters, the relative weight (Wi) of each physicochemical parameter and the proportionality constant k are first calculated an listed in Table 6. The estimated WQIs with 16 parameters and 9 parameters were different one from another for each point (P_1), (P_2) and (P_3) of the dam water (Table 7). The WQIs (9 and 16) were similar in the Cuvette (P1) of Karakou darou (137.24 and 137.14), at Point (P_3) of Nawari (88.95 and 88.64), at point P ($_3$) from Tissarou (86 and 86) and at point (P_3) from Tissarou (58.37 and 58.00). The WQI values of 9 parameters were significantly higher than the WQI of 16 parameters in all areas of the basin of Batran (WQI (P_1) 42.62 and 38.06; WQI (P_2) 40.32 and 33.72; WQI (P_3) 78.93 and 67.50).

After the calculation of the global water quality index (WQI) using the results of physico-chemical analyzes and the values standards from Benin standard (Benin water quality standard, 2002), the water quality classes were determined for 12 samples corresponding to the four dams (Table 6). Thus, we identified four quality classes: good, bad, very bad and not usable without treatment (Table 7). Water from the Karakou Darou dam should not be used without proper treatment (WQI> 100). Poor water quality ($50 \leq WQI \leq 75$) was observed in the Batran water reservoirs at point (P_3), in points (P_1) and (P_2) of Nawari, at points (P_1) and (P3) of Tissarou and a very poor quality of the water ($75 \leq WQI \leq 100$) was found in the reservoirs of Batran (P_3), Nawari (P_1 and P3) and at the point (P_2) of Tissarou.

At points (P_1) and (P_2) of the Batran reservoir, the WQI was less than 50, which shows the good quality of the water in this reservoir. The WQI increases from upstream to downstream and especially in areas of intensive human activities. The presence of ammonium would significantly increase the surface WQI in all the areas of the studied water reservoirs.

Table 6: Weight of physico-chemical parameters (Wi) and Benin standard

Variables	$S_{i\ (standard) Benin}$	1/Si	Wi=K/Si
Color (U.C)	15.00	0.067	0.017
Conductivity (µS/cm)	2000.00	0.001	0.000
Temperature(C°)	30.00	0.033	0.009
Turbidity (UTN)	5.00	0.200	0.051
Dissolved oxygen(mg/L)	5.00	0.200	0.051
pH	7.00	0.143	0.037
Hardness (mg/L)	200.00	0.005	0.001
Calcium (mg/L)	100.00	0.010	0.003
Magnésium (mg/L)	50.00	0,02	0.005
Chlorures (mg/L)	250.00	0.004	0.001
Nitrates (mg/L)	45.00	0.022	0.006
Nitrites (mg/L)	3.20	0.313	0.080
Ammonium (mg/L)	0.50	2.000	0.515
Fluorides (mg/L)	1,5	0.667	0.172
Phosphates (mg/L)	5.00	0.200	0.051
∑1/Si		3.884	
K=1/∑1/Si		0.257	
∑Wi=∑(K/Si)			1.000

Table 7: WQI index values and water quality class of the four dams

Dams	Zoned	WQI **9 P**	Class/quality	WQI **16 P**	Class /quality
Batran	P1	42.620	Good	38.067	Good
	P2	40.324	Good	33.726	Good
	P3	78.939	Very bad	67.508	Bad
	Average	**53.970**	Bad	**46.430**	Good
Karakou Darou	P1	134.147	Waste water	137.248	Waste water
	P2	108.450	Waste water	108.720	Waste water
	Average	**121.300**	Waste water	**123.000**	Waste water
Nawari	P1	73.907	Bad	76.382	Very bad
	P2	67.020	Bad	69.140	Bad
	P3	88.600	Very bad	88.900	Very bad
	Average	**76.520**	Very bad	**78.150**	Very bad
Tissarou	P1	65.640	Bad	69.570	Bad
	P2	86.000	Very bad	86.000	Very bad
	P3	58.000	Bad	58.400	Bad
	Average	**69.820**	Bad	**71.340**	Bad

DISCUSSION

Water is essential for life, but it can also be contaminated with human and animal wastes containing pathogenic microorganisms that cause serious epidemics known as water-borne diseases (Hedahdia and Aliouche, 2016). The presence of faecal coliforms and faecal streptococci in the water indicates faecal pollution, in which bacteria are commonly used to identify the intensity of the faecal pollution (Ghazali and Zaid, 2013). Moreover, WQI is a good indicator of the pollution of rivers by urban effluents (Derwich et al., 2010). The WQI was very high with the presence of ammonium in all areas of the studied Alibori reservoirs.

The water from the study area ranged from good quality in the basin and dyke of Batran water reservoir (25 < WQI > 50), to poor quality (50 < WQI < 75), showing the degradation of the water quality which becomes more intense from upstream to downstream of the water reservoirs. Similar studies showed that the deterioration of water quality from upstream to downstream of rivers is mainly linked to discharges of urban and industrial wastewater and/or the impact of agricultural activities (Talhaoui et al., 2020a). These pollutions can threaten animal and human health. For Derwich et al., (2008), the use of wastewater for irrigation would be the source high contamination of vegetables or other agricultural products or of users.

The physico-chemical water parameters of the four Alibori dams showed that the waters from the dams are within tolerable limits in relation to the weak socio-economic development of the study area. This statement was supported by Akil et al., (2014) on the study of the quality of the surface water of Wadi Guigou in Moroc. The water hardness values varied between 24 and 160 mg/L and would be linked to the lithological nature of the aquifer formation, in particular its magnesium and calcium contents. Our results also show that the nitrite content was very low and did not exceed the WHO standard (0.1 mg/L). In fact, both the physicochemical and biological quality of the water usually did not meet the standards. The WQIs was greater than 50 in most dam water areas except in Batran. The ammonium content that was very low and approximated zero in the water reservoirs of Batran, Nawari and Tissarou suggests this element may not constitute a pollution risk for surface water of the study area; except in Karakou Darou where it was higher than Benin standard. Thus, the environmental degradation of water quality at the Karakou Darou water reservoirs was due to the relatively high concentrations of ammonium and Nitrates which exceed the Benin drinking standards of 0.5 mg/L for ammonium and 45 mg/L for Nitrates. These results are similar to those of Talhaoui et al., (2020a) in the area of Zaida, of Missour and Oued Melloulou and in the communes located along the wadi in Morocco. Similar causes of degradation have been observed along the lower valley of Sébou in Morocco (Talhaoui et al., 2020b) and along the lower valley of Ouémé in Benin (Adjagodo et al., 2016).

The water color reflects an aesthetic nuisance, because drinking water should ideally be clear and colorless. The first sign of water quality is the change in its color which can reflect its potability (Chelli et al., 2013). According to Zekri and Mansouri, (2020) the coloring of water can have several origins, namely: a natural, industrial, chemical or biological origin. It can also be due to the presence of organic matter such as humic substances (humic acids which react, moreover, with chlorine to give undesirable organohalogen compounds.), Tannins, but also metals such as iron and manganese as well, and strongly colored industrial residues. It is therefore important to measure water color, since a high color causes its rejection by the consumer. For drinking water, the maximum acceptable color level is 15 UC from which the consumer can perceive the color of water in a glass of water (Zekri and Mansouri, 2020).

CONCLUSION

This study determined the physico-chemical and bacteriological parameters of dam and reservoirs waters from Batran, Karakou Darou, Nawari and Tissarou in the department of Alibori in northern Benin, to assess their environmental and health risks. The results indicate that both the physicochemical and microbiological quality of the water did not usually meet the water standards. Indeed, the waters were characterized by very low nitrite contents (lower than WHO standard). The ammonium contents at Karakou Darou were higher than the Benin standard. In general, there is a significant presence of faecal feacal coliforms in all the dam waters. The protection of these waters against various contaminations is necessary and imperative for their use without risk of contamination. The WQI increased from upstream to downstream, particularly in Karakou Darou dam. In perspective, the evaluation of water quality of our study environment should integrate other complementary parameters such as microbiological parameters in addition to physicochemical and heavy metal parameters in the WQI calculations and in water quality monitoring. The limitation of this study included the lack of measurement of BOD, organic pollutants, and heavy metals contents due to the deficiency of funding and limited lab facilities, though BOD, organic pollutants, and heavy metals constitute important parameters of surface water pollution. Further studies should mainly focus on these parameters and consider them during their investigations on these studied water reservoirs.

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