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Characterization of Chemical Pollution in the Agbado River Basin in Central Benin

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Authors' contributions

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

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ABSTRACT

The basin of the Agbado River is located across the hills department, between 7°27' and 8°46' north latitude and between 1°39' and 2°44' east longitude. In case to characterize the mineral elements that degrade water quality and to analyze the state of chemical pollution of the waters of the Agbado River, by the characterization of chemical pollution in the Agbado river basin we randomly sampled eight (08) sites throughout along the river. Volumetric and titrimetric methods were used to determine the various physico-chemical parameters in water and sediments. The organic pollution index method was used to assess the water quality of the Agbado River. The results of the

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physicochemical water analysis reflect the pH variations in the water samples. The pH values do not correspond to the standard accepted by the WHO. The pH values obtained are between 6.01 and 6.69; values below the WHO standard (7-9). The electrical conductivity obtained are between 53.8 and 248 µS/cm. In accordance with the recommendations of the WHO for drinking water (conductivity < 2000µS/cm), translates that the waters analyzed are of low mineralization and therefore tolerable. Regarding major and minor ions only phosphorus, ammoniacal, nitric, sodium, iron, calcium, magnesium contents that do not meet the standard set by the WHO. The results from the determination of the Organic Pollution Index indicate that organic pollution is moderate on all eight (08) sampling sites.

Keywords: Agbado River; chemical pollution; physicochemical parameter; sampling sites; organic pollution index.

1. INTRODUCTION

Demographic expansion and the development of human activities in the world are not without consequences for the environment. In West Africa, there is a very severe degradation of water quality and the environment due to the release of varieties of chemical molecules from agropastoral and industrial activities [1-3]. Intensive use of pesticides and fertilizers, poor management of garbage dumps, untreated wastewater discharges from industries, hospitals and households contribute directly or indirectly through runoff or drainage to surface water

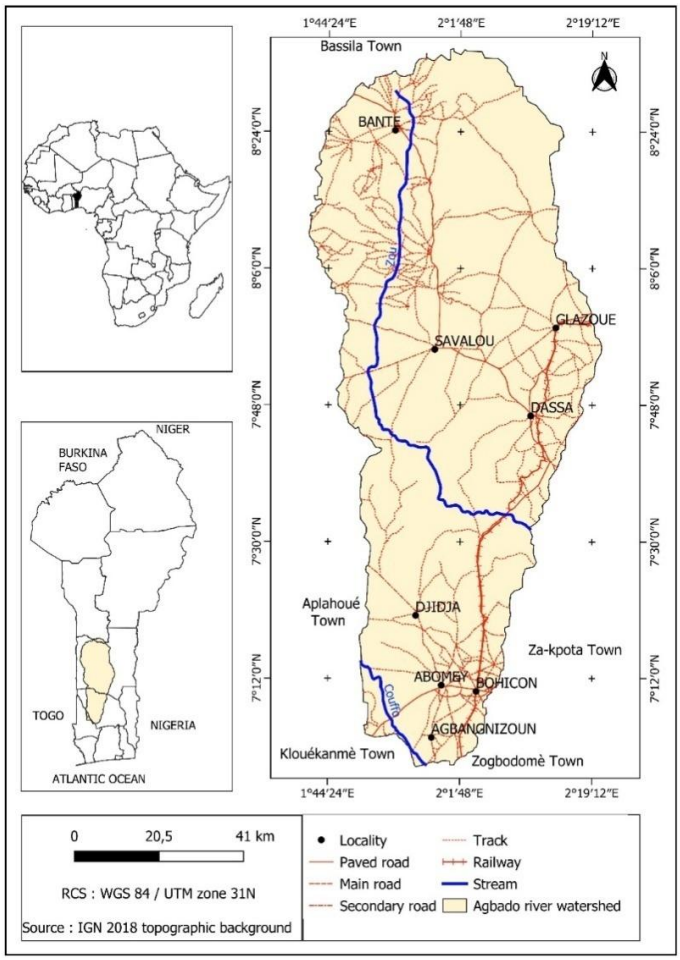

Fig. 1. Geographic location of the Agbado River basin

pollution and influence water characteristics [4]. The physicochemical quality of the water is the basis of the ecology of the watercourse. This serves as a support for aquatic life [5]. The study of the physicochemical quality and the evaluation of the trophic level of watercourses will make it possible to characterize the mineral elements that degrade water quality and threaten aquatic life [6]. In Benin, the water bodies, including the Agbado River, are not spared from chemical pollution problems. The objective of this study is to analyze the state of chemical pollution of the waters of the Agbado River.

1.1 Study Area

The basin of the Agbado River is located across the hills department, between 7°27' and 8°46' north latitude and between 1°39' and 2°44' east longitude (Fig. 1). It straddles the communes of Dassa-Zoumé, Glazoué, Savalou, Bantè to the north and the communes of Djidja, Abomey, Bohicon and Agbangnizoun to the south with an area of approximately 2703 km^2. The Agbado River, which is the main watercourse from which the basin inherits the name, flows into the Zou River at the level of the Atchérigbé classified forest near Setto in the NNW-SSE direction.

The basin is sunny, well lit throughout the year and the annual average insolation at the synoptic station of Savè, for the period from 1956 to 2010 is 2455.6 hours [7,8]. Temperatures remain high all year round but are never excessive. The hydroclimatic averages, which are constantly high and almost homogeneous for the entire sector, do not constitute a limiting factor for agricultural activities. The different crops practiced in this watershed result both from the soil, geological and plant cover aptitudes and the availability of water in their first horizons.

2. MATERIALS AND METHODS

2.1 Water and Sediment Sampling

Water and sediments sampling campaign from the Agbado River was carried out. Sampling sites were selected randomly all along the river (Fig. 2). Three samples were taken at each point, including two water samples for physicochemical analysis. A third sediment sample is taken for the evaluation of contamination with metallic trace elements.

2.2 Measurement of Physicochemical Parameters in Waters and Sediments

The *in-situ* parameter measurements concern the Hydrogen potential (pH), the Temperature (T in °C) and the electrical conductivity (CE in µS). The three *in-situ* parameters are measured using the pH/Oxi meter WTW 340 i device, which displays on its screen the values of pH, temperature and electrical conductivity. The different physicochemical parameters were measured by volumetric and titrimetic methods. Volumetric assays concerned calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}) and chloride ions (Cl^-) and bicarbonate ions (HCO_3^-).

Trace elements such as copper, zinc, cadmium and lead were measured in the water samples taken. The determination of these trace elements was made after prior mineralization of the samples according to standard NF EN ISO 15587-2 (2002). Depending on the suspected concentration range, 20 to 40 mL of the samples were transferred to Digesdhal vials and 4 mL of nitric acid were added. The manipulation was done under a fume hood. The digestion temperature was set at 440°C and the whole was brought to the boil on the hot plate. To the carbonized sample, 10 mL of 50% hydrogen peroxide were added. Excess hydrogen peroxide was evaporated and the fractionating column removed. The mineral is cooled and diluted with distilled water. The measurement of the four metallic trace elements was made in the laboratory by the dithizone method using the DR 2800 molecular absorption spectrophotometer 20 mL f mineralized sample was brought to volume (250 mL); for each sample. This volume is placed in a separating funnel where the sodium citrate buffer is added.

Histograms presenting the levels of variation of the physicochemical parameters were produced with the R studio software. To assess the quality of the water, the results obtained are compared with the quality standard for water intended for consumption in the Republic of Benin and with the WHO directive [9].

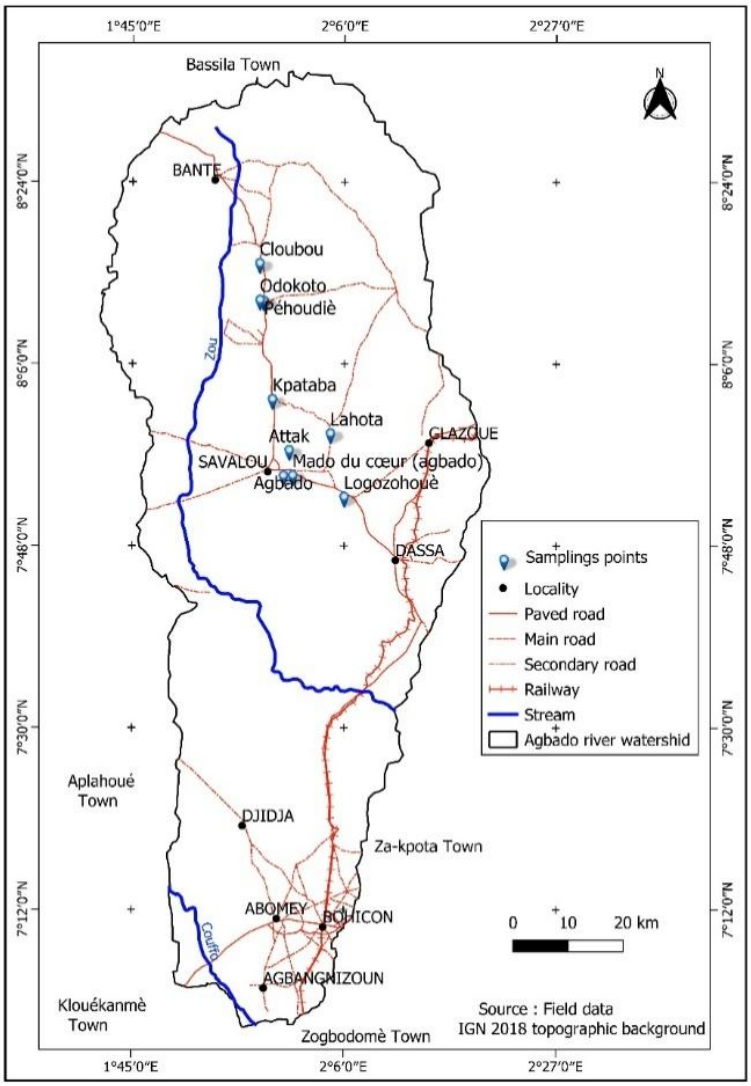

Fig. 2. Spatial distribution of water and sediment sampling points in the Agbado River

3. RESULTS

The various agro-pastoral activities identified in the Agbado River basin influence the quality of surface water. And to assess this influence, the contents of different physicochemical parameters of the waters and sediments were determined.

3.1 Analysis of the Physicochemical Parameters of the Waters of the Agbado River

The Fig. 3 presents the values of pH, electrical conductivity, salinity and the concentration of total dissolved substances (TDS) in the waters of the Agbado River.

pH determines the acidity, alkalinity and neutrality of solutions. It is linked to the nature of the terrain, characterizes a large number of physicochemical balances and depends on multiple factors including the origin of the water [10]. In natural waters, a pH between 6 and 8.5 allows normal development of aquatic fauna and flora [11]. In the waters of the Agbado River, the pH values obtained are between 6.01 and 6.69; values below the WHO standard (7-9). These values indicate an acidity of the analyzed waters and an aggressive character. Dissolved matter in water is in the form of electrically charged ions. And the ability of water to conduct electric current is measured by electrical conductivity [12], the variation of which provides information on mixing or infiltration zones, making it possible to follow the evolution of a pollution. On all the water from

the sampling points, the conductivity varies between a minimum of 58.3 µS/cm and a maximum of 248 µS/cm. In accordance with the recommendations of the WHO for drinking water (conductivity < 2000µS/cm), translates that the waters analyzed are of low mineralization and therefore tolerable.

3.2 Contents of the Waters of the Agbado River in Major Ions

The Fig. 4 presents the values of the major ion contents (potassium, sodium, calcium and magnesium) contained in the water sampled.

In the water sampled, the sodium content varies from 4.16 mg/L to 25.82 mg/L, with an average of 8.57 mg/L. The high grade is obtained at the bank of kpataba. The potassium concentrations vary from 2.51 and 13.41 mg/L with an average of 5.65 mg/L. These values obtained are below the standard set by the WHO which is 50 mg/L for surface water) except that of Logozohè (13.41) which slightly exceeds the required standard. Concerning calcium, the contents obtained are of the order of 3.63 to 22.24 mg/L with an average of 9.93 mg/L; these values are below the standard set by the WHO, which is 75 mg/L for surface water. Magnesium levels are between 2.09 and 4.83 mg/L and are well below the acceptable standard set by the WHO, which is 30 mg/L.

Fig. 5 shows the values of the levels of nitrogen compounds (nitrogen, ammonium, nitrites) and phosphorus (phosphates) contained in the water withdrawn. This figure shows that the ammonium concentration varies between 14.88 mg/L and 21.70 mg/L with an average of 17.42 mg/L. The nitrite concentrations are between 1.26 and 2.97 mg/L with an average of 6.86 mg/L; values above the required WHO standard. All the sampling points show a quantity of phosphorus ranging from 2 mg/L to 19 mg/L with an average of 7.77 mg/L. There is a strong penetration of phosphorus in the rivers (adokoto and logozohè) with a respective rate of 18 mg/L and 19 mg/L. The quantities of nitrates comply with the standards set by the WHO (50 mg/L according to the WHO) except that of Logozohè which relatively exceeds the said standard.

3.3 Water Quality of the Agbado River

Organic pollution was assessed using the organic pollution index [13]. This characterizes the organic pollution from the content of ammonium, nitrites and orthophosphates which are divided into five classes (Table 1: ref {IPO}) of which the average of the class numbers of the three (03) parameters is the index of organic pollution of the constituted sample. The analysis of the results obtained (Table 1 and 2) showed that all the waters are of moderate organic pollution.

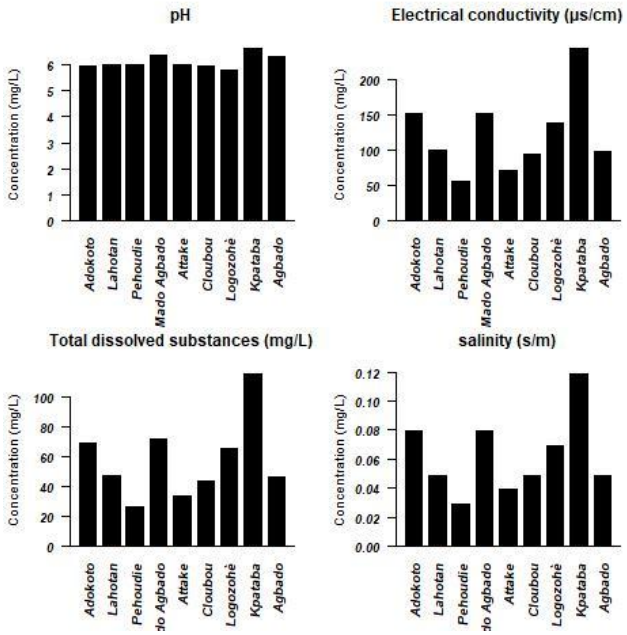

Fig. 3. pH, TDS, Conductivity and salinity of the waters of the Agbado River

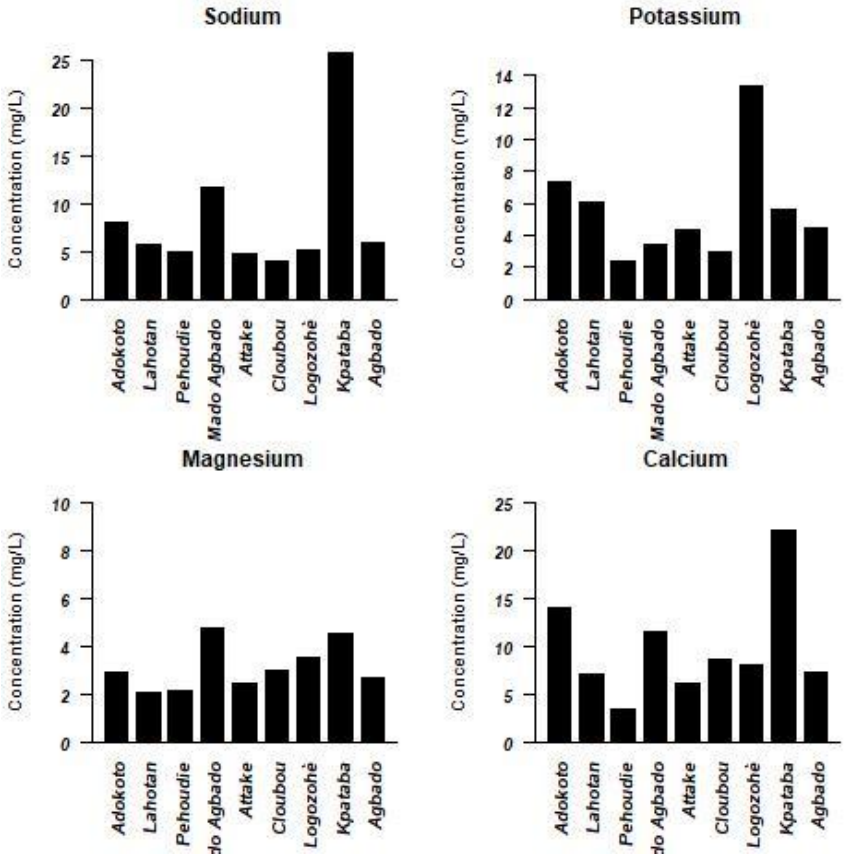

Fig. 4. Sodium, potassium, magnesium and clacium levels in the waters of the Agbado River

Table 1. Class limits of the IPO Organic Pollution Index [14,15]

Classes	Ammonium (mg/L)	Nitrite (µg/L)	Phosphate (µg/L)
5	< 0,1	5	15
4	0,1 - 0,9	6-10	16-75
3	1 - 2,4	11 - 50	76-250
2	2,5-6	51 - 150	251 - 900
1	>6	>150	>900

IPO = Organic pollution index average of three parameters
5-4,6 : no organic pollution, 4,5-4: Low Organic pollution, 3,9-3: Moderate Organic pollution, 2,9-2: Heavy Organic pollution, 1,9-1: Very heavy Organic pollution

Table 2. State of IPO organic pollution of the waters of the Agbado River

Sampling points	Classes			IPO	Type of Organic pollution
	NH^{4+}	NO_2	PO^{2-}_4		
Adokoto	1	5	4	3,66	Moderate Organic pollution
Lahotan	1	5	5	3,66	Moderate Organic pollution
Pehoudie	1	5	5	3,66	Moderate Organic pollution
Mado Agbado	1	5	5	3,66	Moderate Organic pollution
Attake	1	5	5	3,66	Moderate Organic pollution
Cloubou	1	4	4	3	Moderate Organic pollution
Logozohè	1	5	5	3,66	Moderate Organic pollution
Kpataba	1	5	5	3,66	Moderate Organic pollution

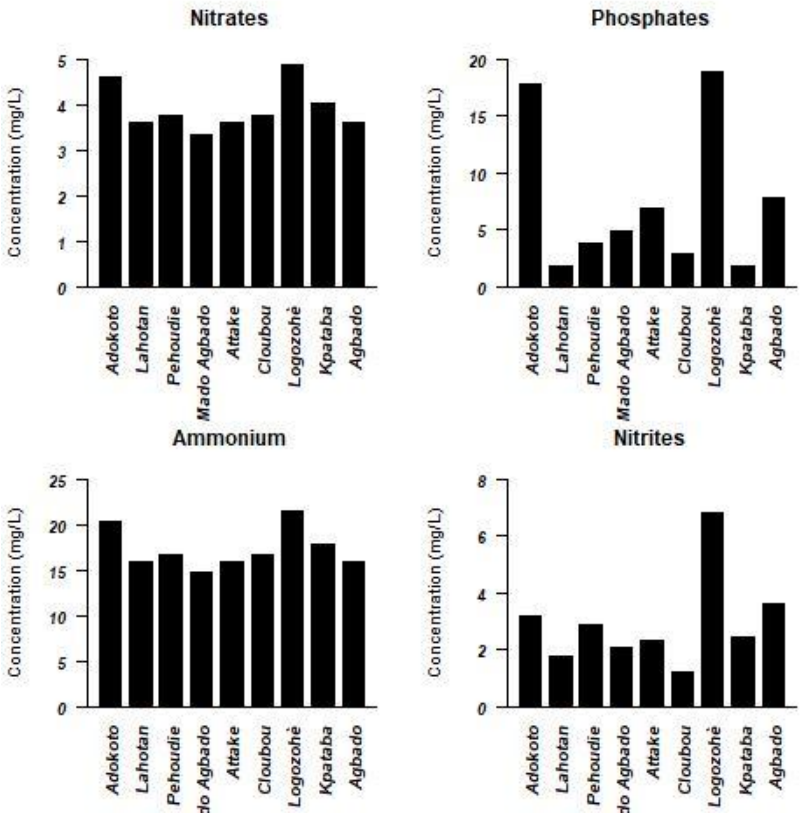

Fig. 5. Contents of nitrogen compounds (nitrites, ammonium, nitrates) and phosphorus (phosphates) contained in the waters of the Agbado River

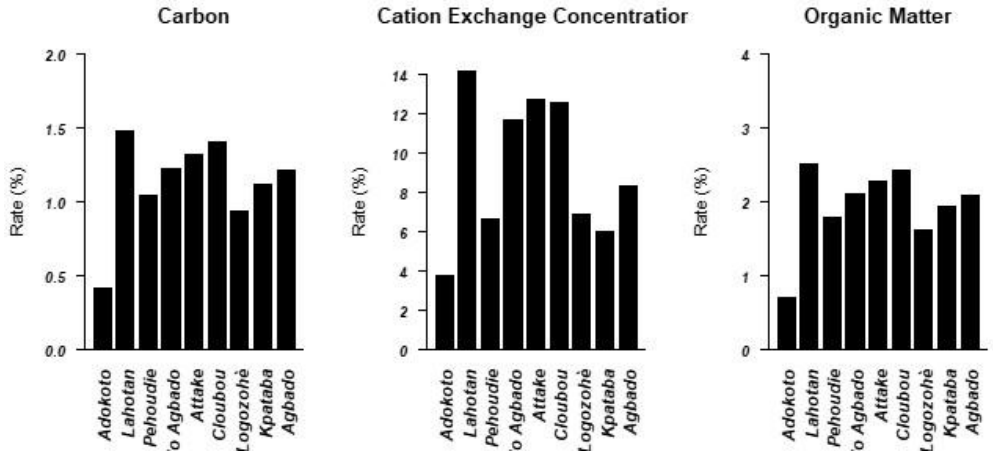

Fig. 6. Values of Carbon (C) rate, the Cation Exchange Concentration (CEC) and the Organic Matter (OM) rate in the sediments of the Agbado River

3.4 Analysis of Physicochemical Parameters in the Sediments of the Agbado River

The Fig. 6 presents the values of the Carbon rate (C), the Cation Exchange Concentration (CEC) and the rate of Organic Matter (OM) in the sediments of the Agbado River. Analysis of the graphs in this figure shows that these rates are relatively low and vary respectively between 0.4% - 1.4%; 4% - 14% then 0.75% - 2.5%. These values obtained indicate a very low

accumulation of organic matter in the bed of the main watercourses. Moreover, the search for metallic trace elements in the various sediments proved fruitless. This finding, which confirms the absence of accumulation of organic matter in the waters of the Agbado River, can also be explained by the period (dry season) during which the samples were taken.

4. DISCUSSION

The results of the physicochemical water analysis reflect the pH variations in the water samples. The pH values do not correspond to the standard accepted by the WHO. The values observed are similar to those obtained by [16] in the municipality of Kétou which are between 5.5 and 6.7. The highest conductivity value is obtained at the Kpataba bank (248 µS/cm), but it does not exceed the standard required by the WHO for consumption, which is 2000 µS/cm. On Lake Adokoto and the shores of Lahotan, Pehoundie, Mado du Coeur, Attake, Cloubou, Logozohouè and Agbado, the conductivities are respectively 153.3 µS/cm, 103.5 µS/cm, 58.3 µS/cm, 155 .5 µS/cm, 73.6 µS/cm, 96 µS/cm, 141.2 µS/cm and 100.6 µS/cm. We can therefore conclude that the water of the Kpataba shore has an accentuated average mineralization, therefore very conductive, while the waters of the 8 other sites mentioned above have a low and average mineralization. These values obtained are similar to those obtained by [16] which vary between 71 and 472 µS/cm. This mineralization would result from significant inputs of organic matter or microbial degradation [17]. Ammonium has a maximum permissible value of 0.5 mg/L. The results obtained after analysis do not comply with the standard. The results obtained are contrary to those found by [18] who found that 100% of the water samples from the different localities of the municipality of Zogbodomey have ammonium concentrations below the WHO standard. The presence of ammonium in the water gives it an unpleasant taste and facilitates the development of germs. With regard to nitrates, the admissible value for the potability of water is 50 mg/L. All surface water sample values (4.15 mg/L, 2.34 mg/L, 3.79 mg/L, 2.70 mg/L, 3.07 mg/L, 1.62 mg/L, 8.84 mg/L, 3.25 mg/L and 4.69 mg/L) comply with the standard. These results are similar to those of [19] who found that 100% of the samples of water used for consumption have their nitrate levels below the standard. Contrary to nitrates, the presence of potassium is noted in the sampled waters. Of all the waters sampled, only the value from the shore of Logozohè (13.41 mg/L) does not meet the standard (10 mg/L). The values of the other eight samples are lower than that set by the WHO.

All the waters sampled have phosphorus, ammoniacal, nitric, sodium, iron, TDS, salinity psu, calcium, magnesium contents that do not meet the standard set by the WHO. These results are contrary to those of [18]. Agro-pastoral activities in the Agbado River watershed have led to pollution of river waters and degradation of water quality.

5. CONCLUSION

At the scale of the Agbado River watershed, various agro-pastoral activities have been developed. The sometimes abusive use of chemical products (chemical fertilizers, insecticides and pesticides) has led to a change in the quality of the waters of the Agbado River. The analysis of the physicochemical parameters of water showed the impact of agro-pastoral activities on water resources in the watershed of the Agbado River. The modification of the quality of water resources due to agro-pastoral practices associated with the degradation of the environment and the vegetation cover would make vulnerable the main rivers in the study area and the local populations who must now develop strategies to adapt to the impacts of climate variability, a guarantee of sustainable development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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