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Characterization of the Physicochemical and Chemical Parameters of the Surface Waters of Keur Momar Sarr in the Louga Region (Senegal)

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Abstract Water brings to every living being a good health and the well-being of his organism. It allows them to meet their basic needs and especially their diet. But, for a beneficial use, the optimal quality of the water is crucial. Here in Senegal most of the regions are fed by the lake Lac de Guiers and the latter is threatened by industrial discharges, hydroagricultural activities that cause a gradual degradation of its quality. In this study, we made a characterization of the physicochemical parameters of the waters of Keur Momar Sarr in order to have visibility on the evolution of ions, temperature, pH, conductivity etc. Then, a comparative study between certain measured chemical elements and the standards of discharges or potability was made. The results obtained show that the surface waters of Keur Momar Sarr are of excellent quality with a dominance of a chlorinated and sulphated calcium facies. We observed a dominance of chloride ion at the anion level and magnesium ion at the cation level. The analyzes also showed that the carbon dioxide content is high at point 5, which corresponds to the water already treated as well as the lead and sodium, compared to the four other points located before treatment of the surface water of the lake. However, the iron, nitrate and phosphate contents are low by WHO standards. It should be noted that the water intended for the drinking water supply of regions downstream from the treatment plant deserves improvement. In fact, almost all of these physicochemical parameters do not comply with the standards established by the World Health Organization.

Keywords: *Guiers Lake, characterization, physicochemical parameter, quality, potability*

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1. Introduction

Today, more than a billion people in the world do not have access to safe drinking water and half of the population of the developing world suffers from diseases due to water contamination [1]. Water quality can be altered in two ways, namely bacteriological and physicochemical pollution [1]. Despite the progress made in recent decades, many parts of the world still face serious problems in the supply of drinking water. The considerable evolution of the demand for water in the world, linked mainly to the rapid growth of the population, the dynamics of urbanization and the rise of living standards, has led to the increase of the storage capacities of surface water [2].

Water quality monitoring data collected over the past decade in urban drinking water distribution networks call for a reassessment of water and health issues in developed countries [3].

Population growth and the degradation of ecosystem integrity have resulted to a large extent in a decline in water resources, the most critical factor for sustainable development [4].

Water is the sector most covered by the European Union and environmental policy [5].

Water and water resources are very important for maintaining an adequate food supply and a productive environment for all living organisms [6].

The use of conventional water treatment processes is becoming increasingly difficult with the identification of more and more contaminants, the rapid growth of population and industrial activities and the decrease in the availability of water resources [7].

With rapid industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture cause heavy and varied pollution in the aquatic environment leading to the deterioration of water quality and depletion of aquatic biota. Due to the use of contaminated water, the human population suffers from waterborne diseases [8].

Lake Guiers is the largest reservoir of surface water in Senegal. Located in the north of the country, it has a morphology characterized by a north-east and south-west elongation. With 50 km long, 7 km wide and a volume of 680 million m^3, it is a flat plat and a little deep lake with a depth estimated to 2 m. Its center north has a free water and its south is dominated by macrophytes, *Typha domingensis* [9]. Its northern part receives water from the Senegal River via the canal of Taouey [10].

In this present work, we have carried out a characterization of the physicochemical and chemical parameters of the waters of Keur Momar in order to gain visibility on the evolution of these parameters. Then, a comparative study between certain chemical elements measured and the discharge or potability standards was carried out.

2. Materials and Methods

2.1. Location of the Project Area and Identification of Measurement Points

The Keur Momar Sarr (KMS II) treatment plant is located south of Lake Guiers, along the D302 departmental road, in the Louga region, in the eponymous department, 3 km north of the town of Keur Momar Sarr, capital of the commune of the same name.

The Figure 1 below shows the location of our study area.

Figure 1. Location map of the Keur Momar Sarr plant (KMS II)

For this work, we have chosen five points for taking analytical samples, which are the measurements, namely:

- Point 1 presents the sample taken from the left bank.
- Point 2 corresponds to the sample taken in the middle of the lake.
- Point 3 corresponds to the sample taken from the right bank.
- Point 4 presents the sample taken from the water intake for treatment in the plant.
- Point 5 corresponds to the sample of water already treated in the plant.

The Figure 2 shows the location of water quality measurement points.

Figure 2. Presentation of water quality measurement points

2.2. Sampling Methods

The waters were sampled at a depth of about 30 cm above the surface for physicochemical analyses. The sampling bottles were rinsed several times with the water to be taken. The sampling is made on an interval of 25 mn from 12h to 15h continuously in May 2021. These samplings have been conserved in polythene bottles at 4°C to be sent to the laboratory of Polytechnic School of Thies (EPT) for analysis.

The Physicochemical parameters such as pH, temperature and conductivity are immediately analyzed in situ with a WTW 330Wi/SET pH meter (0.1 accuracy) and a WTW 318/SET conductivity meter (2us/cm accuracy). The other chemical parameters, namely ions, were measured in the laboratory using the DR/2000 spectrophotometer. The Chemical Oxygen Demand (COD) is dosed 20 days later by the cod reactor digestion method.

2.3. Presentation of the DIAGRAMME Software

The main tool used is the DIAGRAMMES software. It is a hydrochemistry software in free distribution facilitating the exploitation of water analysis. These functions are varied and comprehensive. The diagrams used for this work are Piper, Schoeller-Berkalov, Wilcox, Stabler and Riverside. The calculated parameters include ionic balance, hardness, saturation index, cation contents, and anions. However, not all features were used. We worked for this study with the Piper and Schoeller diagram.

The Piper diagram is used to represent the chemical facies of a set of water samples. It is composed of two triangles to represent the cationic facies and the anionic facies and a diamond synthesizing the global facies.

Piper diagram has been the basis for several important interpretations of the hydrogeochemical data [11].

As for schoeller Berkalov's diagram, it makes it possible to represent the chemical facies of several waters. Each sample is represented by a broken line. The concentration of each chemical element is represented by a vertical line in logarithmic scale. The broken line is formed by connecting all the points representing the different chemical elements. When the lines intersect, a change of facies is highlighted.

The Stabler diagram is used to quickly determine the different titles of a water (alkalimetry title, strong acid salt title and hydrometry title).

The Wilcox diagram is mainly used to assess the risk of soil salinization. It uses electrical conductivity or total dissolved charge for this.

The diagram is divided into four classes of salinity (x-axis) and four classes of risk of sodization (y-axis).

3. Results and Discussion

3.1. Presentation of the Results Obtained after Measurement and Analysis

3.1.1. Physicochemical Parameters

The Table 1 provides information on the results of the analyses obtained after measurement.

Temperature has a significant effect on the ecology of all lake basins [12].

This table shows that the temperature measured at points 1, 2, 3 and 4 has seen a slight variation and is between 26.4 and 26.9°C. These temperature values correspond to those measured on the raw water at Lake level.

However, the temperature value obtained at the level of the treated water in the plant which corresponds to point 5 is 28°C and is slightly higher than the other values of the other measurement points in Table 1. This high temperature could be justified at the time of measurement (13 h 45mn) where we note a strong heat at the time of sampling [13].

The turbidity varies between 26.4 and 28 uTN, the maximum value has been noted at the level of point 1. The turbidity measured at point 3 is substantially equal to that obtained at point 5 which is 26.8 uTN. However, we note that the turbidity is very high compared to the permissible value which is 5 uTN according to the WHO [14]. Turbidity is an indication of the transparency, clarity of water and is caused by fine suspended particles that do not settle in time [15].

The salinity state of the soil can be obtained by measuring the electrical conductivity of water [16].

It is also a function of the temperature of the water, it is more important when the temperature increases [17].

Table 1. Results of chemical and physicochemical parameters obtained from the analyses

Parameters	Measuring points				
	Point 1 (left bank)	Point 2 (middle of the lake)	Point 3 (right bank)	Point 4 (hydrant)	Point 5 (factory)
Temperature (°C)	26,4	26,9	26,6	26,4	28
Turbidity (uTN)	28	23	26,7	25,2	26,8
Conductivity (µS/Cm)	257	260	256	251	271
pH (25°C)	7,64	7,69	7,83	7,87	7,26
pH saturation (Langelier's formula)	8,04	8,07	8,17	8,21	8,35
Langelier index	0,4	0,38	0,34	0,34	1,09
Total alkalinity (mg/L)	82	76	78	64	46
Calcium hardness (mg/L)	44,9	44,89	34,69	38,76	38,77
Total Hardness (mg/L)	104,08	138,78	102,04	97,96	100
CO_2 (Tillman's formula) (mg/L)	3,81	3,14	2,34	1,75	5,13
Total Cations meq/L	1,64	1,52	1,56	1,28	0,92
OH^- (mg/L)	0,01	0,01	0,01	0,01	0,003
HCO_3^- (mg/L)	99,46	92,11	94,3	77,3	55,98
HCO_3^{2-} (mg/L)	0,26	0,28	0,39	0,36	0,06
SO_4^{2-} (mg/L)	16,2	16,1	16,6	16,6	31
Cl^- (mg/L)	39,99	39,53	33,45	36,35	44,53
Sum of anions (meq/L)	3,1	2,97	2,85	2,65	2,82
H^+ (µg/L)	0,0254	0,0226	0,0164	0,0150	0,0609
Ca^{2+} (mg/L)	17,96	17,96	13,88	15,51	15,51
Mg^{2+} (mg/L)	14,38	22,81	16,35	14,38	14,87
Na^+ (mg/L)	25,99	25,7	21,74	23,63	28,95
K^+ (mg/L)	3	2,8	3,1	2,8	3,8
Sum of cations (meq/L)	3,3	3,98	3,08	3,07	3,37
DCO (mg/L)	17	19,2	15,9	19,9	17,9
Zn^{2+} (mg/L)	0,03	0,03	0,03	0,03	0,03
Pb^{2+} (mg/L)	0,82	0,87	0,91	1,09	0,6
PO_4^{3-} (mg/L)	0,39	0,39	0,32	0,18	0,13
Fe^{2+} (mg/L)	0,24	too low	0,13	0,12	too low
NO_3^- (mg/L) de N	too low	0,01	not available	not available	too low
NO_2^- (mg/L) de N	0,01	0,01	0,01	15	too low
Total Nitrogen (mg/L) de N	25	17	Too low	15	too low

The conductivity values measured at the water level of the lake did not exceed the Senegalese discharge standard.

Water acidity and metal contamination are environmental stresses that negatively affect several aquatic organisms in lakes [18].

The acidity or alkalinity of the water is measured in terms of pH or hydrogen ion concentration, neutral water has a pH of 7, if the pH value is less than 7, this water is acidic. Similarly, water is alkaline if the pH value is greater than 7 [19].

The results of analyses of the potential of Hydrogen pH show that the water in the lake is soft in nature. All measured values are between 7 and 8.

A discussion on the measurement of alkalinity in bicarbonate-containing waters and acidic waters is presented as a step towards the development of a standardized approach in aquatic sciences [20].

The results of total alkalinity obtained after analysis show that the value found at point 1 is higher compared to the other points, unlike point 5 where we note a low value compared to the other measured. The results obtained in points 2 and 3 are almost identical in point 4.

Today, the technical importance of water hardness is more concerned about corrosive effects on the calcium hardness is practically constant at points 1 and 2 where we have a value of 44.9 mg / L or 4.49 ° F as well as points 4 and 5 whose value is 38.77 mg / L or 3.877°F, these values show that the water of the lake is soft.

The measured hardness values are high with a maximum of 138.78 in point 2 and a minimum of 97.96 mg/L in point 4. The values obtained in points 1, 3 and 5 are equal to 104.08, 102.04 and 100 mg/L respectively.

3.1.2. Chemical Parameters

The CO_2 content is high at point 5 which is equal to 5.13 mg/L and low at point 4 with 1.75 mg/L. However, a slight variation is noted in points 1 and 2 of respective values 3.81 and 3.14 mg /L. The concentration of CO_2 decreases when the temperature rises and when the water is put in the presence of a gas phase low in CO_2 [21]. CO_2 storage in aquifers is one of the most promising options for reducing atmospheric CO_2 concentration [22].

Anions such as bicarbonate ions HCO_3^- are the majority with a maximum value of 99.46 mg/L in point 1, followed by chloride ions Cl^- whose maximum value is obtained in point 5 which is the sample of water already treated in the plant. We still see in point 5, the sulphate ion (SO_4^{2-}) content is maximum for a 31 mg/L. However the concentration of these sulphate ions remains constant at the other points at the limit of 16.6 mg/L. The presence of sulphates comes from runoff or infiltration in gypsum fields, they also result from the activity of certain bacteria (chlorothiobacteria, rhodothiobacterium, etc [23].

This activity can oxidize hydrogen sulfide (H_2S) to sulphate [24]. Sulphate is likely in this case to cause diarrhea leading to severe dehydration, digestive disorders and nausea can occur and cause acute abdominal pain in some people [25]. OH^- hydroxide ions are extremely low for any measuring point.

As for the cations of the proton ions H^+ are extremely weak at each measuring point.

Compared to other ions, protons (H^+) and hydroxide ions (OH^-) exhibit abnormally high mobilities in aqueous solutions [26].

However, we note a dominance of sodium ions Na^+ with a maximum of 28.95 mg/L followed by ions Mg^{2+}, Ca^{2+}.The permissible magnesium content in natural waters belongs to the range [20-30mg/L] [27]. Based on this indicator, we concluded that the magnesium concentration is low at the other measuring points except point 2 where we have 22.81mg/L.

Regarding the result obtained after the analysis of the electrical conductivity at point 5 which corresponds to the water treated in the Keur Momar Sarr drinking water treatment plant, we can conclude that this value complies with WHO standards. The concentration of iron ions in the treated water admits a value that is too low and is lower than that established by the WHO, as is the nitrate level NO_3^-.Sodium is an abundant metal, always associated with chemical elements There are many minerals containing sodium, mainly in the group of silicates, halides etc [28].

Abnormally high levels may come from industrial or domestic input. The sodium concentration in drinking water is normally less than 50mg/L, but it may increase during softening (by ion exchange) treatments of calcareous water [29].

An epidemiological study has shown that water containing a high sodium content leads to an increase in blood pressure [30].

Nitrates have no toxicity to humans and their limitation in food and drinking water is no longer based on any serious health justification [31].

The measured chemical oxygen demand (COD) has a maximum of 19.9 in point 4 and a minimum of 15.9 mg/L in point 3. The values obtained in points 1, 2 and 5 are respectively equal to 17; 19.2 and 17.9 mg/L.

Heavy metals are low in the study area, the threshold is equal to 1.9 mg/L which corresponds to the lead content at point 4 level.

In this part, we presented the major causes of the differences in values obtained in certain measuring points and also modeled these results in software to have a better visibility on the quality of the water.

The low concentration of iron in water may be related to a lack of phosphate addition, its presence of which leads to an increase in the concentration of iron in water and in some cases, increases in bacterial growth related to the nutrient role of [32]. Iron is an essential element for nutrition, iron deficiencies can have certain effects, including insufficient mental development and activity in children [33].

Nitrates (NO_3^-) are the dominant nitrogenous form in rivers and groundwater. Their concentration rarely exceeds 0.45 mg/l [34]. Higher values indicate discharges of wastewater into the source of water withdrawal and excessive use of fertilizers used in agriculture [35].

Lead is a cumulative toxic element with generalized effects, the effects are mainly neurological, nephrological, hepatic, cardiovascular and hematological [36].

The average threshold for sodium is 200 mg/L in water treated according to WHO standards [37]. However, when comparing with the value obtained on the treated water, we noticed a big difference. We can then say that this threshold does not comply with WHO standards. We have the same remarks about sulphate.

The carbon dioxide ion content in the treated water is also lower than the WHO reported value of 50 mg/L [38].

Scientific findings show a health risk namely decreased cognitive abilities, bone decalcification, kidney calcification and oxidative stress [39].

3.2. Observation and Interpretation of the Results

The use of the Piper diagram allowed us to represent the data of the waters of Keur Momar Sarr in Figure 3.

After sampling and analysis, the samples were presented in the Piper diagram in order to make a characterization of water according to geochemical facies on the one hand and on the other hand to represent the evolution between waters of different geochemistry.

The term hydrochemical facies is a function of solution kinetics, rock-water interactions, geology and contamination sources used to describe the quTantities of water that differ in their chemical composition. A convenient method to classify and compare water types based on ionic composition is proposed by Piper by plotting the chemical data on a trilinear diagram [40]. The examination of the hydrochemical contents of major elements in the different types of water reveals the existence of a certain homogeneity of the dominant cations and anions: magnesium and sodium for cations, chloride and sulphate for anions [41].

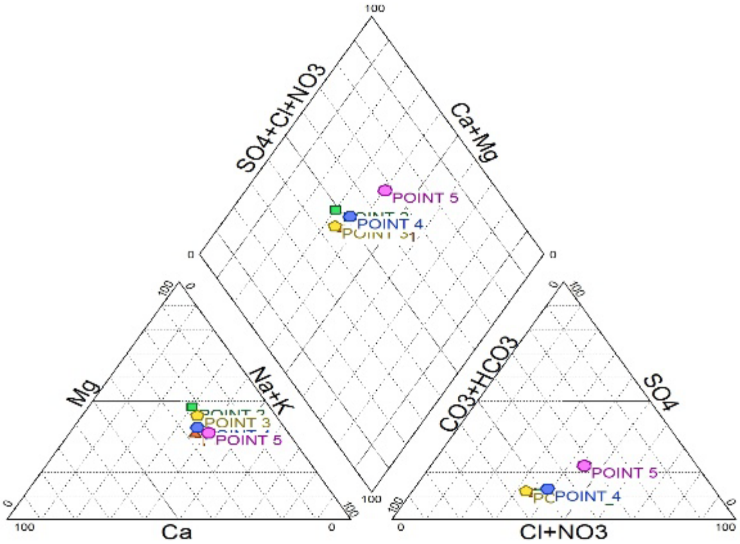

Figure 3. Presentation of Keur Momar Sarr water data on the Piper diagram

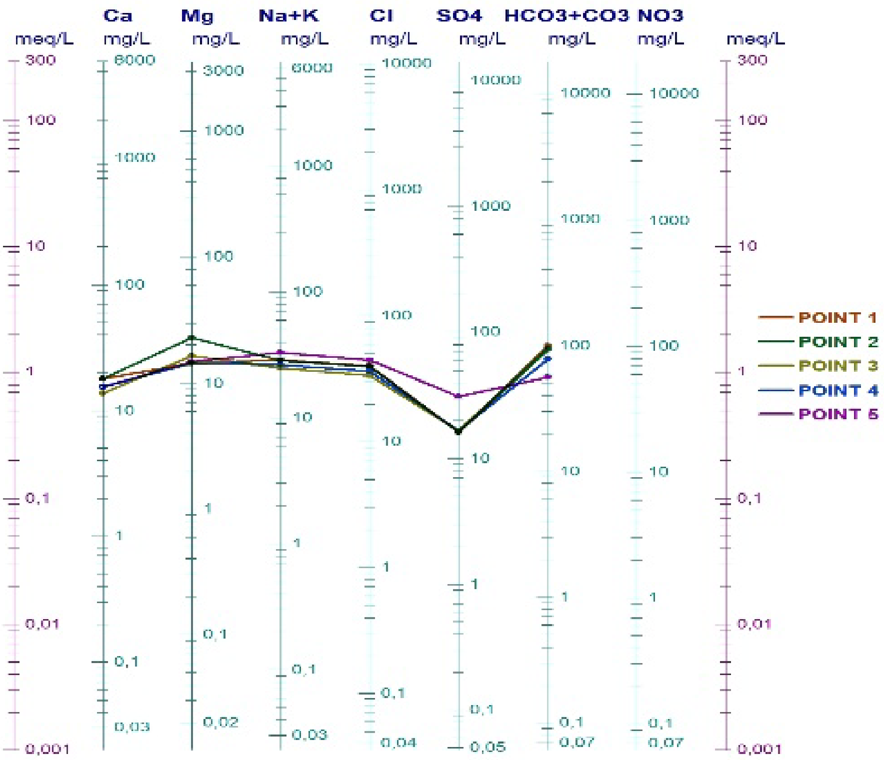

Figure 4. Presentation of Keur Momar Sarr water data on schoeller Berkalov's diagram

We note that the chlorinated and calcium sulphate facies is dominant, in the triangle of cations, the samples are mostly located close to the sodium pole (e.g. Figure 3). In the triangle of anions, we note a migration of ions to the chloride pole.

The Schoeller Berkalov diagram gives the representation of the data of the waters Keur Momar Sarr (e.g. Figure 4).

The Schoeller-Berkaloff diagram allows the representation of several analyses on the same graph, if the concentrations are identical, there is an overlay of lines obtained and if not, there is a relative shift of the latter.

According to Schoeller's classification, we find a dominance of magnesium ion at the level of cations and a dominance of chloride ions at the level of anions followed by sulfate ions.

The Stabler diagram (e.g. Figure 5) shows the results after analysis of the waters of Keur Momar Sarr.

Reading this diagram shows that points 1, 2, 3 and 4 have a high alkalimetry compared to point 5 which represents treated water. The low alkalimetry at point 5 is mainly due to chloride, sodium, and magnesium ions.

The Riverside/Wilson diagrams are given in Figure 6 and Figure 7. These figures represent results after analysis of the waters of Keur Momar Sarr.

They are used to assess the risk of soil salinization. For this, it uses the electrical conductivity or total dissolved charge, both relative to the salinity of the water, and the absorption index of the sodium also called "salinizing power [42].

Recent developments in water quality have significantly improved living conditions of riparian populations, especially in the southern region of the lake. General softening of waters has also accelerated the development of aquatic vegetation already favoured by stabilizing the water level [43].

The results obtained after importing the data at these different diagrams show that the source is of excellent quality as shown in this diagram.

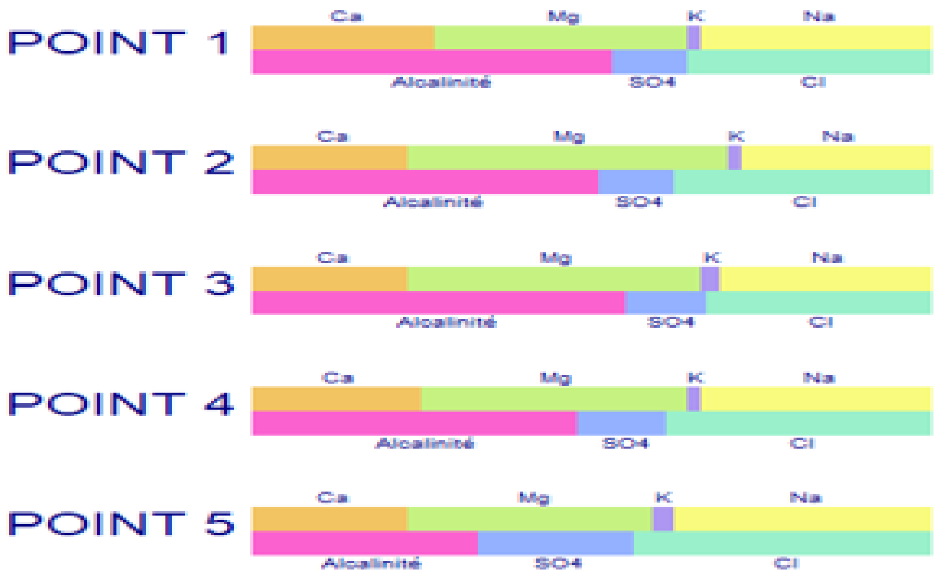

Figure 5. Presentation of the results after analysis of the waters of Keur Momar Sarr on the Stabler diagram

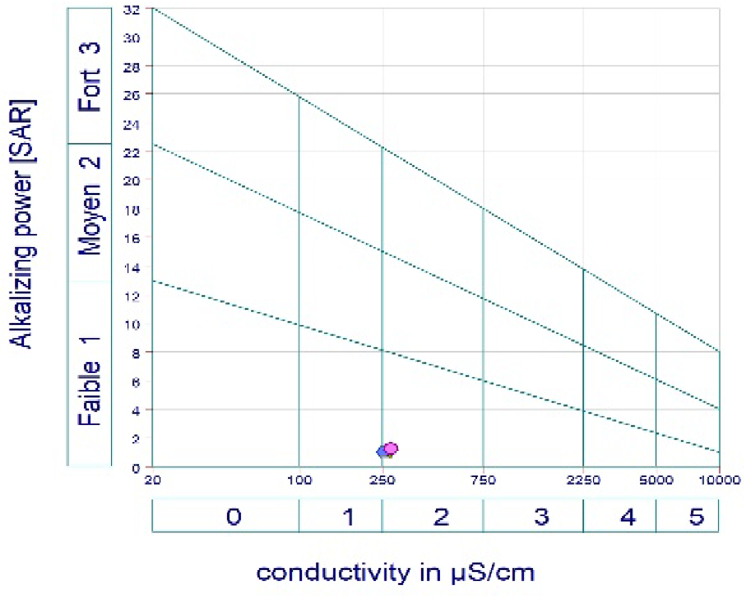

Figure 6. Presentation of the results after analysis of the waters of Keur Momar Sarr on the Wilcox diagram

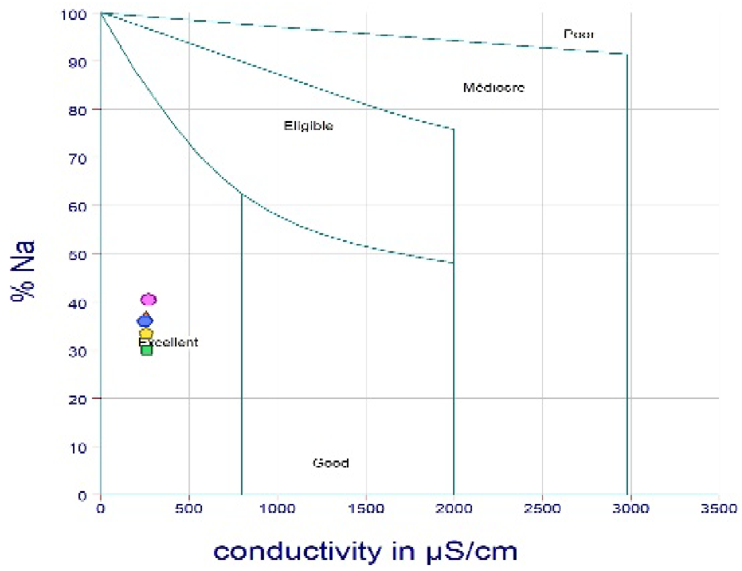

Figure 7. Presentation of the results after analysis of the waters of Keur Momar Sarr on the Riverside diagram

4. Conclusion

Lake Guiers is a shallow lake in West Africa. Its waters are mainly used for irrigation and drinking water. Engineering in the Senegal River Valley has changed the way lakes operate and has led to new water quality conditions.

The objective of this work is to assess the quality of water intended for human consumption in the Dakar part and its surroundings and its impact on human health and has allowed us to highlight a number of parameters that come into play in determining the nature and quality of this water and their use.

The results obtained after importing the data at the level of the different diagrams showed that the source is of excellent quality with a dominance of a chlorinated and sulphate calcium facies. Regarding ions, we noted a dominance of chloride ion at the level of anions and magnesium ion at the level of cations.

The analyses carried out in the laboratory show us that the CO_2 content is high at point 5 which corresponds to the water already treated as well as lead and sodium and also low levels compared to WHO standards of certain chemical elements namely iron, nitrate and carbon dioxide.

However, the mechanism for treating water for the drinking water supply to the regions downstream of the treatment plant merits improvement. Indeed, almost all of these physicochemical parameters do not comply with the standards established by the World Health Organization.

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