American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-01, pp-43-49
www.ajer.org

Research Paper Open Access

Analysis of the impact of anthropic activities on the water chemistry of weathered layer aquifer of M'bahiakro locality (Center of Côte d'Ivoire).

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Abstract: - Water wells are one of the main sources of drinking water for the population of the town of M'bahiakro. However, their quality is very threatened by the behavior of these people themselves. This study aims to improve knowledge of groundwater and to determine the origin of the mineralization of groundwater in the region from a combination of hydro- chemical methods and Principal Component Analysis. The results obtained show that the water is slightly acidic and highly mineralized (832 µS / cm on average). Nitrate levels remain very high with an average higher than the WHO standard (52 mg / L). Hydrochemical classification of water from the diagram Piper and Stiff showed that the waters are divided into two main hydrofacies. It is calcium bicarbonate water (58 %) and calcium chloride- water (42 %). The Principal Component Analysis normalized showed three main classes that are rock dissolution, water salinization and infiltration from surface. Comparative analysis of three classes indicates that the mineralization of groundwater could be controlled by the intrusion of brackish water probably from latrines nearby septic systems.

Keywords: - *Anthropic activities, hydrofacies, mineralization, water resources, M'bahiakro*

I. INTRODUCTION

Groundwater is a major source of drinking water for many people around the world. They may be contaminated from natural sources or many types of human activities such as residential, municipal, commercial, industrial and agricultural. This sensitivity of groundwater pollution due to these activities is a major problem [1]. To help solve this problem, two types of methods have been used. The prevention methods represented by the vulnerability to pollution and curative methods that are statistical tests or biostatistics. In this study, where we have a case of proven pollution, curative methods (statistical tests, biostatistics, hydrofacies characterization and transfer of pollutants) are considered as the most appropriate. Combinations of statistical tests and multivariate analyzes were often used [2]. A multivariate statistical technique is an effective tool for the interpretation of the relationship between water chemistry and the origin of the samples. Works of [3] have used principal component analysis to explore the relationship between trace element hydrochemistry and host rock samples. Multi-criteria analysis was adopted to characterize the geochemical data samples and explain the origin of water sources [4]. These methods allow a better characterization of water quality and determining the likely origin of pollutants in these waters. In Côte d' Ivoire, the application of these methods has already yielded quite interesting results as the works of [5] are shown. However, their importance in a study depends on the objectives.

This study aims to characterize the groundwater resources of this locality and determine the mechanism at the basis of the presence of these parameters in waters. It considers only the water consumed in the locality. The importance of this study lies in the fact that the sectors where contamination is already observed as is the case of M'bahiakro, determining the origin of these pollutants and the main hydrofacies could allow attempts to propose of solution. Indeed, in this area, we note the presence of many individual sanitation and garbage that meet throughout the city.

II. MATERIALS AND METHODS

II-1. Study area

M'Bahiakro locality is in the central part of Côte d'Ivoire between 4°19 and 4°21 W and 7°27 and 7°29 N (Figure1). Geological formations encountered in the area are composed of volcano- sedimentary rocks. The terrain is generally flat plains with altitudes that vary between 120 and 137 m. The hydrographic network is less dense. The average annual rainfall is relatively low at about 1000 mm / year, distributed over four seasons. These are two great seasons with the dry (December to March) and one other rainy (April - July) and 2 small seasons composed of one dry (August - September) and one rainy (October - November). The thickness of the weathered layer are often large, often reaching 70 m. The recharge remains significant at the weathered layer aquifers where it often exceeds 100 mm per season.The local population is estimated at 40,000 inhabitants.

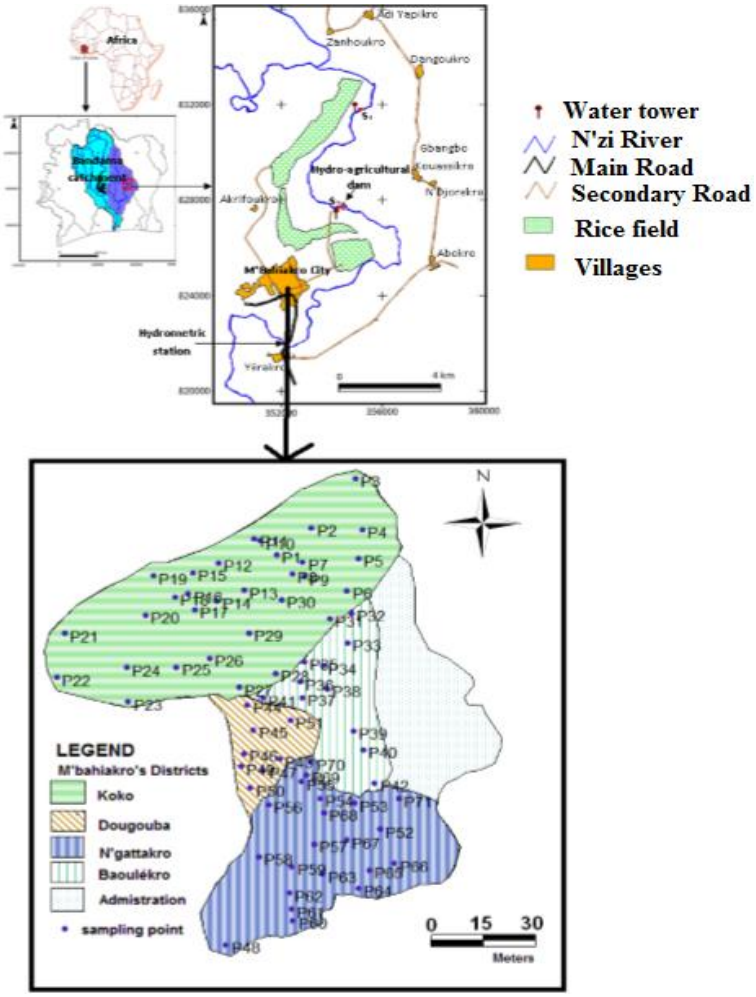

Figure 1. Study area

II-2. Materials

The material is composed of laboratory equipment used for the analysis of samples collected and field equipment consisting of a probe multiparameters, pots of sampling and a GPS. The physico-chemicals data collected during the campaign are composed of physical parameters (pH and electrical conductivity) measured in situ using a multiparameters probe. Samples were then collected on 21 sites and stored at 5 °C in a cooler for a laboratory analysis of the Research Center for Oceanography (CRO) in Abidjan (Côte d'Ivoire). Analytical methods vary depending on the chemical elements, Ca^{2+}, Mg^{2+}, Cl^{-} and HCO_3^{-} by titration (acid titration), Na^{+} and K^{+} by atomic absorption flame SO_4^{2-} and NO_3^{-} spectrometry molecular absorption.

II-3. Methods

In order to characterize these water resources and to determine the probable origin of these pollutants in water resources of the locality of M'bahiakro, hydrogeochemical facies were thirst used to describe the bodies of

groundwater in an aquifer that differ in their chemical composition. The hydrochemical study required the use of two types of diagrams that are Piper and Stiff for the characterization of hydrofacies. The use of these diagrams in the field of water chemistry by [6] often gave very good results. Indeed, the facies are function of the lithology, solution kinetics and flow patterns of the aquifer [7]. Classification of waters depends on the principles of the IAH (International Association of Hydrogeologist) 1979. In these principles, total equivalents of cations and anions were taken as 100 % and ions, as more than 20% (meq/l), were evaluated in the classification. Knowing these key hydrofacies will contribute to the determination of the uses of these water wells that may be agriculture, industry or drinking water.

Then, in order to know the probable origin of pollutants observed in groundwater, statistical tests were performed. Thirst, we adopted standard methods [8 - 10] like spatial analysis to assess spatial variation. The statistical approach that was used to study phenomena at the origin of the mineralization of water is based on Principal Component Analysis. Its application in the study of hydrochemical water was carried out by several authors in other the world and in Africa with very significant results [11]. Statistical analysis was performed from 21 samples and 12 variables (Temperature, pH, conductivity, HCO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, K^+, Na^+ and NO_3^- and NO_2^-). The application of the methods allowed knowing the mechanism of mineralization of water of weathered layer aquifers of locality of M'bahiakro and the probable origin of the pollutants found in these waters. The method of Principal Component Principal Analysis Standardized (PCAS) used for this study is based on the interpretation of the various factors as well as the correlation matrix obtained as a result of data processing. The software used is the NCSS (Number Cruncher Statistic System) version 6.0. The point cloud resulting from this treatment was projected in different factorial plans which are determined in the space of variables

III. RESULTS AND DISCUSSION

The simplified analysis of the different parameters shows that groundwater from subsurface aquifers exploited by traditional wells have generally higher levels to WHO standards. The values of nitrate levels remain very high with an average (52 mg / L) higher than the WHO standard. These values vary between 2.1 and 114.8 mg / L. They are very low in the water surface where they remain below 10 mg / L, whereas in the wells they remain very high. For other parameters, the levels are still relatively low with the exception of some peaks obtained concerning nitrites and sulfates. For the physical parameters, the conductivity remains high also varying from 30 to 1400 µs/cm with an average of 832 µs/cm. As for pH, there is generally normal with values ranging from 5.5 to 7.5.

Hydrochemical classification of water in the Piper diagram highlights two main hydrofacies (Figure 2). The bicarbonated and calcite waters (58%) and sulfated and chlorited waters (42%). The proportions obtained are virtually identical despite a slight dominance of bicarbonated and calcite waters.

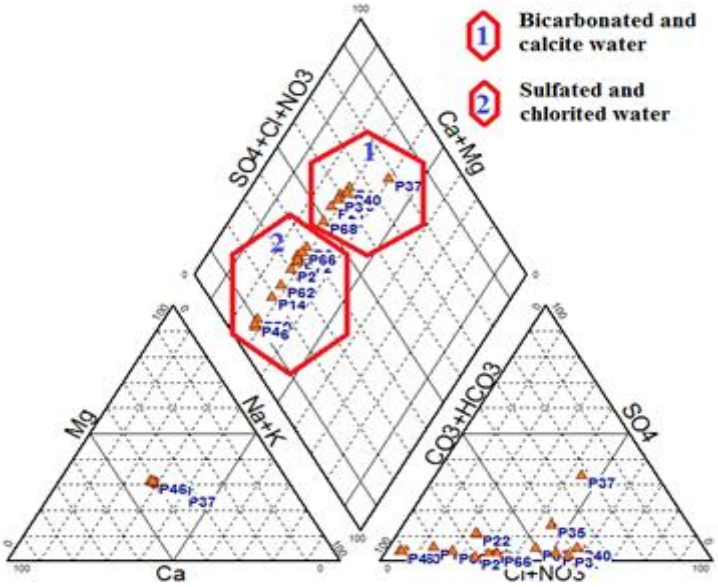

Figure 2. Waters classification by piper diagram

These results are confirmed by the Stiff diagram (Figure 3). This graph shows the influence of bicarbonated and calcite waters on the water resources of this locality, although levels generally remain low. These results show that the hydrochemical characteristics of the water from the wells of M'bahiakro are variable

in space and time. Indeed, given the nature of these formations generally from weathered layers and exposed to seasonal fluctuations, the residence time of water in contact with these rocks is very limited. Water therefore has not enough time to exchange with some parameters of the host rocks. The phenomenon of mineralization is very low as also indicated concentrations of ions from the mineralization that are especially Ca^{2+} and Mg^{2+}. Thus, the pollutants found in the groundwater could come from either diffuse or accidental pollution. The influence of lithology may be limited in contrast to the works of [12; 13] respectively in the synclinal Kourimat in Morocco and in the region of Bondoukou in Côte d'Ivoire.

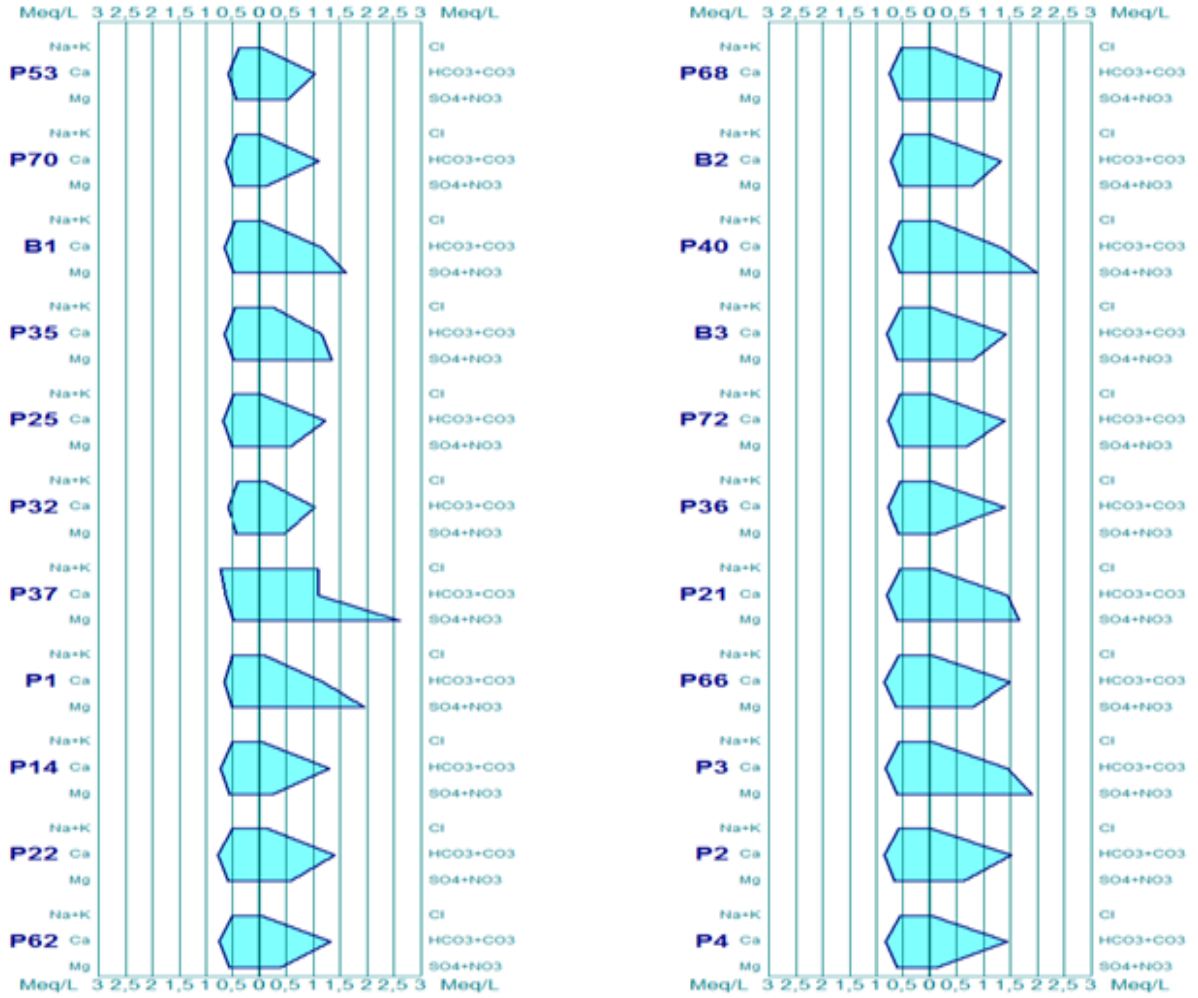

Figure 3: Waters classification by stiff diagram

Groundwaters in these areas also have mixed chemical facies bicarbonate and calcite waters and sulfated and chlorited waters very varied depending mainly on the lithology of the crossed fields. It is the same for the works of [2]. Indeed, in these areas the samples analyzed are dominated by water wells that are generally deep and seasonal influence is weaker.

The results of the statistical analysis give numerous tables which some are summarized in this study. Table of eigenvalues (Table 1) shows that the first three factors represent 71.43% of the variance expressed. They include the maximum variance expressed and are sufficient to translate exactly the information required.

Table1: Table of eigenvalues and percent of principals factors

No.	Eigenvalue	Percent individual	Percent cumulative
1	3.83	31.94	31.94
2	2.83	23.62	55.56
3	1.90	15.86	71.43

The correlation matrix shows the differents correlations necessary for the understanding of the phenomena studied variables is presented in Table 2.

Table 2: Correlation matrix

Temp	pH	Cond	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3^{-}	NO_2^{-}	Variables
1	-0.44	0.48	0.04	0.05	0.31	0.44	0.04	0.30	0.30	0.59	0.06	**Temp**
	1	-0.4	0.11	0.09	-0.42	-0.37	0.11	0.05	0.05	**-0.33**	-0.18	**pH**
		1	-0.3	-0.3	0.05	0.18	-0.3	0.12	0.12	0.46	-0.01	**Cond**
			1	**0.96**	0.15	0.17	**0.94**	0.28	0.28	0.14	-0.01	**Ca^{2+}**
				1	0.16	0.18	**0.94**	0.28	0.28	0.15	0.01	**Mg^{2+}**
					1	**0.76**	0.15	0.04	0.04	0.63	-0.04	**Na^{+}**
						1	0.17	0.48	0.48	0.45	0.02	**K^{+}**
							1	0.28	0.28	0.14	0.01	**HCO_3^{-}**
								1	**0.96**	-0.03	0.07	**Cl^{-}**
									1	-0.03	0.07	**SO_4^{2-}**
											-0.12	**NO_3^{-}**
											1	**NO_2^{-}**

This matrix highlights significant correlations between Mg^{2+}, Ca^{2+} and HCO_3^{-} (0.94) on the one hand and other parts between Cl^{-} and SO_4^{2-} (0.96). There is also to a lesser degree a correlation between variables such as Na^{+} and K^{+} (0.76). These correlations reflect the influence of each parameter in the mineralization of water into alterites of M'bahiakro. Indeed, the correlation between Mg^{2+}, Ca^{2+} and HCO_3^{-} reflects the dissolution of rocks related to the residence time of water in the aquifer. However, low levels obtained for these parameters show that groundwater has not passed a sufficient residence time in contact with these formations that they could have released these ions during alteration of crystalline or cristallophyllienne rocks. The correlation between K^{+} and Na^{+} could highlight salinization due to the proximity of latrines and other places bathroom. These two parameters are logically in its natural state in water, but in very small proportions. However, when the levels become important as in the case of potassium, another origin may be mentioned. In this study, the origin could be wastewater from latrines usually located near these wells. Regarding the correlation between SO_4^{2-} and Cl^{-}, it is explained by an intrusion from surface. This infiltration from surface could also be justified by lack of correlation between these and the NO_3^{-} that could possibly come from latrines near septic tanks [14].

The analysis in the space of variables of different factorial can design highlight three main groupings of variables (Figure 4). This is the main factor F1 (31.94%), gathering the parameters HCO_3^{-}, Mg^{2+} and Ca^{2+}, which represent the dissolution. The factor F2 (23.62%) gathering the variables K^{+} and Na^{+} which represent the salinization of water and F3 factor (15.86%) are made up Cl^{-} and SO_4^{2-} designating from surface infiltration. These groups confirm the results of the correlation matrix.

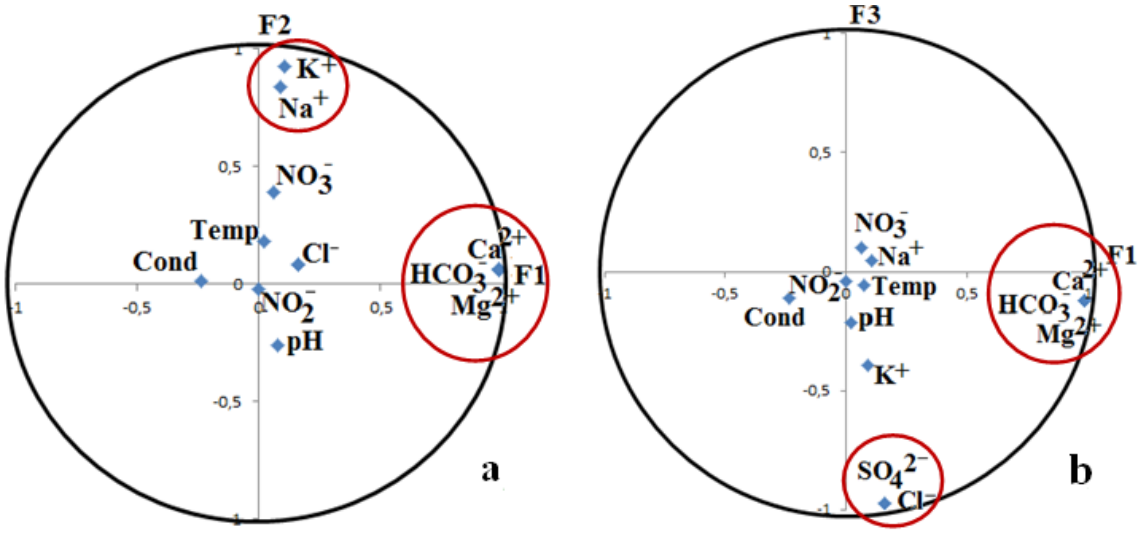

Figure 4: Analysis of factorial plans (a) F1 - F2 and (b) F1 - F3

Analysis of the results of these factorial plans shows that the main parameters that control the factor F1 reveal the existence of a phenomenon of dissolution of rocks considering the combination of these around this axis. However, the levels of these parameters remain very low in the groundwater of the area. Indeed, the presence of Mg^{2+} and Ca^{2+} in groundwater indicates the existence of dissolution rocks in relation to a sufficiently long residence time which may allow the water that was in contact with the rock to dissolve them and into solution. However, within this study we worked on wells where groundwater contained in weathered layer aquifers are vulnerable to seasonal fluctuations and do not have time to dissolve the rocks to get the ions in solution. In addition, the lack of correlation between these parameters and the conductivity is further shown that the presence of these ions in groundwater is not due to dissolution of rocks related to the residence time as indicated by the work of [15]. According to [16], it is called dissolution of rocks related to the residence time when there is a positive correlation between these ions from the dissolution of rocks (Mg^{2+} and Ca^{2+}) and conductivity. This is not the case in this study. The results of the analysis of factors 2 and 3 respectively indicate salinization and water infiltration from surface suggest a superficial pollution. The importance of salinization in groundwater in the area has already been indicated by [17]. However, nitrates are the most representative of a surface origin parameter is correlated with any of the axes. This lack of correlation in one hand with one of the axes and on the other hand with SO_4^{2-} and Cl^- as well as the high levels of nitrates show that the mineralization of the water is probably not the fact to an infiltration from surface. It is due to the intrusion of brackish water which may come from septic systems often located near wells. This could still be explained by the high levels of nitrates obtained in wells located nearby latrines.

IV. CONCLUSION

The analysis of physical and chemical parameters of water from wells and streams in the area of M'bahiakro allowed knowing the main hydrofacies that characterize these water resources and the likely origin of the ions in these waters. The results of this analysis show that groundwater is slightly acidic with pH ranging between 5.5 and 7.5. These waters have a very varied mineralization in all between 30 and 1400 µS/cm with an average of 832 µS/cm. Nitrate levels remain very high with an above average of WHO standard (52 mg / L). Hydrochemical classification of water from the diagram Piper and Stiff showed that the waters are divided into two main hydrofacies that are calcium bicarbonate water (58%) and calcium chloride-water (42%). The Principal Component Analysis normalized highlighted three main classes of water that are rock dissolution, salinization and water infiltration from surface. Comparative analysis of three classes indicates that the mineralization of groundwater could be controlled by the intrusion of brackish water probably from latrines nearby septic systems.

V. ACKNOWLEDGEMENTS

We thank the International Foundation for Science (IFS) for funding this research. We also thank the people of M'bahiakro for their availability and understanding.

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