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RESEARCH ARTICLE

CONTRIBUTION TO THE ASSESSMENT OF THE CHEMICAL QUALITY FROM PEASANT WELLS IN THE CITY OF TINGRELA, IVORY COAST

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ABSTRACT

In order to contribute to the evaluation of the chemical pollution of the drinking water of the city of Tingréla and to determine the different sources of pollution, we analysed the groundwater of 11 peasant wells in different districts of the city of Tingréla. The analyses were carried out in the laboratory using the various standard techniques using a spectrophotometer and an argon plasma ionizing source mass spectrometer (ICP-MS). From the results obtained, we note the presence of major ions that cannot alter the quality of the waters studied. However, the presence of trace metal elements such as arsenic, cadmium, lead and mercury make these waters unfit for consumption. In addition, apart from natural pollution, latrines and domestic wastewater could be sources of anthropogenic pollution.

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INTRODUCTION

All over the world, water is an essential element for life (Haouchine, 2011; Foto *et al*., (2011)) and for the real and sustainable socio-economic development of a country. Drinking water (groundwater from captive and surface water tables are water resources exploited by man for various uses (Prasad *et al*., 2004). The chemical composition of groundwater is very variable. It depends on the geological nature of the soil. where it comes from and also reactive substances that it might have encountered during the flow.Thus, its quantitative and qualitative composition in suspended and dissolved matter, of mineral or organic nature, determines its quality (Jain *et al*., 2005). In addition, the World Health Organization (WHO) estimates that 1.5 billion people in the world do not have safe drinking water and around 30,000 people die every day from drinking unsafe water or due to dehydration (Timoléon *et al*., 2013).

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In order to be able to prevent these scourges and certain diseases linked to the quality of water, access to good quality water becomes a permanent quest. In Ivory coast, the authorities once favoured the availability of water at the expense of its quality. This is the reason for the fragmentary and fragmentary work carried out in this field in sedimentary (Olga, 1998) and basement environments (Biémi, 1992; Goné *et al*., 2001; Soro *et al*., 2002; Yao *et al*., 2009). Moreover, the analyses are only targeted on a few elements, and it is only when the water is cloudy or has an abnormal colouring or even that the taste is unusual that certain particular elements are dosed. Systematic analyses are currently carried out to determine the potability and quality of drinking water (Lasm *et al*., 2008). in the city of Tingréla (Ivory Coast), we are witnessing the development of spontaneous settlements on the outskirts of the city due in particular to the massive lookout for migrants from the sub-region as part of the artisanal exploitation of mineral resources. The rapid expansion of habitable areas is a potential source of contamination of drinking water because it makes it difficult to manage basic urban services, namely the installation of latrines, wastewater management and waste management housewives. In addition, the low availability of drinking water in urban and peri-urban areas forces populations to obtain water from peasant wells, the quality of which is often altered by anthropogenic practices. In order to prevent the dangers associated with the consumption of this water from peasant wells in the city of Tingréla (drinking water), it is important to assess the chemical quality of this water and to determine the possible sources of pollution.

MATERIALS AND METHODS

Presentation of the study area: The commune of Tengréla is located in the Bagoué region in the far north of Ivory Coast. Its capital of the region is Boundiali. The population of the locality of Tengrela is 67,746 inhabitants (RGPH, 2014). Annual rainfall has varied between extremes of between 800 and 2000 mm over the past 50 years, with 60 to 120 days of rain per year (Abergel, 2007). Located in the northern part of the Ivory Coast, it is an essentially flat region, the geological substratum of which consists of calc-alkaline Precambrian granites. The general model is a tabular set of ferruginous cuirasses with gentle ruptures caused by garlands of hills and mounds with rounded reliefs placed on plateaus of medium heights. This geology is not favorable to the presence of large aquifers and the only significant reserves of groundwater are located in the fissures of the granites, in the water tables of the alluvial sediments of the large rivers (Comoé, Haut Bandama and its northern tributaries, haut Sassandra) or in lesser backwater colluvium (Abergel, 2007)

Description of the different sampling stations: The various sampling stations were chosen taking into account the surrounding activities, the density of the population and the probable sources of pollution. Thus, we have selected 11 underground water stations (Fig). Table 1 gives us a detailed description of the different sampling stations. From this study, we retain that the sampling points are located less than 20 m from potential sources of pollution such as illegal dumping and stagnant water. In addition, the studied peasant wells are shallow and their depths do not exceed 1 m. Also, we noted the aging of protective equipment. In addition, we noted the presence of latrines located upstream of the majority of the drinking water sampling stations studied with the exception of the wells in the Tamania (P_2), Tengrela (P_3) and Zanasso (P_8) districts. In addition, the well-latrine distances are all less than that recommended by the WHO, which is 15m.

Sampling: The samples were taken during the month of May 2019. Water samples were taken using 100 mL plastic bottles, filled to the brim and pre-rinsed with the water to be collected. They are then stored in a cooler at a temperature of 4 ° C for the analysis of chemical parameters in the laboratory.

Measurements of physicochemical parameters: The study was carried out on water samples from certain wells in rural areas in the city of Tingréla during the month of May 2019. The water samples taken for the physico-chemical analysis were put in flasks in plastic and then sent to the laboratory for analysis. A total of 11 waters samples were collected. The physico-chemical analyzes concerned the following parameters: T ° C, pH, Electrical conductivity (Cond), Chlorides Cl-, Sulphates SO_4^{2-}, Nitrates (NO_3^-), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Dissolved oxygen (O_2), arsenic (As), cadmium (Cd), chromium (Cr), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb) , zinc (Zn).

Physical parameter measurements: Temperature, pH, salinity, conductivity and dissolved oxygen are measured in situ using a previously calibrated HANNA HI 9828 portable multimeter. The device is switched on a few minutes before handling.

Chemical parameter measurements: The analyzes were carried out in the laboratory using standard techniques (Rodier al., 2009). The nitrates NO_3^-, ortho phosphate PO_4^{3-} and sulfates SO_4^{2-} were determined from the JASCO UV visible spectrophotometer. The content of major cations is determined by atomic absorption with an air-acetylene flame SAA 20 type VARIAN. The analysis is based on the absorption of photons by atoms in the ground state. The levels of metallic trace elements (TME) were obtained using an argon plasma ionizing source mass spectrometer (ICP-MS), according to the EPA and Standard methods. Method for the evaluation of Water and Wastewater (CEAEQ, 2011).

Statistic study: In our study, we carried out a principal component analysis (PCA), with a view to highlighting the relationships between variables on the one hand, the distribution of individuals taking into account all of their physicochemical characteristics (Belghiti, 2013) and to determine the possible vectors of pollution. PCA is a technique for representing data under certain algebraic and geometric criteria, its objective is to extract most of the information contained in the data tables and to provide a graphical representation that is easy to interpret given the data correlations. The statistical processing of the data is carried out by the STATISTICA version 7 software.

RESULTS

Temperature, pH, conductivity, dissolved oxygen in groundwater: In the study region, the results obtained show that the temperature does not show large variations from one well to another (Table 2) with a minimum of 26.7 ° C (P_{10}) and a maximum of 28, 6 ° C (P_{11}). The drinking waters studied are appreciably acidic and basic. Indeed, the measured pH gives us values between 6.85 and 7.18 in well P_1. In addition, they are weakly mineralized. The determined conductivity values do not exceed 200 µS / cm with an average conductivity of 195.3 µS / cm. Relative to other physical parameters, dissolved oxygen exhibits significant variations from one point to another, ranging from 3.97 to 7.03 mg / L. during the study period, the results obtained show that certain wells, in particular P_1 (4.23 mg / L) and P_4 (3.98 mg / L), are slightly under oxygenated.

NO_3^-, HPO_4^{3-}, Cl^- and Ca^{2+} in groundwater

Nitrates are one of the main causes of degradation of groundwater quality and mainly groundwater (Keeney, 1986). Nitrates are present in the drinking water studied with levels that do not exceed 71.5 mg /L. As for orthophosphates, the maximum and minimum concentrations were determined respectively in stations P_1, P_6, P_7, P_8 (0.01mg/L) and P_2 and P_{11} (0.06 mg/ L). In addition, of the ions studied, only the calciums have determined contents greater than 10 mg/L.

Indeed, the minimum concentration of calcium ion in drinking water is 15.2 mg/L (P_4, P_7 and P_9).

Trace metallic elements (TME) studied in groundwater: From the table, we note that we can classify these ETMs analyzed into three groups. In the first we have the elements whose levels determined in the drinking water of the city of Tingréla are in the order of µg / L. In fact, these ETMs are present in this groundwater but at concentrations below 0.001 mg / L. These include nickel (Ni), mercury (Hg) and lead (Pb), the maximum concentrations of which are respectively 9.8 10^{-3} mg / L (P_1), 510^{-4} mg / L (P_2), 1.2 10^{-3} mg / L (P_8). The second group consists of arsenic, chromium, zinc and boron. The levels of these determined trace elements do not exceed 1 mg / L in the drinking water studied. Iron and manganese are part of the latter group. Their presence in the drinking waters studied is limited to concentrations greater than 1 mg/L.

Study of the correlation of the different parameters studied: The correlation matrix gives correlation coefficients between the different variables two by two. The analysis of this table highlights the physical characteristics of peasant wells, in particular the height of the coping is well correlated with the static water level and the distance to the latrine well (HM, NS) ($r = 0.53$; $p<0.05$)), ((HM, DPL) ($r = 0.5$; $p<0.05$)). In addition, it highlights correlations between the physical parameters of peasant wells and the physicochemical parameters of drinking water (groundwater) in particular (Fe, HM) ($r=0.60$; $p<0.05$)), ((Fe, NS) ($r=0.57$; $p<0.05$)), ((Hg, NS) ($r=0.56$; $p<0.05$)), ((SO_4^{2-}, HM) ($r=0.57$; $p<0.05$)), ((SO_4^{2-},NS) ($r=0.47$; $p<0.05$)), ((O_2, NS) ($r=0.58$; $p<0.05$)). In addition, it underlines correlations between the physicochemical parameters of groundwater. Indeed, iron is in association with mercury and pH ((Fe, Hg) ($r = 0.79$; $p<0.05$)), ((Fe, pH) ($r= 0.58$; $p <0.05$)) nickel is with manganese ((Ni, Mn) (p =)), nitrates and Chromium (NO_3^-, Cr) ($r = 0.53$; $p<0.05$)). Also, the temperature of drinking water is very strongly correlated with chromium ((Temp, Cr) ($r = 0.49$; $p<0.05$)), conductivity ((Temp, Cond) (r = 0, 50; $p<0.05$)), chloride ions ((Temp, Cl-) ($r = 0.45$; $p<0.05$)). On the other hand, orthophosphate ions are in association with arsenic ((HPO_4^-, As) ($r = 0.61$; $p<0.05$)), manganese ((HPO_4^-, Mn) ($r = 0.66$; $p<0.05$)), turbidity ((HPO_4^-, Turb) ($r = 0.59$; $p<0.05$)) and conductivity ((HPO_4^-, Cond) ($r = 0.47$; $p <0.05$)). During our study, we noted associations between calcium and arsenic ((Ca^{2+}, As) ($r = 0.60$; $p<0.05$)), chromium ((Ca^{2+}, Cr) ($r = 0.45$; $p<0.05$)), nickel ((Ca^{2+}, Ni) ($r = 0.66$; $p<0.05$)), chloride ions ((Ca^{2+} Cl -) (r = 0, 59; $p<0.05$)) and sulfates ((Ca^{2+}, SO_4^{2-}) ($r = 0.56$; $p<0.05$)).

Principal component analysis: The factor extraction was performed by the principal components method. 5 factors whose eigen values are greater than 1. Were retained according to the criterion of Kaiser (Kaiser, 1958). They correspond to 81.986% of the total variance. From the first factor, the percentage is not high, which implies that many parameters must intervene in the structure of the data. The factor 1 and 2 gives us 46.489 of the expressed variance, which does not explain much of the information contained in these data. However, with the first three factors including F_1, F_2 and F_3 we have 60.24 of the expressed variance which will allow us to explain much of the information contained in these data. Normalized Varimax rotation was applied to these factors to facilitate their interpretation. Table 5 presents the eigenvalues of the five factors and their explained variances. Table 5 gives us the contribution of the different variables to the achievement of the different factors. Thus, the temperature, the chloride ions, boron, iron and lead strongly contribute to the achievement of the factor F_1 26.811% of the cumulative variance. As for the pH, the calcium ions and orthophosphates, are correlated with the factor F_2. Lead also contributes to the F_3 factor as well as conductivity. The factor F_4 which represents 11.355% of the cumulative variance is correlated with the sulphate ions and the chromium. In the end, only lead strongly contributes to the achievement of factor F_5.

DISCUSSION

Our study showed that there were correlations between the physical parameters of peasant wells and certain physicochemical parameters of water. This suggests that the physical aspect of peasant wells has a significant influence on the quality of the groundwater studied. In fact, we noted an association between the static water level, i.e. the depth of peasant wells ((O_2, NS) ($r = 0.58$; $p<0.05$)) and the level of dissolved oxygen present in groundwater. Oxygen is a necessary element of groundwater, allowing it to maintain its qualities. Dissolved O_2 is involved in the natural self-purification process of water, a process which consists in oxidizing a certain load of organic pollution through micro-organisms (Tardat-henry and Beaudry, 1992). In the absence of this, degradation will take place in anaerobic condition and there will be formation of undesirable compounds such as methane, hydrogen sulphide, and light organic acids. Our study shows that only wells P_1 (4.23 mg / L) and P_3 (3.98 mg / L) do not meet the WHO standard which is 5 mg /L(OMS, 2000). the association of this drinking water quality parameter with the depth of the wells ((O_2, NS) ($r = 0.58$; $p<0.05$)) shows that the presence of O_2 in groundwater is due to the dissolution of oxygen in the air. This implies that the depth of peasant wells has a significant influence on the oxygenation mechanisms of drinking water. In addition, occasional variations in the amount of dissolved oxygen for a region can therefore indicate the location of sources of contamination such as a large input of organic matter (Nielsen, 1991).

The temperature of the water is an important factor in organic production. This is because it affects the physical and chemical properties of it; in particular its density, its viscosity, the solubility of its gases (especially that of oxygen) and the speed of chemical and biochemical reactions (HCEFLCD, 2006). In the study region, the results obtained show that the degree this temperature does not exhibit large variations from one well to another (Figure 2), with a minimum of 26.7 ° C (well P_{10}) and a maximum of 28.6 ° C (well P_{11}). Associations have been noted between this, conductivity and chloride ions. They would reflect the fact that a high temperature would dissolve inorganic salts containing chloride ions, thus acting on the mineralization of the drinking waters studied (Miramond *et al.*, 2006). The pH of the drinking water studied is within the range of values recommended by the WHO which is 6.85-7.15(OMS, 2000). From the results obtained for this groundwater quality parameter, it could be said that these studied drinking waters are good for human consumption.

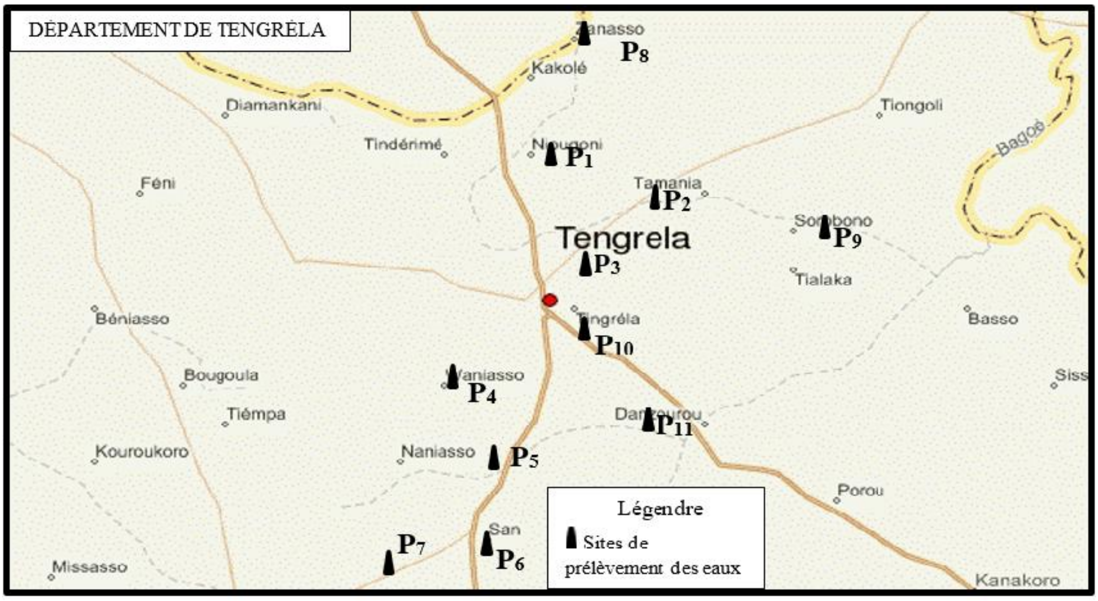

Fig. Sampling stations

Table 1. Physical characteristics of the different farmer wells studied

District	Sampling points	Curb height	Static level (m)	Well-latrine distance (m)
NIOUGONI	P_1	0 .50	2.4	14.50
TAMANIA	P_2	0.83	4.54	14.20
TENGRELA	P_3	0.80	3.5	29.62
MANIASSO	P_4	0.60	2.96	13.30
DRAGNANI	P_5	0.45	4.11	13.13
SAN	P_6	0.42	3.22	14.30
NEGUEPIE	P_7	0.50	2.75	13.70
ZANASSO	P_8	0.50	2.5	14.20
SOROBONO	P_9	0.46	1.4	14.10
TENGRELA	P_{10}	0.90	3.65	16.10
DANZOUROU	P_{11}	0.55	1.70	13.80

Table 2. Concentrations of nitrates (NO_3^-), orthophosphates (HPO_4^{3-}), chlorides (Cl^-) and calcium (Ca^{2+}) in groundwater

Station	T°(C)	pH	O_2 (mg/L)	Turb	Cond (µs/cm)	NO_3^-(mg/L)	HPO_4^-(mg/L)	Cl^-(mg/L)	Ca^{2+}
P_1	28.5	7.18	4.23	0.10	179.3	27.4	0.015	4.70	15.24
P_2	28.4	6.97	6.27	0.12	189	6.25	0.053	6.34	15.9
P_3	27.8	7.1	6.30	0.10	180	15.63	0.033	5.62	15.4
P_4	28.4	7.13	6.11	0.11	182	19.45	0.028	4.85	15.2
P_5	28.4	6.86	3.98	0.10	174	33.22	0.023	4.78	15.6
P_6	28.4	6.95	7.03	0.10	176	40.81	0.011	6.03	15.9
P_7	28.4	7.00	5.75	0.09	179	32.41	0.065	4.70	15.2
P_8	28.4	7.00	6.75	0.09	200	45.6	0.058	4.65	15.7
P_9	27.9	6.85	6.53	0.14	192	71.4	0.037	4.84	15.2
P_{10}	26.7	7.00	6.32	0.10	196	5.85	0.044	5.7	15.27
P11	28.6	7.00	6.01	0.12	194	6.4	0.067	5.62	16.02

Table 3. Concentrations of metallic trace elements in groundwater

Station	As (mg/L)	Cd (g/L)	Cr (mg/L)	Fe (mg/L)	Hg (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)	Mn (mg/L)	B (mg/L)
P_1	0.26	0.03	0.31	3.33	4.10^{-3}	$9.8.10^{-3}$	$0.6.10^{-3}$	0.32	2.70	0.90
P_2	0.28	ND	0.73	3.32	5.10^{-3}	0.0103	$0.1.10^{-3}$	0.30	3.11	0.78
P_3	0.24	ND	0.36	3.30	$3.2.10^{-3}$	$5.4.10^{-3}$	$0.9.10^{-3}$	0.37	2.65	0.84
P_4	0.23	ND	0.51	3.27	$4.9.10^{-3}$	$7.8.10^{-3}$	$1.1.10^{-3}$	0.34	3.23	0.91
P_5	0.26	0.06	0.44	3.05	$3.7.10^{-3}$	0.0102	$0.6.10^{-3}$	0.40	3.05	0.96
P_6	0.29	ND	0.58	2.98	0	$9.1.10^{-3}$	$0.1.10^{-3}$	0.35	2.45	1.00
P_7	0,25	ND	0.65	3.21	$2.6.10^{-3}$	$8,3.10^{-4}$	$0.9.10^{-3}$	0,23	2.78	0.98
P_8	0.26	ND	0.67	3.09	$3.1.10^{-3}$	$8.7.10^{-3}$	$1.2.10^{-3}$	0.28	2.73	0.97
P_9	0.27	0.03	0.66	2.93	$0.9.10^{-3}$	$9.8.10^{-3}$	$1.1.10^{-3}$	0.31	2.80	0.89
P_{10}	0.30	ND	0.39	3.31	$2.4.10^{-3}$	$8.6.10^{-3}$	$0.4.10^{-4}$	0.29	3.16	0.67
P11	0.32	ND	0.64	2.77	0	0.0104	$0.7.10^{-4}$	0.32	3.23	1.00
Normes OMS	0.01	0.01	0.05	0.3	0.001	0.023	0.01	3	0.4	0.5

Table 4. Correlation matrix

	HM	NS	Nbu	DPL	As	Cd	Cr	Fe	Zn	Mn	B	Hg	Ni	Pb	pH	Turb	Cond	Cl-	SO_4^{2-}	O_2	Temp	HPO_4^-	NO_3^-	Ca^{2+}
HM	1.00	0.53	0.86	0.50	0.10	0.4	-0.2	0.60	-0.10	0.40	-0.88	0.37	0.06	-0.28	0.29	0.02	0.31	-0.64	0.57	0.21	0.22	0.57	-0.24	-0.06
NS		1.00	0.50	0.19	-0.13	0.018	-0.2	0.57	0.29	0.15	-0.45	0.56	0.30	-0.58	-0.04	-0.35	-0.33	-0.19	0.47	0.58	-0.18	0.055	0.03	0.18
Nbu			1.00	0.66	0.27	-0.44	-0.28	0.39	0.16	0.058	-0.71	0.04	0.04	-0.52	0.20	0.03	0.10	-0.57	0.81	0.19	0.33	0.52	-0.25	0.17
DPL				1.00	-0.28	-0.23	-0.45	0.32	0.31	-0.31	-0.31	0.06	-0.27	0.11	0.33	-0.15	-0.13	-0.35	0.25	-0.01	0.17	0.10	-0.26	-0.13
As					1.00	-0.15	0.25	-0.52	-0.11	0.23	-0.09	-0.64	0.44	-0.55	-0.36	0.29	0.44	-0.18	0.55	0.03	0.21	0.61	-0.10	0.60
Cd						1.00	-0.32	-0.16	0.49	0.00	0.16	0.12	0.29	0.04	-0.38	0.14	-0.38	0.14	-0.46	-0.50	-0.78	-0,22	0.16	-0.19
Cr							1.00	-0.46	-0.48	0.09	0.31	-0.24	0.29	0.05	-0.51	0.36	0.40	0.38	0.16	0.34	0.49	0.22	0.69	0.45
Fe								1,00	-0.14	0.01	-0.62	0.79	-0.33	-0.12	0.58	-0.39	-0.19	-0.31	0.03	0.09	-0.14	-0.21	-0.21	-0.50
Zn									1,00	-0.01	0.09	0.05	0.28	-0.16	-0.06	0.11	-0.48	0.09	0.14	-0.07	-0.34	0.03	-0.11	0.20
Mn										1.00	-0.33	0.28	0.56	-0.00	-0.03	0.32	0.33	-0.14	0.09	0.09	-0.22	0.66	-0.22	0.05
B											1.00	-0.36	0.09	0.29	-0.12	-0.14	-0.32	0.80	-0.40	0.11	-0.12	-0.41	0.10	0.30
Hg												1.00	0.06	0.07	0.42	-0.23	-0.18	0.07	-0.19	0.13	-0.39	-0.15	-0.01	-0.31
Ni													1.00	-0.40	-0.38	0.31	0.017	0.35	0.34	0.21	-0.39	0.62	0.10	0.66
Pb														1.00	0.14	0.02	0.24	0.09	-0.77	-0.27	0.03	-0.27	0.02	-0.49
pH															1.00	-0.36	-0.12	0.08	-0.09	-0.05	-0.06	-0.17	-0.67	-0.29
Turb																1.00	0.28	-0.00	0.21	-0.50	0.18	0.59	0.43	0.07
Cond																	1.00	-0.34	0.08	-0.03	0.50	0.47	0.12	0.16
Temp																		1.00	-0.22	0.14	-0.24	-0.23	0.19	0.40
Cl^-																			1.00	0.39	0.45	0.60	0.034	0.59
SO_4^{2-}																				1.00	0.29	-0.00	0.03	0.52
O_2																					1.00	0.15	0.30	0.21
HPO_4^-																						1.00	-0.8	0.41
NO_3^-																							1.00	0.15
Ca^{2+}																								1.00

Table 5. Eigenvalues and factor variance

	own value		% variance	
	Individual	**Cumulative**	**Individual**	**Cumulative**
F1	5.362	5.362	26.811	26.811
F2	3.935	9.298	19.678	46.489
F3	2.750	12.047	13.750	60.24
F4	2.271	14.319	11.355	71.6
F5	2.078	16.397	10.391	81.986

Table 6. Factor weights of variables

	F1	F2	F3	F4	F5
HS	-0.93	-0.16	0.19	-0.03	-0.19
NS	-0.70	0.02	-0.61	0.21	-0.13
NbU	-0.89	-0.26	0.03	-0.14	0.29
DPL	-0.55	0.30	0.11	-0.22	0.45
pH	-0.35	0.57	0.22	0.18	0.04
T°	0.61	0.1	-0.43	0.4	-0.03
Cond	-0.05	-0.49	0.69	0.06	-0.29
Turb	0.18	-0.52	0.14	-0.51	-0.26
O2	0.15	0.38	-0.56	-0.32	-0.39
Ca^{2+}	-0.06	0.67	0.42	-0.31	-0.23
NO_3^-	-0.3	0.26	0.07	-0.09	0.13
HPO_4^-	0.33	0.74	-0.07	0.23	0.25
SO_4^{2-}	-0.27	-0.19	-0.31	0.79	0.09
Cl^-	0.61	-0.64	-0.20	0.08	0.32
As	-0.01	-0.87	0.05	-0.12	0.18
Cd	0.38	0.22	-0.5	-0.61	-0.26
Cr	0.40	-0.58	0.13	0.51	-0.16
Fe	0.72	0.56	0.03	0.15	-0.25
Zn	-0.06	0.12	-0.65	-0.51	0.18
Mn	-0.18	-0.36	-0.04	-0.06	-0.76
B	0.84	0.11	-0.25	0.30	0.28
Hg	-0.41	0.53	-0.24	0.19	0.63
Ni	0.05	-0.58	-0.60	-0.03	-0.38
Pb	0.44	0.47	0.52	-0.03	-0.22

The factorial design F_1-F_2 expresses the total variance of the scatter plot, but the factor 1 is the most important, because it expresses on its own. The grouping of the variables in the correlation circle in the factorial plane (F_1, F_2) allows us to distinguish two classes.

Class 1: pH, Hg, DPL, NO_3^- Class 2 : Mn, Cond, Ni, Turb, Cr In the factorial plane (F_1, F_3) there are 4 classes

Class 1: Fe, DPL, pH, NO_3^- Class 2 : SO_4^{2-}, Hg, Cl^- Class 3 : Turb, Cr, HPO_4^- Class 4 : Cd, O_2, Ni, Zn

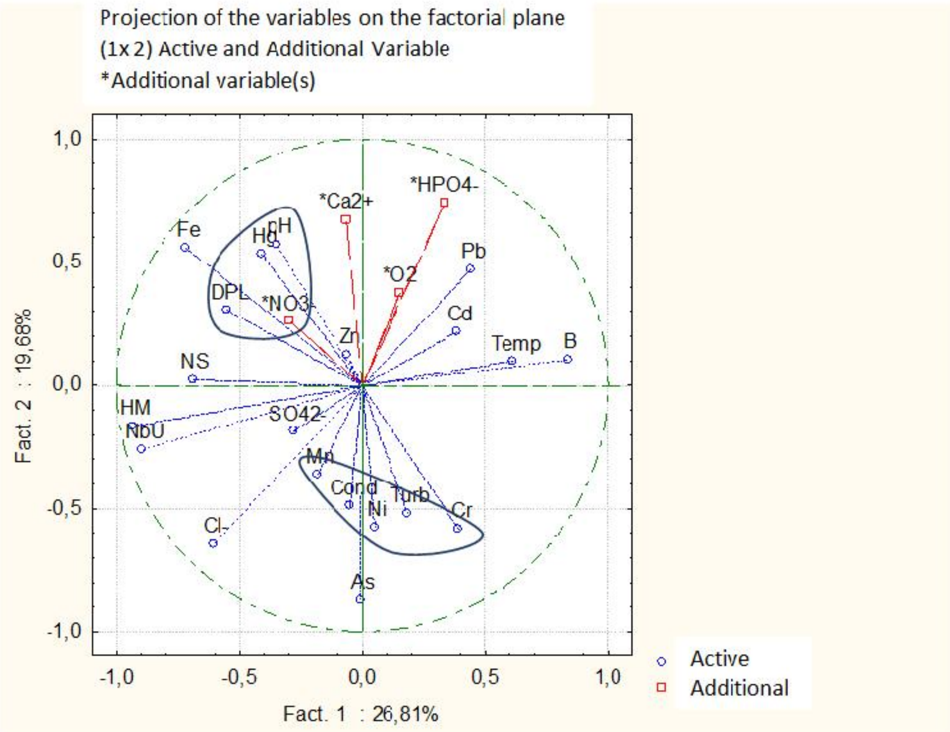

Figure 2. Projection of variables in the factor plane F1 and F2

In fact, in addition, this water quality parameter is correlated with iron. This indicates that it could exist in several oxidation states including Fe^{2+} and Fe^{3+}. In addition, the pH plays an important role in the adsorption of metals. Indeed, an alkaline pH favors the reactions of precipitation and complexation of hydroxides, thus reducing the concentrations of ETM in the aqueous phase (Thorton, 1996). Stations with a pH varying between 7.04 and 7.89 systematically induce an increase in the adsorption rate of trace elements in surface sediments. But the trapping of trace elements is not necessarily definitive. The risks of remobilization, bioavailability and therefore toxicity are to be feared. They constitute, in fact, a permanent danger for the entire aquatic ecosystem when the physico-chemical conditions allow it (François *et al*., 2002), in particular in the trophic chain (Fadil *et al*., 26). In addition, the results obtained for calcium and magnesium in the groundwater studied show that the determined contents do not exceed 20 mg / L. However, the magnesium contents in the groundwater studied exceed the WHO guideline value of 0.4 mg / L (OMS, 2000). These compounds (magnesium and calcium) are thought to come from the hydrolysis of silicate minerals present in the soil (Matini *et al*., 2009). The total hardness of water Tht is related mainly to the amount of calcium and magnesium (Matini *et al*., 2009) in the water. Thus, according to the classification of Durfor and Becker (Dufor, 1964)the drinking waters studied are sweet.

Sulphate, orthophosphate and chloride ions are mineral constituents which can alter the quality of drinking water when their concentrations exceed the guide value. The contents of these elements determined are all lower than the WHO standards (OMS, 2000). Sulphates correlate with arsenic, suggesting that their presence in water is due to the dissolution of sulphurous minerals such as pyrite. In addition, we noted an association between sulfates and calcium ions which would come from gypsum formations. Chloride ions can be linked to human waste, in particular urine and certain cleaning products (Matini *et al*., 2009)(Matini *et al*., 2009). A significant correlation was observed between chloride ions and orthophosphates. The natural concentration of orthophosphates in groundwater varies between 0.02 and 0.04 mg / L (Chery, 2000). Also, the concentrations observed in the drinking waters of the Tamania P_2 (0.053 mg / L), Neguepié P_7 (0.065 mg / l), Zanasso P_8 (0.058 mg / L), Tengrela P_{10} (0.044 mg / L) and Danzourou P_{11} (0.067) districts mg / L) could come from domestic wastewater, animal droppings and fertilizers (Chery, 2000). Chromium, which is one of the toxic substances, can be found in the water table because of human activities such as household waste buried underground without a perimeter of protection (Desbordes, 2001)[30]. Chromium has two oxidation states (+ III and + IV), the most mobile, the most soluble and therefore the most toxic form of which is hexa valent chromium (Jordana *et al*., 2004). The WHO guideline value for chromium in drinking water is 0.05 g / mL(OMS, 2000). Concentrations above the guideline value in drinking water can lead to skin rashes, gastric ulcers, weakened immune system, and even lung cancer (CIRC, 1980). The chromium content in drinking water of drinking water in Tamania P_2 (0.73 mg / L), Maniasso P_4 (0.51 mg / L), San P_6 (0.58 mg / L), Neguepié P_7 (0.65 mg / L), Zanasso P_8 (0.67 mg / L), Sorobono P_9 (0.66 mg / L) and Danzourou P_{11} (0.64 mg / L) are above the guideline value of WHO (0.05 mg / L)(OMS, 2000). Associations of chromium and nitrates seem to show possible anthropogenic sources. Since nitrate contamination originates from the surface of the soil, it is logical to believe that the concentrations in the groundwater will be higher for the shallow depths of the peasant wells covered by our study which do not exceed 5 m (NS < 5m). However, the nitrate concentrations in the drinking water studied are not very high. Indeed, only the groundwater (drinking water) of the Sorobono district ((P_9 (71.4 mg / L)) has nitrate contents higher than the WHO guideline value (50 mg/ L)(OMS, 2000). This finding could be due to the absence of significant vegetation cover in this grassy savannah region of northern Côte d'Ivoire and the absence of strong agricultural activities in the study area. On the other hand, the presence of nitrates in the groundwater studied suggests the presence of anthropogenic sources of pollution due in particular to the aging of the protection installations of peasant wells, to domestic wastewater and to latrines which makes it possible to confirm the correlation between the latter mentioned and nitrate levels in groundwater. The presence of the metallic trace elements studied in groundwater is due in particular to the geochemical characteristics specific to the study area. In addition, there are significant correlations between the metallic trace elements. Indeed, associations have been noted between mercury-iron and nickel-manganese. This confirms that the presence of these MTE in the drinking water studied is due to the geochemical characteristics specific to the different stations. In fact, the water flowing over the walls of peasant wells causes the minerals present there to dissolve (Miramond *et al*., 2006 ; Yapi, 2015).

From our results, we retain that the MTEs studied, arsenic, chromium, mercury, manganese and boron have levels higher than the WHO guide values for drinking water(OMS, 2000). The presence of a metallic trace element such as arsenic, which is a carcinogenic compound including skin cancer for its non-threshold effects, must be a major concern for the population living in our study area. Indeed, this carcinogenic compound is present in all the drinking waters studied and these determined levels are much higher than the WHO guideline value of 0.01 mg /L (10 µg / L)(OMS, 2000).

Factor analysis: Factor analysis shows that the factor F_3 determines the mineralization of groundwater. Indeed, this factor is strongly correlated with conductivity. Also, is it in association with orthophosphate ions and temperature. A high temperature promotes the dissolution of minerals, thus causing the presence of major ions in groundwater, in particular orthophosphate ions. Factors F1 and F4 highlight possible sources of anthropogenic pollution of the drinking water studied. Indeed, these factors are in association with chromium which is not a natural element. The factor F_4 suggests that the presence of sulphate ions in groundwater is not due only to the dissolution of sulphurous minerals or gypsum formations but could come from anthropogenic sources including domestic wastewater. As for the factors F1 highlights due to human rejections. In fact, during this study, the farmer wells studied are very close to the latrines. In fact, latrine well distances are less than those recommended by the WHO, which is 15 m(OMS, 2000).

The analysis of the factorial plane (F_1, F_2) reveals two classes of parameters. In the first class we have a grouping between the well-latrine distance (DPL), the pH, the mercury and nitrates contents of groundwater.

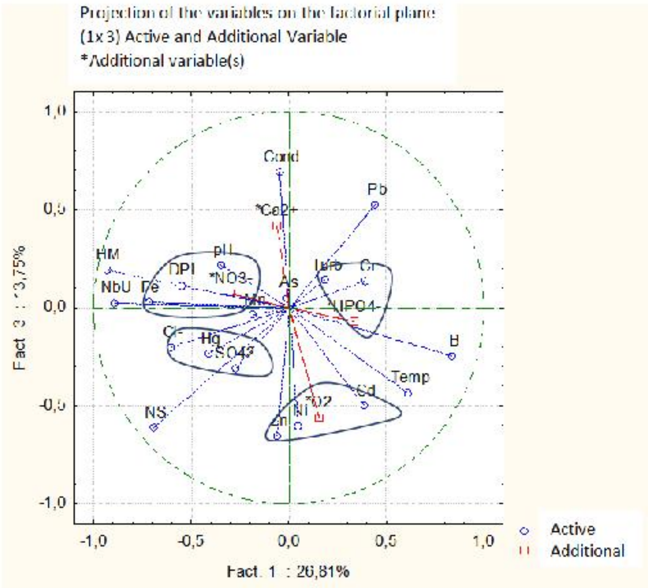

Fig. 3. Projection of variables in the factor plane F1 and F2

This grouping highlights the influence of latrines on water quality parameters, especially pH. Also these anarchic installations are not unrelated to the presence of nitrates in the drinking water studied. Chromium is part of class 2 of parameters. This class summarizes the influence of anthropogenic activities on the quality of drinking water (groundwater) studied. They act in particular on the conductivity and turbidity of the water. Inorganic salts containing nickel and magnesium could be responsible for the turbidity and conductivity of the drinking waters studied. From the study of the second factorial plane (F_1, F_3) we have retained 4 classes of parameters. Classes 1 and 4 would confirm the existence of the different pollution vectors highlighted during the analysis of the factorial plane F_1 and F_2. In addition, we have classes 2 and 4 which respectively group together the parameters SO_4^-, Hg, Cl^- and Cd, O_2, Ni, Zn. Class 2 could highlight the presence of mercury salts in the groundwater studied. In addition, the zinc and cadmium in the waters studied have anthropogenic sources, in particular domestic wastewater containing detergents. The grouping of these parameters with dissolved oxygen shows that domestic water has a significant influence on the quality of drinking water (groundwater) which is the subject of our study. Phosphates: Detergents, animal droppings, fertilizers (Chery, 2000). Unpolluted groundwater contains between 12 and 15 mg / L of chlorides (Taouil, 2012). Phosphorus in groundwater varies between 0.02 and 0.04 mg /L.

CONCLUSION

At the end this study, we note the presence of ionic compounds in groundwater such as nitrates, ortho phosphates, calcium. The levels determined for these compounds are all below WHO standards for potability. Furthermore, the results of this study show the presence of trace metal elements including arsenic, cadmium, mercury and lead in the drinking water studied. In addition, some FTEs with arsenic have determined levels above WHO standards. Therefore, the consumption of these drinking waters from the town of Tingréla could pose health risks to the population living in the study area. In addition, the study of the correlation between the different parameters studied and the Main Component Analysis revealed different sources of groundwater pollution. Apart from a pollution of natural origin due in particular to the geochemical characteristics of the different stations we have highlighted latrines, domestic wastewater

REFERENCES

Abergel J.2007. Le nord de la Côte d'Ivoire, un milieu approprié aux aménagements de petite et moyenne hydraulique. In : CECCHI PHILIPPE (ED.), LÉVÊQUE CHRISTIAN (PRÉF.), AUBERTIN CATHERINE (PRÉF). L'eau en partage : les petits barrages de Côte d'Ivoire. Paris : IRD, 45. 57. (Latitudes 23). ISBN 978. 2. 7099. 1615. 8

Belghiti M. L. 2013. Caractérisation physico. chimiques des eaux de certains puits utilisés comme source d'eau potable en milieu rural dans la région de Meknes (Maroc). ScienceLib Editions Mersenne, Vol. 5, N° 130115.

Biémi J. 1992. Contribution à l'étude géologique, hydrogéologique et par télédétection des bassins versants subsahariens du socle précambrien d'Afrique de l'Ouest: hydro structurale, hydrodynamique, hydrochimie et isotopique des aquifères discontinus de sillons et des aires granitiques de la haut Marahoué (Côte d'Ivoire), thèse de doctorat ès Sciences Naturelles, Université d'Abidjan, Côte d'Ivoire, 480p.

Centre International de Recherche sur le Cance, 1980. Chromium, Nickel and Welding. Lyon, Monographie du CIRC sur les risques de cancérogénicité pour l'homme, Vol.23, 205. 323.

CEAEQ. 2011. Détermination des métaux: méthode par spectrométrie de masse à source ionisante au plasma d'argon, Ministère du Développement durable, de l'Environnement et des parcs du Québec, 32 p.

Chery L. Barbie J., 2000. Le phosphore dans les eaux souterraines de France. Etat des connaissances. Année 1. Rapport BRGM/RP 40857. FR

Desbordes A. 2001 – Qualité, dépollution et traitement des eaux de nappes.Mém. D.E.S.S. « Qualité et Gestion de l'Eau », Fac. Sci., Amiens, 65 p. + annexes

Dufor C. N., Becler E, 1964. Public water supplies of the 100 largest cities in the US». US. Geological Survey Water Supply Paper, 1812, 364

Fadil F., Maarouf A., Zaid. 1997. Utilisation de Gammarus gauthieri pour tester la toxicité des sédiments des eaux douces. Limnol, 32: 73. 78.

Foto M. S., Zebaze T. S. H., Nyamsi T. N. L., Ajeagah G. A. ,Njiné T.,2011. Evolution Spatiale de la Diversité

des Peuplements de Macroinvertébrés Benthiques dans un cours d'eau Anthropisé en Milieu Tropical (Cameroun). European Journal of Scientific Research, Vol.55 No.2, 291. 300

François M., Li D., Dubourguier H. C., Douay F., 2002. Facteurs déterminants de la mobilité (Pb, Cu, Zn) dans les sols contaminés autour de deux usines métallurgiques du Nord de la France, Journées Nationales de l'étude des sols, du 22. 24 octobre, 2002, Orléans.

Goné D. 2001. Contribution de l'étude des paramètres physico. chimiques des eaux souterraines à la compréhension du fonctionnement des systèmes hydrauliques en milieu fissuré de la région semi. montagneuse de Man (Ouest de la Côte d'Ivoire), Thèse 3ème cycle Université d'Abobo. Adjamé (Côte d'Ivoire), 179 p.

Haouchine S.2011. Recherche sur la qualité faunistique et l'écologie des macroinvertébrés benthiques des cours d'eau de Kabylie, mém. Magister sciences bio.

Haut. Commissariat Aux Eaux et Forêt et la Lutte Contre la Désertification (HCEFLCD), 2006. Etude sur la pisciculture au barrage Almassira, CR dar CHAFAAI, Cercle d'ELBROUGE, Province de Settat, 201p

Jain P, Sharma J. D., Sohu D., Sharma P., 2005. Chemical analysis of drinking water of villages of Sanganer Tehsil, Jaipur District. Int. J. Environ. Sci. Tech., Vol. 2, 4373. 379

Jordana S., Batista E., 2004. Natural groundwater quality and health». Geologica Acta, Vol.2, N°2, 175. 188

Kaiser H. F., 1958. The varimax criterion for analytic rotation in factor analysis». Pyrometrical, 23, 187. 200

Keeney D. R.1986. Sources of nitrate to ground water", CRC Critical Reviews in Environmental Control, vol. 16, 257. 304.

Lasm T., Koffi T., Oga Y. M. S., Koffi F. 2008. Analysis of the Physico. Chemical Characteristics of Groundwater in Proterozoic Land Region of the Tiassale Area (Southern Cote D'Ivoire). Kouame European Journal of Scientific Research, Vol.20, No.3, 526. 543

Matini L., Moutou J. M. et Kongo. Mantono M. S. 2009 – Evaluation hydro. chimique des eaux souterraines en milieu urbain au Sud. Ouest de Brazzaville, Congo. Afrique SCIENCE 05(1) (2009) 82 – 98

Miramond N., Miau D., Brochard F. 2006. Diagnostic du Phénomène Drainage Minier Acide (DMA) sur des mines d'or primaire en Guyane françaises. Evaluation des risques associés. Rapport, GEM Impact. DIREN. Guyane française.

Nielsen D. M. 1991. Practical handbook of ground. water monitoring. Lewis publishers, Chelsea, Ml, 717 p.

Oga Y. M S, 1998. Ressources en eau souterraines dans la région du Grand Abidjan (Côte d'Ivoire): Approches hydrochimiques et Isotopiques. Thèse de doctorat, Université de Paris XI, Orsay, France, 212 p.

O.M.S. 2000. Directives de qualité pour l'eau de boisson». 2nd Ed., Vol 2, Critères d'hygiène et documentation à l'appui.

Prasad B. G., Naryana T. S.2004. Subsurface water quality of different sampling stations with some selected parameters at Machilipatnam Town.. Nat. Env. Poll. Tech, 3 (1), 47. 50

RGPH. 2014. Recensement général de la population et de l'habitat,Résultats globaux, 26p.

Rodier J., Bazin C., Broutin J. P., Chambon, Chapsaup H., Rodi L. (2009). L'analyse de l'eau : Eaux naturelles, eaux résiduaires, eaux de mer. Paris, Ed Dunod.

Soro N. 2002. Hydrochimie et géochimie isotopique des eaux souterraines du degré carré de Grand. Lahou et ses environs (Sud. ouest de la Côte d'Ivoire). Implication hydrologique et hydrogéologique. Thèse de doctorat ès Sciences Naturelles, Université de Cocody, Abidjan. Côte d'Ivoire, 272 p.

Taouil H., Ahmed I. S, Hajjaji N., Srhiri A. 2012. Evaluation de la pollution métallique : Mn, Fe, Zn, Co et Cr des eaux de l'oued tislit. talsin. Maroc. ScienceLib Editions Mersenne, 4: 1. 11.

Tardat. Henry and Beaudry J. P, 1992. Chimie des eaux, Les éditions Le Griffon d'argile, Canada, 537 p.

Timoléon A B, Fulbert B, 2013. Caractérisation physicochimique et chloration des eaux de puits consommées dans la ville de Brazzaville. Congo (Physicochemical Characterization and Chlorination of Well Water Consumed in Brazzaville Congo). Journal of Materials Environmental. and Science, 4 (5), 605. 612

Thornton I, 1996. Risk assessment related to metals: the role of the geochemist. Report of the International Wordshop on Risk Assessment of Metals and their Inorganic Compound, International Council on Metals and the Environment, Angers, France.

Yao K T 2009. Hydrodynamisme de l'eau souterraine dans les aquifères de socle cristallin et cristallophyllien du Sud. Ouest de la Côte d'Ivoire : cas du département de Soubré. Apports de la télédétection, de la géomorphologie et de l'hydrogéochimie, Thèse de Doctorat, Conservatoire National des Arts et Métiers, Paris, France.

Yapi Y H A, 2015. Evaluation de la pollution métallique d'un environnement minier aurifère. Cas de la sous prefecture de Hiré (Côte d'Ivoire). Thèse unique, Université Felix Houphouët Boigny, Côte d'Ivoire.

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