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Variations of heavy isotopic contents ($\delta^{18}O$ and $\delta^{2}H$) in individual rainfall events in Abidjan, Ivory Coast.

Variations temporelles des teneurs en isotopes stables (18O, 2H) des eaux des événements pluvieux à la station d'Abidjan Port-Bouët (Côte d'Ivoire)

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Abstract
The present paper deals with the stable oxygen and hydrogen isotopic compositions of meteoric water collected at the meteorological station of Port-Bouët at Abidjan, Ivory Coast. One hundred (100) rainfall events were sampled during the period from September 1995 to August 1996 and analysed for this study. Samples were collected at the end of each rainfall event. The data determine the isotopic signature of Abidjan's precipitation, the local meteoric water line (LMWL) and the meteoric waters.
The individual rainfall events display a wide range. The ^{18}O values vary from -9.0 to +1.5‰, and the $\delta^{2}H$ values vary from -51.8 to +16.6‰. The weighted $\delta^{18}O$ values are from –3.9‰ to –2.4‰, and those of ^{2}H vary from 17.5‰ to –5.6‰ for rainfall events.
The $\delta^{2}H$ vs $\delta^{18}O$ relationship for the whole rainfall events investigated, give the regression line of the local meteoric water line $\delta^{2}H = 7.2\ \delta^{18}O + 10.5‰$.
The rainfall regime at this station is controlled by the monsoon moisture. For the rainfall events occurring during the major rainy season, the local moisture contributes to vapour air masses which are at the origin of precipitation.

Key words:
rainfall, isotopes, climatology, Coastal area, West Africa

Résumé
Cette étude effectuée sur le bassin sédimentaire côtier de la Côte d'Ivoire est basée sur les isotopes stables de l'eau (^{2}H et ^{18}O) et porte sur cent (100) échantillons d'eaux des événements pluvieux de septembre 1995 à août 1996, collectées à la station météorologique à Abidjan Port-Bouët, en zone côtière. Les données disponibles ont permis la caractérisation isotopique des eaux de pluie de la région, la définition de la Droite Météorique locale (DML) et l'origine des masses de vapeur génératrices des précipitations.
Les teneurs en isotopes stables pour l'ensemble de la série analysée varient de –8,8 à +1,4‰ en oxygène-18 et de –52,5 à +16,6‰ en deutérium. Les teneurs pondérées à la hauteur d'eau précipitée varient de –3,9‰ à –2,4‰ en ^{18}O et de –17,5‰ à –5,6‰ en ^{2}H pour les 4 saisons, avec des valeurs moyennes de –3,6‰ pour ^{18}O et de –15,6‰ pour ^{2}H. Dans un diagramme $\delta^{2}H$ vs $\delta^{18}O$, l'ensemble des eaux échantillonnées définit une Droite Météorique Locale d'équation $\delta 2H = 7{,}2\ \delta^{18}O + 10{,}5‰$.
Les précipitations sont engendrées par des masses d'air océaniques (mousson) avec une participation de la vapeur recyclée plus marquée pour les eaux de la grande saison de pluie.

Mots clés :
précipitations, isotopes, climatologie, zone côtière, Afrique de l'ouest

1. Introduction

This study has been undertaken in the framework of a hydrogeochemical research program carried out in the coastal sedimentary basin of the Ivory Coast, it aims in order to improve the understanding of the hydrological behaviour of main aquifer systems within the basin (Oga [1]). A number of documentation is available to date, that points out the great importance of

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stable oxygen and hydrogen isotopes of precipitation in hydrogeological and climatological studies. In the first case, knowledge of the isotopic signature of meteoric water is necessary to better interpret the isotopic data recorded in groundwater in terms of their recharge conditions and flow regime. For climatological studies, it is well documented that variation in the isotopic compositions of rainwater at a given site can reflect variations of (i) some local climatic parameters, such as temperature of condensation and the amount of rainfall known as the "mass effect", and (ii) some geographical parameters such as the altitude of the sampling site above the sea level, or its distance from the coast known as the "continentality effect". In the present paper, the available data will allow to define the isotopic characterisation of the local meteoric water line (LMWL) and does to provide some information on the origin and the condensation processes of vapour masses at the origin of precipitation.

2. Rainfall regime

The rainfall regime at the Port-Bouët meteorological station (5°15'N, 3°56'W; Fig. 1) is controlled by the monsoon moisture which is associated to the northward migration of the Inter-Tropical Convergence Zone (ITCZ). The mean annual precipitation at the sampling site over 30 years records (September 1964 to August 1995) is 1796 mm, with extreme values ranging from 2613 mm to 942 mm, indicating high variability in annual rainfall. In Fig. 2 showing the mean monthly distribution of rainfall at the study site, two well pronounced rainy seasons can be identified; a minor rainy season from September to December during which about 25% of rainfall has been recorded, and a major rainy season from March to July during which about 70% of precipitation falls. The monthly values range from 526 mm in June to less than 15 mm in January. The mean air temperature is 27.3°C, with monthly values ranging from 25.8°C in August to 28.7°C in May. The mean relative humidity is about 83%, the monthly values ranging from 77% in December and January to 88% in August.

Today, we can notice that the changes of climate variability perturb the different season period.

3. Sampling and analytical procedures

One hundred rainfall events were sampled during the period from September 1995 to August 1996 and analysed for this study. Samples were collected at the end of each rainfall event in order to minimise alteration through evaporation of heavy isotope contents. Concomitantly to the samplings, some rainfall data such as the amount, the duration and the type of each rainfall event were also recorded.

Isotopic measurements of rainfall samples were performed at the Laboratoire d'Hydrologie et de Géochimie Isotopique of Paris-Sud University, France. Samples were prepared following the conventional procedures for oxygen-18 (Epstein and Mayeda [2]) and deuterium (Coleman et *al*. [3]), and analysed using a SIRA 10 VG 602C mass spectrometer for ^{18}O and VG 602D for ^2H. Stable isotope contents are reported as delta "δ" notation:

$$\delta\ (‰) = \left(\frac{R_{sample}}{R_{standard}} - 1 \right) x\ 1000$$

where "R" is the stable isotope ratio of water ($^{18}O/^{16}O$ and $^2H/^1H$). The isotope content values are expressed by convention as parts per thousand relative to the standard V-SMOW (Vienna Standard Mean Ocean Water). The errors (standard deviations) are ± 0.2‰ for $\delta^{18}O$ and ± 2‰ for δ^2H.

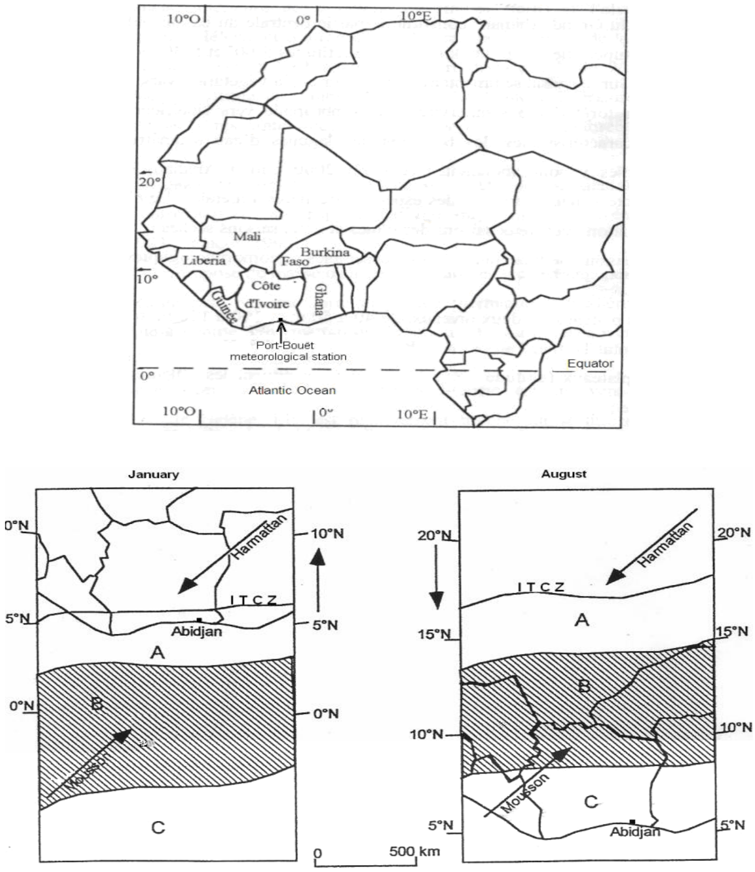

Fig. 1 : Localisation of meteorological station of Port Bouët at Abidjan, (Côte d'Ivoire) and different seasons.

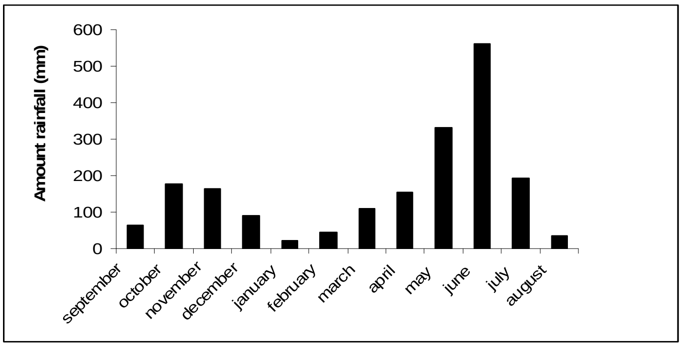

Fig. 2: Monthly variations of mean interannual rainfall at Port-Bouët meteorological station (data recorded within de period from 1963-64 to1994-95).

4. Results and discussions

Rainfall data

The pluviometry recorded at the sampling site from September 1995 to August 1996 was 2235 mm; it represents about 27% above the average value. About 73% of the total rainfall events have been collected and analyzed for this study, of which 81% of rainfall from the minor rainy season and 71% of rain events from the major rainy season.

The individual rainfall events considered for this study show a wide variation in amount. The frequency distribution histogram with respect to the amount of rainfall displayed in Fig 3 show that, the whole rainfall events vary from 1 to 93.5 mm, with about 60 percent of rainfall being less than 10 mm, and 10 percent of individual rainfall events are greater than 50 mm; these either have been collected during the major rainy season.

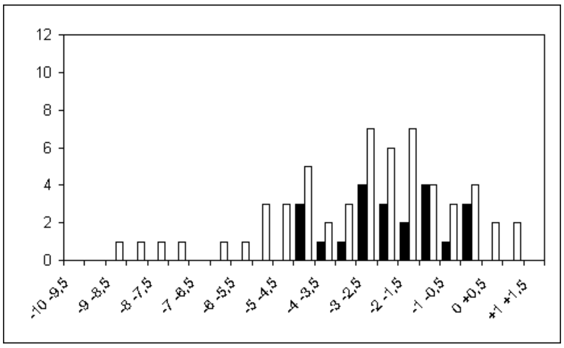

Figure 3: Histogram showing the frequency of amount of rainfall at Port-Bouët meteorological station (from September 1995 to August 1996)

Empty diamonds: major rainy season Full diamonds: minor rainy season.

Oxygen-18 and deuterium data

The heavy isotope data for the whole individual rainfall events investigated for this study are given in Table 1 and represented graphically in Figs. 4 and 5. The individual rainfall events display a wide variation with respect to their isotopic compositions. In Fig. 4 showing the frequency distribution histogram of ^{18}O contents, the whole values vary from -9.0 to +1.5‰, with a mean weighted value of -3.6‰. The δ^2H values vary from -51.8 to +16.6‰ (Table I), with a mean weighted value of -15.4‰. Individual rainfall events from the small rainy season are isotopically more enriched than those from the major rainy season (Fig.4); the mean weighted $\delta^{18}O$ values are -2.9‰ and -3.8‰ for rainfall events from small and major rainy seasons, respectively.

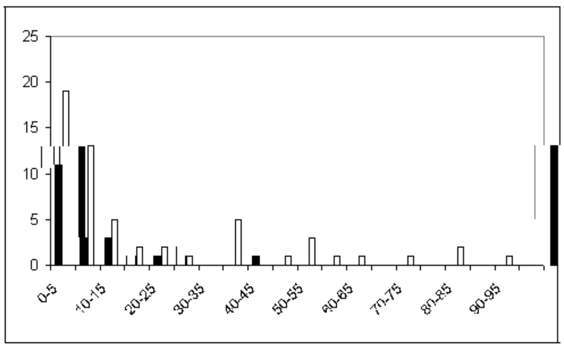

Figure 4. : Distribution of ^{18}O contents in individual rainfall events at Port-Bouët meteorological station (from September 1995 to August 1996).

Empty diamonds: major rainy season Full diamonds: minor rainy season.

In Fig. 5 the δ^2H-$\delta^{18}O$ relationship for the whole rainfall events investigated displaying a regression line for the local meteoric water

$$\delta^2H = 7.2\ \delta^{18}O + 10.5\ (n = 100;\ r = 0.96) \quad (1)$$

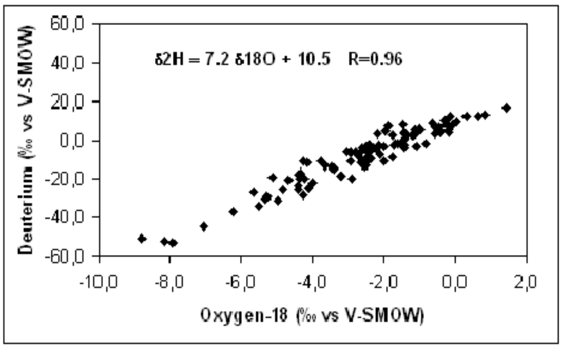

Figure 5: δ^2H *vs* $\delta^{18}O$ in individual rainfall events at Port-Bouët meteorological station (from September 1995 to August 1996).

Thus the local meteoric water line defined is characterised by a slope and an intercept or deuterium excess ($d = \delta^2H - 8.\delta^{18}O$, [4]) very close to those defined worldwide for oceanic meteoric waters which have not been subject to evaporation processes (Craig [4]; Dansgaard [5]; Njitchoua and *al*. [13]; Rozanski and *al*. [14]). However, the value of deuterium excess obtained for all rainfall events is relatively greater than that defined at a global scale for meteoric waters originating from an oceanic source (Craig [4]). This suggests that, part of atmospheric moisture which is at the origin of precipitation could be from local origin. This assumption can be justified when analysing the seasonal variations of meteoric water lines at the study site. In fact, as indicated by equations (2) and (3), the regression line defined for rainfall events from the minor rainy season (September to December) and that established for rainfall events from the major rainy season (March to July) show quite similar slope but differ significantly in their deuterium excess values, suggesting, as formed in provided other studies [10], changing conditions at the source of condensable moisture.

Table I: Oxygen-18 and deuterium contents in individual rainfall events in Abidjan, Côte d'Ivoire (from September 1995 to august 1996)

Date	Period	Rainfall (mm)	Sample	Cl- (mg.l^{-1})	^{18}O (‰ *vs* SMOW)	^{2}H (‰ *vs* SMOW)
Small rainy season						
20/9/95	*16h40-18h20*	*1,1*	*pl 1*	*11,7*	*-1,4*	*0,3*
	22h40-2h20	*4,9*	*pl 2*	*5,7*	*-1,0*	*5,4*
28/9/95	17h40-19h45	14,9	pl 4	2,2	-3,7	-13,7
11/10/95	8h05-9h10	7,7	pl 8	13,1	-1,4	3,4
20/10/95	4h15-7h40	25	pl 11	6,8	-2,1	-7,8
22/10/95	0h15-1h40	4,3	pl 12	11,9	-1,6	-1,7
23/10/95	7h35-8h30	3,6	pl 13	5,7	-2,7	-9,5
24/10/95	1h20-1h50	3,8	pl 15	3,9	-2,6	-5,2
25/10/95	3h15-6h10	19,8	pl 16	3,7	-2,7	-8,6
26-27/10/1995	21h35-2h20	23,1	Pl 17	4,3	-3,2	-18,6
31/10/95	4h35-6h40	26,5	Pl 18	4,0	-4,1	-24,9
1/11/95	22h10-22h30	2,3	Pl 19	12,3	-2,4	-10,1
2/11/95	1h05-7h30	43,3	Pl 20	1,8	-4,4	-25,2
4/11/95	*7h08-7h45*	*3,5*	*Pl 21*	*13,3*	*-1,4*	*-3,7*
	17h45-19h30	*11,9*	*Pl 24*	*2,5*	*-4,4*	*-23,3*
5/11/95	*4h-4h40*	*2*	*Pl 25*	*4,9*	*-2,5*	*-10,3*
	5h05-7h30	*11,1*	*Pl 26*	*5,4*	*-2,6*	*-12,2*
7/11/95	1h50-2h45	1,5	Pl 28	13,4	-1,8	-9,3
11/11/95	7h25-7h50	5,5	Pl 29	9,9	-1,1	-2,9
14-15/11/95	23h35-0h45	6,3	Pl 30	12,5	-0,4	4,9
18/11/95	*0h10-0h35*	*1,5*	*Pl 31*	*33,3*	*-0,1*	*12,5*
	5h05-6h15	*4,5*	*Pl 33*	*6,7*	*-0,3*	*10,4*
Great dry season						
2/12/95	9h12-9h45	1,6	Pl 35	105,2	1,4	16,6
7/12/95	4h40-5h10	2,4	Pl 39	20,5	-1,1	5,2
15/12/95	4h25-5h30	1,1	Pl 41	68,9	-1,2	2,6
20/12/95	*4h05-4h25*	*1,2*	*Pl 43*	*98,9*	*-0,2*	*5,7*
	16h20-18h15	*30,6*	*Pl 44*	*10,4*	*-1,5*	*-2,6*
22/12/95	23h50-1h05	17,6	pl45	6,8	-2,2	-5,0
23/12/95	8h30-10h20	22,8	pl 46	4,5	-2,2	3,2
24/12/95	23h10-3h30	47	pl 47	1,6	-4,2	-19,5
4/3/96	*5h50-6h15*	*7,7*	*pl 2bis*	*12,5*	*0,0*	*9,5*
	8h55-9h15	*3*	*pl 3bis*	*6,2*	*-2,3*	*-3,6*
10/3/96	4h05-5h10	7,1	pl 4bis	10,2	-0,6	6,7
14/3/96	2h10-3h15	1	pl 6bis	66,3	-2,4	-9,8
20/3/96	5h40-6h30	5,5	pl 7bis	33,2	-2,2	-2,3
22/3/96	0h-3h35	15,7	pl8bis	9,1	-2,0	-2,9
Great rainy season						
1/4/96	2h30-3h30	3,5	pl9bis	21,9	-3,0	-7,2
14/4/96	19h45-20h	2,9	pl10bis	36,4	-2,9	-6,3
15/4/96	5h25-6h10	5,3	pl11bis	15,8	-4,4	-19,7
17/4/96	*4h30-9h20*	*54,4*	*pl12bis*	*3,4*	*-5,7*	*-27,0*
17/4/96	*8h10-9h20*	*6,3*	*pl13bis*	*3,1*	*-4,0*	*-22,2*
19/4/95	17h25-18h15	7,2	pl14bis	7,3	-4,4	-16,8
29/4/96	19h43-20h18	2,1	pl17bis	18,3	-2,5	-5,9
5/5/96	*17h50-18h45*	*5,5*	*pl18bis*	*38,2*	*-1,9*	*4,6*
5-6/5/96	*22h15-2h15*	*38,7*	*pl19bis*	*8,6*	*-5,1*	*-19,3*
7/5/96	12h15-12h35	6,2	pl20bis	9,0	-2,4	-5,0
8/5/96	20h15-20h35	7,2	pl21bis	9,6	-2,6	-4,0
9/5/96	6h5-6h40	3,3	pl23bis	9,9	-3,8	-11,5
10/5/96	14h40-16h30*	2,2	pl24bis	30,8	-1,7	-1,6

15/5/96	5h45-6h25*	5,2	pl25bis	28,3	-0,3	10,5
	1h05-1h15	1,5	pl28bis	17,5	-1,0	5,8
18/5/96	5h05-6h10	13,7	pl29bis	14,1	-1,8	2,7
23/5/95	3h20-3h30	1,1	pl30bis	57,6	-2,8	-6,2
24/5/95	1h30-6h15*	93,5	pl32bis	4,1	-3,1	-5,8
	6h40-9h20*	9,3	pl33bis	5,0	-4,2	-12,1
28/5/96	22h30-7h20*	37,8	pl34bis	7,2	-7,1	-45,2
30/5/96	23h35-4h45*	82,4	pl36bis	7,4	-8,1	-51,8
31/5/96	5h15-10h25*	11,9	pl37bis	3,0	-8,8	-50,9
	10h-10h05	1,5	pl39bis	12,4	-5,0	-31,4
5/6/95	1h30-6h40*	6,7	pl42bis	12,6	-5,3	-30,3
	9h50-12h05	21,3	pl43bis	7,5	-7,9	-52,5
10/6/96	0h0-5h15*	2,9	pl45bis	8,6	-3,4	-14,9
	6h15-11h35	11,5	pl46bis	2,3	-4,7	-20,2
	12h15-13h40	9,5	pl48bis	3,8	-3,5	-13,7
	23h05-5h20*	55	pl49bis	3,5	-6,2	-37,1
13/6/96	0h05-5h25	35,6	pl50bis	11,7	-4,4	-17,5
16/6/96	3h10-5h35*	29	pl52bis	8,6	-2,9	-11,4
	9h10-11h25	13,3	pl54bis	5,7	-2,5	-10,6
18/6/96	5h10-6h35	5,3	pl56bis	12,8	-1,0	4,3
19/6/96	7h55-8h45	17,1	pl57bis	6,2	-1,4	2,7
24/6/96	5h00-9h20*	84	pl58bis	5,3	-2,5	-13,3
	11h20-14h05*	3,8	pl59bis	6,9	-1,6	-1,9
26/6/96	10h55-11h35	4	pl61bis	16,4	0,7	12,9
27/6/96	22h40-23h30	8,4	pl62bis	10,1	-1,5	8,3
28/6/96	2h25-3h15	4,2	pl63bis	17,5	0,3	12,7
30/6/96	1h15-2h20	1,2	pl64bis	42,3	0,8	13,3
	14h40-23h35	17	pl65bis	7,3	-1,2	2,3
1/7/96	0h15-3h10	3,1	pl66bis	10,3	-1,4	4,0
	17h30-2h30	53,1	pl67bis	7,8	-1,9	7,4
2/7/96	3h10-15h10	10,7	pl68bis	8,1	-1,7	-2,5
3/7/96	15h15-19h40*	36,4	pl70bis	3,3	-4,8	-25,2
6/7/97	19h10-2h25*	60,1	pl71bis	2,8	-2,0	-10,9
7/7/96	6h50-7h40	2,7	pl72bis	4,1	-2,5	-2,2
	8h35-12h45*	39,9	pl73bis	1,7	-2,9	-20,1
8/7/96	10h45-11h45	20,2	pl74bis	2,2	-4,3	-11,1
9/7/96	4h30-6h35*	50,1	pl75bis	1,4	-2,7	-11,6
13/7/96	11h40-12h30	4,3	pl77bis	17,6	-0,4	4,2
14/7/96	1h35-1h50	1,7	pl78bis	17,1	-0,1	8,6
	4h05-6h10*	1,1	pl79bis	21,9	-0,2	3,7
	7h15-10h55	73,5	pl80bis	1,3	-2,4	-2,5
	18h30-4h25	47,5	pl81bis	2,4	-5,5	-34,0
16/7/96	9h20-14h15	9,7	pl85bis	2,6	-0,6	9,1
18/7/96	1h25-5h20	2,2	pl86bis	24,6	0,0	10,0
Small dry season						
14/8/96	11h15-15h30	14,2	pl 88	9,0	-0,3	8,2
15/8/96	0h45-3h20	2,5	pl89	8,0	-0,5	6,9
18/8/96	7h20-8h20	1,1	Pl90	7,3	-0,6	2,9
	8h40-12h10	5,4	Pl91	10,3	-0,5	6,4
25/8/96	4h50-5h43	19,9	pl92	5,3	-5,3	-29,4
	6h10-17h15	18,8	Pl93	5,0	-4,3	-28,1
31/8/96	22h50-23h05	3	Pl95	46,0	-0,8	-1,9

Zone A : major dry season
Zone B : minor and major rainy season
Zone C : minor dry season.

Minor rainy season $\delta^2H = 8\ \delta^{18}O + 10.6$
(r = 0.96) (2)
(22 samples)

Major rainy season $\delta^2H = 7.4\ \delta^{18}O + 11.8$
(r = 0.96) (3)
(57 samples)

For rainfall events from the minor rainy season (September to December), the d-excess value is very close to 10‰, suggesting that during this period, the investigated rainfall events have been likely generated by atmospheric moisture of oceanic origin. On the opposite, higher d-excess value (about 12‰) defined for rainfall events from the major rainy period (March to July) clearly evidences that local moisture has contributed to vapour air masses which are at the origin of precipitation. These results finding points out the relatively important role that can often play the surface water, notably the lagoon system, upon the local rainfall regime.

Seasonal variations and amount effects

Numerous studies carried out worldwide relative to the isotopic compositions of meteoric waters have shown that variations in both $\delta^{18}O$ and δ^2H values of rainfall events can be related (1) to the geographical location and altitude of a given sampling site, and (2) to some climatological parameters such as the origin of condensable moisture, the temperature of condensation and the dynamic (or rainout process) of the vapour reservoir (Dansgaard [5]; Gonfiantini [7]; Yurtsever and Gat [6]). In tropical regions where the rainfall regime is dominated by monsoon air masses, which is the case of the Port-Bouët station, number of studies have shown that the amount of rainfall is the key factor controlling the isotopic evolution of meteoric waters. This influence of the rainfall amount, also known as "amount effect" (Dansgaard [5]) can be divided finds either in the decrease of the heavy isotopes with the increasing amount of rainfall, or in the seasonal variation of $\delta^{18}O$ and δ^2H values with rainfall events from the heart of the rainy season being isotopically most depleted than those from both beginning and end of the rainy season.

As can be seen in Fig. 6a illustrating the seasonal variation of $\delta^{18}O$ values in precipitation, the most negative isotope values are not typical of rainfall events from the peak of rainy months. In fact, rainfall events from the peak of rainy period (October and December for the minor rainy season and June and July for the major rainy season) are very enriched. Such an abnormal evolution of $\delta^{18}O$ with respect to the period of the rainy seasons seems to indicate that the amount effect is not the major process controlling the isotopic composition of the rainfall events. This assumption is clearly confirmed by Fig. 6b which does not show a clear relationship between both $\delta^{18}O$ values and amount of rainfall; some heavier rain events are not characterized by more negative ^{18}O contents and inversely, some small rain events present very negative isotope composition. The distribution of data points in such a diagram can provide some pertinent information upon the condensation processes of atmospheric moisture at the site under study.

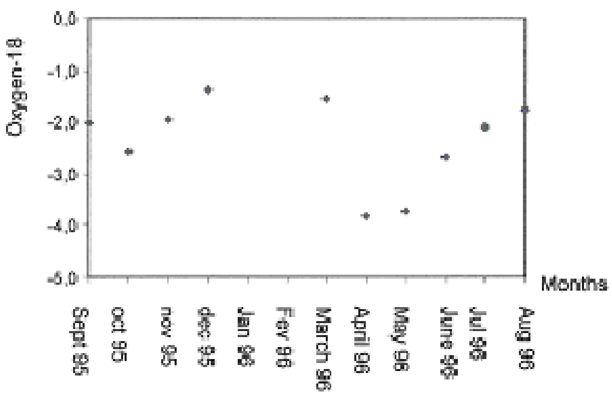

Fig. 6. a Monthly variation of the oxygen-18 contents in rainwater

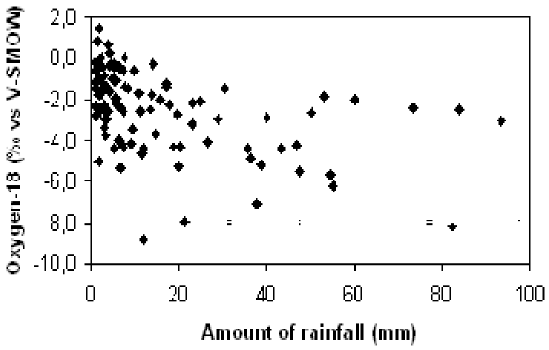

Fig. 6. b Variation of the oxygen-18 contents according to the amount of rainfall

Origin of the generating vapour of rains

The mechanism of condensation of the generating masses of vapour in the Grand Abidjan area was illustrated by the model (Martinelli [16]) showing the evolution along the WML of the isotopic composition of a rainwater formed by a given vapour mass.

It should be stressed that in Abidjan, the oceanic influence is very high; consequently the continental vapour, even when it exists, can sometimes be in balance with the marine water vapour. Contribution of the recycled vapour is in imprinted of the great rainy season due to the fact that evapotranspiration is more significant at this period of the year. The lines of correlation (δ ^{2}H vs δ ^{18}O) would be thus lines of mixture.

The contribution of the of continental vapour in rainfall was already observed and described in many studies on rainwater in western African zone, precisely in the Plain of Accra in Ghana (Akiti [8]), in Mali (Traoré [15]), in Benin (Gallaire and *al*. [9]), in Nigeria (Mbonu and Travi [10]), in Cameroun (Njitchoua and *al* . [13]) and in East Africa (Rozanski and *al.* [17]).

Other works (Monteny [11] and Monteny and Casenave [12]) showed the importance of the recycling water between the coast of the gulf of Guinea and the Sahel (approximately 60 to 75% of the annual rain). The rainwater in the forest and savanna from equatorial Africa are partly reintroduced in the atmosphere through evapotranspiration of vegetation cover and then precipitate more in the north. This observation is confirmed by the study concerning the tropical forest of Côte d'Ivoire which reinjects in the atmosphere about two third of the water precipitated.

Recent studies (Gong & Eltahir [18]) on the sources of the generating moisture of the rains in West Africa indicate 23% for the Atlantic contribution, 27% derived locally and 17% of central Africa. The contribution of evaporation increases towards the continent.

In the Sahel, more than 90% of precipitation would be generated by water vapour recycled by the evapotranspiration (Savenije [19]). The rate of local evaporation in West Africa (27%) is comparable with that of the basin of Amazonia (South America) located in intertropical zone, and where the contribution of the local evapotranspiration to precipitation is estimated at 25% (Eltahir and Bras [20]).

5. Conclusion

The mechanism of condensation of the generating masses of air in most rains occurring in Abidjan have oxygen-18 contents ranging between -2 and -5‰. That corresponds to those measured in the oceanic tropical stations. However, 49% of the samples collected have more enriched ^{18}O contents. Waters enriched in oxygen-18 and deuterium are derived from weak rains ; and they also exhibit high contents chlorides. The contents of stable isotopes suggest two origins of the generating vapour masses namely a vapour mass of oceanic origin and a vapour mass of continental origin.

The stable isotopes contents reveal that the rains resulting from oceanic vapour masses are condensated under conditions close to equilibrium. However, Deuterium excess for the great rain season waters seems to indicate a considerable contribution of the continental vapour as source of precipitations. The influence of monsoon remains dominant.

We suggest to measure on a hydrological scale i) the contents of heavy isotopes of precipitations and water of the Ebrie lagoon in order to confirm and to quantify the contribution of the Ebrie lagoon in the hydrological cycle and ii) the contents of carbon-14 and tritium in water of Grand Abidjan area for the validation of the isotopic signature of the "in put" function of the aquifer systems

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