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# Isotopic Rainfall Tracing and Input Signal Definitions: Example of the City of Bangui in the Central African Republic from 2021 to 2022

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## Abstract

This project involves continuous measurements of stable isotope composition ($^2H$, $^{18}O$) in rainfall in Bangui. The aim is to establish a local meteoric line, determine the effects influencing isotopic composition and assess the potential of these measurements for understanding the humid atmospheric processes prevalent in this geographical area. Over the two years, the results obtained from the mass spectrometry measurements revealed two major physical effects: the latitude/altitude effect, with progressive condensation of the vapour as it is transported to higher latitudes where temperatures are lower, and the altitude effect, with the isotopic composition of the soil becoming increasingly depleted in $^2H$ and $^{18}O$, as is the case for the Bangui-SODECA station, located at an altitude of 391 meters on the Bas-Oubangui hill. Another observed effect is the mass effect with heavy tropical precipitation associated with the passage of the inter-tropical convergence zone, characterized by clouds with large vertical development and heavy showers. The months of August, September and October are marked by heavy precipitation and present strongly depleted isotopic contents: -51.96‰ for □$^2$H and -8.13‰ for □$^{18}$ O. The various correlations of isotopic contents in precipitation in relation to meteorological parameters (temperature, rainfall quantity and altitude) have made it possible to define the input signal or alternatively to calculate a local meteorological line for each of these two stations during these two years: □$^{(2)}$H= 7.35 □$^{(18)}$O + 11.84 ($r^2$=0.98) for SODECA 2021; □$^{(2)}$H= 7.53 □$^{(18)}$O + 11.42 ($r^2$=0.98) for University 2021; and □$^{(2)}$H= 6.53 □$^{(18)}$O + 3.58 ($r^2$=0.99) for SODECA 2022; □$^{(2)}$H= 6.04 □$^{(18)}$O + 4.33 ($r^2$=0.87) for University 2022.

## Keywords

Stable Isotopes, Precipitation, Meteoric, Altitude, Latitude, Temperature

## 1. Introduction

The exploitation of water resources is one of the greatest problems facing mankind today, as the associated problems affect the lives of many millions of people. This has attracted the attention of the United Nations, the International Atomic Energy Agency (IAEA) and the international and regional governmental and non-governmental organizations concerned. Obtaining more and better quality water means continuing and expanding hydrological research. Stable isotopes of water (oxygen-18 and deuterium) have been widely used to study the water cycle and to reconstruct past climates since the 1960s. Until the mid-2000s-2010s, most studies focused on climate archives (ice, speleothems, etc.), or on current precipitation. Since then, widely available technological innovations have made it possible to monitor specific air humidity

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and its isotopic composition.

Stable isotopes of water vapor have been used to study many processes, such as the mixing of air masses [1, 3], the evaporation of rain and, more broadly, the recycling of water vapor [4] and [5, 10]. In the atmosphere, water is likely to undergo numerous phase changes. With each phase change, water isotopes are redistributed unevenly between phases (this is referred to as fractionation). Thus, the isotopic composition of water vapour and precipitation can be considered as a tracer integrating the history of the air mass from evaporation to the study area [20].

The study is based in Bangui (annual average of 1,005 mm for 2021 and 1,348 mm for 2022), where each rainfall event was sampled at the SODECA station at Bangui University during the years 2021 and 2022. The isotope ratio is measured by mass spectrometry (IAEA Laboratory of Hydrology and Isotope Geochemistry) in Vienna, by comparison with a standard (VG micromass 602D and 602C); the measurement error is ±0.2 ‰ for 18 O and ±1 ‰ for 2 H. Isotopic contents are expressed relative to SMOW in parts per thousand (ppm) [20, 30].

## 1.1. Presentation of the Study Area

The Central African Republic (CAR), at the heart of the African continent, stretches over 623,000 km^(2) between the 2^th and 11^th parallels north, and between the 13^th and 27^th meridians east. It is bounded to the east by the watershed between the Nile and the Ubangi-Congo, and its Sudanese neighbor. To the north, it is bounded by the Akouale and Bahr Aouk (Chari) rivers, to the west by the Sangha Basin, to the southwest by the Lobaye Basin and to the south by the Oubangui River. It has a population of around 6 million, with a density of 6.5 inhabitants/km ² The city of Bangui, capital of CAR, is located on the north bank of the Oubangui, in the south of the Central African territory, in the sub-prefecture of Ombella M'poko, and is the subject of this study. The study area lies between 4 °20' and 4 °30' north latitude and between 18 °30' and 18 °45' east longitude (Figure 1). It is bounded by:

1) to the east and southeast by the Oubangui River;
2) to the west by the Bimbo sub-prefecture;
3) to the north by the Boali and Damara sub-prefectures.
4) to the south-west by the Mpoko and Oubangui rivers.

The Oubangui River also forms a natural border between the Central African Republic and the Democratic Republic of Congo.

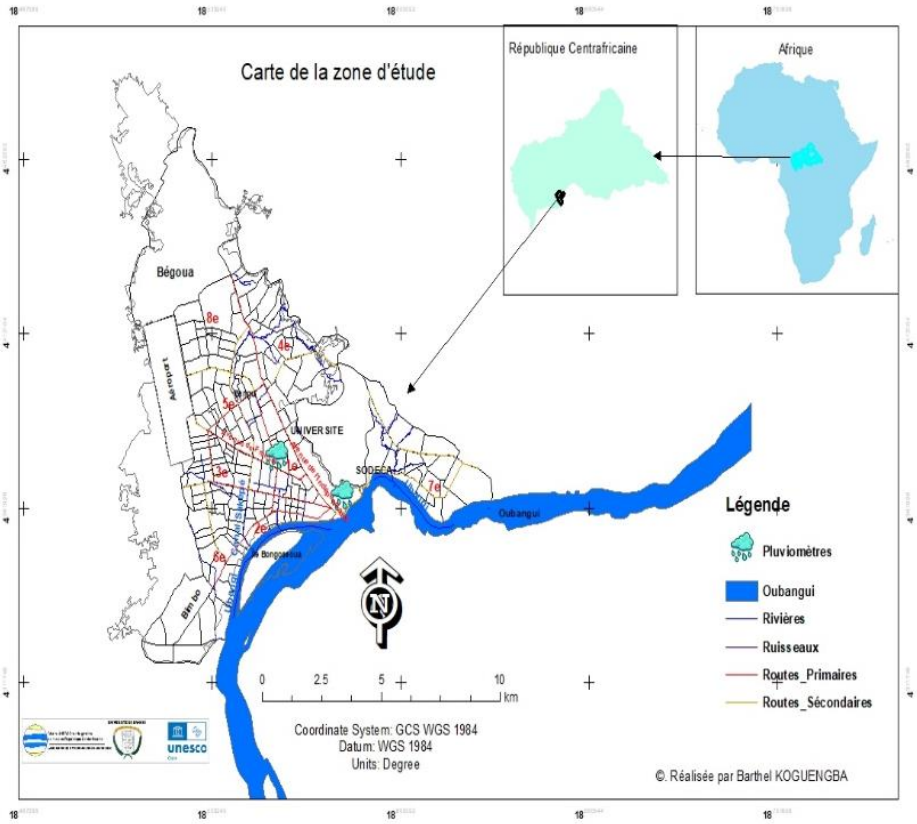


***Figure 1.*** *Map showing location of study and sampling area.*

### 1.2. Climate

Bangui enjoys a tropical climate, with a dry season from December to March. Rain is fairly frequent during the rest of the year, especially from July to October. Bangui is the capital of the Central African Republic and lies in the south of the country, around 4 degrees north of the equator, at an altitude of 350 meters, on the banks of the Oubangui River, beyond which lies the town of Zongo, in the Democratic Republic of Congo (DRC). The highest temperatures are recorded in the dry season, but also in March and April, the first months when the rains begin to gradually increase. However, December to February is also the period with the coolest night-time temperatures. The average temperature of the coldest month (July) is 25.8 °C, while that of the hottest month (March) is 28.5 °C.

## 2. Materials and Methods

As part of this work, all studies were carried out in Bangui, notably at the rain gauge station of the University of Bangui and at that of the Société de distribution des eaux en Centrafrique (Sodeca). These measurements were carried out over a two-year period, from January 2021 to December 2022.

In the course of this study, 40 rainwater samples were taken during the following two periods: March-December 2021 and February-December 2022, at two rainfall stations [25]:

1) Station 1: University of Bangui (coordinates: N04°22'37.9"; E18°33'45.00"; 374m, located on the Bangui plain);
2) Station 2: SODECA (coordinates: N04°21'56.7"; E18°35'14.1"; 391m, at the foot of the Bas-Oubangui hills).


*Figure 2. The multimeter.*

Monthly rainfall sampling is carried out using rain gauges (Figure 2). They were measured (pH, conductivity and temperature) using a multimeter, then stored in 50 ml double-capped polyethylene bottles (figure 4), previously rinsed with distilled water. Stable isotopes of the water molecule ($^{18}O$ and $^{2}H$) were measured using mass spectrometry. $^{2}H$ and $^{18}O$ contents are expressed in units (‰) relative to the V-SMOW standard, with an uncertainty of ± 0.1‰ for $^{18}O$ and ± 1‰ for $^{2}H$.

*Figure 3. The rain gauge.*

*Figure 4. Polyethylene bottle.*

## 3. Results and Discussion

The study of the isotopic composition of rainwater covered in this section will enable isotopic characterization of the rainfall recorded in the Bangui region, in order to establish a local meteoric line and then compare it with the global meteoric line [15, 16].

The available isotopic data, collected on a monthly basis, were examined as such, before being analyzed in annual and seasonal weighted form. This approach enabled us to understand the influence of air masses responsible for rainfall and of local and regional climatic parameters on the evolution of the isotopic composition of rainfall in the Bangui region.

In this study, data from the Global Network for Isotopes in Precipitation (GNIP) are used to produce graphs defining the isotopic signatures of precipitation water [27, 29].

The data collected from these stations (over a two-year period) are used to determine the local meteoric line, in order to identify trends in isotopic content as a function of season, monthly rainfall and inter-annual variations.

### 3.1. Parameters Measured

The results of pH, conductivity, temperature, rainfall, $\delta\,^2H$ and $\delta^{18}O$ measurements for the year 2021 obtained from samples taken at the two rainfall stations of Bangui University and SODECA are shown in Table 1 below.

***Table 1.*** *Sampling results for 2021.*

| 2021 | STATION | pH | EC (µS/cm) | T ℃ | H (mm) | $^2H$ ‰ | $^{18}O$ ‰ |
|---|---|---|---|---|---|---|---|
| January | SODECA | 9,7 | 117,5 | 27,9 | 260 | 21.66 | 1,72 |
| | UNIVERSITY | 6,8 | 31,83 | 27,2 | 300 | 20,81 | 1,40 |
| February | SODECA | No rain | | | | | |
| | UNIVERSITY | | | | | | |
| March | SODECA | 6,21 | 24.7 | 29 | 460 | 16,98 | 0,38 |
| | UNIVERSITY | 6,68 | 8,59 | 29,2 | 200 | | |
| April | SODECA | 5,98 | 51,94 | 32,8 | 112,5 | 21,09 | 1,02 |
| | UNIVERSITY | 3,028 | 210,6 | 30,7 | 349,5 | -0.04 | -1,73 |
| May | SODECA | 9,04 | 23,92 | 27,7 | 1000 | -44,47 | -7,55 |
| | UNIVERSITY | 7,24 | 35,15 | 27,8 | 780 | -17,59 | -3,71 |
| June | SODECA | 7,78 | 36,18 | 26 | 1085 | 14,35 | 0,36 |
| | UNIVERSITY | 6,92 | 29,2 | 27,4 | 925 | | |
| July | SODECA | 6,74 | 12,7 | 26,5 | 1150 | 19,62 | 2,13 |
| | UNIVERSITY | 6,68 | 13,2 | 26,1 | 710 | 22,39 | 2,16 |
| August | SODECA | 4,47 | 9,55 | 27,3 | 2250 | -16,88 | -3,94 |
| | UNIVERSITY | 4,1 | 5,26 | 25,5 | 1715 | -18,91 | -4,01 |
| September | SODECA | 4,5 | 13,99 | 25,9 | 1310 | -27,59 | -5,04 |
| | UNIVERSITY | 5,5 | 5,87 | 25,2 | 1620 | -25,97 | -4,60 |
| October | SODECA | 5,69 | 16,3 | 26 | 1425 | 5,12 | -1,41 |
| | UNIVERSITY | 6,8 | 20 | 26,6 | 1210 | 0,92 | -1,83 |
| November | SODECA | 5,13 | 8,93 | 25,1 | 2300 | 25,58 | 1,10 |
| | UNIVERSITY | 5,19 | 8,02 | 26,3 | 2720 | 23,53 | 0,87 |
| December | SODECA | 6,23 | 21,4 | 29 | 146 | 23,73 | 1,55 |
| | UNIVERSITY | 6,31 | 16,8 | 28,7 | 101 | 25,11 | 1,81 |

Measurements in 2022

Table 2 shows the results of pH, conductivity, temperature, rainfall, $\delta\,^2H$ and $\delta^{18}O$ measurements for the year 2022, obtained from samples taken at the two rainfall stations at Bangui University and SODECA.

***Table 2.*** *Results of sampling in 2022.*

| 2022 | STATION | pH | EC(µS/cm) | T ℃ | H (mm) | $^2H$ ‰ | $^{18}O$ ‰ |
|---|---|---|---|---|---|---|---|
| January | SODECA | No rain | | | | | |

| 2022 | STATION | pH | EC(μS/cm) | T ℃ | H (mm) | $^2H$ □ ‰ | $^{18}O$ □ ‰ |
|---|---|---|---|---|---|---|---|
| | UNIVERSITY | | | | | | |
| February | SODECA | | | | | | |
| | UNIVERSITY | | | | | | |
| March | SODECA | 7,49 | 903 | 26 | 744 | 62,16 | 9,55 |
| | UNIVERSITY | 7,7 | 171,1 | 27,1 | 240 | 36,95 | 4,76 |
| April | SODECA | 6,45 | 386,4 | 25 | 2300 | -13,58 | -2,33 |
| | UNIVERSITY | 6,72 | 14,66 | 24,3 | 1600 | -19,07 | -4,36 |
| May | SODECA | 8,19 | 13,15 | 26,2 | 563 | -10,47 | -1,59 |
| | UNIVERSITY | 8,05 | 17,06 | 23,3 | 425 | -10,88 | -1,64 |
| June | SODECA | 7,5 | 32 | 27 | 1508 | -40,97 | -6,74 |
| | UNIVERSITY | 7,56 | 24,01 | 26,8 | 1200 | 9,6 | -1,14 |
| July | SODECA | 7,29 | 6,07 | 26,7 | 2480 | -26,76 | -5,31 |
| | UNIVERSITY | 6,77 | 6,79 | 26,4 | 1890 | -23,05 | -4,88 |
| August | SODECA | 4,48 | 31,14 | 28,5 | 3068 | -15,32 | -2,89 |
| | UNIVERSITY | 6,77 | 55,22 | 25,5 | 2340 | -11,45 | -1,93 |
| September | SODECA | 6,35 | 1,54 | 24,7 | 800 | -51,96 | -8,13 |
| | UNIVERSITY | 7,31 | 5,77 | 24,5 | 1680 | -33,63 | -5,21 |
| October | SODECA | 5,88 | 4,2 | 26,7 | 1788 | 41,37 | -6,80 |
| | UNIVERSITY | 5,95 | 7,4 | 28,1 | 1400 | 9,68 | 3,44 |
| November | SODECA | 6,88 | 25,5 | 26 | 100 | 27,35 | 2,29 |
| | UNIVERSITY | 7,11 | 31,8 | 26 | 145 | 26,96 | 2,04 |
| December | SODECA | No rain | | | | | |
| | UNIVERSITY | | | | | | |

On the basis of the results of the sampling measurements presented above, we have plotted the following graphs:

(1) level of precipitation;
(2) pH measurements;
(3) conductivity measurements;
(4) temperature measurements;
(5) local meteor lines;
(6) $^{18}O$ variation with precipitation;
(7) $^{2}H$ variation with precipitation.

## 3.2. Precipitation Levels in 2021 and 2022

Figures 5 and 6 show rainfall levels for the years 2021 and 2022 at the Université de Bangui and SODECA sites respectively.

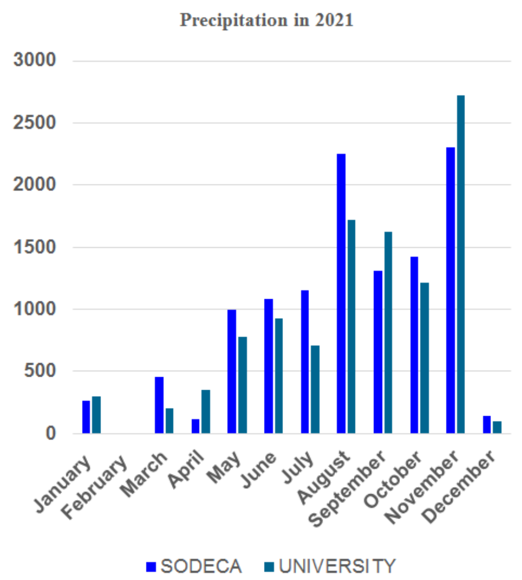


***Figure 5.*** *Precipitation levels for 2021.*

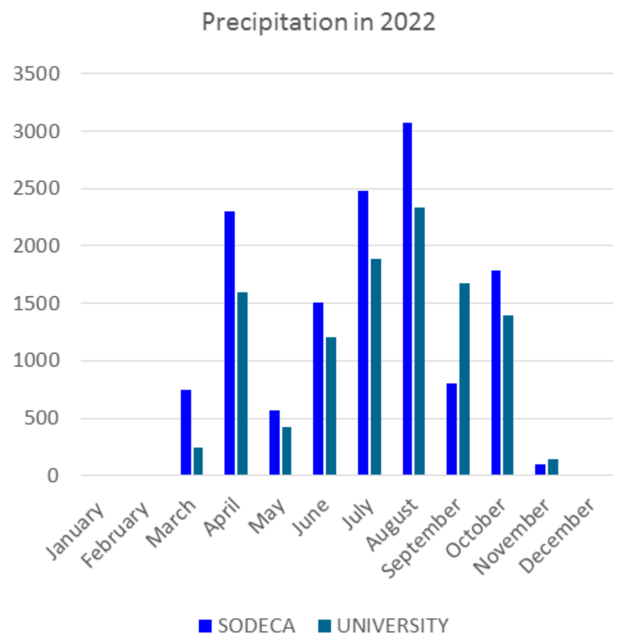


*Figure 6. Precipitation levels in 2022.*

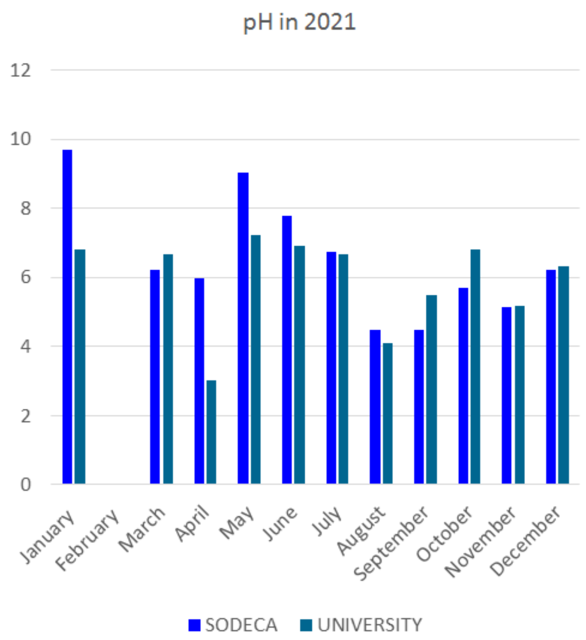


*Figure 7. pH measurement in 2021.*

This is rainwater that reaches the ground in liquid form, i.e. rain or dew, resulting directly from the condensation of atmospheric water vapour.

In this work, carried out in 2021, levels vary from 101 to 2,720 mm at both sites, with an annual average of 1,005.86 mm and one month of no rainfall throughout the year. In 2022, on the other hand, they range from 100 mm to 3,068 mm, with an annual average of 1,348.39 mm and three months with no rainfall. SODECA, located on the hill, is subject to heavy rainfall. This constitutes a natural obstacle to air circulation, which condenses into clouds, developing rapidly along slopes and hillsides, due to the effect of altitude and plant evapotranspiration [11, 14].

### 3.3. PH Measurements at the Two Sites During 2021-2022

The results of pH measurements at the University of Bangui and SODECA sites in 2021 and 2022 are shown in Figures 7 and 8 respectively.

In our 2021 work, pH ranges from 4.1 to 9.7, with an annual average of 6.21, reflecting the absence of precipitation in February. In 2022, on the other hand, it ranges from 4.48 to 8.19, with an average of 6.91, reflecting the acidic nature of the rainwater.

The rise in pH values in May, giving basic pH values for both years, is explained by the return of precipitation [24].

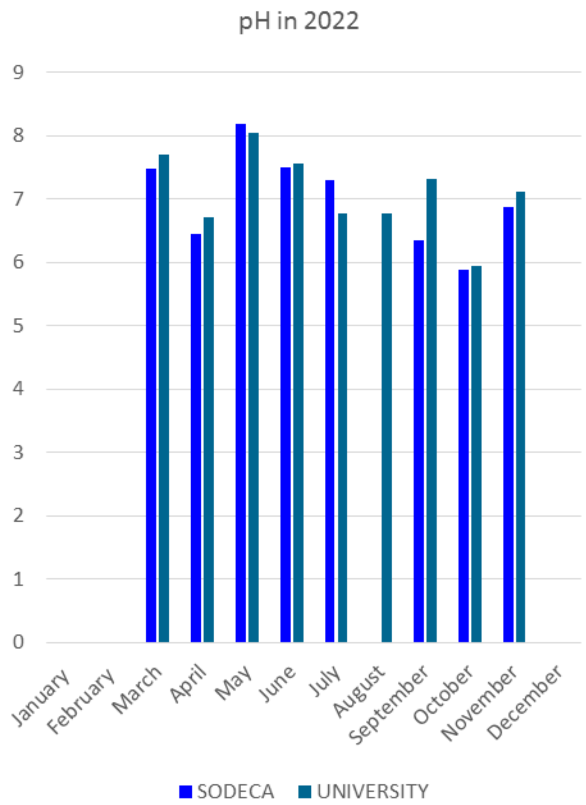


*Figure 8. pH measurement in 2022.*

### 3.4. Conductivity Measurements at the Two Sites in 2021 and 2022

Figures 9 and 10 respectively show the results of conductivity measurements at the two sites of Bangui University and SODECA for the years 2021 and 2022.

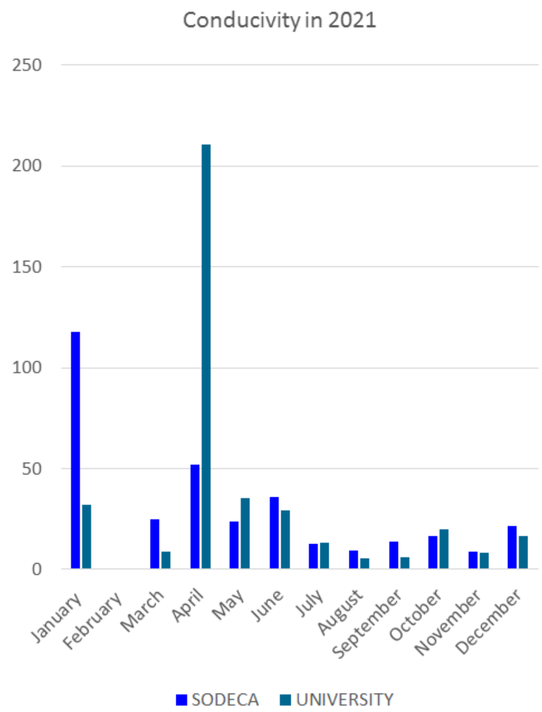


*Figure 9. Conductivity measurement in 2021.*

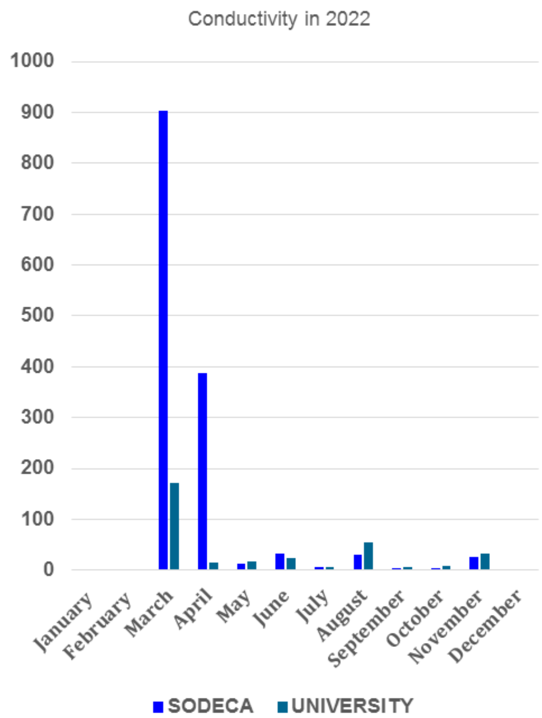


*Figure 10. Conductivity measurement in 2022.*

In 2021, electrical conductivity varies from 5.26 to 210.6 µS/cm at both sites, with an annual average of 6.21 µS/cm. In 2022, on the other hand, its annual variation is from 1.5 to 903 µS/cm, with an annual average of 96.49 µS/cm, due to three months of no rainfall.

The low conductivity reflects the absence of minerals, but the water remains conductive because it is acidic [23], containing carbonic acid in solution from the dissolution of carbon dioxide in the air, which reinforces its ionic composition and pH [12].

The more it rains, the lower the conductivity. The average conductivity values for the two years at the SODECA station are relatively higher than those at the Bangui University station.

### 3.5. Temperature Measurements at the Two Sites in the Years 2021-2022

The results of temperature measurements at the two sites of Bangui University and SODECA for the years 2021 and 2022 are shown in Figures 11 and 12 respectively.

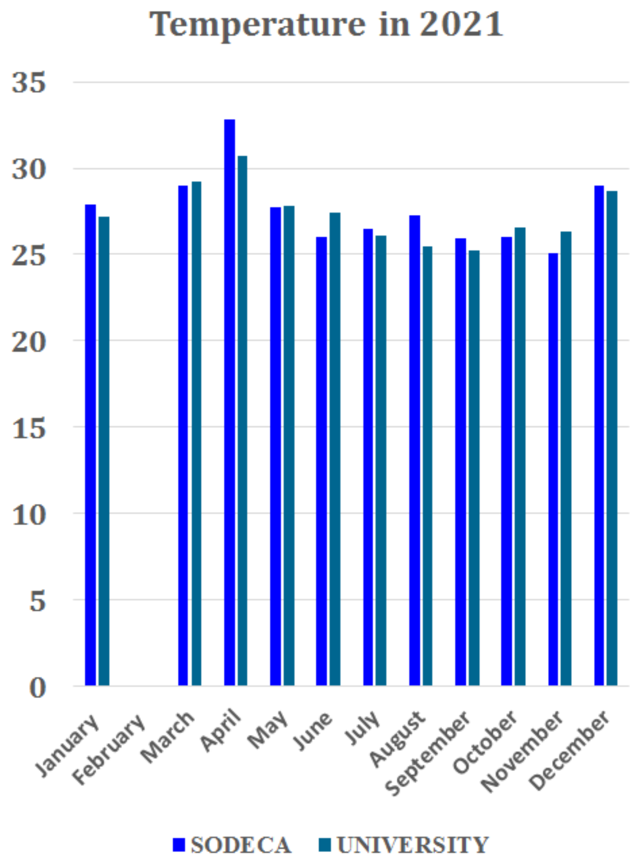


*Figure 11. Temperature measurement in 2021.*

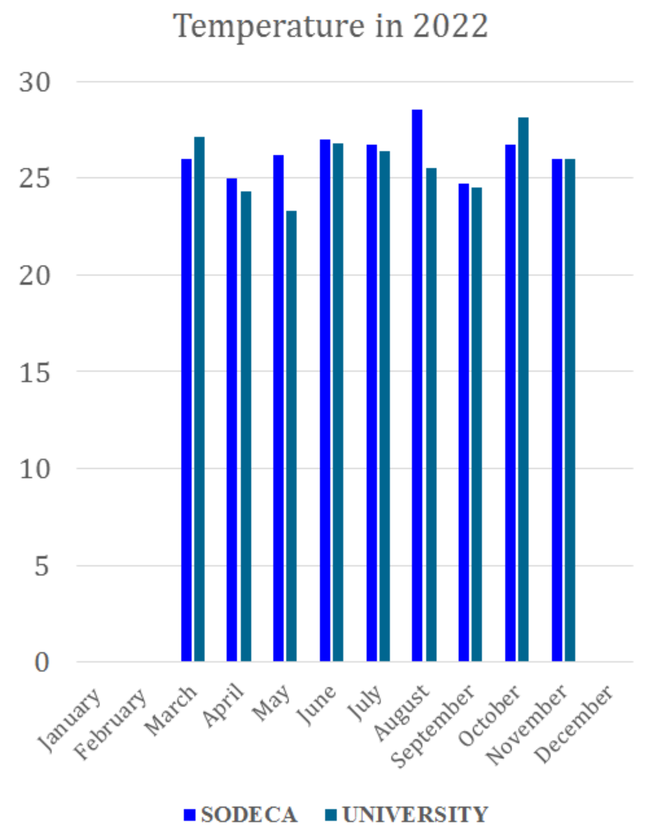


***Figure 12.*** *Temperature measurement in 2022.*

Temperature is the set of variable atmospheric conditions, subjectively translated into relative sensations of hot and cold, the exact assessment of which is provided by the thermometer.

In 2021, the water temperature will range from 25.1 to 32.8 ℃, with an annual average of 27.45 ℃, while in 2022 it will range from 23.3 to 28.1 ℃, with an average of 26.04 ℃, still within the 0-27 ℃ range for rainwater temperatures [28].

Precipitation shows a linear correlation with slope 8, characteristic of the condensation phenomenon which always occurs at saturation, i.e. at equilibrium [9, 18].

## 4. Relationship Between δ 18O and δ 2H

### 4.1. Relationship Between δ 18O and δ 2H at the Sodeca Station in 2021

Figure 13 shows the relationship δ(^(18)O/^(2)H) = f(δ(^(18)O)) at the SODECA rainfall station in 2021.

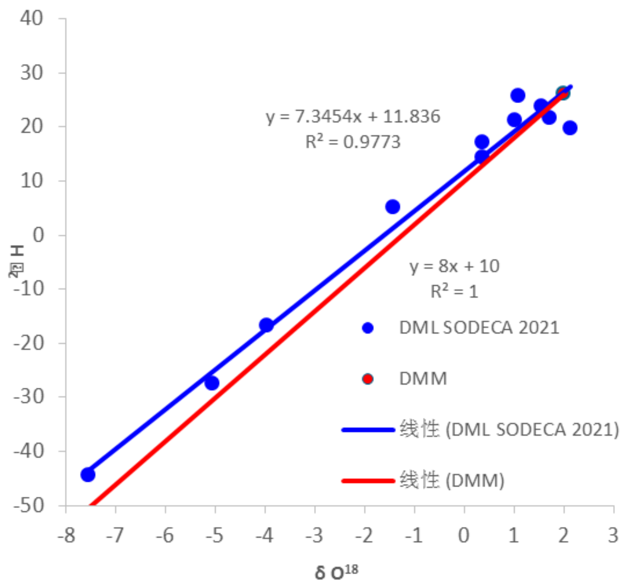


***Figure 13.*** *$\delta\ ^2H = f(\delta^{18}O)$ Relationship at the SODECA rainfall station in 2021.*

### 4.2. Relationship Between $\delta^{18}$O and $\delta\ ^2$H at the Université de Bangui Station in 2021

Figure 14 shows the relationship $\delta\ ^2H = f(\delta^{18}O)$ at the University of Bangui rainfall station in 2021.

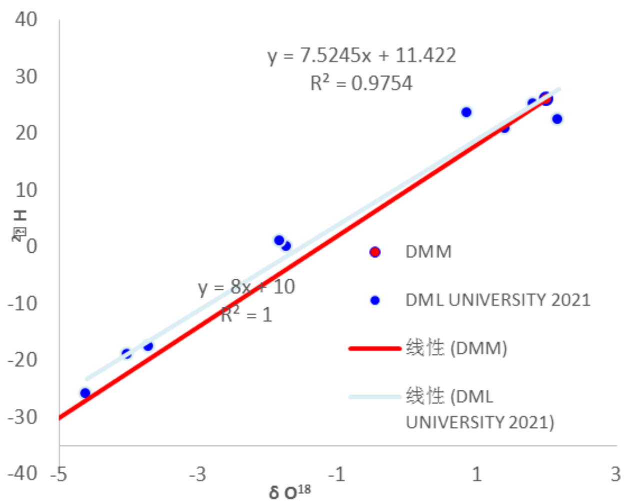


***Figure 14.*** *$\delta\ ^2H = f(\delta^{18}O)$ Relationship at the University rainfall station in 2021.*

### 4.3. Relationship Between δ $^{18}$O and δ $^2$H at the Sodeca Station in 2022

Figure 15 shows the relationship $\delta\ ^2H = f(\delta^{18}O)$ at the SODECA rainfall station in 2022.

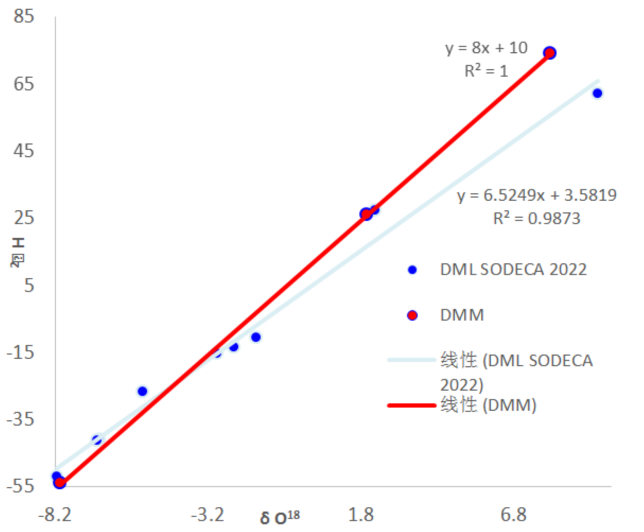


***Figure 15.*** *Relationship* $\delta^2H = f(\delta^{18}O)$ *at the SODECA rainfall station in 2022.*

### 4.4. Relationship Between $\delta^{18}$O and $\delta^2$H at the Universit é de Bangui Station in 2022

Figure 16 shows the relationship $\delta^2H = f(\delta^{18}O)$ at the University of Bangui rainfall station in 2022.

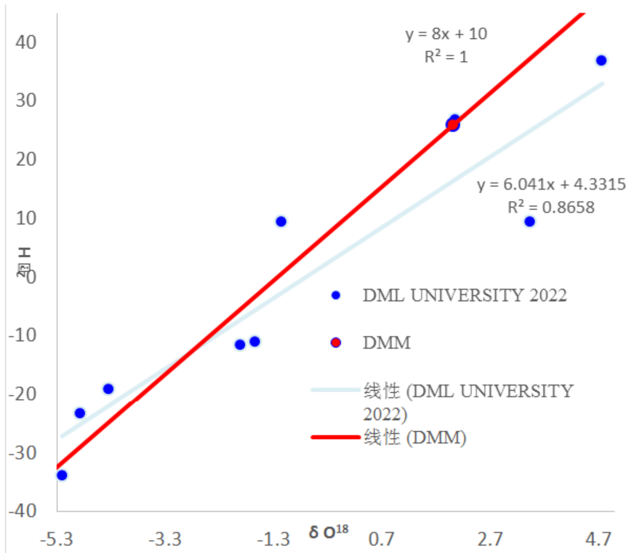


***Figure 16.*** *Relationship* $\delta^2H = f(\delta^{18}O)$ *at the University rainfall station in 2022.*

## 5. Discussion of DML Results

The 18O and 2H contents of monthly rainfall at the SODECA and Bangui University stations illustrate the variations in the rain signal over the seasons. Thirty-eight rain samples (twenty from SODECA and eighteen from Bangui University) were analyzed. The stable isotope content of the rainwater samples collected varied between:

-44.47 to +25.58 □²H ‰; -7.55 to +2.13 □¹⁸O ‰ (SODECA 2021);

-25.97 to +25.11 □2H ‰; -4.60 to +2.17 □18O ‰ (University 2021)

-51.96 to +62.16 □2H ‰; -8.13 to +9.56 □18O ‰ (SODECA 2022)

-33.63 to +36.95 □2H ‰; -5.21 to + 4.76 □18O ‰ (University 2022)

With enriched and impoverished values.

On the □18O versus □2H diagrams, the four figures 13, 14, 15 and 16, the points representing precipitation at each station lie either above or below the global meteoric line. The wide distribution of these points along this line is a sign of the great spatial and temporal variability of climatic parameters, which affect both the slope and the deuterium excess of local weather lines. Points above the MMD show that isotopic contents are linked to the altitudinal gradient and the regional context [21, 22]. However, at the SODECA station, the effect of temperature and vegetation cover on the condensation of cloud masses becomes predominant, leading to an enrichment of isotopic contents. The points below the MMD in the two Figures 15 and 16 for 2022 can be explained by the evaporation of these samples.

The relationship □2H vs □18O defines four regression lines with the following equations:

□2H = 7.35 18O + 11.84 (r2 = 0.98) for SODECA 2021 (figure 13);

□2H = 7.53 18O + 11.42 (r2 = 0.98) for the university, figure 14;

SODECA 2021: □2H = 7.35 18O + 11.84 (r2 = 0.98);

□2H = 6.04 18O + 4.33 (r2 = 0.87) for University 2022, Figure 16.

The correlations between deuterium isotopic composition and oxygen-18 obtained for these stations are close to the straight line of [13], characterizing the general mechanism of condensation and successive evaporation. The coefficients of determination of the local lines are generally close to 1, providing a posteriori proof of the validity of the technique used to measure monthly precipitation. The excess deuterium values (11.84; 11.42) obtained in 2021 are greater than 10 and show a variability that confirms the mixed origin of atmospheric vapour, as well as the enrichment of air masses of oceanic origin by water vapour of continental origin leaving the Gulf of Guinea, crossing the tropical forest where they recharge with water vapour, before precipitating over the Bangui region [7, 19].

The deuterium deficiency values (3.58; 4.33) obtained are below 10 in 2022, indicating considerable evaporation at these two stations in that year.

According to the values obtained, the waters most depleted in 18O and 2H are precipitated in the months of June, July, August, September and October, with high precipitation heights and lower contents, characteristic of countries affected by the monsoon. [18] and [6, 8] Under the influence of monsoon winds, stormier, 18O-depleted precipitation is generated. Precipitation between November. Precipitation from November to May is the most enriched, reflecting evaporation during rainfall at the beginning and end of the rainy season. The slope of the local curve is close to 8. The slight difference is due to measurement uncertainties and the sampling method. This indicates that evaporation of raindrops as they fall is not high, despite the enriched values recorded at the start of the rainy season and during the dry season. Air masses are thus recycled with evaporated water [17, 19].

### 5.1. Variation of $\delta^{18}O$ as a Function of Rainfall in 2021

Figures 17 and 18 respectively illustrate the evolution of the variable $\delta^{18}O$ as a function of rainfall recorded in the years 2021 at the rainfall stations of Bangui University and SODECA.

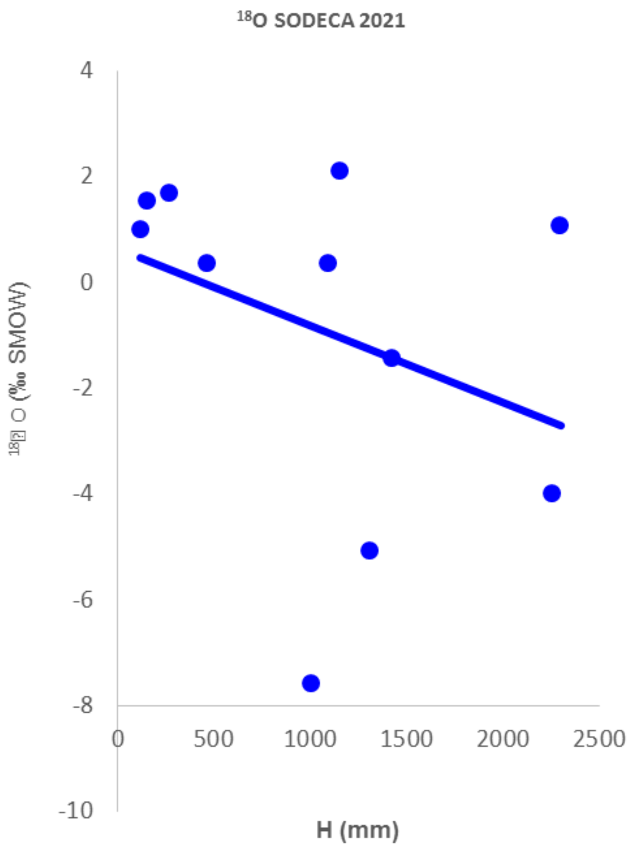


*Figure 17. Variation$\delta^{18}O = f[H(mm)]$ in 2021 at the SODECA station.*

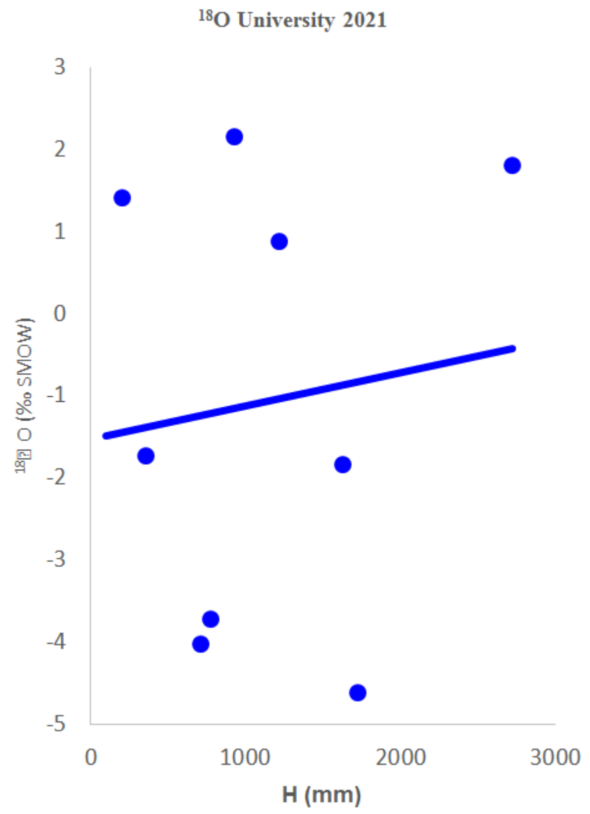


*Figure 18. Variation $\delta^{18}O = f[H(mm)]$ in 2021 at Bangui. University Station.*

### 5.2. Variation of $\delta^{2}H$ as a Function of Rainfall in 2021

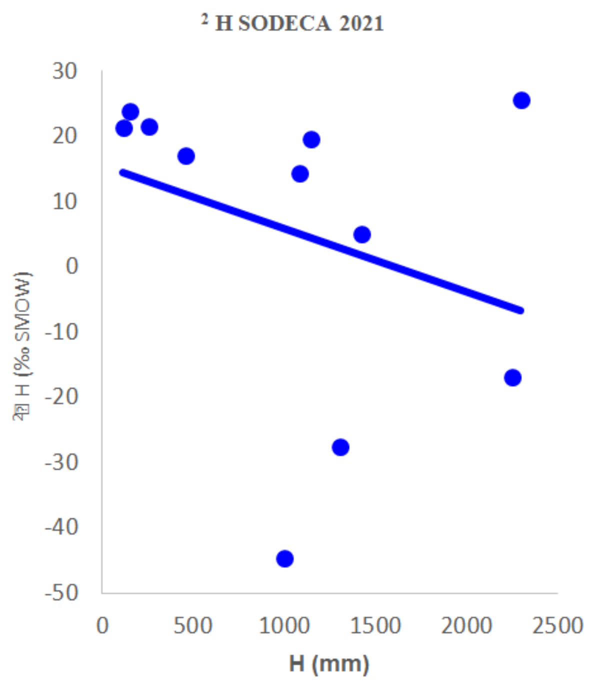


*Figure 19. Variation $\delta^{18}O = f[H(mm)]$ in 2021 at SODECA Station.*

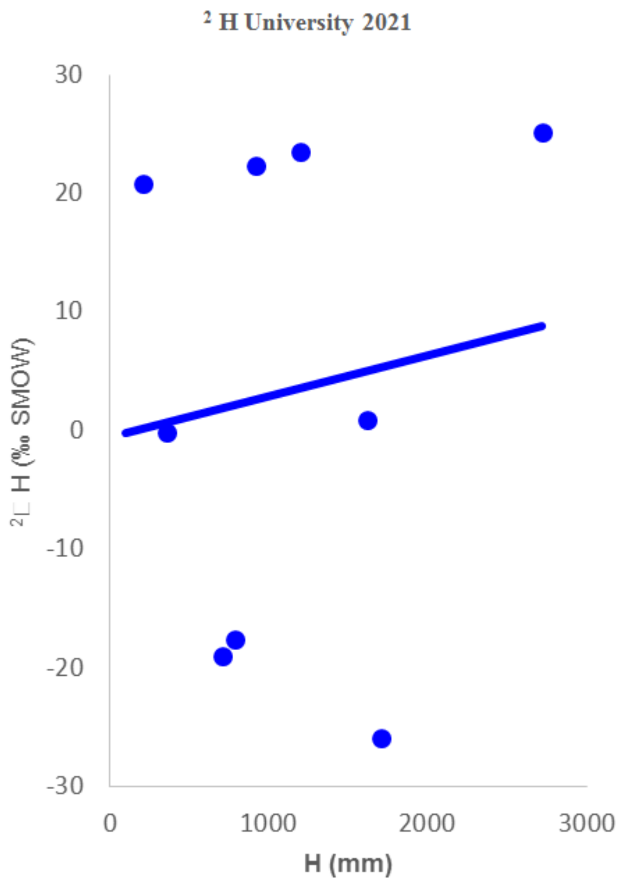


*Figure 20. Variation* $\delta^{18}O = f[H(mm)]$ *in 2021 at University Station.*

Figures 19 and 20 respectively illustrate variations in the quantity of $\delta^2H$ as a function of rainfall intensity during the years 2021, measured at the Bangui University and SODECA rainfall stations respectively.

## 5.3. Discussion of $\delta^2H$ and $\delta^{18}O$ Results as a Function of Rainfall in 2021

The two stations continue to show different trends:

(1) At the SODECA rainfall station, for small rains with heights ranging from 0 to 500 mm, isotopic contents are relatively large (positive values in the range +0.36 to +1.72 δ18O. Consequently, low-intensity rainfall is enriched in $\delta^2H$ and $\delta^{18}O$.

(2) At the Bangui University rainfall station, for rains ranging in intensity from 0 to 1,500 mm, isotopic contents are relatively low (negative values of -25.97 $\delta^2H$. Consequently, high-intensity rains are depleted in δ2H and δ18O.

## 5.4. Variation of δ18O as a Function of Rainfall in 2022

Figures 21 and 22 show, respectively, variations in δ18O as a function of rainfall intensity over the years 2022 at the rainfall stations of Bangui University and SODECA.

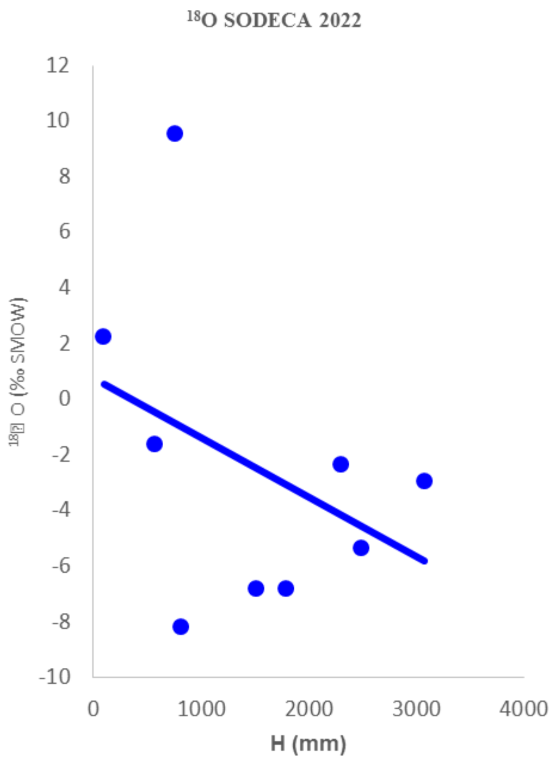


*Figure 21.* $\delta^{18}O = f[H(mm)]$ *variation in 2022 at SODECA Station.*

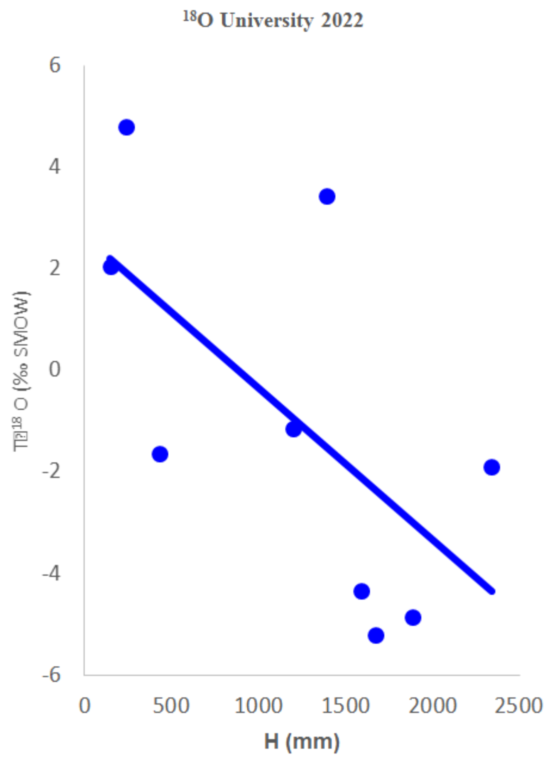


*Figure 22. Variation*$\delta^{18}O = f[H(mm)]$ *in 2022 at Bangui University Station.*

## 5.5. Variation of $\delta^2$H as a Function of Rainfall in 2022

Figures 23 and 24 respectively show $\delta\ ^2H$ variations in rainfall heights during 2022 at the University of Bangui and SODECA rainfall stations.

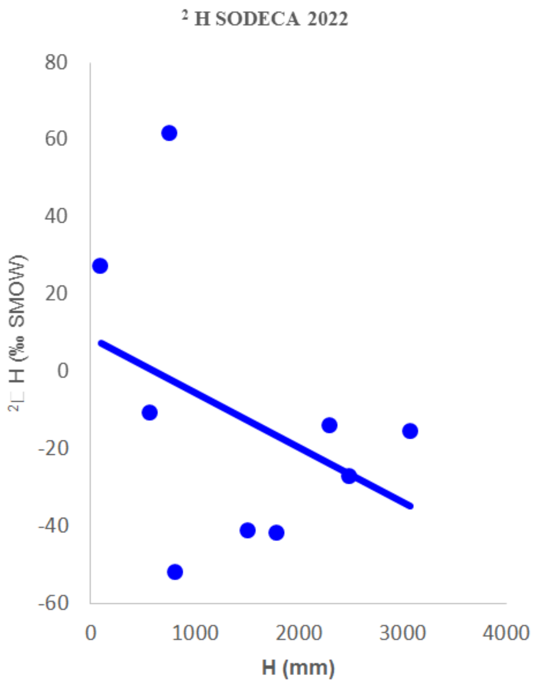


***Figure 23.*** *Variation* $\delta^{18}O = f[H(mm)]$ *in 2022 at SODECA Station.*

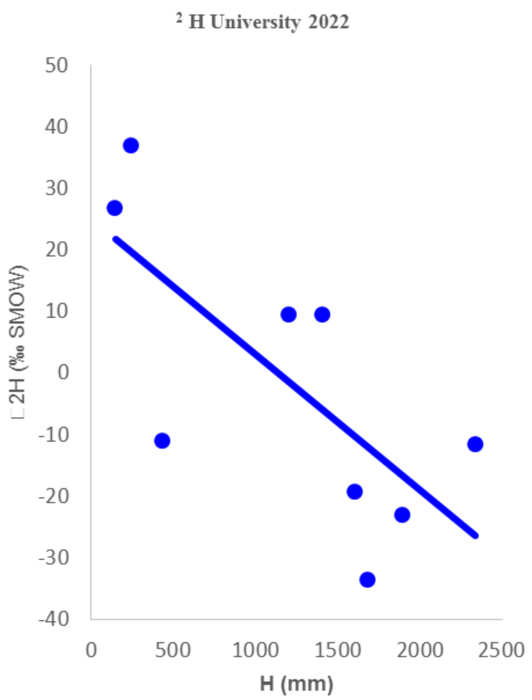


***Figure 24.*** *Variation* $\delta^{18}O = f[H(mm)]$ *in 2022 at Bangui University Station.*

## 5.6. Discussion of $\delta^2$H and $\delta^{18}$O Results as a Function of Rainfall in 2022

The two stations show similar trends:

1. At the SODECA rainfall station, for small rainfalls, i.e. with heights ranging from 0 to 500mm, isotopic contents are relatively high (positive values +62.16 $\delta\ ^2H$). Consequently, low-intensity rainfall is enriched in $\delta^2$H and $\delta^{18}$O;
2. At the Bangui University rainfall station, for rainfall ranging from 0 to 1,500mm, isotopic levels are relatively low (negative values of -33.63 $\delta\ ^2H$). Consequently, high intensity rainfall is depleted in $\delta^2$H and $\delta^{18}$O. [26, 28]

## 6. Conclusion

Isotopic methodology is particularly interesting in a tropical climate. However, this work is laborious, both experimentally and theoretically. The use of precipitation isotopes in the tropics is of great interest, given the current highly contrasting climatic conditions during the rainy season. Isotopes can be used to trace the history of a drop of water through its cycle, and to model the evaporation process directly and physically. Isotopic characterization of the input function has enabled local meteoric lines to be established for both sites for both years (2021-2022). These data provide a basis for comparison for future stable isotope studies in this region, and are of major interest in understanding the characteristics of recharge water over the whole basin. Variations with altitude, water mass and season are among the factors controlling isotopic composition at both sites. The isotopic composition of precipitation at a given station depends on the conditions under which rainfall is formed, notably temperature, but also rainfall.

In the course of this work, we were able to set up an isotopic abundance database of □$_2$H and □$_{18}$O for the Bangui area for the two successive years 2021 and 2022.

The equations of the four different local weather lines were calculated from the data obtained each year at the two sites:

□(2)H= 7.35 $^{18}$O + 11.84 ($r^2$=0.98) for SODECA 2021;

□(2)H= 7.53 $^{18}$O + 11.42 ($r^2$=0.98) for University 2021;

The deuterium excess at the 2 sites thus shows the mixed origin of atmospheric vapour and water vapour of continental origin.

□(2)H= 6.53 $^{18}$O + 3.58 ($r^2$=0.99) for SODECA 2022;

□(2)H= 6.04 $^{18}$O + 4.33 ($r^2$=0.87) for University 2022.

Climate change concerns us all. Isotope hydrology could find solutions to these problems if these studies were extended to the whole country over a sufficiently long period to enable the constitution of a large database predicting certain events linked to climatic upheavals.

## Abbreviations

| | |
|---|---|
| SODECA | Water Company |
| IAEA | International Atomic Energy Agency |
| CAR | Central African Republic |
| V-SMOW | Vienna - Standard Mean Ocean Water |
| DRC | Democratic Republic of Congo |
| GNIP | Global Network for Isotopes in Precipitation |

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## Ethical Approval

All ethical guidelines have been adhered.

## Author Contributions

**Loïc Baba:** Investigation, Writing - Original Draft

**Thierry Narcisse Kouagou Bangassi:** Methodology, Validation, Formal Analysis, Visualization, Supervision

**Eric Foto:** Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review and Editing, Visualization, Supervision, Project Administration

**Oscar Allahdin:** Formal Analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review and Editing, Visualization, Supervision, Project Administration

## Conflicts of Interest

The authors declare no conflicts of interest.

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