

Enhancing the Comprehension of the Groundwater Mineralization (Bekaa's Plain – Lebanon) by Using the Isotope ^{13}C

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Abstract- The stable isotope of the carbon atom (^{13}C) gives information about the type of the mineralization of the groundwater existing during the water seepage and about the recharge conditions of the groundwater. The concentration of the $\text{CO}_{2(\text{aq})}$ dissolved during the infiltration of the water through the soil's layers has effect on the mineralization of the water. The type of the photosynthesis's cycle (C-3 or C-4 carbon cycle) can play a very important role in determining the conditions (closed or open system) of the mineralization of groundwater. The isotope ^{13}C of the dissolved CO_2 in water gives us certain information about the origin and the area of pollution of water. The proportion of the biogenic carbon and its percentage in the mineralization of groundwater are determined by using the isotope ^{13}C .

Keywords- Isotopes; Carbon-13; Mineralization; Pollution; Bekaa; Lebanon

I. INTRODUCTION

Five (5) samples of the soil's gas were analyzed to know the isotopic content in ^{13}C of CO_2 of the soil's gas. The values vary between -22.25 and -17.22 for an average of -19.73 ± 1.63 PDB. The kind of the principal vegetal cover is of C-3 photosynthetic cycle (Calvin-Benson cycle). In the calculation of the groundwater ages, the ^{13}C isotopic content of the CO_2 of soil's gas has been fixed at -20 ‰ PDB. The isotopic content in ^{13}C of the geologic formations (aquifer) varies between -1.53 et +1.83. This isotopic content in $\delta^{13}\text{C}$ of the solid geological formations has been fixed at 0 ‰ PDB.

II. THE CARBON-13 OF THE TOTAL DISSOLVED INORGANIC CARBON

The isotopic content in ^{13}C of the TDIC (Total Dissolved Inorganic Carbon) varies between -12.96 and -5.04 for an average which is about -9.80 ± 1.97 ‰ PDB (Table I). From this value we can conclude that an intervention of the carbonated geological formations takes place in the water's mineralization. The dissolution of the carbonated aquifer by the groundwater is more intense in the Cenomanian than in the Jurassic formations, and it is same for the time of residence of the water in the aquifer.

TABLE I THE RESULTS OF THE STABLES ISOTOPES (^{13}C) ANALYSES

Site	Date	Reference	Type	$\delta^{13}\text{C}_{\text{TDIC}}$ (‰ PDB)	$\delta^{18}\text{O}_{\text{water}}$ (‰ PDB)	$\delta^{13}\text{C}_{\text{CO}_2(\text{eq})}$ (‰ PDB)	$\delta^{13}\text{C}_{(\text{gas of soil})}$ (‰ PDB)	$\delta^{13}\text{C}_{(\text{aquifer})}$ (‰ PDB)
Mount-Lebanon								
Jdita	05/04/2003	C1	Well	-11.08	-4.95	-19.95	-	1.83
Kefrayia	17/04/2004	D1	Well	-12.14	-6.71	-12.62	-	-
Kefrayia	17/04/2004	Wadi el jaouz (S18)	Spring	-7.81	-6.72	-8.32	-	-
Nabi eila	07/04/2003	C4	Well	-9.75	-4.35	-18.27	-17.61	-
Wadi el karm	10/04/2003	A6	Well	-6.41	-6.05	-15.33	-19.20	1.76
Ammick	17/04/2004	D2	Well	-12.68	-5.68	-20.44	-	-
El Mansoura	17/04/2004	D4	Well	-10.01	-7.87	-10.63	-20.57	-
Hermel	09/04/2003	S6	A ñ el zarqa spring	-5.07	-7.97	-13.72	-17.22	-
Hermel	10/04/2003	S8	Ras el mal spring	-5.04	-8.75	-14.21	-	-
Laboue	09/04/2003	S10	El Laboue spring	-9.71	-7.17	-18.43	-	-
Maqne	12/04/2003	B3	Well	-9.70	-6.50	-18.19	-	-
Qasr- Hermel	27/04/2003	S11	Ebbish spring	-	-	-	-22.25	-
Rayack	05/04/2003	C5	Well	-11.08	-4.88	-19.51	-	-
Zabboud	09/04/2003	A8	Well	-11.73	-5.57	-20.01	-	-

Anti-Lebanon								
A fa el Foukhar	19/04/2004	D9	Well	-6.14	-4.10	-15.04	-	-
A fa el Foukhar	19/04/2004	Al Arich (S26)	Spring	-10.25	-6.55	-18.23	-	-
Al Dakoui	17/04/2004	D7	Well	-12.96	-5.44	-12.76	-	-1.53
Bakka	18/04/2004	D8	Well	-12.68	-5.63	-20.42	-	1.79
El khedr	05/04/2003	C10	Well	-6.50	-7.91	-14.67	-	-
Haloua	19/04/2004	D10	Well	-11.62	-5.15	-19.99	-	-
Mdoukha	19/04/2004	D6	Well	-12.93	-5.59	-20.98	-	-
Nabi Chit	05/04/2003	C8	Well	-10.51	-5.72	-19.15	-	-
Orsal	09/04/2003	A9	Well	-8.42	-6.59	-16.63	-	-
Younin	12/04/2003	B6	Well	-9.97	-5.88	-18.66	-	-
Younin	14/04/2003	B5	Well	-11.70	-6.57	-19.75	-	-

III. ORIGIN OF THE MINERALISATION AND CLOSED OR OPEN SYSTEM

An intervention for the biogenic carbon exists in the ^{13}C isotopic content of the recharging water (kind of the photosynthetic cycle is C-3); the infiltration of the evaporated superficial irrigation's water plays an important role in the mineralization. The study of $\delta^{13}\text{C}_{\text{CT}} \text{‰ PDB}$ vs. pH indicates the increase of the isotopic signature with the pH (Fig. 1). This increase is explained by the dissolution of the carbonated aquifer and its essential role in the mineralization of the water.

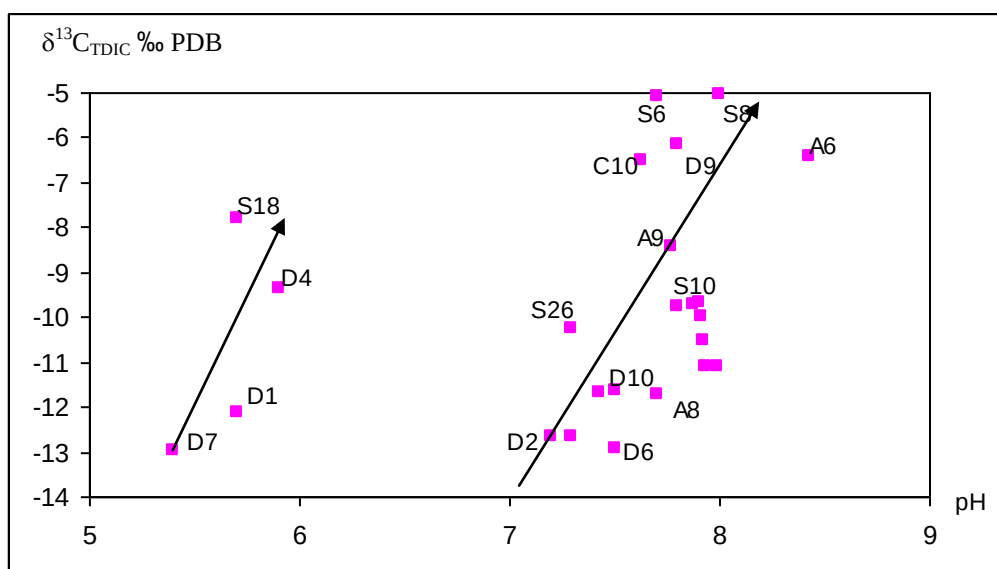
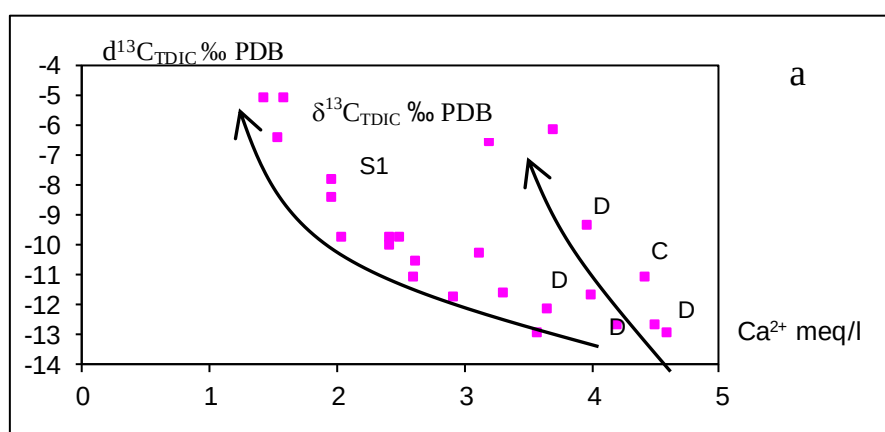
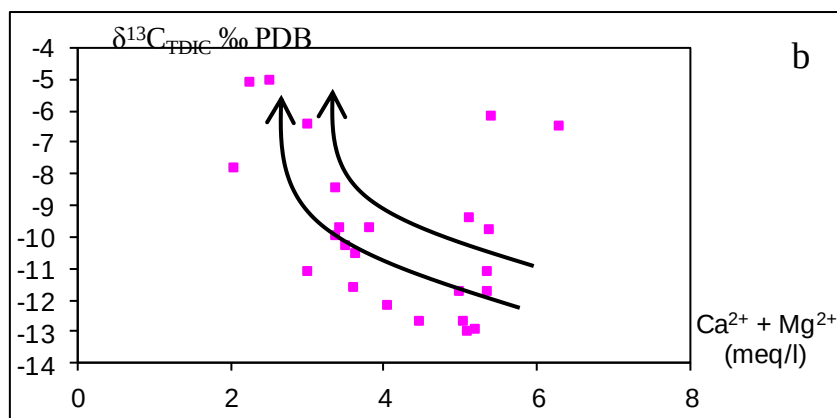


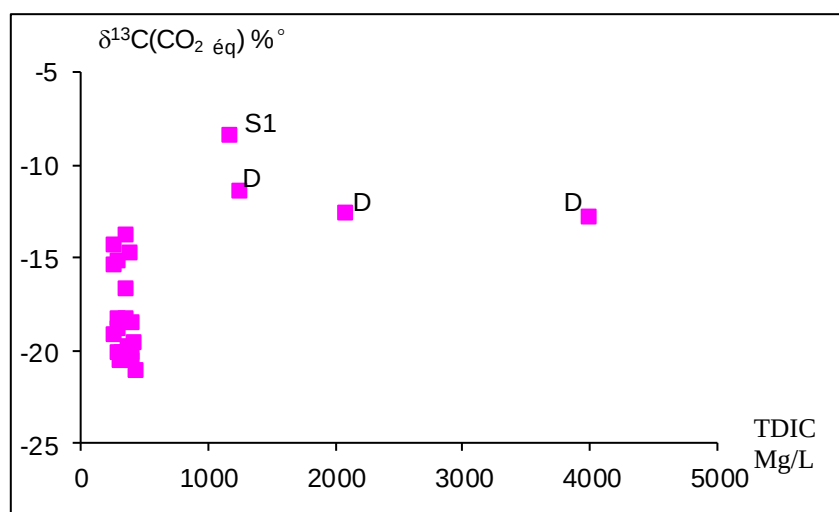
Fig. 1 The intervention of the aquifer in the mineralization of the water to obtain the saturation in calcite

The graph below (Fig. 2) confirms a mineralization of the water in an open system to the atmosphere ($\text{CO}_{2(\text{g})}$). For the old water, the dissolution of the aquifer's rocks plays an important role in the mineralization of water. For the relatively younger water, the biogenic carbon plays the essential role in the mineralization.



Fig. 2 (a and b) The mineralization due to the essential role of the biogenic CO₂

A mixing between the younger superficial irrigation water and the deep water containing juvenile CO₂ exists. The study of the $\delta^{13}\text{C}_{(\text{CO}_2 \text{ eq.})}$ ‰ PDB vs. the TDIC (mg/L) indicates that the water which has the highest contents in TDIC is the same water which has the highest isotopic content in carbon-13 (Fig. 3). This younger water corresponds to the water which reserves the $\delta^{13}\text{C}$ of the atmospheric CO₂ and has the highest content in H₂CO₃ regarding their weak pH.

Fig. 3 The H₂CO₃ is the dominant carbonated form in the very younger water

At the saturation phase towards the calcium, an incongruent dissolution exists. This re-precipitation phenomenon of the calcium asks a long residence time of waters in the aquifers (oldest water). This long residence time is explained by the increase in $\delta^{13}\text{C}_{\text{TDIC}}$ ‰ PDB with the increase of the rate of Mg²⁺/Ca²⁺ (Fig. 4).

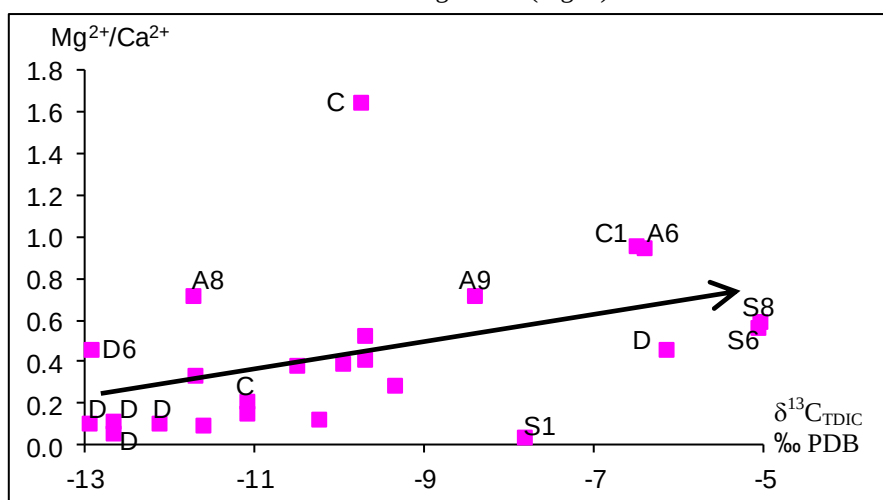


Fig. 4 The incongruent dissolution at saturation towards the calcium

IV. CONCLUSION

Regarding the isotopic content in Carbon-13, the origin of the water's mineralization comes from:

- 1) the dissolution of the atmospheric CO₂,
- 2) the intervention of the biogenic Carbon,
- 3) the dissolution of the carbon existing in the carbonated aquifer,
- 4) the presence of the juvenile CO₂.

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