

Research Article

Impact Assessment of Phosphogypsum Leachate on Groundwater of Sfax-Agareb (Southeast of Tunisia): Using Geochemical and Isotopic Investigation

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The production of phosphoric acid by the Tunisian Chemical Group, in Sfax, Tunisia, led to the degradation of the groundwater quality of the Sfax-Agareb aquifer mainly by the phosphogypsum leachates infiltration. Spatiotemporal monitoring of the quality of groundwater was carried out by performing bimonthly sampling between October 2013 and October 2014. Samples culled in the current study were subject to physicochemical parameters measurements and analysis of the major elements, orthophosphates, fluorine, trace metals, and stable isotopes (^{18}O , ^2H). The obtained results show that the phosphogypsum leachates infiltration has a major effect on the downstream part of the aquifer, where the highest values of conductivity, SO_4^{2-} , Ortho-P, and F^- , and the lowest pH were recorded. In addition, these results indicated that phosphogypsum leachates contained much higher amount of Cr, Cd, Zn, Cu, Fe, and Al compared to the groundwater. Spatiotemporal variation of the conductivity and concentrations of major elements is linked to the phosphogypsum leachates infiltration as well as to a wide range of factors such as the natural conditions of feeding and the water residence time. Contents of ^{18}O and ^2H showed that the water of the Sfax-Agareb aquifer undergoes a large scale evaporation process originated from recent rainfall.

1. Introduction

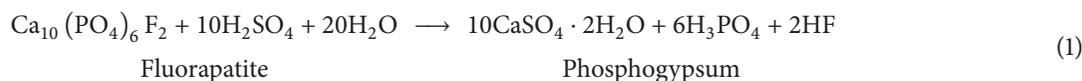
Groundwater pollution proves to be potentially threatening as it puts at jeopardy the hygienic integrity of a huge water reserve. The intensification of industrial activities, as well as the diversification of the storage modes of by-products production, makes groundwater resources vulnerable and can be considered as the main factors responsible for groundwater pollution. The groundwater quality is equally important as its quantity to the suitability of water for various purposes [1]. Variation of groundwater quality in different regions is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities [2]. Groundwater resources of the Mediterranean coastal plains in the southern bank of the basin (Middle East and North Africa) show a qualitative and quantitative deterioration developing in time [3–5] resulting in natural constraints and anthropological activities.

In Tunisia, climatic constraints, with a moderate rainfall contribution, which are unequally distributed in the space and irregular in time, as well as a strong evaporation power, make water resources limited. Socioeconomic development and the spread of industrialization have led to pressuring the resources and increasing the demand. Thus, the water supply, estimated at $472 \text{ m}^3/\text{inhabitant}$ in 2010, will decrease to $315 \text{ m}^3/\text{inhabitant}$ in 20 years [6]. In addition, water pollution related to the increased water use, urban and industrial areas, and agricultural intensification is increasingly threatening both the quality and the amount of groundwater resources. This phenomenon's implications are felt in the satisfaction of water demand as well as water cost.

Urban, industrial, and tourist centers have been developing along the eastern coast of Tunisia. Several industries are located in Sfax area, especially those of the Tunisian Chemical Group (TCG) for the enrichment and transformation of natural phosphate. The TCG activity focuses primarily on

the chemical fertilizers and phosphoric acid production, by the fluorapatite transformation. This production model generates gaseous emissions, liquid discharges, and huge

amounts of phosphogypsum (PG), issued from the treatment of phosphate rock with sulfuric acid [7–14]. This chemical reaction is illustrated in the equation below:



The main environmental contamination associated with PG dump is fluoride, sulfate, calcium, phosphate, and trace elements or radionuclides movement into groundwater [7]. The scope of this study is to appreciate the PG leachates infiltration effect on the Sfax-Agareb aquifer and to identify the factors and the phenomena, which explain the spatial and the temporal variation of the groundwater quality's assessment parameters.

2. Description of the Study Area

The study area is situated in the coast of Sfax, where the TCG plant, a discharge of domestic waste, and a station of wastewater treatment are located (Figure 1). The study area is under the influence of the Mediterranean climate, relatively humid and temperate, with cold and rainy seasons, between December and March, and dry and hot seasons, between June and October. The average annual precipitation is around 250 mm [15]. The mean annual temperature is 20°C [16]. The outcropping geological formations (Figure 2) are composed of sandy clays rich in gypsum and silty sand [17], of Mio-Pliocene to lower Quaternary age [18]. The TCG site takes place in an area covered by recent alluvium, made up by sand and calcareous gypsum crusts. The Sfax-Agareb aquifer, in this case study, is constituted by two sandy levels, ranging from 2 to 5 m in terms of thickness (Figure 3), separated by clay and sandy layers [19]. This aquifer is recharged by meteoric water. Groundwater flow in the study area is Northwest to Southeast.

3. Materials and Methods

3.1. Groundwater Sampling and Analysis. Groundwater samples were culled bimonthly from ten piezometers in the phreatic aquifer of Sfax-Agareb, between October 2013 and October 2014 (Figure 1). Monitoring piezometers purging was accomplished by using a submersible pump. The purge was achieved when the pH and the electrical conductivity (EC) of the ground water have been stabilized. Samples taken were acidified using 0.1N HNO₃ and kept at 4°C until the analysis was thoroughly carried out aiming to optimize the accuracy of the obtained findings. The samples were analyzed for the following parameters, which include EC, pH, T, dissolved O₂, Cl⁻, SO₄²⁻, HCO₃⁻, Na⁺, K⁺, Mg²⁺, Ca²⁺, F⁻, and orthophosphates (Ortho-P). EC, pH, and dissolved oxygen were measured in the field using calibrated portable digital meters. Calcium, magnesium, sodium, and potassium were identified using atomic absorption spectrometer. Carbonate, bicarbonate, chloride, and sulfate were determined

by standard titration methods [21]. Orthophosphates were analyzed by absorption colorimeter [21] and fluoride ion concentrations were measured by specific electrode [21]. The accuracy of the chemical analysis was determined by calculating the ionic balance error, which was generally less than 5%. The trace elements were analyzed using inductivity coupled plasma-atomic emission spectrophotometer (ICP-AES). A summary of the physicochemical and chemical data of all the investigated groundwater during the period 2013-2014 is presented in Table 1. Stable isotope analysis of δ²H and δ¹⁸O was performed by cavity ring down spectrometry using a Picarro L2120 [22] at the laboratory of Applied Geology and Geo-Environment, Ibn Zohr University, Morocco.

3.2. Multivariate Statistical Analysis. The application of multivariate statistical analysis offers a clearer understanding of water quality and enables comparison of the different water samples [23] and making of correlations between chemical parameters and groundwater samples, respectively. The different elements combination (samples and parameters) is used in order to characterize the hydrogeochemical variation of the Sfax-Agareb aquifer, in the site of TCG, in order to predict the future of the PG leachate percolation as well as to assess the spatial variation of the groundwater chemical composition. In this study, only the principal component analysis (PCA) was carried. PCA of the experimental data has been performed using the Xlstat.

4. Results and Discussion

4.1. Characterization of PG Leachate. On global scale, 15% of the PG production is recycled while large quantities are stored in the factories vicinity, which are disposed mostly in big piles. They are located in coastal areas with phosphoric acid plants nearby, both as dry or wet staking and without treatment [24]. Since PG waste is generally transported and disposed as an aqueous slurry, dissolution/leaching of the chemical elements present in the PG can occur. Dissolved elements may be deposited in nearby soils or transferred to groundwater [25]. Thus, it is important to know the characteristics of leachate obtained from the PG waste dump. Table 2 lists the chemical composition of a typical sample of PG leachate sampling from the GCT site of Sfax. The leachate has a very low pH (1.3) and high concentrations of fluoride (3500 mg/L), orthophosphate H₂PO₄⁻ (6730 mg/L), and toxic elements (Cd, Cr, and Zn). For all the analyzed elements, the levels exceeded the Tunisian standard for liquid discharge (NT 106-002).

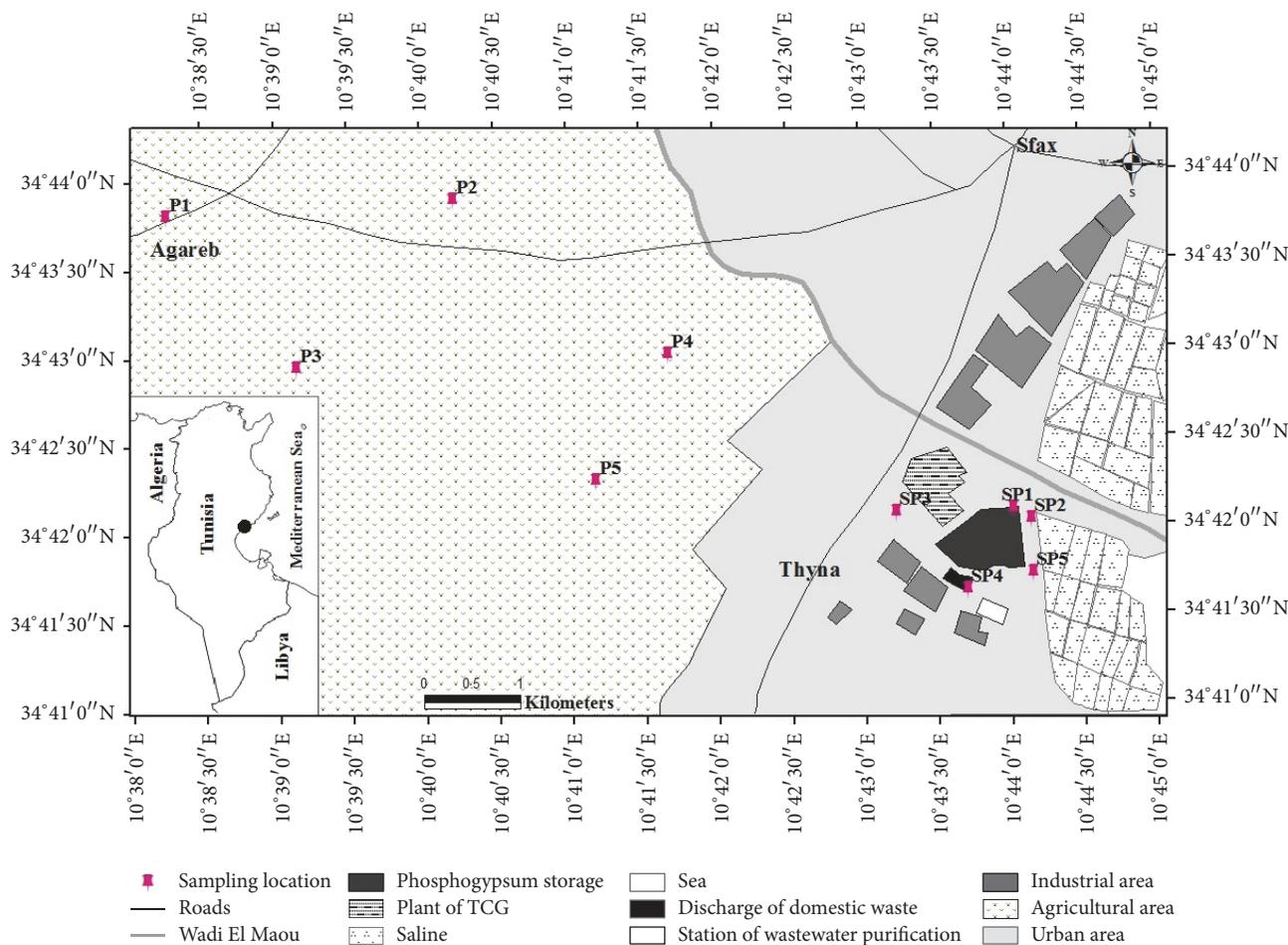


FIGURE 1: Location map of the study area showing piezometers and reference well sampled for groundwater analysis.

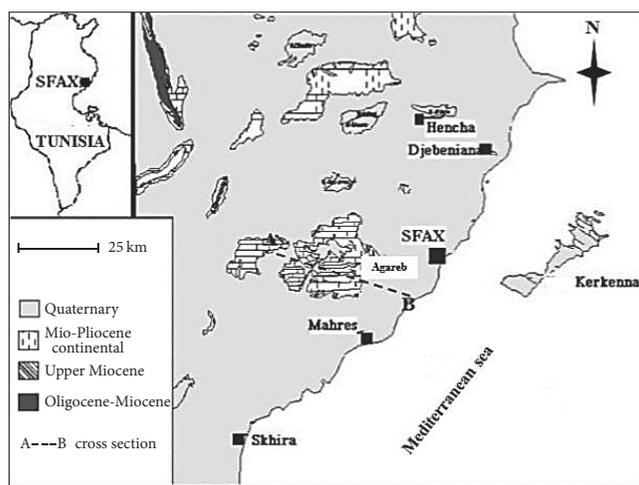


FIGURE 2: Geological map of Sfax [20].

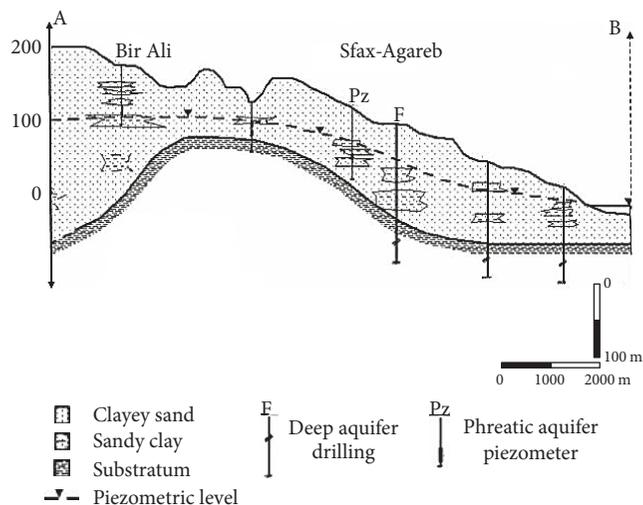


FIGURE 3: Hydrogeological cross-section along transect AB, as indicated in Figure 2 [19].

4.2. Groundwater Geochemical Characteristics and Evolution

4.2.1. *Physicochemical Parameters.* Groundwater temperature tends to vary from 10.1 to 13.9°C. The spatiotemporal variation of this parameter did not show any audible alternation during the whole period of testing (Figure 4(a)). The pH

values remain in the range of 5.18–7.95 as detailed. The lowest values were measured near PG storage site (SP1 and SP4), whereas in the upstream part of the study area (P1, P2, P3, P4, P5, and SP1) they were mainly neutral to slightly alkaline

TABLE 1: Chemical composition of groundwater samples

Months Parameters	Unit	Oct 13		Jan 14		Mar 14		May 14		Aug 14		Oct 14	
		Min	Max										
T	°C	12.1	13.9	10.1	12.8	11	11.7	11.10	12.20	12.2	13.2	12.00	13.1
pH	mg/L	5.18	7.74	5.75	8.1	5.58	7.95	5.56	7.85	5.2	7.79	5.50	7.76
O ₂ dissolved	mg/L	0.9	2.15	0.9	4.2	0.8	3.5	0.80	3.12	0.7	2.9	0.50	2.8
EC	μs/cm	2100	33200	1590	33000	1650	32600	1680	34300	1800	34700	1900	34900
K ⁺	mg/L	2.7	22.70	2.25	19	2.15	19.6	2.60	19.50	2.5	21.2	2.7	23.68
Na ⁺	mg/L	111.5	6965	139.4	6760	142	6300	115.16	6124	198	6600	195	6515
Ca ²⁺	mg/L	59	986	49	904	50	851	54.36	1075	51	1080	58	1020
Mg ²⁺	mg/L	37	945	22.5	920	24	940	29.75	1085	25	1050	35	1080
Cl ⁻	mg/L	110.6	5480	104.3	5396	101	5372.5	151	5475	135.5	5810	112	5632.5
HCO ₃ ⁻	mg/L	256.4	9143.9	195.2	9661.5	271	9533.9	199.20	8533.9	245	9313.9	255	9973
SO ₄ ²⁻	mg/L	215	4396.1	201.5	4295.7	204	4352.9	261.25	4543.7	210	4857.3	210	4948.5
Ortho-P	mg/L	2.15	67.3	2.5	81.7	2.7	71.00	1.90	136.65	1.5	92	1.25	114.95
F ⁻	mg/L	0.6	26	0.6	27	0.50	19.00	0.50	29.00	0.5	17	0.6	19
Al	mg/L	0.02	1.8	0.03	1.57	0.03	0.90	0.06	0.98	0.02	0.96	0.03	0.97
Zn	mg/L	0.03	1.46	0.02	1.41	0.02	1.44	0.03	1.47	0.04	1.51	0.03	1.05

(Figure 4(b)). The contents of dissolved O₂ fluctuate between 0.5 and 4.2 mg/L. The spatial distribution of these values shows an increase as we move further from the site of PG storage, in the direction of groundwater flow (Figure 4(c)). The temporal variation of this parameter depends on the control of the depth of the water table, the recharge rate, the transfer speed of oxygenated water from the upstream to the downstream, and the temperature. The electrical conductivity (EC) ranged from 1590 μs/cm to 34900 μs/cm at 25°C. The highest value characterizes sampled water in the southwest (SP4) and in the southeast (SP5) of the study area, whereas the lowest EC was the main feature of the P1, P2, and P3 piezometers (Figure 4(d)). This spatial variation in the flow direction of the phreatic aquifer (North-West to Southeast) is related to sea water intrusion and to the infiltration of both PG leachate and saline brines. The highest values are recorded during the dry season (May, August, and October), while the lowest values are recorded during the wet season (January and March). The temporal variation is due to the dilution effect with fresh water in the recharge areas during the wet season and the direct evaporation, during the dry season, in areas with low hydraulic gradient and poor permeability [26].

4.2.2. Origin and Geochemical Behavior of Major Elements.

Concentrations of SO₄²⁻, HCO₃⁻, and Ca²⁺ ranged from 201.5 to 4948.5 mg/L, from 195.2 to 9973 mg/L, and from 49 to 1080 mg/L, respectively. During the study period, the higher contents of HCO₃⁻ and Ca²⁺ were registered in SP4 piezometer, whereas the optimal concentrations of SO₄²⁻ were measured in SP5 piezometer, which is located in the east of the PG storage.

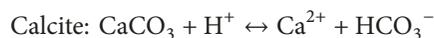
Understanding of the water-rock interaction and the associated reactions in the aquifer is essential to identify the variability of Ca²⁺, HCO₃⁻, and SO₄²⁻ concentrations. The calculation of ions activities and the appreciation of the saturation state with respect to calcite and gypsum help

TABLE 2: Chemical composition of PG leachate in May 2014.

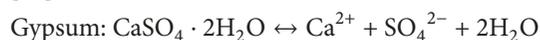
Parameters	Leachate PG	Tunisian standard for liquid discharge (NT 106-002)
EC	22700	
pH	1.3	6.5–8.5
F	3500	3
H ₂ PO ₄ ⁻	6730	0.05
Ca ²⁺	1357	500
SO ₄ ²⁻	3240	600
Mg ²⁺	198	200
Cl ⁻	1560	600
Na ⁺	2000	500
K ⁺	139	50
Cr	1.2	0.5
Cd	0.8	0.005
Zn	4	5
Al	4	5
Cu	0.5	0.5
Fe	6	1

Units in mg/L except pH and EC (μs/cm).

to assess the chemical composition of the groundwater and to identify the controlling geochemical reactions [27]. The flowing dissolution reactions ($T = 25^\circ\text{C}$ and $P = 1\text{ atm}$) are considered:



$$\log K_{\text{ps}} = \log a[\text{Ca}^{2+}] + \log a[\text{HCO}_3^-] + \text{pH} = 1.71 \quad [28]$$



$$\log K_{\text{ps}} = \log a[\text{Ca}^{2+}] + \log a[\text{SO}_4^{2-}] + 2 \log a[\text{H}_2\text{O}] = -4.61 \quad [29]$$

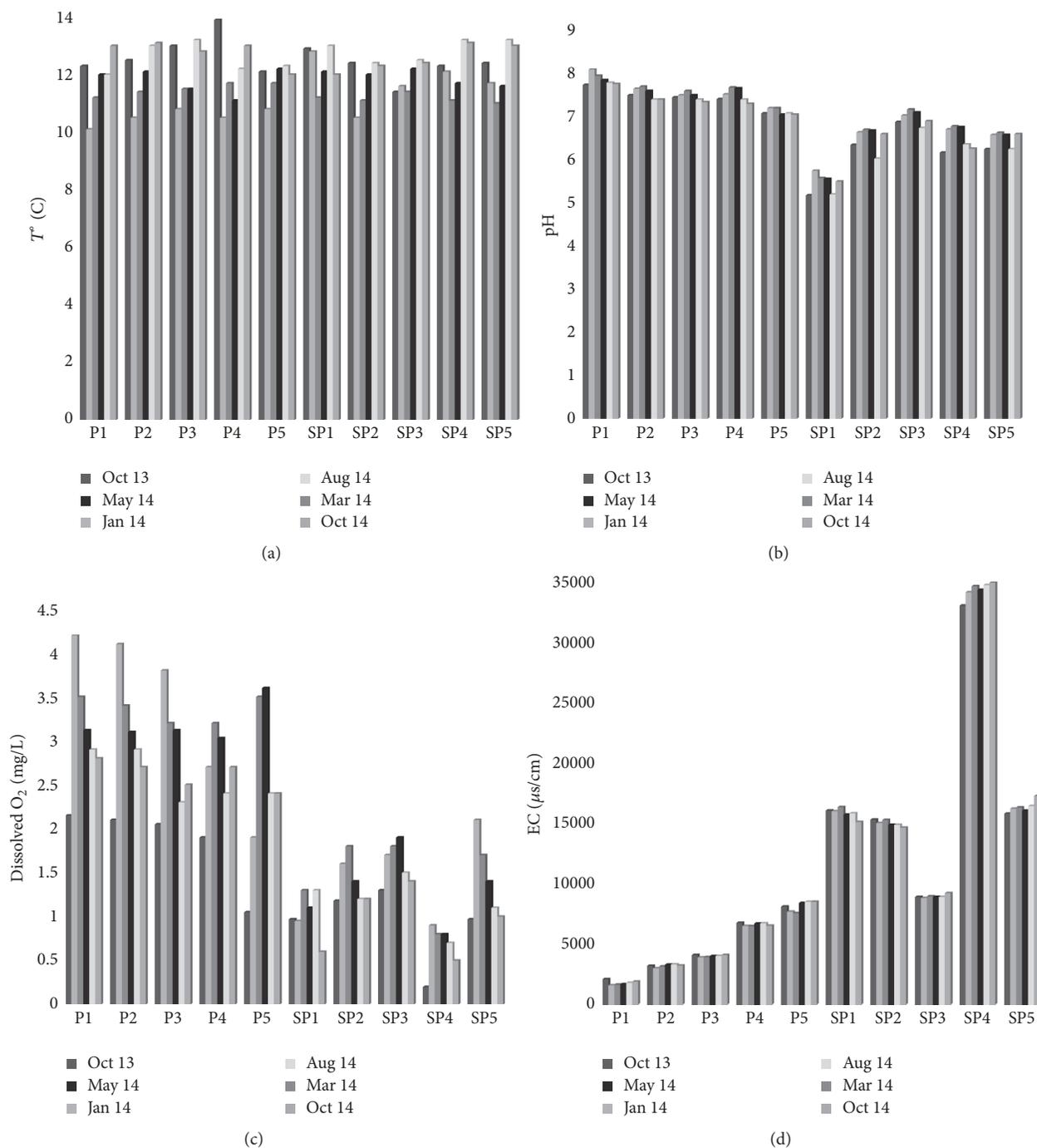


FIGURE 4: Distribution of temperature (a), pH (b), dissolved O_2 (c), and EC (d) in groundwater of Sfax-Agareb aquifer.

In order to calculate activities and ion activity product, the computer code PHREEQC [30] is used. The relation between the solubility product constant (K_{ps}) and the ion activities product (IAP) is given by the saturation index (SI) defined as

$$SI = \log \left(\frac{IAP}{K_{ps}} \right). \quad (2)$$

When $SI < 0$ water is considered undersaturated, whereas when $SI > 0$ water is considered oversaturated compared to the mineral.

The results show that the groundwater of the upstream zone of the phreatic aquifer (P1, P2, P3, P4, P5, and SP3) is undersaturated compared to gypsum (Figure 5), while, in the downstream zone, water with low pH (SP1, SP2, SP4, and SP5) is oversaturated. Compared to this mineral, the

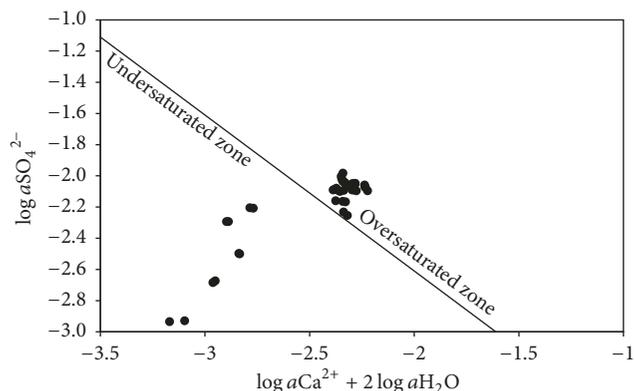


FIGURE 5: Equilibrium diagram of gypsum.

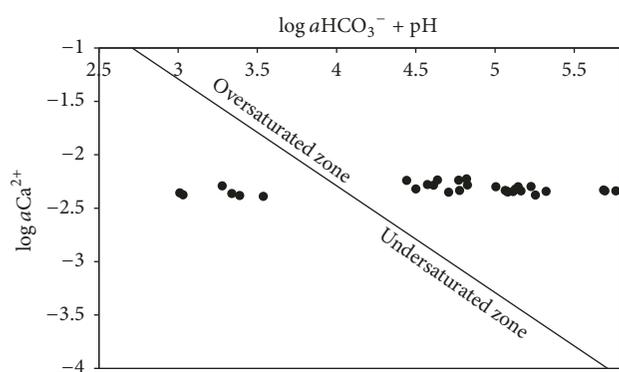
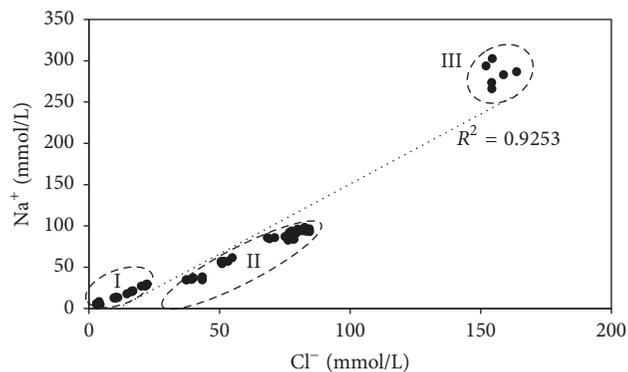
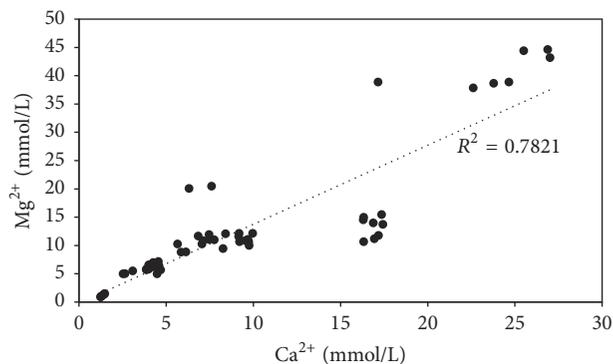


FIGURE 6: Equilibrium diagram of calcite.

groundwater oversaturation, in the TCG site, is explained by the acid PG leachate infiltration, which promotes the dissolution of gypsum and the complexation of Ca^{2+} and SO_4^{2-} ions. The equilibrium diagram Ca^{2+} - HCO_3^- (Figure 6) shows that groundwater, except for SP1 near the PG dump, is widely oversaturated compared to calcite. SP1 water is highly acidic, which prevents saturation with respect to calcite.

The sodium and chloride concentrations varied from 111.5 to 6965 mg/L and from 101 to 5810 mg/L, respectively. The Na^+ - Cl^- plot exhibits three water groups (Figure 7):

- (i) Group I: Na^+ and Cl^- contents are less than 50 mmol/L and 30 mmol/L, respectively. It concerns water of the upstream part of the study area (P1, P2, P3, and P4).
- (ii) Group II: Na^+ and Cl^- concentrations range from 50 to 120 mmol/L and from 30 to 100 mmol/L, respectively. This group encompasses water of the downstream zone, near the evaporation ponds (SP1, SP2, SP3, and SP5).
- (iii) Group III: Na^+ and Cl^- contents are greater than 250 mmol/L and 150 mmol/L, respectively. It includes water of SP4 piezometer, affected by the wastewater and the infiltration of PG leachate relatively rich in Na^+ and Cl^- (Table 2).

FIGURE 7: Plot of Na^+ against Cl^- .FIGURE 8: Plot of Ca^{2+} against Mg^{2+} .

The enrichment in Na^+ and Cl^- , from the upstream to the downstream, would be related to water-reservoir rock interaction, saline water infiltration from the evaporation ponds, and marine intrusion. During the study period, potassium concentrations are almost homogeneous at the same sampling location, with values ranging from 2.15 to 23.68 mg/L. The concentrations of Mg^{2+} , which fluctuate between 22.5 and 1085 mg/L, are positively correlated to Ca^{2+} contents, with a determination coefficient of 0.78, suggesting the same origin, which is the magnesian calcite dissolution (Figure 8). The highest values of the different majors elements are recorded during the dry season (October, August, and May), while the lowest values are recorded during the wet season (January and March). The slight variation is due to the dilution effect with fresh water in the recharge areas during the wet season and evaporation, during the dry season.

4.2.3. Orthophosphates and Fluorine Concentrations. Ortho-P and fluorine concentrations fluctuate between 1.5 and 136.65 mg/L and between 0.5 and 29 mg/L, respectively. Groundwater sampled near the PG discharge site showed high concentration levels of Ortho-P, which are larger in terms of extent and impact than those taken from the upstream part (Figure 9(a)). The highest levels of fluorine were measured in SP4 groundwater (Figure 9(b)). All shallow groundwater samples except P1, P2, and P3 contain $\text{F}^- > 1.5$ mg/L, which is the WHO drinking water standard. The

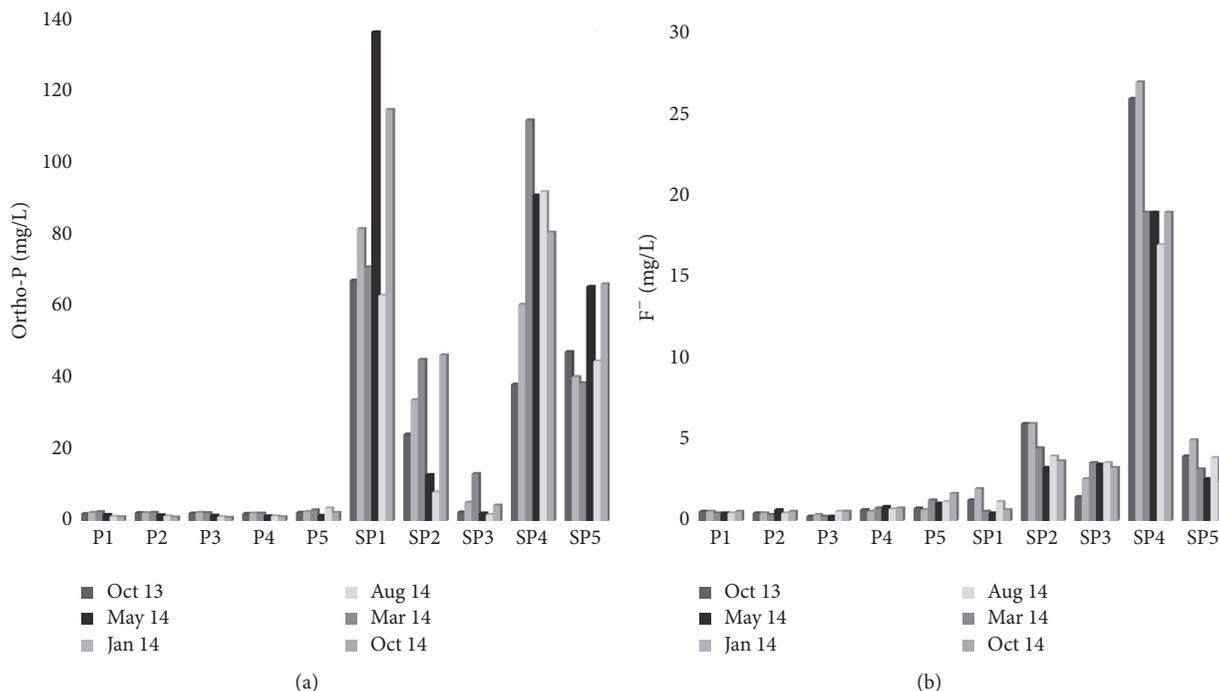


FIGURE 9: Distribution of orthophosphates (a) and fluoride (b) in Sfax-Agareb groundwater.

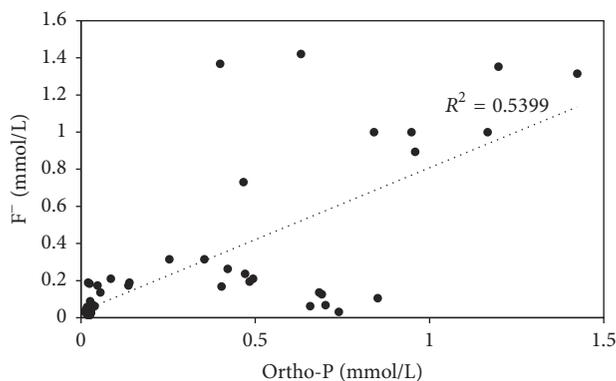


FIGURE 10: Plot of Ortho-P against fluoride.

spatial distribution of F⁻ and Ortho-P contents is related to the diffusion resulting from the flow direction of the aquifer as well as the chemical transformations of the PG leachates in the unsaturated zone. A significant temporal variation was recorded, due to the dilution during the recharging period. Plot of Ortho-P against fluoride (Figure 10) shows tremendous correlation, around the PG dump, suggesting that these elements originate from PG leachate, which are highly concentrated in Ortho-P and F⁻ (Table 2). On the other hand, groundwater of the upstream part does not show an evident correlation, which confirms the natural origin of these elements in this zone [31].

4.2.4. Trace Elements. The source of trace metals in the groundwater could be geogenic, but high concentrations

above the permissible limit of drinking water standards raise the suspicions of industrial contamination sources [32]. The concentrations of Zn and Al in the study area varied from 0.02 to 1.51 mg/L and from 0.02 to 1.8 mg/L, respectively. The higher contents of Zn were registered in SP4 piezometer, whereas the optimal concentrations of Al were measured in SP1 piezometer, which is located near the PG storage. For the majority of the sampled water, the Cr, Cd, and Cu contents do not exceed 0.05 mg/L. Low levels of trace elements noticed in the majority of the analyzed water, despite the gypsum water contamination, are linked to the purifying function of soils. The mechanisms that allow transforming charged surface water with dissolved, mineral, or organic matter into less charged water form the purifying functions of the soil [33].

4.3. Statistical Analysis. To discuss the relationships between the physicochemical parameters, major elements, Ortho-P, and fluoride in groundwater samples, PCA was used to distinguish the contributions of the natural and anthropogenic processes to the Sfax-Agareb aquifer, in the site of TCG.

Two independent factors were extracted, which explain 83.77% of the total variance. The first factor (F1) presents 72.34% of the total inertia. It is defined by EC and the Ca²⁺, Cl⁻, Na⁺, K⁺, Mg²⁺, HCO₃⁻, and SO₄²⁻ contents in a less important measurement by Ortho-P and F⁻. These elements contribute to the mineralization of the groundwater in TCG site. The second factor (F2) explains 11.43% of the total variance with a strong loading with pH and dissolved O₂ (Table 3). The spatial distribution of the variables (chemical parameters) and individuals (samples) in the axe systems F1-F2 shows the presence of two water groups (Figure 11).

TABLE 3: Summary of the PCA results including the loadings and the eigenvalues.

Variables	Axe F1	Axe F2
Na ⁺	0.9902	0.0400
Cl ⁻	0.9537	0.2568
K ⁺	0.9646	-0.0319
Ca ²⁺	0.9162	0.2195
SO ₄ ²⁻	0.7810	-0.3565
Mg ²⁺	0.8930	0.3142
HCO ₃ ²⁺	0.8782	0.4375
T°	0.1665	-0.3803
pH	-0.7253	0.6316
H ₂ PO ₄ ⁻	0.8026	-0.3231
F ⁻	0.8387	0.4741
Dissolved O ₂	-0.8304	0.3433
EC	0.9894	0.1067
Al	0.7383	-0.4214
Zn	0.9474	0.0343
Eigenvalues	10.8513	1.7147
% variance explained	72.3422	11.4312
% cumulative variance	72.3422	83.7734

TABLE 4: Isotopic and chloride composition of selected groundwater samples in October 2014.

	$\delta^{18}\text{O}$ (‰)	$\delta^2\text{H}$ (‰)	Cl ⁻ (mg/L)
P1	-5.97	-36.01	151
P2	-5.88	-35.98	356
P3	-5.64	-35.37	581
P4	-5.61	-35.22	776
P5	-5.57	-32.18	1739.5
SP1	-3.58	-26.80	2627
SP2	-4.12	-27.20	2130
SP3	-5.50	-34.47	745.5
SP4	-3.65	-26.10	5475
SP5	-4.10	-26.88	2094.5
Sfax rainwater	-4.60		10
Seawater	0.00		19000

The PCA confirm the different geochemical correlation and classification of the Sfax-Agareb groundwater, in TCG site, into two types: groundwater samples collected from the downstream part, which are influenced by the anthropogenic processes, largely controlled by the PG leachate percolation and the seawater intrusion. Samples collected from the upstream part of the study area were principally controlled by the natural recharge, with no evidence of high anthropogenic impacts.

4.4. Stable Isotopes (^{18}O , ^2H). The stable isotope composition of water in the study area varies from -5.97‰ to -3.58‰ V-SMOW for $\delta^{18}\text{O}$ and from -36.01‰ to 26.1‰ V-SMOW for $\delta^2\text{H}$. The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values (Table 4), plotted in Figure 12 in relation to the Global Meteoric Water Line

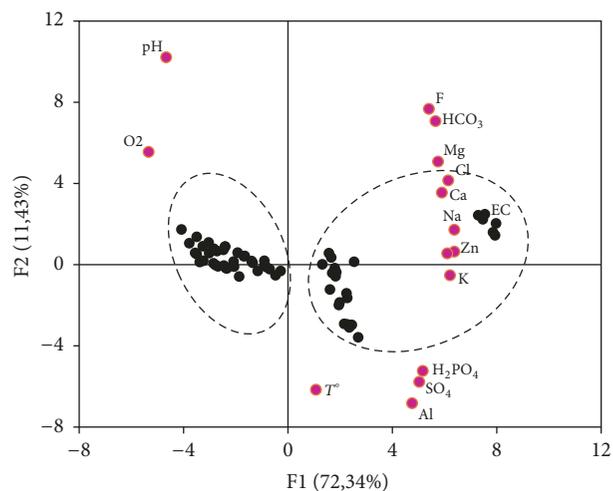


FIGURE 11: Spatial distribution of the variables and individuals in the axes system F.

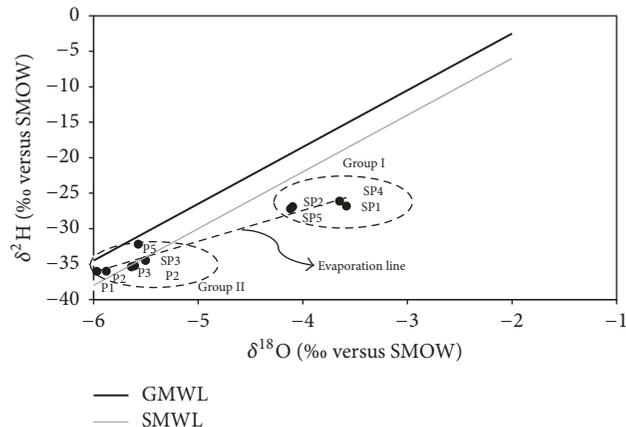


FIGURE 12: $\delta^2\text{H}$ - $\delta^{18}\text{O}$ relationship of Sfax-Agareb groundwater.

(GMWL: $\delta^2\text{H} = 8\delta^{18}\text{O} + 10$) [34] and the Regional Meteoric Water Line of Sfax, Tunisia (SMWL: $\delta^2\text{H} = 8\delta^{18}\text{O} + 13.5$) [35, 36], show that most of the groundwater samples are located below the GMWL and near the SMWL which indicates water evaporation in the unsaturated zone. Therefore, groundwater isotopic enrichment might be the outcome from evaporation of recent precipitation. This is facilitated by the sandy clay lithology of the unsaturated zone and the low depth of the piezometric level, which is less than 10 m. The stable isotope signature of groundwater, in the study area, has identified two groups (Figure 12):

Group I is generated by the most enriched water in isotopes: SP1, SP2, SP4, and SP5 in the downstream part of the water table.

Group II involves water characterized by the lowest levels of $\delta^{18}\text{O}$ and $\delta^2\text{H}$: P1, P2, P3, P4, and SP3 in the upstream part of the water table.

The $\delta^{18}\text{O}/\text{Cl}^-$ diagram [37] confirms the groundwater distribution into two groups (Figure 13), weakly or strongly

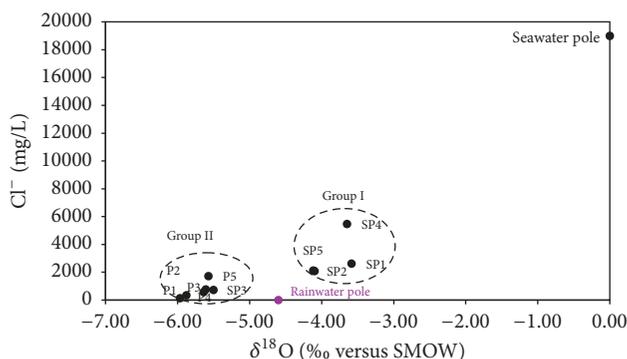


FIGURE 13: Cl^- - $\delta^{18}\text{O}$ relationship of Sfax-Agareb groundwater.

evaporated, which are distinguished by their chlorides and oxygen-18 contents. Indeed, the representative points of these two groups are located on either side of the rainwater pole, characterized by Cl^- and $\delta^{18}\text{O}$ contents, respectively, of 10 mg/L and 4, 6‰ V-SMOW.

The total dissolved solids of group I water, which are characterized by higher contents of Cl^- and $\delta^{18}\text{O}$ than those of rainwater, but lower than those of seawater, are related, in part, to evaporation.

5. Conclusion

The geochemical study of the major elements, Ortho-P, F^- , trace elements, and stable isotopes, elucidated the influence of PG leachates and laid emphasis upon the natural factors intervening in altering the groundwater chemistry of the Sfax-Agareb aquifer. Temporal variation was recorded due to dilution during the recharging period in winter. The groundwater mineralization is related to water-rock interaction processes, saline water, and PG leachates infiltration coupled with marine intrusion. Groundwater below the PG dump and in the downstream part of the aquifer showed the highest concentrations of Ortho-P, F^- , SO_4^{2-} , acidity, and total dissolved solids, which significantly exceed those relevant to the upstream water. Spatial distribution of these contents is presumably related to the diffusion that ensues the flow direction of the aquifer and the water-rock interaction. The groundwater quality is severely deteriorating in the downstream part of the Sfax-Agareb aquifer especially by Zn and Al. The stable isotope data attests that water of the Sfax-Agareb aquifer originated from recent rainwater has evaporated in the unsaturated zone. The result of this study will be helpful for a proper water development and for remediation of strategies to decrease the pollution source.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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