

## Evaluation of the physico-chemical and metallic pollution of groundwater around the Landfill and recovery Center of OumAzza (Rabat Region - Morocco).

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### Abstract

To reduce the impact of solid waste on the natural environment, in particular its effects on water resources, Morocco has made great efforts to manage them. Indeed, in the framework of the National program for household waste, about twenty controlled landfills or landfill and recovery center (CEV) have been built to mitigate the pollution and nuisance of existing wild dumps. However, these controlled landfills remain an alternative whose environmental impacts are difficult to control. Thus, the present work aims to evaluate possible impacts of the solid waste landfill and recovery center (CEV) of OumAzza (Rabat, Morocco) on the quality of the surrounding groundwater. The hydro-chemical quality of these waters intended for the supply of the rural populations of this region was studied through the spatio-temporal monitoring of a certain number of physicochemical and metallic parameters. Thirty-six samples were collected, analyzed and evaluated from nine wells in the four seasons of 2015. The results of this study show that the groundwater of certain wells near the CEV d'OumAzza are highly mineralized and contaminated. This diversified contamination is probably due to anthropogenic effects including organic, nitric and / or metallic

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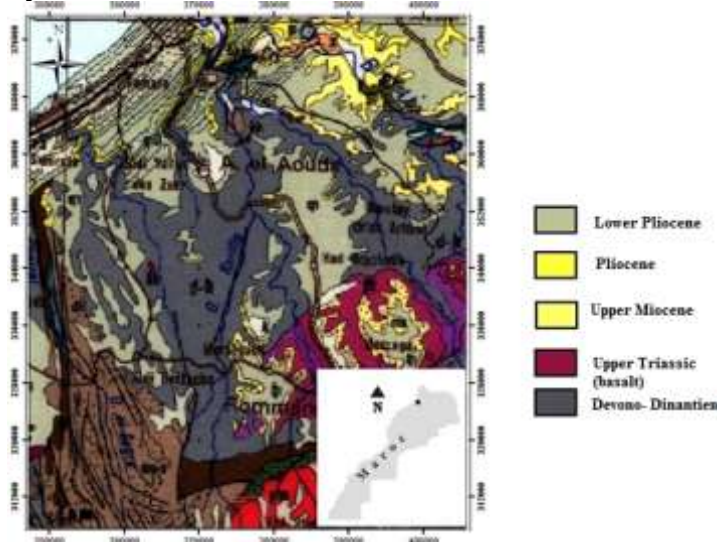
**Keywords:** Oum AZZA CEV, Groundwater, Hydrochemistry, Heavy metals, Mineralization.

## 1. Introduction

The solid household waste generation in Morocco currently reaches about 6 million tons per year with an average of nearly 250 kg / inhabitant / year according to the State Secretariat for Sustainable Development (SEDD). In fact, the waste impacts all the components of the natural environment particularly soil, air, surface and groundwater resources. About one third of the world's population uses groundwater for consumption [1]. Indeed, in Morocco, 70% of groundwater are a source of supply for the Moroccan population, according to the State Secretariat for Water (SEE). However, this resource confronts various problems, namely over-exploitation and degradation of its quality. This degradation is either natural due to geological formations, or anthropogenic caused by leachate infiltration generated by solid wastes, leaching of agricultural fertilizers and wastewater. In Morocco and all over the world, landfilling remains the solution and the most used mode for managing solid waste. Furthermore, the disposal of household waste in landfills is an option whose environmental impacts are difficult to control (leachate, risk of contamination of water resources and soils ...). The present work consists of studying and evaluating the potential impacts of the OumAzza landfill and waste recovery center (CEV) on the quality of the groundwater, sampled on the wells in the vicinity of the CEV. Whose waters are often used for human consumption, for livestock watering and for irrigation. To carry out this study, an approach based on the hydro chemical, statistical and multivariate analysis study, was exploited to treat the data of this investigation related to the hydro geochemical quality, physico-chemical, organic and metallic pollution of these waters.

## 2. Materials and methods

### 2.1. Description of the study area



**Figure 1.** simplified geological map of the studied area.

The township of OumAzzawhich belongs to the plateau of Ain Aouda (Rabat, Morocco), is attached to the field of the coastal Meseta. The most abundant rocks in the region are of Paleozoic age. The study area consists of schists, sandstones and limestones that are strongly tectonized and are uncomfortably surmounted by the Miocene marls and the Plio-Quaternary formations [2-3-4], in intercalations in shale Quartzite or sandstone benches meet [5] (Figure 1 et 2). On the hydro-geological level, an aquifer system is developed at the interface of the fractured and altered basement of the Neogene and Quaternary plateau formations. This free sheet of about 350 km<sup>2</sup> [6] flows in a SE-NW direction [7] is well defined hydrogeologically by the wadi Bouregreg in the North, Akrach in the East and Ykem in the South. The depth of the water table rises Southeast (between 3 and 10 m) to the northwest (greater than 30 m) [23]. The aquifer formation consists of sandstone limestones of the Plio-Quaternary. The bedrock consists of Paleozoic schists

in the southwest and Miocene marls in the north-east [5]. The climate is of semi-arid Mediterranean type with a mild, moderate and rainy maritime influence in winter, the annual rainfall amounts remain below 600mm [5]. In summer, it becomes humid and temperate with days of Chergui (hot wind blowing from the East).



**Figure 2.**synthetic stratigraphic column of the Akrach region, [8], [9].

## 2.2. Sampling

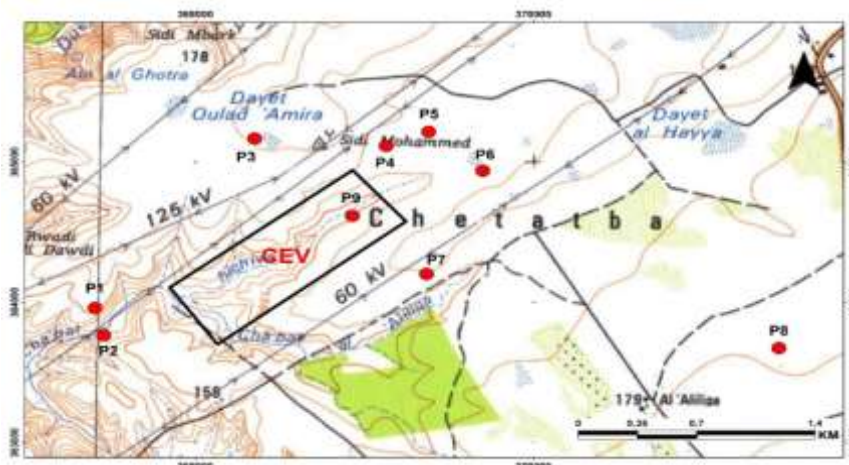
To characterize and evaluate the groundwater quality of the study area, four sampling campaigns were conducted in winter (C1), spring (C2), summer (C3) and autumn (C4) during the year 2015. A total of 36 well water samples were collected, in the vicinity of CEV OumAzza, over a radius of about 3 km. The choice of sampling points was made taking into account the geodetic locations of the wells, compared to the CEV and the direction of the groundwater flow (Figure3 et 4). The samples were taken manually in polyethylene bottles previously rinsed, stored and transported, in coolers at a temperature of 4 ° C, to the Laboratory for analysis. Measurements of temperature T °C, pH, dissolved oxygen (O<sub>2</sub>) and conductivity were made in situ using a multi-parameter probe, while physicochemical parameters were measured in the National Laboratory for Pollution Monitoring and Studies (LNESP) of the SEDD, according to standardized analysis methods (Table 1) and the metallic parameters at the Laboratory of the Technical Support Unit for Scientific Research (UATRS) under the National Technical Scientific Research Center (CNRST) all headquartered in Rabat.

## 2.3. Methodology

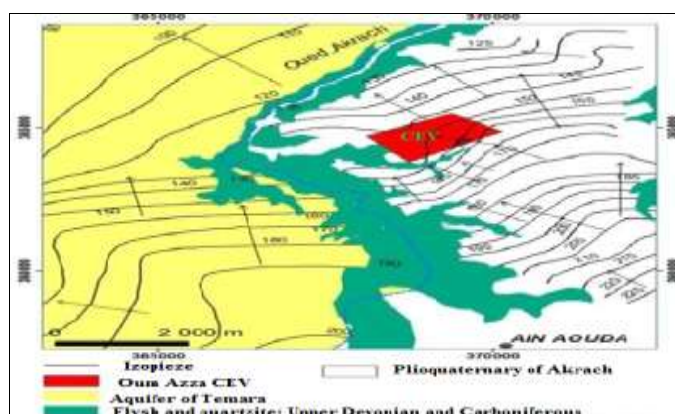
The results of the various physicochemical analyses and the measurements of the metallic trace elements (ETM), obtained from the various samples, were treated using a combination of hydro-chemical and statistical methods:

- The hydro-geochemical classification of the investigated waters was carried out, by projection of the chemical data in the Piper diagram.
- The descriptive statistical approach is based on Principal Component Analysis (PCA), which allows the chemical evolution of groundwater to be monitored. This descriptive multidimensional method is often used as a tool to assist in the interpretation of a data matrix [10]. It allows synthesizing and classifying a large number of data in order to extract the main factors which are at the origin of the simultaneous evolution of the variables and of their own relation. The PCA was carried out on 9 descriptors and 23 variables and it was carried out using the software XLSTAT 2016. The

combination of these methods in this study brings knowledge about the qualitative evolution of the waters, as well as an understanding of the mineralogical enrichment mode of the studied groundwater.



**Figure 3.**location of the sampled points.



**Figure 4.**piezometric map of the study area (Temara plain and Akrach Plateau) [22].

**Table 1.**Physicochemical parameters monitored and used methods.

Parameter	Reference	Unit abbreviation	method
Potential hydrogen	pH	-	ISO 10523-2008
Conductivity	CE	$\mu\text{S}/\text{cm}$	ISO 7888-1985
Temperature	T	$^{\circ}\text{C}$	ISO 7888-1985
Chemical demand for oxygen.	DCO	$\text{mgO}_2/\text{l}$	ISO 6060-1989
Nitrate	$\text{NO}_3^-$	$\text{mg/l}$	DIN 38405-D9-2
Chloride	$\text{Cl}^-$	$\text{mg/l}$	DIN 38405-D1-1
Sulfate	$\text{SO}_4^{2-}$	$\text{mg/l}$	NF T90-040)
Ammonium	$\text{NH}_4^+$	$\text{mg/l}$	ISO/DIS 7150
Full alkalimetric title	TAC	$\text{CaCO}_3 \text{ mg/l}$	ISO 9963-1 (1996)
Calcium	$\text{Ca}^{2+}$	$\text{mg/l}$	ISO 6059:1984
Magnesium	$\text{Mg}^{2+}$	$\text{mg/l}$	
Sodium	$\text{Na}^+$	$\text{mg/l}$	ICP-AES : Atomic Emission
Potassium	$\text{K}^+$	$\text{mg/l}$	Spectrometry (with induction coupled plasma)

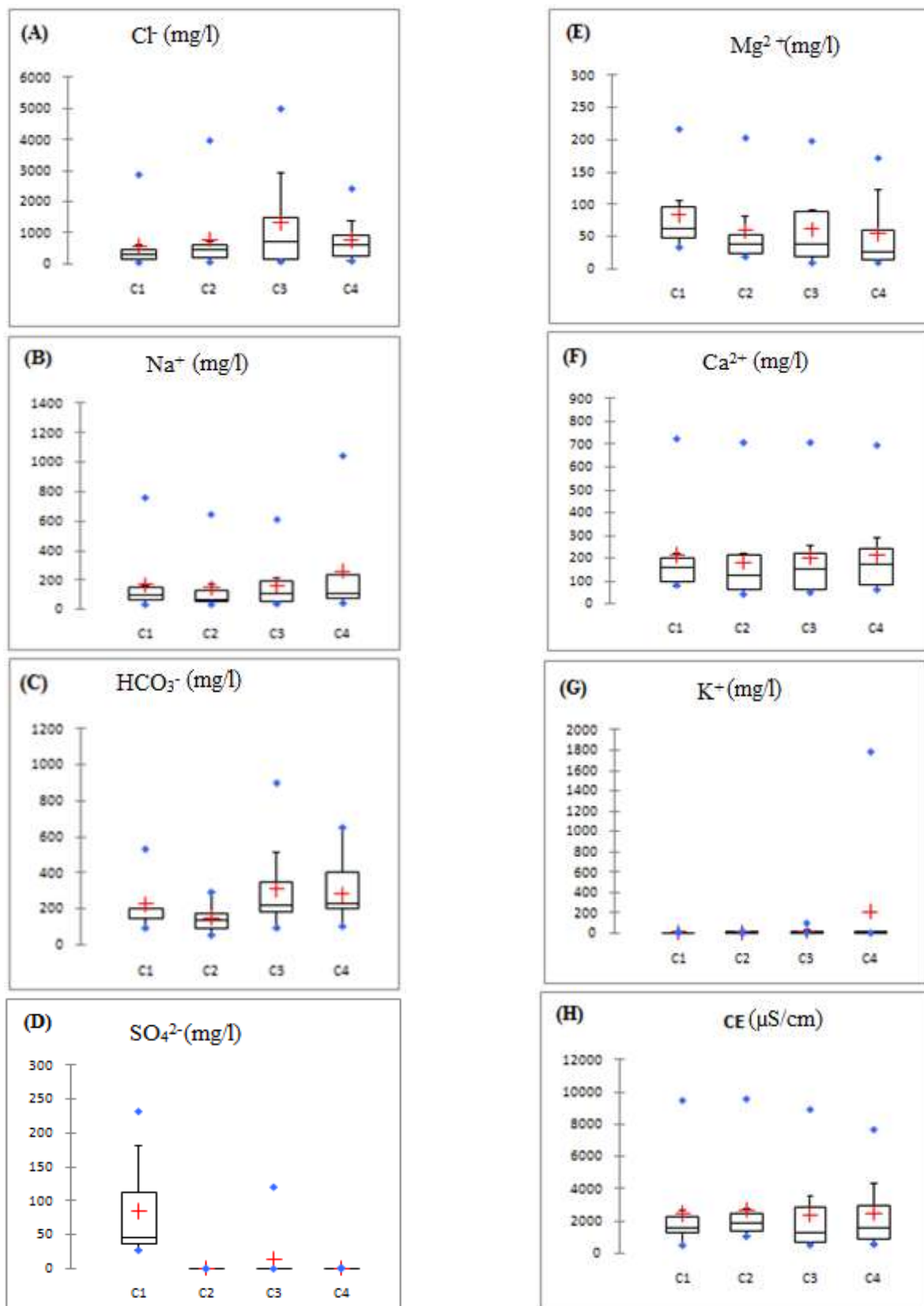


### 3.Results and Discussions

#### 3.1.hydro-chemical characteristics of water

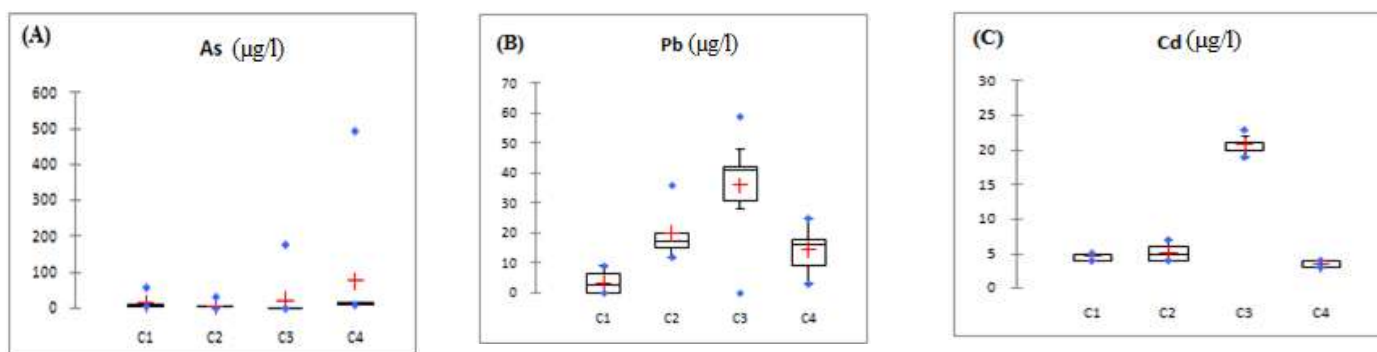
The different physicochemical parameters of the groundwater were measured and analyzed statistically and are compared with the Moroccan standards in terms of the water quality intended for human consumption (NM03.7.001) [11] and that of the World Health Organization WHO [22]. The pH of the four sampling campaigns C1, C2, C3, and C4 varies between 6.55 and 7.79 with averages ranging from 7.04 to 7.18. The obtained pH values are, thus, are fairly close to neutrality with a slight tendency towards basicity. The average water temperatures of the wells studied for the four seasons ranged from 21.27 to 23.34° C. Nevertheless, the P7 well records the highest temperature values of 32; 31 and 40.7 respectively during campaigns C1, C3 and C4, all the more since vapors emanate from this well during the campaign C4. These high temperature values recorded at well P7 are probably due to the influence of the close proximity of the CEV. With respect to dissolved oxygen, the respective average levels recorded during the four campaigns are 1.12; 4.37; 3.87 and 4.60 mg/l. We note that the respective rates of 100%; 66% of the C1 and C3 seasons and the 55% of the C2 and C4 season wells are below the allowable values [11]. On the other hand, the average values of the chemical oxygen demand (COD) varies between 9 and 59 mg (O<sub>2</sub>)/l, with maximums recorded, at the level of the P7 well during the campaigns C1, C2 and C4, of 80; 26 and 182 mg (O<sub>2</sub>)/l, and at the level of the well P8 during the C3 campaign with a value of 201 mg(O<sub>2</sub>)/l. Well P8 is vulnerable to pollution because of its shallow depth, which does not exceed three (3) meters on average. Ammonium (NH<sub>4</sub><sup>+</sup>) ions ranged from values below the limit of detection (0.05) to 5 mg/l during the four measurement runs. Only Well P7 has the highest values of 0.65 and 5 mg/l during C3 and C4 campaigns respectively exceeding the recommended standards (0.5mg /l) [11-22]. It should be noted that the concentrations of NH<sub>4</sub><sup>+</sup> ions are below the limit of detection for all sampled waters during the C1 campaign. Concerning nitrates (NO<sub>3</sub><sup>-</sup>) the respective average contents are 18,61; 20.40; 20.47 and 17.57 mg/l during the C1, C2, C3 and C4 campaigns. Wells P8 and P1 record the highest levels ranging from 55 to 81.5mg/l exceeding the standards in force [11-22]. The respective average of the conductivity measured during the four periods varies between 2390 and 2680 µS/cm. That higher values of EC might be sign of anthropogenic environmental pollution [24]. The maximum values recorded vary between 7710 and 9520 µS/cm obtained at the well P8. Thus the wells P7 in (C3 and C4), P9 in (C2, C3 and C4) and P8 for the four campaigns exceed the recommended standard (2700 µS/cm) [11]. The investigated waters are characterized by a strong localized mineralization mainly linked to the major ions (Fig.5H).Indeed, the chlorides record averages oscillating between 560 and 1306 mg/l. It presents a great heterogeneity translated by the important values of the standard deviation (1600mg/l) and contents which exceed in majority the Moroccan norm (750mg/l) [11]. The highest concentrations are recorded during the C3 campaign with levels ranging from 63.81 to 4998 mg/l. Well P8 showed the highest values for all measurement campaigns (Fig.5A). Sodium (Na<sup>+</sup>) has average concentrations ranging from 146 to 258 mg/ l. The highest levels are recorded during the C4 campaign with a maximum of 1045 mg/l. Wells P8 and P9 have the highest values during the first three seasons for the first well and during the fourth season for the second well (Fig.5B). Concerning Alkalinity (HCO<sub>3</sub><sup>-</sup>) the average recorded contents vary between 147 and 308 mg/l. The C3 campaign raises the highest concentration to 900 mg /l. The P7 well records the highest levels during the four seasons (Fig.5C). However, sulfate record low concentrations not exceeding the recommended standard (400 mg / l) [11], (Fig.5D). Alkaline earths are elements that reflect the dissolution of limestone rocks in addition to other minerals. The average calcium (Ca<sup>2+</sup>) values vary between 183 and 217 mg/l with a maximum recorded during the C1 campaign with a value of 721 mg/l. However, the mean values of magnesium (Mg<sup>2+</sup>) vary between 54 and 81 mg/l with a maximum recorded during the C1 campaign with a value of 217 mg/l. The maximum levels recorded during the four seasons are met at the P8 well. Calcium and magnesium show no marked variation during all measurement campaigns (Fig.5E and F). Potassium (K<sup>+</sup>) has a low concentration in

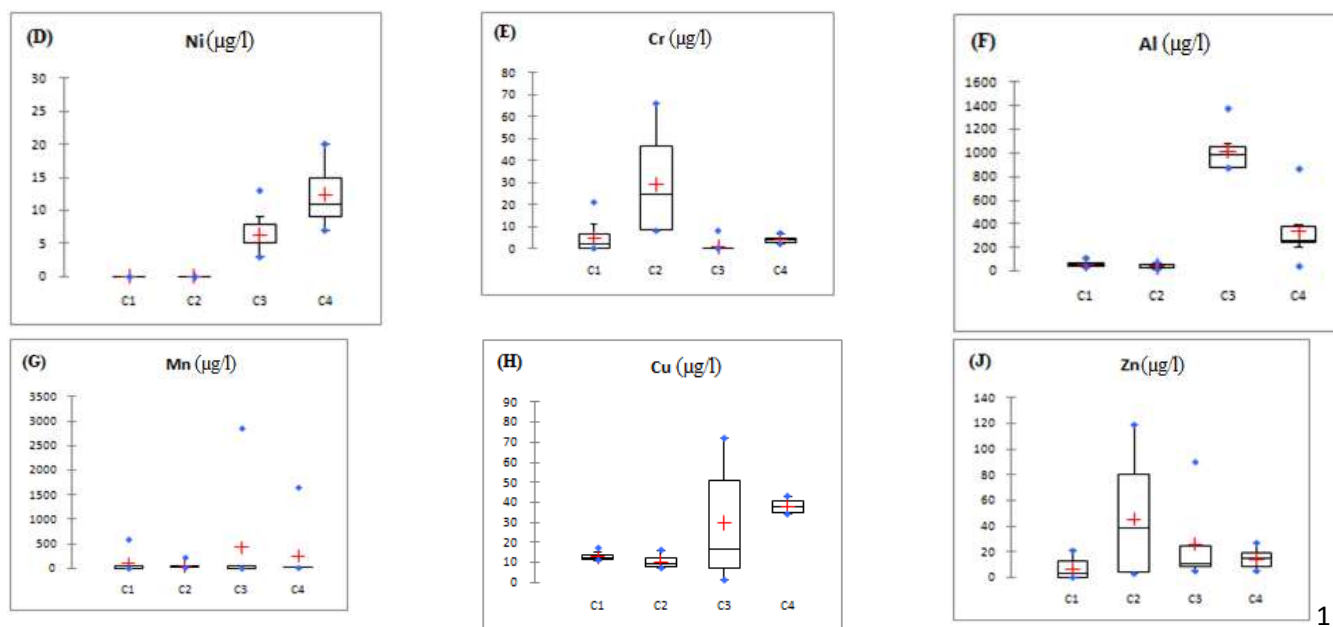
comparison with the other ions measured during the first three campaigns whereas during the C4 campaign there is a sharp increase in the content of this ion, in particular at the P9 well with a value of 1785 mg /l,(Fig.5G).



**Figure 5.** Spatio-temporal variation of the mineral contents (A):Cl<sup>-</sup>, (B):Na<sup>+</sup>, (C):HCO<sub>3</sub><sup>-</sup>, (D):SO<sub>4</sub><sup>2-</sup>, (E):Mg<sup>2+</sup>, (F):Ca<sup>2+</sup>, (G):K<sup>+</sup>, (H):CE.

Concerning the metallic trace elements analyzed, the results obtained for the arsenic element (As) reveal a heterogeneity between the different campaigns and even at the level of the same campaign. The average values of arsenic vary between 6.88 and 75.77 µg/l. However, the respective maximum levels recorded during the C1, C2, C3 and C4 campaigns are 58, 32, 178 and 495 µg/l, all met at the P7 Well, in this case the high results of As are probably due to domestic waste dumps of the neighborhood rich in heavy metals [25]. It should be noted that the C4 campaign shows an arsenic fortification of all and then exceeding the Moroccan standard and that of the WHO (10 µg/l), whereas for the other campaigns and with the exception of the well P7 all the wells conform to the recommended standards [11-22] (Fig.6A). Lead (Pb) records average levels ranging from 3.77 to 16 µg/l. The C3 campaign has the highest value of 59 µg/l at the P4 well. The majority of the wells do not comply with the recommended standards (10 µg/l) with the exception of the waters of the C1 wells which are all below the detection limit of the device ( $\leq 0.006$ ) (Fig.6B). Cadmium (Cd) shows concentrations ranging from 3 to 23 µg/l, with averages of 4.62; 5.11; 20.77 and 3.44 µg/l respectively recorded during periods C1, C2, C3 and C4. The C3 campaign shows the highest values compared to other campaigns. Lead enrichment of the water in all the wells during the first three seasons exceeds the recommended standard (3 µg/l). However, the C4 campaign recorded a 44% rate of water non-compliance with the standard (Fig.6C). Nickel (Ni) shows increasing enrichment during the C3 and C4 campaigns with respective averages of 6.33 and 12.44 µg/l. It is noted that the C1 and C2 season wells are Nickel free. In addition, the C3 and C4 campaigns comply with the standard (20 µg/l), (Fig.6D). The chromium at the analyzed wells shows low levels and complies with standards (50 µg/l), [11-22], with the exception of wells P1 and P6 of the C2 campaign which exceeds these standards (Fig.6E). For Aluminum, the respective average grades recorded during C1, C2, C3 and C4 campaigns are 62; 40; 1019 and 334 µg/l. the C3 campaign reveals a significant enrichment in aluminum. The majority of waters investigated during the C3 and C4 campaigns are non-compliant with the standard (200 µg/l) (Fig.6F). The average Manganese (Mn) contents during the four measurement campaigns vary between 53 and 424 µg/l. Mn displays great heterogeneity especially during the C3 and C4 campaigns. The respective maximum values recorded are 587, (923, 2841) and 1649 µg/l in wells P1, P7 and P9 during the C1, C3 and C4 campaigns. The majority of wells conform to standards [11-22], (Fig.6G). Copper (Cu) and Zinc (Zn), whose respective average contents vary between 10 and 38 µg/l and 6.75 and 45 µg/l remain well below the maximum permissible values for water intended for human consumption [11] which are 3000 and 2000 µg/l for Cu and Zn respectively (Fig.6H, J).





**Figure 6.** Spatio-temporal variation of metal trace element contents. (A): As, (B): Pb, (C): Cd, (D): Ni, (E): Cr, (F): Al, (G): Mn, (H): Cu, (J): Zn.

### 3.2. Water typologies of the studied area

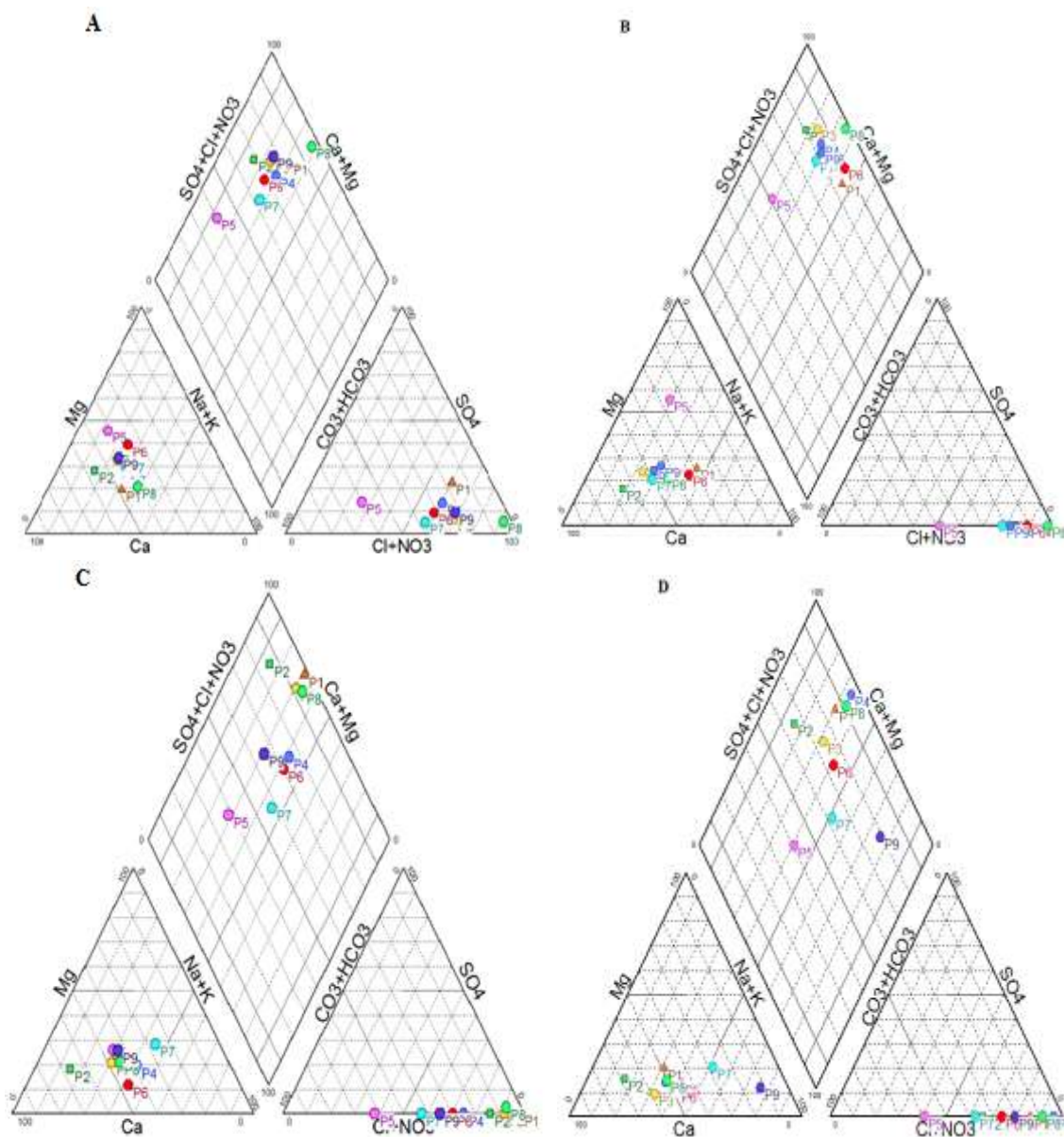
#### 3.2.1 Piper Diagram

The hydro geochemical study makes it possible to determine the chemical facies of the water of the sampled wells. The Piper diagram was established to determine the impact of geological formations in the study area on water quality and also to illustrate the evolution of chemical facies in aquifers over time (Fig.7).

- The Piper diagram of the C1 campaign illustrates two facies the first is that of calcium chloride and magnesium. It includes the majority of wells investigated while the second is the facies of calcium and magnesium bicarbonate that characterized the well P5.
- The Piper diagram of the C2 campaign shows that the evolution of the chemical facies of the studied waters leans towards the individualization of the chemical facies illustrated by that of the calcium and magnesium chloride.
- The Piper chart of the C3 campaign illustrates the same facies as that of the C1 campaign.
- The Piper diagram of the C4 campaign makes it possible to distinguish three facies of which the dominant one is that of the calcium and magnesium chlorides that characterizes the wells P1, P2, P3, P4 and P6. Chloride-sodium-potassium facies characterize the P7 and P9 wells while the calcium bicarbonate facies characterize the P5 well.

The study of the chemical facies of the waters investigated during the year 2015 makes it possible to follow the evolution of these facies during the four seasons, which clearly illustrates that the composition of the groundwater is unstable and that these waters are likely to be modified. Following ion exchange reactions. [12], these [Tapez une équation ici](#) results show that the chemistry of the analyzed water changes over time and that the transition from the rainy period to the summer period is accompanied by a depletion of  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  and an enrichment of  $\text{Na}^+$  and  $\text{HCO}_3^-$  and  $\text{Cl}^-$  which reflects the lithological diversity of the study area but also recharge conditions.





**Figure.7:**Piper Diagram of the C1 (A), C2 (B), C3 (C) and C4 (D) Campaigns.

### 3.2.2 Multifactor analysis: ACP

The multifactor analysis (PCA) used allows us to classify and analyze the data relating to the physicochemical and metallic parameters of the waters of the investigated wells. The objective is to establish correlations between all the variables of the analyzed waters and to highlight the wells having undergone possible contaminations. For the C1 campaign, the projection of the individuals on factorial F1-F2; F1- F3 and F1-F4 represent 94.02% of the total inertia. The PCA determines the individualization of the groups corresponding to the different qualities of water. Axis F1, which represents 33.47% of the total inertness, is essentially determined by the elements of mineralization with which it is positively correlated namely the EC,  $\text{Cl}^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$  and  $\text{NO}_3^-$ . It is defined as the axis of mineralization. It should be noted that the  $\text{NO}_3^-$  significantly contribute to this pole of mineralization that the characteristic elements of the chemical facies of the analyzed waters. The F2 axis is positively defined by  $\text{T}^\circ$ , COD,  $\text{HCO}_3^-$ ,  $\text{K}^+$ , As and negatively with the pH. This axis is defined as the axis of organic pollution. The F3 axis is defined

mainly by the metals: Al, Cd, Cr, Cu and Zn thus expressing metallic pollution. Axis F4 expresses pollution by Pb on the positive side and Mn on the negative side. In the space of individuals three main groups are identified:

**Group 1:** this group located at the positive end of the F1 axis characterized by a strong mineralization composed of the well P8.

**Group2:** characterized by pronounced organic and Aspollution, characterizing the P7 well.

**Group 3:** groups most of the wells characterized by metallic pollution This group contains wells P2, P4 and P5 characterized by (Al, Cd, Cr, Cu and Zn) and wells P1, P6 characterized by (Pb and Mn).

For the C2 campaign the projection of the individuals on factorial F1-F2 and F1-F3 represents 79.14% of the total inertia. The F1 axis is essentially determined by EC,  $\text{Cl}^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$  and  $\text{NO}_3^-$  in addition to  $\text{NH}_4^+$  and Cu. It is defined as the axis of mineralization. The F2 axis is positively defined by the COD,  $\text{HCO}_3^-$ ,  $\text{K}^+$ , As, Mn and negatively with the pH, dissolved  $\text{O}_2$ , Cr and Zn. This axis is defined by an organometallic pollution. The F3 axis is defined by T°, Al and Pb with a contribution of Cu, Cr and Zn thus expressing a metallic pollution. In the space of individuals three main groups are identified:

**Group 1:** this group located at the positive end of the F1 axis characterized by a strong mineralization composed of the well P8.

**Group 2:** characterized by a metallic organic pollution, characterizing well P7 and P9.

**Group 3:** groups wells remaining P1, P2, P3, P4, P5 and P6 characterized by medium to strong heavy metal pollution.

For the C3 season, the projection of individuals on factorial F1-F2 and F1-F3 represents 79.14% of the total inertia. The F1 axis is positively correlated with CE, COD,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ ,  $\text{HCO}_3^-$  and on the opposite it is correlated with Pb. It is always defined as the axis of mineralization. F2 axis is defined significantly and positively by the T °,  $\text{NH}_4^+$ ,  $\text{K}^+$ , As, Cr and to a lesser extent with the Mn and Ni it is also negatively correlated with the Zn. This axis is defined by an organometallic pollution. The F3 axis is defined positively by Al,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ , Cu and negatively with pH and Cd. This axis reveals an anthropogenic pollution probably of agricultural origin and/or resulting from the CEV. In the space of individuals three main groups are identified:

**Group 1:** this group consisting of well P8 located at the positive end of the F1 axis characterized by a very strong mineralization.

**Group 2:** characterized by metallic pollution, characterizing well P1, P7 and P9.

**Group 3:** groups wells remaining P2, P3, P4, P5 and P6 characterized by a medium to strong nitrate and metallic pollution.

For the C4 season, the projection of individuals on factorial F1-F2 and F1-F3 plots represents 75.29% of the total inertia. The F1 axis is positively correlated with CE,  $\text{Cl}^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ ,  $\text{HCO}_3^-$ , Cr, Mn and on the contrary it is correlated with Ni, it also has a lower correlation with  $\text{NO}_3^-$ . It is always defined as axis of mineralization but with a contribution of the metallic trace elements. The F2 axis is defined significantly and positively by T°,  $\text{NH}_4^+$ , As, Cd, Cu and to a lesser extent with  $\text{HCO}_3^-$ , it is also negatively correlated with dissolved  $\text{O}_2$ . This axis is defined by an organometallic pollution. The axis F3 is defined positively by Al,  $\text{K}^+$ , Pb, and negatively with Zn. In the space of individuals three main groups are identified:

**Group 1:** this group consisting of wells P2, P3, P5 and P6 and P8 which is located at the positive end of the F1 axis characterized by a very strong mineralization.

**Group 2:** characterized by metallic pollution, characterizing well P4, P7 and P9.

**Group 3:** groups wells remaining P2, P3, P4, P5 and P6 characterized by a pronounced pollution in  $\text{K}^+$  and Al revealing a pollution probably of agricultural origin and/or from the CEV.

## 4. Discussions

The hydro-chemical facies of the OumAzza groundwater shown in the Piper diagram (Fig.7) during the study period show that they differ from one sampling community to another, so we noted three facies to namely: chlorides-calcium-magnesium, bicarbonates-calcium-magnesium and chlorides-sodium- potassium. The presence of chloride-calcium-magnesium facies and the identified bicarbonate-calcium-magnesium are probably related to the geological formations of the study area where calcites, dolomites, and limestone rocks are found. The study also showed that the  $\text{Ca}^{2+}$  ion content is higher than the  $\text{Mg}^{2+}$  ion content, which is related to the dominance of chloride-calcium facies encountered in the study area. However, the onset of chloride-sodium-potassium facies in the warm period, which characterizes the P7 and P9 wells, the first located close to the CEV on the south side and the second well inside the CEV, thus implying a very probable influence of the anthropogenic contribution of the CEV on the hydro-chemical facies of the studied zone. Exceeding the maximum allowable values of nitrate levels recorded (50 mg/l) during the C1 and C2 campaigns for the P8 well and during the C3 and C4 campaigns for the P5 well assumes an anthropogenic contamination of these wells by the use of fertilizers in agriculture, septic tanks, the CEV [13] and also could be generated from livestock breeding [26]. It should be noted that during the rainy season (C1, C2) the nitrates have a very good affinity with the elements of mineralization which pleads for a leaching of these ions by the rains towards the groundwater in particular those with shallow depth, as is the case of the P8 well, the average depth of which does not exceed three meters. However, during the warm periods (C3, C4) these ions record a correlation with the bicarbonates which are strongly correlated with organic pollutants, in particular the COD and  $\text{NH}_4^+$ , which suggests the same origin of these elements which can be linked to infiltration of  $\text{NO}_3^-$ -rich leachates. In addition, the presence of nitrate ion at levels exceeding 10 mg/l can have adverse effects on the health of infants [9]. Regarding COD, the high values recorded at the P7 wells during the C1, C2 and C4 campaigns and the P8 wells during the C3 campaign coincide with the low dissolved oxygen values, which vary between 0.2 and 0.8 mg/l for the P7 well and 4.94 mg/l for the P8 well. The deficit of dissolved oxygen is the result of the degradation of organic matter; either by chemical oxidation reactions or by biological oxidation, which subsequently causes the generation of  $\text{NH}_4^+$  ions [15]. Ammonium ions indicative of anthropogenic pollution [16-17] are present in significant quantities at the P7 well, particularly during the C3 and C4 campaign (0.65 and 5 mg/l), thus exceeding the recommended standard (0.5 mg/l). This presence is probably due to infiltration of leachates generated by the neighboring CEV. The geological nature, particularly that of the bedrock of the study area, confirms the affinities observed between the conductivity and the mineral elements. However, the existence of a correlation between conductivity and COD during C3 (0.96), between EC and  $\text{NH}_4^+$  (0.96) and between CE and  $\text{NO}_3^-$  (0.87) implies that some of this mineralization is attributed to human activity: discharges of wastewater and/or discharges of landfill leachates [18-19]. Given the significant correlation of pH and bicarbonates during the C1 (0.96) and C2 (0.80) campaigns and the carbonic equilibrium established by this affinity, it is estimated that gas exchange ( $\text{CO}_2$ ) is responsible for the increase of bicarbonate ions in these waters. However, during the C3 and C4 campaigns this correlation with the pH is low, but it is significant with the pollution indicators, in particular with COD (0.81 in C3) and with  $\text{NH}_4^+$  (0.88 in C3 and 0.71 in C4). This argues in favor of a contamination of anthropogenic organic origin confirmed by the high levels recorded at the wells P7 and P9 reaching the 900 mg/l. During the two seasons C1 and C2 one raises very good affinities of As with DCO (0.9) and with  $\text{HCO}_3^-$  (0.95) as well as Mn with  $\text{HCO}_3^-$  (0.78), according to Bourg [20] carbonates can incorporate metallic cations in their crystal lattice. Besides, the existence of a strong correlation between the COD and  $\text{HCO}_3^-$  (0.95), allows us to deduce that these elements trapped in the organic matter is due to likely contamination from CEV

leachate infiltration. Moreover, the temperature in the presence of organic matter can increase its degradation, which can produce acidic and complexing substances [21], which corroborates with our results in particular the good correlation between As and T° (0.92) and the COD and T° (0.84) and by recording temperatures reaching 32 ° at the P7 well during the winter period. The grouping of the metallic elements in particular Zn, Al, Cu and Cr around the same factorial axis in opposition to the Cd implies that these elements come from the same origin. In addition, Copper is correlated with aluminum (0.66) and is also correlated with nitrate (0.79) which suggests that these elements are of anthropogenic origin, essentially due to the infiltration of leachates generated by the CEV as they can be due to agricultural activities which remains a timid activity in the study area. Pb has no correlation hence its exogenous origin. For campaigns C3 and C4 we first note that As and Cr are very significantly correlated, and are also strongly correlated with pollution indicators, especially COD and  $\text{NH}_4^+$  (0.98), thus reflecting the origin of a certain anthropogenic organic pollution. In a second time, a contribution of Zn to the mineralization of the waters studied is recorded. In fact, Zn is correlated with COD (0.70), which reflects an anthropogenic contribution to the mineralization of the waters investigated. Moreover, Ni and Mn have a respective affinity for bicarbonates of (0.59) and (0.56). These elements originate from a contamination likely by the leachate infiltration of the CEV, given that the bicarbonates define the axis factorial of organic pollution according to the ACP. For the nitrates they reveal very important affinities with the chlorides (0.91) but also with the copper (0.58) indicating probably a pollution of agricultural origin and/or leachates of the CEV of OumAzza origin.

## 5. Conclusion

The hydro-chemical measurements carried out on the groundwater collected at the level of the traditional wells around the CEV OumAzza made it possible to define the major contamination traits of these waters, translated by a natural and an anthropogenic origin. The groundwater of the OumAzza zone are characterized by very strong localized mineralization during the four measurement periods and are characterized by chloride-calcium-magnesium facies; bicarbonate-calcium-magnesium and chlorides-sodium- potassium with a clear dominance of the chloride-calcium-magnesium facies which reflects the lithological formation of the calcareous study area. Moreover, it is clear from this study that the acquisition of significant mineralization resulting in high conductivity and  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions during the precipitation campaigns (C1 and C2) is well justified by the dissolution of the carbonate formation, a characteristic of the study area. However, the organic and metallic pollution is pronounced in the dry period (C3 and C4) in particular by COD, Pb, Ni, Mn, Cu, Cd, As, and Al. The analyzed waters recovered downstream of the CEV are the most contaminated. And this phenomenon is all the more accentuated during the dry seasons C3 and C4, in particular the waters of wells P7 and P9 which are loaded with organic and metallic pollutants. The pollutions could be attributed on the one hand to the infiltration and overflow of leachates generated by the landfill and waste recovery center. On the other hand, they can also be due to agricultural activities which are generally shy as they can be attributed to the poor hygiene of wells. This water pollution pronounced at some points, of anthropic origin resulting from urban activities (CEV), local domestic and agricultural makes these waters unfit for human consumption hence the need to continuously treat and monitor the groundwater of this area and to review the management system of the CEV of OumAzza.

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