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Research Article

PIG BASED WATER QUALITY ASSESSMENT IN EL-HAI RIVER BASIN, EL-KANTARA PLAIN, ALGERIA

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ABSTRACT

Groundwater of the El-Kantara plain needs greater attention, because it is the alternative source of water for domestic and agricultural purposes. Water pollution affects both water quality and human health. Hence it is essential for continuous monitoring of the quality of groundwater so that pollution can be minimized. This study aims to evaluate the degree and extent of contamination of the Mio-Plio-Quaternary alluvial aquifer, in the El-Kantara area, Northern Biskra region (Algeria). A pollution index of groundwater (PIG) is proposed for quantification of water contamination at eleven (11) sampling different wells during four times at each well (dry period: September 2011/2014 and wet period February 2012/2015). PIG quantifies the status of concentrations of water quality measures with respect to their drinking water quality standards. The computed values of Pollution Index Groundwater (PIG) of El-Kantara aquifer in El-Hai River Basin vary from 0.746 (Insignificant pollution during wet period; February 2015) to 6.287(Very high pollution during dry period; September 2014). Spatial variation map has been prepared using GIS reveled that most of the study area accounts for very high pollution zones (61.36% of samples).

Keywords: Aquifer of El-Kantara; Drinking-water; Water quality standards; Hydrogeochimistry; El-Hai Basin River; Algeria.

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1. INTRODUCTION

The shortage of surface water and underground water became a paramount problem lived by all companies of countries in the process of development and particularly those of the zones semi-arid. Algeria knew these last years, a very significant fall of the reserves which represent sometimes the only resources of water for the drinking water supply of the populations because of the scarcity of these resources and a great deterioration of quality of groundwater [1,2]. Due to the semi-desert area of the El-Kantara, groundwater is a most precious natural resource, providing reliable water supplies for population of this area. Indeed, the groundwater contamination has become a grave problem due to rapid demographic growth accompanied by a fast urbanization which causes many disturbances for the natural environments, expansion of irrigation activities and the use not rational of manures and pesticides, industrialization and high rate of urbanization in El-Kantara [1-5]. The zone of study belongs to the urban district of El-Kantara in the South-east of Algeria. It knows very significant urban, agricultural and industry development during last decade's 2003/2020 [3]. The site of study receives nearly 4.92 tons per day of solid waste of origins urban and industrial (of small companies specialized in the manufacture of building materials (ceramic), food and the drinks (mills of Ezibane), the recycling of the batteries, of the plastic, the washing of the vehicles… stored directly on the ground [2,3]. The untreated industrial effluents discharged into the surface water and groundwater sources cause severe groundwater (GW) pollution in the industrial belt [6]. After the analysis of the situation of the land, the present work comes in an important moment to establish the hydro chemicals characteristics and pollution not only affects water quality but also threatens human health and socioeconomic development, of an aquifer surface whose water is used much for drinking and irrigation of some 22 000 palms [2,3] . There are different ways for assessing water quality. One of the techniques for demarcating groundwater quality and its suitability for domestic purposes is Pollution Index of Groundwater (PIG). It is a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption [7]. It serves in understanding of water quality by integrating complex data and generating a score that describes water quality status [8]. In this context an attempt has been made to quantify the pollution for the present study area

2. STUDY MATERIALS AND METHODS

2.1. DESCRIPTION OF THE STUDY AREA

The region studied, presented on figure 1, is located in the south-east of Algeria. It is situated in the territory of the Wilaya of Biskra. It occupies of the Northern limit part of the Wilaya of Biskra, at halfway (50 km) between Batna and Biskra. between 35° 57’ 53’’ to 35° 32’ 37’’ North latitude and 5° 28’ 50’’ to 5° 48’ 53’’ ' East longitude [3,9].

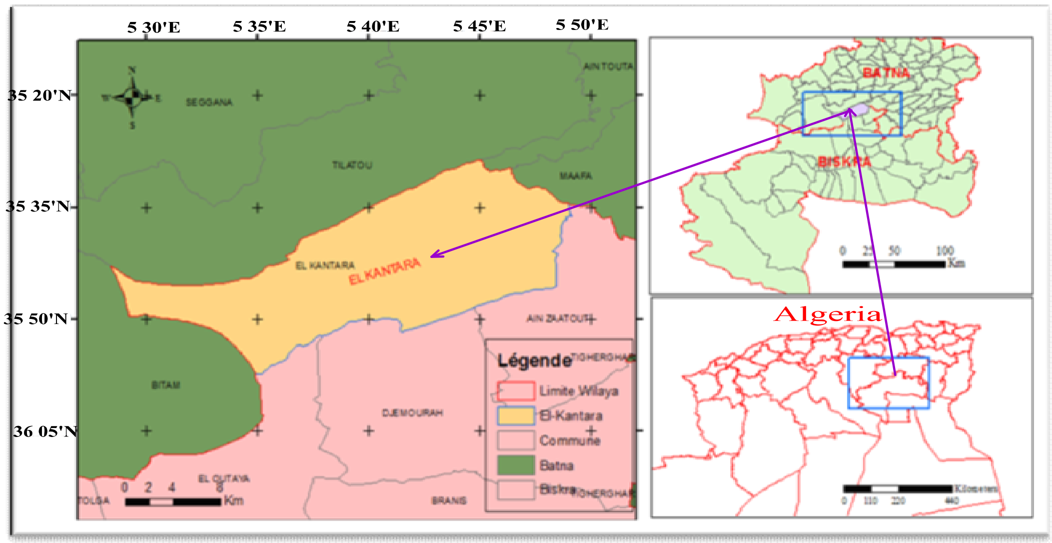

Fig.1. Map of study area [9]

The region studied occupies the downstream part of the El-Hai Sub-Basin River, which represents part of the large Chott Melghir Basin. It is one of the most important rivers in the Eastern Saharan Atlas (Fig.2.A). It takes its source in the massifs of Aurès at altitude which exceeds 2000 m and it joins the Abdi River from where it takes the name of the river Biskra which emerges in the Chott Melghir South of Biskra after a route of 150 km thus forming an endorheic system typical of arid and semi-arid regions (Fig.2.B). The Sub-hydrographic basin of El-Hai river is limited from the North by the Highlands of Constantine Basin, from the East by the Medjerda river Basin, from the West by the Chott Hodna Basin and from the South by the Sahara Basin (Fig.2.A). The hydrographic network of the study area is moderate dense. The most significant rivers are the main El-Hai River (El-Kantara) and its tributaries like Tilatou and Fedhal (Fig.3.C). Surfaces waters of the El-Hai River sub-basin are collected through the

Fontaine des Gazelles Dam which regulates a volume of water around 14 Hm3 per year (Fig.2.A) and (Fig.3.C).

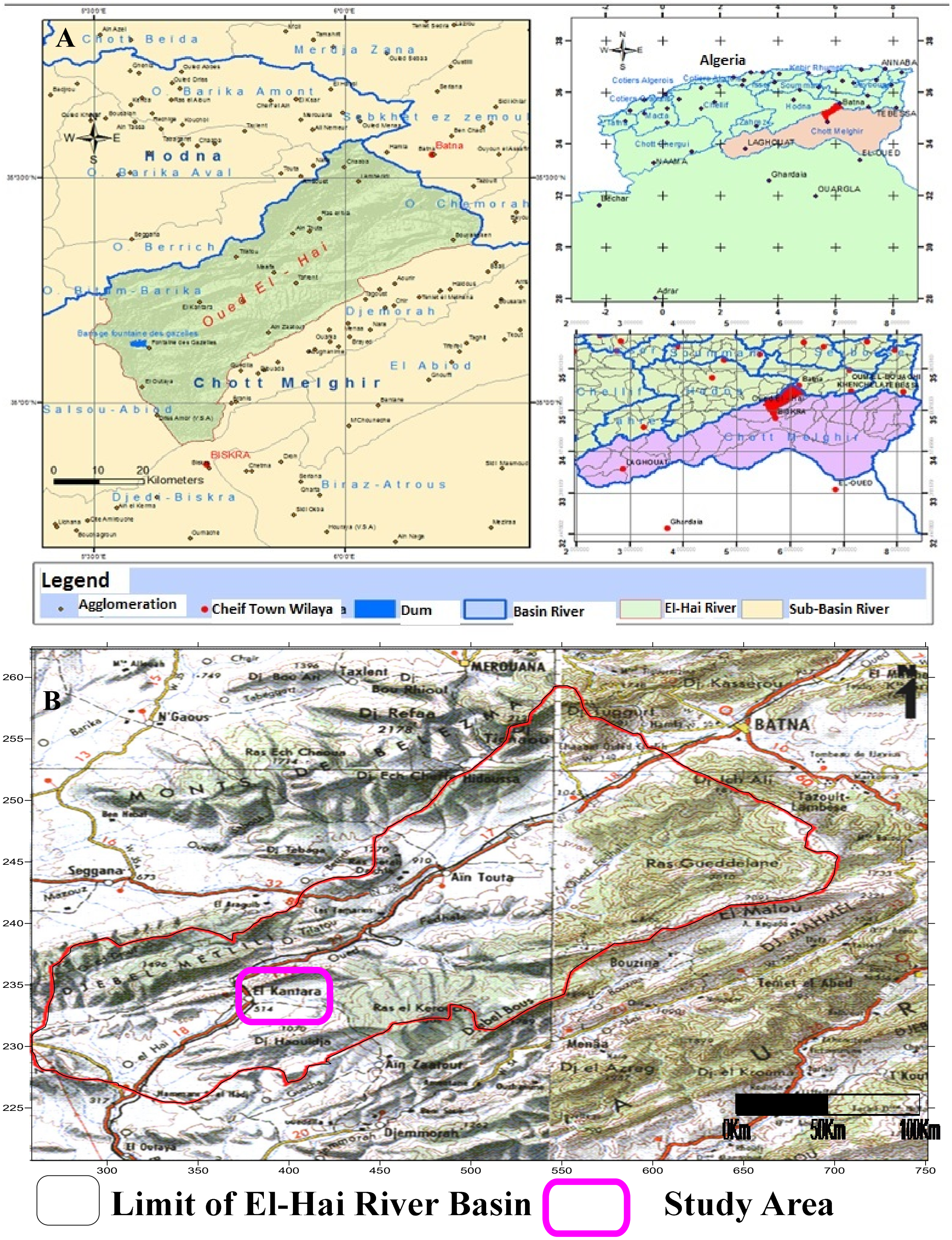

Fig.2. A) Geographical location of the El-Hai Basin River [10] modified B) Geographical location of study area in relation to El-Hai Basin River [2]

The plain lies between the massif of Metlili in the North-west and Djebl Haouidja, Ras El Kerouche and Djebel Bousse in South-east (Fig.2.B) and (Fig.3.C). The altitude varies between 950 to 1200 m (Fig.3.A) where the slope is between 0% and more than 94%.

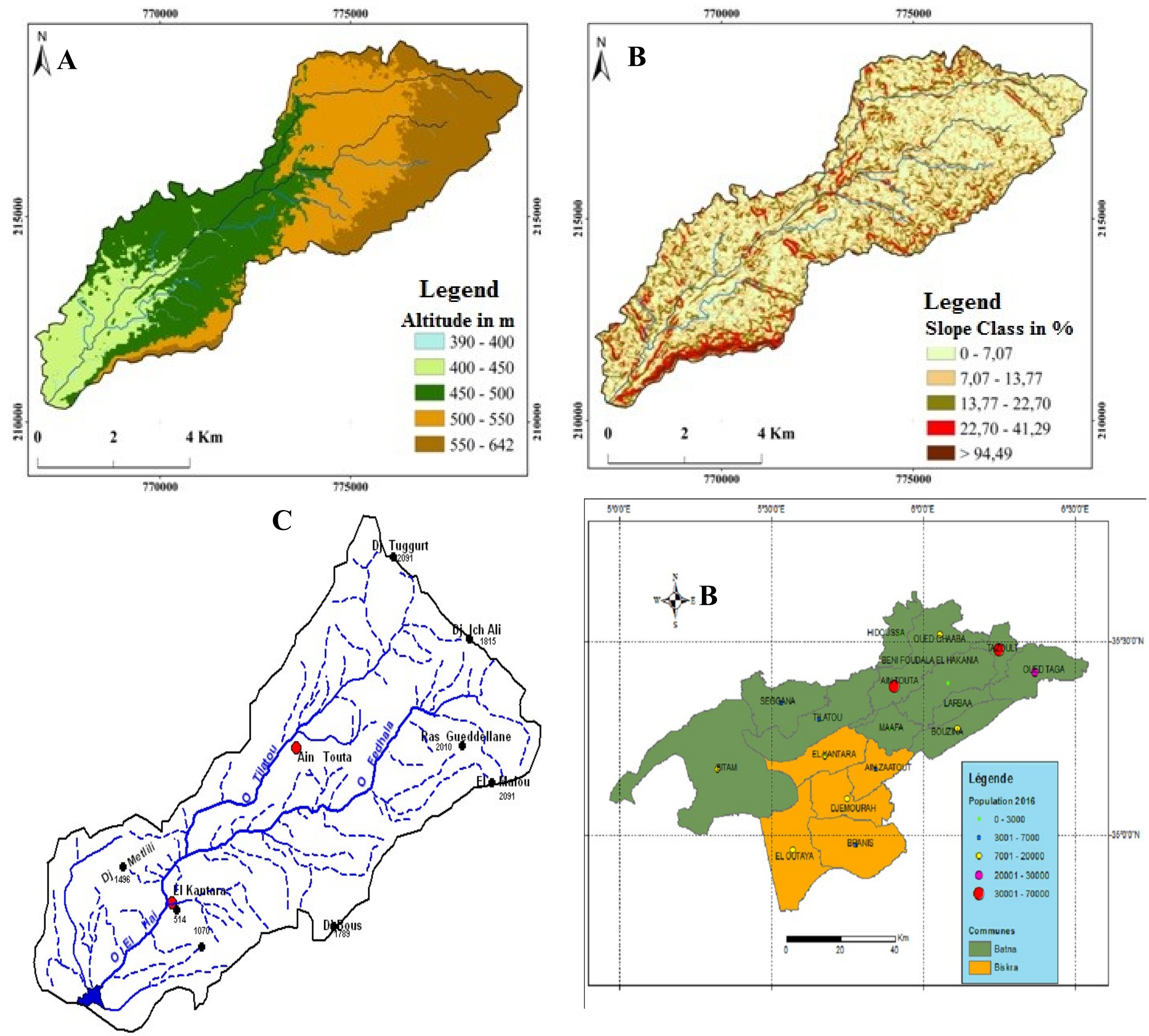

Fig.3. A) El-Kantara Altitude map [own elaboration], B) El-Kantara Slope map [own elaboration], C) El-Kantara Hydrographic network map [2], D) El-Kantara Population [3]

The total capacity of the dam is 55 Hm^3; this capacity is slightly reduced under the effect of siltation accompanying the runoff from the tributaries of El-Hai River, estimated at 0.30 Hm^3 / year. The area of the sub-basin is estimated at 1660 km^2 while the area bow Dum is around 5.66 km². The dam lake is located between three municipalities, Outaya, El-Kantara in the wilaya of Biskra and Bitam in the territories of the wilaya of Batna. The official census of 2008 estimated the population of El-Kantara at 11583 inhabitants. This population increases about 2.05% which enables us to consider the population current at 11,583x 1, 0205 = 11820 (Fig.3.D) [1, 3, 9, 10], its principal activity is agriculture, visible especially in the Southern part where palmerais are much developed few 22000 palm trees [3]. The study area is characterized by a Semi-arid climate, with hot dry summer and cold rainy winter. The case study area, experiences by a semi-arid climate, respectively with average rainfall and temperature of about 261 mm /year and 22.46°C [1].

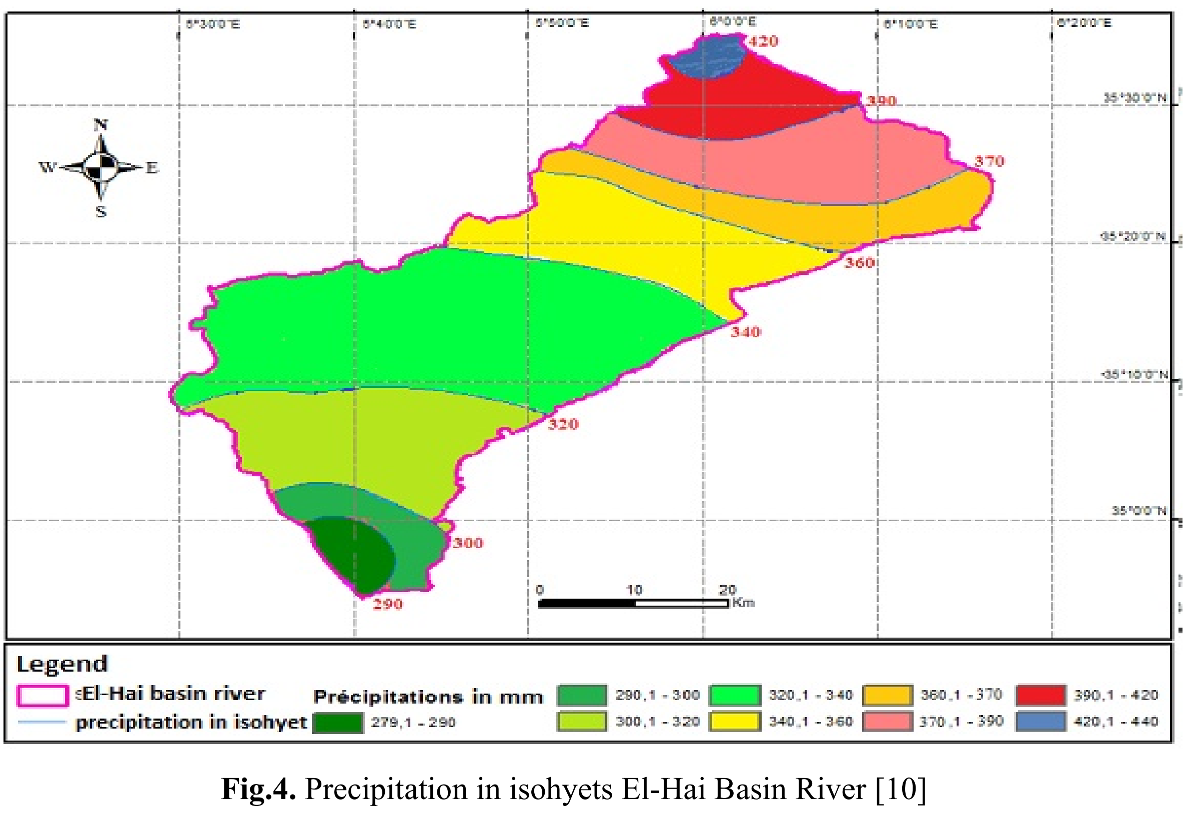

Fig.4. Precipitation in isohyets El-Hai Basin River [10]

The calculation of the total hydrous assessment on a monthly scale shows that it is overdrawn, but it could be surplus if it were established on the scale day. This situation of dryness accentuates the drawdown of water resource especially during the last decade because the renewal of this resource is very weak. Indeed, the dry climate, the atmospheric dust, and low intensity of precipitation can also affect the groundwater quality generally causing increased salt content [1-5].

2.2. GEOLOGICAL AND HYDROGEOLOGICAL OF THE STUDY AREA

According to several authors Laffitte, Bellion, Guiraud, and Yahiaoui [11-14], the study area belongs to the chains of Maghrebides and series of before Atlasic country. From stratigraphic and sedimentological point of view, the study area is characterized by a complete sedimentary sequence, from Secondary to the Quaternary formations (Fig.5.) and (Fig.6.). The Quaternary terrains occupy the central part; they are consisted by old and recent alluvial deposits, conglomerates, sands, crusts limestones of El-Hai River.

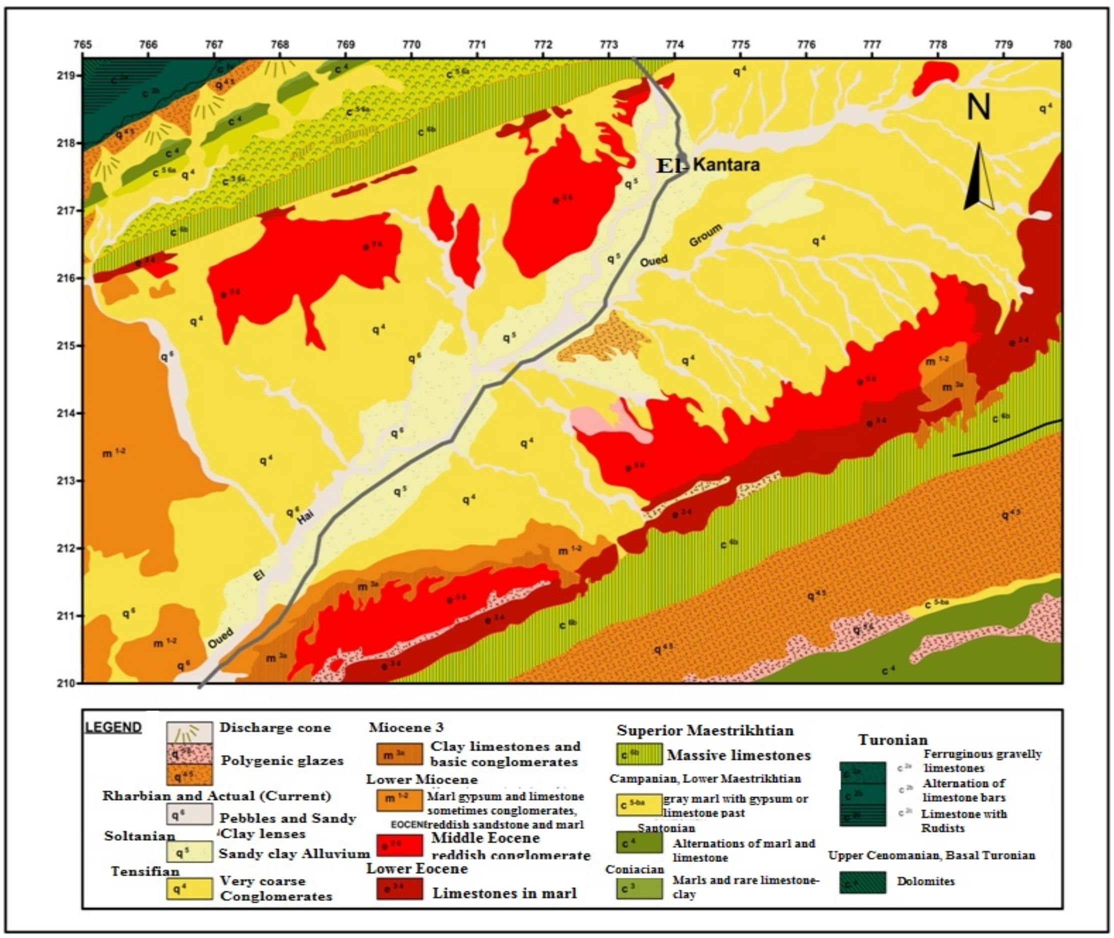

Fig.5. Geological map in the El-Kantara plain According to R. Guiraud [13], modified [1]

The structural analysis has showed that the study area is located at the foot of the massif Aures and consisted of Atlasic structures direction affected by transverse and longitudinal faults. Among these series of anticlines and synclines:

The anticline of Djebel Metlili (NE-SW) (Fig.6)**:** Is a vast cased fold of ante age - Miocene which was taken again by the post-Miocene movements.

The synclinal of El-Kantara: Is a court and very regular synclinal, it is rather a slightly asymmetrical basin (Fig.6).

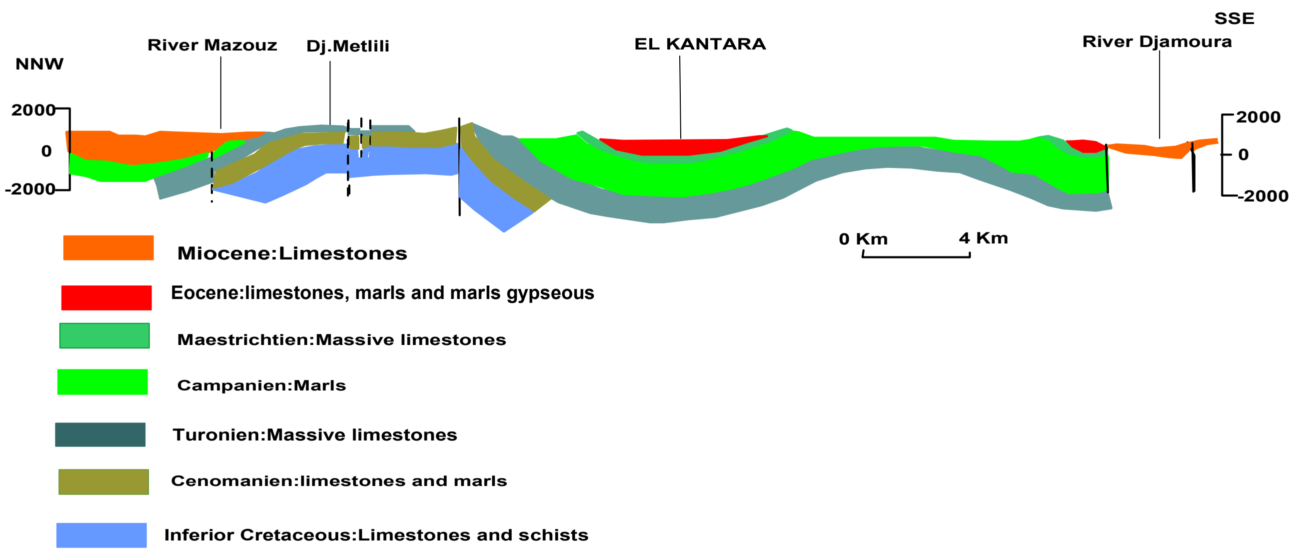

Fig.6. Cross in the downstream of El-Kantara. According to R.Guiraud [13], modified [1]

The analysis of geological tools (maps and lithological columns), soundings and boreholes and hydrogeological tools (Log-Hydrolithostratigraphic) shows that there is a large part of alluvial formations and permeable limestones, allowing the creation of alluvial aquifer and possible Karstic aquifers (Fig.5.) and (Fig.6.). While the rest of the clay and marl formations have a low permeability, thus playing the role of impermeable substratum allowing surface water runoff [1,4,5]. In summary, the study area shows the presence of three aquifers formations (Fig.7):

- The Mio-Plio-Quaternary aquifer;
- The Maestrichtien aquifer;
- The Turonian aquifer.

The El- Kantara Mio-Plio-Quaternary aquifer (aim of this study) of great extension occupies the major part in the old and recent alluvial which rest into major part on impermeable bases of the Oligocene. This aquifer is limited to the West by Eocene limestone, in the East by Maestrichtien

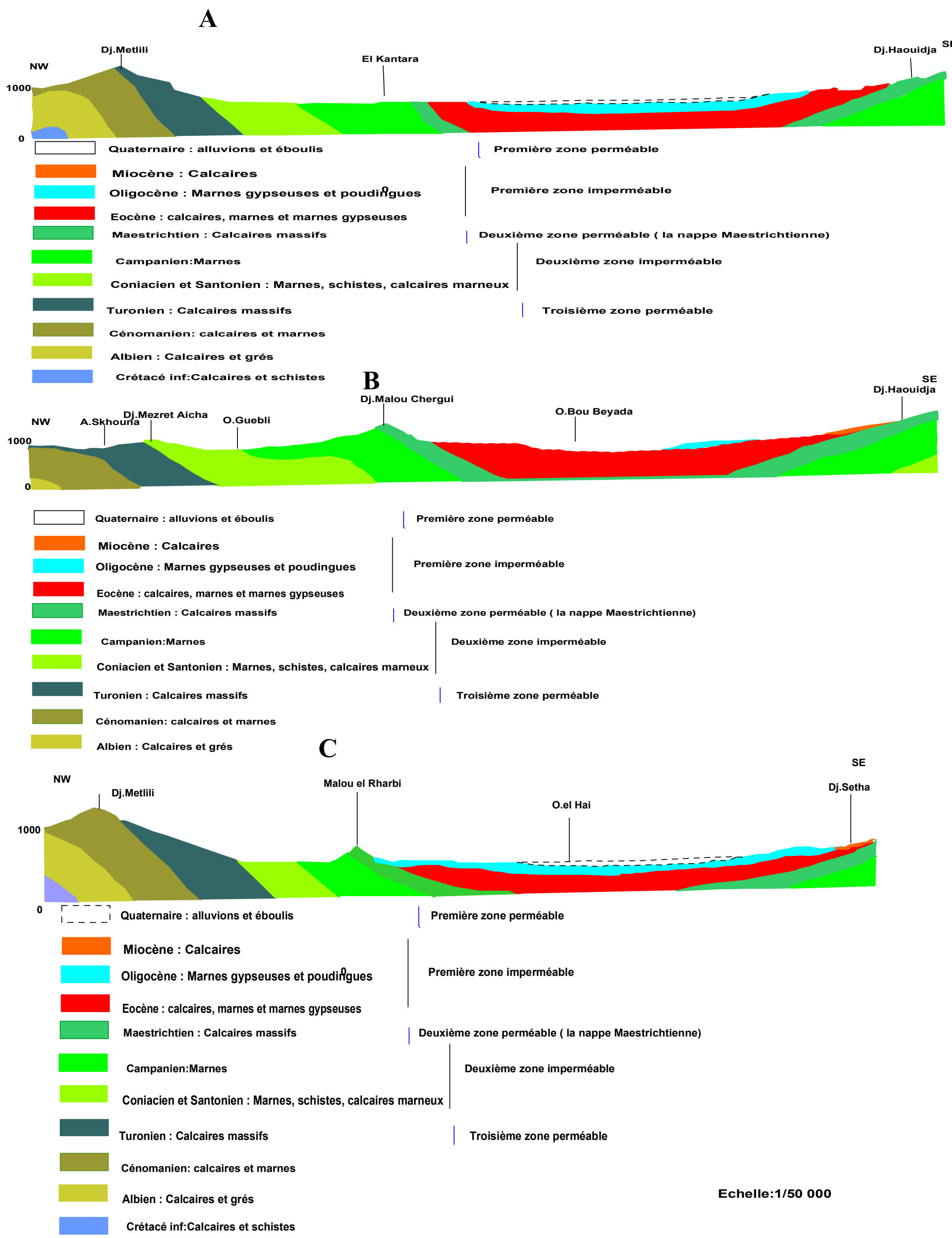

Fig.7. NW-SE orientation hydrogeological[1] [1]sections

limestone. This aquifer plays an important role in the supply of drinking water for the inhabitants of this area and irrigation [1,4,5]. The depth of water level varies from 5 to 30m below the ground level [1]. The establishment of the Potentiometric surface map shows that the Northern part constitutes a limit with entering flow, whereas the Southern part constitutes a limit with outgoing flow. The general flow of groundwater coincides with topography (Fig.8), is done towards the South with a variable hydraulic gradient. The values of the transmisivity T of the alluvial aquifer are between 1,6 X 103 $^{-}$ and 6, 45x 103 $^{-}$ m^2 / S [1]. Under these conditions, hydraulic exchanges between polluted surface water and the groundwater are likely to have negative impacts on public health, on ecosystems and on the economy itself.

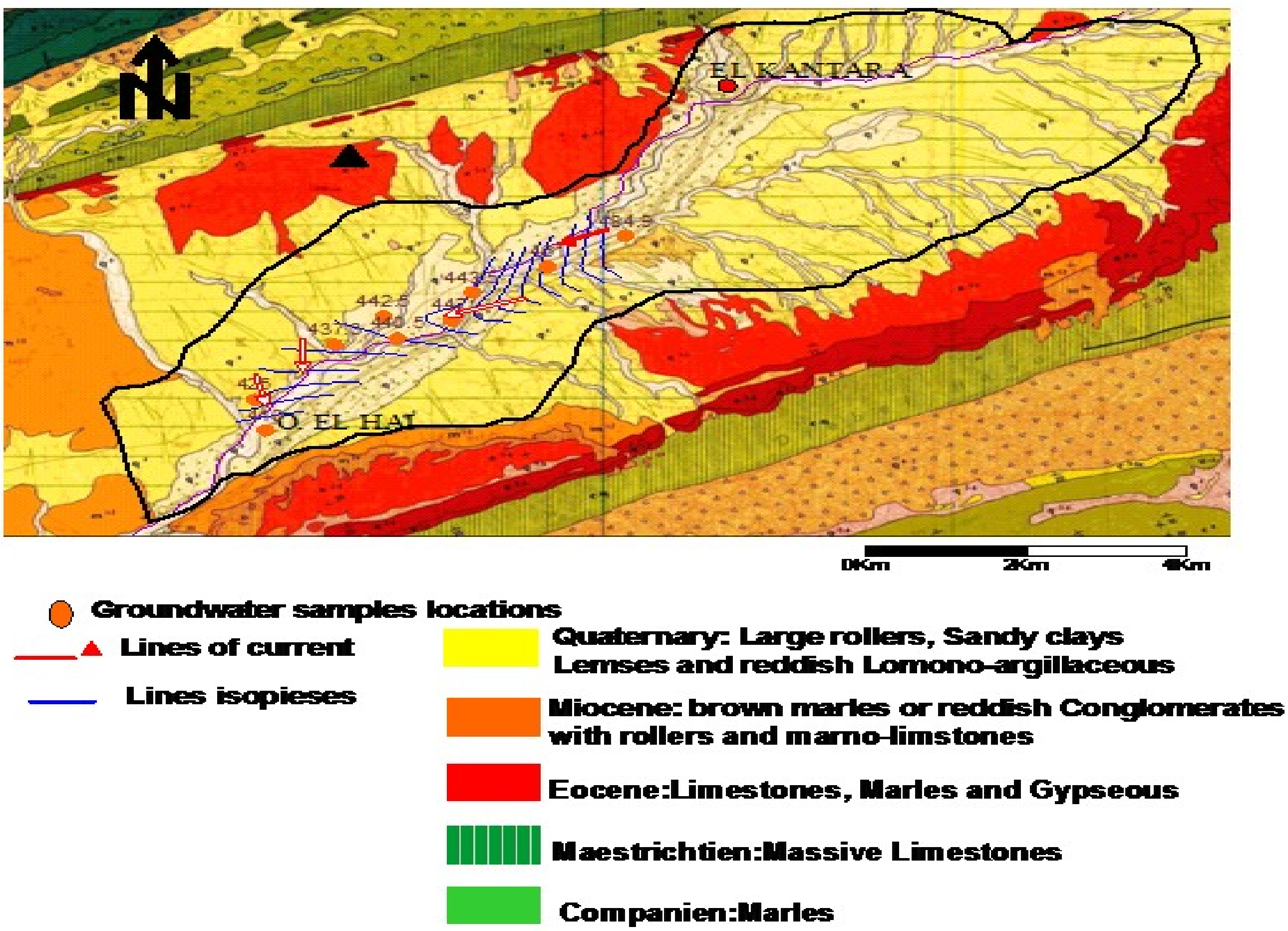

Fig.8. Piezometric map shows the water sampling, geology of the case study area and Quaternary groundwater aquifer of El-Kantara District [1]

2.3. MATERIALS AND METHODS

2.3. 1.FIELD WORK

A survey was carried in El-Hai River basin; El-Kantara plain, and 11 samples were collected from different open dug wells during four times at each well (dry period: September 2011/2014 and wet period February 2012/2015) (Fig.8.). Water samples were collected in clean polythene bottles (250 cm3), washed thoroughly with dilute nitric acid then rinsed with distilled water, and again rinsed with representative water samples. Before sampling, the pump was allowed to work for 15 min and once the values of water characteristics (T, EC, and pH) reached a constant quantity, then the samples were taken. The water samples were filtered to separate possible suspended solids. All the samples were stored in an ice chest at a temperature lower than 4 °C and later transferred to the laboratory. Further, to prevent unpredictable variations in water composition, samples were stored in a refrigerator below 4°C. Immediately after sampling, physical parameters such as the electrical conductivity (EC), water temperature (T) and pH values were measured in the field (at the site) using a multi-parameter WTW Universal Conductivity Meter.

2.3.2. LABORATORY WORK

The chemical parameters of the groundwater samples like major cations, calcium (Ca^{++}), magnesium (Mg^{++}) were determined by EDTA titration method (volumetric titrations) . Sodium (Na^{+}) and potassium (K^{+}) were determined by flame photometric method (flame spectrophotometer (Jenway clinical PFP7). Anions like bicarbonate (HCO^{-}_{3}) were measured by titration to the methyl orange endpoint. The amount of chloride (Cl^{-}) present in groundwater samples was determined by titration and precipitation of AgCl until silver chromate appears. Sulfate (SO^{2-}_{4}) was determined by precipitation of BaSO4 and then measuring the absorbency with spectrophotometer. Trace metals namely iron (Fe), copper (Cu), and lead (Pb) were analyzed using atomic absorption spectrophotometer (AAS(WFX-110B)). Organic matter such as nitrite (No_2), ammonium (NH_4) and nitrate (No_3) was measured by the phenol disulfonic acid method. The Biological oxygen demand (BOD5) and chemical oxygen demand (COD) are determined according to the AFNOR NT F 90-101 standard. All these chemical analyses were carried out in the laboratory of the National Agency of Hydraulic Resources (Fr. Agence Nationale des Ressources Hydrauliques –ANRH), Constantine, Algeria. The accuracy of the chemical analyzes was checked by calculation of the ionic balance, which were generally lower than 5%.

2.3.3. STATISTICAL ANALYSIS

The statistical package for the social sciences (SPSS 19 version) was employed to statistically analyze the data. Descriptive statistics were computed such as the minimum, maximum, mean, median, standard deviation and covariance coefficient values. Multivariate non-parametric regression's analysis (r) and Pearson's correlation coefficients were also calculated between the quality parameters of the GW samples.

2.3.4. GEOSTATISTICAL ANALYSES

The spatial analysis tool of (SURFER 11 version) software was used to analyze the spatial variation of the GW quality parameters. The simple Kriging algorithms; selected the lowest error by comparing the sampled and the predicted values through employing the empirical best-fitted semivariograms models.

2.3.5. COMPUTATION OF POLLUTION INDEX OF GROUNDWATER (PIG):

The analyzed data during four times at each well (dry period: September 2011/2014 and wet period February 2012/2015) has been used in the computations (Tables: 1, 2, 3and 4).

Table.1. Summary of the statistical analysis of the physicochemical characteristics and pollution index groundwater PIG of the GW samples (Dry period September 2011) [own elaboration]

Statisics		PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	DBO5	NO2	NH4+	Pb	DCO	PIG SEP 2011
N	Valid	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Range		,7	1740	355,00	345	31,28	86,13	62,2842	6,038	96,89	416,72	,2602	1,7789	124	7,1	,060	,091	138	2,624
Minimum		6,9	2130	127,80	1488	5,23	14,40	67,6452	,6932	106,78	304,49	,0609	,0000	10	1,2	,208	,021	27	2,591
Maximum		7,6	3870	482,80	1833	36,51	100,53	129,929	6,731	203,66	721,21	,3211	1,7789	134	8,2	,268	,112	165	5,216
Mean		7,39	2949,09	293,681	1671,22	22,0864	60,7116	99,7673	2,839	175,475	536,371	,208382	,406055	50,55	4,976	,24064	,0591	90,73	4,18995
Std. Deviation		,230	553,307	92,6963	126,297	11,0764	30,5202	15,0158	1,835	28,1713	114,096	,075679	,669323	47,645	2,501	,021369	,0331	51,74	,833895
Median		7,43	2980,00	269,800	1680,00	24,2400	66,7340	99,1866	2,390	187,105	528,520	,210400	,008400	27,00[a]	5,470	,23900[a]	,0490	70,00	4,09342[a]
Mode		7,6	2130	127,80[b]	1536[b]	5,23[b]	14,40[b]	98,7873	,6932	106,78[b]	304,49[b]	,0609[b]	,0000	20[b]	1,2[b]	,218	,021[b]	27[b]	2,591
Variance		,053	306149,	8592,61	15951,0	122,688	931,486	225,477	3,370	793,624	13017,9	,006	,448	2270,07	6,258	,000	,001	2677,	,695
Skewness		-1,07	,057	,351	-,009	-,334	-,327	-,180	1,170	-1,728	-,550	-,375	1,352	1,179	-,327	-,075	,584	,172	-,627
Kurtosis		,625	-,374	1,131	-1,533	-1,192	-1,201	2,736	,881	2,917	,629	-,032	,162	-,279	-1,20	-1,525	-1,31	-1,78	-,384
Quartiles	25	7,267[c]	2650,00	253,825	1560,00	10,9225[c]	30,0425[c]	93,6968	1,529	167,235	477,907	,161975[c]	,000700[c]	18,67[c]	2,463	,22300[c]	,0312	41,75	3,71879[c]
	50	7,433	2980,00	269,800	1680,00	24,2400	66,7340	99,1866	2,390	187,105	528,520	,210400	,008400	27,00	5,470	,23900	,0490	70,00	4,09342
	75	7,570	3267,50	353,225	1788,00	31,3100	86,1930	107,171	3,425	192,247	616,182	,274075	,944975	84,00	7,065	,26275	,0895	141,7	4,92720

Table.2. Summary of the statistical analysis of the physicochemical characteristics and pollution index groundwater PIG of the GW samples (wet period February 2012) [own elaboration]

Statisics		PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	DBO5	NO2	NH4+	Pb	DCO	PIG SEP 2011
N	Valid	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Range		,7	1740	355,00	345	31,28	86,13	62,2842	6,038	96,89	416,72	,2602	1,7789	124	7,1	,060	,091	138	2,624
Minimum		6,9	2130	127,80	1488	5,23	14,40	67,6452	,6932	106,78	304,49	,0609	,0000	10	1,2	,208	,021	27	2,591
Maximum		7,6	3870	482,80	1833	36,51	100,53	129,929	6,731	203,66	721,21	,3211	1,7789	134	8,2	,268	,112	165	5,216
Mean		7,39	2949,09	293,681	1671,22	22,0864	60,7116	99,7673	2,839	175,475	536,371	,208382	,406055	50,55	4,976	,24064	,0591	90,73	4,18995
Std. Deviation		,230	553,307	92,6963	126,297	11,0764	30,5202	15,0158	1,835	28,1713	114,096	,075679	,669323	47,645	2,501	,021369	,0331	51,74	,833895
Median		7,43	2980,00	269,800	1680,00	24,2400	66,7340	99,1866	2,390	187,105	528,520	,210400	,008400	27,00[a]	5,470	,23900[a]	,0490	70,00	4,09342[a]
Mode		7,6	2130	127,80[b]	1536[b]	5,23[b]	14,40[b]	98,7873	,6932	106,78[b]	304,49[b]	,0609[b]	,0000	20[b]	1,2[b]	,218	,021[b]	27[b]	2,591
Variance		,053	306149,	8592,61	15951,0	122,688	931,486	225,477	3,370	793,624	13017,9	,006	,448	2270,07	6,258	,000	,001	2677,	,695
Skewness		-1,07	,057	,351	-,009	-,334	-,327	-,180	1,170	-1,728	-,550	-,375	1,352	1,179	-,327	-,075	,584	,172	-,627
Kurtosis		,625	-,374	1,131	-1,533	-1,192	-1,201	2,736	,881	2,917	,629	-,032	,162	-,279	-1,20	-1,525	-1,31	-1,78	-,384
Quartiles	25	7,267[c]	2650,00	253,825	1560,00	10,9225[c]	30,0425[c]	93,6968	1,529	167,235	477,907	,161975[c]	,000700[c]	18,67[c]	2,463	,22300[c]	,0312	41,75	3,71879[c]
	50	7,433	2980,00	269,800	1680,00	24,2400	66,7340	99,1866	2,390	187,105	528,520	,210400	,008400	27,00	5,470	,23900	,0490	70,00	4,09342
	75	7,570	3267,50	353,225	1788,00	31,3100	86,1930	107,171	3,425	192,247	616,182	,274075	,944975	84,00	7,065	,26275	,0895	141,7	4,92720

Table.3. Summary of the statistical analysis of the physicochemical characteristics and pollution index groundwater PIG of the GW samples (Dry period September 2014) [own elaboration]

Statisics		PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG SEP 2014
N	Valid	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Range		,7	1740	355,00	372,0	31,28	86,132	82,284240	6,038505	116,555	416,72	,2602	1,7787	7,44	,060	,112	3,6408248
Minimum		6,7	2150	147,80	1508,0	7,23	34,396	87,645220	5,693290	107,105	324,49	,2609	,1002	2,80	,308	,010	2,6460752
Maximum		7,4	3890	502,80	1880,0	38,51	120,528	169,929460	11,731795	223,660	741,21	,5211	1,8789	10,24	,368	,122	6,2869000
Mean		7,19	2905,45	313,68	1707,58	24,086	80,7116	119,767338	7,5664777	167,294	556,371	,40838	,50640	6,7945	,34064	,06064	4,65847228
Std. Deviation		,242	588,530	92,696	138,609	11,076	30,5202	19,2177234	1,8677603	44,0561	114,096	,07567	,66909	2,7728	,02136	,03551	1,31373284
Median		7,20	2920,00	289,80	1748,00	26,240	86,7340	118,787340	7,0887300	184,005	548,520	,41040	,10840	7,4700	,33900	,05300	4,85904600
Mode		7,4	2150	147,80[a]	1556,0[a]	7,23[a]	34,396[a]	118,787340	5,693290[a]	107,105[a]	324,49[a]	,2609[a]	,1008[a]	2,80[a]	,318	,010[a]	2,6460752[a]
Variance		,059	346367,2	8592,6	19212,6	122,68	931,486	369,321	3,489	1940,94	13017,9	,006	,448	7,688	,000	,001	1,726
Skewness		-1,20	,266	,351	-,133	-,334	-,327	1,588	1,580	-,293	-,550	-,375	1,352	-,464	-,075	,711	-,364
Kurtosis		,550	-,854	1,131	-1,780	-1,192	-1,201	5,784	1,760	-1,760	,629	-,032	,163	-1,186	-1,525	-,353	-1,124
Quartiles	25	7,100	2300,00	272,05	1556,00	10,080	42,2040	112,798470	6,3900600	115,605	487,530	,36060	,10080	3,1800	,31800	,03800	3,55499220
	50	7,200	2920,00	289,80	1748,00	26,240	86,7340	118,787340	7,0887300	184,005	548,520	,41040	,10840	7,4700	,33900	,05300	4,85904600
	75	7,400	3340,00	375,00	1844,00	34,620	109,792	119,985115	7,6894900	208,225	637,030	,48240	1,3151	9,3600	,36300	,09200	5,98496060

Table.4. Summary of the statistical analysis of the physicochemical characteristics and pollution index groundwater PIG of the GW samples (wet period February 2015) [own elaboration]

Statisics		PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG FEV 2015
N	Valid	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Range		,8	1821	299,10	1687	31,91	242,5	393,95	26,95	102,80	344,35	39,69	8,84	,0730	,0540	,0830	3,9657567
Minimum		7,1	1500	79 ,85	420	2,60	147,9	61,90	1,75	48 ,70	78,50	1,01	0,34	0,010	0,0080	0,0090	0,746
Maximum		8,1	3301	359,85	2087	33,51	370,4	445,85	28,00	141,50	404,85	40,50	9,08	,0740	,0600	,0910	4,7119246
Mean		7,79	2696,82	144,13	1476,64	10,206	259,64	312,652	17,640	102,77	239,85	8,9891	1,9609	,01654	,03445	,04072	1,76817097
Std. Deviation		,234	533,943	81,835	413,918	10,526	80,942	156,864	9,2610	31,826	98,045	13,868	2,4406	,02691	,02020	,03178	1,05183701
Median		7,80	2960,00	122,00	1478,00	6,4000	248,40	380,530	17,500	105,20	232,50	3,4600	1,2200	,00500	,03100	,02700	1,38250400
Mode		7,7[a]	1480[a]	139,75	1430	1,60[a]	333,8	51,90[a]	28,00	38,70[a]	60,50[a]	,81[a]	,24[a]	,0010	,0600	,0080[a]	,7461679[a]
Variance		,055	285095,3	6697,0	171328,4	110,80	6551,6	24606,3	85,766	1012,9	9612,9	192,34	5,957	,001	,000	,001	1,106
Skewness		-,93	-1,136	1,997	-1,677	1,495	-,161	-1,098	-,883	-,938	-,325	1,961	2,937	1,873	,003	,688	2,508
Kurtosis		,613	1,424	5,133	5,182	1,289	-1,473	-,774	-,042	,624	,230	2,445	9,187	1,995	-1,644	-1,232	7,292
	25	7,70	2381,00	104,25	1430,00	3,0000	190,00	90,0000	15,000	95,240	212,46	2,5800	,7800	,00100	,01300	,01300	1,21900980
Quartiles	50	7,80	2960,00	122,00	1478,00	6,4000	248,40	380,530	17,500	105,20	232,50	3,4600	1,2200	,00500	,03100	,02700	1,38250400
	75	8,00	3100,00	157,50	1708,00	16,450	333,80	429,650	24,000	128,32	319,90	4,1300	2,0200	,01000	,05500	,07200	2,01046230

The standards for drinking purposes as recommended by WHO, BIS and Algeria have been considered for the calculation of Pollution index of ground water (PIG) [15-7]. There are different steps for computing PIG which includes assigning a weight to each chemical parameter according to its relative importance in the overall quality [18,19]. PIG is a numerical scale, quantifying the extent of contamination. It reflects a composite influence of individual water quality measures on overall water quality of aquifer [20-23]. The algorithm to compute PIG is given as follows:

2.3.5. 1.DESIGNATION OF RELATIVE WEIGHT (Rw)

A numerical value, referred to as the relative weight (Rw), between 1 and 5, is assigned to each parameter, reflecting its degree of influence on water quality, taking into consideration its impact on human health and on aquatic life preservation [20-25]. For instance, the value of 5 of the Rw is assigned to pH, SO4, NO_2, NH_4, and NO_3; 4 to Na^+, Cl^-, Fe, Pb, BOD5 and COD; 3 to HCO3 and EC; 2 to Ca, Cu and Mg and a minimum weight of 1 to K (Table .5). A minimum value of 1 of the Rw corresponds to the lowest significant role, whereas the maximum value of 5 of the Rw reflects the highest significant role on health [21,22]. These weights have been decided based on the judgment of the authors and the experience gained from the literature [20-27].

Table.5. Relative weight (Rw) and weight parameter (Wp) of physico-chemical parameter according to Algerian Drinking water quality standard [own elaboration]

Chemical parameters (Water quality measure)	Units	(Relative weight) (Rw) SEP 2011/FEB 2012	(Weight parameter) (Wp) SEP 2011/ FEB 2012	(Relative weight) (Rw) SEP 2014/ FEB 2015	(Weight parameter) (Wp) SEP 2014/ FEB 2015	(Algerian Drinking water quality standard (Ds)*) [16]	(WHO Drinking water quality standard (Ds)*) [15]
PH	/	5	0,0806	5	0,0926	6,5 - 9	6.2 - 9.22
Ca^{+2}	mg/l	2	0,0323	2	0,0370	200	200
Mg^{+2}	mg/l	2	0,0323	2	0,0370	150	150
Na^{+}	mg/l	4	0,0645	4	0,0741	200	200-500
K^{+}	mg/l	1	0,0161	1	0,0185	12	10
SO_4^{2-}	mg/l	5	0,0806	5	0,0926	400	250
HCO_3^{-}	mg/l	3	0,0484	3	0,0556	300	/
Cl^{-}	mg/l	4	0,0645	4	0,0741	350	200-500
NO2	mg/l	5	0,0806	5	0,0926	0,2	0 ,1
NO_3^{-}	mg/l	5	0,0806	5	0,0926	50	40
NH^{4+}	mg/l	5	0,0806	5	0,0926	0,5	0,2
Cu^{+2}	mg/l	2	0,0323	2	0,0370	2	0,05
Fe^{+2}	mg/l	4	0,0645	4	0,0741	0,3	0,2
Pb	mg/l	4	0,0645	4	0,0741	0,01	0,01
EC	(µS/cm)	3	0,0484	3	0,0556	2 800	1500
DBO5	mg/l	4	0,0645	/	/	5	/
DCO	mg/l	4	0,0645	/	/	20	/
Sum (Σ)		62	1,0000	54	1,0000	/	/

2.3.5. 2.COMPUTATION OF WEIGHT PARAMETER (Wp)

Weight parameter is the ratio of Rw of every water quality measure to the sum of all relative weights. Weight parameter enables to know about the relative share of each water quality measure on overall water quality (Table .5). The Wp is given by the equation (1):

$$Wp = Rw / \Sigma Rw \quad (1)$$

2.3.5. 3.STATUS OF CONCENTRATION (Sc)

The status of concentration (Sc) of water quality measure of each water sample with respect to its drinking water quality standard (Ds). The Sc is computed by dividing the concentration (C) of each water quality measure of every water sample by its respective drinking water quality standard (Ds) (2):

$$Sc = C / Ds \quad (2)$$

2.3.5. 4.OVERALL WATER QUALITY (Ow)

The overall water quality is computed by taking the product of each water quality measure with its corresponding status of concentration. Ow reflects overall water quality and also enables to understand the nature of weight parameter with respect to concentration of each water quality measure. Ow is calculated by (3):

$$Ow = Wp * Sc \quad (3).$$

2.3.5. 5.POLLUTION INDEX OF GROUNDWATER (PIG)

Pollution index of groundwater is computed by adding all values of Ow contributed by all water quality measures of every water sample. PIG is given by (4):

$$PIG = \Sigma Ow \quad (4)$$

2.3.5. 6.PIG CLASSIFICATION

The classification of PIG is based on water quality standard for drinking purpose. PIG classification could also be used in the assessment of groundwater contamination. When both the values of quality of particular water sample and concentration of water quality measure are same then their impact on health could be insignificant. With an account of this, when the PIG value is less than 1.0, it could be considered as a non-pollution index and when PIG exceeds more than 1.0, then it may be the contribution from a contaminant into an aquifer thus polluting [21].

Table.6. PIG based Pollution Zones [21]

PIG	Quality Status
PIG <1.0	Insignificant pollution
1.0< PIG <1.5	Low pollution
1.5< PIG <2.0	Moderate pollution
2.0< PIG <2.5	High pollution
PIG >2.5	Very high pollution

3. RESULTS AND DISCUSSION:

3.1. DESCRIPTIVE STATISTICAL MEASURES

The descriptive statistics used for pollution index groundwater PIG were carried out by implementing (SPSS 19 version) and investigated along with the World Health Organization and Algerian standards [15, 16]. The elements of descriptive-statistics included rang minimum, maximum, mean, Std. Deviation, median, Mode, Variance, Skewness, Kurtosis, quartile 1, and quartile 3. The statistics of the water chemistry is represented in Tables 1, 2, 3 and 4 and Box plots figures 9 and 10. The Box plots were used to represent temporal concentration of the physicochemical parameters and the values of pollution index groundwater (PIG). The upper and lower quartiles of the data define the top and the bottom of a rectangle box. The line inside the box represents the median value and the size of the box represents the spread of the central value.

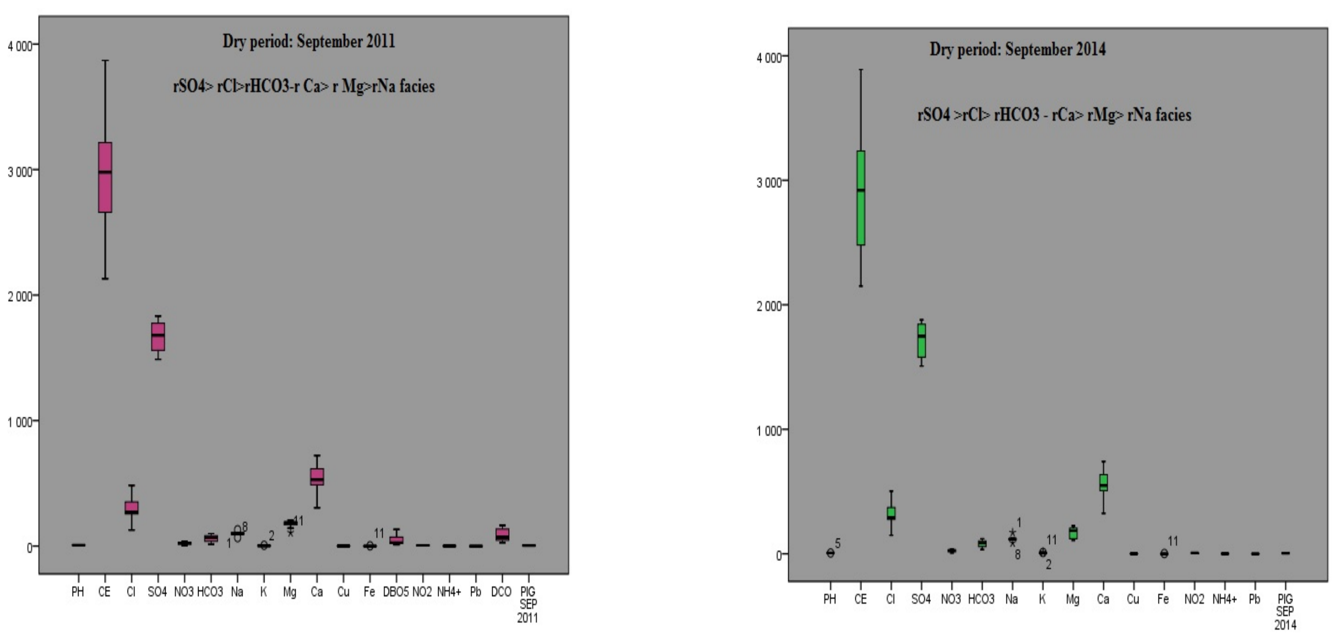

Fig.9. Box plot of physicochemical parameters and pollution index groundwater (PIG) of the Tow dry campaigns [own elaboration]

Groundwater was generally low acidic to low alkaline with pH ranging from 6.7 to 7.6 and 7.1 to 8.1 during dry period and wet period, respectively. However, the observed values of the pH are within the permissible limits of WHO guidelines and Algerian standard for drinking (Table.5).

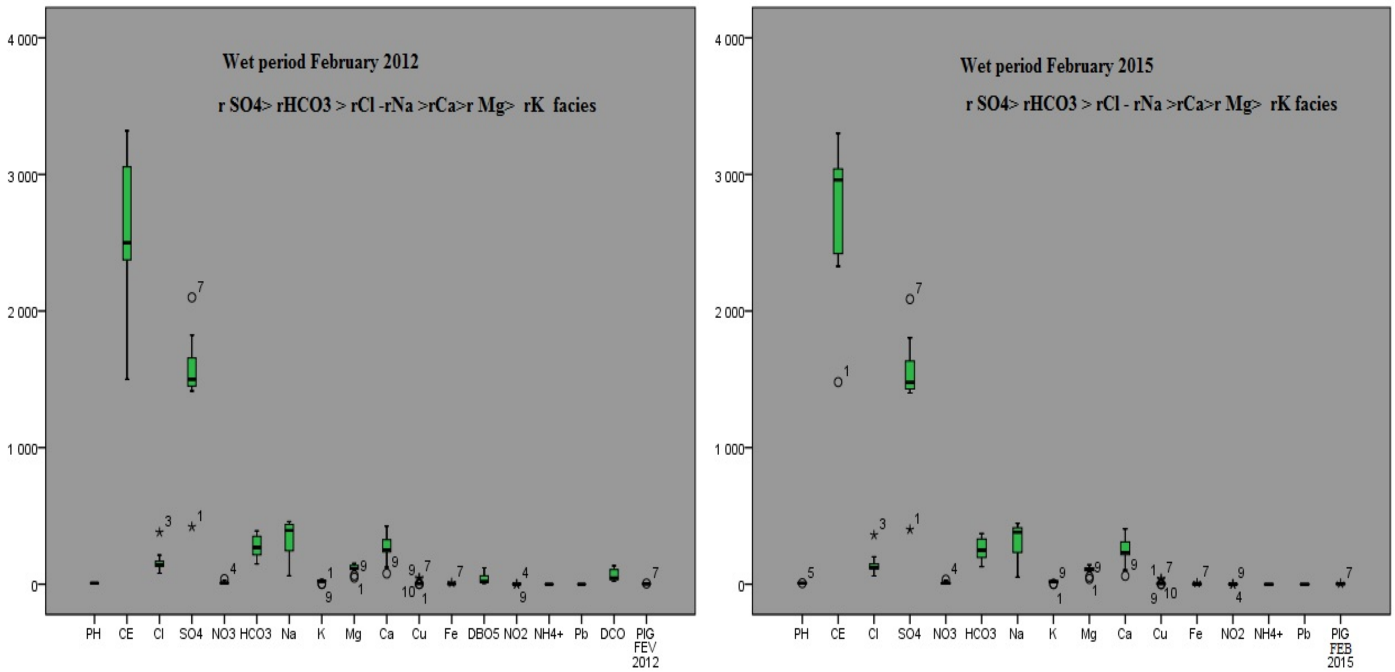

Fig.10. Box plot of physicochemical parameters and pollution index groundwater PIG of the Tow wet campaigns [own elaboration]

According to Zghibi et al [28], PH variation in groundwater may be indicating an influence of the anthropogenic pollution of groundwater by the infiltration of domestic and industrial waste water. During the study period, the electrical conductivity (EC) values are between a minimum of 1480 µS /cm recorded during the wet period (FEB 2015) and a maximum of 2949.02 µ.S / cm recorded during the dry period (SEP 2011). The values of the electrical conductivity of the water in the study area undergo a remarkable evolution in time (there is a slight decrease in the average of EC during the wet period) and in space which is linked to the phenomenon of dilution. Most of the values are very high and exceed the standard recommend value by WHO 2008, (1500 µS/cm), while a large number of values are conform to the Algerian drinking standard 2011 fixed at 2800 µS /cm. This suggests that groundwater in the study area is high mineralized. It depends on the lithology of the aquifer, climate conditions, and anthropogenic pollution. As shown in Figures 8 and 9 and in tables 1,2,3,4 and 5 , the major cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} are all low except

Ca^{2+},with minimum mean concentrations of 232.50±98.045, 102.77±31.826, 99.767±15.0158 and 2.839±1.835 mg/l and maximum mean concentrations of 556.371 ±114.096, 175.475±28.171, 327.107±159.667 and 20.84±10.59 mg/l, respectively. The major anions Cl^-, SO_4^{2-}, and HCO_3^- are also low except SO_4^{2-} , with minimum mean concentrations of 144.13±81.835, 1476.64±413.918 and 60.7116±30.5202 mg/l and maximum mean concentrations of 313.68±92.696, 1707.58±138.609 and 281.464±82.9736 mg/l, respectively. The concentration of dissolved major anions and cations in the alluvial aquifer of El-Kantara was in the order of rSO_4^2> $rHCO_3^-$ > rCl^- - rNa^+> rCa^{2+}> rMg^{2+}> rK^+ and rSO_4^2> rCl^- > $rHCO_3^-$- rCa^{2+}> rMg^{2+}> rNa^+> rK+ during wet period and dry period respectively (Fig.8) and (Fig.9) . Concerning indicators of agricultural pollution: NO2, NO_3^- and NH^{4+} are in the range of (0.001 to 10.24, 2.60 to 38.51 and 0,008 to 0.368), with minimum mean concentrations of 0.0165 ± 0.0269, 10.206±10.526 and 0.0165±0.0269 mg/l and maximum mean concentrations of 6.794±2.772, 24.086±11.076and0.0406±0.02136mg/l, respectively. The presence of organic nitrogenous forms (nitrates, nitrites and ammoniac) in groundwater is generally safe by standards. While it is alarming and worrying and pose a danger according to the standards especially during the dry period. This is due to the excessive use of fertilizers and pesticides in agricultural activities. The ammonium, nitrite and nitrate contents perfectly follow those of BOD5 and COD and indicate that the high concentrations of the latter are accompanied by a high pollutant load. In accordance with this scenario, the majority of the wells in this area have high concentrations of BOD5 and COD compared to WHO and Algerian standard. The concentrations of trace metals namely Cu^{+2}, Fe^{+2} and Pb are high and exceed the standard recommend value by WHO 2008 and Algerian drinking standard 2011, with minimum mean concentrations of 0.208 ± 0.0756, 0.406 ± 0.6693 and 0. 0407 ± 0.0317 mg/l and maximum mean concentrations of 10.2309 ± 15.9857, 2.322 ± 2.982 and 0. 0606 ± 0.0355 mg/l, respectively. The El-Kantara alluvial aquifer is characterized by a great variation in the concentrations of chemical elements (Fig. 9) and (Fig. 10). Note that the deviation from the average is considerable for a large number of elements.

3.2. RESULTS AND DISCUSSION OF THE GROUNDWATER POLLUTION INDEX (PIG) METHOD AND APPLICATION OF STATISTICAL ANALYSIS AND GIS:

After the calculation of the Groundwater Pollution Index (PIG) using the results of physicochemical analyzes and the values of the Algerian standards (Algerian Water Quality

Standards, 2011), the water pollution class is determined for the 44 samples relating to the 11 sampling stations during the four campaigns (Table.7). Thus, five pollution classes (insignificant, low, medium, strong and very strong) are identified during the study period.

Table.7. State of degree of water pollution during the period of study [own elaboration]

Degree of pollution	Dry period SEP 2011		Wet period FEB 2012		Dry period SEP 2014		Wet period FEB 2015		Total	
	Number of samples	%	Number of samples	%	Number of samples	%	Number of samples	%	Number of samples	%
No pollution	0	0	0	0	0	0	1	9,09	1	2,27
Low pollution	0	0	1	9,09	0	0	5	45,45	6	13,64
Average pollution	0	0	4	36,36	0	0	2	18,18	6	13,64
Strong pollution	0	0	2	18,18	0	0	2	18,18	4	9,09
Very strong pollution	11	100	4	36,36	11	100	1	9,09	27	61,36

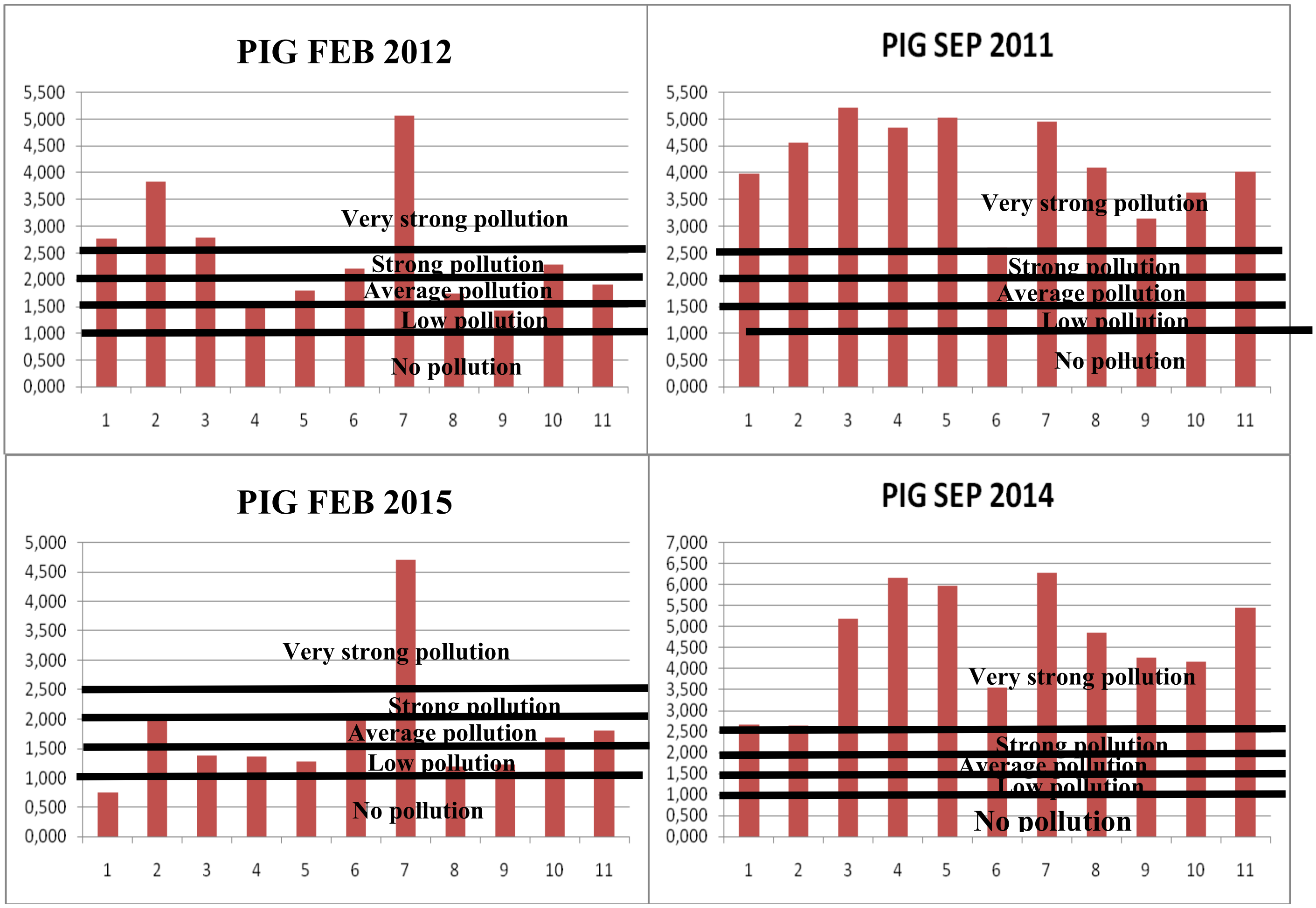

Fig.11. Sample-wise PIG values. Dotted line denotes range of pollution intensity [own elaboration]

According to the tables 1,2,3,4 and 7 and figures 9,10 and11 the values of the PIG index are between a minimum of 0.746 and a maximum of 6.287 with an average of 3.276 and a standard deviation of 1.60, which generally indicates a very strong pollution of the study area during this period of work.

-POLLUTION INDEX GROUNDWATER PIG FOR THE SEPTEMBER 2011 CAMPAIGN: For this campaign, the values of the PIG vary from a minimum of 2.591 recorded at the sample groundwater point (6) and a maximum of 5.216 recorded at the sample groundwater point (3) with an average of 4.190 and a standard deviation of 0.83 (Table .1) and (Fig .11).

According to the PIG classification (Table. 6), all the water samples studied during this campaign, show a very high pollution (Table .7).

-POLLUTION INDEX GROUNDWATER PIG FOR THE FEBRUARY 2012 CAMPAIGN: For this campaign, the values of the PIG vary from a minimum of 1.430 recorded at the sample groundwater point (9) and a maximum of 5.064 recorded at the sample groundwater point (7) with an average of 2.486 and a standard deviation of 1.10 (Table .2) and (Fig .11). According to the values of the PIG, the classification of water points during this campaign is as follows (Table.7):

- 36, 36% of water points present very high pollution;
- 18.18% of water points are highly polluted;
- 36, 36% of water points have average pollution;
- 9.1% of water points have low pollution.

-POLLUTION INDEX GROUNDWATER PIG FOR THE SEPTEMBER 2014 CAMPAIGN:

- For this campaign, the calculated PIG values range from a minimum of 2,646 recorded at the sample groundwater point (2) and a maximum of 6,287 recorded at the sample groundwater point (7) with an average of 4,658 and a standard deviation of 1,31 (Table .3) and (Fig .11). According to the PIG classification (Table.6), all the water samples studied during this campaign, show a very high pollution (Table .7).

-POLLUTION INDEX GROUNDWATER PIG FOR THE FEBRUARY 2015 CAMPAIGN: For this campaign, the values of the PIG vary from a minimum of 1.430 recorded at the sample groundwater point (9) and a maximum of 5,064 recorded at the sample groundwater point (7) with an average of 2,486 and a standard deviation of 1.10 (Table .4) and (Fig .11). According to the values of the PIG, the classification of water points during this campaign is as follows (Table.7):

- 9.1% of water points have insignificant pollution.
- 45.44% of water points have low pollution.
- 18.18% of water points have average pollution;
- 18.18% of water points are highly polluted;
- 9.1% of water points present very high pollution.

3.2.1. APPLICATION OF STATISTICAL ANALYSIS

CORRELATION MATRIX

The correlation matrix is a square matrix characterized by a correlation coefficient which can be used to distinguish the relationship between two parameters. Four correlation matrices were carried out for all the groundwater samples analyzed Tables 8,9,10 and 11.

Table.8. Correlation matrix for the September 2011 campaign [own elaboration]

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	DBO5	NO2	NH4+	Pb	DCO	PIG SEP 2011
PH	1,000																	
CE	-,199	1,000																
Cl	,099	-,049	1,000															
SO4	-,409	,396	,174	1,000														
NO3	-,508	-,100	-,208	,308	1,000													
HCO3	-,509	-,100	-,207	,307	1,000	1,000												
Na	-,226	,582	,504	,577	-,255	-,254	1,000											
K	,156	-,739	,541	-,099	-,155	-,153	,019	1,000										
Mg	,012	,633	,433	,409	-,283	-,285	,455	-,315	1,000									
Ca	,041	,827	-,091	,119	-,357	-,357	,280	-,737	,643	1,000								
Cu	,222	-,287	,374	-,650	-,239	-,237	-,052	,458	-,259	-,347	1,000							
Fe	,323	-,535	,114	-,460	-,480	-,478	-,058	,734	-,497	-,506	,644	1,000						
DBO5	,276	,058	,657	-,271	-,518	-,517	,264	,101	,361	,291	,349	-,006	1,000					
NO2	-,509	-,100	-,207	,307	1,000	1,000	-,254	-,153	-,285	-,357	-,237	-,478	-,517	1,000				
NH4+	-,243	-,479	,438	-,150	,165	,169	-,137	,575	-,038	-,489	,321	,248	,131	,169	1,000			
Pb	,019	-,053	,147	-,103	-,147	-,143	,047	,373	-,202	-,153	,525	,609	-,118	-,143	,223	1,000		
DCO	-,018	-,001	,502	-,042	-,301	-,304	,193	,028	,443	,112	,154	-,213	,754	-,304	,073	-,390	1,000	
PIG	-,380	-,144	,420	,110	,665	,666	-,031	,100	-,083	-,296	,220	-,338	,235	,666	,412	,016	,260	1,000

Table.9. Correlation matrix for the February 2012 campaign [own elaboration]

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	DBO5	NO2	NH4+	Pb	DCO	PIG FEB 2012
PH	1,000																	
CE	,133	1,000																
Cl	,144	,353	1,000															
SO4	,036	,875	,252	1,000														
NO3	-,178	,483	,577	,391	1,000													
HCO3	-,015	-,507	-,140	-,156	-,558	1,000												
Na	-,222	,115	-,099	,368	-,313	,670	1,000											
K	,029	,262	,667	,432	,090	,469	,601	1,000										
Mg	-,195	,384	,702	,447	,345	,237	,532	,784	1,000									
Ca	-,218	,529	,626	,535	,264	,076	,542	,759	,918	1,000								
Cu	,153	,245	,017	,376	-,227	,177	,343	,185	,411	,445	1,000							
Fe	-,034	,351	-,002	,447	-,167	-,034	,237	,191	,250	,499	,697	1,000						
DBO5	,253	-,572	,184	-,633	-,206	,118	-,376	-,029	-,196	-,248	-,255	-,090	1,000					
NO2	-,071	,471	-,044	,394	,750	-,666	-,354	-,399	-,194	-,201	-,266	-,183	-,376	1,000				
NH4+	-,295	,174	,429	,176	,500	,014	,068	,360	,328	,215	-,589	-,320	,141	,232	1,000			
Pb	-,029	,458	,099	,435	-,144	,094	,515	,426	,391	,626	,227	,657	-,096	-,213	,209	1,000		
DCO	,010	-,674	,071	-,692	-,260	,301	-,230	-,134	-,013	-,252	-,021	-,318	,697	-,453	,048	-,414	1,000	
PIG	,131	,078	,189	,149	-,264	,156	,188	,311	,324	,470	,601	,841	,396	-,438	-,156	,607	,136	1,000

Table.10. Correlation matrix for the September 2014 campaign [own elaboration]

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG SEP 2014
PH	1,000															
CE	,077	1,000														
Cl	,099	-,125	1,000													
SO4	-,363	,508	,260	1,000												
NO3	-,588	-,249	-,208	,116	1,000											
HCO3	-,589	-,250	-,207	,115	1,000	1,000										
Na	-,125	,510	,489	,638	-,369	-,368	1,000									
K	,286	-,694	,559	-,232	-,203	-,202	-,041	1,000								
Mg	,000	,444	,271	-,058	-,406	-,403	,375	-,162	1,000							

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG SEP 2014
PH	1,000															
CE	,077	1,000														
Cl	,099	-,125	1,000													
SO4	-,363	,508	,260	1,000												
NO3	-,588	-,249	-,208	,116	1,000											
HCO3	-,589	-,250	-,207	,115	1,000	1,000										
Na	-,125	,510	,489	,638	-,369	-,368	1,000									
K	,286	-,694	,559	-,232	-,203	-,202	-,041	1,000								
Mg	,000	,444	,271	-,058	-,406	-,403	,375	-,162	1,000							

Table.10. (Continued).

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG SEP 2014
Ca	,116	,806	-,091	,319	-,357	-,357	,328	-,692	,368	1,000						
Cu	,216	-,273	,374	-,570	-,239	-,237	,089	,469	,402	-,347	1,000					
Fe	,309	-,431	,113	-,488	-,480	-,478	-,048	,722	,064	-,506	,644	1,000				
NO2	-,564	-,239	-,288	,076	,994	,994	-,425	-,236	-,438	-,359	-,256	-,459	1,000			
NH4+	-,319	-,580	,438	-,274	,165	,169	-,146	,440	,169	-,489	,321	,248	,145	1,000		
Pb	-,230	,323	-,390	-,079	,178	,180	-,064	-,278	,143	,022	,248	,233	,235	-,134	1,000	
PIG	-,573	-,193	-,323	,037	,951	,952	-,400	-,211	-,376	-,386	-,133	-,304	,968	,140	,458	1,000

Table.11. Correlation matrix for the February 2015 campaign [own elaboration]

Corrélations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	NO2	NH4+	Pb	PIG FEB 2015
PH	1,000															
CE	-,113	1,000														
Cl	,142	,316	1,000													
SO4	,043	,867	,281	1,000												
NO3	-,156	,454	,619	,390	1,000											
HCO3	-,085	-,398	-,145	-,155	-,549	1,000										
Na	-,265	,168	-,080	,365	-,299	,671	1,000									
K	,029	,247	,654	,429	,096	,474	,599	1,000								
Mg	-,238	,409	,744	,424	,418	,230	,514	,775	1,000							
Ca	-,214	,519	,633	,539	,290	,066	,538	,739	,902	1,000						
Cu	,173	,196	,020	,382	-,215	,193	,340	,189	,303	,443	1,000					
Fe	-,019	,309	-,009	,466	-,169	-,030	,240	,205	,179	,499	,696	1,000				
NO2	-,066	,403	-,035	,396	,720	-,653	-,353	-,412	-,182	-,209	-,251	-,163	1,000			
NH4+	-,428	,360	,400	,181	,539	-,030	,065	,245	,414	,198	-,577	-,355	,279	1,000		
Pb	-,076	,408	,069	,423	-,140	,049	,504	,370	,370	,616	,236	,659	-,205	,152	1,000	
PIG	-,004	,443	,092	,608	-,117	,063	,443	,369	,386	,665	,758	,955	-,174	-,255	,745	1,000

CORRELATION: Correlation is measured by what is called coefficient of correlation (r). Its numerical value ranges from +1.0 to -1.0. It gives us an indication of the strength of relationship. In general, r > 0 indicates positive relationship, r < 0 indicates negative relationship while r = 0 indicates no relationship (or that the variables are independent and not related). Here r = +1.0 describes a perfect positive correlation and r = -1.0 describes a perfect negative correlation. Closer the coefficients are to +1.0 and -1.0; greater is the strength of the relationship between the variables. According to the r classification, the physicochemical parameters of water samples studied during this period of work, can divided at 6 groups (Table .8), (Table .9), (Table .10) and (Table .11). **Group 1:** Parameters with a correlation coefficient greater than 0.9 have a very large linear relationship. **Group 2:** Parameters with a correlation coefficient between (0.85-0.90) have a great linear relationship. **Group 3:** Parameters which have a correlation coefficient between (0.80-0.85) have a signifying linear relation. **Group 4:** The parameters with a correlation coefficient between (0.70-0.80), have a good linear relationship. **Group 5:** Parameters which have a correlation coefficient between (0.60-0.70) have an average to acceptable relationship. **Group 6:** Parameters with a correlation coefficient less than 0.60 have a weak to very weak linear relationship.

The examination of the correlation matrices allowed us to establish some correlations and more precisely the significant correlations between the various elements and the PIG (Table .12).

Table.12. Correlation coefficient of PIG during the four campaigns [own elaboration]

Correlations	PH	CE	Cl	SO4	NO3	HCO3	Na	K	Mg	Ca	Cu	Fe	DBO5	NO2	NH4+	Pb	DCO
Dry period PIG SEP 2011	-,380	-,144	,420	,110	,665	,666	-,031	,100	-,083	-,296	,220	-,338	,235	,666	,412	,016	,260
Wet period PIG FEB 2012	,131	,078	,189	,149	-,264	,156	,188	,311	,324	,470	,601	,841	,396	-,438	-,156	,607	,136
Dry period PIG SEP 2014	-,573	-,193	-,323	,037	,951	,952	-,400	-,211	-,376	-,386	-,133	-,304	/	,968	,140	,458	/
Wet period PIG FEB 2015	-,004	,443	,092	,608	-,117	,063	,443	,369	,386	,665	,758	,955	/	-,174	-,255	,745	/

For the Dry period (SEP 2011), the PIG is moderately correlated with NO_3^- (0,665), HCO_3 (0,666) and NO_2 (0,666).While, the PIG is strongly correlated with $^-$ (0,951), HCO_3 (0,952) and NO_2 (0,968) during the Dry period (SEP 2014) . For the Wet period (FEB 2012) , the PIG is moderately correlated with Cu (0,601), Pb (0,607) and strongly correlated with Fe (0,841). While, the PIG is moderately correlated with SO_4^{2-} (0,608) and Ca (0,665) and it is strongly correlated with Cu (0,758), Pb (0,745) and Fe (0,955).

3.2.1. APPLICATION OF THE GIS:

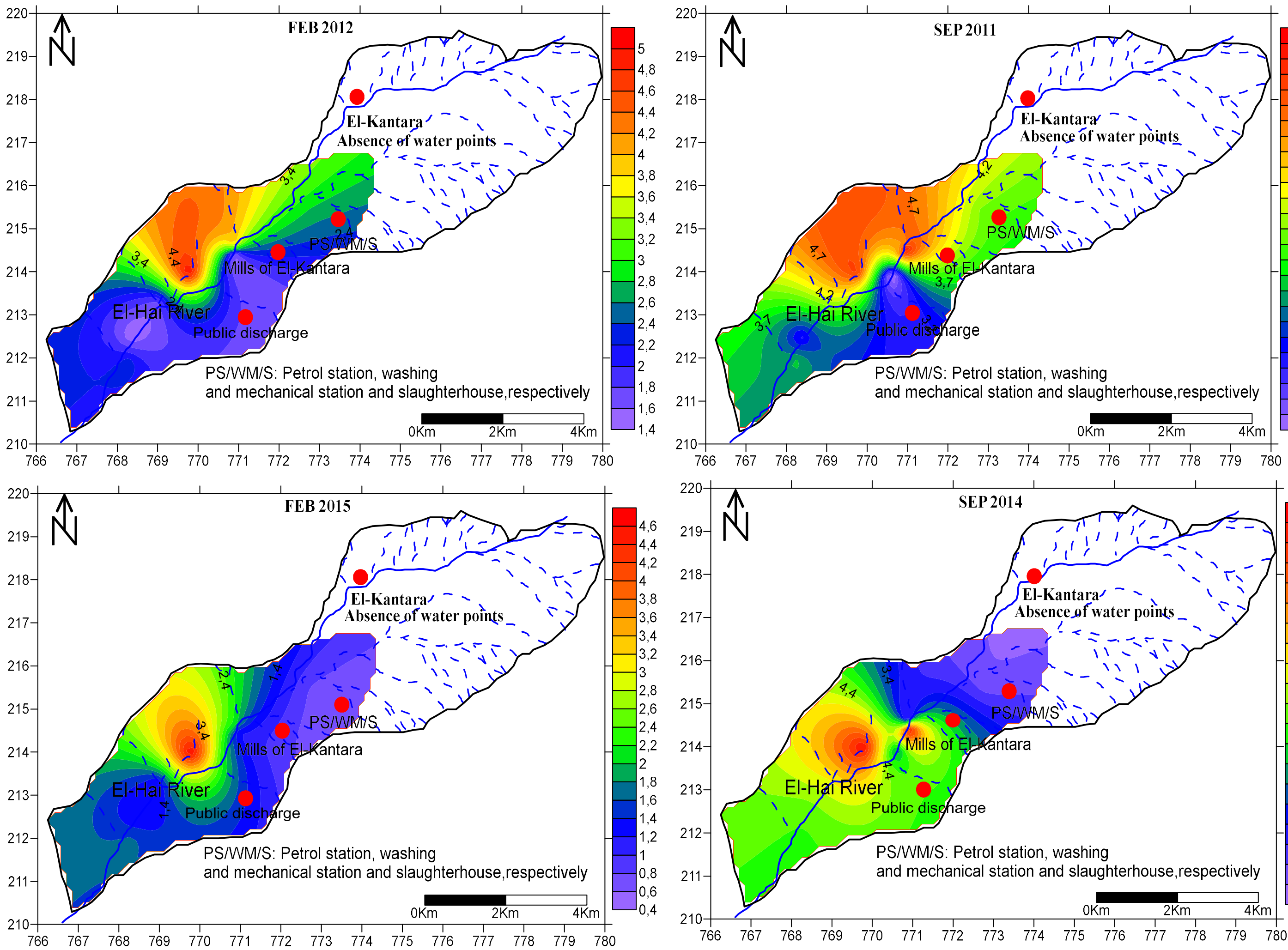

Fig.12. Spatial distribution of groundwater pollution zones in the case study area (El-Hai River Basin, El-Kantara District, Algeria) based on PIG [own elaboration]

The degree of pollution of the groundwater of El-Hai River Basin, El-Kantara district, calculated on the basis of the pollution index groundwater PIG, indicate that 61,36% of the samples (27 samples) show a very strong pollution (very high pollution) which occupied all of the land at September 2011and with a lesser degree September 2014. It is located in the North -west sector at wet period. The remaining samples belong respectively to the low, average, strong and no pollution classes with 13,64% or (6 samples); which is important during wet period and in particular in February 2015, 13,64% or (6 samples); which is important during wet period and in particular in February 2012, 13,64% or (6 samples), 9,09% or (4 samples) and 2,27% or (1 sample). Spatial distribution map of zones of PIG has been prepared using GIS [29, 30, 31] (Fig.12). The variation map depicts that very high pollution zone high pollution zone by 61,36% and high pollution zone by 9,09% are covering the majority of the study area; where the topography is low (downstream area) and the groundwater samples collected from the El-Kantara district wells which located near the sources of pollution. The globality of the results show that certain chemical elements exceed the acceptable standards (WHO 2008 and Algerian 2011) and justifies the strong concentrations by heavy metals (Fe, Cu and Pb) , HCO_3, NO_3^-, NO_2 and with less degree SO_4^{2-} in the activity zone(waste water especially of the small industry: petrol stations, of washing and mechanical stations, semolina factory, slaughter-house…). Thus, the increase in the contents of toxic elements is supported by scrubbing of waste of the discharge, the drain and the infiltration of surface waters. The absence of preliminary treatment of the urban and industrial wastes would be in great part responsible for the contamination of subsoil and ground waters in the area case study.

4. CONCLUSIONS

The Pollution Index Groundwater PIG approach is primarily designed to accurately identify the degree of degradation of water quality to target pollution control programs. In the case study area (El-Hai River Basin, El-Kantara District) the computed values of PIG are between a minimum of 0.746 and a maximum of 6.287 with an average of 3.276 and a standard deviation of 1.60, which generally indicates a very strong pollution of the study area during this period of work. The results obtained from the study indicate that groundwater is not suitable for both drinking and domestic purpose. This pollution is mainly related to the strong concentrations by heavy metals (Fe, Cu and Pb), HCO_3, NO_3^-, NO_2 and with less degree SO_4^{2-} which is compatible at the sites subjected to wastewater discharges from the Town of El-Kantara, the small activity and industrial zone (waste water especially of the small industry: petrol stations, of washing and mechanical stations, semolina factory, slaughter-house…). Faced to this situation, it is recommended to take protective management measures for this aquifer and to establish rigorous control of domestic and industrial discharges by the construction of a purification station and to regulate agricultural activity especially around wells and boreholes that are intended for human consumption.

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