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Alteration of the Aquifer Water in Hyperarid Climate, by Wastewater: Cases of Groundwater from Ouargla (Northern Sahara, Algeria)

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Abstract: The present study is registered, on the area of Ouargla (the Sahara septentrional, Algeria) reports of the aquifer contamination by the anarchistic urban rejections. By its geomorphology (basin), its hyperarid climate and the presence of chotts, the area is subjected to an important degree of vulnerability, encouraged by the discharges of wastewater (domestic and irrigation). These factors expose aquifer's water to a severe pollution. In order to evaluate this pollution, a regular monitoring of the quality of aquifer's water and the collecting canal's water, was conducted over seven months (January- July 2005). The statistical processing, the space-time chart and the calculation of pollution index of physicochemical, organic and bacteriological analyses data, made it possible to identify the behavior of these parameters according to the temperature, evaporation and salinity. The complementarity of the results shows that aquifer's water is exposed to a permanent danger, degrading the environment. The situation imposes possible solutions, by optimization of a wastewater treatment process meets the standards required, based on a combined treatment (biological and physicochemical).

Key words: Urban effluents, pollution index, biodegradation, eutrophication, self-purification

INTRODUCTION

The pollution affects as well the industrialized countries as those in the process of development. The problem is particularly serious for the countries whose climate is arid. Because of a pronounced hydrous deficit, the concentration of the pollutants in water remains high whereas their capacity of recycling is very low.

In the case of the basin of Ouargla, the pollution generated by the discharge of wastewater has reached an alarming level due to the diversity of pollutants and the large quantity of wastewater (40906 m^3 day^{-1} for the year 2005)[11]. The surface aquifer, is exploited by wells for agricultural and domestic purposes, crossed by a collecting in the open air canal, pollution deteriorates quality and limit its uses.

Thus we make state of the contamination of the surface aquifer water by the anarchistic urban rejections. The main factor influence this situation is topography: The total height is 9 m only, between the highest point (Ksar) and the lowest (chott), for a site which extends in its broad dimensions from, 5 km from East to West and 8 km from North to South This natural constraint obliged that the realization of the collectors, which flow by gravity, must have the slope and thus progress in-depth. Two figures summarize the extent of the anomalies on the main network: 15% of flowing sections against slope and 55% have a slope lower than 5%[3]. The direct infiltration without any water treatment, highly mineralized (urban and agricultural); from the deep aquifers, Complex Terminal (CT) and Continental Intercalary (CI), through sandy clay gypseous of Quaternary on the surface, gain the surface aquifer of the Basin and therefore, a rebound of his piezometric level in a region, where the topography is flat with no outlet (endoreic basin).

The determination of Organic Pollution Index (OPI), Eutrophication Index (EI) and Microbiological Quality Index (MQI) with the physicochemical study of waters coupled with the distribution of organic parameters in the wastewater collector and aquifer's water, can draw some conclusions as to the biodegradation of organic matter and power self-purification of the water.

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MATERIALS AND METHODS

The area of Ouargla is situated north-east of the Great Algerian Sahara, it is distant 850 km from the capital Algiers. It is limited to the north by Djelfa and El-Oued departments, to the south by Illizi and Tamanrasset departments, to the west by Ghardaia department and east by Tunisia. The Basin of Ouargla corresponding to a great depression (a big Oasis of the Algerian Sahara), which covers an area of about 750 km^2 (Fig. 1). Its natural limits are defined males: it is limited to the west by a calcareous plate, to the east by a plate whose boundaries are not clear; to the south by a massive dune covers the ruins of Sedrata and the North by Zabret Bouaroua.

The appearance climate of the region is desert or hyperarid: precipitations are low and erratic, ranging from 0.01 and 17.2 mm by exceptional year[2]. Temperatures vary greatly between night and day. The average annual temperature ranges from 06°C (January) and 43°C (July). The evapotranspiration, also varies between 380 (July) and 112 mm (January).

From hydrogeological a surface aquifer is located at depths ranging from 1-3 m in urban areas and 0.5-0.9 m in agricultural areas, it surfaced in the Chotts and may reach 15 m deep in the border areas (sandstone relief).

The lithology of the aquifer consists of fine to medium sand clay, rarely coarse south of Ouargla and more to the North (N'goussa) sands are rich in gypsum (Fig. 2), which becomes dominant Sebkhet Safioune[10].

- Zone A: It is the most spread class, it represents approximately of 75% of the soils
- Zone B: It characterizes the chotts and the sebkhas
- Zone C: It characterizes the slopes of the basin and the Mio-Pliocene plate

At the basin of Ouargla the surface aquifer is not exploited because of the rate of salt contained in its waters. It is thick from 1 to 8 m and is based on a tight impermeable level, which occupies the bottom of the valley of Ouargla and isolates it from the underlying aquifers. The aquifer is recharged by:

- Wastewater discharges of domestic origin
- Excess water tied to a palm irrigation irrational
- Runoff from the upper sections and the input of the three Wadis flooding in the bassin (N'sa, M'zab and M'ya)

The harmful effects of the rising water in the basin are mitigated by the existence of the drainage systems

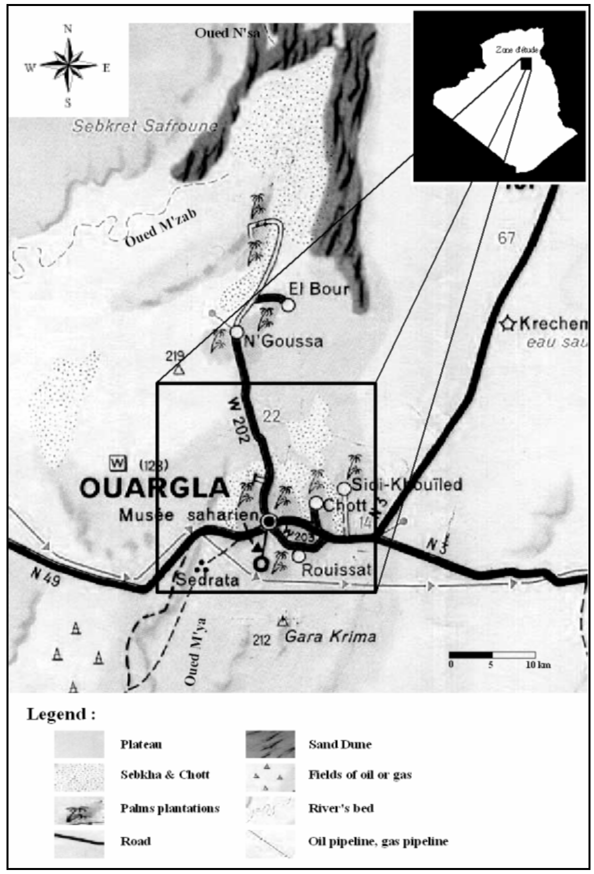

Fig. 1: Localization of the study area

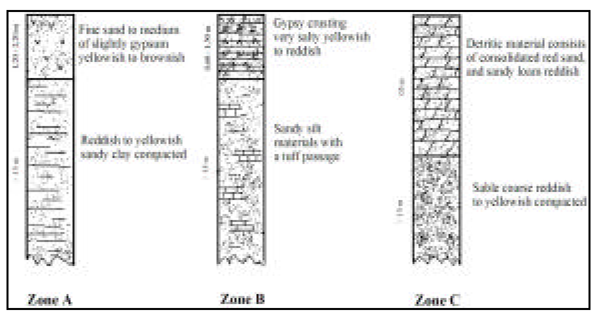

Fig. 2: Lithological log of the surface aquifer

(canals), including those of palm (total length 80 km) and the crossing of Sebkha Bamendil and the entire northern part of Ouargla (10.5 km). All these effluent water is pumped evacuated to the Sebkha Oum-Raneb (Fig. 3) located 8 km north of the town of Ouargla.

The total flow of wastewater is 29900 m^3 day^{-1} for the year 2005, with 61% network and 39% individual assainissement, 12900 m^3 day^{-1} deversed in the aquifer and 17000 m^3 day^{-1} in the surface (drains and chotts)[3].

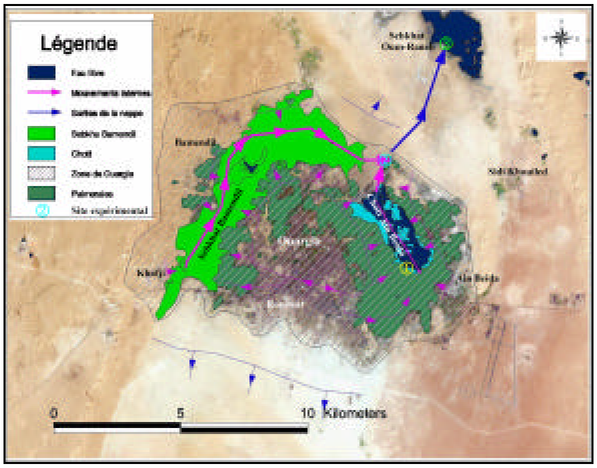

Fig. 3: The water flow in the basin of Ouargla (source: BG, 2004)

In order to monitor the behavior of pollution in the aquifer and the canal, we used physico-chemical and bacteriological data (Slimani, 2006)[11] complemented by measures of organic parameters in the piezometers (aquifer) and of upstream downstream in the discharge stations (canal).

The analyses are carried out according to standard AFNOR[11]. Eight sampling campaigns were made between January and July (2005) with a time interval of 25-30 days, three piezometers (PZ1, PZ2 and PZ3) installed respectively near each rejection point (R1, R2 and R3).

The methods developed in the interpretation of data are based on a statistical treatment using the application of software Aquexmono.xls [7], resulting in the calculation of Organic Pollution Index (OPI), Eutrophication Index (EI), Microbiological Quality Index (MQI) and Biodegradability Index (BI).

The principle of the OPI is to spread the values of polluting elements in 5 classes (Table 1) and then determine, from its own measures, the number of corresponding class for each parameter and then to make the average[07].

The Evaluation of eutrophication: There's no reliable index to evaluate the level of eutrophication from chemistry. Experiments with artificial pollution have shown that nitrates alone do not entail a significant increase in crop production while a low intake of phosphates enough to trigger the proliferation plant. It is well known that the phosphorus is the limiting factor. As it is very expensive to eliminate sewage, the problem of eutrophication persists for a long time (LECLERCQ L, 2001)[7].

Table 1: Classes of organic pollution

Parameters classes	DBO5 ($mg\text{-}O_2\ L^{-1}$)	Ammonium ($mg\text{-}N\ L^{-1}$)	Nitrites ($\mu g\text{-}N\ L^{-1}$)	Phosphates ($\mu g\text{-}P\ L^{-1}$)
5	<02	<0.1	<05	<15
4	2.1-05	0.1-0.9	06-10	16-75
3	5.1-10	1.0-2.4	11-50	76-250
2	10.1-15	2.5-6.0	51-150	251-900
1	>15	>6	>150	>900

OPI = average number of classes of 4 parameters (at best):
- 5.0-4.6: Null organic pollution
- 4.5-4.0: Low organic pollution
- 3.9-3.0: Moderate organic pollution
- 2.9-2.0: High organic pollution
- 1.9-1.0: Very high organic pollution

Table 2: Classes of bacteriological pollution

Class No.	Bact. tot. (mL^{-1})	Colif. f. (mL^{-1})	Strepto. f. (mL^{-1})
5	<2000	<100	<05
4	2000-9000	100-500	05-10
3	9000-45000	500-2500	10-50
2	45000-360000	2500-20000	50-500
1	>360000	>20000	>500

The average number of MQI classes is like calculating the OPI by the following interpretat ion:
- 4.3-5.0: Null Fecal contamination
- 3.5-4.2: Low Fecal contamination
- 2.7-3.4: Moderate Fecal contamination
- 1.9-2.6: High Fecal contamination
- 1.0-1.8: Very high Fecal contamination

Calculation of microbiological quality (MQI): The limits of the classes (Table 2) were established by BOVESSE and DEPELCHIN, 1980[7].

RESULTS AND DISCUSSION

Chemical facies: The representation of physicochemical data on the Piper diagram (Fig. 4) shows a chemical facies which still depends on the geological nature of the aquifer (responsible geochemical)[1] and agricultural and industrial activities (anthropic).

Generally Piper diagram shows a single chemical facies, whatever the effluent water or underground water, is Cl-Na but the points are closer to sulphated limit, for a facies Cl-SO_4-Na. The circles of mineralization (D = TDS*0.2) show that water of the aquifer is more mineral-bearing than that of water of rejections.

The biodegradability index (BI): The indices indicate the biodegradability classes' auto-purification biodegradability describing environments rich or poor in organic matter.

The space-time variation of the report DCO/DBO5 showed a biodegradability index between 2 and 3. This situation (Fig. 5) indicates that the wastewaters

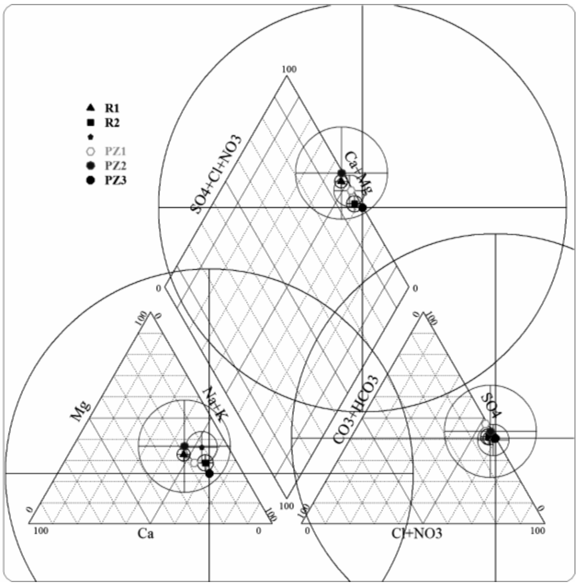

Fig. 4: The chemical facies representation in Piper diagram for discharges points and piezometers

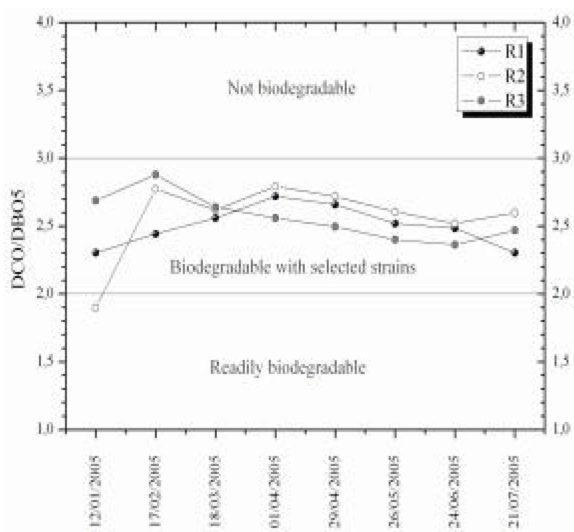

Fig. 5: Variation of biodegradability index at discharges points according to time (year 2005)

effluents are biodegradable domestic effluents with selected strains, requiring a combined treatment (biological and physicochemical)[12].

The Organic Pollution Index (OPI): The index values of organic pollution indicate the space-time variation of the pollution classes by decomposition or auto-purification water. Figure 6 shows families relating to the wastewater indices ranged from 1.66-1, showing a

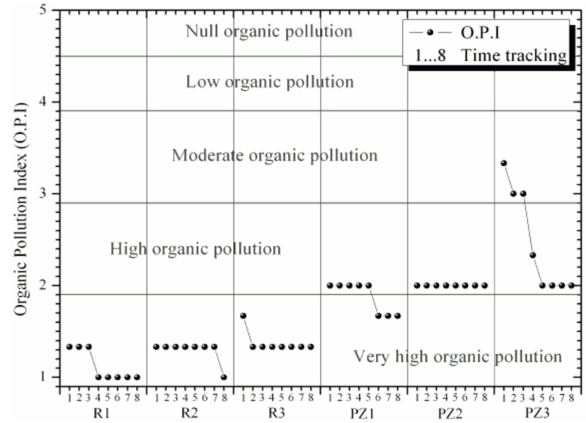

Fig. 6: Variation of the organic pollution index for discharge points and piezometers according to time (year 2005)

single class of organic pollution very high, with spatial evolution reflecting low auto-purification progressive going downstream (Sebkhet Oum-Raneb), against their developments show a low temporal degradation in the warmer months.

Groundwater has indices ranging from 1.66-3.33, showed three classes of organic pollution (very high, high and moderate). The spatial evolution reflects a net auto-purification progressive ranging from upstream (PZ1), the nearest point of surface pollution, towards downstream (PZ3). The self-purification is more important while going about the warmer months. This is explained by the phenomenon of evaporation - concentration.

Thus very high pollution characterizes the upstream part like zone of contribution (City and palm plantations) and the pollution moderated by self-purification[9] characterizes the downstream part like zone of rejection (Sebkhet Oum-Raneb). This pollution increases in estival period (intense evaporation "concentration") in a plane relief.

The Eutrophication Index (EI) and behavior of mineral nutrients: The nitrogen and phosphorus are also parameters indicative of eutrophication. The fragility of the environment study was taken into account by tracking mineral nutrients in the water and the canal (NO_3, NH_4 and PO_4)[4].

Nitrates-ammonium: The space-time variation of nitrates and ammonium in waste and underground water (Fig. 7) shows a high content nitrates (40-130 mg L^{-1}) in water of the channel, on the other hand a fall in groundwater (60-10 mg L^{-1}). The spatial evolution

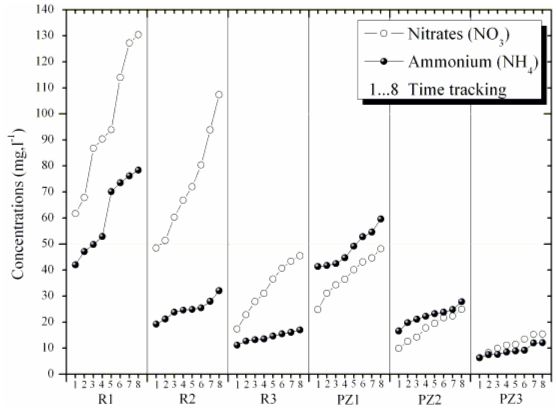

Fig. 7: Variation of NO_3 and NH_4 for discharge points and piezometers according to time (year 2005)

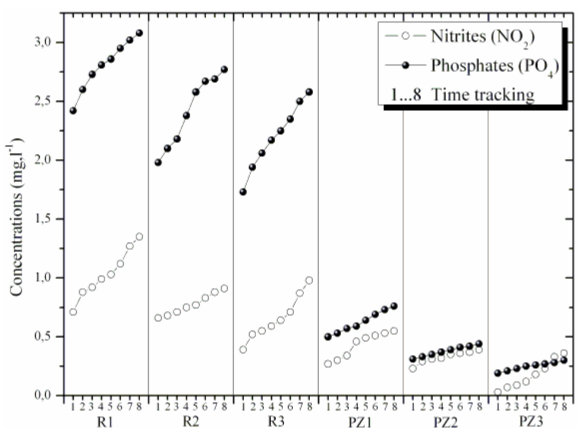

Fig. 8: Variation of the NO_2 and PO_4 for discharge points and piezometers according to time (year 2005)

shows a decrease downstream, against the temporal evolution is increasing in estival period, this is explained by the phenomenon combined nitrification (fertilizer) by the waters feeding the canal and denitrification in the reductive water (low oxygen). On the same figure (Fig. 7), the reverse in the ammonium. The presence of ammonium fertilizer used comes in irrigated (upstream) and a contamination by organic matter at the level of human rejection zones (open channel). This nitrogenized form becomes dominant as nitrates in groundwater (PZ1 and PZ2).

Nitrites-phosphates: The space-time evolution of nitrites and phosphates in water of the channel and underground (Fig. 8) shows a high content of phosphates (2.6-3.1 mg L^{-1}) in wastewater, on the other hand a fall in ground waters (0.7-0.3 mg L^{-1}).

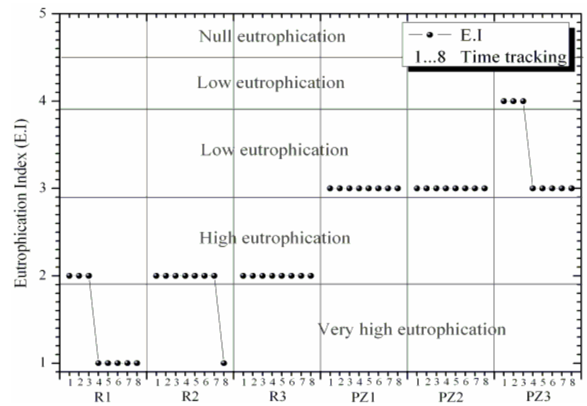

Fig. 9: Variation of the eutrophication index for discharge points and piezometers according to time (year 2005)

The spatial evolution shows a decrease towards the downstream, against the temporal evolution grow during the summer, but with a slight increase in groundwater than reject water. This is due to the fertilizer and discharges from domestic waters feeding the canal, as well as the precipitation of phosphatic minerals (Apatite) by its low solubility[5] in reducing water highly mineralized (ground water).

The spatial evolution of nitrites shows a decrease downstream, against the temporal evolution is increasing in estival period, this is explained by the phenomenon combined nitrification-denitrification.

The Eutrophication Index (EI): The index values indicate the space-time variations of the eutrophication classes by a wealth or poverty of nutrients.

The wastewater is classed between 1 and 2 (Fig. 9) indicating a high to very high degree of eutrophication. The spatial evolution shows very slight decrease nutrients (NO_3 and PO_4) by going downstream (Sebkhet Oum-Raneb) and their temporal trends show an enrichment in terms of nutrients in the summer months especially upstream and remains constant downstream.

Groundwater eutrophication shows a moderate to low, with an EI from 3-4 (Fig. 9). The spatial evolution shows a consistency of nutrients for a moderate level except that in the downstream (Sebkhet Oum-Raneb) a slight decrease during the winter reflecting the low level of eutrophication.

The Microbiological Quality Index (MQI): The enumeration of fecal coliforms and fecal streptococci is an indicator of fecal contamination. The MQI ranged from 1.33 (R1) to 2.33 (R3) and 3.67 (PZ1) to 5 (PZ3) (Fig. 10).

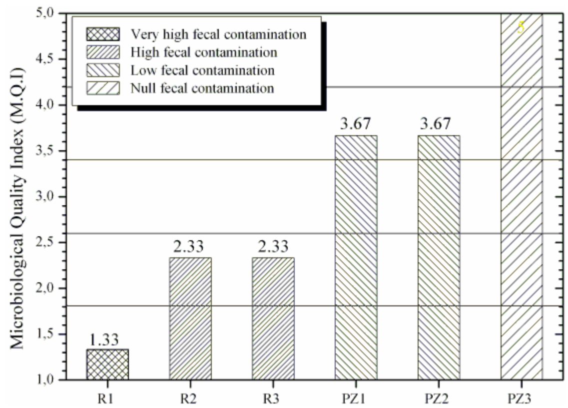

Fig. 10: Variation of the microbiological quality index for discharge points and piezometers

Wastewaters are indications of microbiological quality showing a very high fecal contamination in the discharge point R1 (upstream) and a relatively lower fecal contamination (high) to R2 and R3. This decrease downstream explained by the distance of the source of contamination and the loss of organic matter by biodegradation[8].

Groundwater showing signs of microbiological quality for piezometers PZ1 and PZ2 by low fecal contamination, this due to the enabling environment for this increased by the presence of organic matter and temperature. By contrast, PZ3 shows a zero fecal contamination, that due to sterility by the very high salinity (sebkha Oum-Raneb).

CONCLUSION

This work has seven months results (eight samples) out of three experimental sites of the upstream① towards the downstream③, each site relates to a discharge point and a piezometer, in a sand gypseous basin has a flat topography, under hyperarid climate.

The monitoring of the physicochemical and organic parameters made it possible to detect a temporal increase in the concentrations of all elements (chemical and organic), from January to July still under the effect of temperature by evaporation of surface and underground water.

The spatial evolution shows a decrease downstream nutrients and organic matter of anthropic (pollution), it is caused primarily by the distance from sources of pollution (agricultural and domestic) and the biodegradation organic matter.

The calculation of pollution index allowed to classify the wastewater in biodegradable domestic effluent with selected strains showing a very high organic pollution and bacteriological by an anthropic contribution rich in organic matter and nutrients upstream. The eutrophication index ranks water of rejection in high eutrophication by a wealth of nutrients which promotes algal proliferation at surface water (chott and sebkha) reflecting an anoxia.

Groundwater shows high organic pollution, which results in an infiltration of pollutants through the unsaturated zone permeable and low thickness (in our case 0.2-1.2 m) of a lithology consists of fine to medium sandy clay rich in gypsum towards the sebkhas, reflecting the sensitive area vulnerable to pollution. The eutrophication index shows a moderate level, which can impact on surface water by the rising waters.

The high organic, bacteriological and eutrophic pollution in a sensitive area has adverse impacts on the environment and public health, which requires a combined treatment (biological and physicochemical).

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