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Research on ground water pollution : comportment of soil and groundwater of Soukra plain with the use of seasonal irrigation by the urbain and treated sewage of Tunis city.

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ABSTRACT

This paper presents results of study carried out in the area of Soukra near the city of Tunis, to determine effects of seasonal irrigation use from domestic and treated sewage on the quality of ground waters.

Numerous analysis are carried out for both ground waters and irrigation effluent. Detailed sampling survey of aquifer took place over 20 months from March 1977 to november 1978. Samples are collected at the frequency of 9 every 15 day. Irrigation flow is sampled during irrigation season generally in dry season from June to november. 60 samples vere collected during August 1977 at the frequency of 9 in the week taken generally on thursday saturday and Monday. 30 samples of 24 hours each one were collected each day in August 1978. They were analysed for both dissolved and representative constituents of this flow. Interpretation of results showed effects on both soil and ground waters. In the soil, two months after the begining of irrigation increasing accumulation of dissolved constituents took place caused by the use of irrigation. Four months after, these substances were washed to the aquifer. In the aquifer these two reactions are reflected in the variation of ground water compositon. For dissolved elements when increasing accumulation took place in the soil, the receiving aquifer contained low contents, with decreasing accumulation in the soil, significant contamination of the aquifer took place, for detergents and phosphates results indicate contamination of the aquifer. Comparison of irrigation water concentration and ground water variation shows clearly relation belween potentiel of contamination in the aquifer and quality of irrigation flow, variation of phosphates and boron in 1977 and 1978 demonstrates this relation.

I.- INTRODUCTION : The data base :

The water resource division / DRES initiated in 1976 a program to investigate questions about pollùtion of water supplies and to study phenomena that effect the spread of pollutants through surface and ground waters. The major initial effort under this program was and appraisal of the existing situation in Soukra aquifer with irrigation from domestic and treated sewage of city capital.

I.1 Geological and hydrogeological background

The Soukra plain is situated in the north east of Tunis - Fig (1). Choutrana plain was selected for this study, geological formation is from recent quaternay and consists of coastly sand dune of Soukra.

Soukra plain contains a lentiform aquifer which is in contact with free marine waters, thickness is 1 m in studied area, Since 1952, because the increasing of salinity from see water a detailed plan for irrigation use by domestic and treated sewage of Tunis city was drawn up.

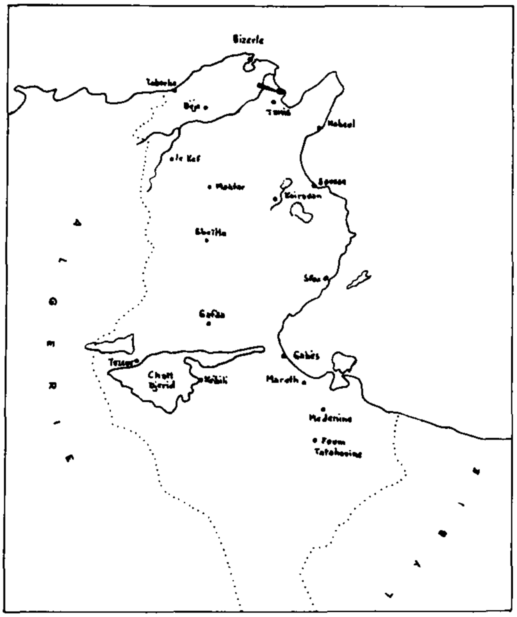


Fig (1). Map showing studied area

Values of transmissivity (T) were 10^{-4} m2/s - 7.10^{-4} m2/s. Permeability values (K) were 10^{-4} m/s - 7.10^{-4} m/s.

The direction of flow is towards the north, to Sebka Ariana*. The ground water gradient is 1 ‰; the water table is at - 2, - 4 m deph. Ground water recharge depends principally of rainfall supply, it is estimated from THORNWHAITE method, some 66.000 m3. Hydrodynamical reserves are 10.000 m3/year. Aquifer volume is some 240.000 m3.

I.2 Organization and importance of irrigation use.

The region studied has an area of 300 ha. Treated water pumped from epuration station of Cherguia is carried to the irrigation area in closed pipes. Waste water treatment is the second stage and consists of «activated sludge process». In irrigation area, water is discharged into Soukra reservoir which constitutes the distributor to irrigated parcels.

In 1977 application of water is daily from 1 July to 28 november, distributed quantities are metered and are 850.000 m3. In 1978 they began earlier, with more regularity - In 1977 they irrigated from 6 o'clock to 18 o'clock in 1978 it is from 6 o'clok 23 o'clok - from 1 June, quantities reased to 1.000 000 m3.

* time lagoon reduced to salt crust in dry season.

I.3 Network

Ground water sampling has been done from shallow piezometers. A number of 9 has been set in the most and regular irrigated parcels. Methods of measuring specifics pollutants were classic and consists of colorimetric and flame photométric tecknics.

II - QUALITY CHARACTERISTIC OF IRRIGATION FLOW

Information on the quality of irrigation water are summarized in follows table. Caracteristics are :

- high concentration with considérable variation in 1977.
- with the exception of boron, all the others presented lower and homogeneous contents, it is due to the more efficient equipment in treatment plants.

Compared to water quality standard of European authority «General case» water in 1978 is satisfactory to be discharged immediately into rivers. It seems that irrigation from this effluent will not be danger to ground-water accordingly to the soil purification power.

Elements	Data of 1977			Data of 1978			Defined standard of water to be discharged into rivers
	av.val	max.val	min.val	av.val	max.val	min.val	
p^H	7	8.4	6.7	8.0	8.4	7.0	surrounding nentral value
Conductivity $mmhos.cm^{4}$	2.0	4.5	0.8	1.5	2.8	0.5	
Detergents mg/l	0.7	1.5	0.5	0.7	1.2	0.5	2
boron mg/l	0.2	0.8	0.0	1.0	4.0	0.4	0.5
phosphates mg/l	11.0	18.5	2.5	5.0	12.0	0.5	must be fixed with opinion of agriculture ministry and health ministry
Cl^- mg/l	300	1000	200.0	300.0	400.0	80	" " "
$So4^=$ mg/l	250.0	1000	150	250.0	325	70	" " "
Na^+ mg/l	225.0	810.0	140.0	175.0	220	60	" " "
Ca^{2+} mg/l	150.0	260.0	100.0	90.0	120.0	55	" " "
Mg^{2+} mg/l	50.0	120.0	30.0	50.0	120.0	10	(1000 mg/l
K^+ mg/l	30.0	50.0	20.0	30.0	40.0	5	(400 mg/l
No_3^- mg/l	20.0	145.0	0.0	5.0	15.0	0.0	
NH_4^+ mg/l	30.0	396.0	1.8	1.8	7.0	0.0	40.0
DBO_5 mg/l	50.0	11.5	8.0	20.0	45.0	3.0	30 mg/l for samples of 24 hours
DCO mg/l	180.0	320.0	60.0	50.0	120.0	10.0	90 mg/l for samples of 24 hours

III - COMPORTMENT OF SOIL WITH IRRIGATION USE

III.1 - Mineralogical character of the soil

Mineralogical composition indicate that interaction between soil and percolating water constituent is low : 50% of quartz, 30% of calcite and 20% of clay. Clay fraction consists of the least active minerals : 10% of hard crystalline kaolinites and 10% of illites crystallizing in semectites.

III.2 - Humus proportion in the soil.

Measures of the exchange capacity value has been considered. Results of 10 samples (3 me%) illustrate a significant effect of organic matters.

III.3 - Study of pedological profiles Fig (2)

In addition to these determinations, pedological profiles are studied by examining the soil in its natural field conditions. Vertical sections are examined at frequent intervals : two monts before the irrigation, two months after and four months after.

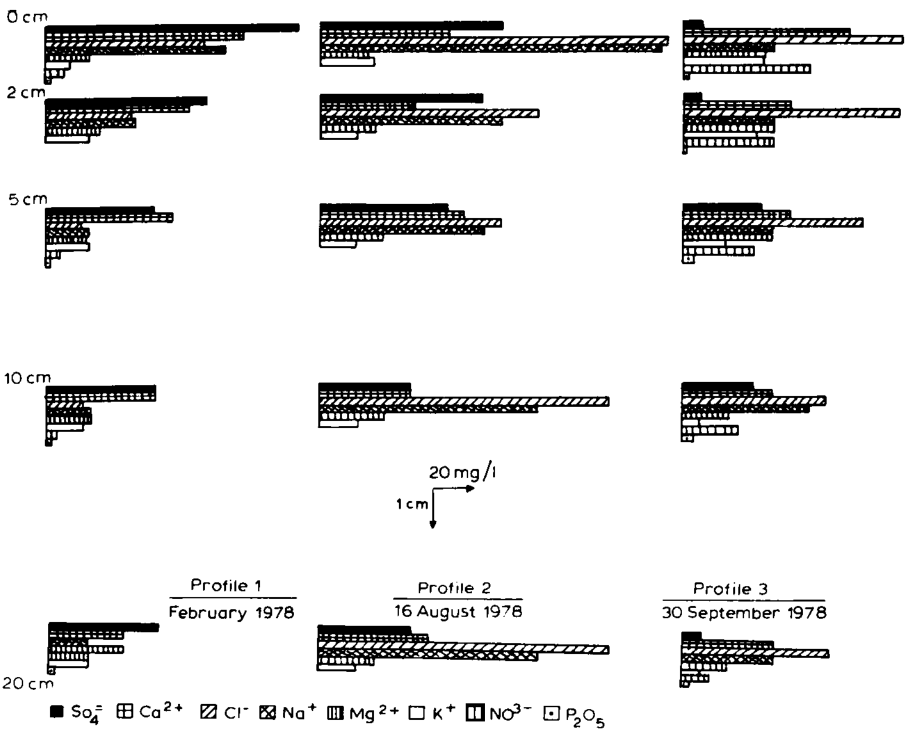


Fig. 2 . Pedological profiles

Profile N° 1. It is carried out before the spread of manure and fertilizer. Nutrients which had been accumulated during humid season were certainly washed with rainfall of March, April and May.

Sulphates and calcium. Concentations follow very similar patterns : considerable values at surface (0,0 cm - 2,0 cm), lower and constant values at deph. Hight values are caused by organic matter degradation.

Chloride and Sodium duplicate the pattern of sulphates and calcium. Na^{+}contents are relatively high than Cl^{-} contents, it is attributable to its lower movement in the soil.

Potassium and Magnesium present the same variation but in lower contents due to the fixation by organic matters.

Nitrates and phosphates are present along all the profile, but phosphates in lower unchanginy contents.

Profile N° 2. Sulphates are lower, the average irrigation water concentration is 250 mg/l. This remarkable decreasing should be attributable to their reduction in sulphides, but this isn't identified considering the unchanged sulphides composition of the aquifer.

Calcium is lower at surface and higher from 5,0 cm deph. It seems that with humus effect calcite is partilly dissolved in Ca-bicarbonates which is leaching with percolating waters. Comparison with profile (1) shows that there is no significant variation, calcium then brought by irrigation waters (100 mg/l) is adsorbed and the mobile calcium is due to dissolution of the calcite.

Clorides increase considerably, certainly due to the enrichment by irrigation waters (300 mg/l), also levels are variable along the profile due to its high geochemical mobility. Sodium, contents are variable and higher in deph, then it is partially washed .

Magnesium contents are constant. Irrigation waters magnesium is then fixed.

Potassium. Contents increase slightly at surface (0,0 cm), an enrichment from irrigation water is then possible (30 mg/l). At 2,0 cm deph, contents have been decreased and from 5,0 cm deph they leave unchangeable ; it seems that irrigation water tends to destroy the ex-equilibrium.

Profil N° 3. Now sulphates and chlorides are considerably lower due to the decreasing of soil activity. Percolating waters leached these elements.

Na^{+}ions have been less important. They are then leached or fixed by the soil.

A similar conclusion can be reached for $K^{+}$and Mg^{2+}ions variations show that the ex-equilibrium is totally distroyed : The power that the soil has to epurate is gradually reduced with continued irrigation use.

Calcium levels leave unchanged. The power that the organic matter has to fix seems selective and oriented to Ca^{2+}ions.

$No3^{-}$ ions are in more quantities along the profile, they are then washed down.

$P0_4^{3-}$ ions leave constant, phosphates of irrigation water are then fixed.

In conclusion soil liquid chemistry reponds rapidly to changes with percolating waters. Its behaviour is :

- A transit for Cl^{-} $S04^{2-}$ and $N03^{-}$ ions, they show a very high geochemical mobility.
- A receiving and regulariting for K^{+}, $Mg^{2+}$and Na^{+}ions, but these phenomena are limited in the time, with continued irrigation, Potassium and Magnesium equilibrium have been distroyed and concentration becane more important.
- A receiving for Ca^{2+}ions.

In consequence, eventual modification of chemical aquifer is possible, certainly contamination with increasing chlorides, sulphates and nitrates.

IV - CHEMICAL VARIATION STUDY IN THE AQUIFER.

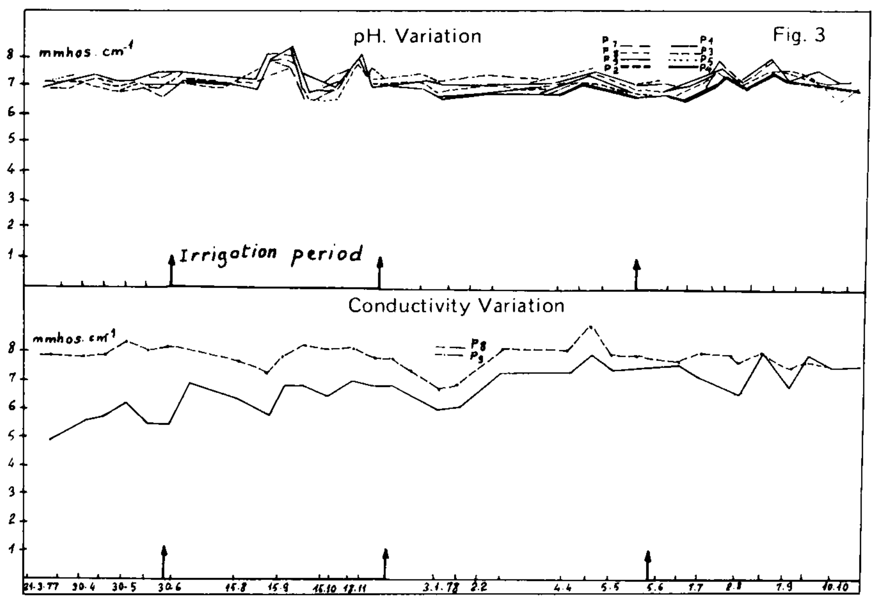
IV.1 - Physico- Chemical parameters Fig 3

PH variation. Before irrigation, pH is constant (6,7 - 7,8). With irrigation use, it changes and presents basic values (8,5). The first perturbation appears the 5/9/ in 1977 and 26/7/in 1978 - two months after the irrigation. This time corresponds to the water percolation through the unsaturated layer.

Factors affecting these modifications are :
- basic irrigation waters.
- soil micro-organism effect. DROUINEAU and LEFEVRE (1949-1951) found that soluble or easily decomposable organic matter facilitates «saprophetic flora» which has repercussion in nitrification process : possible blocking reaction with enrichment of NH_4^+ ions.
- development of alkaline milieu : we have seen in pedological profiles an enrichment with Na^+ and Mg^{2+} ions.

Conductivity evolution. Variation took place 40 days after the begining of the irrigation - 15/8/ in 1977 and 7/7/ in 1978. Modification appears earlier than pH variation, this is due to the soil reaction and aquifer power «tampon». Conductivity variation during these two climatic cycles shows different responses exhibiting increased values during periods and decreased during others. All informations show :
- conductivity values tend to decrease before the irrigation use. These variations are certainly due to pluvial water dilution (0,15 $mmhos.cm^{-1}$).
- regularization of this parameter (by regularization we mean low variations).
- values present a marked tendency to decrease from 15/8/ in 1977 and 7/7/ in 1978. That dilution compared to the preceding is lower and corresponds to percolating irrigation waters showing more salt contents (0,8 $mmhos.cm^{-1}$, 4,5 $mmhos.cm^{-1}$ - 0,5 $mmhos.cm^{-1}$, 2,5 $mmhos.cm^{-1}$).
- augmentation of values, in 1977, this phenomenon appears clearly, generally from 1 october, but in 1978, values present more variation.

All these data show :
- a good agreement with pedological profiles informations, percolating waters are less concentrated according to the soil activity, with degradation of this power percolating waters became more concentrated.
- effluent conductivity is lower in 1978, less variations are subsequently introduced into the aquifer.
- importance and regularity of irrigation use. In 1977, irrigation is less intensive and less regular. These factors favorise concentration by evaporation. In 1978, the presence of these factors made percolation more rapid and limited the evaporation effects.



IV.2 - Specific parameters of domestic sewage. Fig 4

Evolution of anionic detergents. Before irrigation, detergents are presented in traces $<$0,05 mg/l, with irrigation, contents increase up to 0,08 mg/l. The relatively high values stress clearly contamination by this effluent.

Data of this element can be used to estimate the amount of infiltrated waters, this will be as follows :

$$C_d = \frac{V_2}{V_1 + V_2}$$

: dilution cœfficient 10%
: aquifer volume : 240 000 m3
: affluent water volume : 26 000 m3

We have seen that regularity and importance of irrigation contribute to a rapid percolation. This mecanism which characterized 1978 season is clearly evidenced by the follows table : Aquifer response is detected in the same time.

Irrigation period	1/7/1977 - 28/11/1977 6 O'clock to18 O'clok	1/6/1978 - 28/11/1978 6 O'clok -to23 O'clock
Quantity of distributed water	800.000 m3	1.000.000 m3
K $Cm.s^{-1}$	P_1^* = 0,012 P_6 = 0,014 P_2 = 0,01 P_7 = 0,01 P_3 = 0,01 P_8 = 0,003 P_4 = 0,01 P_9 = 0,002 P_5 = 0,01	
Aquifer response	P_5, P_6 = 15/7/77- 5/8/77 P_3, P_1,P_2= 15/8/77- 5/9/77 P_8, P_9 = 5/9/77-15/9/77	P_3,P_5,P_7,P_1 et P_2 = 7/7/78 - 26/7/78 P_8, P_9 = 26/7/78-2/8/78

* Piezometers and their number

Born evolution : This element is always present, sometimes with impressive values. Graphics show the relation between effluent concentration and aquifer values. In 1978, variations are higher due to the higher contents of irrigation flow (0,2 mg/l compared to 1 mg/l).

Phosphates evolution : Before irrigation we have tracers, during irrigation, contents are higher. In 1978, lower variation corresponds certainly to the lower effluent amounts. 5 mg/l compared to 11 mg/l.

IV.3 - Evolution of Major Elements. Fig 5.

Anions follow very similar patterns showing same variation as the conductivity.

Chlorides evolution. Follows table indicates that the receiving aquifer tends to respond differently during irrigation seasons indicating a strong contribution of irrigation modality.

	1977	1978
Conductivity	from 15/8	from 7/7
Detergents	15/7 - 5/8 , P_5, P_6 15/8 - 5/9 = P_3, P_1,P_2 5/9 -15/9 P_8, P_9	7/7 - 26/7 P_3 P_7, P_1, P_2 26/7 - 2/8 P_8, P_9
Chlorides	5/9 - 15/9 = P_1 ....P_9	22/6 - 7/7 P_5, P_7,P_8,P_9 26/7 - 2/8 P_2

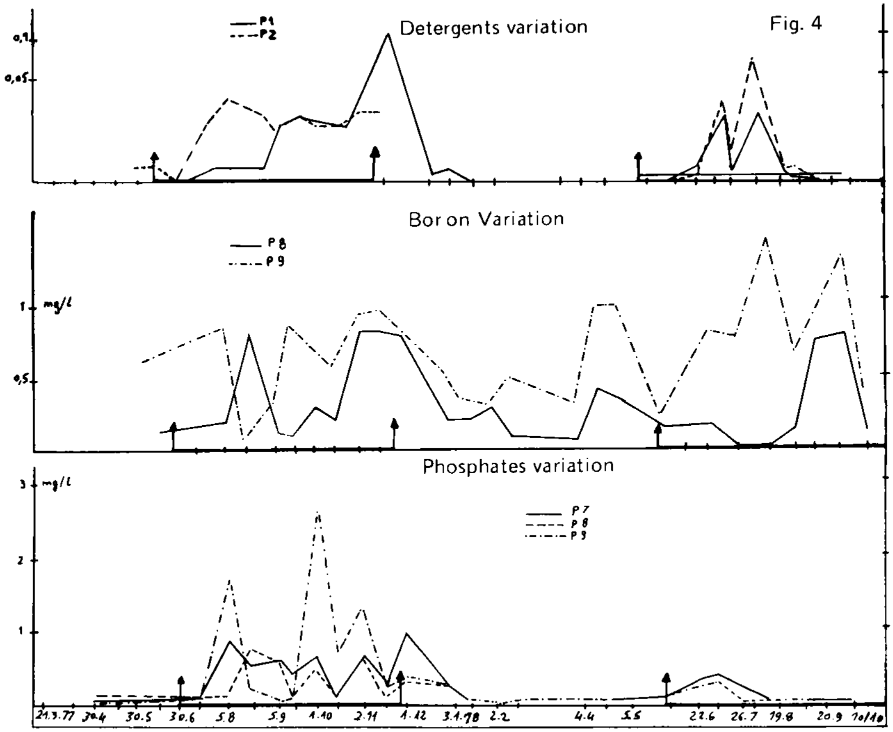

Detergents variation
P1
P2
0,1
0,05
Boron Variation
P8
P9
1 mg/l
0,5
Phosphates variation
3 mg/l
2
1
P7
P8
P9
21.3.77 30.4 30.5 30.6 5.8 5.9 1.10 2.11 1.12 3.1.78 2.2 4.4 5.5 22.6 26.7 19.8 20.9 10/10

Fig. 4

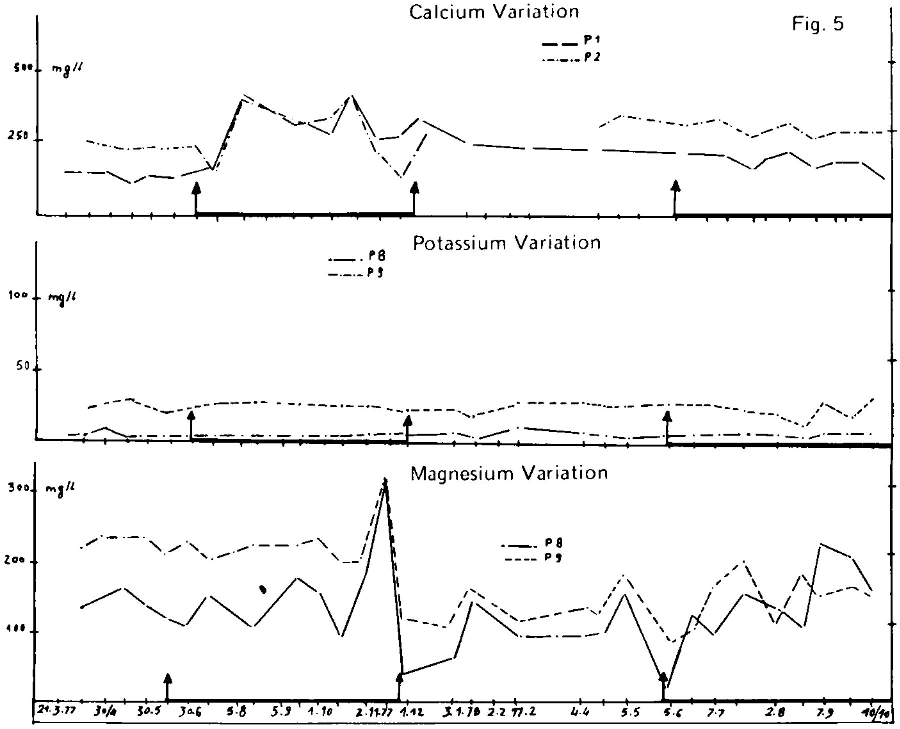

Calcium Variation
P1
P2
500 mg/l
250
Potassium Variation
P8
P9
100 mg/l
50
Magnesium Variation
300 mg/l
200
100
P8
P9
21.3.77 30/4 30.5 30.6 5.8 5.9 1.10 2.11.77 1.12 3.1.78 2.2 17.2 4.4 5.5 5.6 7.7 2.8 7.9 10/10

Fig. 5

In 1977, detergents are detected in the aquifer before the dilution of chlorides, that is why detergents can be chosen as urbain effluent tracers.

Sulphates evolution : Data appearing in follows table are of some further comments, they confirmed results concerning infiltration mecanism.

	Cl^-	$SO_4^=$	décalage of time
1977 pluvial water	15/7/1977-P_I, P_2, P_5, P_6	5/9/1977-P_I,P_2,P_5	2 months
	30/6/1977-P_8, P_9	P_6,P_8,P_9	
	1/10/ 977-P_I, P_2	2/11/1977-P_I, P_2	1 month
	15/9/1977-P_5, P_6	2/11/1977-P_5,P_6	1 month 15 days
	5/9/1977-P_8, P_9	1/10/1977-P_8,P_9	1 month
1978 pluvial water	5/6/1978 - P_2	2/8/78 - P_2	2 months
	19/4/1978 - P_5, P_6	5/6/78 - P_5, P_6	"
	4/4/1978 - P_8, P_9	5/6/78 - P_8, P_9	"
	19/8/1978 - P_2	20/9/78 -	1 month
	7/7/1978 - P_5	2/8/78 -	1 month
	7/7/1978 - P_8, P_9	2/8/78 -	1 month

Dilution of sulphate pluvial waters is chifted two months back, for pluvial waters, dilution is one month back. These data show that chlorides can be chosen as tracers and irrigation waters percolation is more rapid.

Evolution of cations. Fig. 5. Results are in good agreement with pedological profiles data, Ca^{2+} and K^+levels are appreciably constant with tendency of dilution. For Mg^{2+} levels, waters are enriched according to its more geochemical mobility.

IV.4 - Evolution of organic parameters.

Values of Nitrates, dissolved oxygen and DCO show that the aquifer is manifestly polluted. NO_3- contents and DCO values increase up - 900 mg/l for nitrates, DCO, before irrigation (40 mg/l - 350 mg/l) during they are between 150 mg/l - 400 mg/l, simultaneously dissolved oxygen values decrease (3,0 - 6 mg/l, 2,5 - 4,5 mg/l).

V - CONCLUSION

Main conclusion is : Analysed ground waters show wide variations with irrigation use, waters have been enriched in specific and Major elements. Taking into consideration irrigation water quality, contamination observed should be explained by geological and hydrogeological conditions peculiar to the considered area.

REFERENCES :

J.K BAARS : Pollution of ground water (A.I.H.S) TORONTO 1957

J. BOURALY : Note sur les sols et les eaux de la région de Soukra - DRES - TUNIS

R. CABRIDENC : Propriétés biologiques de quelques agents de surface anioniques, incidence vis à vis de l'environnement (T.S.M 1976).

J. FRIED, J.L GARNIER : Etude quantitative d'une pollution de nappe phréatique dans le département du Haut Rhin (Hydrogéologie N° 1, 1971).

A. LAGARDE : Quelques exemples de l'influence de l'activité de l'homme sur les eaux souterraines (XIIIème Journées de l'hydraulique 1974) Bordeaux

S. PINI : Carte geéologique de la Tunisie, Feuille d'Ariana 1971 - Tunisie

G. SCHWAB : Soil and water conservation engineering (1959).

H. SCHOELLER : Pollution des eaux souterraines, colloque de Moscou (1971).

A. TALBOT : Contribution à l'étude de la pollution des eaux superficielles et souterraines (étude particulière de l'Aude 1970).

Y. VUILLAUME : Les conditions de l'épuration naturelle des eaux souterraines pour les roches aquifères filtrantes (1966).