

Almeida, C. e M. L. Silva (1987)

Incidence of Agriculture on water quality at Campina de Faro (South Portugal)

Hidrogeologia y Recursos Hidráulicos, t. XII, p. 249-257.

IV SIMPOSIO DE HIDROGEOLOGÍA

INCIDENCE OF AGRICULTURE ON WATER QUALITY AT CAMPINA DE FARO (SOUTH PORTUGAL)

ALMEIDA, Carlos

SILVA, Mário Lourenço

Departamento de Geologia da Faculdade de Ciências da Universidade de Lisboa. Centro de Geologia da Universidade de Lisboa (INIC).

RESUMEN

La Campina de Faro (Algarve, Portugal) tiene una área aproximada de 20km², siendo constituida por aluviones recientes, por arenas, arcillas y gravas plio-kuaternárias y por calizas, margas y areniscas miocénicas. Los depósitos superiores constituyen un acuífero livre que se sobrepone a un acuífero cautivo carbonatado.

Una de las características más notables de la hidroquímica del sector es la ocurrencia, en algunos puntos, de una concentración elevada de ciertos iones, por ej. sulfatos y nitratos. Estos dos iones tienen una correlación muy significativa lo que permite suponer que el enriquecimiento observado se debe a una misma causa, la utilización de abonos.

La comparación de la razón SO₄ / NO₃ en los abonos más usados en el sector y en las aguas subterráneas permite concluir que aproximadamente 20% del nitrato adicionado al suelo bajo la forma de abonos se incorpora en las aguas subterráneas.

INTRODUCTION

The Campina de Faro is a region located North of the town of Faro, with an approximate area of 20 km² where intensive agriculture is practised.

Water sampling done in 27 points (bore-hole and dug wells) showed that nitrate content is, in several of them, largely beyond the limits recommended by international organizations such as EEC and WHO, both for man and cattle consumption.

This fact indicates that the Pliocene and Miocene aquifers of the zone are being contaminated.

Since there is no sign that nitrate enrichment of the waters is due to organic contamination it was done an enquiry about the type of fertilizers used by local farmers. Knowing the relation of SO₄ / NO₃ entering in the composition of the fertilizers and determining the same one in groundwater it is possible to evaluate the nitrate content which enters in the groundwater circuit.

GEOLOGICAL AND HYDROGEOLOGICAL SETTING

The Campina de Faro is located in a region extending from Faro to Olhão, Province of Algarve, Portugal, has a rectangular shape with its maximum length in the N-S direction and an area of 5x4 km (Fig. 1).

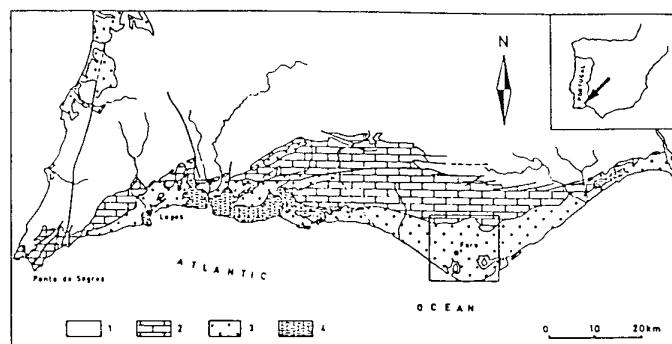


Fig. 1. Simplified geological map of southern Portugal (from the geological map of Portugal, 1:500,000 scale).

1 - basement (Carboniferous); 2 - permeable limestones and dolomitic limestones (Jurassic); 3 - medium to moderate permeable terrains (Cretaceous, Plio-Quaternary and Quaternary); 4 - permeable limestones (Miocene).

Its soil type and the amenable climate of the Province with a dry and warm season (mean annual temperature at Faro weather station is 17°C) makes the zone suitable for an intensive agricultural activity all the year around either under shelters for horticulture or at open air for citrus plantation and horticulture.

The region is part of a Plio-Quaternary aplanation, mainly formed of recent dunes, Quaternary alluvial deposits and sands and Miocene limestones, arenaceous limestones and sandstones. Plio-Quaternary deposits may eventually reach the thickness varying from 20 to 30 m, whereas the underlying miocene formations, directly supporting those deposits may attain the thickness of 200 metres (GEINAERT et al., 1982).

The N limit of those formations consists of jurassic limestones or cretaceous arenitic limestones and carbonate sandstones (Fig.2). Groundwater at Campina de Faro is intensively exploited both for irrigation and municipal public water supply.

Infiltration, wick occurs both in situ or in jurassic and cretaceous formations cropping out to the North recharges two separate aquifers: a watertable one and a Miocene artesian aquifer. The top aquifer has a much smaller discharge rate than the deeper one.

Municipal borehole wells have supplied in the last years an average of 700,000 m³/year and have contributed with about 23% of the water consumption in the township.

SAMPLING AND ANALYSIS

From May 1983 to January 1984, 27 water points located at Campina de Faro and in the adjacent area were sampled. Corresponding temperature, pH and electrical conductivity were measured at the site sampling and within a time interval below 6 hours after sampling it was determined alkalinity and CO₂, both by titration with pH control.

Boric acid was added to every sample in the site, and all of them were stored in a refrigerator till nitrate analysis was done.

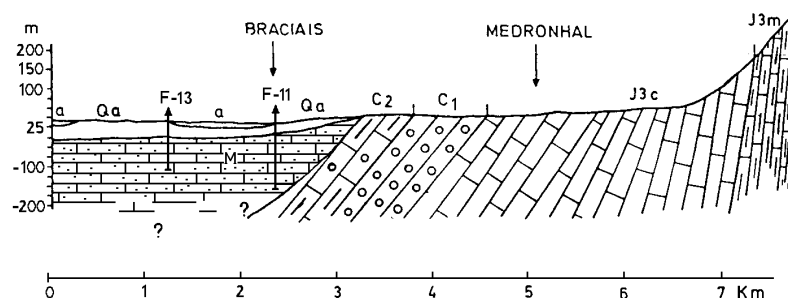


Fig. 2. N-S cross section at Campina de Faro.
J3m - marly limestones (Jurassic); J3c - limestones and dolomitic limestones (Jurassic); C1 - sandstones, conglomerates and mudstones (Cretaceous); C2 - marly limestones and marls (Cretaceous); M - limestones and sandy limestones (Miocene); Qa - sandstones and argillaceous sandstones (Plio-Quaternary); a - alluvial deposits (Recent).

The parameters analysed in the laboratory and the methods used were:

- sulfate - gravimetry
- chloride - Mohr method
- calcium, total hardness - complexometry by EDTA
- nitrate - potentiometry
- sodium and potassium - atomic absorption spectrophotometry
- silica - absorption spectrophotometry

Nitrate content was determined within the time interval below 24 hours after sampling.

Data analysis were treated by the program HIDROQ (ALMEIDA, 1979) for microcomputer. Analysis showing a balance error greater than 5% were not used. Table I shows the values obtained for each parameter.

HYDROCHEMISTRY

Water sample analyses show a significant hardness and are highly mineralized. They are of the chloride to bicarbonate type. However the sulfate component is also very important. This aspect distinguishes the water of Campina de Faro from the one of the other miocene aquifers (SILVA & ALMEIDA, 1983). Another important aspect is the high concentration of NO_3 . In more than half of the wells sampled it exceeds the 20% of total anions.

One of the difficulties to be faced in studying the waters of the carbonate aquifer and of the top detrital one is the fact that wells intersect both aquifers and therefore water samples are a mixture coming from those two aquifers.

Table I

Ref. no.	Temp	Cond	pH	CO2	HCO3	SO4	Cl	NO3	Na	K	Ca	Mg
1	18.7	1017	7.12	20.6	241	19	157	124	75	3.4	106	14
2	22.6	1182	7.08	31.6	319	163	117	40	76	6.5	130	45
3	19.8	939	7.07	13.0	138	21	162	143	108	7.1	57	30
4	19.2	834	4.97	47.2	16	6	190	149	110	6.1	16	26
5	19.5	1512	6.08	59.0	75	86	332	130	220	1.5	40	31
6	18.1	2690	7.23	30.8	317	225	504	347	190	5.2	352	58
7	19.7	1799	7.50	16.2	288	308	226	118	115	7.1	211	60
8	18.9	1165	7.44	18.2	330	82	115	118	79	2.5	119	32
9	20.4	913	7.20	26.0	329	33	102	39	55	2.5	102	25
10	18.8	3582	7.21	26.0	279	213	902	254	385	13.3	375	49
11	19.1	939	6.52	45.8	139	54	125	155	104	8.2	70	25
12	18.4	1321	6.70	50.2	229	114	162	205	130	6.6	117	40
13	19.3	1373	7.00	45.2	362	66	179	158	98	2.6	147	38
14	19.8	1634	7.05	34.0	313	154	178	304	145	2.6	187	39
15	21.7	1078	7.33	17.6	277	33	177	42	102	6.6	87	30
16	18.9	780	6.75	32.8	172	24	130	71	72	8.2	71	22
17	18.1	2495	6.93	45.0	32	414	362	298	135	18.3	308	67
18	18.7	1799	6.90	43.7	280	159	269	254	101	7.8	237	26
19	18.1	1956	6.99	40.0	310	193	213	434	135	3.0	224	48
20	19.6	1208	5.95	79.8	66	30	192	322	148	5.7	60	26
21	19.1	1556	7.11	26.8	269	117	232	161	115	4.7	156	41
22	18.0	2330	7.08	27.0	238	138	426	409	114	2.9	323	34
23	19.3	1104	6.89	36.4	317	54	134	99	68	2.2	134	28
24	20.3	913	7.00	39.7	349	28	92	48	65	2.2	105	29
25	18.1	1817	6.99	42.6	304	115	298	180	105	2.9	216	48
26	18.4	947	6.92	46.0	306	25	132	49	74	4.1	116	11
27	21.3	1086	7.56	13.0	433	22	121	38	81	3.4	93	49
28	19.0	921	7.09	40.0	240	52	115	83	38	3.2	87	25

Note: ions are expressed in mg/l.

Calcite saturation index (SI) can be used as an indicator of relative percentages of each water in the mixture. In fact SI values of the top aquifer are much lower than the ones of the carbonate aquifer, whose waters show calcite supersaturation.

Table II shows, for each parameter analysed, the values of mean (\bar{x}) median (M), standard deviation (SD) and extremes values. Mean concentration of nitrate is higher than the recommended value by WHO (50 mg/l) and some samples have much higher concentration.

TABLE II

	Temp	Cond	pH	CO ₂	HCO ₃	SO ₄	Cl	NO ₃	Na	K	Ca	Mg
\bar{X}	19.3	1460	6.92	35.5	249	105	226	116	5.4	5.4	152	22
SD	1.1	664	0.52	15.0	105	98	167	66	3.7	3.7	96	14
M	19.1	1195	7.03	35.2	280	74	177	104	4.4	4.4	118	32
MAX	22.6	3582	7.56	79.8	433	414	902	385	18.3	18.3	375	67
Min	18.0	780	4.97	13.0	16	6	92	38	1.5	1.5	16	11

Note: ions are expressed in mg/l.

Fig. 3 and 4 show spatial variation of Nitrate and Chloride. From the plot of Na versus Cl concentration (Fig. 5) one notices that the samples fall mainly in two fields: one on the line of equality and the other situated below that one showing therefore a deficiency of Na with regards to Cl.

Also the projection of $\text{SO}_4 + \text{HCO}_3$ versus Ca^{2+} (Fig.6) shows that the points are located in two fields: one over the line of equality and other situated above that line showing therefore an excess of Ca. These two graphs suggest the existence of ion exchange of sodium by calcium.

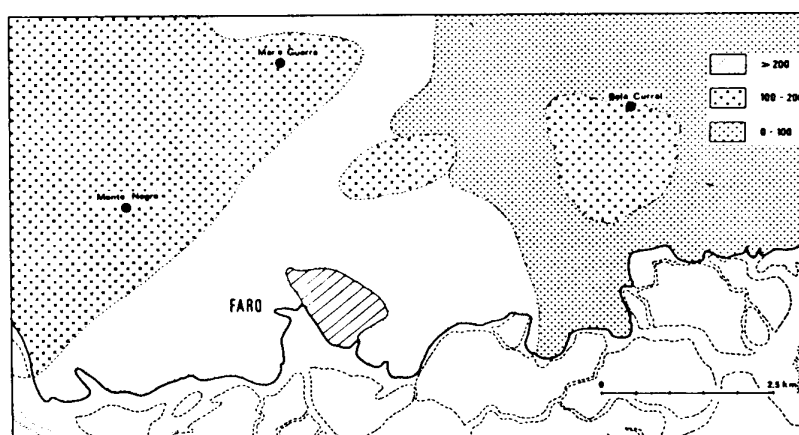


Fig. 3. Groundwater nitrate content (mg/l) at Campina de Faro.

Fig. 7 shows the projection of SO_4^{2-} versus NO_3^- . The relation of those two anions for the wells 2, 7, 17 suggests that the high concentration of sulfate of those water sites may be due to gypsum dissolution whereas well no. 20 may have been affected by organic matter contamination.

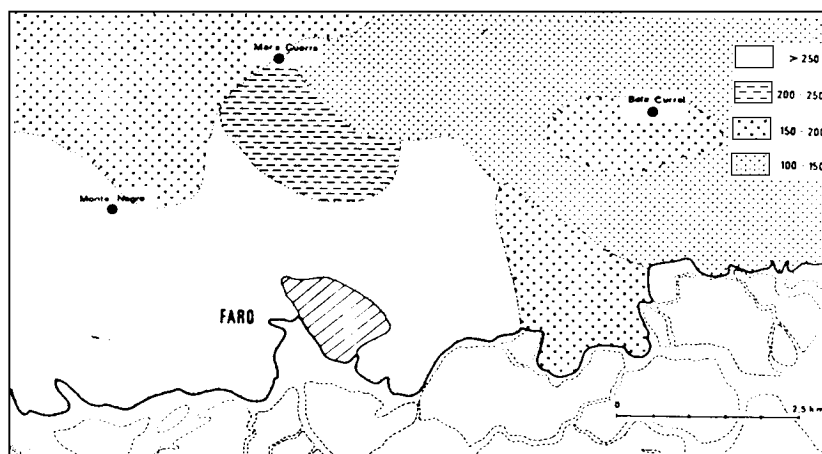


Fig. 4. Groundwater chloride content (mg/l) at Campina de Faro.

The astonishing high rise of nitrate content of the underground water all over the area lies on a transport mechanism caused by infiltration of rain and irrigation water.

Since the sulfate ion, which is also part of composition of the fertilizers is entirely carried by water during infiltration, comparison of the ratio of SO_4/NO_3 in the fertilizers with that one found in underground waters provides an evaluation of the amount of NO_3 ion which is not absorbed and therefore enters to the composition of the water (CUSTODIO, 1982).

Based on an enquiry done by Quimigal EP. in 1982 containing data of 32 sampling units with 283 fields it is estimated that about 784 metric tons of Nitrogen were used in Campina de Faro as part of several fertilizers, mainly in the form of NO_3 , NH_4 and Urea. According to that enquiry it was used in same area about 370 metric tons of sulfate, as part of the fertilizers ammonium sulfate, used in greenhouse agriculture and superphosphate 18%. There are other fertilizers with sulfate composition (e.g. magnesium sulfate) but the amount used in the area is not relevant.

Through those 784 tons of Nitrogen used at Campina, which correspond to 3472 Tons of NO_3 , the ratio SO_4/NO_3 in the fertilizers is:

$$\text{SO}_4/\text{NO}_3 = 371/3472 = 11\%$$

The groundwater of the area has a ratio SO_4/NO_3 of 62/100 (which is equal to 11/18 parts) found by linear regression (Fig.7). Therefore assuming that all the sulfate goes to the aquifer, the initial ratio 11/100 of the fertilizers ends up in the groundwater in the ratio 11/18, which means that from the initial 100 parts of NO_3 only 18 parts reach the aquifer, being the remaining 82 absorbed. These values are very close to the ones found by CUSTODIO (1982) for the Maresma area (20%) and by THIERNY & SEGUIN (1985): between 15% and 21%.

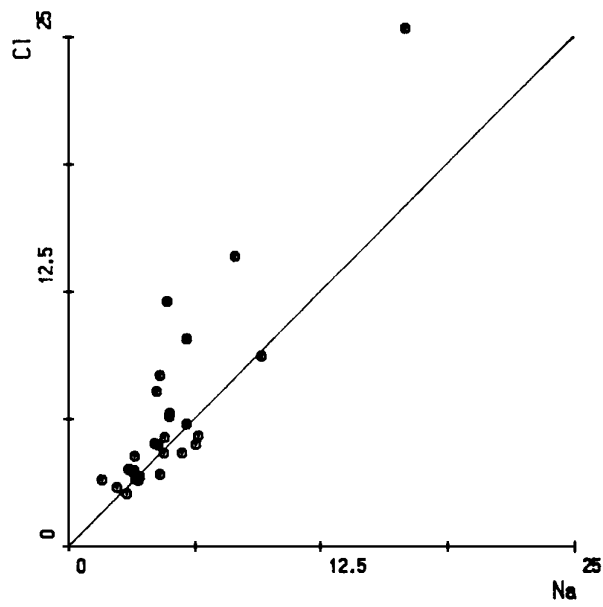


Fig. 5. Sodium and Chloride (meq/l) relationship.

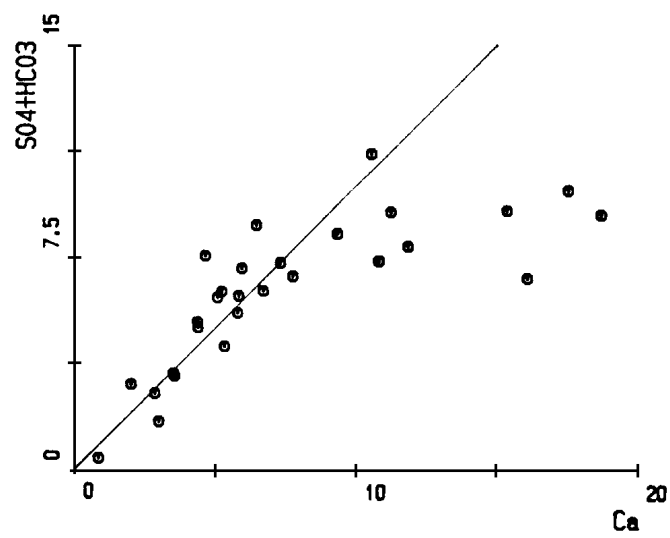


Fig. 6. SO_4+HCO_3 and Ca (meq/l) relationship.

POLLUTION MECHANISM

The study of the pollution mechanism of the confined aquifer will be a task for the near future. However several possibilities are right now put forward.

Contaminants coming from the fertilizers may get into the aquifers in two ways:

- 1) - at the recharge zones, followed then by dispersion;
- 2) - fluid interchange of the top aquifer, which is contaminated by direct infiltration, with the deep aquifer.

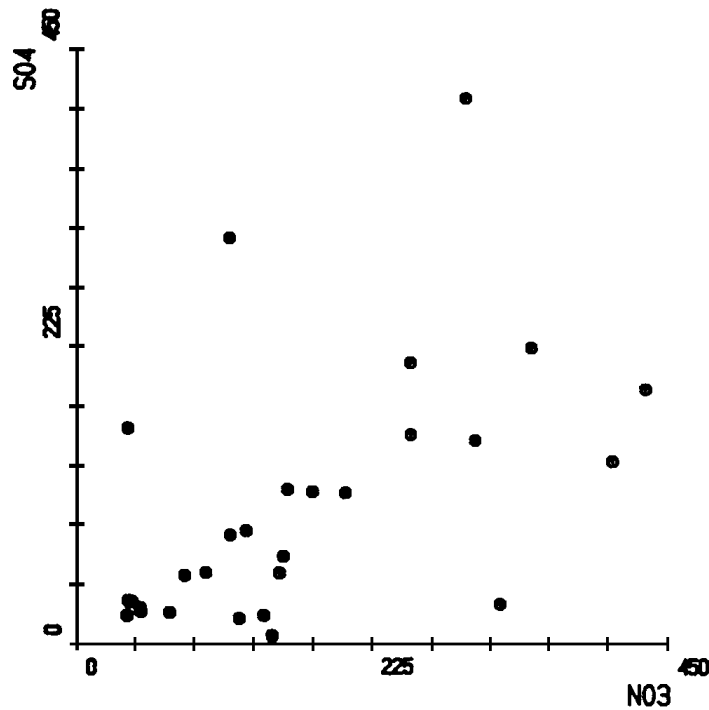


Fig. 7. Sulfate and nitrate (mg/l) relationship.

The first possibility seems to be confirmed by the rise of nitrate content at the borehole wells located in jurassic terrain.

However it seems obvious that most of the contamination is done through the second possibility.

CONCLUSIONS

Due to agricultural activities it was found an increase of nitrate, sulfate and other ions content in the groundwater of Campina de Faro aquifers.

It is estimated that 18% of the nitrate used enters in the groundwater circuit mostly at the recharge zone and due to fluid interchange in the top aquifer with the deep one.

ACKNOWLEDGMENTS

We thank Mrs. Vaz Milheiro and Simão Guilherme, Engineers of Quimigal Comp. (E. P.) at the Agricultural Development Center, Sacavém, for supplying data on the composition and amount of the fertilizers mostly used in the agricultural activities at Campina de Faro.

References

Geirnaert, W., P.H. van Beers, J. J. de Vries & H. Hoogeveen (1982) - "A geoelectric survey of the Miocene aquifer between Quarteira and Olhão, Algarve, Portugal". III Semana de Hidrogeologia. Volume das Comunicações. Dep. de Geologia da Fac. de Ciências de Lisboa.

Almeida, C. (1979). "Programas para calculadora de bolso com aplicações em Hidrogeologia". Boletim do Museu Mineralógico e Geológico da Fac. de Ciências de Lisboa, vol. 16(1), p. 101-122.

Silva, M. & C. Almeida (1983). "Aspectos hidrogeológicos das formações miocénicas do Algarve litoral". I Congresso Nacional de Geologia, Resumos das Comunicações, Aveiro.

Custodio, E. (1982). "Nitrate Build-up in Catalonia Coastal Aquifers". International Symposium on Impact of Agric. on Ground Water, Memoires, vol. XVI, Part 1, p. 171-181. Prague.

Thiery, D. & J. J. Seguin (1985). "First model of nitrate transfer over a river basin with a lumped model". Hydrogeology in the service of Man, Memoires of the 18th Congress of Int. Ass. of Hydrogeologists, part 3, p.188-198. Cambridge.