INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 3, No. 10, p. 139-152, 2013

RESEARCH PAPER OPEN ACCESS

Groundwater fauna can be used as indicators of anthropogenic impacts on aquifers: A case study from Meknes area, Morocco

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Key words: Wells, stygobiontic fauna, water quality, indicators of water quality.

doi: http://dx.doi.org/10.12692/ijb/3.10.139-152 Article published on October 12, 2013

Abstract

The groundwater in the plain of Fez-Meknes constitutes a major resource in the region. The study highlights the importance of this resource, especially its irreplaceability. However, a number of inferences of point source pollution or diffuse were made. In this context, this study aimed at showing the possible relationships between the water quality of wells and springs and the diversity of the aquatic fauna which occurs in these habitats. To this end, the water quality and the fauna were regularly investigated in several stations (8 wells and 2 springs) selected in the region. The stations were chosen considering visible differences related to both their fauna and also some evident characteristics i.e. water table depth, nature of geological substratum, protection and human use, so that it was possible to expect certain diversity. The total faunal richness of stations was poorly correlated with water quality but, in contrast, the specific richness of the stygobiontic fauna (the subterranean species living in groundwater), and moreover the abundance of these stygobiontic species decreased significantly in case of water pollution. Thus the stygobiontic fauna and especially the peracarid crustaceans appear to be good indicators of water quality in the studied wells and springs.

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Introduction

In the last few decades, groundwater ecology has developed rapidly forming a fertile discipline of aquatic ecology (Gibert *et al.* 1994). Whereas the subterranean domain has long been considered as a species-poor environment, worldwide syntheses revealed an unexpectedly high diversity of living forms in groundwater (Botosaneanu 1986, Juberthie and Decu 1994, 1998, and 2001). Botosaneanu (1986) listed about 7000 obligate groundwater species worldwide. Groundwater ecosystems harbor different kinds of animal organisms from typically accidental obligate-surface water species (i.e.stygoxenes) to a highly specialized obligate groundwater fauna (i.e. stygobionts), the members of which developed adaptive strategies for life in a dark and energy-limited environment (Marmonier *et al.* 1993; Langecker 2000). Because most stygobionts have a narrow distribution range, the risk of species extinction is expectedly high in face of the increase in multiple anthropogenic pressures (Malard *et al.* 1996; Gibert and Deharveng 2002; Danielopol *et al.* 2003). The high level of endemicity in groundwater systems requires specific protection measures for maintaining their ecological integrity and biological diversity (Notenboom *et al.* 1994).

Over the last 50 years, our knowledge of groundwater biodiversity has considerably increased due to the discovery of an unexpectedly high diversity of living forms in all groundwater ecosystems of the world (Gibert & Culver, 2009). These organisms (called stygobionts) are characterized by adaptations for living in dark environments in which space and food are generally in short supply. Morphological adaptations include reduction or loss of pigmentation and eyes, and sometimes elongated appendages. Stygobiotic organisms are known in all animal groups (i.e., both invertebrates and vertebrates) (Botoseanu, 1986; Gunn, 2003; Ballian *et al.*, 2008), but crustaceans constitute 43% of their total known diversity (Gibert & Culver, 2009) and represent 9.5% of the world's total species diversity in fresh waters (Balian *et al.,* 2008).

Groundwater biodiversity exhibits several peculiarities, including high proportions of either phylogenetic or distributional relics ('living fossils') and a high proportion of endemic species (Gibert and Deharveng, 2002). Constraints, including scarce food resources and often low oxygen levels, have forced groundwater animals to evolve remarkable adaptations in their physiology and life cycles. These features mean that the aquatic subterranean fauna ranks among the most precious biological heritage on our planet, but they may also increase the risk of extinction due to anthropogenic disturbance. Although environmental determinants of groundwater biodiversity have been also discussed in a few synthesis papers, these relationships have been addressed in a general way and at the continental rather than regional scale (Holsinger, 1993; Stoch, 1995; Gibert *et al.,* 2009).

The main factors influencing the transport of the pollutants in the ground are: the underground water level, the quantity of pollutants, their type, and soil bedding (Bedient *et al.,* 1999). The ground water quality depends not only on natural factors such as the lithology of the aquifer, the quality of recharge water and the type of interaction between water and aquifer, but also on human activities, which can alter these groundwater systems either by polluting them or by changing the hydrological cycle (Farooq *et al.,* 2010).

The role of groundwater ecosystems in hydrogeochemical cycling and enhancing groundwater quality, and the functional ecological significance of the biodiversity of groundwater recosystems is still poorly understood (Boulton *et al.,* 2008). However it is thought that feeding, movement and excretion by groundwater fauna (stygobites and stygophiles) can enhance water purification, bioremediation and water infiltration (Boutlon *et al.,* 2008; Tomlinson and Boulton, 2008). Hallam *et al.* (2008) found bacteria in the digestive tract of two stygobite crustacean species in Morocco and concluded that bacteria may be a nutritional resource for stygobites.

The Moroccan groundwater fauna was still poorly known until the beginning of the eighties (Chappuis, 1953; Balazuc & Ruffo, 1953; Karaman & Pesce, 1980; Pesce *et al.*, 1981). More systematic stygobiological investigations were recently performed, first in the Marrakesh region (Messouli, 1994; Boulanouar, 1995, Yacoubi-Khebiza,1996) then in other parts of Morocco: Goulmima (Benazzouz, 1983), Tiznit (Boulal, 1988), Guelmim (Idbennacer, 1990), Fes (Mathieu *et al* 1999; Berrady *et al* 2000), El Jadida (Fakher El Abiari, 1999) and the Rifian region. These last sampling were performed with the aim of both making more complete the inventory of known stygobiontic taxa from Morocco and testing once more the possible relationships between the biodiversity of the subterranean aquatic fauna and groundwater quality. However, very few studies have been conducted regarding the impact of anthropogenic factors on the groundwater ecosystems. This paper finally presents the first data on the stygobiontic fauna of Meknès area, as well as the relationships between factors anthropogenic and stygofauna .

Materials and methods

Study area

The study area is the aquifer of Saiss basin of Meknes,The shallow aquifer Saïss Basin is located in the centre of Sebou watershed (Fig.1), and corresponds geographically to the plain of Fez - Meknes. This aquifer is bordered by the valleys of Sebou and Beht respectively from the East and the West (ABHS, 2005).

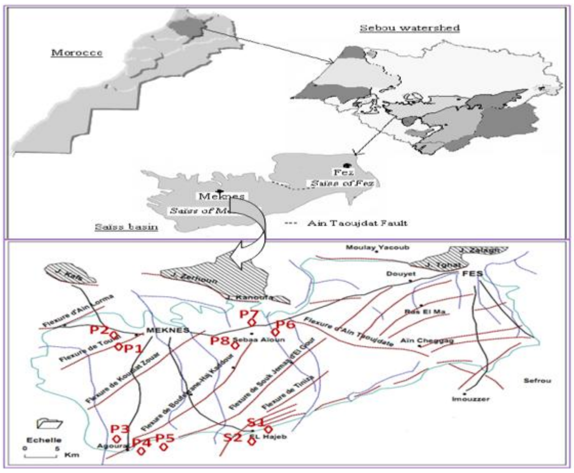

Fig. 1. The study area (P= wells; S= springs).

The Saïss basin which is the study area, is one of the sub basins of Sebou, it extends over a length of 100 km and a width of 30 km between the Lambert coordinates: 465 <X <545 km and 335 <Y <385 km. It is bounded on the north by the Pre-rif, east through the valley of Wadi Sebu, west by the tributaries of the wadi Beht and south by the Middle Atlas Causse. This basin includes two structural units, the Saïss plain to the east and the plateau to the west of Meknes.

The circulation of this aquifer occurs primarily in the sands, sandstones, conglomerates and Sahelian Pliocene lacustrine limestones and locally in the travertine. Tortonian deposits of marl are the nature impermeable bedrock of the aquifer. Cuts derived from lithological columns stratigraphic drilling Plateau Meknes (Fig.2) indicates that the Plio-Quaternary deposits show a wide variation facies of a well to another (Cirac P., 2008).

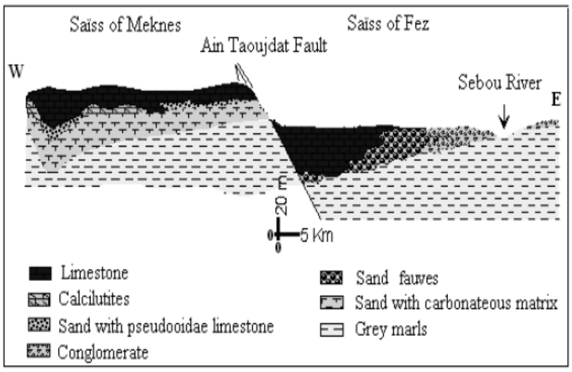

Fig. 2. Lithology of Saïss basin.

A Hydrogeological point of view, the watershed is the subject of several studies saw its water potential and its major activity, it contains two layers of uneven interest and are counted among the major aquifer systems in Morocco.

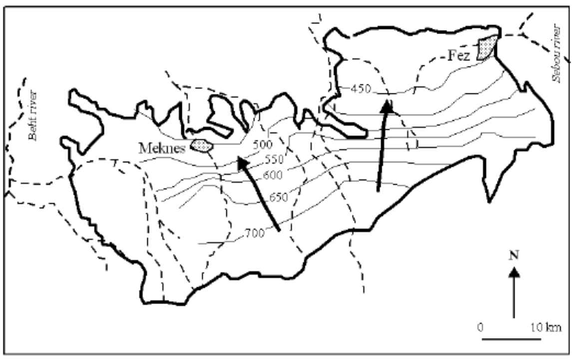

Fig. 3. Piezometric map of Saïss basin.

Groundwater: flowing through the sands, conglomerates and limestones in parts of the lacustrine Plio-Villafranchian. On the hydrodynamics of the food web is through rainwater infiltration, the drainage of the deep aquifer and the return of irrigation water. And it is the most accessible reservoir region of Fez-Meknes.

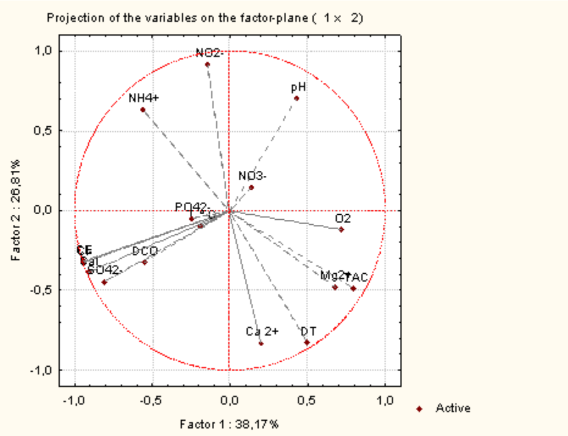

Fig. 4. Projections of physical-chemical variables of water from the 10 stations (as given in Tab.2)on the plan of the two first axes of the PCA (axis 1 horizontal and axis 2 vertical).

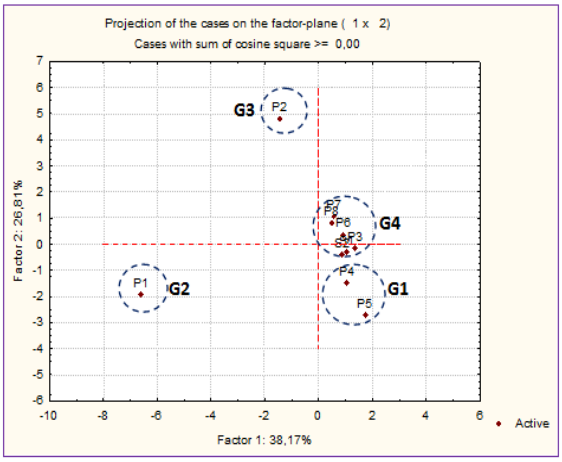

Fig. 5. Projections of the four groups of studied stations based on the physicochemical characteristics of their water, on the plan of axis 1 (horizontal) and axis 2 (vertical) of the PCA

The deep aquifer: circulating in the dolomitic limestones of the Lias and starts to charge under the thick series of Miocene marls raincoats. This aquifer has an area of artesian important, but its overuse causes a decline in its area of artesian. These two aquifers are separated by a thick series of marls of Miocene (Amraoui F., 2005).

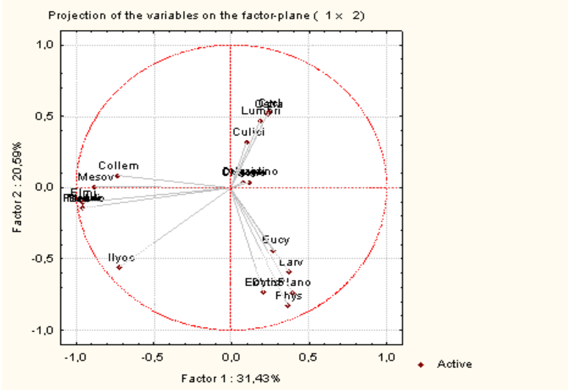

Fig. 6. Projections of sampled taxa on the plan of the two first axes of the PCA (axis 1 horizontal and axis 2 vertical). Names of taxa like above.

The piezometric map (Fig. 3) of the shallow aquifer shows that the dominant flow is generally from south to north with the individualization of both flow directions. The first is South-east to north-west towards the plateau of Meknes and the second southwest to north-east. These two directions of flow are governed by the flexure of Ain Taoujdate, and are partly governed by a call for water to the north where the main irrigation schemes (Sendide O., 2002).

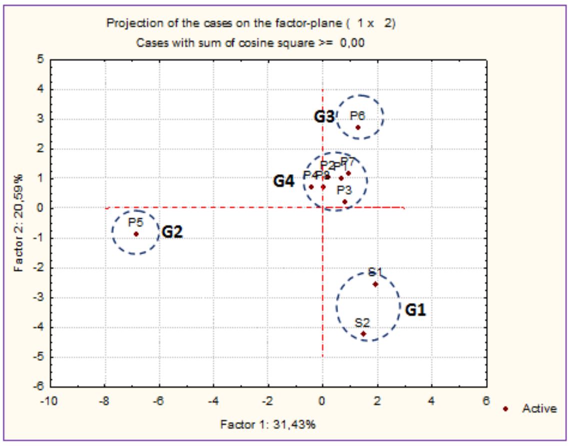

Fig. 7. Projections of stations, described by their fauna (from Tab. 4), on the plan of the two first axes of the PCA (axis 1 horizontal and axis 2 vertical).

Most of the 8 study wells and 2 prings are used for agricultural or domestic purposes, and are located near a landfill (P1 and P2). Six wells (P3, P4, P5, P6,P7, P8) and 2 springs (S1, S2) are located near a man-made pollution . The characteristics of the wells are summarized in Table 1.

Sampling methods

All the samples, collected in tight capped high-quality polyethylene bottles, were immediately transported to the laboratory under low temperature conditions in the icebox and stored in the laboratory. The temperature, dissolved oxygen and conductivity of the water were measured in situ, while calcium, magnesium, total hardness and chlorine concentrations were measured by the volumetric method. Ammonium, nitrates, nitrites, sulphate, and orthophosphates were measured by spectrophotometry (Rodier *et al.,* 2009).

Fauna was collected in each well four times from February to July 2013 times from February to July 2013 with two types of sampling equipment: a phreatobiological net sampler (Cvetkov 1968; Bou 1974) 20 cm in diameter at the opening, composed of a cone fi lter with a 150 µm mesh, drawn up 10 times in each well through the entire water column, which was of different depths in the various wells; a nasse-type baited trap developed by Boutin and Boulanouar (1983). The traps were set in contact with the bottom for 24 hours. The fauna of springs was sampled with a net settled at the source when stringing the sediments just upstream from the water emergence (MESSOULI, 1994).

The same number of traps was placed in each well throughout the sampling period, with the same time of immersion. The samples were fixed in 5% formalin in the field. After the sorting, individuals were preserved in the field in 70% ethanol before being identified. All animals were identified to the lowest taxonomical level possible using published and informal keys.

Results and discussion

Abiotic characteristics of the water

Six sampling campaigns were successively performed from February to July 2013 in the region. The eight wells and two or so springs were prospected within a range of 40 km, surrounding the Meknes city. Sixteen physico-chemical parameters of water quality were measured or analysed in the study area (Table 2).

Table 1. Characteristics of the 10 studied stations (P= wells; S= springs).

Stations	Diameter (m)	Mean water level below the soil (m)	piezometric level	Protection	Usage	Environment
P1	1,6	14	9	Unprotected	Livestock watering	Waste and leachate
P2	1,3	25	2	Unprotected	Domestic purposes	Waste and leachate
P3	1,7	25	16	protected	agricultural or domestic purposes	dig in a house
P4	1,2	18	4	protected	agricultural or domestic purposes	dig in a house
P5	1,2	24	8	protected	Drinking water	dig in a garden
P6	1,5	26	3	protected	Drinking water	dig in a house
P7	1,6	27	4	Unprotected	agricultural or domestic purposes	dig in a house
P8	1,4	30	12	Unprotected	Drinking water	dig in a garden
S1	-	-	-	Unprotected	Drinking water	-
S2	-	-	-	Unprotected	Drinking water	-

The pH varies from 6.8 to 7.21 in the study area. These values indicate water from medium acidic to alkaline, with the lowest mean value (6.8) measured in wells P1. This low pH could contribute to the high EC of the well waters as low pH waters have been reported to increase the tendency of water to dissolve minerals and metal, thereby increasing EC [36].Water temperatures range between 16.2 and 18.1°C. Then, water is highly mineralized in all the area with conductivities and salinity respectively above 507 µS/cm and 280 mg/l. This mineralization is greater in the water of wells compared to the springs. The conductivity reaches maximum values of 13840 µS/cm in the wells P1. This high mineralization may be influenced by anthropogenic sources, especially the landfill such as wells P1 and P2. In the region of Meknes, the CaCO3 concentrations indicate water of high hardness, varying from 75 mg in wells P2 to 522.5 mg in wells P5. The calcium concentrations are very high with respect to those of magnesium, due to the calcareous nature of the ground; the geological structure of the soil through the region of Meknes, groundwater is mainly constituted by the sands, conglomerates and locally lacustrine limestone (Essahlaoui, 2000). Groundwater was generally under-saturated with dissolved oxygen, the DO concentrations ranging from 2.88 mg/l at P1 to 9.05 mg/l at S2; the highest values occurred in the springs S2.The chloride concentrations varying from 17.75 mg in springs S1 to 4082.5 mg in wells P1.

Table 3. Mean values of the physical-chemical parameters of water from the 10 studied stations (P = wells; S = springs).

Stations	pH	O2	T	TH	Ca^{2+}	Mg^{2+}	Salinity	EC	ACT	Cl^-	COD	SO_4^{2-}	NO_2^-	NO_3^-	PO_4^{2-}	NH_4^+
		mg/L	° C	° F	mg/L	mg/L	mg/L	µs/cm	° F	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P1	6,8	2,88	17,5	23,5	215	20	7670	13840	13	4082,5	40	187,26	0,013	12,73	0,231	0,872
P2	7,16	5,12	16,75	7,5	45	30	7,08	1324	15,5	124,25	16	37,19	0,523	13,16	0,185	1,901
P3	7,15	8,96	17,2	34	175	165	398	747	22	53,25	10	63,21	0,004	17,47	0,32	0,133
P4	6,92	7,03	17,8	39	295	95	485	906	28	71	20	38,7	0,009	32,55	0,231	0,121
P5	6,95	7,75	16,5	52,25	335	187,5	679	1277	28,75	124,25	25,2	66,98	0,013	10,44	0,092	0,109
P6	7,12	8,96	18,1	30,5	180	125	355	785	22	53,25	30	3,43	0,115	30,83	0,203	0,303
P7	7,21	4,36	17,5	27,5	230	45	350	654	21	35,5	20	5,15	0,138	37,49	0,097	0,024
P8	7,14	8,36	16,5	24,25	195	47,5	352	663	19	39,05	35,5	28,8	0,105	34,7	0,0021	0,012
S1	6,91	5,46	16,2	32	170	150	262	507	25,5	17,75	18,55	27,77	0,073	1,13	0,002	0,291
S2	6,99	9,06	16,7	29,4	155	139	280	531	22,5	26,98	23,54	60,19	0,001	2,01	0,157	0,157

T° = Temperature; EC = Electrical Conductivity; O2 = Dissolved Oxygen; COD = Chemical Oxygen Demand ; TH= Total Hardness ;ACT= Alcalimétriques Complete Title; NO_3^- = Nitrates; NO_2^- = Nitrites; NH_4^+ = Ammonium; PO_4^{3-} ; Orthophosphate; $SO_4^{\ 2-}$ = sulphates; Ca^{2+} = Calcium; Mg^{2+}= Magnesium ; Cl^- = chloride.

The nitrate concentrations vary from 1.13 mg l21 in springs S1 to 37.47 mg in wells P7. A relatively high concentration (37.47 mg) is recorded at stationP7 (near the manure), This high value may be influenced by anthropogenic sources, especially the manure. However, the nitrite levels are much lower, generally between 0.001 mg in springs and 0.523 mg in wells P2.

Ammonium is always evidence of organic pollution. It is present when the levels of oxygen are not sufficient to assure its transformation. In general, it is not observed in the study area, which is well oxygenated; the concentrations recorded at certain stations. The value is higher in the station P2, about 1.9 mg. the levels of ammonium vary from 0.012 mg to 1.901 mg. Regarding phosphates, our study deals only with orthophosphates. In natural waters, concentrations higher than 0.2 mg indicate pollution from domestic effluent containing organic phosphates; it clearly visible for the case of wells P1 about 0.231mg (near de landfill) .The overall data show that the waters of the region of Meknes are calcareous, hard and slightly acidic.

Cluster analysis

Cluster analysis is the method used for finding different classes and groups within the obtained data. A number of studies used this technique to successfully classify water samples (Alther, 1979; Williams, 1982; Farnham *et al.*, 2000; Alberto *et al.*, 2001; Meng and Maynard, 2001). The cluster analysis is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess (Danielsson, 1999). The levels of similarity at which observations are merged are used to construct a dendrogram (Chen, 2007).

Table 4. Faunal list of the taxa in the water of the 10 studied stations (P= wells; S= springs) (**: Stygobiont).

Taxa		P1	P2	P3	P4	P5	P6	P7	P8	S1	S2
plathelminta	Dugesia gonocephala						11	22	14		
Oligochaeta	Lumbriculidae						3				
	Tubificidae					4					
	Naididae			2							
Gastropoda	Planorbidae			2						3	2
	Physa sp									7	5
Copepoda	** Cyclopidae						12	2			
Ostracoda	Eucypris virens									4	
	Ilyocypris sp.					3					2
	** Ostracoda Indt			15							
Amphipoda	**Echinogammarus sp.										2
	** Pseudoniphargidae					3					
	**Metacrangonyctidae					2					
Collembola	Collembola			2	1	4		2	3		
Heteroptera	Mesovellidae		1		1	2					
Diptera	Culicidae	23	36		2			2			
	Chironomidae		2	11	13				2		3
Coleoptera	Dytiscidae										1
	Elmidae		3		1	3					
	Larvae ind.	4						3		2	3
Total Taxonomic Richness		23	42	32	18	21	26	31	19	16	18

A Principal Component Analysis (PCA) was performed on a data matrix consisting of 10 lines representing the stations and the 16 columns representing physicochemical variables measured or analyzed. The analysis generated two factors which together account for 64.98 % of variance. The factors are given in descending order depending on the variance. Factor 1 exhibit 38.17% of the total variance of 82.89% with high loadings of the dissolved oxygen,Mg2+, HCO3-, and moderate to loadings of Ca2+, SO42- and Cl-. This factor reveals that the EC and salinity in the study area are mainly due to Mg2+ and HCO3-, though Ca2+, SO42- and Cl- also play a substantial role to determining EC and salinity. This factor accounts for temporary hardness of the water.

Factor 2 exhibits 26.81% of the total variance with positive loading on pH, NH4+ and NO2− and negative loading on Ca2+ and total hardness. This water is calcium dominated, with high total hardness, and it also has low concentrations of sulphate. The hierarchical classification of stations on the basis of physico-chemical water quality has allowed us to distinguish four groups of stations (Figures 4 and 5): The analysis of factorial plans F1-F2 (Fig.4 and 5) reveals four major groups of physic chemical parameters:

Analysis of the first Groups G1

The group 1 contains of the samples from the wells P4 and P5 is dominated by TH and Ca^{2+} and has low Cl^- concentrations. Main source of Ca^{2+}ions in the water of this region is due to dissolution limestone, dolomite and from anthropogenic activities. The statistical units corresponding to this group G2 indicate that wells have water that evolve in oxidizing conditions and are characterized by high values of redox potential, ie by low pH values.

Analysis of the second groups G2

In this group G2, the water is characterized by high mineralization water compared to the water of the first groups G1. The water of the group is high in SO_4^{2-}. There is also a small but significant correlation between EC and Temperature (0.23). This high mineralization may be influenced by anthropogenic sources, especially the landfill such as wells P1

Analysis of the third groups G3

For this group G3 composed of the wells P2 situated close to landfill. The water from this well is highly ammonium-loaded ion (1.9 mg l-1), exceeds the value determined by the WHO standard for drinking water is of the order of 0.3 mg / L. This high value of ammonium may be influenced by anthropogenic sources, especially the landfill**.**

Analysis of the fourth groups G4

This group includes all other stations, whose waters are mediocre to poor. They are the richest effect ion indicators of organic pollution, the concentrations frequently exceed the standards set by the WHO. Nitrites such are always present at concentrations ranging from 0.1 to 0.5 mg L-1 and even the ammonium ions are detected in these wells despite the fact that the water is oxygenated (with 4.36 to 9.06 mg / L dissolved oxygen) in the stations in groups 2 and 3 (Table. 3). The water from these wells therefore poses a potential risk to the health of local populations who consume them.

These results and field observations, it appears that, throughout the study area, the water is highly mineralized, including high values of total hardness, salinity and sulphate content, all these ions from limestone or saline through which the groundwater it certainly does not represent a danger to users. However, if some stations reveal a slight organic pollution, others however (all those in group 2 and 3) show a serious pollution.

Biotic communities of the groundwater

The fauna sampled from all the stations is relatively diversified, comprising 20 taxa in the study area. In the latter, the most represented groups are Oligochaeta with 3 species, Gastropoda with 2 species, Crustacea with 7 species and larvae of Insecta with 7 taxa. The proportion of stygobitic species is rather high, i.e. 5 species or 25% of the community.

The invertebrate fauna collected in the wells and springs consisted of a combination of epigean and hypogean taxa, the latter represented mainly by crustaceans. Among the seven crustacean taxa, five were stygobiont. The most diverse groups were Amphipoda (3 taxa), followed by Ostracoda (1 taxa) and Copepoda Cyclopidae. The last taxon might be a stygobiont species. [48] Note that copepoda are particularly sensitive to microhabitat characteristics and therefore are good indicators of anthropogenically induced changes in water quality and hydrological regime. Groundwater is characterized in the study area by 20 aquatic biodiversity taxa (Table 3). Some taxa are stygobiont species, it is essentially amphipod: Metacrangonyctidae, Pseudoniphargidae and Echinogammarus sp; copepods: Cyclopidae. Other species are sometimes aquatic forms stygophiles as ostracods: Eucypris virens sp Ilyocypris or forms stygoxènes represented mainly by insect larvae and young imagos.

The region of Meknes appears to be very different from those of subterranean waters of Algeria, Libya, Egypt (Pesce *et al.* 1981), as well as Italy (Pesce 1985) and Germany (Botosaneanu 1986; Juberthie & Decu 1994). However, like Boutin (1993), we think that the Moroccan stygofauna is certainly much diversified but probably like that of the other countries of the Maghreb and Mediterranean basin; the apparent poverty of the fauna in these countries reflects the relative lack of attention given to the stygofauna. Although the total richness is lower than that of the subterranean waters of the Balkan regions, southern France or America (Culver 1982; Botosaneanu 1986; Ward & Voelz 1990; Gibert *et al.* 1994; Juberthie & Decu 1994), this richness does not seem so much lower, especially that of the Crustacea, Peracarida, Isopoda and Amphipoda, when one considers the long history of research in Europe and America.

The mean taxonomic richness in the 8 wells and 2 springs in our study area is lower than that observed in other region of Morocco, e.g. by Boutin and Dias (1987) at Marrakech (a mean of 12 species in 11 wells), by Boulal (1988) in Tiznit region in the northern Anti-atlas (a mean of 14 species in 10 wells) and by Boutin and Idbennacer (1989) in the southern Anti-atlas (a mean of 10.8 species in 7 wells). Moreover, the subterranean aquatic fauna collected in this study is characterized by relatively low taxonomic richness: 11 and 18 stygobitic species were reported in previous studies of wells in Morocco (Boulal 1988; Boulanouar 1986); this low taxonomic richness in our study area may be influenced by anthropogenic sources.

This relationship between water quality and richness of stygofauna has already been shown in the case of organic (Ait Boughrous *et al,* 2007) or inorganic e.g. (El Adnani *et al,* 2006; El Adnani *et al,* 2007) pollution. These studies have frequently highlighted a relationship between the effect of pollution from land application of wastewater (Ait Boughrous *et al*, 2007; Capasso, R, 1995) or the infiltration of leachate (El Adnani *et al,* 2006) and the sensitivity of the subterranean fauna. Experiments conducted in the laboratory with crustacea peracarid stygobites confirmed these findings (Boulanouar, M. 1995; Plenet, S, 1993). High levels of nitrite appear to be limiting for amphipods Metacrangonyx spinicaudatus, Metacrangonyx paurosexualis and the isopod Typhlocirolana haouzensis (Fakher El Abiari, *et al* , 1998). It appears from these studies that the research of stygofauna or requires good water quality. The stygobitic species can be susceptible to deterioration of groundwater quality but the sensitivity varies from one to another species (Fakher El Abiari, *et al* , 1998; Boutin, C., 1996). This work therefore complements these results.

Cluster analysis

The Principal Component Analysis performed on a data matrix composed of 10 columns representing the sampled stations and 20 lines representing the taxa collected have shown (Figure 6) that stygobitic species Metacrangonyctidae and Pseudoniphargidae, contribute negatively to the expression of the axis F1, which accumulated 20.59% of the inertia, and oppose other epigeic taxa. F2 axis, which cumulates an inertial rate of 31.43%, mainly opposed Cyclopidae and Ostracoda, which contribute positively to the expression of this axis, and oppose other epigeic taxa. The hierarchical classification of stations based on their population, has allowed distinguishing four different groups (Fig. 7):

Analysis of the first Groups G1

In this group includes both two springs S1 and S2 that have similar faunal composition, as well as epigeic and stygobitic taxa. These springs are distinguished from other stations by a higher proportion of epigeic taxa that may be due to the characteristics of these ecosystems largely open and unprotected, compared to the wells. They are therefore more favorable to the installation of epigeal species.

Analysis of the second groups G2

This group isolates the wells P5, which hosts the most diversified stands, with 8 taxa, located far from anthropogenic pollution. Of the most characteristic species of this wells is mostly amphipod crustaceans stygobitic such as family Pseudoniphargidae and Metacrangonyctidae, which are more sensitive to pollution.

Analysis of the third groups G3

This group composed of single wells P6. Biodiversity is relatively low; one notes the presence of a single family stygobie is Cyclopidae. The populating is formed mainly epigeal forms. One notes the presence of a single species stygobie more than 5% the total richness species. the stygophile and stygoxène fauna original epigeal hosting groundwater tolerated waters rich in organic matter and is often indicative of an poor water quality it is the case of Oligochaeta, ostracoda, copepoda and larvae Diptera Chironomidae and Culicidae, generally found in waters in oxygen low and rich in organic matter, in unprotected wells and disturbed by human activity e.g (Gibert, J, 1997; El Adnani *et al,* 2006).

Analysis of the fourth groups G4

For this group includes all 11 other wells P1, P2, P3, P4, P7 and P8. These wells are characterized by the complete absence of stygobitic species and total biological richness quite low, not to exceed five taxa. It should be recalled here that almost all of these wells are opened unprotected and vulnerable to the other local pollution.

The analysis of the faunal data presented in Table 4 shows that the composition of the stands is highly variable from well to well another and whereas the specific richness appears to be related to the overall water quality of the water well as the condition Protection of wells. The populating of this region appears very abundant and diverse, a testament to adequate living conditions for the majority of species found, which are probably sensitive to various sources of pollution.

Conclusions

In conclusion, this study has concluded that surveys of groundwater fauna can be used as indicators of environmental health in aquifers, and that stygofauna should be incorporated into groundwater management and protection programmes. Our results show that a stygobic species react first. In a contamination of the water, they may disappear completely in case of a major spill. For this reason and in relation to their sensitivity regarding mineral and organic pollutants, stygobiont animal population could be used as soon as the stygofauna of the region is known as an indicator of anthropogenic pollution. It would thus constitute an additional tool of physicochemical analysis, useful for assessing the quality of groundwater or an alternative and less costly. There are many threats to groundwater fauna and it is likely that anthropogenic activities have caused and will cause the extinction of the endemic groundwater species.

Acknowledgments

Many thanks to the specialists C Boutin and M Boulanour for the help with field work and for interesting discussions.

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