sciendo

Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 41, No. 3, p. 219–227, 2022

DOI:10.2478/eko-2022-0022

CHARACTERIZATION AND DIVERSITY OF MACROINVERTEBRATES IN GROUNDWATER IN THE REGION OF SOUK-AHRAS (NORTH-EAST OF ALGERIA)

AMIRA CHORFI[1], HINDA HAFID[2], AFFEF BAALOUDJ ✉[1], HADIA RIZI[1], HANI AMIR AOUISSI[3], SARA CHAIB[1], MOSTAFA ABABSA[3], NOUA ALLAOUA[2], MOUSSA HOUHAMDI[1]

[1]Biology, Water and Environment Laboratory (LBEE), SNV-STU Faculty, University May 8, 1945., BP. 401 24000 Guelma, Algeria; e-mail: bafef@yahoo.fr, baaloudj.affef@univguelma.dz
[2]Natural Resources and Sensitive Environments Development Laboratory (RNMAS), University of Oum El-Bouaghi, Department of Biology, Algeria
[3]Scientific and Technical Research on Arid Regions (CRSTRA), Campus Mohamed Kheider, Biskra, 07000, Algeria

✉ Corresponding author

Received: 7.3.2022 / **Accepted:** 13.6.2022

Abstract

Chorfi A., Hafid H., Baaloudj A., Rizi H., Aouissi H.A., Chaib S., Ababsa M., Allaoua N., Houhamdi M.: Characterization and diversity of macroinvertebrates in groundwater in the region of Souk-Ahras (North-East of Algeria). Ekológia (Bratislava), Vol. 41, No. 3, p. 219–227, 2022.

A preliminary inventory of macroinvertebrate communities and a regular physicochemical analysis of groundwater were carried out in the Souk Ahras region (north-eastern Algeria). It aims to study and analyze the structure and distribution of underground aquatic species, thus determining the relationship that may exist between the quality of water in wells and springs with the diversity of aquatic fauna present in the habitats. Through 2018, 14 stations (10 wells and 4 springs) were monitored on a monthly basis, while water and aquatic fauna samples were taken. A principal component analysis (PCA) of the physicochemical quality parameters was carried out from the average values of each parameter. It has been observed that the waters are highly mineralized, due to the high values of total hardness, salinity, and sulfate levels in certain stations. The sources of contamination are mainly due to the raw wastewater circulating in the small canals. Also "seguias" are used either to evacuate wastewater or for irrigation, which seeps down to the water table. The collected aquatic fauna in all the 14 stations is diversified and contains 29 families which correspond to 4 taxa.

Key words: macroinvertebrate communities, ground water, Algeria.

Introduction

In Algeria, ground water is an essential source of supply of potable water. The estimate across the country at 6.7 billion m^3 is poorly distributed barely 25% of groundwater and it is located in the north of the country, where more than 70% of the population is living (Bellil, Kharchi, 2015). The underground environment is not only a vast reservoir of water but also a biotope hosting many taxonomic groups. Current data show that all types of underground aquatic biotopes have been colonized from equatorial areas, up to the subarctic zones (Juberthie, Decu, 1994, 1998, 2001).

It is also the reservoir of an original biological diversity made up of organisms, most of which have no equivalent in surface aquatic ecosystems and some lineages are several million years old (Boutin, Idbennacer, 1989). Unicellular, microscopic living organisms (bacteria and protozoa) of the animal kingdom are mainly represented in the groundwater by the class of worms; indeed, the class of Mollusca is the most abundant and best studied stygobic fauna and even that of crustaceans (Bou, Rouch, 1967). Stygobites are species with morphological, behavioral, and metabolic adaptations directly related to the underground environment, and which carry out their entire life cycle in this environment (Marmonier et al., 1993; Gibert et al., 1994).

The underground environment has been considered to be colonized by only a few very specialized species. On the contrary, current data show that rich communities of species are composed mainly of invertebrates but also vertebrates and micro-organisms (Issartel, 2007).

Additionally, pollution poses a constant threat to all of our valuable reserves. Therefore, regular water monitoring, including physicochemical and microbiological analyses, is required (Sari, 2014).

In North Africa, knowledge of the diversity of underground aquatic fauna remains restricted due to the studies that have been carried out in Morocco (Boutin, Boulaouar, 1983; Messouli, 1988; Yacoubi-Khébiza, 1990). This research showed that the richness of the stygobia fauna varied greatly from one region to another due to the endemic nature of these species (Boutin, 1996). In Algeria, the underground fauna has been the subject of systematic studies to inventory the stygobal species of the alluvial waters of Oued Tafna in Tlemcen (Belaidi et al., 2004, 2011; Mahi 2007). The underground aquatic fauna of Northeastern Algeria has also been the subject of several contributions (Merzoug et al., 2010).

© The Author(s) 2022. This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

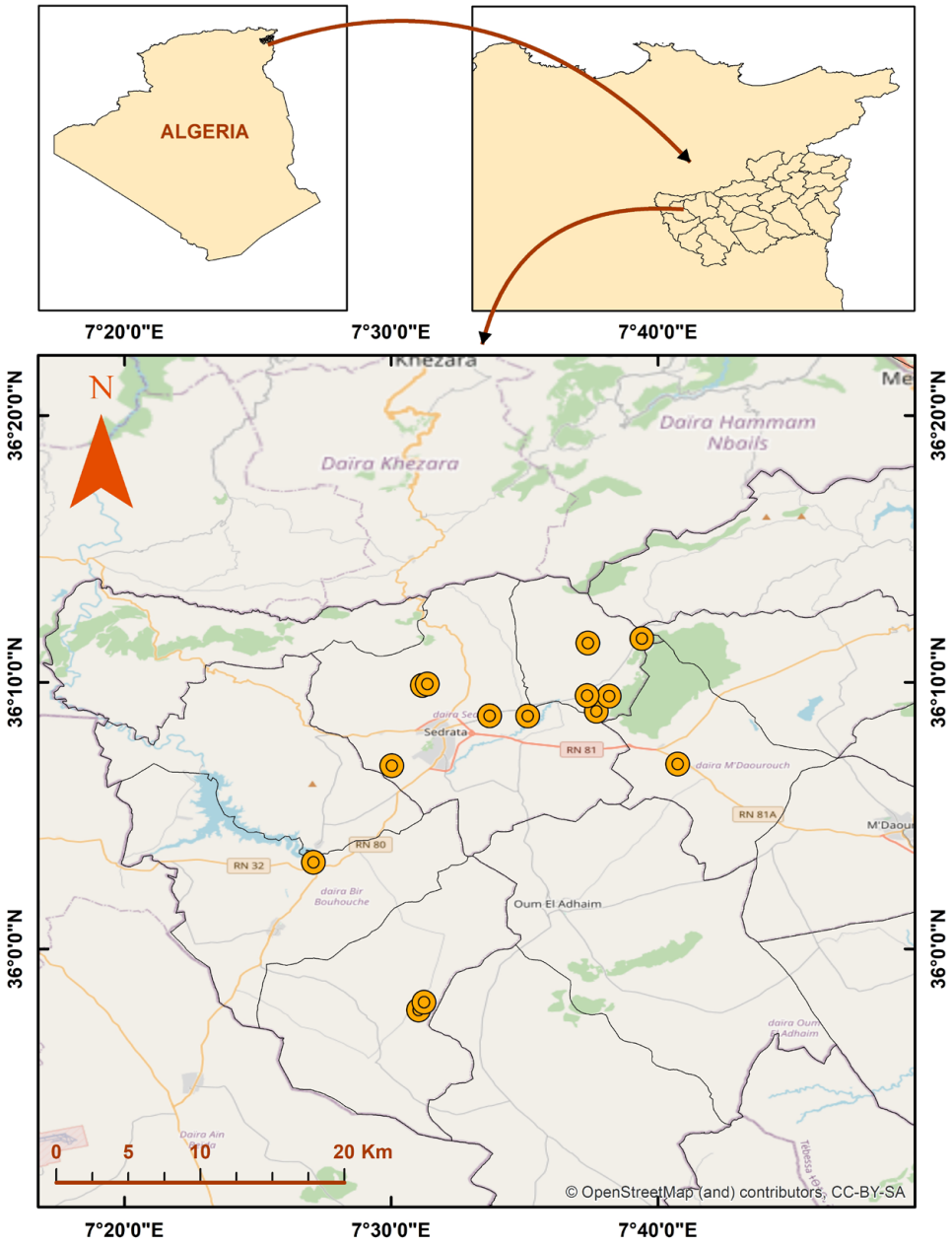


Fig. 1. Study area.

Our study aimed to determine the ecology and biodiversity of underground aquatic fauna and to represent the results of stygobiological research through wells in the region of Souk-Ahras (Northeastern Algeria).

Material and methods

Study area

Souk-Ahras area is located in Northeastern Algeria (36°17'11"N, 7°57'4"E). It is limited to the northeast by the wilaya of El Taraf, to the northwest by the wilaya of Guelma, to the south by the wilaya of Tebessa, to the southwest by the wilaya of Oum El Bouaghi, and the east by Tunisia (Fig. 1). It covers an area of 4,359.65 km² which is divided into 26 municipalities. It presents a rugged relief with an average altitude of 1,000 m in the north and 650 m in the south.

The stations

The stations bring together 10 wells and four sources, spread over six municipalities of the wilaya (Khemissa, Sedrata, Zouabi, Ragouba, Safel El Ouidene, and Oum EL Adhayem) (Table 1). The study focused preferably on wells used by the population for irri-

Table 1. Location of 14 study stations.

Stations	Geographical coordinates		Village
P1	**X:** 36°11.65'N	**Y:** 7°39.386'E	Khemissa
P2	**X:**36°06.882'N	**Y: 7**°30.013'E	Sedrata
P3	**X:**36°09.512'N	**Y:** 7°37.339'E	Khemissa
P4	**X:**36°09.495'N	**Y:**7°38.1603E	Khemissa
P5	**X:**36°09.944'N	**Y:** 7°31.350'E	Sedrata
P6	**X :**36°6'56.50N	**Y :**7°40'43.82E	Ragouba
P7	**X :**36°3'15.61N	**Y:**7°27'4.52E	Zouabi
P8	**X :**35°58.011N	**Y :** 7°31.224'E	Safel El Ouidene
P9	**X :**35°57.722'N	**Y :** 7°31.021'E	Safel El Ouidene
P10	**X :**36°08.75'N	**Y :**7°35.1073'E	Oum El Adhayem
S1	**X:** 36°09.892'N	**Y:** 7°31.159'E	Sedrata
S2	**X :** 36° 8'55.46»N	**Y :** 7°37'41.15»E	Khemissa
S3	**X:** 36°11.480'N	**Y:** 7°37.362'E	Khemissa
S4	**X :** 36° 8'45.37»N	**Y :** 7°33'40.77»E	Sedrata

Notes: P – wells; S – source.

Table 2. Average values of the physicochemical variables of the water of 14 stations.

Variable	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	S1	S2	S3	S4
T	18	20.1	15.3	19.6	14.5	21.2	16	20.1	17.1	16.8	16.4	16.6	17.1	18.6
pH	7.04	12.2	6.27	7.6	6.69	8.18	6.39	7.23	7.68	6.54	6.42	6.22	6.22	6.83
CE	821	274.5	677.5	908	610	280.5	987.5	1,238	1,182.5	737	605	647.5	606.5	703
Sal	2.77	0.54	0.29	0.14	0.3	1.95	0.48	0.78	0.6	0.29	0.32	0.68	0.36	0.46
Tac	920	68	64	90	140	40	100	40	72	20	10	120	12	14
SO_4^{2-}	369.32	229.46	40.17	80.48	109.64	508.28	96.43	183.45	223.99	47.004	112.39	113.74	371.6	36.52
NO_3^-	0.817	0.96	0.161	0.845	1.075	1.276	1.219	0.932	1.046	0.845	1.0469	1.305	1.248	1.161
NH_4^+	34.94	21.99	1.3075	1.5807	1.6906	31.56	1.6202	8.48	11.28	1.78	1.6185	2.1391	1.3521	1.8575
Cl	212.17	295.13	4,422.092	556.62	556.62	214.83	340.161	340.161	565.33	420.19	524.41	255.12	0	1020.483
PO_4^{2-}	0.0007	0.0005	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0007	0.0005	0.0005	0.0005	0.0005	0.0005
DT	1,300	1,354	260	370	400	1,200	210	500	500	420	380	186	180	260

gation and for drinking water, which offers the possibility of carrying out regular faunal surveys, under comparable conditions.

Physicochemical analyses of water

The physicochemical descriptors of water such as temperature, pH, conductivity, and salinity were measured in the field, immediately using a multiparameter and a HANNA brand conductivity meter. The samples of water intended for the analysis were taken in 0.5l plastic mineral water bottles and kept cool, and the chemical analyses of the parameters of sulfates, ammonium, nitrates, chlorides, and complete alkalimetric titers were carried out using a Thermo brand spectrophotometer in the analysis laboratory.

Study of the fauna

The harvesting of the underground fauna was carried out at the wells and springs, each of which presents specific methods, with monthly sampling during the period from January to April 2018 with a minimum of 10 outings (round trip).

Sampling at well level

The well requires different sampling methods adapted to the fauna that composes it. However, it is often necessary to resort to multiple techniques, each of which has advantages and disadvantages (Graf, 1966; Vigna Taglianti, 1969). In our study, we used both, for each well, two types of sampling, photobiological net (Cvetkov, 1968) and baited traps of the "trap" type for 24 hours developed by Boutin (Mahi, 2007). We used a fragment of the fresh liver as bait. Once the bottle is baited, it is placed at the bottom of the well by a rope and held at the bottom by a small rock fixed to the bottle, to ensure certain stability of the device. The organisms sampled are immediately placed in plastic bottles and fixed with 95% ethanol before being transported to the laboratory for sorting, counting, and then identification.

Sampling at source level

For sampling, two techniques were carried out: one with a net of 300 mm mesh performed all first by creating turbulence inside

Table 3. Bartlett's sphericity test.

Khi² (observed value)	158,827
Khi² (critical value)	38,958
DDL	55
p-value (bilateral)	< 0,0001
Alpha	0,95

Table 4. Clean values.

	F1	F2	F3
Clean value	4,906	2,048	1,865
Variability (%)	44,603	18,614	16,955
Cumulative (%)	44,603	63,218	80,173

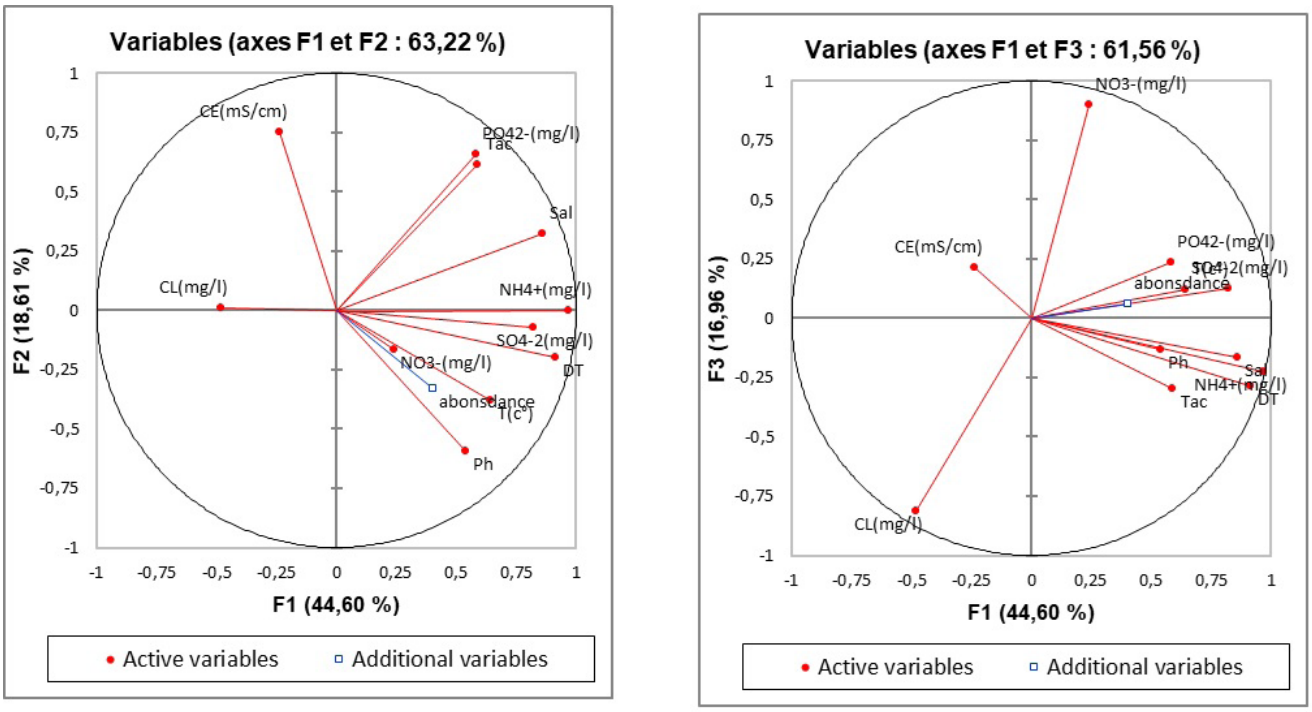


Fig. 2. Circle of correlations of physicochemical water variables.

the resurgence of the source using a stick by fixing the net for a few minutes at the resurgence point to filter; the other by scraping the source substrate (Bellil, Kharachi, 2015).

Technique for sorting and determining the fauna harvested

In the laboratory, all the samples are sorted. Observation and identification were carried out using a binocular magnifying glass using different identification keys (Tachet et al., 1980, 2002).

Statistical analysis

Principal component analyses (PCA) were carried out with the XL-STAT 2018 software, from the average values of each of the physicochemical factors of water on the one hand and the faunal data on the other hand used as descriptors of the 14 wells. The purpose of these analyses is to establish the correlations that may exist between the different physicochemical variables of the water and the occurrence of the taxa collected to objectively define the groups of stations resulting from PCAs.

Results and discussion

Physicochemical study of well water

The average values of the physicochemical parameters of the water of 14 stations are grouped in Table 2. The temperatures have values between 14.5 °C (P5) and 20.1 °C (P2). The recorded pH measurements show that the values vary between 6.22 and 8.18 except for one well (P2) where pH = 12. The values of the conductivity recorded in the ten wells and the four sources vary between 605ms (source 1) and 1182.5ms (well 9). For salinity, the values e varied between 0.29 and 2.77% so the greatest values were recorded at the level of then P1 and P6. Alkalinity values vary between 10 and 920 mg/l respectively in stations (S1) and (P1). The sulfate values in the waters studied are very variable between 36, 52, and 508.28 mg/l in the stations (S4) and (P6). The nitrate levels are between 0.161 mg/L recorded at the station (P3) and 1.305 mg/l at the station (S2). Ammonium concentrations at wells and springs are above 0.5 mg/l, especially at P1, P2, P6, P, and P9. These very strong tenures in the waters of the preceding wells are certainly caused by the accumulation of ex-

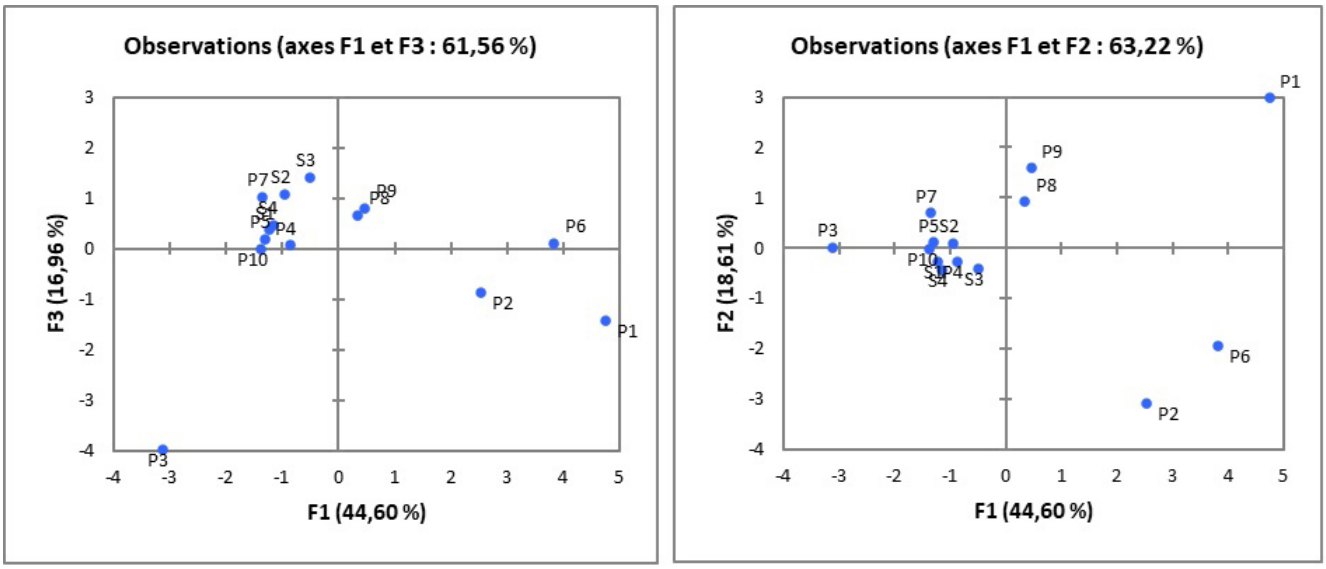


Fig. 3. Factorial map of individuals (stations) of water.

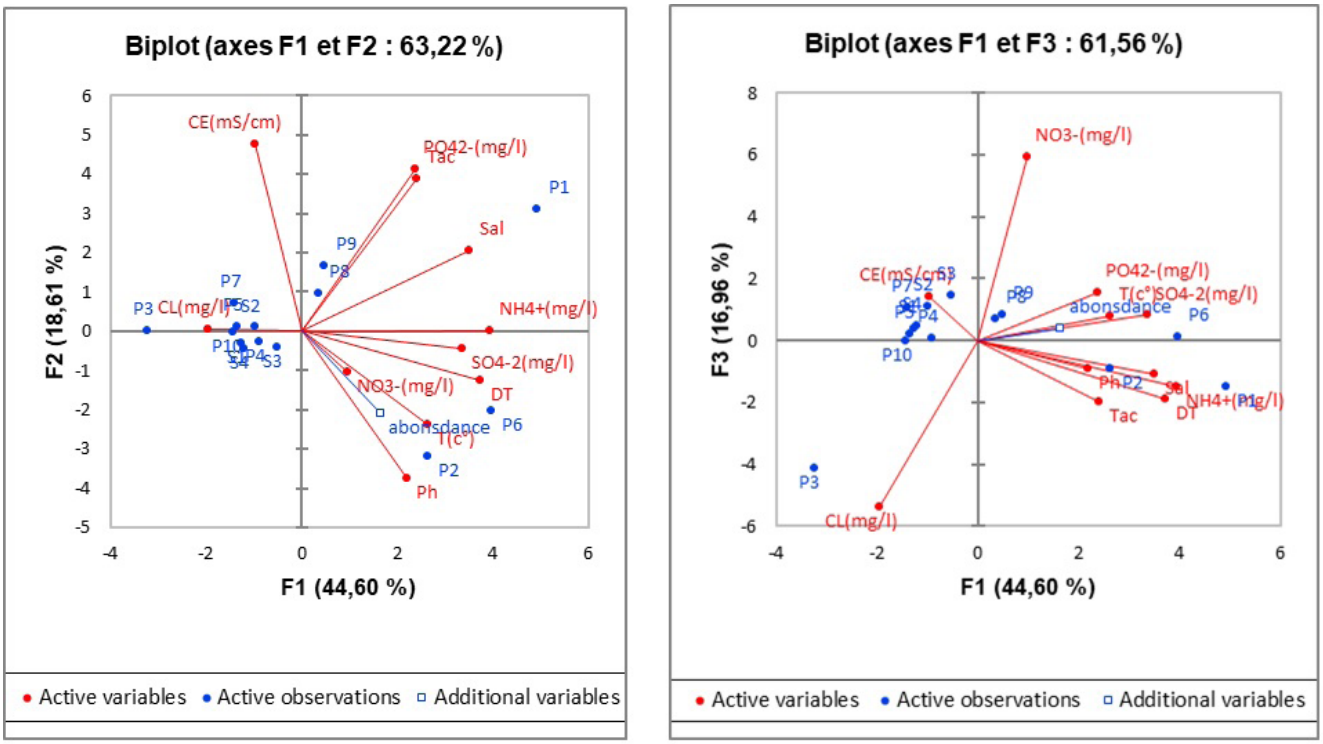


Fig. 4. Simultaneous representation.

crement from the corpses of pigeons, which makes the environment very low in dissolved oxygen and therefore not very oxidizing or even relatively reducing and subsequently promotes the transformation of nitrogenous ions in the form of ammonium. The maximum chloride content was recorded at the level of P3 (4,422.092 mg/l), S4 (1,020.483 mg/l), P4 and P5 (556.62 mg/l) and the minimum value at the level of S3 (0). The concentrations of phosphates (PO4-3) recorded at the level of the wells and the sources studied varied between 0.0004 and 0.0007 mg/l. The results show that the turbidity values vary between 180 (S3) and 1,354 (P2).

According to the WHO, the temperatures, pH measurements, electrical conductivity, sulfates, and nitrates recorded from all the wells and sources are within the range of the pota-

Table 5. Inventory of fauna sampled within all stations.

Taxons				P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	S1	S2	S3	S4
Phylum	**Class**	**Order**	**Family**														
Arthropods	**Crustacea**	Amphipoda	Gammaridae			**17**			**133**								
			Pseudonephargidae							1							1
		Cladocera	Daphynidae						550	32							
		Ostracoda	Cylindroleberididae	2		1											
	Insecta	Diptera	Culicidae			2	1			5		18	26	6	2		
			Muscidae			1											
			Uenoidae	1													
			Chrinomidae	8					1	1		1	86	6	157	8	
		Lepidoptera					1										
		Coleoptera	Eliminatae			2											
			Notomectidae			2											
			Dytiscidae			4											
			Gabaridae					7									
			Hydrophilidae										3				
			Hydraenidae										3				
			Spercheidae										3				
			Chrysomelidae											1			
		Ephemeroptera	Beatidae	39					32		32		130	140			
			Caenidae	6													
			Ephemerillidae	25													
			Heptageniidae	6													
		Heteroptera	Naucoridae						4								
			Aphelocheiridae			4											
			Formicidae							3							
		Plecoptera	Perllidae										2				
		Odonata	Libellulidae						19					6			
Mollusca	**Gastropoda**	Basommatophora	Physidae			3	36		18		1					2	
			Planorbidae						2								
Annelida	**Clitellata**	Arhynchobdellida	Hurinidae														112

bility standard except for well 2 whose value of pH exceeds the standard (pH=12) and well 6 where the sulfate value exceeds the standard.The first results of our PCA contain the correlation matrix demonstrated before and a Bartlett sphericity test representing the overall significance of the correlations between the variables. Table 3 shows that at least one of the correlations between the variables is significantly different from 0 (P<0.0001). From Table 4 of eigenvalues, the cumulative inertia explained by the first three axes is equal to 80.17% of the expressed variance, which gives us a good representation of variables and individuals using two planes (F1; F2) and (F1; F3).

The projection of the variables on the factorial plan F1 and F2 with 63.22% of explained variance shows the projection of the variables: T(c°), Sal, SO4-2(mg/l), NH4+ (mg/l), NH4+ (mg/l), DT, and abundance on the F1 axis in a positive side, indicating a positive correlation between these variables. While the F2 axis opposes the variables CE (mS/cm), Tac, PO42-(mg/l) on the positive side with pH which comes in the negative direction (Fig. 2).

On the other hand, the factorial planes F1 and F3 with 61.56% of explained variance show in addition to the information relating to the projection of the variables on F1; the F3 axis shows an opposition of NO3-(mg/l) on the positive side with CL (mg/l) and taxon which comes in the negative direction.

The projection of the variables on the F1 and F2 factorial plane shows the opposition of P1 and P6 on the F1 axis on the positive side and P5, P7, P10, S1, and S4 on the negative side (Fig. 3). While the F2 axis shows the projection of P2 and P9 from the positive side.

The factorial plans F1 and F3 show in addition to the information relating to F1, the axis F3 opposes the individuals: P3 and S2 are located on the positive side and the individual S3 on the negative side.

The simultaneous representation of variables and individuals on the factorial plane will help us to combine the link between the direction of variation of the variables. Thus, our factorial plan brings together the group of variables T(c°), Sal, SO4-2(mg/l), NH4+(mg/l), NH4+(mg/l), DT, and the abundance of macroinvertebrate taxa on the F1 axis in a positive side with the two wells (P1 and P6), which indicates that these two sampling points show a high abundance and the elements Sal, SO4-2 (mg/l), NH4 (mg/l), NH4+(mg/l), DT which increase positively with the temperature T(c°), whereas the stations (P5, P7, P10, S1, and S4) show a rupture of these elements.

Similarly, for F2 which brings together the group of variables CE (mS/cm), Tac, and PO42-(mg/l) with the two wells (P2 and P9) on the positive side which vary negatively with the pH (Fig. 4).

The factor F3 in the second factorial plane brings the variable NO3-(mg/l) closer to the two wells (P3 and S2) which are located on the positive side and the variable CL (mg/l) increases positively with the Taxa of Station S3.

Study of the underground fauna of wells

Our study allowed us to identify 1715 individuals belonging to 4 classes and 29 families.

The study of groundwater macroinvertebrates in the Souk-Ahras region (North-East of Algeria) made it possible to collect 1715 individuals belonging to 4 classes and 29 families (Table 5). Spatial (inter-site) variability in the richness of taxonomic orders

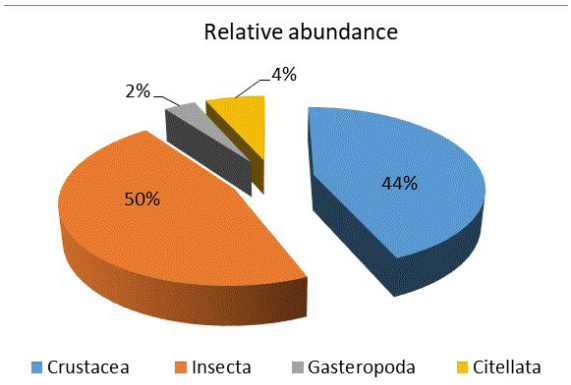


Fig. 5. Relative abundance of faunal groups in 14 stations.

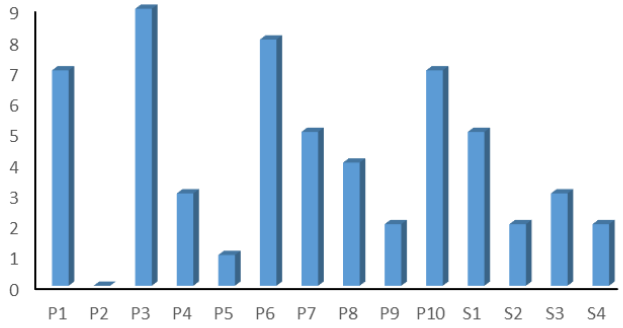


Fig. 6. Variation in the taxonomic richness of the fauna collected in 14 stations.

was detected. Our results reveal that the majority of macroinvertebrates in the studied environments are similar to those in the temporary superficial studied habitats in Morocco (Giudicelli, Thiéry, 1998), Italy (Bazzanti et al.,1996, 2009; Bagella et al., 2010), Spain (Boix et al., 2004, 2008, 2009), and in Algeria (Lounaci et al., 2000; Khelifa, 2019; Khelifa et al., 2016; Meziane et al, 2020, Baaloudj et al., 2020, 2022; Rouibi et al., 2021). A total of 29 taxa and 1715 individuals were collected during this study. This richness is lower than that recorded in the 16 wells of the North Constantinos region of Northeastern Algeria (Aidaoui et al, 2018). This varied number of taxa is probably linked to the contamination of water in many studied wells, by infiltration of wastewater and agricultural fertilizers in particular and pollution. But this number also remains much lower than in previous studies conducted in the Oum El Bouaghi region (Merzoug et al., 2010).

The obtained results show that all the harvested stands during the study period (Fig. 5). The insects represent the highest percentage (50%), followed by crustaceans with a percentage of (44%), then the Citellata with (4%) of the total wealth, and finally, the lowest percentage was represented by the Gastropods with 2%.

By comparison, groundwater populations are much less diversified compared to watercourses, in particular, those of watercourses in Kabylie Djurdjura (Lounaci, 2005), Wadi Djedir and

Wadi M'zi (Sellam et al., 2017), Oued Boumerzoug (Bekhouche et al., 2017), watershed of the Soummam (Zouggaghe, 2020), Oued Sybousse (Baaloudj et al., 2020, 2022), and Wadi Bouhamdane (Rouibi et al., 2021). Figure 6 represents the spatial distribution of taxonomic richness, which revealed variation from one well to another. In a total of the 29 listed taxa, this number varies between 0 and 29, or the minimum was 0 taxa recorded at the level of well P2 and a maximum of 9 taxa collected at the level of P6. In addition, species resistant to pollution of airborne origin are present in the majority of surveyed wells, such as the larvae of Chironomidae and Culicidae insects (Lakhdari, Dubost, 2014).

Conclusion

This preliminary study, in the region of Souk Ahras, focuses on the quality of water in 14 stations (between wells and springs) during an annual cycle. Some stations reveal light pollution such as sources S1, S2, S3, P5, P7, and others, on the other hand, show serious pollution in the case of wells P1, P6, and P2. Water pollution is mainly due to raw wastewater circulating in the small "seguias" canals used either to evacuate wastewater or for irrigation, which infiltrates the water table manure and sewage runoff from sheepfolds and stables also represent another source of water pollution. The use of chemical fertilizers causes some pollution in wells located in agricultural areas. The stations whose water is generally of good quality are located far from sources of pollution. By noting, thus, that the quality of the water deteriorates while approaching the residential areas. The spatiotemporal distribution of taxonomic richness shows a variation in richness from one station to another. Finally, the analysis of the physicochemical data and the settlement made it possible to deduce that in the wells protected and located far from the sources of pollution, the waters are of good physicochemical quality and they host a rich and diversified fauna. While the fauna living in polluted waters is generally of the epigeal type (insect larvae), it appears that wealth reflects water quality. It can be a simple tool to assess the quality of this water.

References

Aidaoui, S., Nouidjem, Y., Saheb, M., Houhamdi, M. & Kebbab D. (2018). Ecology and biodiversity of underground water in the region of Nord Constantinois (Northeast Algeria). *World Journal of Environmental Biosciences,* 7(1), 52–58. www.environmentaljournals.org

Baaloudj, A., De los Ríos-Escalanteb, P.R. & Essed C. (2022). Benthic community ecology for Algerian river Seybouse. *Braz. J. Biol.*, 84, e251566. DOI: 10.1590/1519-6984.251566.

Baaloudj, A., Ouarab, S., Kerfouf, A., Bouriach, M., Ali Hussein, A., Hammana, C. & N'diaye Djeneba H. (2020). Use of macroinvertebrates to assess the quality of Seybouse River (North-East of Algeria). *Ukrainian Journal of Ecology,* 10(4), 60–66. DOI: 10.15421/2020_168.

Bagella, S., Caria, M.C. & Zuccarello V. (2010). Patterns of emblematic habitat types in Mediterranean temporary wetlands. *C. R. Biol.,* 333, 694–700. DOI: 10.1016/j.crvi.2010.06.006.

Bazzanti, M., Baldoni, S. & Seminara M. (1996). Invertebrate macrofauna of a temporary pond in Central Italy: composition, community parameters and temporal succession. *Arch. Hydrobiol.,* 137, 77–94. DOI: 10.1127/archiv-hydrobiol/137/1996/77.

Bazzanti, M., Bella, V.D. & Grezzi F. (2009). Functional characteristics of macroinvertebrate communities in Mediterranean ponds (Central Italy): influence of water permanence and microhabitat type. *Ann. Limnol.,* 45, 29–39. DOI: 10.1051/limn/09005.

Bekhouche, N., Marniche, F. & Ouldjaoui A. (2017). Contribution to the study of the biodiversity of benthic invertebrates and the biological quality of some rivers in the watershed Boumerzoug (east of Algeria). *Journal of Fundamental and Applied Sciences*, 9(1), 234–260. DOI: 10.4314/jfas.v9i1.16.

Belaidi, N., Taleb, A. & Gagneur J. (2004). Composition and dynamics of hyporheic and surface fauna in a semi-arid stream about the management of a polluted reservoir. *Ann. Limnol.*, 40(3), 237–248. DOI: 10.1051/limn/2004020.

Belaidi, N., Taleb, A., Mahi, A. & Messana G. (2011). Composition and distribution of stygobionts in the Tafna alluvial aquifer (north-western Algeria). *Subterranean Biology*, 8, 21–32. DOI: 10.3897/subtbiol.8.1227.

Bellil, S. & Kharchi A. (2015). *Contribution à l'étude de la qualité physicochimique et bactériologique de l'eau souterraine dans la région d'Ain (Oum El Bouaghi)*. Fac. Des SEV et Science Exacte, Dép. Biologie. Univ.

Boix, D., Gascón, S., Sala, J., Badosa, A., Brucet, S., López-Flores, R., Martinoy, M., Gifre, J. & Quintana X.D. (2008). Patterns of composition and species richness of crustaceans and aquatic insects along environmental gradients in Mediterranean water bodies. *Hydrobiologia,* 597, 53–69. DOI: 10.1007/s10750-007-9221-z.

Boix, D., Sala, J., Gascón, S., Ruhi, A. & Quintana X.D. (2009). Structure of invertebrate assemblages' contribution to the ecological functioning of the Mediterranean temporary ponds. In P. Fraga & I. Arguimbau (Eds.), *International Conference on Medi-terranean Temporary Ponds* (pp. 153–189). Proceedings & Abstracts. Maó, Menorca, Spain: Consell Insular de Menorca, Recerca.

Boix, D., Sala, J., Quintana, X.D. & Moreno-Amich R. (2004). Succession of the animal community in a Mediterranean temporary pond. *Journal of North American Benthological Society,* 23, 29–49. DOI: 10.1899/0887-3593(2004)023<0029:SOTACI>2.0.CO;2.

Bou, C. & Rouch R. (1967). Un nouveau champ de recherches sur la faune aquatique souterraine. *Comptes Rendus de l'Académie des Sciences de Paris,* 265, 369–370.

Boutin, C. (1996). Conductivité thermique du béton cellulaire autoclavé: modélisation par méthode autocohérente. *Materials and Structures*, 29(10), 609–615. DOI: 10.1007/BF02485968.

Boutin, C. & Boulanouar M. (1983). Methodes de capture de la faune stygobie. Expérimentation de différents types de pièges appâtés dans les puits de Marrakech. *Bull. Fac. Sc. Marrakech*, 2, 5–21.

Boutin, C. & Idbennacer B. (1989). Faune stygobie du Sud de l'Anti-Atlas marocain premiers résultats. *Rev. Sci. l'Eau*, 2(4), 891–904. DOI: 10.7202/705061ar

Cvetkov, L. (1968). Un filet phréatobiologique. *Bulletin de l'institut de Zoologie et Musée de l'Académie Bulgare de la Science*, 27, 215–218.

Gibert, J., Stanford, J.A., Dole-Olivier, M.J. & Ward J.V. (1994). Basic attributes of groundwater ecosystems and prospects for research. In J. Gibert, D.L. Danielopol & J.A. Stanford (Eds.), *Groundwater ecology* (pp. 7–40). San Diego: Academic Press.

Giudicelli, J. & Thiéry A. (1998). La faune des mares temporaires, son originalité et son intérêt pour la biodiversité des eaux continentales méditerranéennes. *Ecol. Mediterr.,* 24(2), 135–143.

Graf, D.L. (1966). *The origin of saline formation waters, III: Calcium chloride waters*. Illinois.

Issartel, J. (2007). *Adaptation de la faune souterraine aux basses températures : mécanismes et enjeux écologiques*. Lyon: Université Claude Bernard.

Juberthie, C. & Decu V. (1994). *Encyclopaedia Biospeologica I*. Société de Biospéologie.

Juberthie, C. & Decu V. (1998). *Encyclopaedia Biospeologica II.* Société de Biospéologie.

Juberthie, C. & Decu V. (2001). *Encyclopaedia Biospeologica III*. Société de Biospéologie.

Khelifa, R. (2019). Sensitivity of biodiversity indices to the life-history stage, habitat type, and landscape in Odonata community. *Biol. Conserv.,* 23, 63–69. DOI: 10.1016/j.biocon.2019.06.010.

Khelifa, R., Zebsa, R., Amari, H., Mellal, M.K., Mahd-joub, H. & Kahalerras A. (2016). A hot spot for threatened Mediterranean odonates in the Seybouse River (North-east Algeria): are IUCN population sizes drastically underestimated? *International Journal of Odonatology*, 19, 1–11. DOI: 10.1080/13887890.2015.1133331.

Lakhdari, F. & Dubost D. (2014). L'eau et ses enjeux en zone aride. La région de l'Oued Righ (Algérie), un système hydraulique complexe et fragile. In A. Ballouche & N. Taibi (Eds.), *Eau, Milieux, Aménagement. Une recherche au service des territoires* (pp. 45–52). Presses de l'Université d'Angers.

Lounaci, A. (2005). *Recherche sur la faunistique, l'écologie et la biogéographie des macroinvertébrés des cours d'eau de Kabylie (Tizi-Ouzou, Algérie)*. Masters thesis, Tizi-Ouzou, Université Mouloud Mammeri de Tizi-Ouzou.

Lounaci, A., Brosse, S., Thomas, A. & Lek S. (2000). Abundance, diversity, and community structure of macroinvertebrates in an Algerian stream: the Sébaou stream. *Ann. Limnol.*, 36(2), 123–133. DOI: 10.1051/limn/2000008.

Mahi, A. (2007). *Contribution à l'étude de la faune ywi ygobie de la région Tlemcen nord – ouest Algérien*. Fac. des Sciences, Dép. de Biologie, University Tlemcen.

Marmonier, P., Vervier, P., Gibert, J., & Dole-Olivier M.J. (1993). Biodiversity in ground waters. *Trends in Ecology & Evolution*, 8(11), 392–395. DOI: 10.1016/0169-5347(93)90039-R.

Merzoug, D., Khiari, A., Boughrous, A.A. & Boutin C. (2010). Faune aquatique et qualité de l'eau des puits et sources de la région d'Oum-El-Bouaghi (Nord-Est Algérien). *Hydroécologie Appliquée*, 17, 77–97. DOI: 10.1051/hydro/2010001.

Messouli, M. (1988). *Les Crustacés Amphipodes souterrains du Groupe Metacrangonyx. Répartition, Systématique, Phylogénie*. Thèse de 3ème Cycle, Faculté des Sciences Marrakech.

Meziane, K., Kerfouf, A. & Baaloudj A. (2020). Checklist of gastropod mollusks on the west coast of Algeria. *International Journal of Aquatic Biology*, 8, 224–227. www.ij-aquaticbiology.com

Rouibi, A., Baaloudj, A., Chahrour, F., Kerfouf, A., Rizi, H., Berdja, R., Belkhiria, W., Chaib, S. & Gharbi M. (2021). Characterization and diversity of macroinvertebrates of the Bouhamdane stream (Northeast of Algeria). *Zoology and Ecology,* 31(1), 45–52. DOI: 10.35513/21658005.2021.1.8.

Sari, H. (2014). *Contribution à l'étude de la qualité physicochimique et bactériologique de l'eau de la source el thar (Tlemcen)*. Fac. Des SEV et S.de la terre et l'Univers., University Tlemcen.

Sellam, N., Zouggache, F., Pinel-Alloul, B., Mimouni, A. & Moulai R. (2017). Taxa richness and community structure of macroinvertebrates in rivers of different bioclimatic regions of Algeria. *Journal of Materials and Environmental Sciences*, 8(5), 1574–1588.

Tachet, H., Bournaud, M. & Richoux P. (1980). *Introduction à l'étude des macro invertébrés des eaux douces*. Systématique Élémentaire et Aperçu Écologique Broché.

Tachet, H., Richoux, P., Bournaud, M. & Usseglio-Polatera P. (2002). *Invertébrés d'eau douce: Systématique, biologie, écologie*. CNRS.

Vigna Taglianti, A., Cottarelli, V. & Argano R. (1969). Messa a punto di metodiche per la raccolta della fauna interstiziale e freatica. *Archivio Botanico e Biogeografico Italiano*, 45(14), 375–380.

Yacoubi-Khebiza, M. (1990). *Écologie, Biogéographie des biocénoses aquatiques des nappes alluviales de quelques vallées du Haut-Atlas de Marrakech (Maroc)*. Paléogéographie des crustacés phréatiques. Thèse doctorat 3éme cycle, Université Cadi Ayyad, Fac. Sci. Semlalia Marrakech.

Zouggaghe, F. (2020). Structure et distribution des macro-invertébrés aquatiques de la Kabylie de la Soummam (nord de l'Algérie). *Bulletin de la Société Zoologique de France*, 145(3), 295–310.