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Impacts of Anthropogenic Factors on the Groundwater Ecosystem of Fezouata in South-East of Morocco

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ABSTRACT

The depletion of aquifer systems in arid and semiarid regions worldwide is causing acute water scarcity and quality degradation, and leading to extensive ecosystem damages. Groundwater is exposed to a variety of anthropogenic water pollution, such as raw wastewater disposal in the Draa Wadi and the use of septic tanks. In this respect, a study performed in some wells of Fezouata (South-east of Morocco) aimed at both discovering the main components of the aquatic subterranean fauna unknown up to now in this area, and the potential relationships between this fauna and the water quality The principal physico-chemical characteristics of water were measured between November 2019 to March 2021 for 15 wells, which were selected considering their position with respect to the pollution sources known in surface. The Fezouata groundwater is distinguished by its high salinity with an increasing gradient from upstream to downstream. The aquatic fauna in the 15 wells showed 12 stygofauna species. In the protected wells which are situated far from the pollution sources, the fauna is dominated by Cirolanidae, Hydrobiidae, Metacrangonctydae, Stenasellidae, and Thermosbaenacea. On the other hand, in the less protected well, close to the pollution sources, the fauna is made of epigean species, such as insect's larva, mainly Culicidae and Chironomidae. The analysis of the water quality and the subterranean biodiversity shows that the latter decreases with increasing groundwater pollution. It seems that the impact of the acute pollution affected the stygocenose even by reducing drastically the biodiversity.

Keywords: groundwater pollution, stygobiont fauna, Fezouata aquifer, water quality, Morocco.

INTRODUCTION

In Morocco, groundwater is a very important part of hydraulic heritage. Compared to surface water, they present definite advantages in terms of covering needs. According to the estimates of the High Commission for Planning (2006), there are 32 deep aquifers and more than 46 surface water tables and the mobilizable groundwater resources are estimated at 4 billion m^3, unequally distributed in the different regions of Morocco. However, groundwater in arid and semi-arid areas provides the primary source to supply the populations in water, and they are extremely fundamental to social and economic development. In the area of Zagora, the groundwater is threatened by overexploitation and the insidious long-term probable effects of the pollution. In the Fezouata area, the water resources, especially groundwater, are very significant as a source of drinking water. Nevertheless, this water is exposed to excessive exploitation and a variety of anthropogenic water pollution as raw wastewater disposal in the Draa Wadi and the use of septic tanks.

The subterranean aquatic organisms can provide additional information that can be used to assess the water quality. Indeed, the stygobiont species are generally sensitive to water pollution (Notemboom et al. 1994; Boulal et al. 2017). Moreover, it can be used to ameliorate water purification, bioremediation and water filtration (Boutlon et al., 2008; Tomlinson & 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. Several studies were performed on stygobiological investigations, first in Marrakesh area (Boutin & Boulanouar, 1983; de Bovee et al., 1995; El Adnani et al., 2007), next to other parts of Morocco: Goulmima (Benazzouz, 1983), Guelmim (Boutin & Idbennacer, 2005), Fez and Rifian region (Mathieu et al., 1999; Berrady et al., 2000), El Jadida (Fakher El Abiari, 1999), Meknes (ElMoustaine et al., 2014), Tiznit (Boulal et al., 2017). All these studies were performed with the aim of both making the inventory of known stygobiontic taxa from Morocco more complete and testing once more the possible relationships between the stygofauna and the groundwater quality.The present study performed in some wells of Fezouata aimed at both discovering the main components of the aquatic subterranean fauna unknown up to now in this area, as well as the relationships linking some physicochemical parameters to the stygofauna species.

MATERIAL AND METHODS

Study area

The Fezouata region is extending from 30°19' to 30°9' North latitude and 5°50' to 5°30' East longitude (Fig. 1). The desert of Draa fed by the Mansour Eddahbi dam upstream the Fezouata aquifer is located in the middle of Draa basin southern-east of Morocco, between the aquifers of Tarnata and Tagonite. This area is one of the six oases organized around the Draa with a surface of 110 km^2, belonging the basin of Draa Wadi, especially the middle Draa. This basin is characterized by an hyperaridity marked by a low rainfall. Indeed, the annual precipitation varies between 108 mm in the upstream part of the study area (Mezguita) to 54 mm in the downstream part (M'Hamid), with an average of potential evaporation of up to 3000 mm (Klose, 2016). Furthermore, a stormy character, and large fluctuations in daily as well as yearly temperatures are noted.

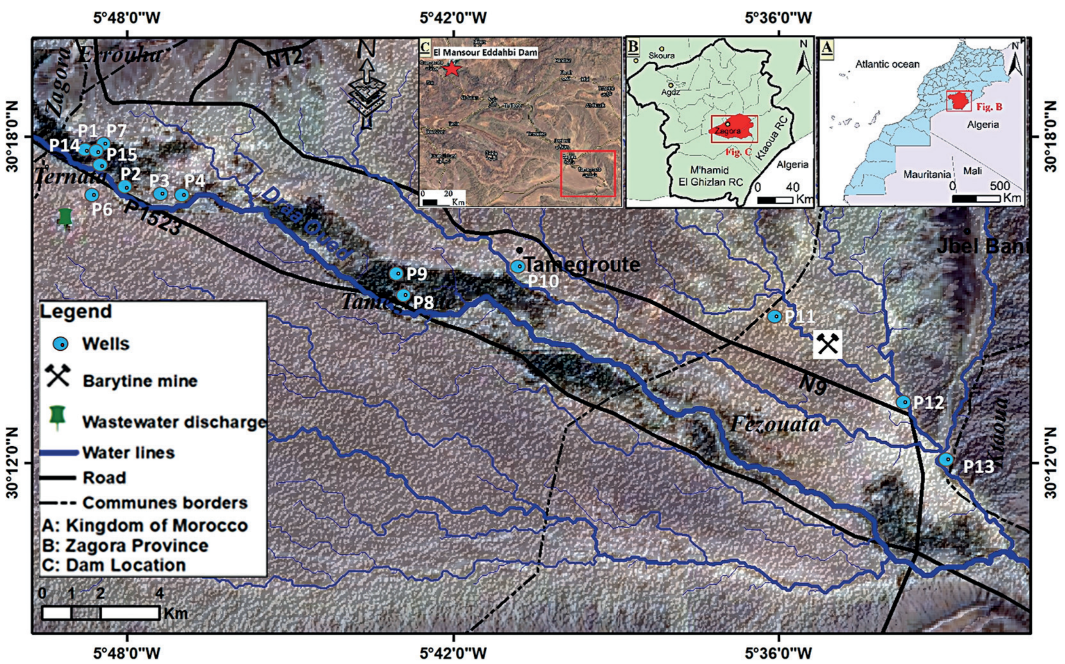

Fig. 1. The study area (P = wells)

The alluvial aquifers are hydraulically connected to each other to form a cascade of aquifers, in which underflow can pass through the alluvial sediments of adjacent highly weathered zones and the barriers of relatively small flowing parts in the fractures of an adjacent highly weathered zone (Klose, et al., 2008). The hydrological system depends to an extent on water runoff from the High Atlas Mountains, located north of Ouarzazate city. However, scarce surface water supplies in the MDV result in high dependence on groundwater pumping, which, in fact, increased in the six oases from 2000 pumps in 1977 to 10,000 in 2011 (Karmaoui et al., 2016). For this study, 15 stations were selected and prospected (Fig. 1, Table 1); two wells were selected near to the tanks septic (P7 and P10). Nine wells used for agriculture; one well before the wastewater treatment plant (P5), five farther from the wastewater discharge (P1, P8, P9, P14 and P15 and four wells nearby the discharge (P2, P3, P4 and P6); in addition three wells in vicinity of mines at the Southern-east; one well situated in downstream (P11) and two in upstream (P12 and P13) were selected. Some pictures of wells P2, P3, P4 and P8 are shown in (Fig. 2) and the characteristics of 15 studied stations have been given in (Table 1).

Water and faunal sampling

The water samples and fauna were collected monthly from November 2019 to March 2021 at each well. The temperature (T°C), total dissolved solids (TDS), electrical conductivity (EC), hydrogen ion concentration (pH), turbidity (Tur) and dissolved oxygen were measured in situ with a HI 9829 multi-parameter probe (HANNA). Water samples were transported to the laboratory in a cooler at approximately 4°C. The others physico-chemical parameters such as; phosphates (PO_4), nitrates (NO_3^-) and nitrites (NO_2^-), sulfates (SO_4^{2-}), Chloride (Cl^-), bicarbonate (HCO_3^-) and total hardness (TH) were measured following Rodier (2009). Aquatic fauna was collected eight times in each well, with a phreatobiological net sampler developed by (Cvetkov, 1983). Experience had shown that it must be drawn up 10 times in each well through the entire water column for different depths in the various wells to make sure all the pelagic specimens are collected; Beside the pelagic fauna, a nasse-type baited trap developed by (Boutin., Boulanouar, 1983), was usedto collect the benthic fauna. The traps were set in contact with the bottom for an immersion time between 18 to 24 hours. The samples were fixed in 5% formalin in the field. After the sorting, individuals were preserved in the field in 70% ethanol before

Table 1. Characteristics of the 15 studied stations (S = station; De = depth; D = diameter of the well; Pl = piezometric level)

S	Latitude	Longitude	D (m)	De (m)	Pl	Use	Protection	Source of pollution
P1	30°17’51.92”N	5°48’40.45”O	1.80	12	11.4	Agricultural purposes	Unprotected	Manure and wastes
P2	30°17’7.66”N	5°48’10.87”O	1.80	9	6	Agricultural purposes	Unprotected	Manure and wastes
P3	30°16’52.84”N	5°47’22.57”O	1.80	6	4.8	Agricultural purposes	Unprotected	Manure and wastes
P4	30°17’1.58”N	5°47’7.41”O	1.80	8	7.4	Agricultural purposes	Unprotected	Manure and wastes
P5	30°17’10.92”N	5°48’48.64”O	1.90	7	5.6	Agricultural purposes	Unprotected	Waste water
P6	30°16’43.22”N	5°48’32.32”O	1.5	18	14	Agricultural purposes	Protected	Waste water
P7	30°17’57.23”N	5°48’21.53”O	1.40	13	11.8	Livestock watering and domestic purposes	Protected	Septic tanks
P8	30°15’8.97”N	5°43’0.60”O	1.60	9	8.4	Livestock watering and domestic purposes	Unprotected	Waste water
P9	30°15’30.33”N	5°43’3.44”O	1.80	10	9.4	Agricultural purposes	Unprotected	Waste water
P10	30°15’30.45”N	5°40’50.06”O	1.70	11	10	Domestic purposes	Unprotected	Septic tanks
P11	30°14’19.77”N	5°36’17.88”O	1.40	11.5	10	Livestock watering	Unprotected	Activities mining
P12	30°12’46.90”N	5°34’3.80”O	1.40	12	9	Agricultural and domestic purposes	Protected	Activities mining
P13	30°12’23.58”N	5°33’43.11”O	1.80	12	6	Not used	Unprotected	Activities mining
P14	30°17’45.90”N	5°48’46.69”O	1.80	16	15.5	Agricultural purposes	Unprotected	Manure and wastes
P15	30°17’40.04”N	5°48’23.88”O	1.80	19	17.5	Agricultural purposes	Protected	Manure and wastes

Fig. 2. Examples of studied wells

being identified. All animals were identified to the lowest taxonomical level possible using the published and informative keys. The principal component analysis (PCA) and Hierarchical Clustering (HA) were performed for the two sets of criteria (Shrestha & Kazama, 2007) by providing the correlation between measured chemical variables and their multivariate patterns based upon the correlation or covariance matrix (Helena et al., 2020). The Ward's method was applied by Euclidean distance as a similarity measure in dendrograms (Ward, 1963).The results are statistically analyzed by using the R 2020 software version R.3.6.3.

RESULTS AND DISCUSSIONS

Physicochemical parameters

The mean values of physicochemical parameters are given in (Tables 2 and 3). They show the difference from the upstream to the downstream: the pH is neutral to mildly alkaline, maybe explained by the increase of sodium ions and their alkalizing effect (Cherkaoui et al., 2007). The water temperature was nearly constant and did not exceed 5°C of difference. The groundwater temperature was nearly that obtained in the Souss region. This relative thermal constancy of subterranean waters has been observed and highlighted by Vandel (1964), Ginet and Decou (1977) in Europe and in North Africa by Merzoug et al. (2010), Boulal et al. (2017), El Moustaine et al. (2014). The water quality in the Fezouata area is characterized by high mineralization; it ranged from 2003.50 µS/cm in the wells P7 upstream to 8186.75 µS/cm in P13 downstream. These results were similar to that obtained in the area of Marrakech, especially close to the Draa Sfar Mine by Boujghad (2020). It can be represented by very high levels of the main element, i.e. Na^+, Cl^-, SO_4^{2-}, Mg^{2+}, Ca^{2+}, and HCO_3^-. The high mineralization would be of natural origin (soil and sediment composition), but also of exogenous origin of the atmosphere (Warner et al., 2013; Cherkaoui et al., 2007). The enrichment of well sulfate could be related to the dissolution of evaporated minerals (anhydrite and gypsum) by meteoric water before its infiltration into the Plio-Quaternary aquifer (Ait Lamkadem et al., 2010). The mean values of the total hardness (TH) are explained by the geology, nature structure of aquifers, indeed the calcium concentration is very high in comparison with magnesium. The high values observed in

Table 2. The groundwater physico-chemical variables of water of the 15 wells (P = wells; Ec = Conductivity; TDs = Total dissolved salt)

Wells	T °C	Ec (µS/Cm)	Salinity (PSU)	TDs (mg/L)	pH	DO (mg/L)	DCO (mg/L)	TH °f	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)
P1	21.93	6100.25	1.60	3148.00	7.00	6.80	25.33	45.00	288.42	161.58
P2	23.20	2205.75	2.83	1043.00	7.39	7.42	0.00	24.00	145.00	95.00
P3	26.69	2559.50	3.50	1215.50	7.22	5.65	0.00	16.00	96.00	64.00
P4	23.12	2331.75	2.30	1131.00	7.49	6.70	0.00	18.00	95.62	84.38
P5	24.62	3109.00	1.13	1468.50	7.36	7.60	0.00	21.00	111.56	98.44
P6	24.86	2626.00	1.53	1304.50	6.95	9.60	2.13	19.80	116.85	81.15
P7	23.50	2003.50	0.47	964.50	7.45	6.90	0.00	16.00	133.82	26.18
P8	21.20	5785.50	2.33	3043.50	6.93	3.96	0.00	86.00	507.54	352.46
P9	20.05	7894.67	4.10	4108.00	4.28	4.80	0.00	81.00	460.33	319.67
P10	20.10	6387.33	0.70	2385.00	7.50	5.60	0.00	54.80	351.35	196.65
P11	21.69	4978.75	5.43	2481.00	6.03	4.52	0.00	43.00	253.77	176.23
P12	25.20	8146.00	0.98	5014.50	6.90	2.35	0.00	66.00	389.51	270.49
P13	23.19	8186.75	3.37	3931.00	6.91	3.04	24.23	70.80	453.93	254.07
P14	21.01	6381.67	0.85	2984.00	7.10	3.85	0.00	59.20	312.00	280.00
P15	20.80	6730.00	0.50	3264.00	7.20	4.05	522.25	44.80	236.00	212.00

Table 3. Continued

Wells	TAC (mg/L)	NO_3^- (mg/L)	NH_4^+ (mg/L)	NO_2^- (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)	Na^+ (mg/L)	K^+ (mg/L)
P1	612.12	4.20	0.23	0.06	0.21	962.67	5184.56	2663.50	96.55
P2	196.72	2.75	0.34	0.05	0.30	740.00	1155.19	684.03	33.10
P3	202.98	4.16	0.84	0.05	0.15	860.25	1239.89	1010.54	38.40
P4	233.90	1.22	0.34	0.27	0.45	832.50	1353.81	894.16	34.66
P5	285.56	2.21	0.37	0.06	0.41	989.13	1727.67	1561.80	32.88
P6	538.98	28.86	0.35	0.14	0.82	551.38	1283.71	771.53	43.58
P7	294.10	44.07	0.37	0.05	0.38	1067.00	816.37	792.15	49.38
P8	519.86	6.66	0.46	0.19	0.34	1085.88	4920.14	2309.80	66.44
P9	319.73	31.97	0.45	0.12	0.74	1281.00	5242.21	2305.75	83.85
P10	620.74	107.02	0.44	0.13	1.42	1064.67	2335.21	1902.50	140.77
P11	321.68	9.78	0.46	0.08	0.68	1201.63	3358.81	2441.00	21.96
P12	285.56	4.66	0.72	0.06	0.90	1271.25	4426.52	3045.75	35.53
P13	268.96	1.51	0.88	0.08	1.43	1191.50	4540.49	2161.08	24.54
P14	460.68	1.23	0.35	0.01	0.61	1197.00	4595.93	2142.58	40.73
P15	519.56	2.38	0.40	0.01	0.47	805.00	4739.21	2351.00	52.80

nitrogen element (No_3^-) suggest that the groundwater samples from the septic tanks near the P10 station are contaminated by wastewater.

Typology of the studied wells

Principal component analysis (PCA) was performed using 17 physicochemical parameters for 15 wells studied (Fig. 3 and 4). The preserved two factors (F1 and F2) represent 61.6% of total samples variance (47.1% for F1 and 14.5% for F2) (Fig. 3). The first axis (F1) was principally defined by nitrate, Demand complete oxygen, bicarbonate and potassium on positive side and turbidity, ammonium and temperature on the negative side (47.1% of variability). The F2 axis was essentially described by electrical conductivity, sulfates, chloride, calcium, sodium, magnesium and the total dissolved solids on the positive side correlated with this axis and nitrites, dissolved oxygen negatively correlated with the F2 axis (14.50% of variability). The hierarchical

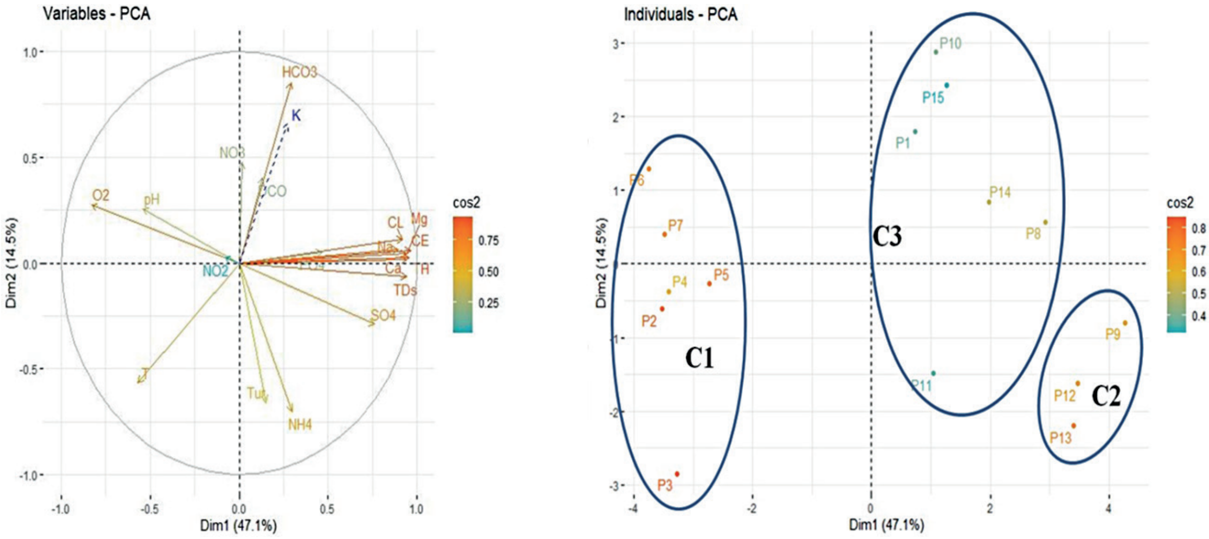

Fig. 3. Principal component analysis of physico-chemical parameters from 15 sampled stations (P = wells; C = cluster)

classification of the stations resulting from the PCA (Fig. 4) was performed using the first data set of 17 parameters after grouping into the three major classes, C1, C2, and C3 obtained through cluster analysis (CA).

Cluster I: (P2, P3, P4, P5, P6 and P7) with lower mineralization. The water nitrogenous elements, especially nitrate is very low except the wells 6 and 7 having high values of nitrates linking to the septic tanks for P6, and nearly to the wastewater treatment plant for P7.

Cluster II: (P9, P12, and P13), which groundwater analyzed are rich in chemical elements. Moreover, the stations are located around the barite mines, especially at upstream give clear signs of mining contamination

Cluster III: contains the wells where water is marked by high mineral values (P1, P8, P10,

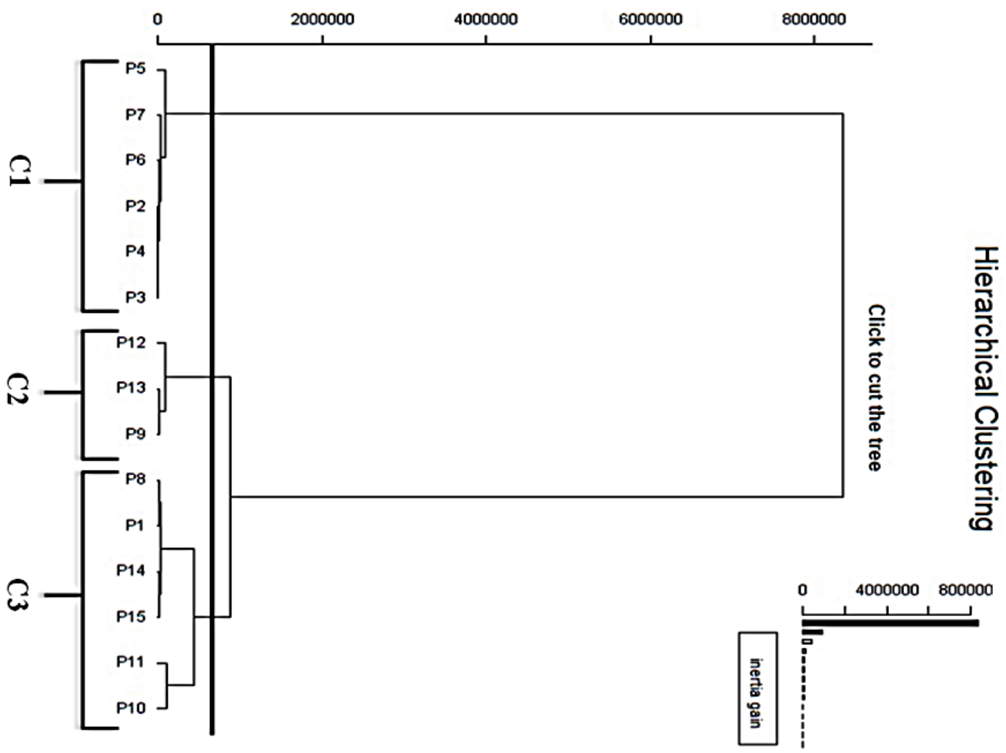

Fig. 4. Dendrogram showing clusters from hiearchical analysis

P11, P14 and P15). The waters of this group are used for the irrigation and show high values in alkalinity, potassium up to 96.55 mg/L, explained by anthropogenic inputs (related to the use of fertilizers).

P10 is located in the Tamegroute municipality, these populations use the septic tanks, and this indicates that drainage infiltration may be responsible for these increases.

Faunal data

The results are presented in Table 3, and show that the faunistic composition changes widely from a well to another. The list includes 20 aquatic taxa, with 8 epigean and 12 hypogean; the latter is entirely represented by Crustacean taxa. The most diverse groups were Gastropoda (5 taxa), followed by Amphipoda (5 taxa), Isopoda (3taxa), Ostracoda (2 taxa) and Thermosbenacea (1taxon). Among the twelve hypogean taxa, three are new and under description, one belonging to the family of Cironalida (Crustacea: Isopoda) and two Moitessieridae (Mollusca: Gastropoda). These aquatic species belong mainly to 3 branch lines: Plathelminths, Arthropods and Molluscs. However, different taxa were determined at the genera and species level. The study of biotic communities of the groundwater can give the information on characteristics of the wells water flowing, and thereby they are considered as a "look on groundwater" (Angelier, 1953). The fauna of the Fezouta aquifer has a taxonomic diversity that varies from one well to another, depending on various parameters, such as water quality and the protection of the studied wells, which directly influences the distribution of the stygofauna. These parameters can have an effect on the distribution of the stygofauna for example; in wells P5, P8 and P13 only "no pollution" sensitive species were collected. They were dominated by epigean taxa such as Culicidae and Chironomidae. On the other hand, in wells P1, P2, P3, P6, P7 the most abundant faunal stand is hypogeal species indicated by amphipod and isopod crustaceans, allowing to classify these stations as wells with good water quality. The taxonomic richness of all stations of Fezouata aquifer demonstrate a difference from the set of taxa in each well, number of communities obtained and report epigean and hypogean taxa (Fig. 5), there were 12 taxa, with a minimum recorded in P5, P8, P9 and P13 and the maximum collected in P6 (6 stygofauna). The collection of different taxa was composed of 41% Insect, 16% for Gasteropoda, Ostracoda and Amphipoda, with just 8% isopoda and the last percentage is 3% for copepod. Despite the fauna sampling is dominated by insects (41%), we do not identify more than stygobiontic species; this identification is performed by specialists in each group, these species are generally dominated by amphipods, isopods, and copepods (Deharveng et al., 2009; Halse et al., 2014).

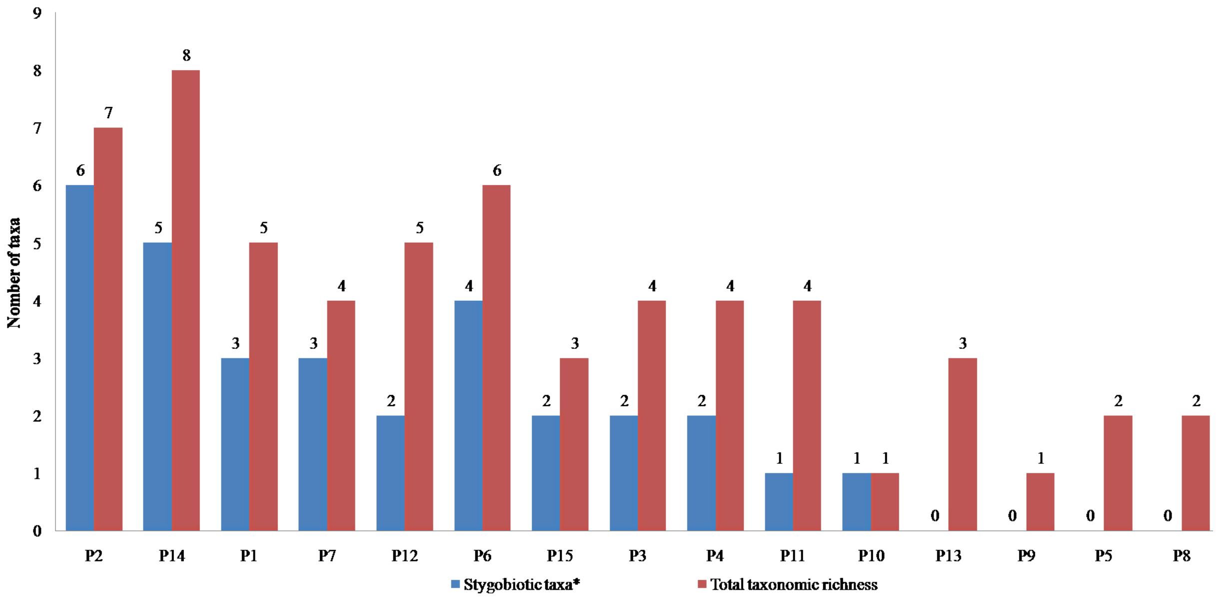

Fig. 5. Relative abundance of crustaceans (epigean + stygobitic) collected with the two sampling techniques

The stygal fauna collected in the Fezouata aquifer were dominated by crustaceans, among them 5 species of amphipoda (two species of Magrebidiella sp, and three species of Metacrangonyx sp), and one species of Cirolanidae. Nowadays, 11 species of this genus have been identified in Morocco; this species belongs to the genus Typhlocirolana, which have been recorded by El Filali (2010). The present species have an especially characteristic their taxonomy requires the creation of a new genus new species. Concerning Thermosbaenacea, one species was delivered in three stations (P2, P6 and P10); it is very abundant in well P10. Besides, the stygofauna in this region contains two species of Ostracoda and three of Gastropoda, the latter represent many morphological features, which belong to two new species of Atebbania (Ghamizi & Bodon 1999). In Morocco, many turriculate species of stygobiont Hydrobiid mollusks have been described; Iglica soussensis by (Ghamizi & Boulal et al., 2017); Heideella makhfamensis by (Ghamizi & Bodon, 1999). Heideella andrea by (Backhuys & Boeters, 1974); "Iglica" seyadi by (Backhuys & Boeters, 1974). The genus Atebbania, only recorded from the Tiznit plain, is firstly recorded of the studied zone. The stygobiotic richness in the sampling stations was similar to that obtained in other region in Morocco, e.g. by (Boulal et al., 2017) in the Tiznit area (12 species of stygobionts), against 12 species of stygobionts were collected. However, stygobitic richness in the sampling sites was very high ranging from 10 to 24, with means of 14.5 species, in the Tiznit area, stygobiontic fauna was represented by, Amphipoda especially Metacrangonyx sp, Gastropoda ; Atebbania Bernasconi new species, their fundamental characteristics were described by (Ghamizi et al., 1999) and mercuria sp. Nevertheless, in this study, Isopoda (a genre of Typhlocirolana) is only represented by a species with unique characteristics of this region, which is also a new scientific species.

The stygobiontic richness in the sampling wells is lower than that of southern Anti-Atlas with a mean of 10.8 species in 7 wells (Boutin & Idbennacer, 1989) at Guelmim and by (Boutin & Boulanouar, 1984. Boulanouar 1986) in Marrakech. It is significantly higher than that of the wells of Meknes studied by El Moustaine et al., (2014) with a mean of 5 species in 8 wells and two springs, and by (El Adnani et al., 2007) in some wells situated around a mining site in Marrakech region, the taxonomic richness is much lower, ranging between 0 and 6 species, with a mean of 2 species in 7 wells. This preliminary prospecting of the groundwater fauna in Fezouata aquifer is very promising. It is similar to the study carried out, for many years, in the north of Anti-Atlas, which had delivered 14 taxa on average in 10 wells (Boulal, 2017), in Tafilalt by Ait Boughrouss et al. (2007) which had delivered 15 taxa in 11 stations, and 18 stygobitic species were observed in other area of Morocco in 11 sites. In another country of Africa, this study showed that the stygofauna richness is moderately lower in comparison to some area in Algeria, where 26 taxa are in 18 wells (Khammar et al., 2019). In the case of north-eastern Algeria, in the 16 wells in the Oum-El-Bouaghi region the richness taxa varied from 7 to 12 (Merzoug et al. 2010).

In Cameron, 23 taxa in 14 wells were collected and 15 taxa in 11 springs, taxonomic richness is not very different in the two types of habitat: 4.6 in wells and 4.9 in springs (Togouet et al., 2009), against the average of 3.9 in 15 wells in our study area. However, in Morocco and according to the recently studies about stygofauna, the authors of this paper think that stygofauna is surely much diversified although maybe similar to that of the other countries of the Maghreb and Mediterranean basin (Boutin, 1993). A principal component analysis (PCA) was performed using 20 taxa for 15 wells (the sampled stations) (Table 4). The preserved two factors represent 45.10% of total samples variance (22.80% for F1 and 22.30% for F2) (Fig. 6 and Fig. 7). The first axis (F1) is well correlated on the positive side with Thyphlocirolanasp, Metacrangonyx sp1, and correlated on the negative side with Ostracoda und, Cyclopoda und, Atebbania sp1 and Atebbania sp2. The axis (F2) was correlated on the positive side with Magnezia cf. gardei, Monodella sp, Heidella sp, and correlated on the negative side with Metacrangonyx (sp1 and sp3), Magrebidiella (sp1 and sp2). The remaining taxa confirm short relationship with individuals axes. The hierarchical classification of the stations corresponding from the PCA (Fig. 6) was carried out using the fauna data set of 20 taxa after grouping into the three major classes, C1, C2 and C3 obtained through cluster analysis (CA).

Cluster I: this cluster brings together the majority of the water samples (P3, P4, P15 and P6). The taxonomic richness, especially the stygobic species are highest.

Cluster II: This cluster contains six wells, the taxonomic richness is very low, the stygobic

Table 4. Faunal list of the taxa in the water of the 15 studied wells during the study period

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P1	P11	P12	P13	P14	P15
Insecta															
Culicidea	■		■	■	■	■		■			■	■	■	■	
Chironomus sp	■	■	■	■	■		■	■	■		■	■	■	■	
Euphemeroptera	■														
Acarida															
Gamasida											■				
Amphipoda															
*Metacrangonyx sp1**	■	■					■					■		■	
*Metacrangonyx sp2**	■														
*Metacrangonyx sp3**		■												■	
*Magrebidiella sp1**														■	
*Magrebidiella sp2**														■	
Gastropoda															
*Heideellasp **		■				■									
*Atebbania sp1**												■			
*Atebbania sp2**															
Mercuria sp															■
Physa acuta															
Isopoda															
*Typhlocirolanasp**	■	■	■				■							■	
*Monodellasp**		■				■				■				■	
*Magneziacf .gardei **		■	■	■		■									■
Copepoda															
Cyclopodae						■						■			
Ostracoda															
*Ostracoda1**											■				
Ostracoda 2						■	■								
*Plathelmintasp**				■											
Stygobiotic taxa*	3	6	2	2	0	4	3	0	0	1	1	2	0	5	2
Total taxonomic richness	5	7	4	4	2	6	4	2	1	1	4	5	3	8	3

species were not present in four studied wells (P5, P8, P9 and P13), and two wells have a lower taxonomic richness, including one stygobic species (P10 and P11).

Cluster III: including five wells (P1, P2, P7, P12 and P14) the taxonomic richness is highest; it varied from 2 to 6 species, the high number recording in P2 and P14.

Distribution and correlation between stygofauna and water quality

This study shows that Fezouta stygofauna is much diversified, different from one well to another, and their distribution is controlled by many factors. Upstream, the water samples are characterized by a good quality, aquifer is home to stygofauna, particularly Stenasellidea and Typhlocirolana. However, downstream sampling showed some very mineralized chemical elements, such as chloride (Cl^-) and sodium (Na^+). In addition to those high concentrations of chemical elements recorded in some wells (P8, P9 and P13), the invertebrate fauna collected in the wells showed just epigean species. Moreover, certain wells near to septic tanks or wastewater, their fauna are characterized by the absence of the Typhlocirolana and Stenasellidea species (P5, P4), this indicates the anthropogenic impact to the health of ecosystem and stygofauna, the main causes of sampling water pollution from these wells are most probably related to the discharge of raw wastewater that circulates in the Draa river, the risk of species extinction is unexpectedly

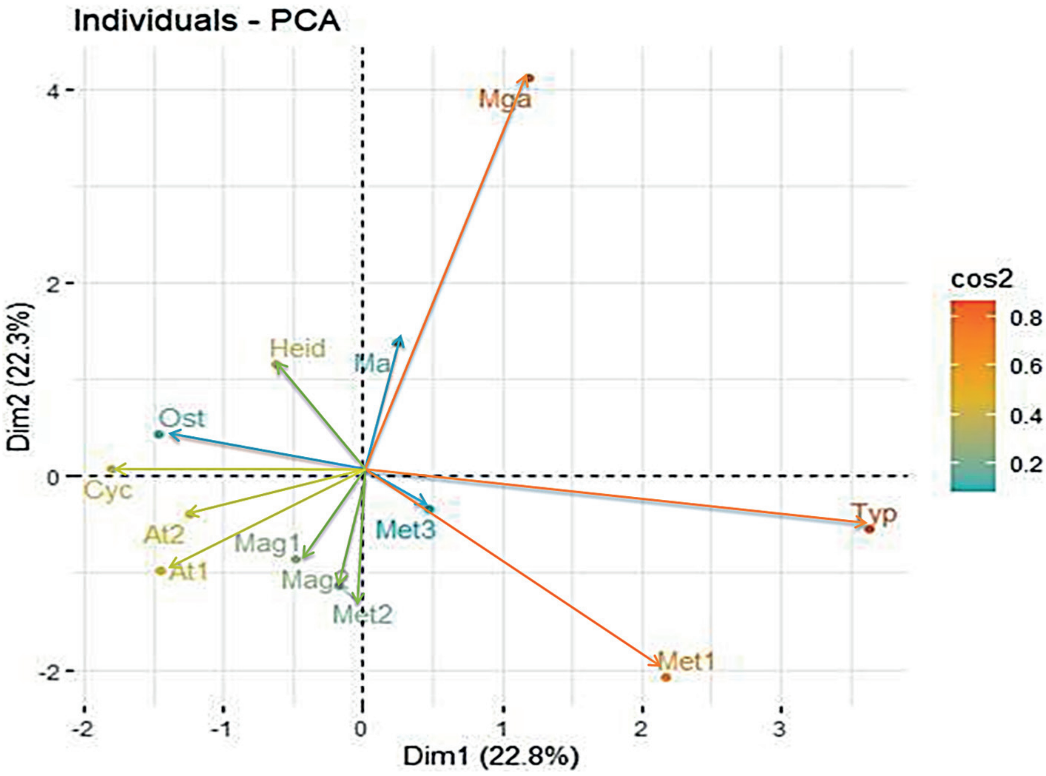

Fig. 6. Principle component analysis factor scores of taxa from 15 sampled stations

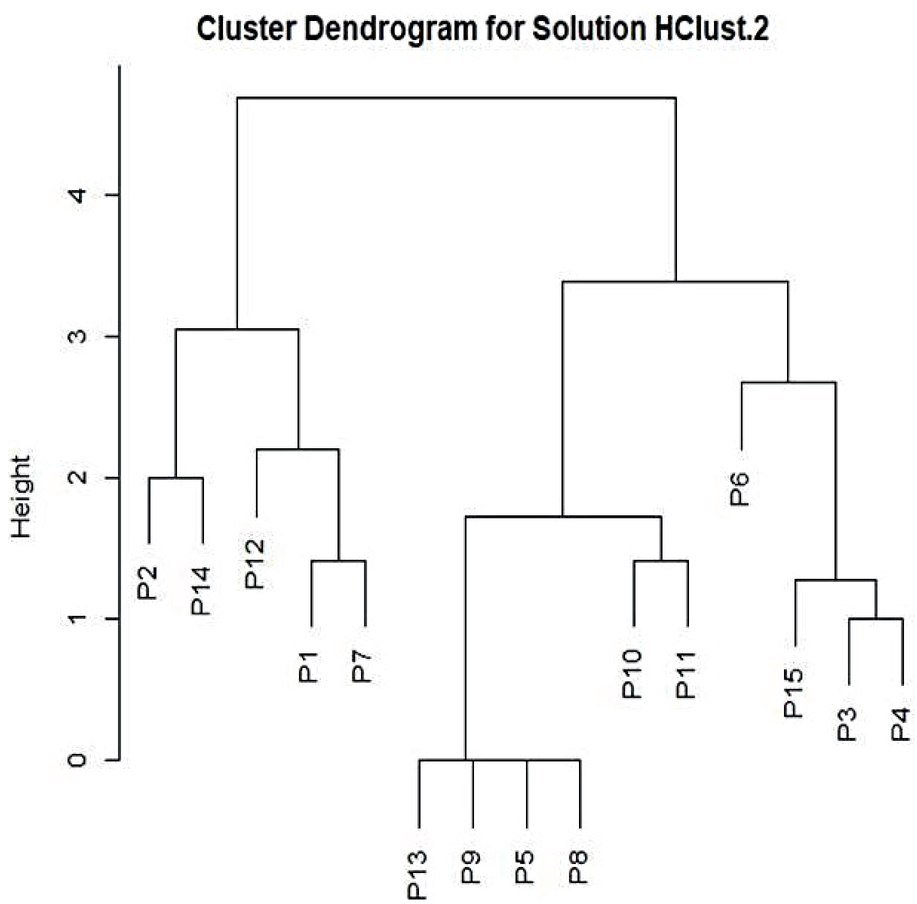

Fig. 7. Dendrogram showing clustering of studied stations described by their fauna

high in the face of the increase in multiple anthropogenic pressures (Danielopol et al. 2003).

The Gastropoda, mainly *mercuria sp* and *Atebbania sp,* can be found in a large space, even with high conductivity. In turn, the epigean species just are living downstream, except for some wells such as P5 and P6, a complete lack of stygobiontic fauna (no pollution sensitive species) was noticed in the wells or the conductivity is very high like P13. Then, and according to this study, the presence of stygofauna is considerably lower. The TDS parameter is very important for the distribution of stygobiontic in this area as well. This was observed in the station localized near the mining activity region and raw wastewater disposal in the Draa wadi P8 and P9.In the study area, the pH is acidic to neutral and ranged in the recommended by World Health Organization (WHO) threshold values (6.5–8.5)(OMS, 2014), bearing in mind that the most diverse stygal communities can inhabit calcareous environments ranging from pH 7.2 and 8.2 (Humphreys, 2008), and that the low pH restricts distribution (Reeves et al. 2007). However, the fauna is not sensitive to the changes in water temperature as long as they do not exceed from 6 to 10°C for some crustaceans (Castaño-Sánchez et al., 2020).

These results show also that groundwater in the study area is saturated, increasing upstream to downstream. Indeed, the presence or absence of stygobiontic fauna in some wells with low dissolved oxygen concentrations shows that the latter does not influence the existence of these microorganisms. However, in P8, P9, P13 no stygofauna was recorded (Fig. 5), a low influence of dissolved oxygen is therefore well noticed; previous studies have observed this negligible influence. However, generally the presence or absence of stygofauna is influenced by other factors, i.e. organic matter content and the abundance of microorganisms in the aquifer (Malard, 1999).The nitrate values exceed the critical level of 50 mg/L, as fixed by standards recommended in Morocco and (WHO) for drinking water. P10 is located in the commune of Tamegroute, where the sewage is discharged directly into the septic tanks; this station is close to the point of sewage collection, less than one km from the point of discharge. In this station, only thermosbenacea were collected, which proves the impact of anthropogenic factors.As for ammonium, the groundwater samples do not present a noticeable contamination of this parameter, since the values ranged from 0.23 to 0.88 mg/L. Such values would be explained, by a removal in Fezouata groundwater due to biodegradability by biological processes like the nitrification-denitrification process (Grady et al. 2011; Skrzypiec, Gajewska 2017).

According to Johns et al. (2015), this distribution is directly controlled by water quality assessment, protection of some wells, natural soil, infiltration of a large amount of groundwater used in irrigation, linked to spatial and temporal, (in the winter, fauna are abundant, but in two samples of the study there was no stygobic fauna in the summer of 2020)heterogeneity of groundwater and the hosting aquifer, it is depending onmany factors, namely, groundwater recharge (Hölting et al., 2019), cropping (Korbel et al., 2013), and irrigation cycles (Hose et al., 2015). According to the results, there is clustering physicochemical parameters of the studied stations and therefore the cluster fauna of studied wells. The primary data shows a significant correlation. Indeed, when the water is far polluted, the absence of crustaceans, especially cirolanida is noticed; this is often the case of wells (P8, P9, P10, P11, P12, and P13), these stations are characterized by a high level mineralization. However, the groundwater samples in cluster I (P2, P3, P4, P5, P6 and P7) are characterized by lower mineralization and contain a level richness fauna (6taxa) in P6. However, in P4 and P5, the stygobiontic fauna is absent despite their water quality. That maybe explained by other factors, e.g the protection of the station; P4 is not protected and situated in Fields. Furthermore, P5 is near wastewater. This means that the stygobiontic fauna can be used to assess the water quality (biological index). Indeed, the absence of some taxa such as cirolanida in the wells contaminated by sewage, as well as the increase in salinity or the protection against various local or diffuses pollution were observed. This is shown by some authors (El Abiari et al., 1998; El Adnani et al., 2007; Aït Boughrous 2007; Ghlala et al., 2009). This relationship has been observed in other parts of Morocco (Idbennacer et al., 1990; El Abiari, 1999; Boulal, 2002; Ait Boughrous, 2010; El moustaine, 2014; Boulal, 2017). Aquatic abundance appears to be an effective tool for monitoring the environment and protecting human health. Additionally, it may minimize the cost of expensive analyses.Therefore,it appears that a sufficiently high level of pollution of the well water strongly limits the presence of species invertebrate animal crustaceans, particularly those belonging to the genus Metacrangonyx and to a lesser extent the Isopods of the genus Typhlocirolana which are among the most resistant. In contrast, pollutant-resistant taxa such as many Oligochaeta, Copepoda and Ostracoda, predominate when the water is more heavily polluted.

CONCLUSIONS

The present study is a contribution to evaluating the impact of anthropogenic activities on groundwater quality of the Fezouata area located in Zagora region. The analysis of physicochemical parameters of groundwater samples, show that the quality is so much altered even by point and non-point sources of pollution. Biologically, the groundwater of the studied area is rich in aquatic fauna, delivering 20 taxa, including twelvestygobic species, the aquatic taxonomic richness ranging from 0 to 6 species, with a mean of 3.9 species in 15 wells. This diversity varied from well to well. The rich collection of stygobic species was composed mainly of Gastropod, Amphipod and Isopod crustaceans, showing that generally the groundwater is greatly altered by anthropogenic activities. Furthermore, the wells located close to mining waste or domestic sewage, are the poorest ones in stygobic fauna. Consequently, the use of this fauna reflects accurately the quality of groundwater and it is an inexpensive efficient tool for assessing this parameter.

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