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Effects of anthropogenic factors on groundwater ecosystem in Meknes area (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. This study shows that by including environmental damages, especially the anthropogenic factors into the analytical results, results can change substantially depending on human activities. The analysis of water from wells and springs in Meknes area, showed that their physicochemical and biological quality is largely influenced by the human activities, high values of electrical conductivity (13840 µS/cm) and low value of dissolved oxygen (2.88 mg/L) were recorded in P1 water. This well is located near the landfill. The analysis of the total wells and springs water fauna showed a great taxonomic richness with variations in time and space. The biodiversity decreases, in groundwater polluted by the waste, lixiviats and the landfill fauna disappears completely if the degree of contamination of groundwater is high. Therefore of these strong requirements they are highly sensitive to any disturbance in their environment (both quality and quantity) and consequently their risk to be threatened are higher that turn to greater chances of extinction.

***Keywords*:** biodiversity, ecosystem, anthropogenic factors, physicochemical parameters.

1. Introduction
Groundwater accounts for over 97% of all freshwaters available on earth (excluding glaciers and ice caps) being the largest drinking freshwater reservoir in the world (almost 75% EU inhabitants depends on groundwater for their water supply) [1]. It represents also a significant resource for industry and agriculture and an important component of the global hydrological cycle [2; 3]. But groundwater can be recognized also as complex ecosystems varying in structure, dimension, and connectivity, and harbor a vast and almost unrecognized diversity of groundwater fauna [3]. Globally, it is only in the last years that the groundwater biodiversity has been acknowledged [4,5]. The groundwater fauna have been shown to be in some areas as diverse as those of the associated surface ecosystems, and especially in karst terrains [1]. The groundwater biodiversity has attracted much consideration in the last years due to the distinct assemblages when compared to surface water ecosystems. The groundwater lacks or have reduced diversification of insects, allowing the development of crustaceans. Consequently this makes groundwater to be more similar to marine waters than to freshwaters [5]. Furthermore, the endemism in groundwater is very common, and species are narrowly distributed on small areas, sometimes reduced to one single aquifer or even to a single site location [5,6]. The groundwater fauna is a living component that highly illustrates the quality of the subterranean waters. A number of studies have demonstrated the applicability of groundwater fauna for monitoring purposes related to any kind of disturbance (i.e. water pollution or drought) [7-9]. Specifically the obligate groundwater-dwelling species termed stygofauna (Styx = in greek mythology Styx was the river formed at the boundary between the Earth and Underworld, guarded by Phlegyas, who passes the souls from one side to another of the river), and its stygobite fraction (species restricted to groundwater only) have the strongest potential to be reliable indicators of groundwater ecosystem health [10]. 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 [11,12]. Because most stygobionts have a narrow distribution range, the risk of species extinction is unexpectedly high in face of the increase in multiple anthropogenic pressures [13-15]. 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 Meknes area, as well as the impact of the factors anthropogenic on groundwater ecosystem.

2. Material and methods

2.1. 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. 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 [16].

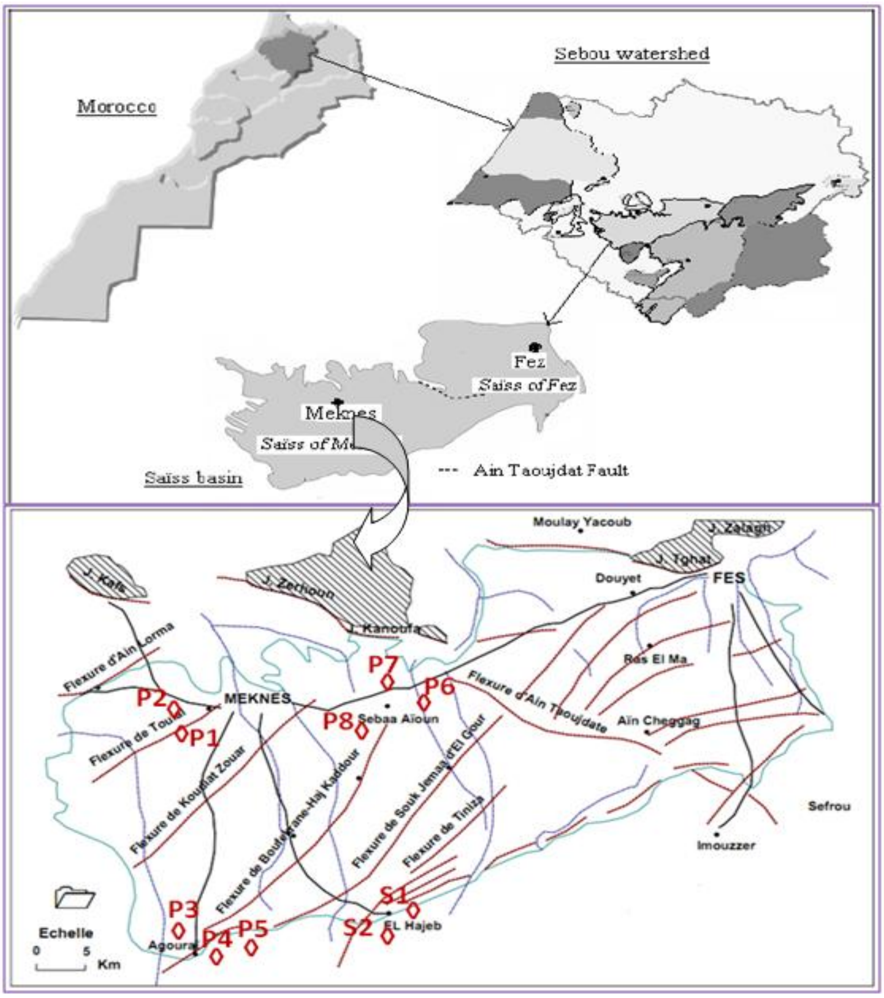

Fig 1. Map of study area (P= wells; S= springs)

2.2. Sampling methods

Temperature, pH, conductivity, salinity and dissolved oxygen were measured *in situ* with a WTW multi-parameter probe. The other physico-chemical parameters (Chemical Oxygen Demand ,Total Hardness ,Alcalimétriques Complete Title, Nitrates, Nitrites, Ammonium, Orthophosphate, Sulphates, Calcium, Magnesium and chloride) were measured in laboratory to assess the groundwater quality. Fauna was collected in each well four times from February to July 2013 with two types of sampling equipment: a phreatobiological net sampler ([17; 18]) 20 cm in diameter at the opening, composed of a cone filter 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 [19] (fig.2). The traps were set in contact with the bottom for 24 hours. 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. The characteristics of the wells and springs are summarized in Table 1.

Table 1. Characteristics of the wells and springs samples chosen in this study (P= wells; S= springs).

Stations	Diameter (m)	Mean water level below the soil (m)	piezometric level	Protection	Usage	Source of pollution
P1	1.6	14	9	Unprotected	Livestock watering	landfill
P2	1.3	25	2	Unprotected	domestic purposes	landfill
P3	1.7	25	16	protected	agricultural or domestic purposes	Manure and wastes
P4	1.2	18	4	protected	agricultural or domestic purposes	Manure and wastes
P5	1.2	24	8	protected	Drinking water	Manure and wastes
P6	1.5	26	3	protected	Drinking water	Manure and wastes
P7	1.6	27	4	Unprotected	agricultural or domestic purposes	Manure and wastes
P8	1.4	30	12	Unprotected	Drinking water	Manure and wastes
S1	-	-	-	Unprotected	Drinking water	wastes
S2	-	-	-	Unprotected	Drinking water	wastes

3. Results and discussion

3.1. Physico-chemical variables

The some physicochemical factors of well and springs water analyzed during February to July in Meknes area. together with the average value of each factor are presented in Fig 2. The mean temperatures recorded in the wells and springs varied from16.2°C to 18.1°C. with the minimum (16.2°C) measured in springs S1 and the maximum measured in the wills P6. Strayer. D [20] suggest that groundwater organisms may not be sensitive to changes in water temperature. The pH ranged from 7.3 to 7.2. with the lowest mean value (6.8) measured in well 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 [21]. Based on this data. The optimal pH range for stygofauna presence appears to be between pH 6.95 and pH 7.21. This is consistent with results from some authors [22]. Additionally, many of the aquifer with these pH levels did not contain stygofauna, indicating that pH is not the sole determinant of stygofauna presence or its absence. 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. The available data indicated that. if the EC is> 10 000 µS/cm. the likelihood of detecting stygofauna during is significantly reduced [22]. 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 presence of DO is vital for stygofauna survival. There was little available information regarding the optimal level of DO that is required for sustaining stygofauna populations. DO concentrations in groundwater can be very heterogeneous and influenced by factors such as sediment composition, formation structure, hydraulic exchange, organic matter content and the abundance of microorganisms in the aquifer [23]. The endemic characteristics of some stygofauna communities may be linked to the DO available in each aquifer type [24].

The relationship between $NO_3^-$and NH_4^+, which is relatively high in the wells P7 and P8 is believed to cause of low biodiversity at these stations, where a few taxa known by their resistance to pollution insects are present in these wells. Relatively high ratios between these two parameters are known to be responsible for the absence of aquatic life into other aquatic systems [25].

3.2. Faunal data

The analysis of the faunal list presented in Table 2 showed that the composition of the population varies from well to well and species richness appears to be related to the overall water quality of the water well as the state protection of the wells. 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 (Fig.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 mean taxonomic richness in the 8 wells and 2 springs is lower than that observed in other region in Morocco. e.g. by [26] at Marrakech (a mean of 12 species in 11 wells). By [27] in Tiznit region in the northern Anti-atlas (a mean of 14 species in 10 wells) and by [28] 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 other region of Morocco [27; 29]. Accordingly. Groundwater fauna is characterized by low local diversity in relation to regional diversity. In conclusion. The risk of species extinction is unexpectedly high in face of the increase in multiple anthropogenic pressures (e.g. Waste and Manure; landfill).

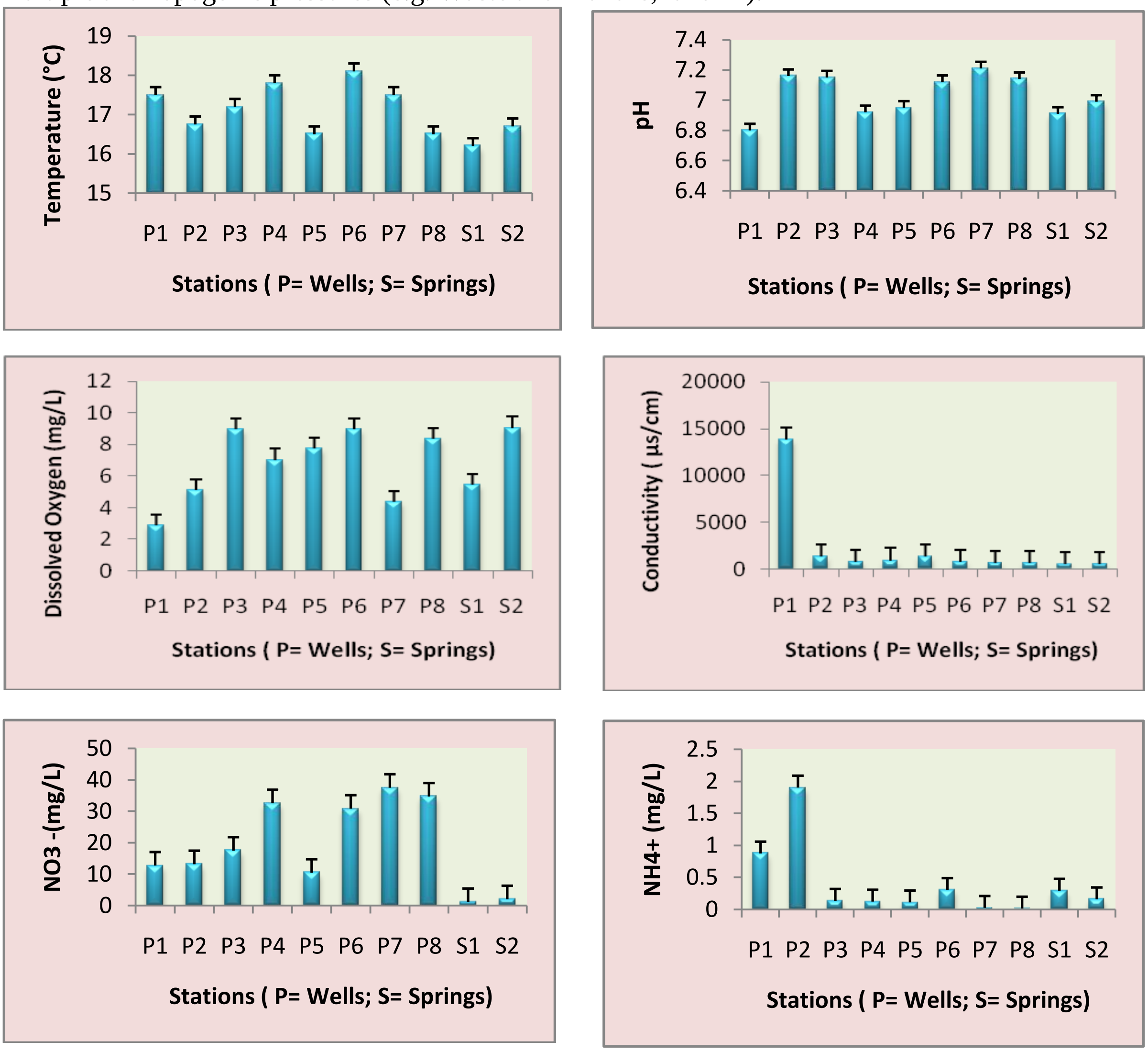

Figure 2. Mean value of the main groundwater physico-chemical variables in the Meknes area aquifer (Bars represent standard deviations).

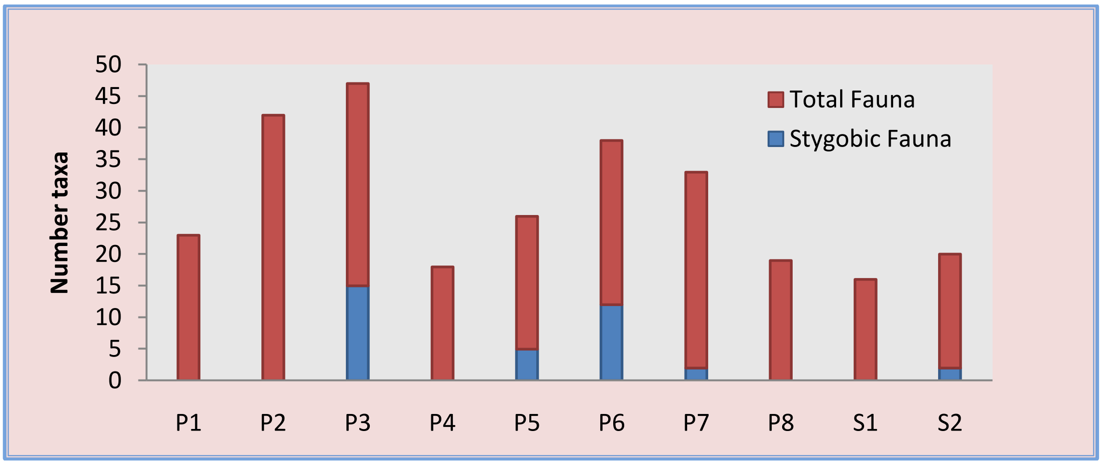

Figure 3. Total number of taxa (epigean + stygobitic) and of stygobitic taxa collected in the wells and sp

Table 2: Faunal list of the taxa in the water of the 10 studied stations (P= wells; S= springs) (**: Stygobiont).

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
plathelminta	Dugesia gonocephala						11	22	14		
Oligochaeta	Lumbriculidae						3				
Oligochaeta	Tubificidae					4					
	Naididae			2							
Gastropoda	Planorbidae			2						3	
Gastropoda Copepoda	*Physa sp*									7	
	** Cyclopidae						12	2			
Ostracoda	*Eucypris virens*									4	
Ostracoda Amphipoda	*Ilyocypris* sp.					3					
	** *Ostracoda Indt*			15							
	***Echinogammarus* sp.										
Amphipoda Collembola	** *Pseudoniphargidae*					3					
	***Metacrangonyctidae*					2					
	Collembola			2	1	4		2	3		
Heteroptera	Mesovellidae		1		1	2					
Diptera	Culicidae	23	36		2			2			
Diptera Coleoptera	Chironomidae		2	11	13				2		
	Dytiscidae										
Coleoptera Total Taxonomic Richness	Elmidae		3		1	3					
	Larvae ind.	4						3		2	
	23	**42**	**32**	**18**	**21**	**26**	**31**	**19**	**16**	**18**	

Conclusion

Groundwater is a common pool resource characterized by rivalry in consumption and nonexclusion. We found that water quality significantly varied as a function of the two water sources (springs. wells) and those human activities have influenced all water sources. With wells being the most impacted. The analysis of the subterranean stands related to the water quality shows in particular some physico-chemical parameters that in case of local pollution of the wells. the richness of the groundwater fauna of the wells decreases. And that the stygofauna in the first decreases and disappears completely in the case of strong pollution.

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