Bio-Evaluation of Groundwater Quality in the Souk Naamane and Ain M’lila region (Oum El Bouaghi, High Plain of Eastern Algeria)

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Abstract
The present study was carried out to assess the quality of groundwater in the western region of Oum El Bouaghi district, (commune of Souk Naamane and commune of Ain M'lila). A total of nine wells and two water springs were tested in the two communes for eight months, from October 2017 to May 2018. The fauna was sampled using two methods: the net phreatobiological and the baited trap method. Some Physico-chemical properties of the wells were measured during each campaign. A total of 1237 individuals belonging to 47 families were recorded during the sampling.

From a physical-chemical point of view, the principal component analysis (PCA) indicates that the water is highly mineralized (with high electrical conductivity), which might be explained by the dissolution of the limestone, saline, and gypsum rocks of the terrains covering the study area, in addition, anthropogenic action would be added to natural action. The results revealed that parameters such as pH, Ammonium ions, Sulphates and electrical conductivity were within the accepted standards. Nevertheless, relatively important fluctuations in Hardness, alkalinity and Chlorides were recorded.

Keywords
Groundwater, Physico-chemical properties, Aquatic fauna, Wells, Springs, Souk Naamane, Ain M'lila.

Introduction
Groundwater is a hidden, discreet, and poorly known resource. As an essential component of the hydrological cycle, this water constitutes the world's largest freshwater reservoir containing 95% of the world's fresh water (Morris et al., 2003). They are considered an indispensable source of water supply and are generally a complement to the easily accessible surface water. They provide a stable habitat for a rich and diverse biocenosis adapted to these environments. They play an important role in the sustainability of many terrestrial ecosystems, and a crucial role in human life and socio-economic...
development (Liu et al., 2020). In recent years, ecological research on the underground aquatic fauna and in particular on the water table at the wells represents one of the aspects of applied phreatobiology known as the appropriate method of updating (Cvetkov, 1968). In Algeria, the underground fauna was being explored since the beginning of the 20th century, thanks to the studies of some species led by Racovitza (1912). Indeed, until some years ago, investigations on the ecology of Algerian groundwater were rare and partial, including the work of Gurney, 1908; Monod, 1924; Nourrisson, 1956; Delmare Deboutteville, 1966; Pesce et Tete, 1978; Pesce et al., 1981 and Lakhdari, 2014.

In recent years, underground fauna has been the subject of systematic studies aimed at inventorying the stygoby species of the alluvial water table of Wadi Tafna (Chebika, 2003; Belaidi, 2004; Benouada, 2005; Mahi, 2007; Haicha, 2013; Belaidi et al, 2011 and Allaoua N et al, 2015).

This study aims to complete the work already carried out in this field, focusing on the west part of Oum El Bouaghi, by accessible routes such as wells and springs to contribute to the establishment of an exhaustive list of stygoby species in Algeria and to assess the physicochemical quality of these habitats.

**Materials and Methods**

*Description of Study Area*

The study area belongs to the High Plains of Eastern Algeria, which is a region composed of mountains, valleys and plateaus between the Mediterranean Sea and the Sahara Desert, where the landscape is dominated by steppe vegetation, and the basin is characterized by a semi-arid climate with a cold winter. Our choice focused on two different regions located west of OumelBouaghi city, Souk Naaman (230 km²) with geographical range 35° 53’ 45″ N, 6° 23’ 22″ E and Ain Mlila (236 km2) geographical range 36° 1’ 60″ N, 6° 34’ 60″ E (Figure 1).

![Figure 1. Geographic location of the study area and location of sampled stations.](image-url)
Physico-chemical Analysis

Nine wells and two springs were prosecuted during the academic year (2017 to 2018) to assess water quality and ecosystem diversity of invertebrates. Five of them are located in Souk Naamane and six in Ain Milila. Temperature, pH, conductivity, and salinity were measured in the field using a multi-parameter WTW (Multiline P3 pH/LF SET). Water intended for chemical analysis was filtered beforehand, then placed in 1.5 L polyethylene bottles and stored at a temperature of 4°C, then transported to the laboratory. The chemical analyses were carried out in the Department of Natural Sciences, University Oum El Bouaghi’s laboratory. The total hardness or hydrotimetric titer (TH) was obtained by the complexometric method by titration with EDTA using the specific-colored indicator (eriochrome black T at 0.5%) and in a buffered medium pH = 10 (Rodier, 2009). Principal component analysis (PCA) was the main multivariate statistical method used in this study to analyze the different physicochemical parameters of the water. The statistical analyses were performed using XLSTAT.

Fauna Sampling

The faunal sampling at the wells was carried out using a phreatobiology net based on the model initially developed by Cvetkov (1968) and slightly modified by Boutin (1996). (Boutin and Boulanouar, 1983) recognized the effectiveness of this sampling method for the capture of planktonic and nektonic fauna. The spring fauna was sampled by direct filtration of the water through a 300 µm silk net (Messouli, 1984). Samples were preserved in 100% ethanol and then transported to the laboratory, where they sorted carefully under a binocular loupe, and identified at the family level using a key of Tachet et al. (1980) and Tachet et al. (2000).

Results

The Physico-chemical Characteristics of Water

The results of the Physico-chemical analyses of the 11 stations during the study period are shown in Table 1. All pollution parameters are within WHO standards, except for Ammonium, which is slightly higher in well P3. The water temperature recorded did not show great variations, with 18°C in most wells, except P6 (20°C) and S1 (22°C). There is no substantial variance in the pH readings, which remain closer to neutral in all study stations. The electrical conductivity values indicate the high mineralization of groundwater in the study area, which were ranging from 620 μs/cm (S2) to 6480 μs/cm in well (P3). Hardness shows high values and great variations, where the maximum value was recorded in well P3 (1048mg/L) and the minimum in P5 (208 mg/L). The recorded alkalinity contents vary between 210mg/L (P7) and 1000mg/L (P3), the high values of which are probably due to the circulation of these waters in the aquifer reservoir of calcairo-dolomitic nature.

The average value of Sulphates in the waters of the study area was around 250 mg/L, which shows that the waters in question comply with Algerian standards. Chlorides are important inorganic anions with various concentrations in natural waters, generally in the form of Sodium (NaCl) and Potassium (KCl) salts. The concentrations of Chloride ions were found to range from 129.3mg/L (S2) to 680.3mg/L (P3). Nitrate can be issued from the decomposition of plant or animal matter, fertilizers used in agriculture, manure, domestic and industrial wastewater, precipitation, or geological formations containing soluble nitrogen compounds. Nitrate levels show that most tested groundwater contained low levels, except for well P3 (75.24 mg/L). The ammonium content varies between 0.1mg/L (P8) and 35.2mg/L (P3). The amount of Orthophosphate is found to be less than 1 mg/L.

A Principal Component Analysis (PCA) was carried out to establish a relationship between the different physicochemical parameters. The correlation matrix between 11 physicochemical parameters studied (Table 2) shows significant positive associations between most parameters.
Table 1. Main physicochemical characteristics of the water from the nine studied wells and two sources.

<table>
<thead>
<tr>
<th>Station</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>S1</th>
<th>S2</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
</tr>
</thead>
<tbody>
<tr>
<td>T (°C)</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>22</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>20</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>pH</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6.5</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>CE (μs/cm)</td>
<td>1580</td>
<td>940</td>
<td>6480</td>
<td>1380</td>
<td>620</td>
<td>1680</td>
<td>1300</td>
<td>1650</td>
<td>780</td>
<td>780</td>
<td>840</td>
</tr>
<tr>
<td>Sal (mg/L)</td>
<td>790</td>
<td>440</td>
<td>3300</td>
<td>680</td>
<td>300</td>
<td>820</td>
<td>620</td>
<td>800</td>
<td>400</td>
<td>380</td>
<td>410</td>
</tr>
<tr>
<td>TAC (mg/L)</td>
<td>420</td>
<td>260</td>
<td>800</td>
<td>246</td>
<td>240</td>
<td>388</td>
<td>244</td>
<td>390</td>
<td>210</td>
<td>260</td>
<td>280</td>
</tr>
<tr>
<td>SO4 (mg/L)</td>
<td>243.7</td>
<td>193.83</td>
<td>767</td>
<td>216.24</td>
<td>164.55</td>
<td>267.47</td>
<td>240.48</td>
<td>339.51</td>
<td>152.59</td>
<td>124.25</td>
<td>154.48</td>
</tr>
<tr>
<td>NO3 (mg/L)</td>
<td>14</td>
<td>14.61</td>
<td>75.24</td>
<td>10.48</td>
<td>16.81</td>
<td>15.64</td>
<td>21.38</td>
<td>10.35</td>
<td>12.2</td>
<td>24.5</td>
<td>15.3</td>
</tr>
<tr>
<td>NH4 (mg/L)</td>
<td>0.198</td>
<td>0.223</td>
<td>35.237</td>
<td>0.201</td>
<td>0.402</td>
<td>0.443</td>
<td>0.12</td>
<td>0.123</td>
<td>0.126</td>
<td>0.1</td>
<td>0.142</td>
</tr>
<tr>
<td>Cl (mg/L)</td>
<td>408.19</td>
<td>241.5</td>
<td>680.32</td>
<td>278.33</td>
<td>129.26</td>
<td>581.68</td>
<td>366.01</td>
<td>442.21</td>
<td>204.09</td>
<td>201.77</td>
<td>255.12</td>
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<tr>
<td>PO4 (mg/L)</td>
<td>0.0006</td>
<td>0.0007</td>
<td>0.0013</td>
<td>0.0006</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.0006</td>
<td>0.0006</td>
<td></td>
</tr>
<tr>
<td>DT (mg/L)</td>
<td>590</td>
<td>380</td>
<td>1048</td>
<td>352</td>
<td>252</td>
<td>250</td>
<td>208</td>
<td>226</td>
<td>270</td>
<td>500</td>
<td>302</td>
</tr>
</tbody>
</table>

Table 2. Correlation matrix between the physicochemical variables of the study stations.

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>pH</th>
<th>CE</th>
<th>Sal</th>
<th>TAC</th>
<th>SO4</th>
<th>NO3</th>
<th>NH4</th>
<th>Cl</th>
<th>PO4</th>
<th>DT</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1</td>
<td>-0.5</td>
<td>0.59</td>
<td>1</td>
<td>0.94</td>
<td>0.94</td>
<td>1</td>
<td>-0.33</td>
<td>0.33</td>
<td>0.76</td>
<td>0.95</td>
</tr>
<tr>
<td>pH</td>
<td>-0.5</td>
<td>1</td>
<td>0.6</td>
<td>0.59</td>
<td>0.47</td>
<td>-0.5</td>
<td>0.46</td>
<td>0.51</td>
<td>0.69</td>
<td>0.69</td>
<td>0.34</td>
</tr>
<tr>
<td>CE</td>
<td>0.59</td>
<td>0.6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.94</td>
<td>0.24</td>
<td>0.38</td>
<td>0.92</td>
<td>0.77</td>
<td>0.96</td>
</tr>
<tr>
<td>Sal</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.94</td>
<td>0.25</td>
<td>0.38</td>
<td>0.92</td>
<td>0.76</td>
<td>0.95</td>
</tr>
<tr>
<td>TAC</td>
<td>0.94</td>
<td>0.24</td>
<td>0.25</td>
<td>0.33</td>
<td>1</td>
<td>0.33</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
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<tr>
<td>SO4</td>
<td>0.94</td>
<td>0.25</td>
<td>0.33</td>
<td>0.33</td>
<td>0.12</td>
<td>1</td>
<td>0.29</td>
<td>0.39</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>NO3</td>
<td>0.97</td>
<td>0.56</td>
<td>0.56</td>
<td>0.29</td>
<td>0.12</td>
<td>0.12</td>
<td>1</td>
<td>0.56</td>
<td>0.91</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>NH4</td>
<td>1</td>
<td>0.67</td>
<td>0.67</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.67</td>
<td>1</td>
<td>0.78</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>Cl</td>
<td>0.12</td>
<td>0.45</td>
<td>0.45</td>
<td>0.34</td>
<td>0.45</td>
<td>0.45</td>
<td>0.91</td>
<td>0.91</td>
<td>1</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>PO4</td>
<td>0.12</td>
<td>0.39</td>
<td>0.39</td>
<td>0.39</td>
<td>0.39</td>
<td>0.39</td>
<td>0.91</td>
<td>0.91</td>
<td>0.91</td>
<td>1</td>
<td>0.78</td>
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<tr>
<td>DT</td>
<td>0.12</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.89</td>
<td>0.89</td>
<td>0.89</td>
<td>0.78</td>
<td>1</td>
</tr>
</tbody>
</table>

Factor 1 (Figure 2) expresses 75.9% of the variance of the data and shows high and positive correlations of electrical conductivity as well as major elements (such as sulfates, chlorides and hardness), polluting elements (ammonium, nitrate and orthophosphate) and negatively correlated with temperature.

The Factor 2 expresses 10.81% of the variance of the data, showing a good positive correlation with the temperature and a negative correlation with the pH. The analysis of the circle performed by the two factors F1 and F2 shows a correlation between all the chemical elements constituting the mineralization of the waters as well as the pollution elements. These interpretations allow us to consider factor 1 as the mineralization factor related to the dissolution of geological formations and the pollution factors.

The hierarchy of stations based on the physical-chemical descriptors of water allows distinguishing three different groups:

Group 1: it included the well P3, which is a well without a cover, therefore not protected from various wind contributions. It presents water of poor to bad quality. It is, as indicated above, richer in organic pollution indicator ions, ammonium ions whose contents often exceed the standards set by the WHO.
Group 2: This group includes a set of five wells: P1, P4, P6, P7, P8, and two springs, whose water presents excessive mineralization and an important hardness as well. They are often richer in organic pollution indicator ions, with contents sometimes exceeding the standards set by the WHO.

Group 3: involves three wells, P2, P5, P9, all unprotected, from wind contributions but located quite far from inhabited areas. The water in these wells has lower organic or mineral pollution indices than that from the well P3, whose water is highly mineralized. It is, as indicated above, richer in pollution indicator ions (ammonium ions) exceeding WHO standards, therefore, presenting a serious potential risk to the local population’s health.

Faunal Diversity

Analysis of the fauna harvested in the studied sites revealed the presence of 1237 individuals belonging to four phyla: Arthropods, Molluscs, Plathelminths and Annelids. Insects are the most abundant with 880 individuals (71.14%) followed by gastropods, 147 individuals (11.88%), crustaceans 106 individuals (8.57%) and Plathelminths with 96 individuals (7.76%). Hydracariens and Annelids are the least represented, five individuals and three individuals respectively (Figure 3).
The Abundance of Studied Groundwater

- **Insects**

The class of insects is the most abundant (71.14%); it includes 36 families that belong to seven orders, with Diptera (insects) being the most abundant and important group numerically 47.73% represented strongly by the Culicidae.

- **Molluscs**

They represent 11.88% of the total number of harvested samples, comprising a single class of gastropods presented by four families: a dominating Hydrobiidae with 50%, Ferrissidae 39.5%, Physidae 1.36% and Planorbidae 0.68% (scarce).
Crustaceans represent 8.569% of the harvested fauna, with dominating Ostracods (98.11%), while Isopods are poorly represented with only 1.89%.

Plathelminths and Arachnids constitute a low and very low abundance respectively.

Discussion
During the study period, the results showed that water is highly mineralized. Allaoua et al. (2015) argued that all these ions come mainly from rocks, limestone, or salt sometimes crossed by water in addition to anthropogenic stressors such as agricultural practices (Bouakkaz et al., 2017). The water temperature showed relatively little variation in wells (18°C-20°C). According to Rodier (2009), groundwater is less sensitive to temperature variations than surface water, and the variation in pH between stations generally does not exceed one pH unit, ranging between 6.5 and 8, which indicates the degree of alkalinity of the environment. The conductivity recorded values showed high and significant variations, ranging from 620 μS/cm to 6480 μS/cm, these high values (above 1000 μS/cm) are normal in eastern Algeria (Ramzi et al., 2020). The hardness, exhibits high values with a great variation from 208 mg/L to 1048 mg/L. Rodier et al. (1984) indicated that this parameter is directly related to the quantity of calcium and magnesium in the water and these high values are probably related to the lithological nature of the geological formation of the water table, in particular, to its dolomite composition which is rich in magnesium and calcium. In the study stations, the sulfate was around 250 mg/L, denoting that the waters in question comply with Algerian standards, throughout, according to Meybeck et al. (1996), the presence of sulfates in "unpolluted" natural waters invokes the presence of gypsum or pyrite. High levels of pollution elements (ammonium, nitrate and orthophosphate) affect species sensitive to pollution (Lylia et al., 2020). This is the case of P3, which presents water of poor to bad quality, this well is strongly represented by Diptera 92%, mainly the most resistant to pollution such as Psychodidae, which is considered as indicators of pollution (Mastrantuono, 1985).
Conclusion

Water is a vital natural resource essential to life in all ecosystems. 11 stations located in two regions, Souk Naamane and Ain M'lila, have been the subject of physical-chemical analyses and benthic macro-invertebrate sampling.

The physical-chemical results show that all pollution parameters are within WHO standards except for Ammonium (NH4+-) which is higher in S3 and P8. The strong mineralization recorded in the stations could be explained by the dissolution of the limestone, saline and gypsum rocks of the terrains covering the study area. In addition, anthropogenic action would be added to natural action. Indeed, agricultural practices do not influence the stations, and this is justified by the total absence of nitrate and orthophosphate contamination.

Throughout this work, the study carried out in the 11 selected stations made it possible to harvest 1237 individuals. Despite the low number of individuals, 47 families were identified revealing a large abundance of the epigenetic fauna in the water of the prospected wells. These results are consistent with previous work. Beetles are the best-represented faunal group (16 families). After that comes the Diptera and the Gasteropods, with eight and four families respectively, the Hydracariens (four families) and the Trichoptera (three families), the Hymenoptera and the Ephemeroptera have two families each; however, the Megaloptera, the Triclades and the Citellata only have one.

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References


