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Study of water quality on the plain of Maghnia (Western Algeria)

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ABSTRACT

The contamination of surface and ground water by pollution related to human activities remains a major global concern. The study of the physicochemical characteristics of surface and ground water of the Maghnia region will allow evaluation of the quality of the water in this region and will therefore lead to an examination of the possibility of pollutant transfer from watercourses and groundwater as long as aquifer-stream exchanges can occur where the hydrogeological conditions are met. The aim of this paper was to evaluate the quality of the water resources in the plain of Maghnia and investigate the contamination of ground water by pollution carried by surface water. We also evaluated the impact of anthropogenic and industrial pollution on the water in the region. For this study, sampling sites, including five stations monitoring the surface water along two main polluted rivers (Mouillah and Ouerdefou Rivers), were selected. Ten wells were selected around the Mouillah River and near the town of Maghnia to survey the quality of the groundwater. Five outfalls of waste water in the region were sampled for this study. The temperature, pH, electrical conductivity, and dissolved oxygen content of the water were measured. The major ions, phosphates, ammonium, chemical oxygen dissolved, and biochemistry oxygen dissolved (BOD) in five days were analyzed in the laboratory.

Keywords: Physicochemical; Analysis; Salinity; Pollution; Contamination; Aquifer

1. Introduction

The resources of freshwater are limited to 2.6% of all water on earth [1], of which 97% is groundwater. Of the world's population, 75–90% use water of underground origin [2,3], so preservation of this underground water from any form of contamination is essential [4].

Accurate knowledge of the state of water resources in Algeria remains one of the major concerns of both public authorities and scientists. Until recently, Algeria suffered from a critical shortage of water. To deal with this situation, the public authorities have opted for a strong policy focused primarily on exploiting aquifers and constructing dams and seawater

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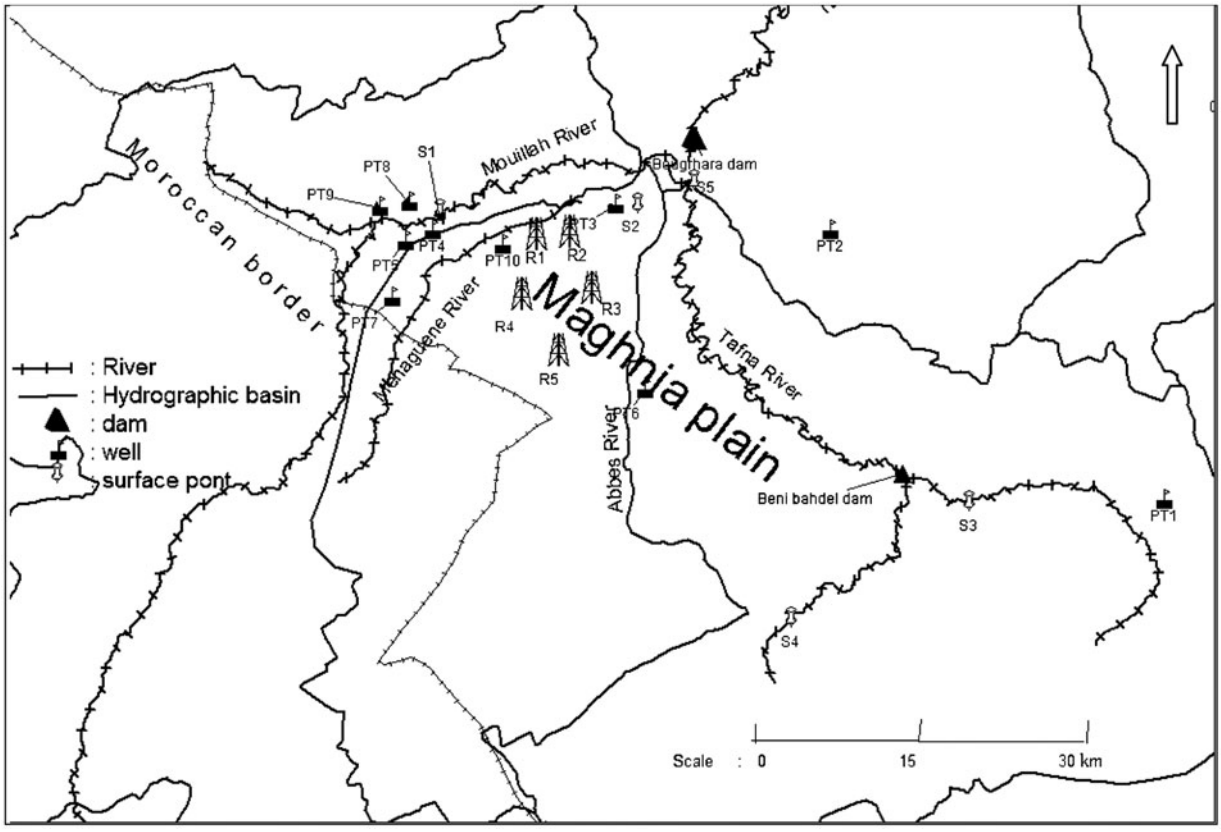

Fig. 1. Location map showing sampling points in and around the Maghnia Plain.

desalination plants. This diversified approach has significantly increased the water supply in Algeria.

The current focus of policy in Algeria is on protecting water resources against waste [5] and all known pollution risks (uncontrolled urban and industrial wastewater releases).

To participate in this effort, the qualitative monitoring of the water resources in the Maghnia Plain has become imperative, because the region is deemed to be very vulnerable to pollution. The Maghnia Plain is crossed by several streams exposed to pollution caused by industrial units in the region.

The impact of anthropogenic pollution on the quality of groundwater has been studied by several researchers [6], focusing on nitrates of agricultural origin. In identifying and quantifying pollution in groundwater, researchers have found that the use of wastewater for irrigation purposes increases the infiltration and dispersion of pollution to groundwater. Moreover, the geology and hydrogeology of an aquifer strongly affect the dispersion of pollutants, with deep aquifers providing greater protection from surface water contamination.

The main outcome of this study is related to the evaluation of the quality of the surface water in this region, which is very poor and degraded. An important source of pollution was detected at the Mouillah and Ouerdefou Rivers where chemical oxygen demand (COD) values exceeded 200 mg/L and the concentration of ammonium was greater than 10 mg/L. This pollution is carried by discharges of water from industrial units into the Mouillah River.

Other results indicate that the ground waters of the Maghnia region are not being affected by wastewater discharged into watercourses. Because the saturated zone begins relatively deep, polluted water is seeping slowly through the unsaturated zone, which has low permeability, thereby promoting self-cleaning.

However, the groundwater could become contaminated over the long term if the watercourses become polluted.

In this study, we assessed the quality of the water resources in the plain of Maghnia and the impact of anthropogenic pollution on the water in the region.

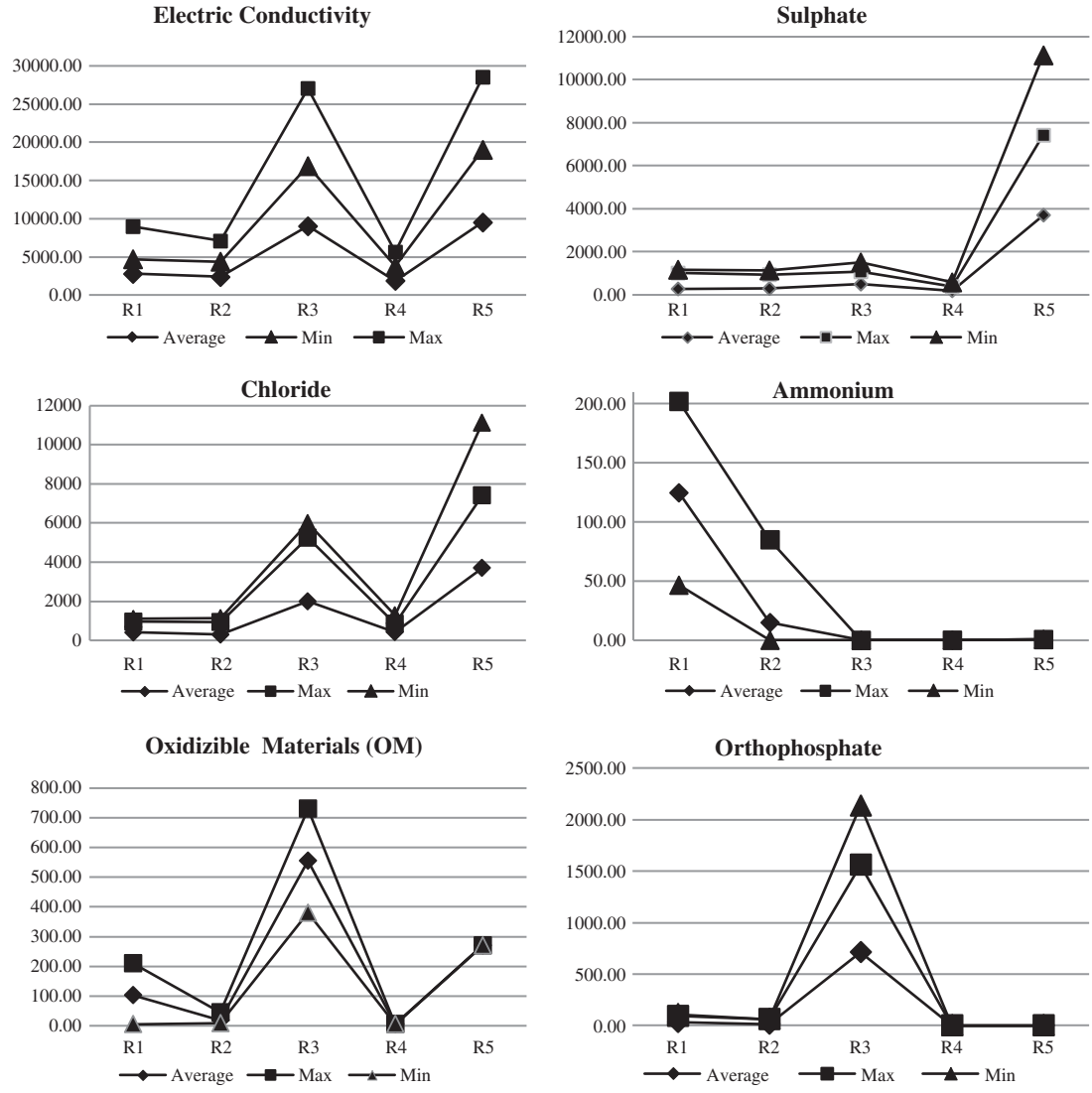

Fig. 2. Developments of the chemical parameters of discharges into the Maghnia Plain.

Samples were collected periodically at several points on the rivers. Samples were also collected at local and industrial discharges and wells at different depths. Several physicochemical parameters were taken into consideration to better evaluate the chemical quality of the waters of the plain of Maghnia.

2. Presentation of the study area

This study focuses on the Plain of Maghnia, which has an area of approximately 350 km² (Fig. 1). The Maghnia Plain is located in the Tafna Basin in northwestern Algeria, approximately 150 km to the southwest of Oran. The catchment of the Tafna Basin has been studied previously because of its important water resources [7]. The Plain of Maghnia is bounded to the north by the Traras Mountains, to the south by the Tlemcen Mountains, to the west by the Moroccan border and to the east by the Valley of the Tafna. The altitude of the plain varies between 350 and 550 m.

2.1. Geology and hydrogeology

The plain of Maghnia corresponds tectonically to a pit elongated in the ENE–WSW direction and surrounded by emerging Jurassic reliefs and limited by faults.

Table 1
Points of sample collections in and around Maghnia Plain

Selected points	Name
PT1	AIN TAGA
PT2	SABRA 1
PT3	EAC-EX-DJABER
PT4	BRAZI AEK
PT5	STATION SNTF
PT6	ZAHZOUH OUASSINI
PT7	TASOURI
PT8	S Mohamed
PT9	MENOUAR Mohamed
PT10	Wash Legfaf
S1	Mouillah
S2	Legfaf
S3	Béni Bahdel
S4	Zahra
S5	Village Tafna
S1	Mouillah
S2	Legfaf
S3	Béni Bahdel
S4	Zahra
S5	Village Tafna
R1	Entrance Station of waste water treatment of Maghnia town (E/STEP)
R2	Treatment plant output (S/STEP)
R3	Rejection of the maiserie unit
R4	ECVO Maghnia plant
R5	Unity of the body fat (ENCG)

Bounded to the north by the parched Syncline of Djebel Fellaoucene and to the south by the great Rhar Rouban Anticline, the bowl is filled by erosion from Neogene sediments.

The lower Neogene geologic formations correspond to Kimmeridgian limestone, sandstone of the Sequanien and the Callovian-Oxfordian ages, calcareous marl of the Bajocian/Bathonian period, limestone, and conglomerates of the Lias and coarse red Permo-Triassic sandstone [8].

The Maghnia Plain is traversed by two separate rivers: the Mouillah River (an extension of the Moroccan Bounaim River) and the Ouerdefou River, which is the confluence of the El Abbes, El Aouina, and Mehaguène Rivers (Fig. 2). The Ouerdefou River is the most polluted river in the region, because it is the primary destination of wastewater from the town of Maghnia and its industrial units.

The flows estimated for the volume of the Mouillah are approximately 1.9 Mm^3/year. Because of a decrease in the piezometric level between 1976 and 1989, the areas drained by the river flows were slightly lower at the end of the year 1980.

The flow of the Mehaguène, El Aouina and El Abbes and the Ouerdefou, evaluated is about 11 Mm^3/year. However, at the end of the 1960, the Mehaguène and El Aouina were perennial rivers, while in the late 1980s, these rivers continuously drained more water.

The volume of water drained by the temporary streams and the Ouerdefou River for the years 2000–2003 is 5.6 Mm^3/year (data from the hydrological station for the Ouerdefou River).

These rates are overestimated because the presence of sewage being released into the stream flows does not match the drainage of the water upstream. The proportion of these flows is not known, so it is difficult to determine the water flow actually drained by the river.

Regarding its hydrogeology, the main aquifer of the plain of Maghnia corresponds to the Plio-Quaternary alluvium. Miocene marls form the substratum of this aquifer.

The Plio-Quaternary fill of variable thickness is very heterogeneous. This fill is a complex series of discontinuous deposits of very mixed elements that intersect (clays, fine or coarse sands, gravel, pebbles and lacustrine limestone).

The geological logs of a number of boreholes show that the Plio-Quaternary covering has a maximum thickness at the center of the plain (borehole G3 with Lambert coordinates $X = 88.70$ and $Y = 178$) and then becomes thinner to the southeast (borehole B24 with Lambert coordinates $X = 98.575$ and $Y = 171$).

Because of vertical and horizontal lithological heterogeneity, the groundwater, divided by impermeable lenses, is located in a channel-oriented WSW–ENE corresponding to an ancient river valley cut into the Miocene marl and filled by alluvium. The productive alluviums are therefore located in the first 50–60 m.

Beyond this point, alluviums are less permeable and may even constitute, in addition to sealed Miocene marls, a substratum for groundwater.

The Maghnia aquifer has numerous wells and boreholes for the purposes of irrigation and potable water, supplied by:

- The direct infiltration at the level of the water.
- At the Angads Plain near Morocco, the estimated average throughput at the border Rivers in 1967 was 40 L/s/km.
- To the south, the plain is fed by overflow aquifers from the Jurassic. The total average rate of flood

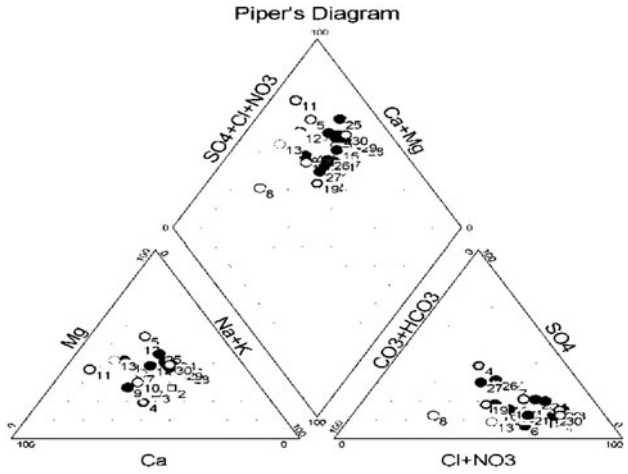

Fig. 3. Piper diagram for the waters of Maghnia Plain.

was quantified in 1967 in their model as 35 L/s/km.

- There is infiltration of irrigation water.

3. Materials and methods

3.1. Sampling

The sampling sites were chosen to cover the main polluted area located near the Mouillah and Ouerdefou Rivers.

Five measurement points along the main river crossing the plain were selected and chosen to survey the surface water pollution. Ten wells on the Maghnia Plain were sampled to track the quality of the ground water. Five release points were selected; these points carry a large part of the urban and industrial pollution, especially near the town of Maghnia (Fig. 2).

A monthly survey was performed during the 2011–2012 period for the measurements at the fixed point.

Acidification of sample with sulfuric acid to pH < 2 is necessary to analyze COD. Biochemical oxygen dissolved (BOD_5) was also analyzed. During transport, samples were kept at 4°C in polyethylene bottles and then analyzed within the following hours at two laboratories (LSTGP at the University and the Laboratory of Hydraulic Resources of the National Agency ANRH) (Table 1).

3.2. Analysis methods

Analysis methods that were applied are given by the standard AFNOR [9–11]. Temperature, pH, electrical conductivity, and dissolved oxygen (DO) parameters were determined on site in unfiltered samples; pH measurements were performed with a WTW T20 pH meter; electrical conductivity and temperature were measured using an HD 3406 apparatus. DO concentrations were determined by Winkler titration. A portion of the filtered samples was retained for chloride analysis by titration with $AgNO_3$.

COD and BOD_5 were analyzed in the laboratory at ANRH using a volumetric method. Sulfate (SO_4^{2-}), ammonium (NH_4^+), and orthophosphate (PO_4^{3-}) ions were analyzed by spectrophotometer (UV/Visible Lambda 25 Sherwood410 PerkinElmer). Oxidizable matter (OM) was defined by the Water Agency to evaluate the organic pollution of wastewater to tax pollution [11]. The OM corresponds to the two global parameters COD and BOD_5 using the following expression related to the wastewater flow.

$$OM = [2(BOD_5) + COD]/3 \quad (1)$$

4. Results and discussion

4.1. Qualitative study of wastewater from the town of Maghnia

The treatment of the results of the chemical analyses allowed us to draw the graph in Fig. 3 and determine the evolution of the various parameters.

Wastewater from the town of Maghnia is led directly to the wastewater treatment plant (WWTP), where the waters undergo treatment before being released into the Ouerdefou River. The results of the analysis (R1, R2) show that the values of conductivity, chloride, sulfate, ammonium, and phosphate for treated water are only slightly lower compared with raw water. Insufficient treatment (WWTP malfunction) or a pollutant load too high to treat may be the cause of the ineffectiveness of the treatment.

Water discharged from industrial plants (R3, R4, and R5) has chemical parameters higher than the wastewater from the city of Maghnia, as well as a yellowish color and a very unpleasant odor.

Industrial units (R3, R5) that are also equipped with water treatment units discharge the water directly into the Abbes River. The flow of water discharged is very low, but the quality of this water is very poor [12] with orthophosphate values >500 mg/L. For oxidizable materials related to the organic pollution of the water, the values are very high (>400 mg/L). Ammonium ions were not detected at the three points (R3, R4, R5), an observation that can be explained by the complete degradation of the organic matter [13].

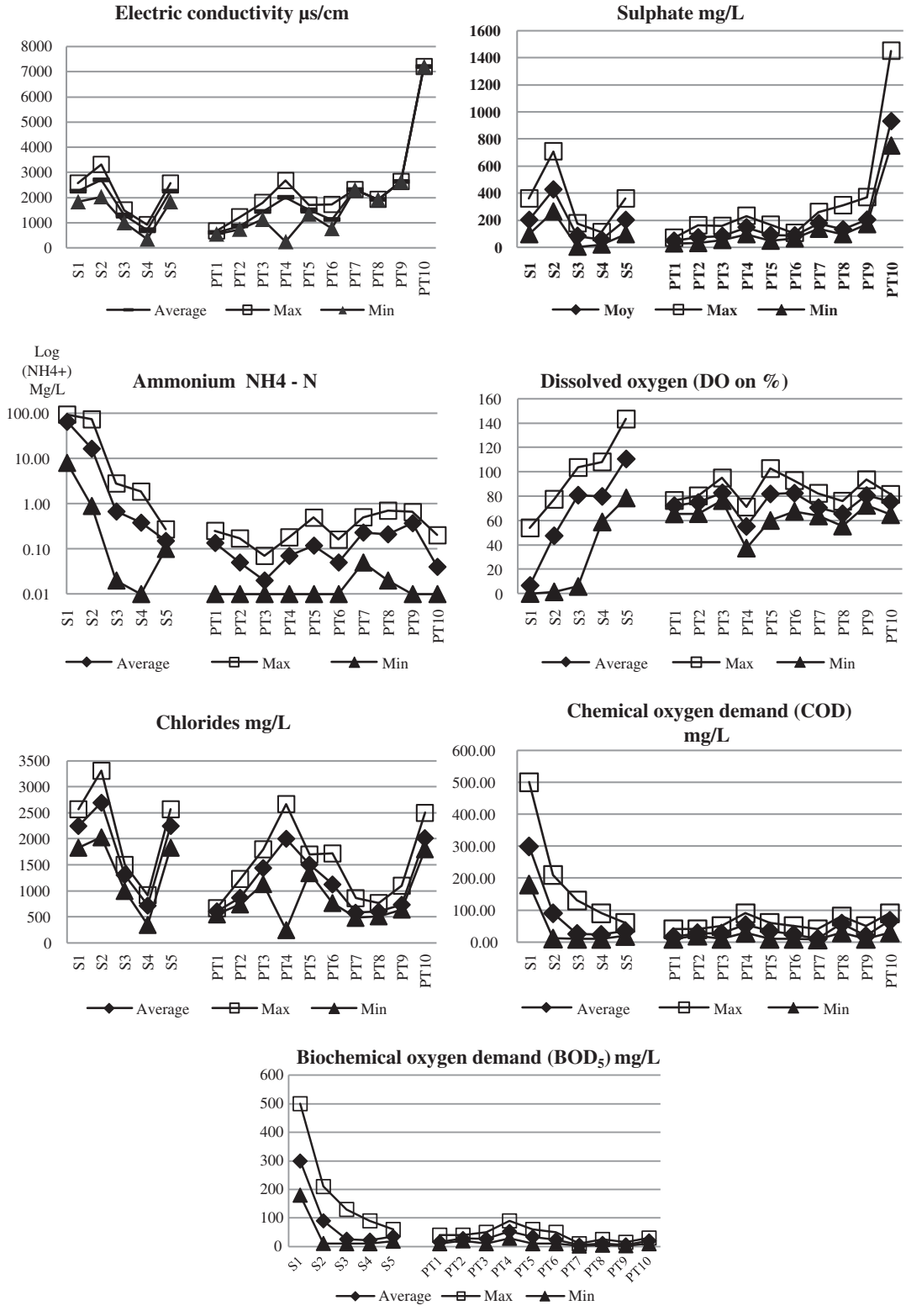

Fig. 4. Variation in the concentration of salinity, chlorides, sulfates, ammonium, DO, COD and BOD_5 in water of Maghnia Plain.

4.2. Qualitative study of the waters of the plain

Assessment of the quality of groundwater following the analysis of the physicochemical data collected from the Oran/ANRH and at more than 48 water structures (1996–2001) reveals that 60% of the measured points have values of dry residues above the limit recommended by the WHO (1,000 mg/L). For chloride ions, 73% of the values fall between 250 and 1,000 mg/L, with a heterogeneous distribution of concentrations (Fig. 4). Regarding the sulfate concentration, about 80% of the points are below the value recommended by the WHO (250 mg/L) [13–15]. The mineral quality of the groundwater is, therefore, good for the majority of the physicochemical parameters.

4.3. Relationship between surface water pollution and water quality in the Maghnia Plain

To compare quality between surface water and groundwater (given in the graphs below (Fig. 4)), new samples were taken from the same sites selected above.

The underground mineral water quality is good for the majority of the physicochemical parameters.

The water quality in the Maghnia region was determined following measurements of samples. A comparison between surface and groundwater quality is presented in the graphs below (Fig. 4).

In water captured by wells, chlorides predominate, with concentrations exceeding 600 mg/L. However, at surface stations, the chloride concentration is approximately 500 mg/L. For sulfates, ground waters have concentrations below 200 mg/L. At the station Legfaf (S2), which continues to receive untreated raw water, very high concentrations are recorded (700 mg/L). However, the conductivity of the water, whether surface or groundwater, remains moderate (between 2,000 and 2,500 μs/cm).

For ammonium, which is of major interest for assessing pollution, concentrations recorded at stations on the Mouillah and Legfaf Rivers greatly exceed 5 mg/L, reflecting severe degradation of the water quality, especially in the Mouillah River. For wells, the concentration of ammonium remains very low (<0.1 mg/L). These values indicate that the groundwater is not contaminated by the surface water. The COD and BOD_5 values are also higher for the surface water compared with the groundwater.

The COD and BOD_5 concentrations for the surface water exceed the limits recommended by the WHO (>120 mg/L).

5. Conclusion

The results of this study indicate that the ground waters of the Maghnia region are not being affected by wastewater discharged into the watercourses. Because the saturated zone is relatively deep, polluted water seeps slowly through the unsaturated zone, which has low permeability, thus promoting self-cleaning.

Groundwaters, with no outlet to outside the basin, are concentrated along the low points of the region, represented by the Mouillah River. The rivers drain the northern part of the aquifer reservoir, consistent with the permeable formations. The Plio-Quaternary participates in the dilution of the surface water, and thus, the rate of pollution is reduced. Because of the dilution of the surface water, drainage reduces the rate of pollution.

This study reveals that the water of the Maghnia Plain is currently not affected by anthropogenic pollution carried by watercourses. However, the ground water may become contaminated over the long term if the watercourses become polluted. Continuous, qualitative monitoring of both the surface water and the ground water in the region is necessary.

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