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Elucidating the mechanisms of water quality deterioration in Oued El Abid River -Morocco-

Ismail KARAOUI[1]*, Abdelkrim ARIOUA[1], Abdelkhalek EL AMRANI IDRISSI[2], Wafae NOUAIM[3], Driss ELHAMDOUNI[1], kamal AIT OUHAMCHICH[1], Rachid HNINI[1]

1. Sultan Moulay Slimane University, Faculty of Sciences and Technologies Beni Mellal, Morocco.
2. Oum Er-Rbia Hydraulic Basin Agency, Beni Mellal, Morocco.
3. Ibn Tofail University, Faculty of Sciences Kenitra, Morocco

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I KARAOUI
i.karaoui@usms.ma
+212642665908

Abstract

Recently, according to a survey carried out in Oued El Abid River by Oum Er-Rbia Hydraulic Basin Agency concerned the surface water quality, the downstream course is undergoing continual degradation in its water quality comparable to the upstream. This study comes to localize the sources of pollution and explain the process of degradation, which affect the water quality in that area. For this purpose, an inspection of the place has been done during January 2017 to cover the entire zone limited the affected part of river, followed by a survey, which interests to water quality and the groundwater depth. The inspection doesn't show any direct liquid discharge into the river, meanwhile the water quality degradation is related to the underground sources through river- shallow- aquifer exchange process, when the obtained results from the survey showed that severe parameters are involved in the degradation of groundwater, as the geology and agricultural activities. Combining these results with flow direction in groundwater, it is clear that pollutants are transported to the river via the river-shallow aquifer exchange process, which affects its quality. Based on the finding results, this study will give the decision makers a simple view to a complex pollution processing.

1. Introduction

Over the past centuries, human water uses have no impact on water availability till the middle of nineteen century [1] when the population had tripled from 2.3 to 7.3 billion human beings between 1940-2015 [2,3]. Meanwhile the water consumption per capita, has jumped from 400 to 800 m3 per year [1]. Such disequilibria is probably impossible to control, especially in some countries such as Africa and Asia which have a major lack of water quantity and quality, while some other parts of Asia, Latin America and Europe risk to face the same situation [4].

The quality of surface waters is a very influential factor, which involves anthropogenic treats and influence urban, industrial, agricultural activities and natural processes which conduct to a degradation of surface waters and limitation of their use in industrial and agricultural fields [5].

Human alteration of the landscape has an extensive influence over the water resource [6], [7], and the heat balance [8], which lead to increase the temperature of water [9] and modify the biogeochemical processes in river that rise nutrient, oxygen, and sediment cycle[10]. Therefore, the determination of spatial and temporal changes in water quality in river basins has been an objective of several studies in France, United Kingdom , Bulgaria, Greece, Canada, United State of America, South Korea, Nepal and central Asia [11–19]. These studies showed that the anthropogenic activities greatly deteriorate the water quality in major rivers, passing through communities with an absence or inadequate wastewater treatment facilities [14].

In Oued El Abid River, based on the last sampling field trip made by Oum Er-Rbia Hydraulic Basin Agency to control Oued El Abid River water quality, the downstream Course of the river faces a deterioration in its quality comparable to the upstream course although the absence of industrial activities and any direct eliminate of liquid waste from the communities nearby the river where people use septic tanks or rather eliminate heir waste on

nature far away from the water courses. For this reason, the deterioration may be caused by groundwater, which transfers its pollutants to river through the river- shallow aquifer exchange processes.
The exchange between rivers and shallow aquifers greatly affects the quality of water resources, which is related to maintain the groundwater discharge during dry periods of the base-flow in rivers when there is no direct runoff from the land surface, and vice versa during the high flows [20], [21]. Where there are large exchanges of water between rivers and shallow aquifers, their physical characteristics and chemical constituents will be similar [22]. To assess exchanges between ground and surface waters, different methods are used depending on the spatial scale of interest. At a point of river, stream piezometers and chemical composition can be used to determine the vertical hydraulic gradient between ground and surface waters and identify regions where ground water discharges into the river [23].
For this purpose, inspiring from several studies [22,24] done to characterize the river-shallow aquifer exchange process, we attempts on the this research article to spot the relation river-shallow aquifer and its impact on Oued El Abid River quality deterioration in the downstream part.

2. Materials and methods

The study started by making an inventory about pollution sources in the study area from documents collected in communes crossed by Oued El Abid River and diagnostic field trips of the current state of the study area. It is followed by measurement of groundwater depth and samples collection for analysis. To do this, a GPS (Garmin GPSMAP 62S) and a piezometric probe (100 meters) were used to localize wells and measure their groundwater depth. These measures later serve us as tools to develop several thematic maps that will help to localize the groundwater-river exchange places and determine its direction. Concerning water quality, samples were taken along Oued El Abid River and the groundwater of the study area. These samples were selected in a well-defined way to give an overview of the variation in the overall quality of the Oued El Abid River and the groundwater from one area to another. During field sampling, the in situ parameters were measured using a portable digital multi-parameter (3430, WTW®) which measures the pH, electrical conductivity and dissolved oxygen. These samples were then transported in a glacier to maintain their same characteristics as in nature. At the laboratory, physic-chimical and bacteriological measurement was carried out (**Table 1, 2**) in order to complement other parameters necessary for surface and groundwater characterization. These analyses have been made in the Oum Er-Rbia Hydraulic Basin Agency laboratory (ABH) according to Moroccan standards of water quality [25].
The coupling of depth results and laboratory measurements will allow us to define the effect of shallow aquifer and Oued El Abid River exchange process on water quality deterioration observed in the river. The following methodology designed below (**Figure 1**) gives the main axes of our study.

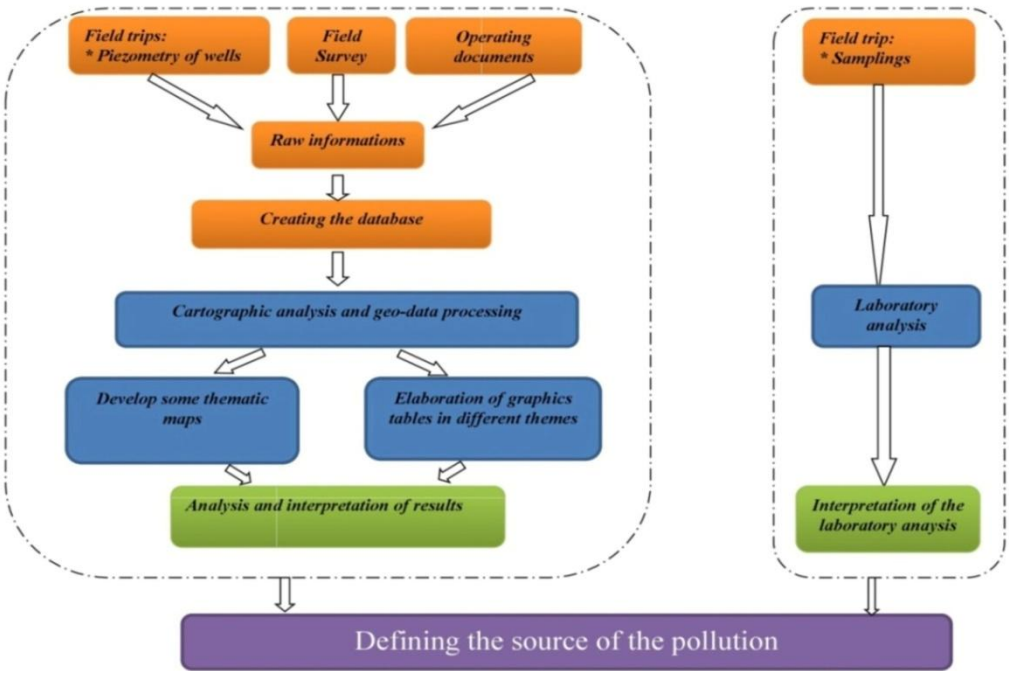

Figure 1: The diagram of work methodology

3. Study area and geologic setting

The study area limits run from Bzou town to the outlet of Oued El Abid watershed, in Beni Mellal-Khénifra region, Morocco, stretching over 1094 Km2 under semi-arid to arid climate (**Figure 2**). The annual rainfall varies from 637 mm as Max. and 38 mm as Min. with a mean of 350 mm [26].

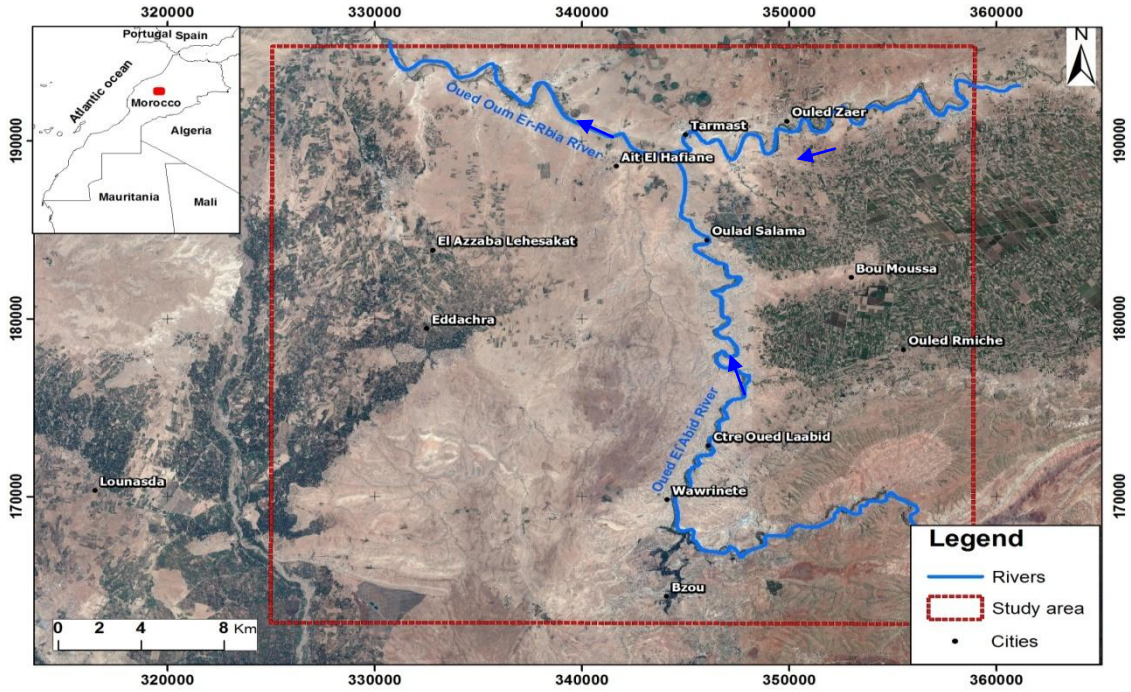

Figure 2: Location of the study area

From hydrogeological aspect, two types of aquifers are encountered in the study area, the deep Turonian aquifer and the phreatic Plio-Quaternary aquifers, Beni Moussa in the East and Tassaout downstream in the West [27]. Stratigraphically, the study area embodies a various startigraphic units ranging in age from Triassic to Quaternary (Pleistocene) as shown in **Figure 3**.

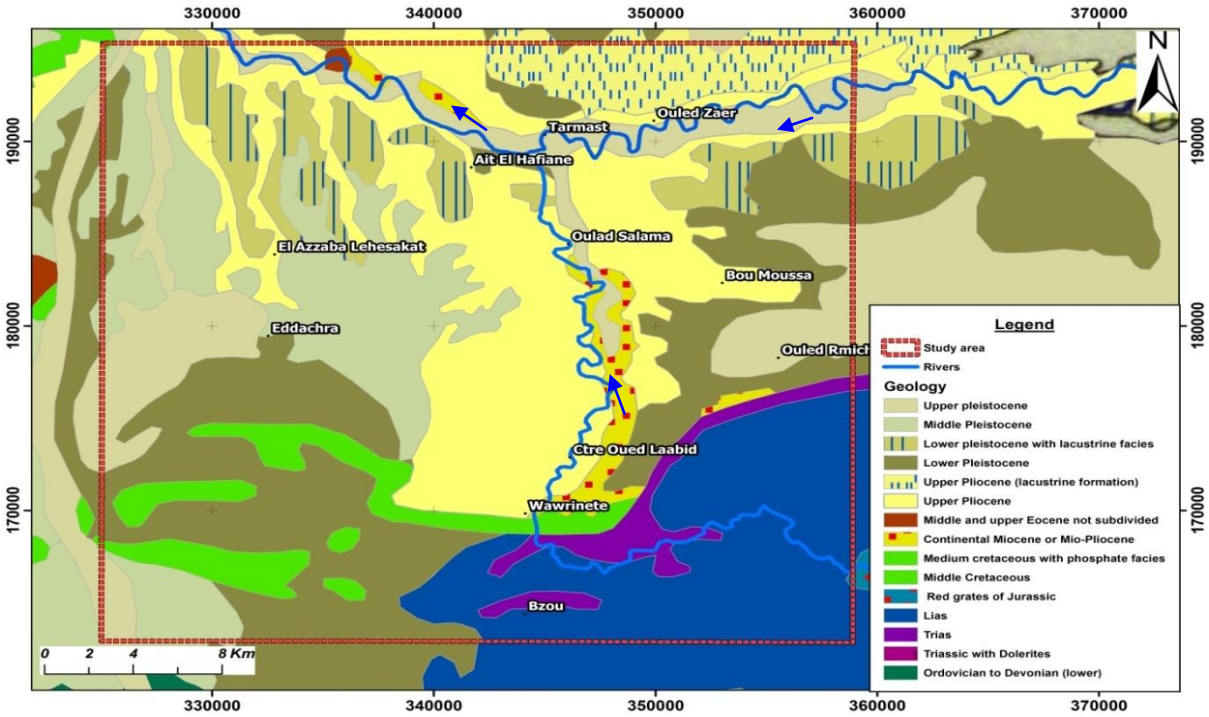

Figure 3: Geologic map of the study area

The stratigraphic units are classified from base to top as following:

Triassic: exist in the southern part of the study area. They are characterized by clay-bearing formations with evaporate minerals.

Jurassic: is localized towards the chains of the high atlas. It is represented by limestones, dolomites and marly limestone-bearing formations.

Cretaceous: appears on the surface at the Bzou region. It is characterized by intercalation of marls and limestone slabs.

Pliocene: is mostly represented in the study area. It is represented by lacustrine limestone, sand and marl.

Pleistocene: is the last age of the quaternary in this region. It is characterized by the presence of the continental conglomerate, sand and clay.

4. Results

The results obtained in Oued El Abid River characterization (**Table 1**) revealed that the overall water quality decreased sharply starting from Bzou town comparably to the upstream part. We assume the sampling point (R1) as a reference of Oued El Abid water quality before deterioration. Figure 4 shows the overall surface quality in Oued El Abid watershed.

Table 1: Laboratory results of the last four river samples

Sample	EC	pH	DO	TA	TAC	TH	PO_4^{2-}	Ca^{2+}	Cl^-	Mg^{2+}	SO_4^{2-}	NO_2^-	NO_3^-	OM	COD	BOD
Unit	µS/cm	-	mg/l	°F	°F	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
R1	661	7.93	7.0	0	21.5	30.6	0.006	112.0	56.8	13.10	80.53	0.007	2.27	2.40	1.71	0.69
R2	1028	8.17	6.4	0.5	23.5	33.2	0.006	120.8	163.3	22.17	82.49	0.015	13.45	1.60	1.14	0.46
R3	1289	8.18	6.9	0	21.5	35.8	0.006	116.0	213.0	32.25	93.22	0.039	17.10	1.76	1.26	0.50
R4	1623	8.18	7.8	1.5	23.0	41.2	0.006	147.2	390.5	31.24	69.47	0.019	19.00	3.52	2.52	1.01

EC: Electrical Conductivity. **pH**: Potential of Hydrogen. **DO**: Dissolved Oxygen. **TA**: Total Alcalinity. **TAC**: Complete Alkalimetric title. **TH**: Total Hardness. **OM**: Organic Matter. **COD**: Chemical Oxygen Demand. **BOD**: Biochemical Oxygen Demand.

According to the map above (**Figure 4**), the overall quality of Oued El Abid River is of good quality till the study area where it had changes and become of average quality. Meanwhile, the two tributaries of the Oued El Abid River, Assif N -Ahançal and Assif Melloul are of excellent quality.

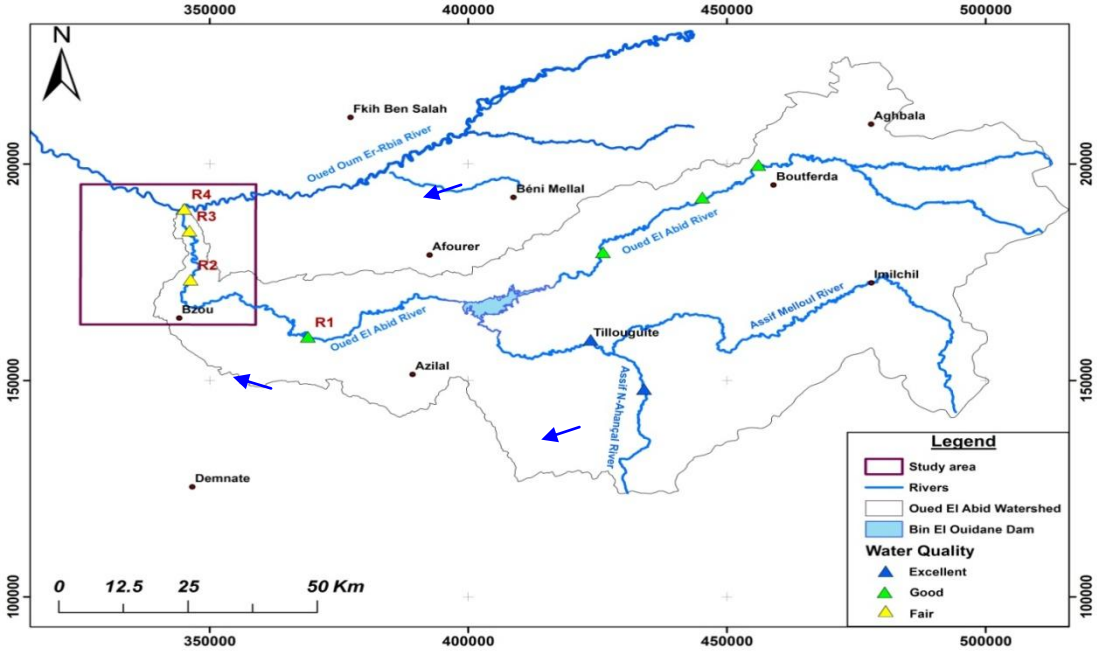

Figure 4: Water quality status in Oued El Abid River and its tributaries

Regarding the groundwater quality status, 10 well-dispersed samples on the study area were taken (**Figure 5**) in a manner to give a global vision and localize zones where groundwater undergo a degradation of its overall quality. The following table gives the obtained results in laboratory by analyzing the well samples and the last four points of Oued El Abid River (**Table 2**).

Table 2: Groundwater laboratory results

Sample	EC	pH	DO	TAC	TH	PO_4^{2-}	Ca^{2+}	Cl^-	Mg^{2+}	SO_4^{2-}	NO_2^-	NO_3^-	OM	FC	SF	TC
Unit	µS/cm	-	mg/l	°F	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	UFC/100ml	UFC/100ml	UFC/100ml
P1	610	7.78	9.8	23.5	40	0.11	66.4	24.85	58.97	7.65	0.087	20.86	2.48	950	150	2000
P2	740	8.04	8.3	25.5	36	0.02	81.6	71.00	39.31	64.67	0.012	19.18	1.84	0	0	0
P3	1234	7.92	3.4	20	38	0.01	132	227.20	12.60	25.22	0.023	21.57	2.96	-	-	-
P4	2430	7.30	7.9	22.5	38.4	0.01	144	582.20	6.05	100.71	0.025	21.13	3.36	150	900	104
P5	7690	7.26	8.1	23.5	96	0.14	376	1988.00	5.04	201.18	0.011	20.50	6.00	200	450	3000
P6	3500	7.64	7.3	21.5	40	0.01	152	603.50	5.04	172.05	0.003	20.33	3.28	120	12	600
P7	761	7.34	8.4	15	34	0.01	56	42.60	50.4	61.82	0.001	9.30	1.92	-	-	-
P8	583	7.43	7.9	20.5	28	0.02	80	42.60	20.16	40.67	0.109	18.10	2.00	-	-	-
P9	4250	7.10	7.0	22.5	36	0.03	136	871.88	5.04	165.63	0.001	15.70	4.32	-	-	-
P10	6892	7.10	9.3	15	18	0.03	32	17.75	25.20	117.96	0.003	17.00	5.60	-	-	

FC: Fecal Coliforms. **SF**: Fecal Streptococci. **TC**: Total Coliforms.

Comparing laboratory results with groundwater quality standards in Morocco [27], It is found that the wells P1, P2, P3, P7 and P8 are of good quality, while the P4 has an average quality due to electrical conductivity and chlorine that are classified in average category. Concerning the wells P5, P6, P9 and P10 are of poor quality by reason of high electrical conductivity which exceeds Moroccan standards, Chlorine and organic matter ratios of averages to poor quality.

To check and verify the relation between water quality degradation and those wells revealed of mediocre and bad quality, we made a measurement of depth at 44 wells that are well-dispersed to cover the study area, in order to produce a map of groundwater level variation (**Figure 6**), and then determine where the groundwater is near the surface and threatened by pollution.

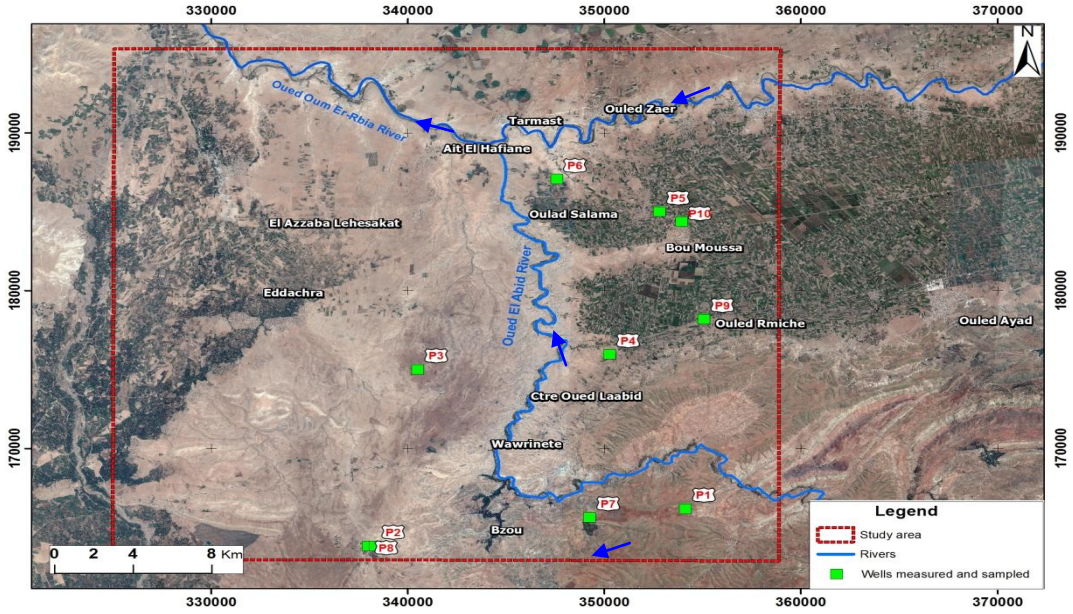

Figure 5: Location of wells samples in the study area

According to the depth map above (**Figure 6**), it can be seen that a large part of Oued El Abid River in the study area is not crossing a groundwater very deeply (varying between 9m to 27m), which makes it close to the surface.

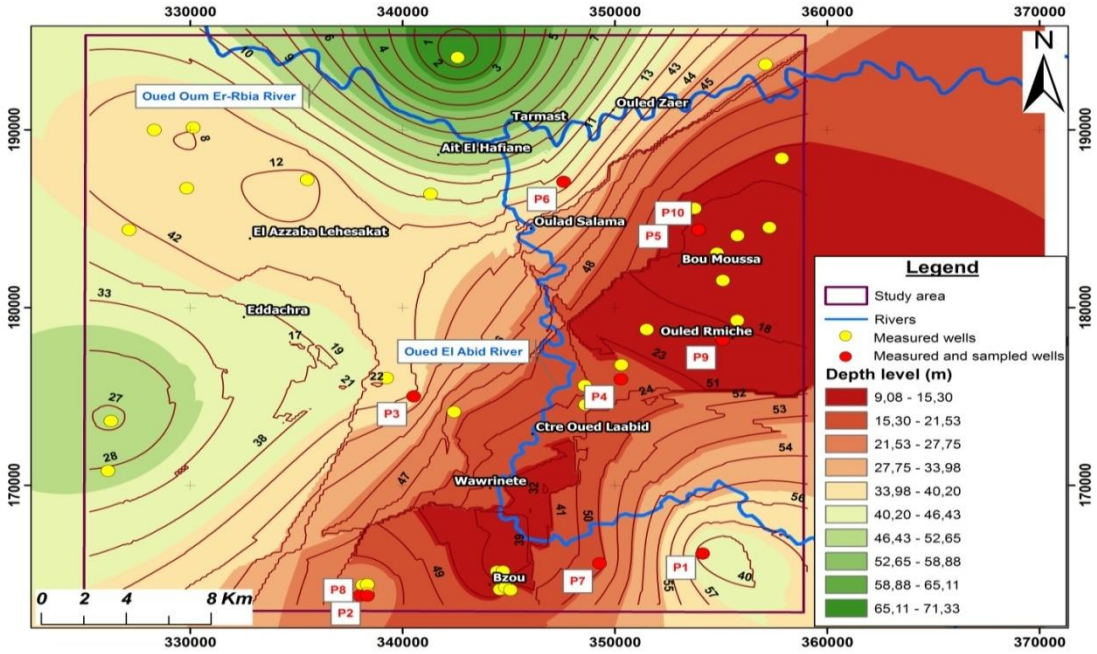

Figure 6: Depth variation of groundwater in the study area

5. Discussion

The laboratory results indicate that the eastern part of Oued El Abid River displays pollutions in its water quality caused by high concentration of mineral salt. This is expressed by high level of electrical conductivity at the wells P4, P5, P6, P9 and P10. The high levels could be explained in a way that groundwater flows through geological formations of Liasic to Plio-Quaternary age (**Figure 2**), of lacustrine origin and are rich in evaporates [28], [29]. In the study area, the evaporate -bearing formations are generally composed of gypsum, which is easily diluted in water contact [30]. The high concentration of chlorine and slight concentration of nitrate could be explained by the returning of irrigation water rich in fertilizers to the shallow aquifer due to high aquifer transmissivity in Beni Moussa irrigated perimeter [26], [31], [32]. These fertilizers are generally used in the right bank of the El Abid River (**Figure 1**), to increase beet yield and wheat production, which represent the major part of the main agricultural activities in this area [33].

Concerning the groundwater flow direction, as several studies done in Beni Moussa irrigated perimeter shows, it takes place towards the South West, going to Oued El Abid River [34], [26], [35]. This Flow direction coupled with high transmissivity in the study area can lead to drainage of the loaded waters with the different pollutants to the river.

In bacteriological point of view, we analyze the indicators of pollution parameters which include Total Coliforms, Fecal Coliforms, and Fecal Streptococci, these three parameters allow us to define the pollution origin which is related to the quantitative ratio of Fecal Coliforms on Fecal Streptococci (CF / SF). When this CF / SF ratio is greater than 4, the pollution is essentially human (discharge of the waste water) [36], and origin animal when it is less than 0.7 [37]. For our case, the pollution is related to human activity (sampled point P1) near Bzou city, in which people use much degraded septic tanks [38], while in the other sites, the pollutions are related to animals, due to agricultural and livestock activities.

By comparing the various parameters measured at wells with those taken in Oued El Abid River, it is observed that starting from sampled point R2, there is a correlation between the high levels of chemical parameters among the river and groundwater (**Table 1, 2**). Therefore, it might be said that the Oued El Abid River drains the Beni Moussa groundwater and eventually becomes polluted also. In addition to that, the liquid discharges from degraded septic tanks of Bzou center imports its bacterial pollution to groundwater and subsequently Oued El Abid River.

Conclusions

The results obtained in this study show that the source of pollution in Oued El Abid surface waters is strongly linked to the exchange river aquifer that is revealed in the direction of Oued El Abid River, which drains the groundwater from Beni Moussa shallow aquifer. These underground waters were analyzed in the laboratory, and it was found that they are degraded by the anthropogenic activities of the neighboring river agglomeration.

Those agglomerations are using fertilizers to increase the yield of their agricultural products and well degraded septic tanks which infiltrate wastewater into groundwater. These two parameters are the main source of anthropogenic pollution in the study area. Natural degradation also affects the water quality of Oued El Abid River; this is observed in the study area with the high concentration of mineral salts resulting from geological origin and lead to high electrical conductivity values.
However, the aim of our study is to determine the reasons behind Oued El Abid downstream course water quality deterioration is achieved, to this effect, it is necessary to react preserving this vital source against the main sources of anthropogenic pollutions, which will lead to a deterioration that will be much worse if it is not stopped at the moment.

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