

## DOES THE EXPLOITATION OF THE DAMOUS WADI AQUIFER MAKE IT VULNERABLE TO MARINE INTRUSION?

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### ABSTRACT

The Damous wadi aquifer in the coastal city of Tipaza in Algeria provides the town of Damous with potable water as well as the irrigation of the crops grown in the valley.

In order to see the effect of this exploitation on the level of the water table, we measured during five campaigns the depth at which the water is found in seven wells. Four of these wells are located near the sea, one far from it and two intermediate wells. We also measured other parameters such as a conductivity and the level of chlorides in the water from these wells to see if the groundwater is polluted by seawater.

The results obtained showed that the water is 3 m or 4 m away except for the well farthest from the sea where the water is more than 6 m away. For wells close to the sea, the conductivity reaches for some 3000  $\mu\text{S}/\text{cm}$  and the chlorides concentration 300 mg/l. These results remain consistent with Algerian standards. The Damous wadi aquifer seems to resist the marine intrusion to which it is sometimes subject thanks to the good rainfall and the releases from the Kef Eddir dam from which it benefits.

**Keywords:** Chlorides; Conductivity; Damous wadi aquifer; Depth, Marine intrusion.

## 1 INTRODUCTION

Groundwater represents approximately 97% of total liquid continental freshwater, it is used by 75 % to 90 % of the world's population [1] and by 2025, 3.5 billion people humans will live in watersheds where water is scarce [2]. In view of these figures, the preservation of this water and its quality is a necessity. However, this natural resource is overexploited throughout the world, and subject to various types of pollution which degrade its water.

In November 1939, north of Munich (Germany), 4,000 litres of gasoline leaked and polluted the water, while in 1956 in Winterthur (Switzerland), the water from a well revealed a high content of fuel oil to the flow and infiltration of 120 m<sup>3</sup> of the latter [3]. In the United States, according to the Environmental Protection Agency (EPA), the main threat to water quality is diffuse pollution which comes from soil leaching, industrial waste and erosion of agricultural land [4]. In 2014, France was the second country using phytosanitary products in Europe and its aquatic environments in areas of large crops, arboriculture and viticulture recorded the highest levels of pesticides [5]. Groundwater in the Hahoté-Kpogamé phosphate mining area in Togo recorded levels of 24.74  $\mu\text{g}/\text{l}$  of cadmium and 258.9  $\mu\text{g}/\text{l}$  of lead. These contents are higher than the OMS standards for potable water [6].

The bacteriological quality of groundwater can also be altered. This is the case of the waters of the plio-quaternary aquifer in the Meknes region of Morocco [7]. The groundwater of Ouled Driss in Algeria records lead and sodium levels exceeding Algerian potable standards and presents germs indicative of bacteriological pollution [8]. The groundwater of El Harrouch in Skikda in Algeria presents chemical and bacteriological pollution [9].

The overexploitation of underground resources causes their water levels to drop. In fact, the Ogallala aquifer in the United States experienced a lowering of 30 m following withdrawals to meet the irrigation needs of the region [2]. In 1979, the water table fell by 114 m under Milwaukee and 274 m under Chicago [2]. In Mexico, of the 459 aquifers identified, it has been established that 130 are in a situation of overexploitation [2]. In France, in 2012, the Beauce water table experienced an exceptional drop in its level in the Blésois region after around ten years of rainfall deficit and significant withdrawals for irrigation [10].

When it comes to coastal aquifers, lowering the water level can cause the phenomenon of marine intrusion. In the United States, this phenomenon is a concern along the Atlantic coast, from Cape Cod to Miami [2]. The excessive withdrawal in the Aquitaine basin in France since the years 1950 threatens this last of marine intrusion following the drop in its level below that of the sea [11]. The increase in the population of the Niger Delta increases the problem of shortage of drinking water. Excessive pumping of groundwater contaminates this resource through the introduction of seawater [12]. The Teboulba aquifer of the Tunisian Sahel also sees its waters polluted by seawater following its overexploitation [13].

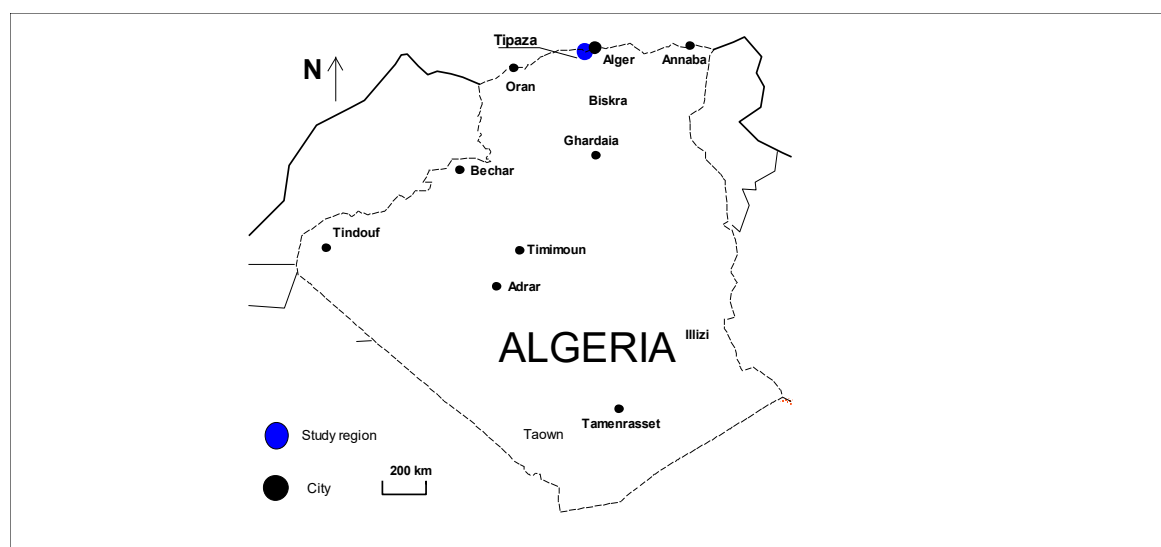
The problem of marine intrusion is now reported along the Algerian coast. The water tables of the plains wadi Nador, wadi Mazafran and the region of Bordj El Bahri are affected [14], while for the Mitidja plain this phenomenon has been reported for years 1980 with salinity which increases significantly as we approach the sea [15]. The regions of Skikda, Oran and Annaba respectively record salinities of 5 g/l [16], 3 g/l [17], 4 g/l [18]. While the conductivity of groundwater in the Tipaza city reached 9000  $\mu\text{S}/\text{cm}$  in 1995 [19] [20] [21]. In 2012, a study showed that the piezometric level of the Nador aquifer is at an altitude of 0. This makes it very sensitive to marine intrusion and is reflected by a conductivity which exceeds 2500  $\mu\text{S}/\text{cm}$  [22].

The coastal aquifer of wadi Damous located in the city of Tipaza, which supplies the town of Damous with potable and through which crops are irrigated, may be subject to overexploitation which can lower its water level and therefore make it vulnerable to marine intrusion which will degrade its quality. During five measurement campaigns and thanks to the wells of seven farmers located along Damous's wadi, we monitored its level and measured the temperature, TDS (total dissolved solids) and conductivity. We also took samples to analyse the level of chlorides in the water which are a good indicator of seawater pollution.

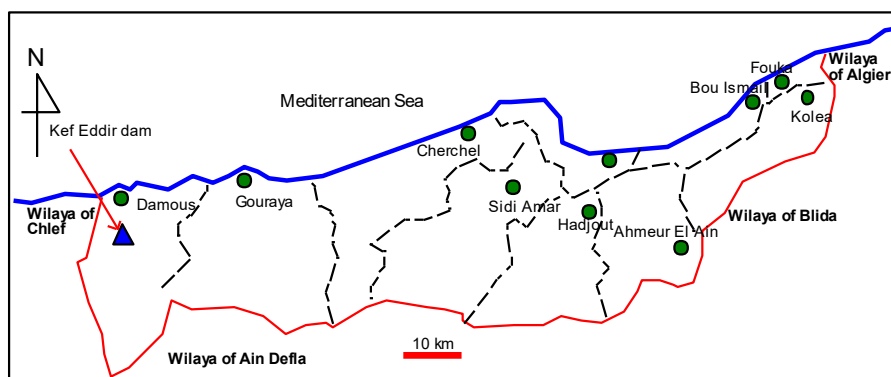
## 2 STUDY REGION AND METHODOLOGY

### 2.1 Study region

Damous, located 145 km east of Algiers, is a town in the wilaya of Tipaza. It is an agricultural and coastal town (Fig.1 and 2) [23]. Damous is a town with an area of 7458 ha and coordinates  $36^{\circ}32'56''$  north and  $1^{\circ}42'20''$  east. The relief is mountainous with an altitude of 0 at sea level and 909 m to the south of the town [24].



*Figure 1. Situation of the wilaya of Tipaza*



**Figure 2.** The town of Damous

The wilaya of Tipaza has a mediterranean climate. Between May and September, the hot season extends, while the rainy season is between October and May. The average annual precipitations are 567.30 mm and the average annual temperature is 17° C [25].

The geomorphology of northern Algeria is dominated by steeply sloped reliefs and an essentially marly lithologic with little or no permeability, which puts it at a disadvantage in terms of groundwater except for the large plio-quaternary alluvial plains [26]. These formations cover the alluvial terraces of the main wadis of Tipaza (Mazafran, El Hachem, Nador, Messelmoune and Damous).

The Damous wadi takes its source in the mountain ranges of the Atlas Tellien and flows into the Mediterranean Sea. It is located in the Cheliff-Zahrez hydrographic basin with a length of 43 km. Its watershed is 482 km<sup>2</sup> and an average slope of 2% [27].

The alluvial deposits of the Damous wadi aquifer, made up of shale clays, sandy gravels and pebbles, constitute an interesting aquifer, particularly at the mouth of the wadi [24] [25]. The replenishment of the Damous wadi aquifer is very important because it allows the supply of the locality with potable water as well as the irrigation of the different crops on the banks of the watercourse.

## 2.2 Methodology

On the watercourse of Damous' wadi, there is significant agricultural activity. Thanks to traditional wells (with a depth of 12 to 15 meters according to farmers) equipped with pumps, irrigation is ensured (Fig. 3 and 4). This exploitation of the aquifer can lower its level and make it vulnerable to marine intrusion. It should be noted that when farmers suspect seawater pollution to their wells, they avoid irrigating with this water.



*Figure 3. Irrigation by the Damous wadi aquifer*



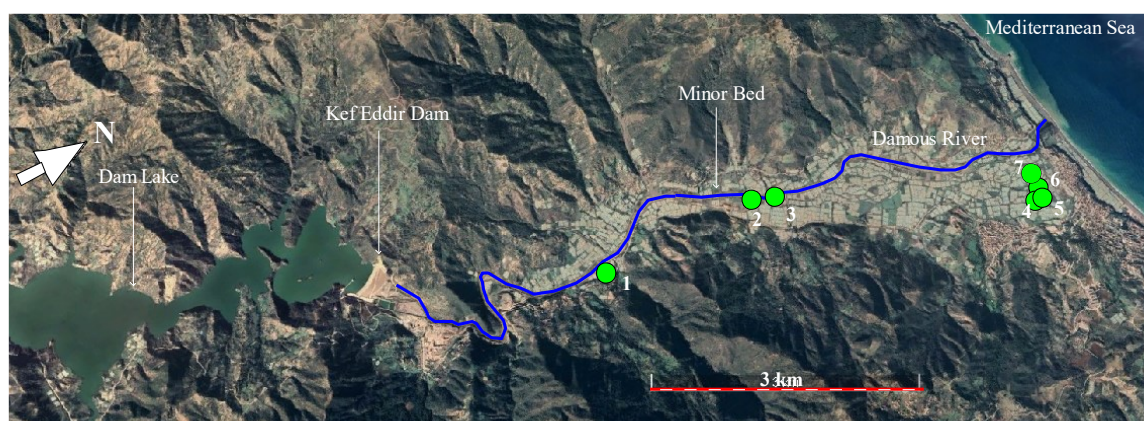
*Figure 4. Well equipped with pumps*

In this work, we monitored the level of groundwater in seven wells during five campaigns (February 7th, March 11th, May 6th, July 18th and September 16th) using a light probe (KL 010 TMC) which also allows us to measure temperature, TDS and conductivity in-situ (Fig. 5).



*Figure 5. In-situ measurements*

Figure 6 shows the seven wells affected by the measurements: one well far from the sea, four wells near it and two intermediate wells. Table 1 gives the distances of these wells in relation to the sea and in relation to the watercourse.



*Figure 6. Location of wells*

*Table 1. Position of wells in relation to the sea and the watercourse*

Wells	P1	P2	P3	P4	P5	P6	P7
Distance from the sea (km)	6.96	4.82	4.28	1.07	0.86	0.86	0.75
Distance from the watercourse (m)	210	160	107	750	750	535	321

Chlorides are good indicators of pollution by seawater. Samples to analyse their concentration were taken during these campaigns. The analyses are carried out by the laboratory of the national water resources agency (ANRH) by volumetry.

For the months of July and September, we were unable to take measurements of well 7 following the farmer's refusal.

### 3 RESULTS AND DISCUSSION

Among the parameters measured in-situ, we have the temperature. Table 2 gives the values in degrees Celsius.

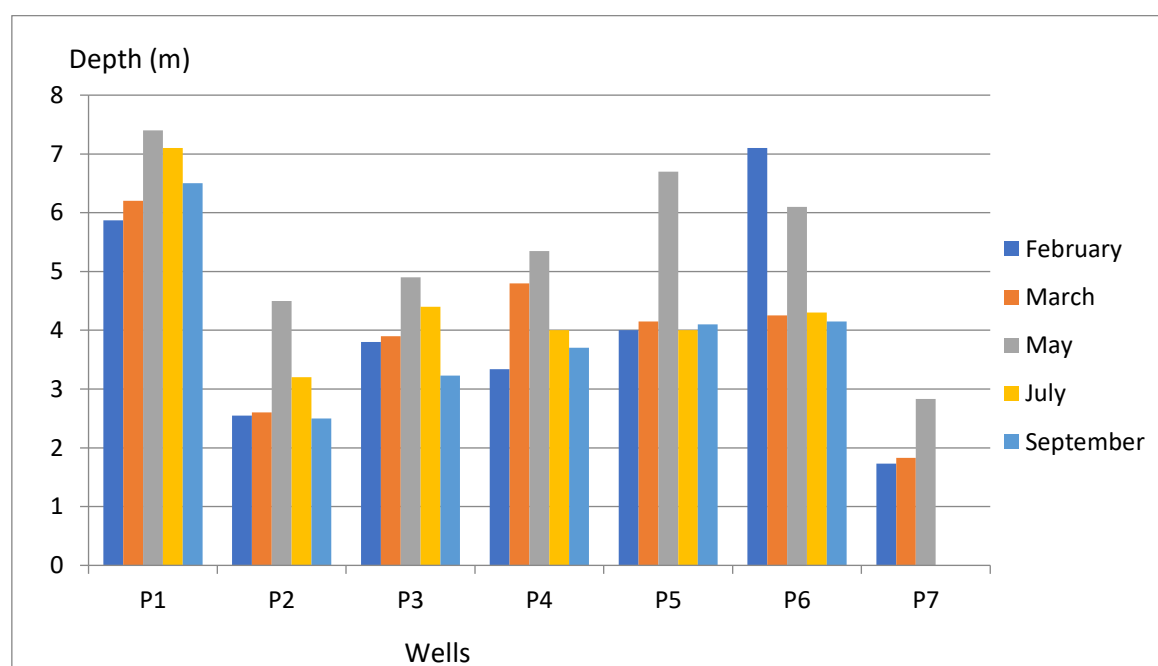
*Table 2. Well water temperatures*

	P1	P2	P3	P4	P5	P6	P7
February	19.4	19.8	19.5	19.8	19.7	18.5	20.5
March	19.6	20.4	19.6	20.4	19.8	20.2	20.3
May	19.7	21.1	19.1	20	19.8	20.3	20.2
July	19.7	23.7	26.2	20.3	20.1	21.6	
September	19.7	26.3	25.5	20.5	20.5	21.6	

With the exception of three measurements recorded in summer, in the months of July and September for well 3, and month of September for well 2, the temperatures recorded are below 25° C and therefore comply with Algerian standards for underground waters.

For the same month, we note that the temperature variations between the wells can reach 6.5 °C (the month of July, between wells 1 and 3), while for the same well, a variation of 7.1° C is recorded between May and July for well 3.

Figure 7 represents the depth at which water is found in the wells during the different campaigns. The Damous watercourse is a wadi and the flow is intermittent. But during our campaigns, a flow of 20 cm is observed (Fig. 8). It should be noted that the February and March measurements followed a rainy period in the Damous region. During the months of May, June and July, the flow is due to the releases of the kef Eddir dam built across the river. The water level is approximately the same in five out of seven wells (1, 2, 3, 5 and 7). The water level at well 4 between these two months fell by 1.5 m, while at well 6, the water table level increased by 3 m. Measurements of May show, depending on the wells, that the water table level has fallen 0.5m to 2.5 m. But during the month of July, the water levels improve for all the wells particularly for wells 4, 5 and 6 which gain between 1.3 m and 2.7 m. Depending on the wells, stability or even an improvement in the water level is still observed for the September measurements. For this period of measurements (the five campaigns), water is found for all wells at depths which do not exceed 4m except for well 1, where water is found at a depth which exceeds 6 m.

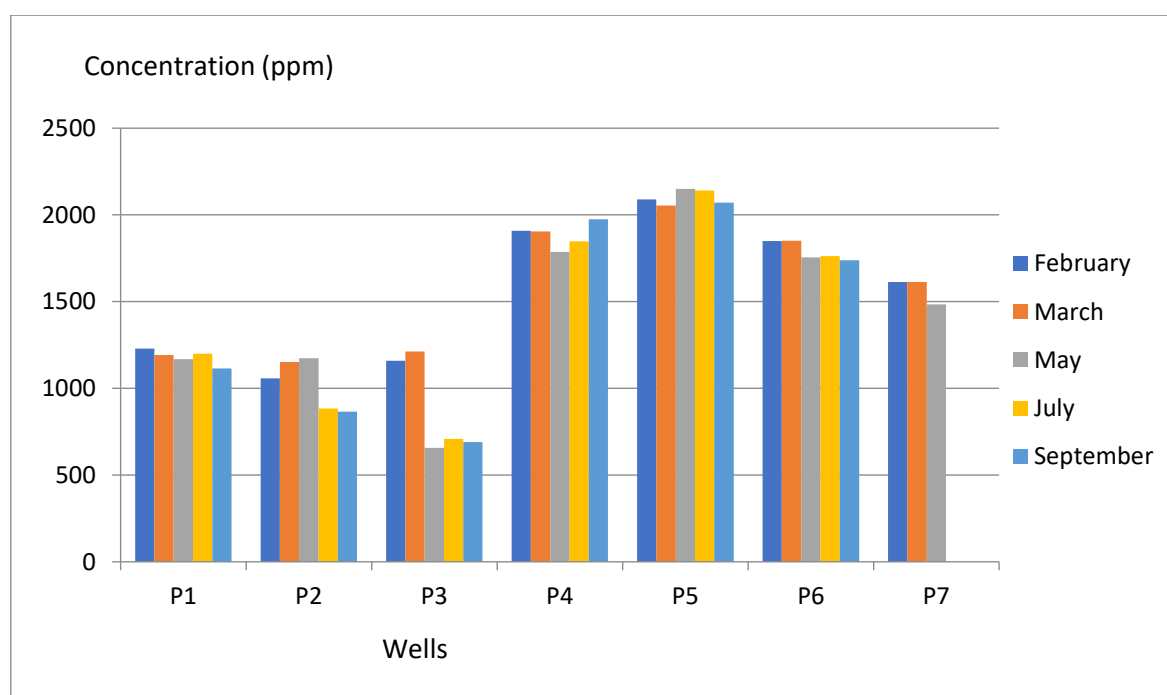


*Figure 7. Water depth in well*



**Figure 8.** *The flow in the bed of the wadi*

In Figures 9 and 10 which represent the variation in concentration and conductivity in the wells, we see that wells located near the sea record the highest concentrations and therefore also highest conductivities. While the conductivity of the water of the wadi is  $1020 \mu\text{S}/\text{cm}$ , the conductivity of the water from these wells varies between  $2200 \mu\text{S}/\text{cm}$  and  $3200 \mu\text{S}/\text{cm}$  at  $25^\circ \text{C}$  and does not vary much over time. These measures meet Algerian potable water and irrigation standards ( $2800 \mu\text{S}/\text{cm}$  for potable water and  $3000 \mu\text{S}/\text{cm}$  for irrigation water at  $20^\circ \text{C}$  [28]). The conductivity for the other three wells is less than  $2000 \mu\text{S}/\text{cm}$ . We also note that the conductivity does not vary much over time except for well 3 where a drop of  $800 \mu\text{S}/\text{cm}$  is noted, and well 2 where it drops by  $500 \mu\text{S}/\text{cm}$ .



**Figure 9.** *Concentration in wells water*

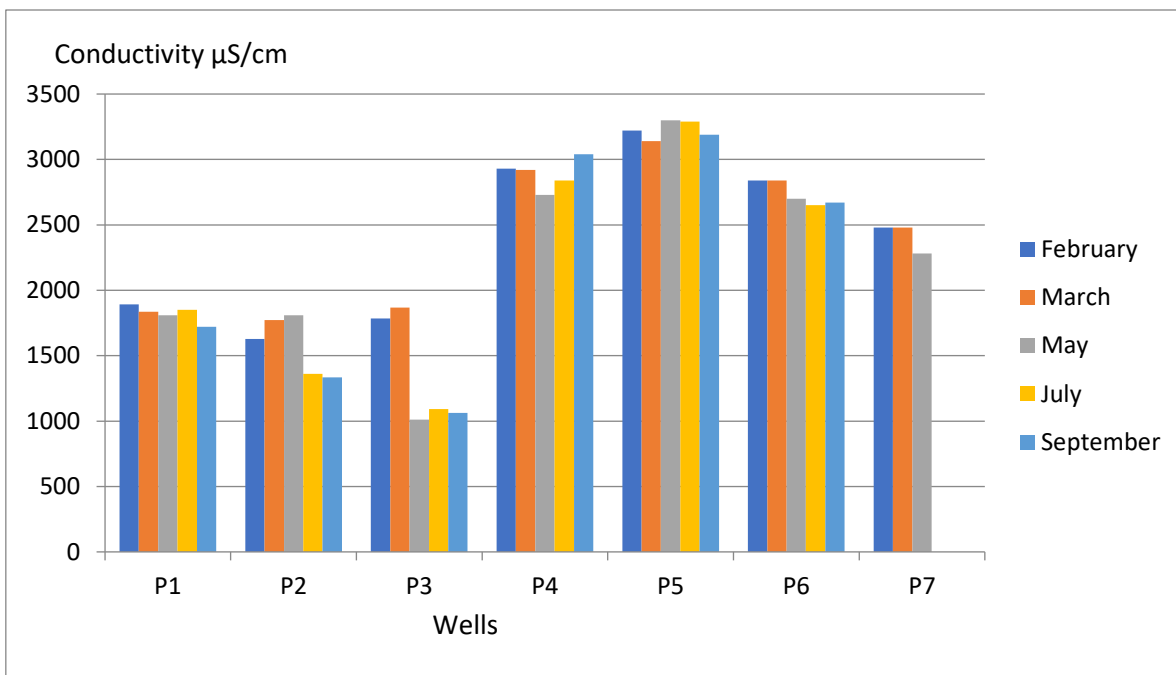


Figure 10. Conductivity of wells water

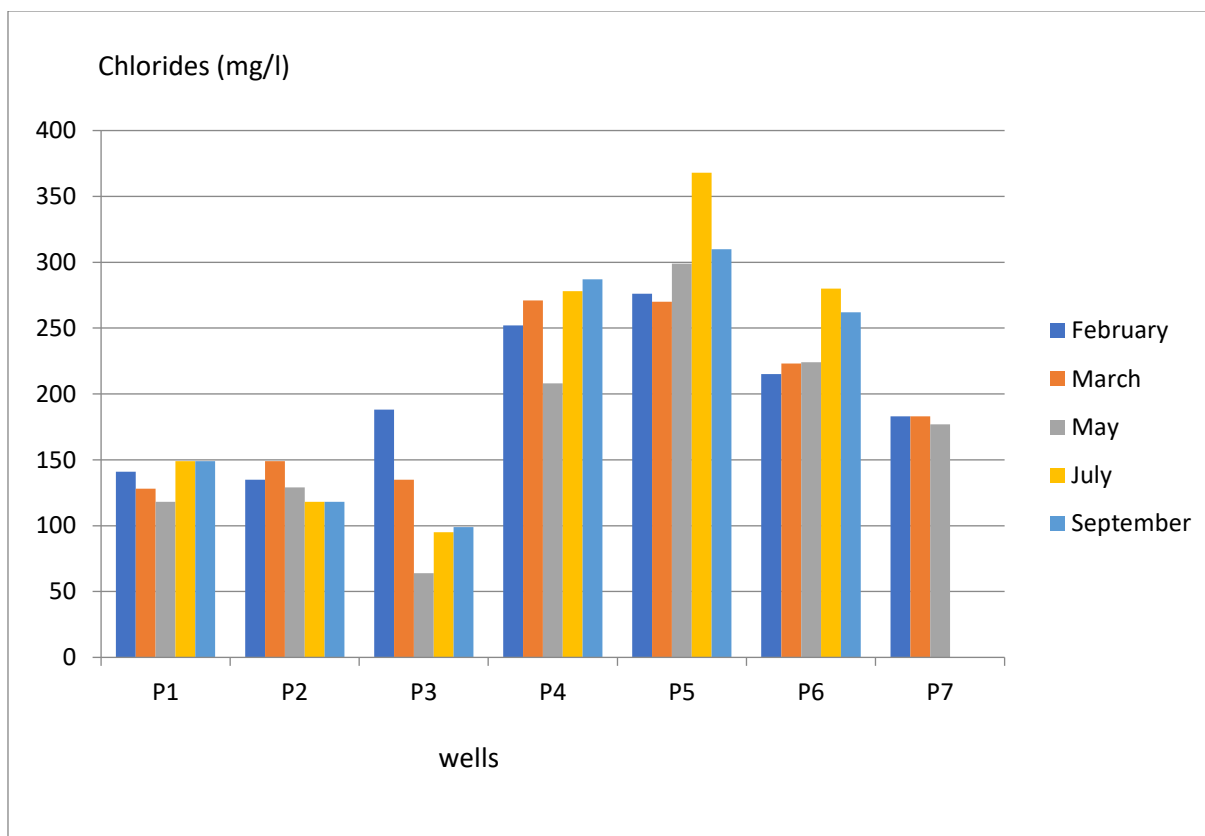


Figure 11. Chlorides levels in wells water

In Figure 11 representing the variation of concentration of chlorides over time, the chlorides level recorded for all the wells does not exceed the 500 mg/l recommended by Algerian standards [28]. As for conductivity, wells closest

to the sea record the highest rates with values between 180 and 370 mg/l. We also note that the chlorides level in wells 6 and 7, relatively close to the watercourse, is slightly lower than in wells 4 and 5. For other wells, chlorides do not exceed 200 mg/l. For wells 3, 4, 5 and 6, we note sometimes significant variations in the level of chlorides in the water.

During our discussions with farmers in the region, they told us about marine intrusion, particularly for wells close to the sea. But the chlorides concentration found can be naturally present in groundwater. The fact that these concentrations are great for wells close to the sea may indicate a marine intrusion which is not very advanced in the water table and not established over time. The releases of the Kef Eddir dam, particularly in summer, allow this aquifer to be recharged until 2 m [23] and the marine level is therefore pushed back.

## 4 CONCLUSION

Groundwater is in high demand and often subject to various types of pollution. Marine intrusion is a phenomenon that affects coastal groundwater. It manifests itself when the level of the water table drops and is therefore linked to its overexploitation.

The Damous wadi water table boarded by the sea allows irrigation and the supply of potable water to the inhabitants of the town of Damous. This situation can cause its level to drop and sea water risks polluting its water.

In this present work, the level of the Damous wadi water table was monitored. We also measured the conductivity and the level of chlorides in the water from wells located along the wadi in order to see if it is overexploited and polluted by sea water.

The measurements of the depths at which the water is found give acceptable values below 4m for six of seven wells, and one well where the water is beyond 6 m throughout the measurement period.

For the four wells located near the sea, the conductivity and the level of chlorides in the water are relatively high. Between 2500  $\mu\text{S}/\text{cm}$  and 3000  $\mu\text{S}/\text{cm}$  for the conductivity and greater than 200 mg/l for the chlorides. But these values remain consistent with Algerian standards.

Although heavily exploited for irrigation and potable water supply, the level of the Damous wadi aquifer is at an acceptable level. Naturally through good rainfall or artificially thanks to the releases of the Kef Eddir dam from which it benefits, the water table recharges. This situation allows it to resist the phenomenon of marine intrusion to which it is sometimes subject.

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