Phreatic aquifer water upwelling: causes, consequences and remedies

Răsuflarea apelor acvifere freatice: cauze, consecințe și remedii

Alia Basma ABBA[1], Asma ABBAS[1], Oum Elkheir BACHI[2], Sofiane SAGGAÏ[1]

[1]Laboratory of water and environment engineering in Saharan milieu (GEEMS). University KASDI Merbah, 30000 Ouargla, Algeria.
sofianeaero@yahoo.fr , saggai.so@univ-ouargla.dz,
[2]Laboratory of Saharan Bio-Resource(BRS): Preservation and Valorization. University KASDI Merbah, 30000 Ouargla, Algeria

Abstract. *Ouargla has suffered a lot from water upwelling that has affected negatively human and environment. The present paper consists in presenting the quality of phreatic aquifer water, exposing the causes of water upwelling, consequences of the rise of water level over the surface ground and impacts of the mega project of fight against the water upwelling that has been realized between the end of 2006 and 2009.*
Obtained results from the comparison between stats of phreatic aquifer before and after works have shown that there were a positive impacts in the Ouargla city center: downwelling of phreatic aquifer water, reduction in salt concentration and elimination of nitrate nitrogen.

Key words: phreatic aquifer, water upwelling, mega project, impacts, Ouargla.

DOI: 10.37789/rjce.2021.12.3.4

1. Introduction

Increase in water demand in Algerian Sahara has led to recourse more and more to the exploitation of groundwater. This has entailed an important increase in exploited water flows, as much in new agriculture perimeters as in traditional palms groves, associated, especially, with a use often badly reasoned of water resources, which has led to important wasting, revealing appreciable amounts of water surplus.

Ouargla constitutes a typical case in which overexploitation of groundwater, deteriorated by an absence of an effective device of management of these resources downstream, has led to appearance of enormous quantities of water surplus that made this oasis a sick basin of too much water.

2. Study area

Ouargla is one of main oases of Algerian Sahara, It is situated at a distance of 800 km from the capital Algiers (31° N, 005° E). It is installed in a basin, which constitutes an outcome of hydrographic course of oued M'ya and it presents a morphological context favorable to water stagnation.

For its climate, Ouargla is situated in zone with extreme climatic conditions. It is characterized by clearly marked aridity and an almost permanent drought.

The average annual temperature, measured over the period 200-2012, is 23.4 °C, maxima average and minima average are of 44.8°C and 2.8°C, respectively, during July and January, the average annual thermal amplitude is thus of about 42°C. For precipitation, the average annual, during the same period, is 56.7 mm.

In Ouargla, as for all Algerian Sahara, water used in different sectors is an underground water. Besides the phreatic aquifer, there are two large sets of water-bearing formations well known: continental intercalaire (CI) and complexe terminal (CT).

The phreatic aquifer water is characterized by a high total mineralization that exceed, sometimes, 6g/l. water of the CI and the CT are of mediocre quality; their measured values of electric conductivity indicate a high mineralization because they are globally more than 1 mS/cm. furthermore, they correspond to values of total mineralization exceeding world health organization (WHO) standards (1.5 g/l) [1]. For water temperature of different aquifers, measured values indicate: about 20°C for phreatic aquifer, between 25°C and 29°C for the CT and more than 55°C for the CI [2].

3. Causes of water upwelling

The problem of phreatic aquifer water upwelling is of an unbalance between brought volume of water and that evacuated. According to Côte [3], in traditional system, mobilized water, coming from wadis and phreatic aquifer, is discharged in cesspools after domestic use and in spraying areas after agricultural use. Non-evaporated part percolates and joins the phreatic aquifer. Between brought volume of water and that evacuated a balance becomes established on long term and water level in the phreatic aquifer remains stable.

According to the same author, appeal to big aquifers, because of the increase in water demand, generates an unbalance. Strong flows introduced into circuit of water use are at origin of strong volumes of wastewater that do not return to deep aquifers (CI and CT), neither are they evacuated outside of hydraulic pond (morphological context favorable to the stagnation of water). They will, unfortunately, join phreatic aquifer, which they swell of so much.

When water brought coming from the depth (large aquifers) is powerful and continuous in time, water level in the phreatic aquifer rises, eventually close to ground surface. There are cases when phreatic water appears on ground surface, reveling an ecological imbalance.

4. Consequences of water upwelling

Water of phreatic aquifer in Ouargla are of bad quality. By referring to made studies, phreatic aquifer water is of alkaline character (pH>7) [4], with an electric conductivity of more than 1000 µS/cm and which reaches sometimes 6000 µS/cm and more, either of a total mineralization exceeding WHO standards (1500 mg/l). According to WHO standards of water drinkability, total water hardness of phreatic aquifer water in Ouargla exceeds 54°F, which shows that this water is very hard. Chemical facies of water samples of phreatic aquifer show that water is sodium and potassium chloride [4].

Concerning pollution parameters, analyses of water samples have shown that nitrate nitrogen concentrations are very high (10 to 114 mg/l). Same remarks have been done for orthophosphate with concentration of more than 1 mg/l. These high concentrations are caused by the discharged wastewater that join the phreatic aquifer. Therefore, for concluding, we can say that water of phreatic aquifer is salted and polluted.

This phreatic aquifer water quality has negative effects on soil, plants, constructions environment, etc…

According to El Fergougui and Boutoutaou [5] and El Fergougui et al. [6], in Ouargla water level in phreatic aquifer is close to ground surface (0-1.5 m). In the presence of very severe climatic conditions, evaporation process from phreatic aquifer contributes, largely, to the salinization of soil and its degradation [5, 6, 7]. The degradation of soil affects crops and plants, especially palm groves [8].

Saltwater, very close to ground surface or which appears on ground surface, affects rhizosphere what is going, possibly, to kill crops and plants.

Concerning constructions and according to Saggaî et al [9], water upwelling, because of the bad quality, affects negatively constructions (buildings, roads, etc…). For sulfate, majority of registered values were between 446 and63280 mg /l, which means that this water was of high aggressiveness for constructions if we refer to standards [10]. Concerning chlorine, values were between 655 and 169797 mg/l, these values exceed tolerated values [11], and by consequence a fatal effect on constructions. Finally, for magnesium, values of the analyzed water were altogether superior to the value recommended by specialists (> 3000 mg / l) [10]; what involves that this water represents a risk for the constructions.

For environmental effects, water upwelling has created zones of stagnation of polluted water which does not stop emitting bad smells. These milieus represent a danger for population, in particular children, and are favorable for genesis of insects, in particular mosquitoes.

5. The fight against the water upwelling

5.1. Mega-project of fight against the water upwelling

To remedy to these problems of water upwelling, Algerian authorities launched a mega-project of fight against this phenomenon.

Realization of this project was confided to national and international companies. It has as objectives:

- Realization of sewerage network of 104 Km length;
- Construction of 26 stations (16 pumping stations and 10 Lifting stations);
- Construction of 03 wastewater treatment stations of: 400 000 population equivalent (PE.) in Said Otba location (aerated lagoon process), 11 000 PE in N'Goussa location (reed bed filtration)and 10 000 PE in Sidi Khouiled location (aerated lagoon);
- Realization of water transfer channel of 39.5 Km;
- Construction of pumping station of drainage water (400 l/s); and
- Realization of drainage network of 77 Km.

The mega-project has started on 2006 and was completed on 2009. Management of different structures is insured by National Office of Sanitation (NOS).

5.2. Effects of Mega-project

To know effects of mega-project, we have made a comparison between states of phreatic aquifer before and after realization of different works.

The main factor that we have evaluated is the piezometer level (water level in phreatic aquifer). For that, we have taken 12 piezometers in Ouargla region (see figure 1).

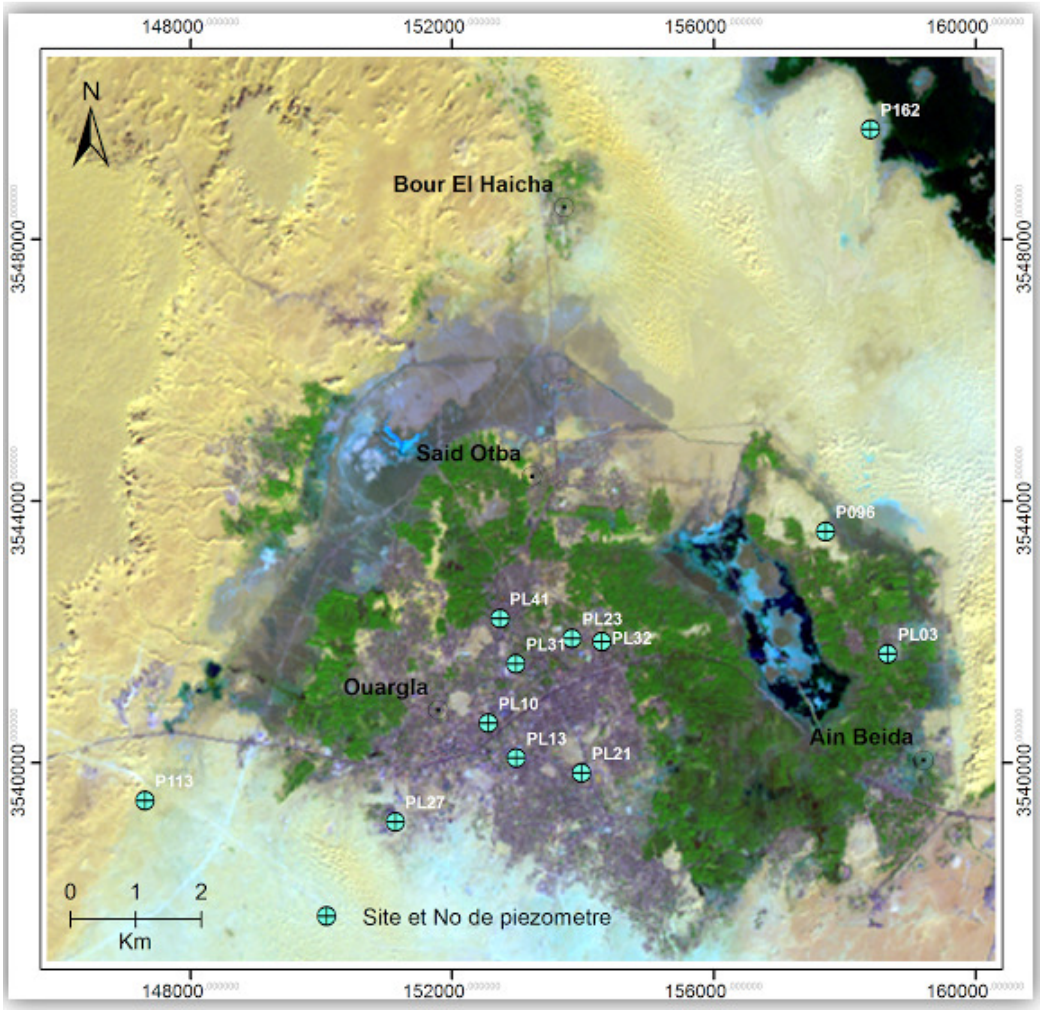

Fig.. 1. Position of Piezometers

Figure 2 shows natural terrain ratings. It is well seeing that when going from SE to NW for a distance of more than 24 Km, elevation of ground becomes higher.

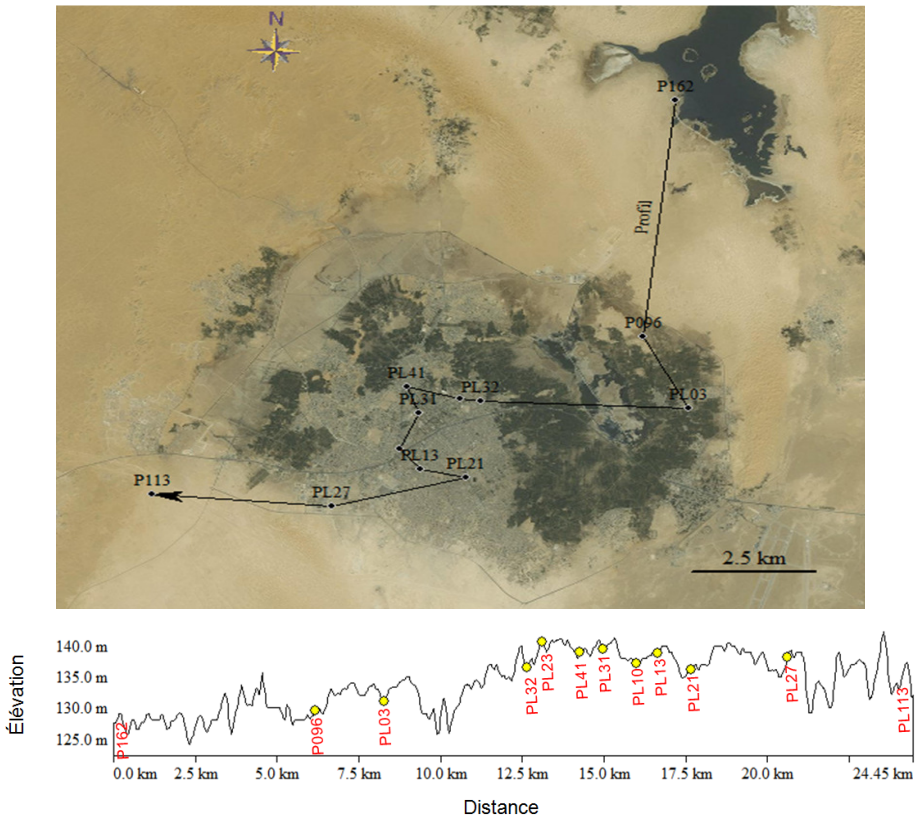

Fig.. 2. Altitude of different piezometers

For checking variation of phreatic aquifer water level, we have measured water level in piezometers during 2006 and 2014 and used surfer software to draw piezometric maps. Figures 3 and 4 present the obteined piezometric maps.

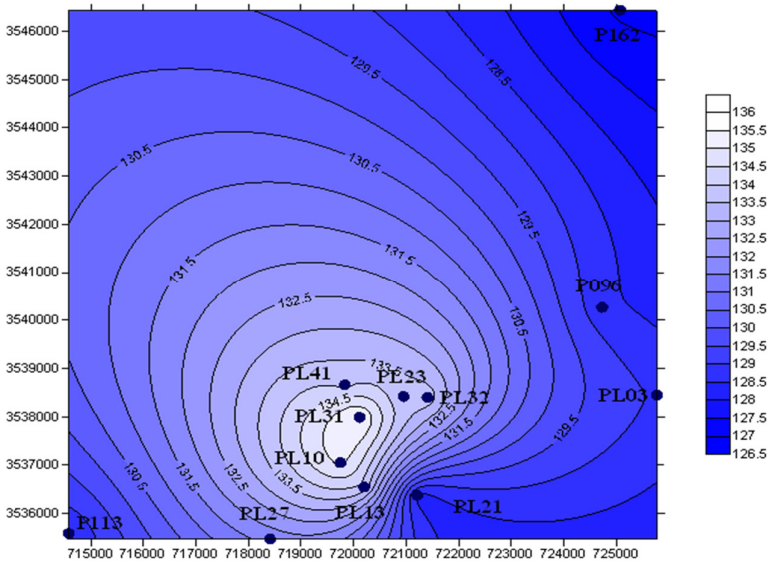

Fig. 3. Phreatic aquifer water level on 2006

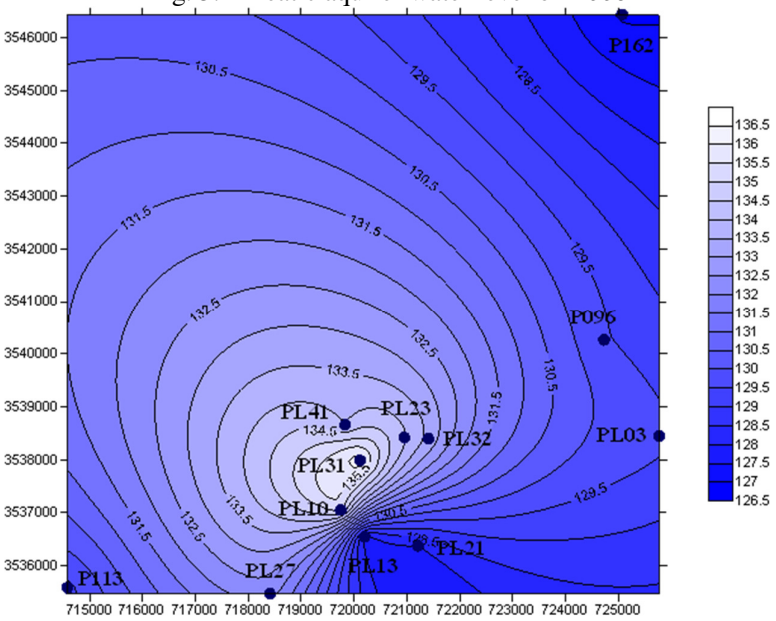

Fig. 4. Phreatic aquifer water level on 2014

We have represented also the phreatic aquifer water depths on 2006 and on 2014 by histograms (See figure 5).

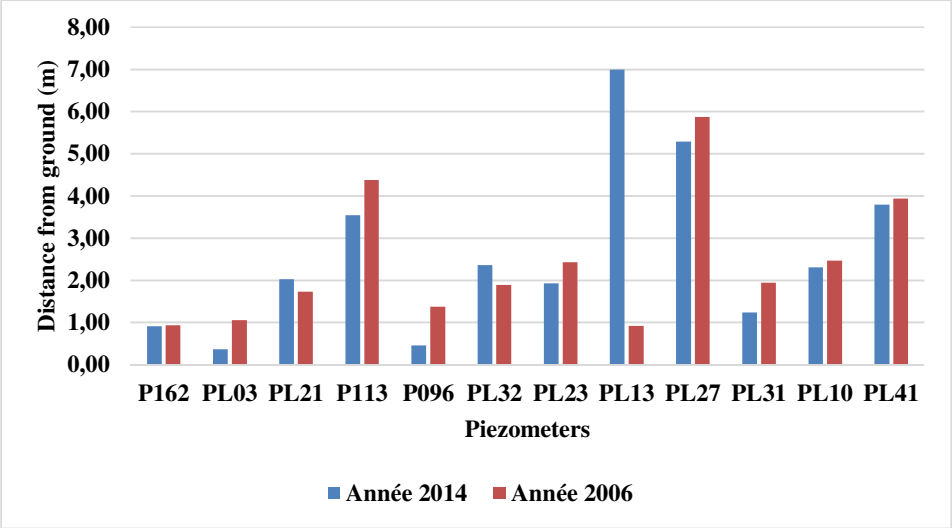

Fig. 5. The phreatic aquifer water depths

From figures (3, 4 and 5), it is well seeing that there were water downwelling in Ouargla city center (PL13, PL21 and PL32). However, in other points (piezometers) water level rises or remains stable.

Concerning phreatic aquifer water quality, we have analyzed two parameters: electric conductivity (EC) and nitrate nitrogen (NO3) concentration. Obtained results have shown an increase in EC on 2014 compared to that of 2006. For the NO3 results have indicated a significant decrease of concentration: 37.42 mg/l on 2006 and 1.56 mg/l on 2014.

6. General discussion

The comparison between the stat of phreatic aquifer before and after the mega-project intended to fight against the water upwelling by wastewater discharge has shown that:

Concerning the water level in the phreatic aquifer, we have remarked a water downwelling in Ouargla city center (piezometers PL13, PL21 and PL32). However, in palm groves and agricultural perimeters, there is a light increase of water level in the phreatic aquifer.

The water downwelling in Ouargla city center resulted from the good sewage disposal by the new installations (new sewage network). For other zones (palm groves and agricultural perimeters), the increase of water level is resulted from the continuous pumping from the deep aquifers (CT and CI) by realizing of new water drillings which

are mostly illegal. Therefore, the overexploitation of groundwater generates an important supply of the phreatic aquifer and by consequence a water upwelling.

For the water quality of phreatic aquifer, the EC and by consequence, the global mineralization has slightly increased (an average of 35 mS/cm on 2006 and of 37 mS/cm on 2014). However, this trend was not observed in the city center where this EC has decreased (an average of 10.33 mS/cm on 2006 and an average of 9.07 mS/cm on 2014). Origin of this general increase in EC, noticed particularly in palm groves and agricultural perimeters, is the quality of water used for irrigation and that comes from deep aquifers (saltwater).

Concerning nitrate nitrogen which is taken as an indicator of water pollution degrees, obtained results have shown that the mega-project has had reduced significantly the concentration of this pollution parameter (37 mg/l on 2006 and 1.5 mg/l on 2014). In Ouargla city center (piezometers PL13. PL21 and PL32), the nitrate nitrogen concentration was 0 mg/l on 2014 which means that the mega project has manages to end the problem of the pollution of the phreatic aquifer by the transfer wastewater towards a wastewater treatment station and discharging it in a release.

7. Conclusion

The water upwelling in Ouargla is a phenomenon that has affected negatively humans and environment because of its quality (salty and polluted). The necessity of water downwelling is requested to preserve the human health, the environment and even buildings. The Mega-project of fight against the water upwelling was come to resolute this problem and results of comparison between the stats before and after realization of works have shown that there is a positive impact in the Ouargla city-center: decrease in water level, decrease in salt concentrations and absence on pollution elements (nitrates nitrogen). Out of Ouargla town, except the nitrates nitrogen concentration which has not reduced, all other parameters (salinity and phreatic aquifer water level) have remained stable or increased just little. To conclude, we can say that the project has positively contributed on water downwelling and by analyzing the situation, the water upwelling and the water salinity out of Ouargla town is caused by the pumping of water from deep aquifers (CI and CT).

Acknowledgement

Authors would like to thank all staff of National Agency of Hydric Resources (ANRH) especially Mr. BENHEMIDA Slimane.

References

[1] WHO; International Standards for Drinking Water; World Health Organization; Geneva, 1972.

[2] W.Chaib, N. Bouchahm, N. Harrat, F. Zahi, N. Boughrira and L.Djabri, ,,Caractérisation hydrogéochimique des eaux géothermales de la nappe du Continental Intercalaire de la région de l'Oued Righ'' ; Algerien Journal of Arid Areas Special Issue N°12 (2013).

[3] M. Côte, ,,Des oasis malades de trop d'eau'', Sécheresse, Vol. 2, no. 9, 1998, pp.123-130.

[4] N. Tabouche and S. Achour, ,,Étude de la qualité des eaux souterraines de la région orientale du Sahara septentrional algérien'', Larhyss Journal 3 :99-113(2004).

[5] ELFERGOUGUI M. M. and BOUTOUTAOU D. ; Relation entre l'evaporation de la nappe phreatique et le pouvoir évaporant de l'atmosphère en zone arides ; *Courrier du Savoir* 13 :09-12 (2012).

[6] ELFERGOUGUI M. M., BOUTOUTAOU D. and MEZA N. ; Etude de l'évaporation de la nappe phréatique des zones arides : cas de Ouargla (Algérie) ; *Hydrological Sciences Journal* (2016). http://dx.doi.org/10.1080/02626667.2016.1257855

[7] DUBOST D. ; *Ecologie, Aménagement et développement agricole des oasis algériennes*; Ed: CRSTRA. Biskra, p 423 (2002).

[8] SAKER M. L., DADDI BOUHOUN M., HACINI M., OULD EL HADJ M. D. and BRINIS L.; Remontée des nappes phréatiques à Oued Righ : situation actuelle et perspectives d'aménagement (Sud Est Algérien). *Annales des Sciences et Technologie* Vol. 3, N° 1(2011).

[9] SAGGAÏ S., BACHI OEK, and SAGGAÏ A.; Effect of quality of phreatic aquifer water and water upwelling on constructions. A case study of Ouargla. *AIP Conference Proceedings* 1758, 030026 (2016); http://dx.doi.org/10.1063/1.4959422

[10] ANONYM. *; Le béton selon la norme SN EN 206-1*. Holcim (Suisse) SA, 15p (2013).

[11] GONZÁLEZ J.A., OTERO E., FELIU S., BAUTISTA A., RAMÍREZ E., RODRÍGUEZ P. and LÓPEZ W.; Some considerations on the effect of chloride ions on the corrosion of steel reinforcements embedded in concrete structures. *Magazine of Concrete Research* Vol. 50(3):189-199(1998). http://www.holcim.ch/fileadmin/templates/CH/doc/Fachliteratur/Brochure_Le_beton_selon_SN_EN_206-1_F.pdf