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Contribution to the study of the effect of urban wastewater on the degradation of ground water quality and to the treatment by filtration on dune sand of the city of Bechar (Algeria)

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ABSTRACT

The survey led on six residuary water stations localized on the course of the river of Bechar and ground waters used by the riparian population for drinking or irrigation, permitted to value the impact of wastewater on the quality of the ground water. The analyses done (April 2008, 2009 and July 2009), revealed a chemical pollution of the ground waters by the superficial out-flows of the river of Bechar whose waste waters undergo a slow percolation. This is confirmed by the raised contents in chlorides that pass 1,000 mg/l, in sulfur that exceeds 900 mg/l, which explains the conductivity values that reach 4,500 μS/cm. The calcium and magnesium exceed 200 mg/l. Bromine, zinc, iodine and the manganese are also more or less present with important contents, the contents in nitrates, reaching 99.23 mg/l, in nitrite 8 mg/l, prove a nitric pollution of the studied ground water. In other words, the degree of contamination varies from one site to another according to the remoteness of the source of pollution, the depth of the water table and according to the maintenance of the well and its surroundings. Because of its known advantages and expected potentialities, the study, exploitation and valorization of the sand filter has been chosen as a simple and effective process in its implementation and operation. Moreover, sand is virtually the only material available in South West Algeria.

Keywords: River of Bechar; Wastewater; Ground waters; Physicochemical analysis; Sand dune (Western Erg) Algeria

1. Introduction

The region of Bechar (Southwest of Algeria) is a semi-arid region in which the hydrous resource is strongly solicited for the agricultural activities and the domestic needs especially in the period of summer. The deterioration of the ground water quality is provoked, on the one hand, by the nature of soil with chalky dominance that permits an easy infiltration, and on the other hand by the wastewater. The load of this wastewater is continuously increasing with the demographic development of the city of Bechar. The uncontrolled tipping of these wastewaters constitutes a source of pollution for the agricultural lands and the

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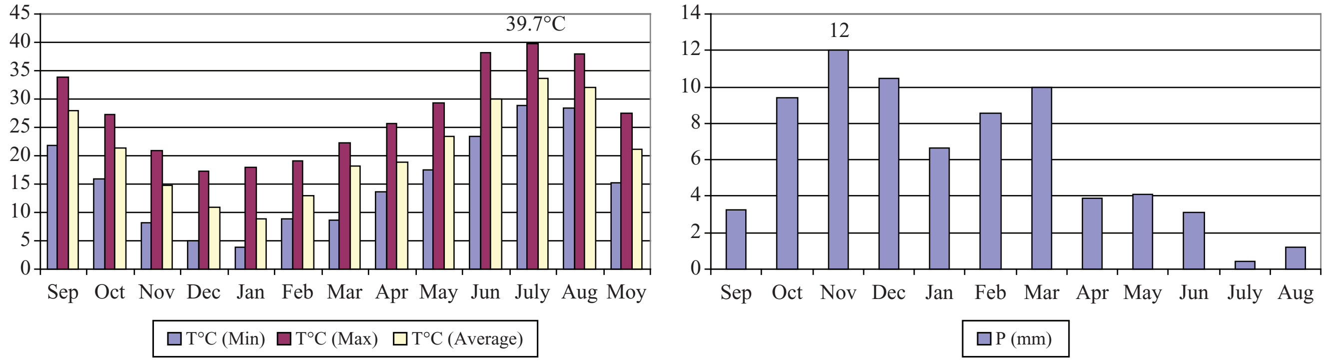

Fig. 1. Rain and temperatures variation in the studied region during the period from 1985 to 2006). Source .A.N.R.H. of Bechar.

riparian wells. The remoteness of a point of water in relation to the source of pollution and the depth of the water table constitutes two criteria in the determination of the quality of the ground water.

An organoleptic diagnosis permitted to make some relative observations to the quality of the waters of the wells near of the out-flow of wastewater of the city of Bechar, revealing a strong salinity and sometimes a bad smell. A preliminary physicochemical survey of the majority of the wells on the two banks of the river showed the possibility of a contamination of the ground waters by wastewater infiltrations. The present survey aims to determine the state of deterioration of the ground waters of the city of Bechar by the permanent out-flow of residuary water carried by the river.

2. Materials and methods

2.1. General and demographic frame

The city of Bechar, with 5,050 km^2 of surface and a density of 31.44 inhabitants/km^2 situated 1,000 km to the southwest of Algiers, the capital.

The population of Bechar increased from 1,58,789 inhabitants according to 31/12/2006 statistics, to 159,135 in 2007. About 80% of the drinking water is supplied by the local production department (ADE), from the Djorf Tourba dam and 20% comes from the ground waters. The main activity of the population is agriculture and cattle farming.

2.2. Hydrogeology

On the bioclimatic term, the city of Bechar is located in a semi-arid area in cold winter. In the middle yearly pluviometer, the maximum appears in November with 12 mm. The minimum is in July with 0.39 mm, the yearly middle precipitation is of 72.97 mm, with the exception of the period of rise in the water level that the city of Bechar witnessed in October 2008 when the precipitation exceeded 100 mm. The rainy season spreads from October to March, with a maximum in November (Fig. 2). The minimal temperatures vary from 3.8 to 28.8°C and the maximal temperatures reaches 17.2 in 39.7°C (Fig. 1).

2.3. Sampling campaigns

In April 2008, the ground water samples noted as SB_i, of the source and of wastewaters noted as R_i (April 2008–2009 and July 2009) has been achieved (Fig. 2), according to the recommendations of the WHO (1999) [14]. The choice of the sites has been fixed in the light of a preliminary study of the physicochemical parameters, the frequency of use by the riparian populations, the polluting source (the river of Bechar) for ground waters; and according to the upstream and downstream flow direction of residuary waters. We take in polyethylene bottles a volume of 1.5 l destined to physicochemical analyses from 14 wells, and from six wastewater stations. The sampling bottles were transported to the laboratory in a low temperature icebox (4°C). The physicochemical parameters (temperature, conductivity, pH and salinity) have been measured in situ by means of multi-parameter (Consort 861).

At the laboratory, the dosing methods used [1] are as follows:

- the volumetric method is applied to the quantitative analysis of calcium and magnesium NFT90-003.
- the nitrates are dosed by the potentiometric method (HI 121) using a specific electrode.
- the spectrophotometer is used for the dosage of the sulfates; NF T 90 – 009 (Spectrophotometer UV-Visible SHIMADZU 1600/1700).
- A colorimeter is used for the determination of the content in bromine, iodine, zinc, manganese, phosphate and phosphor; multi-parameter (HANNA model C200).
- A flame spectrometer is used for the determination of the sodium and potassium content.

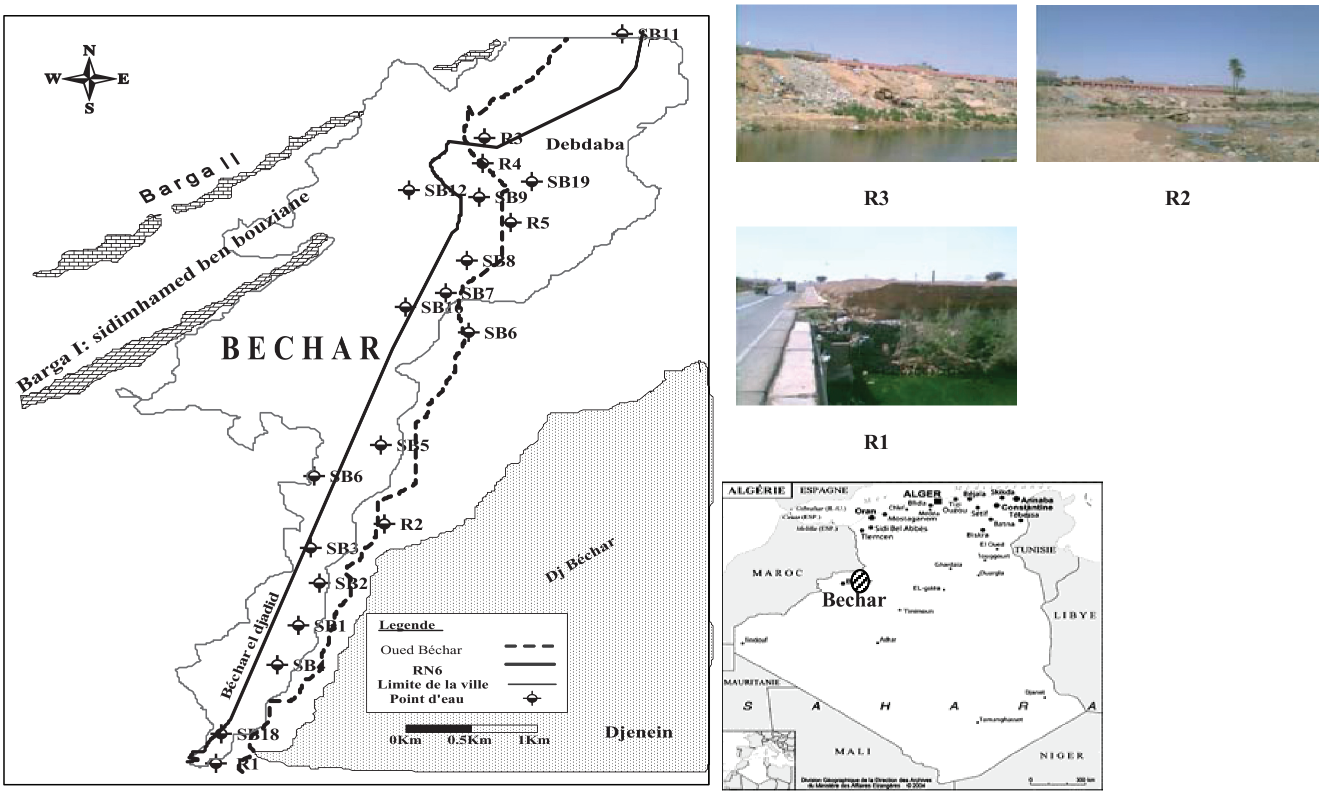

Fig. 2. Localization of the survey zone and prospected sites of the city of Bechar.

3. Results and discussion

The results of this survey are exposed while discussing the measured parameters, notably the measures done *in situ* and those done at the laboratory. We will mention the results relative to the wastewater (average of tree campaigns) and those of the ground waters.

3.1. Conductivity, salinity, TDS (Total Dissolved Salt) and pH

The R4 wastewater and R3 represented in (Fig. 3a), show the most important conductivities, which are respectively, 4913,33 and 3956,67 µS/cm. The conductivity of the residuary waters of the river of Bechar increases to the south (2132.33 µS/cm) and to north (4913.33 µS/cm) against the out-flow sense, denoting a same pace of dissolved salts carried by these waters. One notes the same variation of the saltiness also, which proves that the analyzed samples are charged. The residuary waters of the river of Bechar are characterized by a little alkali pH, between 7.5 5 downstream and 8.29 upstream. The ground waters are characterized by a little alkali pH whose value is included between 7.2 (SB9) and 8.12 (SB3) (Fig. 3b) which presents the variation of the North to the South of the (pH, conductivity, Salinity and the TDS) parameters. The variation of the pH presents a light fluctuation, the conductivity is more or less variable and their spatial distribution shows that the total mineralization of the levels captured evolves rudely following the out-flow line of the ground waters. It increases considerably and exceeds 2,230 mg/l mg for deep drills.

3.2. Sulfate and chloride

The sulfates and the chlorides present very important concentrations with a maximum of 768 mg/l recorded in R4 and 1,641 mg/l for R5. These contents can very probably be due to the fact that wastewater of urban nature contains a sulfite-based detergent (metastable state) that is transformed into sulfate (by oxidization). An even more important spatial evolution shows itself for the chlorides that vary between downstream 689.5 and upstream 1641.62 mg/l (Fig. 4a).

Chloride is a major constituent of natural waters and is generally a good tracer of salinity-increase sources [2].

The chloride concentration undergoes an important reduction from R5 to R4, respectively 1641.62 to 669.47 mg/l, linked either to a complexation of the chlorides and their decanting along the out-flow journey

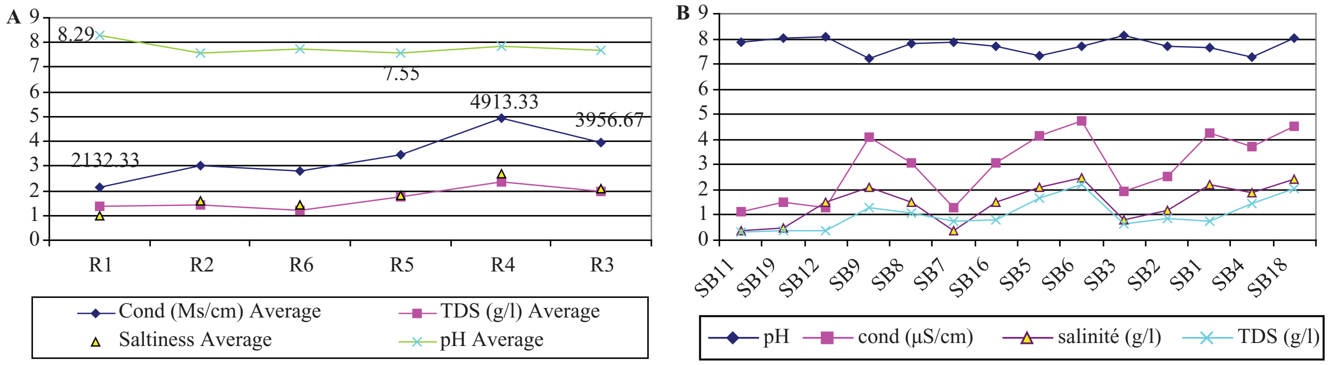

Fig. 3. Evolution of (conductivity, salinity, TDS and pH) of the different wastewater samples (R_i) and ground waters (SB_i)

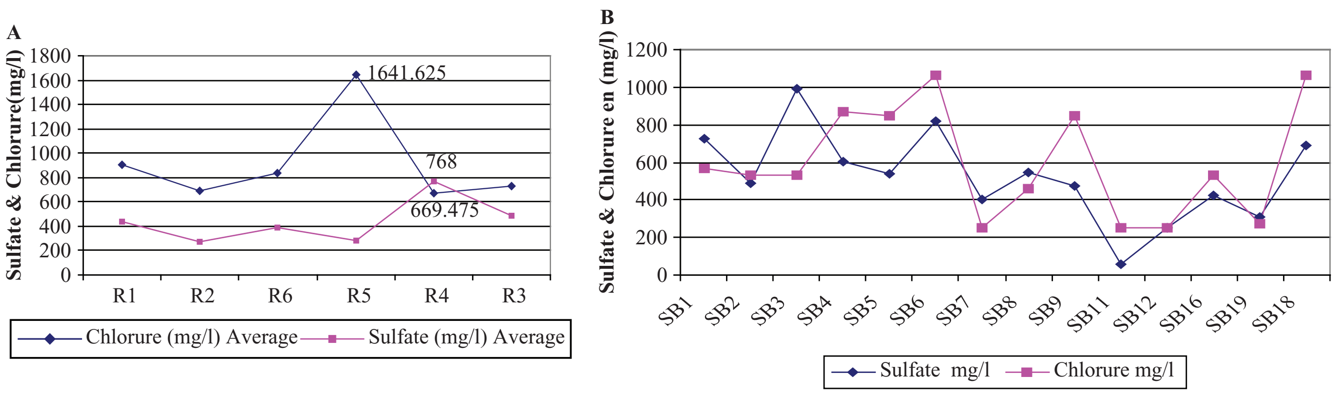

Fig. 4. Evolution of (chloride and sulfate) of the different samples of wastewater (R_i) and ground water (SB_i).

of the residuary waters with a possible infiltration, with a chemical transformation that prevents their emphasis [3].

Similarly important contents as have been observed for the ground waters, the sulfates and the chlorides localized respectively in SB6 822.36 and 1,060 mg/l (Fig. 4b).

3.3. Nitrates and nitrites

The analyses of the wastewater show that the nitrates and the nitrites have elevated concentrations, a maximum (21 mg/l) of nitrite has been observed in R4 (Fig. 5a). Urine is the main indicator of the nitrogen presence in the urban residuary waters, as well as ammonium-based detergents. Ammonification reactions can take place transforming this organic nitrogen into NH_4^+, indeed the demand in oxygen by ammonium is raised sharply and these molecules (nitrogenous compound) are a the origin of the bad. The maximum value of the nitrates is of 150.43 mg/l for R6 (Fig. 5a).

As shown in Fig. 5b, the undesirable substances (nitrates) for the ground waters vary in such a way as to present very serious threat. It is necessary to mention that the city of Bechar is situated on lacustrine limestone; a condition which encourages the infiltrations of the wastewater rich in nitrates, the presence of the nitrites is nonnegligible and present less important variations than those of the nitrates.

The results obtained reveal that the majority of the wells have some contents in nitrites that pass the threshold potability of 0.1 mg/l. The contents in nitrites in the studied ground waters record weak spatial variations (Fig. 5b). These alarming contents vary between 1 and 8 mg/l and that can result in urban wastewater contamination.

The results of the nitrates analyses for the ground waters show that their contents oscillate between 9.75 mg/l in the SB3 well and 99.23 mg/l in the SB6 well. The nitrate contents in waters belonging to the four studied wells (Fig. 5b, SB 1, 4, 6, 8 and 9) exceeds the 50 mg/l suggested by the World Health Organization, which indicates water contamination.

3.4. Calcium and magnesium

The average content in calcium of the residuary waters reached a maximum of (210.76 mg/l) Ca^{2+}

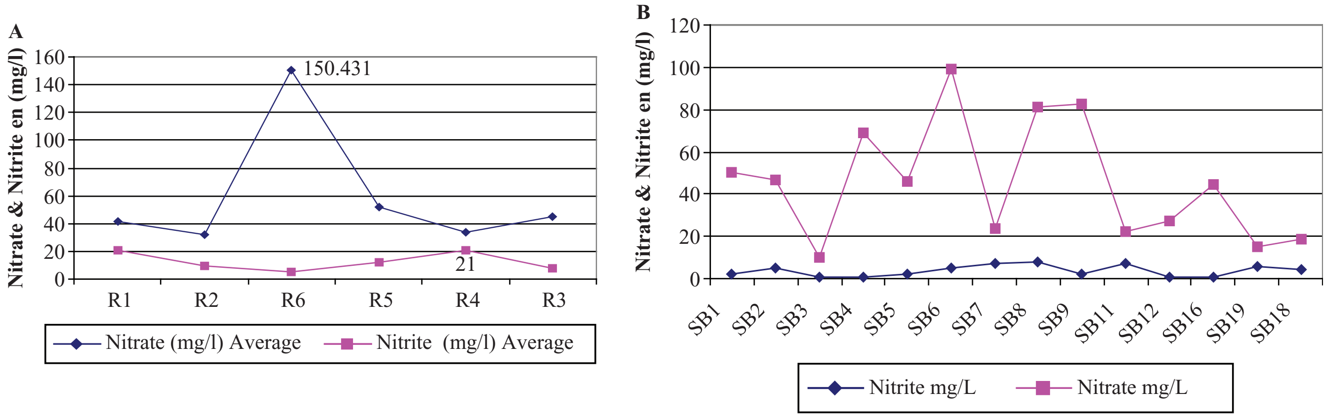

Fig. 5. Evolution of (nitrate and nitrite) of the different samples of wastewater (R_i) and ground waters (SB_i).

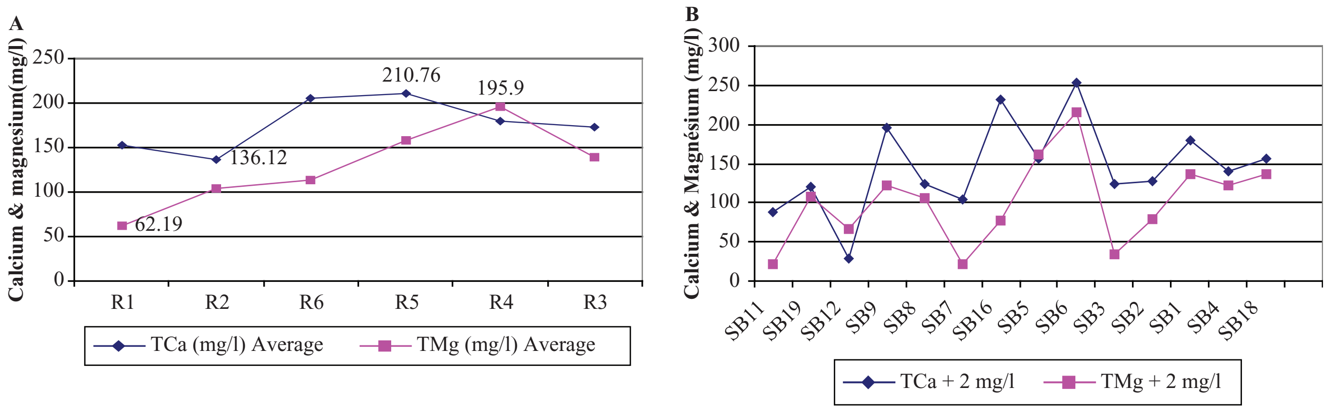

Fig. 6. Evolution of (calcium and magnesium) of the different samples of wastewater (R_i) and ground waters (SB_i).

(R5) and (195.9 mg/l) of Mg^{2+} (R4) north of the river of Bechar. An important reduction in this concentration is observed, reaching 136.12 mg/l of Ca^{2+} and 62.19 mg/l of Mg^{2+} (Fig. 6a), a complexation of these ions with others can explain this evolution-downstream and upstream.

This reduction seems sufficient to question the residuary water infiltration, but we can also evoke other parameters to explain the calcic ground water load that reaches a maximum of 254 mg/l of Ca^{2+} and 214.8 mg/l of Mg^{2+} (SB6) (Fig. 6b) north of the river of Bechar, notably the nature of the studied soils. Certainly, the residuary water infiltration brings a supplement of calcium and magnesium to the ground water; however, the nature of the marno-chalky basement, seem to play a determining role in the calcic and magnesium load of the ground water [4]. The successive rain waters can solubilise the Ca^{2+} ions from the carbonated rocks and Mg^{2+} from the dolomite rocks [1] and send them until the ground water. The solubility of $CaCO_3$ is increased in presence of proteins and weak acids, resulting in the organic matter oxidizations [5].

3.5. Sodium and potassium

The content in sodium of the residuary waters reached a maximum of 1703.23 and 8.14 mg/l of potassium for R6. Patterson [6] note that the use of sodium in the household products contributes to the important presence of this element in the urban wastewater. A strong reduction of the sodium concentration is observed, reaching 924.4 mg/l for the north urban wastewater that can be assigned to the infiltration during the flow of the river (Fig. 7a). For the ground waters, the present potassium is also of weak variation reaching a maximum of 7.8 mg/l, sodium presents a gradient increase of the north and south (Fig. 7b).

3.6. Dissolved oxygen

The content in oxygen dissolved in the studied residuary waters varies from 1.74 mg of O_2/l for R1, to (5.18 mg of O_2/l) for R3. This can be an indicator that these wastewaters are not charged in organic matter of which the deterioration by the microorganisms consumes the oxygen. The R1 is charged therefore in

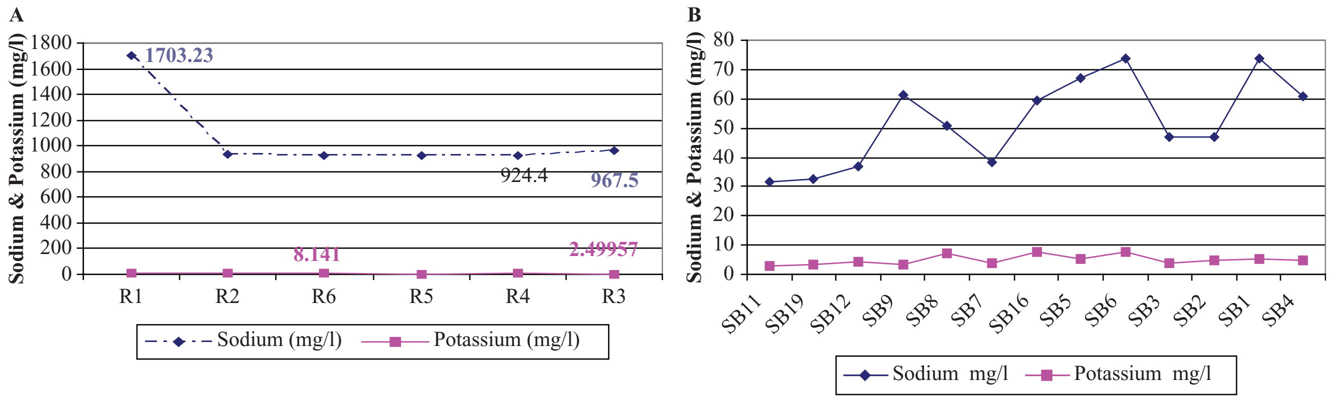

Fig. 7. Evolution of (sodium and potassium) of the different samples of wastewater (R_i) and ground waters (SB_i).

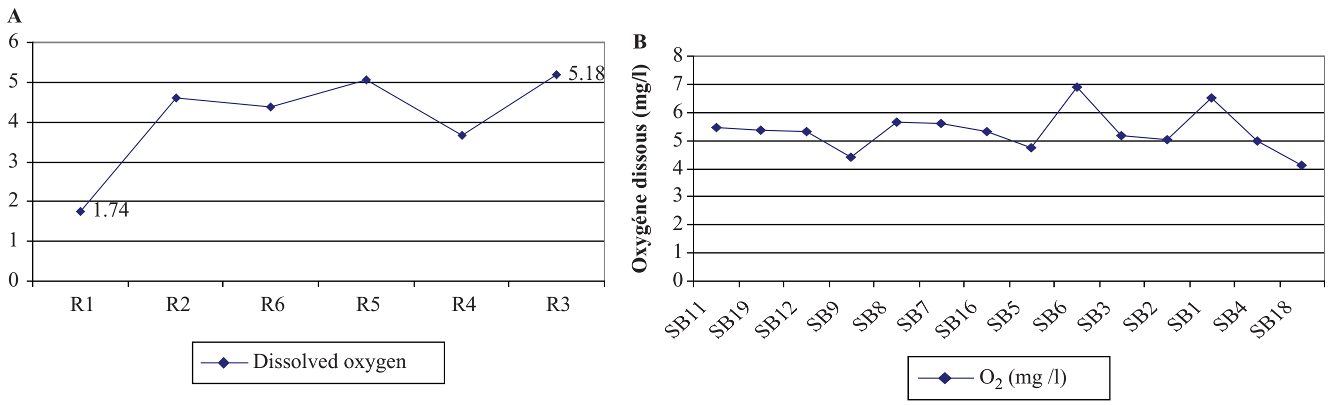

Fig. 8. Evolution of (O_2 dissolved) of the different samples of wastewater (R_i) and ground waters (SB_i).

organic matter regarding the weak content of the oxygen compared to the other wastewaters. The contribution in organic matter encourages the development of the microorganisms, which reverberates on the content in dissolved oxygen. The weak content in dissolved oxygen recorded for R1 is witness of the big consumption of the oxygen by the organic garbage oxydable matter [7]. The ground waters present some contents in dissolved oxygen of 4.14–6.89 mg/l (Fig. 8b). The SB6 well presents the maximal content in dissolved oxygen, which can be explained by the receiving river remoteness from the wastewater. However, the out-flow of a superficial water table in this well added to the water table depth, can explain his richness in dissolved oxygen. The turbulences caused by such a tipping of an altitude of about 53 m bring an important quantity in oxygen.

3.7. Bromide, zinc, iodine and manganese

The metallic pollutants are distinguishable from the other chemical pollutants by a weak biodegradability and an important ability of bioaccumulation along the tropical chain [7], which could be harmful to the population as wall as to the fauna and flora.

For wastewater, the bromine presents some concentrations (Fig. 9a) that varies from 0.16 mg/l for R3 to 0.49 mg/l for R5 presenting a weak enough fluctuation thus for the whole samples analyzed, bromide is also a minor component of natural waters. However, a groundwater quality criterion of 1 mg/l has been established in literature [8] based on toxicity data. The iodine presents an important enough concentration the maximum has been observed in R5 with a content of 2.7 mg/l. Zinc and manganese have presented a import variation, the maximum was 6 and 3.2 mg/l.

The variation of the manganese and iodine are represented in (Fig. 9b) some variations shown for the ground waters considerably important for some wells, this shows that the presence of these two elements in the browsed layer is very limited. The reduction of zinc of the North to the South is on the other hand sensitive to that of the bromine; it presents a light variation with the exception of SB6 that presents a strong

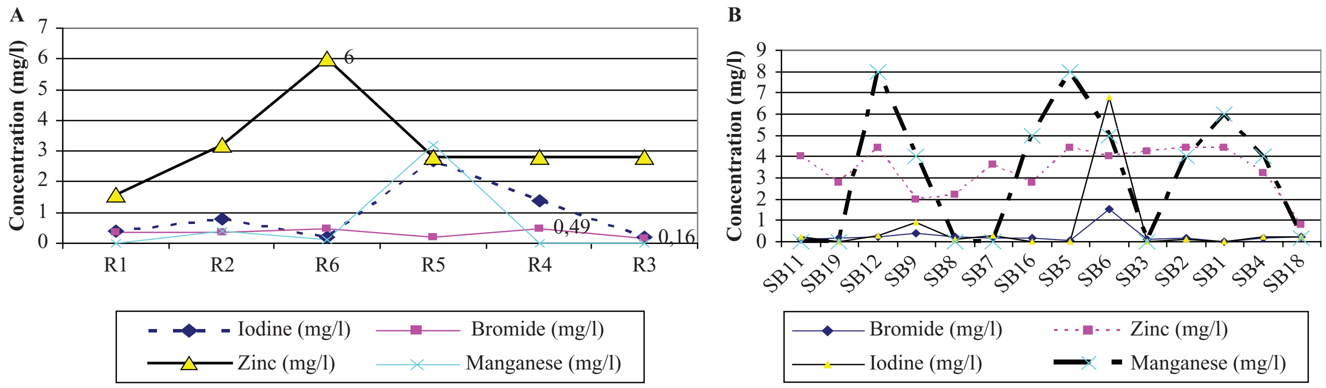

Fig. 9. Evolution of (bromide, zinc, iodine and manganese) of the different samples of wastewater (R_i) and ground waters (SB_i).

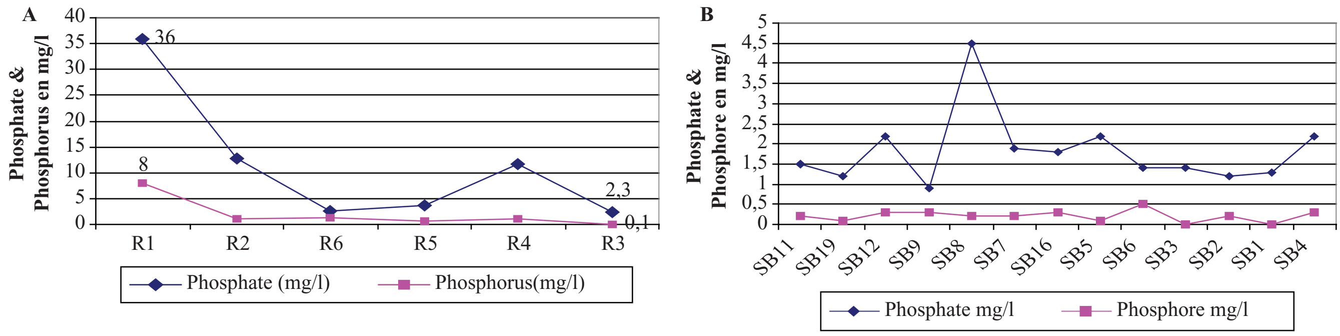

Fig. 10. Evolution of (phosphate and phosphorus) of the different samples of wastewater (R_i) and ground waters (SB_i).

concentration. Recent studies have revealed that a substantial percentage of Br^- could be converted to bromate BrO^-_3 or brominated organic molecules (trihalomethanes, bromoacetic acid, bromoacetonitriles, etc.) by drinking water disinfection processes [10,11]. In this way, the slightly toxic Br^- ion in water can be transformed into highly toxic and carcinogenic disinfection by-products (DBPs) with very low values ranging from 0.0004 mg/l (1,2-dibromoethane) to 0.1 mg/l (Bromoform) [12,13].

3.8. Phosphate and phosphorus

The phosphate and phosphorus of the residuary waters vary respectively 2.3–36 mg/l and of 0.1–8. These contents answer, to a decreasing gradient of the northbound south has the exception of R4 (Fig. 10a). This let suppose either a decanting or a complexation along the journey of the out-flow of the residuary waters, the contents in phosphates are important, they indicate a strong enough variation of the south in the north, part against the phosphors testifies a weak variation compared to the phosphate, the middle content in P-PO_4^{3-}, of 50 μg/l [15] is considered like a signal of eutrophisation; what permits to classify river of Béchar among the surroundings euthrophes. For the ground waters, the contents in phosphate vary between 0,9 mg/l (SB9) and 4.5 mg/l (SB8) and in phosphor vary between 0 mg/l (SB3) and 0.5 mg/l (SB6). However, we observe for the phosphors a weak spatial variation (Fig. 10b) has the one of the phosphates comparatively.

The phenomena intervening in the contamination of the waters of well by the phosphates and phosphors can be the contribution of manure in excessive quantities, the nature of the lands crossed and the residuary wastewater in the natural habitat. However, we think that an interrelationship exists between the contents in phosphates and residuary water phosphors and those of the waters of well.

4. Filtration contribution

For a possible treatment of urban studied residuary waters rejected in the open in the river of Bechar and in perspectives of the achieved works [9], we aimed to implement the process of filtration on sand dune (Taghit and Béni Abbés). The characterization physico-chemical and granulometric showed that these are

Table 1
Physical features of the sand

Sands	Taghit	Béni abbes
Thinness module thinness (MF)	2.77	0.787
Effective diameter d_{10} mm	0.19	0.22
Uniformity coefficient (CU)	1.05	1.39
spécifique Area of material cm^{-1} (A_s)	211.92	156.78
Permeability α(m/s) 10^{-4}	0.906	0.976
Volumic Mass abs kg/m^3	2.50	2.63
Porosity (ε)%	36	41.39

porous surroundings very uniforms, to sandy texture; essentially of quartz [16,17]. Tables 1 and 2 summarize some properties of the sand used.

The whole results obtained are given in what follows.

4.1. Iodine

The elimination of iodine in the two types of sand (Taghit and Béni abbés) were important and of the same order of size 33.33%. Fig. 11 gives the contribution of the filtration of residuary waters R1 and R2.

4.2. Sulfate and chloride

The exhaustion of the chlorides in the sand of Béni Abbés is slightly superior compared to the one observed respectively in the sand of Taghit 14.88% and 12.92% (Fig. 12). Whereas for the sulfates there has been an increase of the content of 45.84% for the sand of Béni Abbés and of 8.22% for the sand of Taghit.

4.3. Calcium and magnesium

For Fig. 13 magnesium in the sand of Beni Abbés presented no contribution, on the other hand the sand of Taghit presented an important increase of the order of 37.83%.

Fig. 14 presents the exhaustion of the calcium in the two filters in Taghit (40.24%) and Béni Abbés (8.33%).

4.4. Sodum and potassium

An exhaustion of sodium Fig. 15 is also observed in both filters in Taghit (63.80%) and Béni Abbés (30.91%).

On the other hand as Fig. 16 shows for the two filters, potassium presented an increases in the content, Taghit (83.33%) and Béni Abbés (79.56%).

5. Conclusion

The results obtained during this survey show that the waste waters are charged enough and that an infiltration is likely to happen. The studied ground waters are of a much degraded quality with certain heterogeneity in their composition. Wastewaters of the river of Bechar prove to be globally enough loaded and constitute a true threat for the environment of the region and notably for the underground waters that require a pretreatment to protect the water table and the ecosystem as a whole.

With maximal contents of the ground waters are as follows: 99.23 mg/l in nitrates, 8 mg/l in nitrite, 1,060 mg/l in chlorides, 990 mg/l in sulfates, 254 mg/l of Ca^{2+}, 214.8 mg/l of Mg^{2+}, 74 mg/l of Na^+, 7.8 mg/l of K^+, 6.8 mg/l of iodine, 1.53 mg/l brome, 4.4 mg/l of zinc, 8 mg/l of manganese and a conductivity of 4,540 μS/cm. These waters could be the result of urban wastewater contamination.

The average maximal contents of three campaigns, respectively, the chlorides and sulfates of the wastewater are: 1641.62 and 768 mg/l, of 150.43 mg/l in nitrates, 21 mg/l in nitrite, 246.15 mg/l of Ca^{2+} and 202.72 mg/l of Mg^{2+}, 1703.23 mg/l of Na^+, 7.94 mg/l of K^+, 2.7 mg/l of iodine, 0.49 mg/l of brome, 6 mg/l of zinc, 3.2 mg/l of manganese and a conductivity of 4913.33 μS/cm.

The set of the results obtained show that the studied ground waters present signs of deterioration since the majority of the analyses largely exceed the norms recommended by the WHO as well as the Algerians norms, which confirms the hypothesis of the contamination of the ground waters, extensively.

The elimination of iodine in the residuary waters for the two types of sand (Taghit and Béni Abbés) were important and of the same order of size 33.33%.

The exhaustion of the chlorides in the sand of Béni Abbés was slightly superior to the one observed respectively in the sand of Taghit 14.88% and 12.92%. Whereas for the sulfates there has been an increase in the content with 45.84% for the sand of Béni Abbés and

Table 2
Chemical composition (% in weight) of the sands: Taghit, and Béni Abbés

	Cr_2O_3	Fe_2O_3	Al_2O_3	K_2O	Na_2O	MnO	CaO	MgO	SiO_2
S. Béni abbes	0.004	0.18	0.17	0.008	0.008	00	1.15	0.015	97.44
S.Taghit	0.002	0.389	0.27	0.119	0.031	00	0.94	0.011	98.45

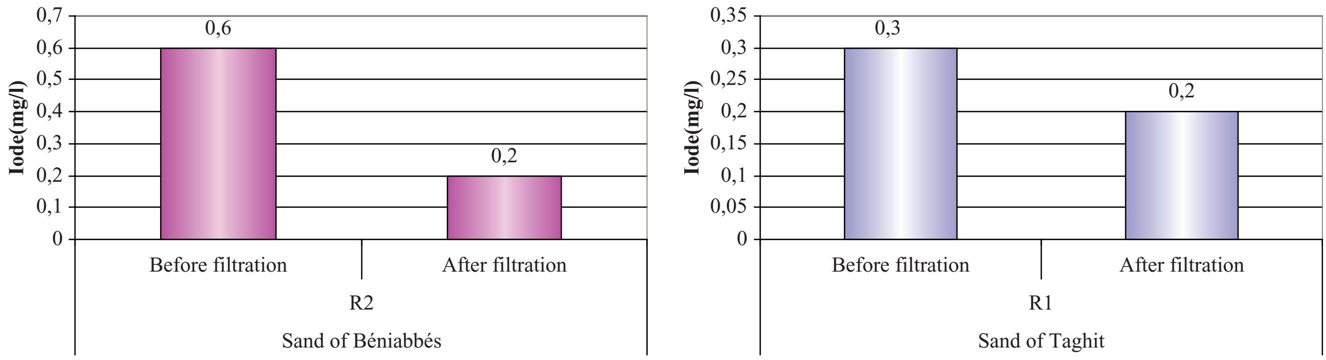

Fig. 11. Contribution of the filtration of the residuary waters (iodine).

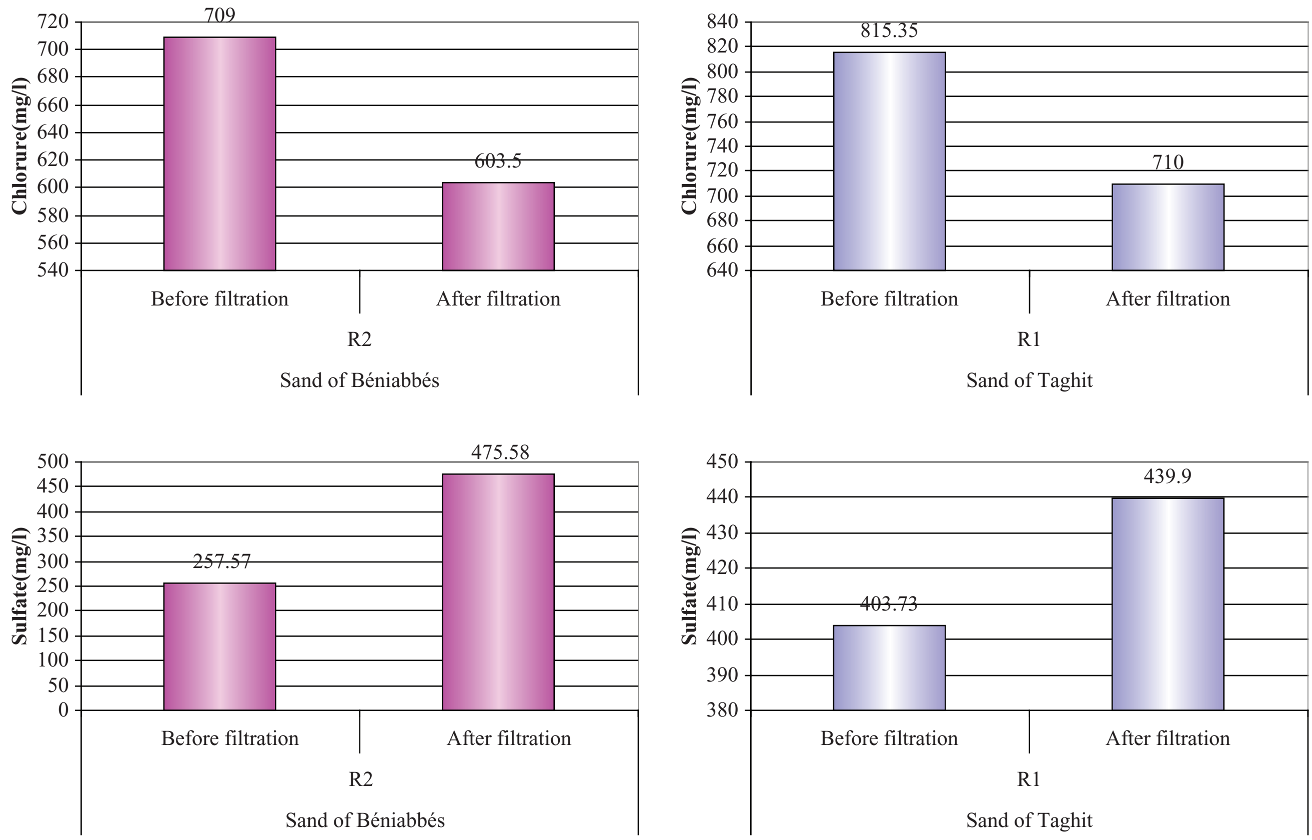

Fig. 12. Contribution of the filtration of the residuary waters (R_i) (chloride and sulphate).

of 8.22% for the sand of Taghit. For magnesium, the sand of Béni abbés presented no contribution, on the other hand the sand of Taghit presented an important increase of the order of 37.83%.

The exhaustion of calcium is observed in the two filters Taghit (40.24%) and Béni abbés (8.33%).

An exhaustion of sodium is also observed in the two filters in Taghit (63.80%) and Béni Abbés (30.91%). On the other hand potassium presented increases in content for the two filters, Taghit (83.33%) and Béni Abbés (79.56%).

The sand of dune of the Western Erg offers some ways capable to be exploited; the survey of these extents is to take in charge scientifically in order to discover the potentialities that these sandy sites can offer.

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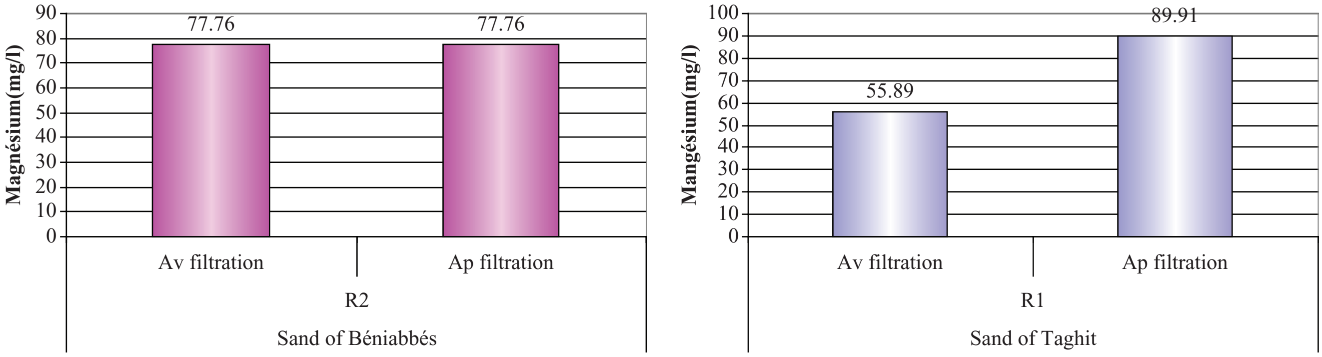

Fig. 13. Contribution of the filtration of the residuary waters (R_i) (magnesium).

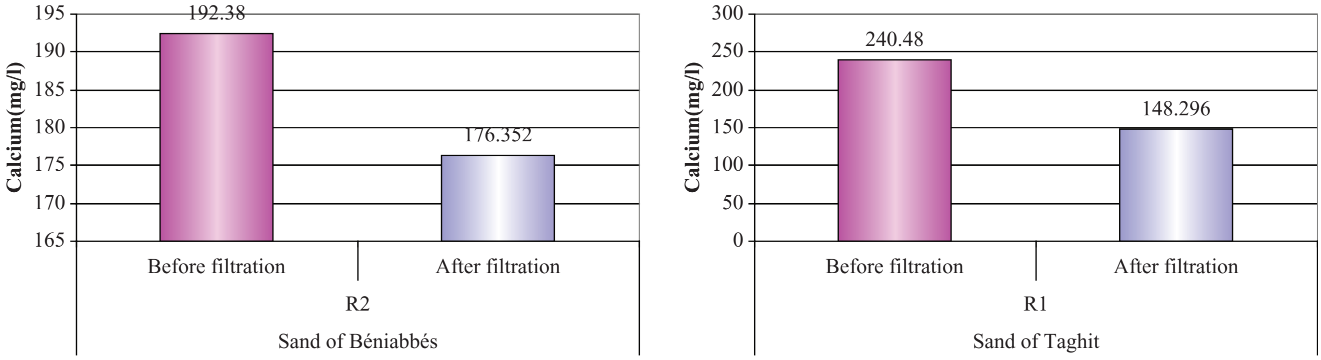

Fig. 14. Contribution of the residuary waters filtration (R_i) (calcium).

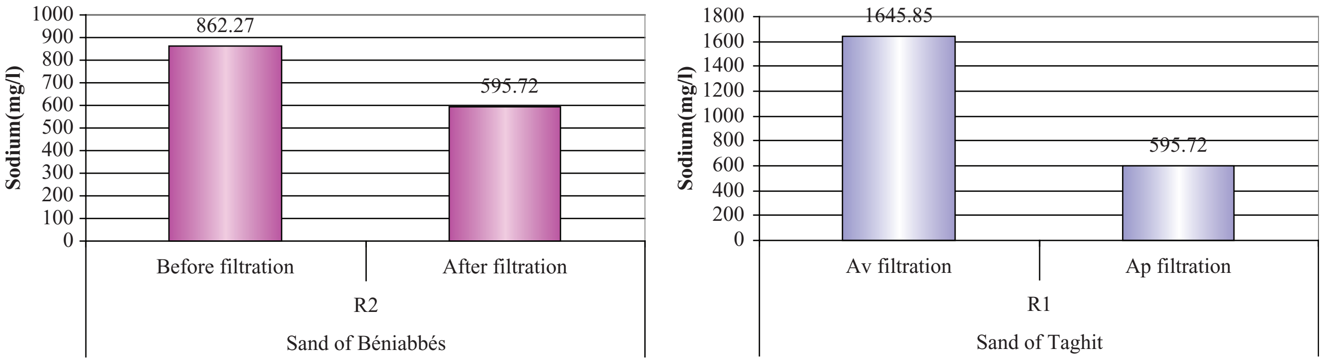

Fig. 15. Contribution of the residuary waters filtration (R_i) (sodium).

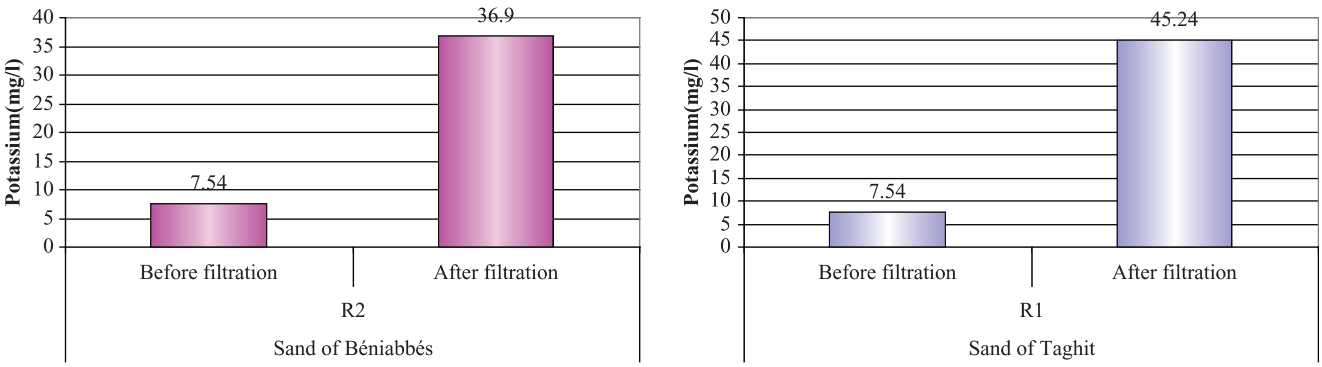

Fig. 16. Contribution of the residuary waters filtration (R_i) (potassium).

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