THE EFFECT OF URBAN WASTEWATER ON THE 
DEGRADATION OF BECHAR GROUND WATER QUALITY 
(ALGERIA).

IMPACTS DES EAUX USEES URBAINS SUR LA QUALITE DES 
EAUX SOUTERRAINES DE LA VILLE DE BECHAR (ALGERIE).

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ABSTRACT: The survey led on six residiary water stations localized on 
the course of the river of Béchar 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 2010), revealed a chemical pollution of the ground waters 
by the superficial out-flows of the river of Béchar whose waste waters 
undergo a slow percolation. This is confirmed by the raised contents in 
chlorides that pass 1000 mg/l, in sulfur that exceeds 900 mg/l, which 
explains the conductivity values that reach 4500 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.

Keywords: Wastewater, Groundwater, physicochemical analysis, 
Bechar (Algeria).

Résumé. L’étude menée sur six stations d’eaux résiduaires localisées sur le 
parcours de l’oued de Béchar et les eaux souterraine utilisées par la
population riveraine comme eau de consommation ou d’irrigation, a permis d’évaluer l’impact des eaux usées sur la qualité des eaux de la nappe. Les analyses effectuées (avril 2008,2009 et 2010), ont révélé une pollution chimique des eaux de la nappe par les écoulements superficiels de l’oued de Béchar, dont les eaux usées subissent une percolation lente à travers les couches triasiques. Ceci est confirmé par les teneurs élevées en chlorures, qui dépassent 1000 mg/l, en sulfate qui dépassent 900 mg/l ce qui explique les valeurs de la conductivité qui atteignent 4500 μs/cm. Toutefois, une influence lithologique ne peut être exclue. Le calcium et le magnésium dépassent 200 mg/l, le brome, zinc, iode et le manganèse sont présents aussi avec des teneurs plus ou moins important, les teneurs en nitrates, atteignant 99,23 mg/l, en nitrite 8 mg/l, prouvent une pollution nitrique des eaux souterraines étudiées. Par ailleurs, le degré de contamination diffère d’un site à l’autre selon la distance d’éloignement de la source de pollution, la profondeur de la nappe et aussi selon l'entretien du puits et son entourage.

Mots clés : eaux usées urbains, eaux souterraines, paramètres physicochimique, Béchar (Algérie).

INTRODUCTION

The region of Béchar (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 Béchar. The uncontrolled tipping of these wastewaters constitutes a source of pollution for the agricultural lands and the 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 Béchar, 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 Béchar by the permanent out-flow of residuary water carried by the river.

MATERIALS AND METHODS

General and demographic frame

The city of Béchar, with 5050 km$^2$ of surface and a density of 31,44 inhabitants/km$^2$ situated 1000 km to the southwest of Algiers, the capital. The population of Béchar increased from 158789 inhabitants according to 31/12 /2006 statistics, to 159135 in 2007. About 80% of the drinking water is supplied by the local production department (ADE), from the Djorf Torba dam and 20% comes from the ground waters. The main activity of the population is agriculture and cattle farming.

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 12mm. The minimum is in July with 0,39mm, the yearly middle precipitation is of 72,97mm, 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 100mm. 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).

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

In April 2008, the ground water samples noted as SB\textsubscript{i}, of the source and of wastewaters noted as R\textsubscript{i} (April 2008-2009 2010) has been achieved (Fig.2), according to the recommendations of the WHO (1999). 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 Béchar) 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 (Rodier, 1996) 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.
RESULTS AND DISCUSSIONS

The results of this survey are exposed while discussing the measured parameters, notably the measures done \textit{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.

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 $\mu$S/cm. The conductivity of the residuary waters of the river of Béchar increases to the south (2132,33 $\mu$S/cm) and to north (4913,33 $\mu$S/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 Béchar 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 2230 mg/l mg for deep drills.

**Fig.3.** Evolution of Conductivity, Salinity, TDS and pH of the different wastewater samples (R_i) and ground waters (SBi)

**Sulfate and Chloride**

The sulfates and the chlorides present very important concentrations with a maximum of 768 mg/l recorded in R4 and 1641 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 [Walter D’Alessandro and all 2008].

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 of the residiary waters with a possible infiltration, with a chemical transformation that prevents their emphasis (Bontoux, 1993).
Similarly important contents as have been observed for the ground waters, the sulfates and the chlorides localized respectively in SB6 822,36 and 1060mg/l (Fig.4b).

**Fig. 4.** Evolution of (Chloride and Sulfate) of the different samples of wastewater (R$_i$) and ground waters (SB$i$)

**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 Béchar is situated on lacustrine limestone; a condition which encourages the infiltrations of the wastewater rich in nitrates, the presence of the nitrites is non-negligible 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. 5 b). These alarming contents vary between 1 and 8mg/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. 5 b, SB 1, 4, 6, 8 and 9) exceeds the 50 mg/l suggested by the World Health Organization.

![Graph](image)

**Fig. 5.** Evolution of (Nitrate and Nitrite) of the different samples of wastewater (R_i) and ground waters (SB_i)

**Calcium and magnesium**

The average content in calcium of the residuary waters reached a maximum of (210.76 mg/l) Ca\(^{2+}\) (R5) and (195.9 mg/l) of Mg\(^{2+}\) (R4) north of the river of Béchar. 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 (Pearson and als, 1987). The successive rain waters can solubilize the Ca\(^{2+}\) ions from the carbonated rocks and Mg\(^{2+}\) from the dolomite rocks (Rodier, 1996) 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 (Hagedorn and als, 1999).
Fig. 6. Evolution of (Calcium and Magnesium) of the different samples of wastewater ($R_i$) and ground waters (SBi)

Sodium and Potassium

The content in sodium of the residuary waters reached a maximum of 1703.23 mg/l and 8.14 mg/l of potassium for R6. [Patterson, R.A., 2001] 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).

Fig. 7. Evolution of (Sodium and Potassium) of the different samples of wastewater ($R_i$) and ground waters (SBi)
Dissolved oxygen

The content in oxygen dissolved in the studied residuary waters varies from 1.74 mg of O₂/l for R1, to (5.18 mg of O₂/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 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 (Nassali and all, 2002). The ground waters present some contents in dissolved oxygen of 4.14 to 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.

Fig.8. Evolution of (O₂ dissolved) of the different samples of wastewater (Rᵢ) and ground waters (SBᵢ)

Bromide, Zinc, Iodine and Manganese

The metallic pollutants are distinguishable from the other chemical pollutants by a weak biodegradability and an important ability of bio-accumulation along the trophical chain [H. NASSALI and all 2002], which could be harmful to the population as well 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 (Flury and Papritz, 1993) 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 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, bromoacetanitriles, etc.) by drinking water disinfection processes (Bätjer et al. 1980; Richardson et al. 2003). 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) (WHO 2000, 2004).

a.  

b.  

**Fig.9.** Evolution of (Bromide, Zinc, Iodine and Manganese) of the different samples of wastewater ($R_i$) and ground waters ($SB_i$)
Phosphate and Phosphorus

The Phosphate and Phosphorus of the residuary waters vary respectively 2.3 to 36 mg/l and of 0.1 to 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 [Turin A. 1991] is considered like a signal of eutrophication; what permits to classify river of Béchar among the surroundings eutrophic. 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 0mg/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.

![Fig.10. Evolution of (Phosphate and Phosphorus) of the different samples of wastewater (R$_i$) and ground waters (SB$_i$)](image-url)
CONCLUSION

The results obtained during this survey show that the wastes 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 Béchar 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, 1060 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 of brome, 4.4 mg/l of zinc, 8 mg/l of manganese and a conductivity of 4540 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.

Acknowledgement

The authors would like to express their gratitude to the MESRS, Algeria.

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