WASTEWATER REJECTIONS IMPACT ON GROUNDWATER QUALITY IN A SEMI ARID REGION. CASE OF TEBESSA AQUIFER

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ABSTRACT:
Les eaux souterraines sont soumises, de plus en plus intensivement, aux rejets volontaires d'effluents polluants, eaux usées ou eau de ruissellement pluvial en milieu urbainGroundwater is exposed, more and more intensively, to deliberate discharges of polluting effluents, sewage or storm water runoff in urban areas. A l'approche des villes, les sources de contamination des eaux souterraines sont multiples et sont liées à de nombreuses activités urbainNear cities, the sources of groundwater contamination are numerous and are related to many urban activities. Les eaux urbaines constituent une source de contamination des eaux souterraines par leur concentration en constituants organique et inorganique. The urban water is a source of contamination of groundwater by their concentration in organic and inorganic constituents. D'autres sources peuvent être ajoutées telles que pollution de l'air, pluie, lessivage des chaussées,c. However, their origins can be complex and include stormwater, wastewater leakage networks. Les lixiviats d'ordures ménagères, les fosses septique sont considérés comme des sources de contamination chargées en polluants et qui ont des impacts environnementaux majeurs sur les ressources en eau disponibles. Leachates of municipal waste, septic tank are considered as sources of contamination and carry pollutants that have major environmental impacts on water resources available.
Sur le sous bassin versant de l'Oued El kebir à Tébessa, l'intensification des activités industrielles et agricoles, ainsi que la diversification des modes de sous-produits de production ou des déchets après consommation, rendent vulnérables les ressources en eau souterraines. In the Oued El Kebir basin in Tebessa, increased industrial and agricultural activities, and the alternative by-products of production or post consumer waste, make groundwater resources vulnerable. The plan changes leading to changes in groundwater levels by pumping in urban areas can also lead to contamination of interconnected flows. The impact may be a hydrological from substantial exploitation of the resource has an action on the hydrodynamic behavior of the aquifer.
In this perspective, we try to examine the state of the groundwater resources of Tebessa plain, the last cut by the Oued El Kebir, which drains the wastewater from the entire urban area of the city and which location can contaminate groundwater.

Keywords: *groundwater, wastewater rejection, urban area, Tebessa aquifer.*

1. INTRODUCTION

Wastewater can have a significant impact on the quality of groundwater. Nitrate and chloride pollution of surface water is of high concern as it may have negative impacts on water supply and ecosystems (*Postma et al. 1991 et al., Rouabhia et al. 2004*, *2008, Baali et al. 2007*). High nitrate concentrations in water serving as a source for drinking water is a serious health problem, being known for many years as the cause of blue baby syndrome and related to increased levels of diarrhoea of children (*Fehdi et al. 2008*).

Wastewater Irrigation may increase the salt, nitrate, and chloride concentrations of the receiving water bodies, limiting their agricultural, industrial, urban, and ecological uses.

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Irrigated agriculture with wastewater in semi-arid areas significantly contributes to crops productivity, stability, and diversification. However, the wastewater is considered a major diffuse contributor to the contamination of surface and groundwater bodies (*Rouabhia et al. 2004*).

The main aims of this study are: (1) to identify the spatial and temporal trends of nitrate in groundwater, and (2) to evaluate the characteristics, spatial distribution, and variations in groundwater chemistry as a result of irrigation with wastewater practices.

1.1. Location

The area of study is near the city of Tebessa in eastern Algeria (**Fig. 1A**). This area lies in the semi-arid region of Algeria and is susceptible to the various threats common in both growing urban areas and developing agricultural areas. The city of Tebessa (**Fig. 1B**) and the surrounding villages (Bekkaria and Youkous les bains: Hammamet) have seen a great deal of growth in the past decade, with the establishment of new industries and farms. The most important economic activity of the area is agriculture. Large amounts of synthetic nitrogen fertilizers, such as urea 46%, ammonium nitrate 33.5%, liquid fertilizer N-32%, or commercial complex fertilizers with different proportions of nitrogen, phosphorous, and potassium, are applied during farming season (summer and autumn).

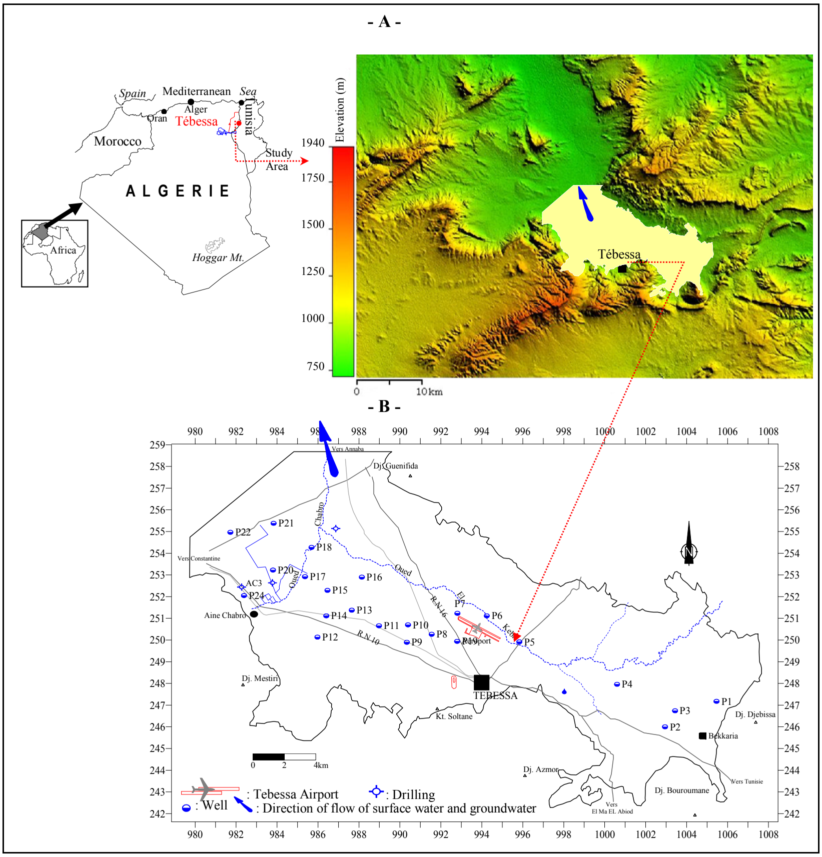

Fig. 1 Location of the study area in Algeria.
A. The topographic map; B. The boundaries of the study area

1.2. Climate and precipitation

Annual precipitation in the studied area ranges from 200 to 320 mm (*Rouabhia et al. 2009*), thus this considered to be a semi-desert area. Summer temperatures can reach 45°C. This situation of dryness accentuates the drawdown of water resource especially during the last decade because the renewal of this resource is very weak. Dryness generates sometimes very unfavorable effects on groundwaters. (Aquifer refill decreases considerably whereas the exploitation increases). The dry climate, atmospheric dust and low precipitation can also affect the water quality generally causing increased salt content (*Fehdi et al. 2011*).

1.3. Geological and hydrological setting

The Tebessa area contains two aquifers: the limestone aquifer and the alluvial aquifer. In general, the shallow groundwater in Merdja area is found in the alluvial fan deposits from plio-quaternary age (**Fig. 2**). This aquifer overlies geologic formations consisting of cenomanian marly layers. The recharge of this alluvial aquifer is combined and is done from: (1) highlands of Dyr Bouroumane on the East and Doukkane on the West (precipitation infiltrating through alluvial fans where the mountain range meets the plain); (2) from losing streams; and (3) through cross-formational flow.

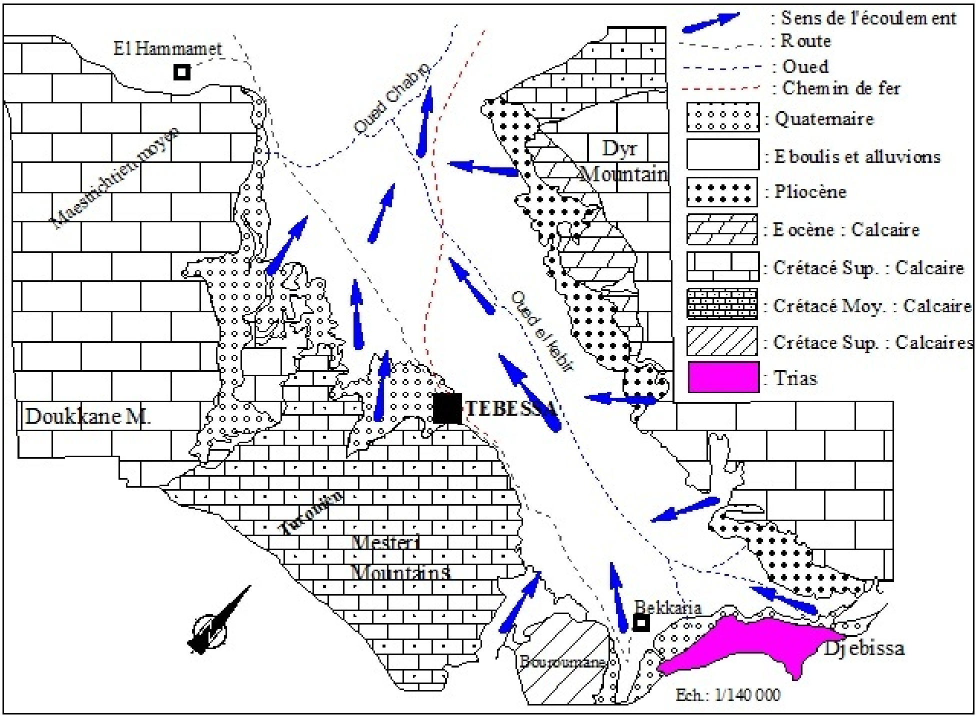

Fig. 2 Geological map of the study area. In Rouabhia 2010.

2. METHODOLOGY

The physico-chemical and chemical data of all the investigated groundwater are summarised in **Table 1**. According to the analytical data, Parameters values range widely except for the pH and dissolved Oxygen (DO) and nitrate concentrations. DO and pH values increase slightly eastwards up to a maximum value of 8.6 mg/l and 7.92 respectively, whereas nitrate concentration increases westwards, with a maximum of 281 mg/l in December 2008. Significant changes in water quality occur along the river course due to the influence of its tributaries, wastewater disposal, agricultural activities, and large seasonal variations in the discharge rate of the Merdja Plaine. Variations in selected water-quality parameters (EC, NO_3^-, Cl^-, SO_4^{2-},and Na^{2+}) along the Merdja plain are illustrated in **Fig. 4**. In general, water quality becomes considerably worse downstream of the Merdja plain due to a significant increase in SO_4^{2-} (>800 mg/l) and NO_3^- (>50 mg/l) concentrations. This is attributed to the use of wastewater of Wadi el Kebir in irrigation.

3. RESULTS AND DISCUSSION

3.1 Hydrochemistry

Results of analysed parameters in groundwater samples are given in **Table 1**. The quality parameters have wider ranges due to spatial changes in the lithology of the alluvial sediments that constitute the aquifer and seasonal changes in fertilizer application and irrigation practices.

Table 1. Chemical composition of groundwater from the Merdja aquifer, 2010.

well	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	PO_4^{2-}	NO_3^-	NO_2^-	EC (µS/cm)
	(Mg.L^{-1})										
1	589	113	229	91,16	5,6	129	159	0.07	28,5	<0.1	682
2	824	0,14	0,46	37,59	138	104	91,6	0.11	11,6	0.12	784
3	881	105	231,6	96,8	4	92	249	1.55	38,4	2.22	1272
4	377	187	228,8	54,51	3,2	97	138	0.07	11,5	0.51	398
5	1071	157	225,7	34,77	6	226	111	0.13	7,3	3.21	2320
6	920	199	233	139,1	3,4	360	255	0.11	13,4	3.66	2682
7	1039	--	175	116,5	4,4	397	350	0.12	18,3	0.40	1324
8	2176	146	233,3	37,59	2,4	221	92	0.23	12,8	1.90	3250
9	922	132	116,7	--	2,4	148	94	0.05	8,6	0.11	530
10	1400	81	234,5	34,77	3,6	223	192	0.27	1,2	0.26	2553
11	676	80	140,1	113,7	3,9	176	350	0.15	31,1	0.30	2859
12	432	188	231	139,1	5,9	97	243	0.07	49,3	0.20	539
14	627	100	227,4	48,87	2,5	153	67	1.56	9,6	0.40	1606
15	460	159	134,8	65,79	3,8	129	134	0.18	13,4	2.50	1766
16	737	188	232	46,05	4	129	65	0.11	9,9	2.41	2784
17	988	176	130,9	99,62	4,6	177	149	0.19	36	1.14	1428
19	1079	187	238,5	57,33	2,7	223	76	0.09	5,1	0.60	590
20	571	204	223,5	71,43	4,4	329	49	0.05	8,8	0.60	1031

The spatial distribution of the values of EC, NO_3^- and SO_4^{2-} in groundwater in December 2010 shown in **Fig. 3**, **4** and **5** These maps provide a basis for making area wide generalizations concerning the distribution of water quality parameters. EC and NO_3^- spatial distribution patterns are very similar, and show that the dissolution of evaporites significantly affect groundwater chemistry. Mention should be made of the high concentrations of SO_4^{2-} (>800 mg/l) and NO_3^- (> 50 mg/l) in wells located between Tébessa and Chabro wadi and downstream of the Ain Chabro.

Other sources of sulfate in groundwater may be agricultural practices, although fertilizers containing sulfate are not commonly used in the study area.

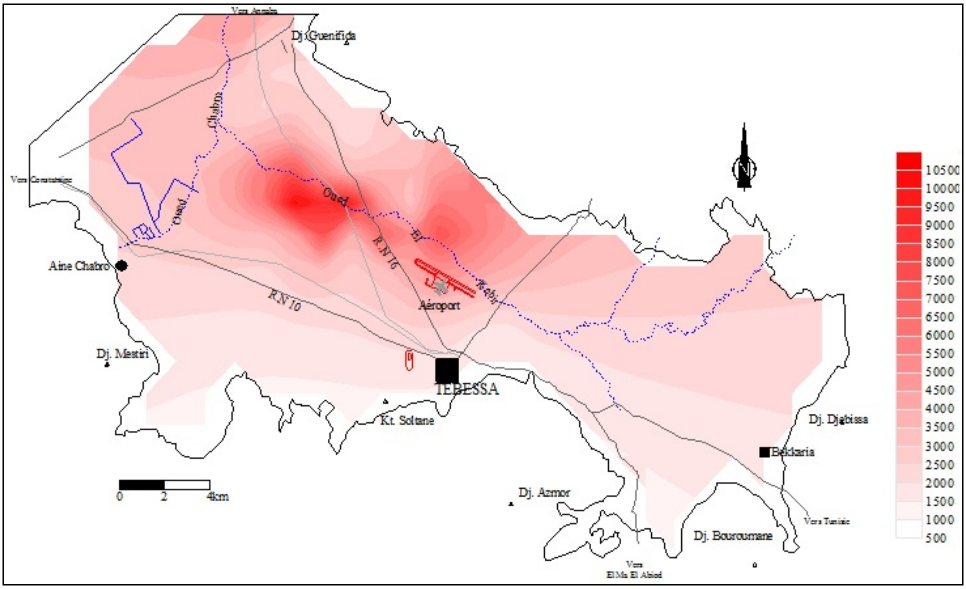

Fig. 3 Electrical conductivity (EC) distribution in groundwater of the study area.

3.2 Water quality

The purpose of this section is to characterize groundwater for both domestic as well as for irrigation purposes. Water was classified based on total hardness according to the classification of Sawyer and McCarty (1967).

Hardness is defined by the presence of divalent cations of which calcium and magnesium are the most abundant in groundwater.

Total hardness (TH) is calculated through the following equation (*Todd, 1980*):

$$TH = 2.5\ Ca(mg\ l^{-1}) + 4.1\ Mg\ (mg\ l^{-1})$$

All sampled wells, located in the studied area are characterized as hard except the well M2 located in the eastern part, classified as a very hard water type.

Nitrate is a major contaminant of drinking water. It is currently frequently found in aquifers. In arid and semi-arid regions, sources of nitrate in groundwater have either been linked to direct anthropic pollution in urban areas or to leaching of fertilizers in agricultural areas (*Girard, Hillaire 1997*). Nitrate (NO_3) concentrations of the phreatic waters (**Table 1**) were found far above the World Health Organization (*WHO, 1998*) recommended limit (45 mg 1-1) especially for those samples occurring in rural areas. Almost 65% of samples from dug wells showed concentrations greater than 45 mg 1-1.

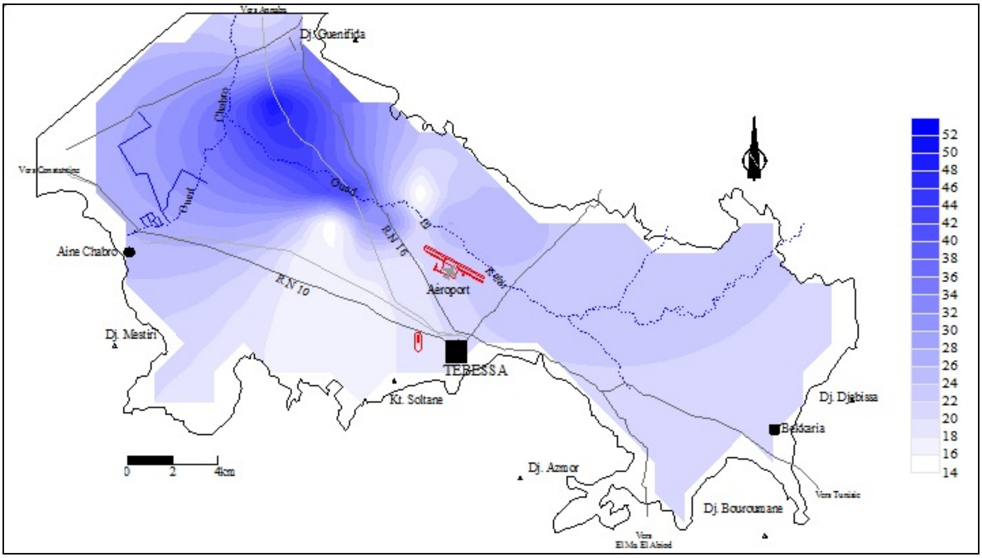

Fig. 4 Nitrate distribution in groundwater of the study area. (mg l^{-1})

The presence of high nitrate concentrations in the phreatic waters is not only the direct consequence of a massive usage of artificial fertilizers, but is also a consequence of contamination by domestic septic tanks. The latter are unfortunately favoured by the absence of a sanitation network in the whole region where more than 800 septic tanks are in use. This fact contributes to the nitrification of groundwaters according to the process.

Nitrate concentrations vary greatly from18 mg l-1 at P11 to 80 mg l-1 P18. The highest concentrations were found in the middle and the west part of the studied area.

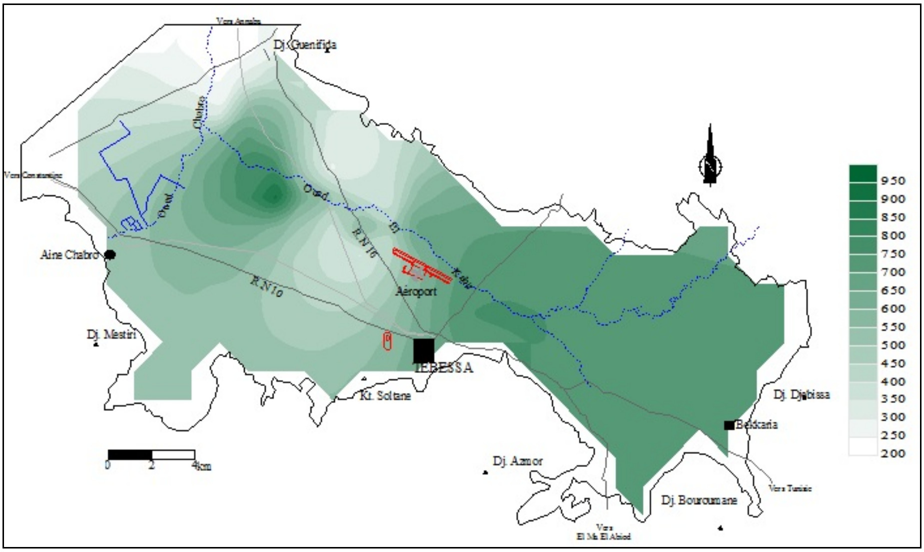

Fig. 5 Sulfate distribution in groundwater of the study area. (mg l^{-1})

3.3 Anthropogenic inputs

Lithology and human activities controlled the hydrogeochemical characteristics of groundwater. Variation in TDS in groundwater may be related to land use and also to pollution (*Rouabhia 2009*). Cl^-, SO_4^{2-}, NO_3^- and Na^+ ions are mostly derived from agricultural practices and use of wastewater in irrigation, animal wastes and industrial and municipal sewage (*Rouabhia 2010*).

Correlation of these ions with TDS can be used to indicate the influence of human activities on the water chemistry. The relationship between various anions and cations with TDS is illustrated in **Fig. 6**. The Na+ concentrations show an increasing trend with increasing TDS (**Fig. 6.1**) and in addition to the weathering of silicate minerals it may be related to the anthropogenic sources such as sewage, household waste, engineering work effluents, deicing road salt,c. Increase of Ca^{2+} concentrations with increasing TDS (**Fig. 6.2, 6.3**) supports the anthropogenic input mainly domestic and industrial waste (*Rouabhia 2009*).

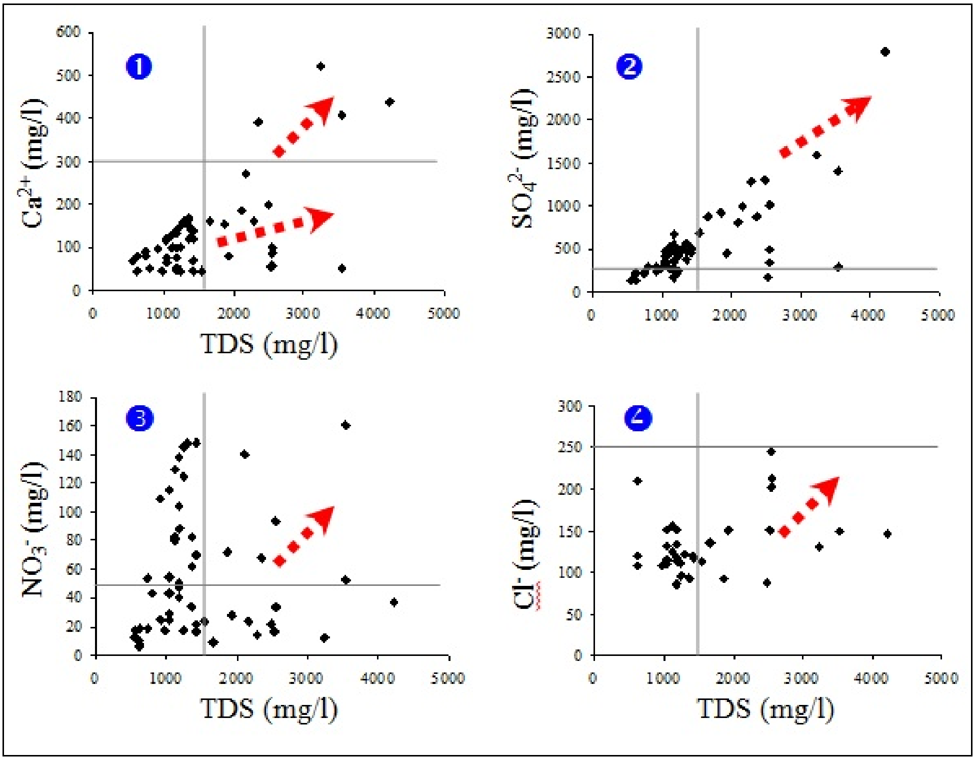

Fig. 6 Relationship between TDS and cations/anions

Cl^- and NO_3^- show a good trend of increasing concentration with increasing TDS (**Fig. 6.4**), suggesting same source and can be used as pollution indicators for anthropogenic input (*Rouabhia, 2008*). The SO_4^{2-} appears to show a good trend of increasing concentration with increasing TDS.

In presence of geological source the other possible source of SO_4^{2-}in study area is mainly use of wastewater in irrigation, industrial effluents and domestic sewage. A poor correlation between NO_3^- and SO_4^{2-} is observed suggesting different source of both ions as agricultural activity observed in the study area (**Fig. 7**).

Higher correlation between Cl^- and NO_3^- above 0.35, indicate common source and input from anthropogenic activities. In the study area positive correlation between Cl^- and NO_3^- ($r = 0.54$) (**Fig. 7**) have been observed, suggesting same source for these ions.

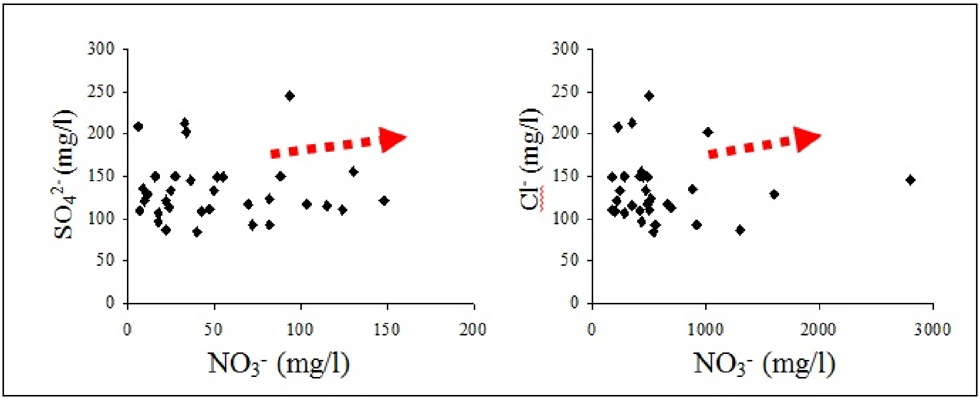

Fig. 7 Relationship between **a** NO_3^- and Cl^- and **b** SO_4^{2-} and NO_3^-

4. CONCLUSIONS

Present study adds to our understanding the impact of urbanization on groundwater resources. Chemical properties of groundwater are controlled both by natural geochemical processes and anthropogenic activities. Our studies suggest that Na^+ is mostly derived from both natural as well as anthropogenic sources. The variation of TDS and its correlation with other ions supports the contribution of anthropogenic inputs to the groundwater contamination. The major pollutant in the groundwater of study area is NO_3^-. High concentration of NO_3^- is due use of wastewater in irrigation. Majority of the samples have high NO_3^- concentration and become unfit for human consumption, particularly infants. Majority of the samples are good for irrigation in almost all type of soils with little danger of exchangeable sodium as they fall in very high salinity–low sodium field.

The study reveals that the central part of the study area is more prone to groundwater pollution owing to the generation of bulk sewage and solid waste coupled with improper disposal of sewage and urban solid waste. In the study area, pheratic zone is more polluted than the deeper zone and hence preventive steps should be taken up to protect them.

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REFERENCES

Postma D., Boesen C., Kristiansen H., Larsen F., (1991), *Nitrate reduction in an unconfined sandy aquifer: water chemistry, reduction processes, and geochemical modeling*. Water Resour Res 27:2027–2045.

Rouabhia A., Baali F., Kherici N., Djabri L., (2004,) *Vulnérabilité et risque de pollution des eaux souterraines de la nappe des sables miocènes de la plaine d'El MA EL Abiod (Algérie).* Revue Sécheresse 15:347–352.

Rouabhia A., Fehdi Ch., Baali F., Djabri L., Rouabhi R., (2008), *Impact of human activities on quality and geochemistry of groundwater in the Merdja area, Tebessa, Algeria*. Environ Geol. ISSN 0943-0105 (Print) 1432-0495 (Online). doi:10.1007/s00254-008-1225-0.

Rouabhia A., Baali F., Fehdi Ch., (2009), *Impact of agricultural activity and lithology on groundwater quality in the Merdja area, Tebessa, Algeria*. Arabian journal of Geosciences by Springer. DOI: 10.1007/s12517-009-0087-4.

Baali F., Rouabhia A., Kherici N., Djabri L., Bouchaou L., Hani A., (2007), *Qualité des eaux souterraines et risque de pollution en milieu semi aride. Cas de la cuvette de Chéria. NE algérien.* Journal of Estudios Geologicos. Vol. 63. CSIC, Spain.

Fehdi Ch., Aek Rouabhia, Baali F., Boudoukha A., (2009), *The hydrogeochemical characterization of Morsott-El Aouinet aquifer, Northeastern Algeria.* Environ Geol 58:1611–1620. doi: 10.1007/s00254-008-1667-4.

Fehdi Ch., Rouabhia A., Baali F., Boudoukha A., (2008), *The hydrogeochemical characterization of Morsott-El Aouinet aquifer, Northeastern Algeria.* Environ Geol. doi:10.1007/s00254-008-1667-4.

Todd, (1980), *Ground water hydrology*. (2nd edn). Wiley, New York Water Authority (North Jordan resource investigation project stalt) (1989) Yarmouk basin water resources study, draft tinalreport.

Girard P., Hillaire M., Oga M.S., (1997), *Determining the recharge mode of Sahelian aquifers using water isotopes*. J Hydrol 197:189–202.

WHO, (1998), *Guidelines for drinking water quality.* Addendum to vol 2, 2nd edn. Health criteria and other supporting information (WHO/EOS/98.1), World Health Organization.