Measures aimed at ensuring the rational use of water and soil resources and the preservation of oasis potential in the basin of Ouargla, Algeria.

Fadila Ammour, Yourcef Touil, Ahmed Kettab and Samia Houli

Abstract: In the arid and semi arid areas, the misuse of water resources, the inadequate irrigation techniques (gravitational submersion) and the lack of an adequate and efficient drainage system , have had, ecologically and economically, a very negative impact. Large areas with high agricultural potential including the palm plantation of Ouargla, are now threatened by the flooding of chott areas and rising groundwater.
In this context, and in order to slow the rise of the groundwater that touches the ground in some places and that increasingly threatens date palms in the Ouargla region, we have set as a main objective the desalination of drainage water and its re-use in irrigation and/or groundwater supply, after improving the existing drainage system.

Keywords: arid regions, agriculture, salinization, drainage, re-use, purification, desalination.

Fadila AMMOUR ✉
Samia HOULI
Laboratory of Mobilization and Valorization of Water Resources (M.V.R.E.)
National High School for Hydraulics (ENSH)
1, Blida, Blida
Algeria
Tel. (213) 550070068

Yourcef TOUIL,
Faculty of Science and Engineering
University of Ouargla
Ouargla, Algeria
youcef_touil@yahoo.fr

Ahmed KETTAB
Laboratory of Water Sciences
National Polytechnic School of Algiers
10 Avenue Hassen Badi Alger
Algeria
kettab@yahoo.fr

F. AMMOUR ✉
fasonidz@yahoo.fr

Samia HOULI
houliros@yahoo.fr

Received: 19 october 2010 / Accepted: 18 november 2010
Published online: 31 december 2010

Riassunto: *Nelle aree aride e semi aride, l'uso delle risorse acquifere, le tecniche inadeguate di irrigazione (gravitary submersion) e la mancanza di un adeguato ed efficiente sistema di drenaggio, ha avuto un impatto molto negativo da un punto di vista economico e per quanto riguarda l'ecologia. Ampie aree con un alta possibilità di essere coltivate, inclusa la palma di Ouargla , sono ora minacciate dall'inondazione di aree CHOTT e dalla risalita delle acque sotterranee.*
In questo contesto, e con il fine di rallentare la risalita delle falde che toccano il suolo in molte zone, e che sempre più minacciano la palma da datteri nella regione di Ouargla, noi ci siamo posti come obbiettivo primario la desalinizzazione delle acque di drenaggio e il loro riuso nell'irrigazione e/o nella ricarica delle falde, dopo il miglioramento del drenaggio esistente.
L'Algeria ha un importante potenziale di oasi che possono contribuire a creare un bilancio del bioclima in diverse aree del Nord Sahara Algerino.
Queste oasi sono andate recentemente verso la decadenza, una distruzione allarmante e senza precedenti ha avuto inizio. Come altre oasi, quella della palma di Ouargla, è anch'essa minacciata dall'allagamento delle aree e dalla risalita delle falde. I fattori principali resposnsabili di questo disastro ecologico sono di natura tecnica, socio-economica o amministrativa.
Così, l'uso delle risorse acquifere, il deterioramento del sistema di drenaggio e l'assenza di un efficiente sistema di condutture, ha avuto delle conseguenze molto negative in termini sia economici che ecologici.
Parlare di eccesso di acqua nelle regioni aride puo sembrare assurdo. Ma questa è una realtà che minaccia tutti gli ambienti delle oasi. L'uso delle risorse acquifere è all'origine di molti problemi le cui le conseguenze socio-economiche sono molto importanti:

- *Esaurimento degli acquiferi Fossili*
- *Trasformazione delle piantagioni di palme in SEBKA*
- *Risalita delle acque sotterranee*
- *Salinizzazione e conseguente sterilità dei suoli agricoli*

In questo contesto e per un miglior contributo alla risoluzione del problema della desertificazione, noi ci siamo posti come obbiettivo il drenaggio

Introduction

The ancient city of Ouargla is surrounded by a palm plantation (2317 ha) which constitutes a belt to protect the city against high winds, softens the atmosphere and produces food (dates) essential for the region. This palm grove is now threatened by flooding of chott[1] areas and rising groundwater. The main factors responsible for this ecological disaster are technical, socio-economic or administrative.

Thus, the misuse of water resources, the deterioration of the drain-

[1] *Chott is a permanent lake of salt water, with changing shore, located in semi-arid areas. Chotts are fed intermittently during the rare rains, and suffer high evaporation, which accumulates the salts to the surface of the silt, sometimes exploited.*

 DOI 10.4409/Am-022-10-0023

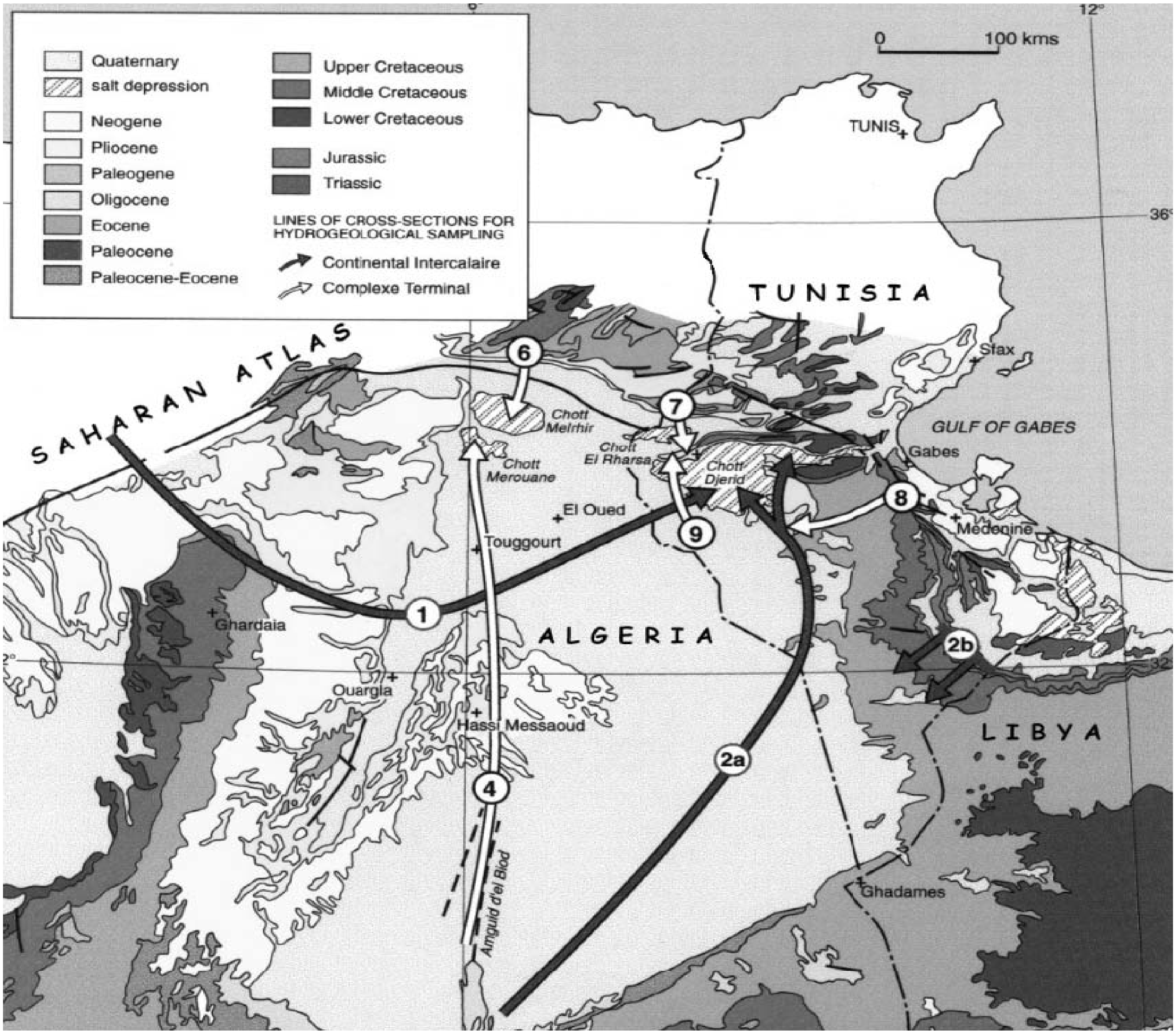

Fig. 1: *Hydrogeological map of the Great Eastern Erg.*

age system and the absence of an efficient sewerage system, are at the origin of many problems whose socio-economic consequences are very important:

1. Exhaustion of fossil aquifers
2. Transformation of the palm plantation in sebkha[2]
3. Rising groundwater.
4. Salinization and sterilization of agricultural soils.

During the last three decades, the expansion of chott areas and sebkhas has caused the destruction of 180 hectares of date palms.

In this context and for contributing better to the resolution of the problems which arise, we have set three main objectives:

1) The treatment of wastewater by biological filters of sand to avoid the contamination of groundwater.

2) Improvement of the existing drainage system and a proposed master drainage study area, to reduce the rising water.

[2] *Sebkha: In North Africa, sebkha means a salt marsh, sometimes temporarily dried up, which occupies the bottom of a depression.*

3) The re-use of drainage water and treated wastewater, after desalination, for irrigation of the palm plantations and/or groundwater supply.

Hydrogeological Conditions

The sedimentary basin of the northern Sahara covers about 780,000 km^2 (including 700,000 in Algeria). It is bounded to the north by the Moroccan border to the Gulf of Gabes in the Saharan Atlas, to the west through the valley of the Saura, south by the edge of the plateau land of ancient central Sahara (Hammad Tademait and Tinrhert) and to the east by the Mediterranean (Gulf of Gabes), for the relief of Jebel Dahar (Tunisia) and conventionally the Algerian-Libyan border (Fig. 1). It comprises two main aquifers (Fig. 2).

The Continental Midsole tank covers about 600,000 km^2. It is contained in the continental formations of horizons and sandy clay and Cretaceous sandstone (Cornet, 1964). The backbone of M'zab, the real structural bridge between the Saharan Atlas and the plateau of

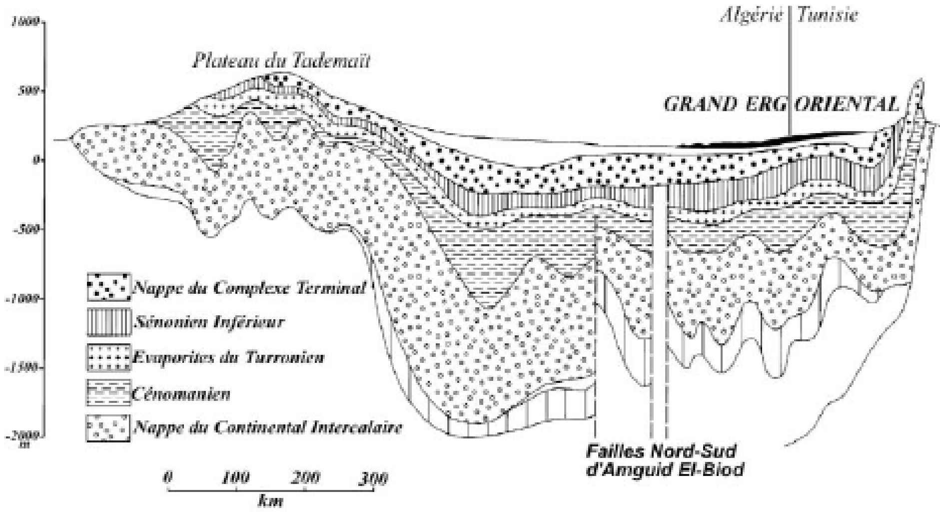

Fig. 2: *Hydrogeological Cup NE-SW sub-basin of the Great Eastern Erg.*

Tademaït divides the area of the reservoir into two basins; one western and one eastern.

The Tank Terminal Complex groups under one name several aquifers located in different geological formations. This web may move in one or three lithostratigraphic formations:

- Senonian and Eocene carbonate
- Miopliocène sandy (Continental Terminal)
- Quaternary dune sands, sand clay and gypsum

The study region is an endoreic area which belongs to the Great Eastern Erg, fueled by floods in the north of Wadi N'sa, south by the Wadi Mya and west by infiltration of wadi water Metlili and M'zad. The valley is oriented southwest / northeast (Rouvilois, 1975).

It is characterized by an arid climate and has very important water potential consisting of three complexes.

The intercropping complex which contains the Albien groundwater: It is one of the largest reservoirs in Africa. Its water is very warm (57°C). It is captured at a depth of about 1300 m and operated without pumping at a rate of 200 l/s by drilling. The salinity of this water is about 2 g/l. It is mainly used for drinking water.

The mio-pléocéne groundwater:

Water is collected at a depth of 60 to 140 m by pumping with an average flow of 30 l/s. Its salinity varies from 2 to 7 g/l. It is used especially for irrigation.

The sénonien groundwater:

Water is collected at a depth of 120 to 180 m by pumping with an average flow of 30 l/s. Its salinity is about 1.8 to 3 g/l. It is used primarily as drinking water.

The Quaternary groundwater :

It is located at a depth of about ten metres in some urban areas and outcrop in low-lying areas (sebkha and chott) and some palm plantations . This water is not exploited because of its high salinity (more than 15 g/l) and its wastewater pollution.

Assignment and Sewage Treatment

The non-functioning of the sewage treatment plant since 1980, has resulted in a catastrophic situation in the region. Wastewater is disposed of in an anarchic way and at several points, some are close to the palms (Fig.1 and photo1).

Moreover, some of this sewage and without any treatment, joins the main collector and mixes with drainage water. The treatment of these waters is more than a necessity in order to prevent contamination of groundwater and to develop an additional source of water for irrigation.

Technique of treatment:

The state of degradation and outdatedness of the sewage treatment plant is such that no rehabilitation is possible. Thus the recourse to other techniques such as biological filtration, by using a local material, offers a very promising alternative for cleansing in the area.

Indeed, the biological filtration of the wastewater, on granular support and at low speed has become a process of purification particularly attractive. In addition to the mechanical retention of MES, this technique allows the biological breakdown of organic, phosphorated and nitrogenized pollution (Gougoussi, 1979; CNERIB, 1993). The rehabilitation of the sewage network is underway. The sanitation master plan is maintained, ie evacuation to seven points of rejection.

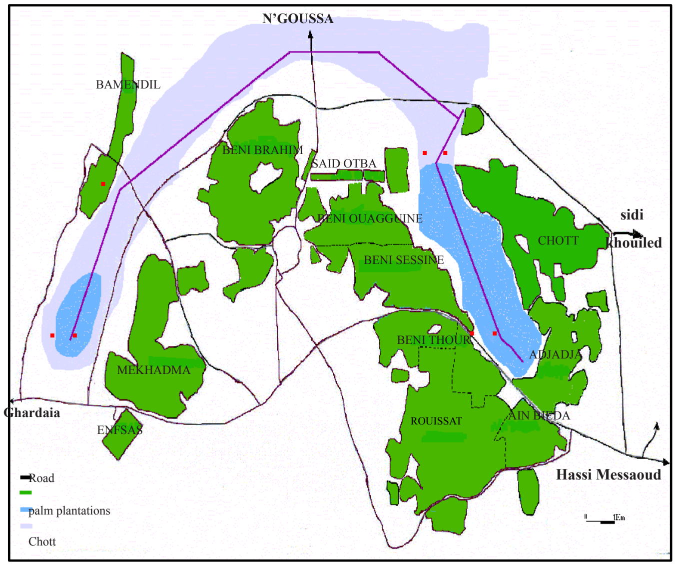

Fig. 3: *The situational plan of the area.*

DOI 10.4409/Am-022-10-0023

Photo 1: *Wastewater spill near the palm plantations.*

Choice of the filter background:

On the basis of a preliminary study carried out on several grounds in the area, it has been determined that the sands of the dunes and rude sands show characteristics favourable to their use as filtering backgrounds. The results of the qualitative analysis of these two supports are shown in Table 1.These sands are soils with textures of fine sand and coarse sand, slightly alkaline with a very low salinity; both soils are composed mainly of quartz. The dunes sand has features which favour its use as a filter.

The study of the performance of sand dunes in the cleansing of wastewater, has been the subject of another publication. The results are very encouraging. The rate of elimination varies between 62% and 97% for BOD5 and between 72% and 96% for COD (Ammour and Touil, 2008a).

Tab. 1: *Physicochemical parameters of sand.*

Paramètres	Sand of dunes	Coarse sand
pH	8.53	7.80
Electrical conductivity (mS/cm)	0.52	0.82
Insolubles (%)	87.94	94.65
Organic matter (%)	0.120	0.086
Permeability (m/d)	0.307	.043
Density (10^3. kg/m^3)	2.60	2.62
The coefficient of uniformity	1.69	2.4

Reconstruction of the Drainage Network

Through this investigation we found the destructive role of excess water in the palm grove, as shown in the photos 2, 3 and 4.

In this section we present the drainage of the palm plantation in determining the amount of water needed for the leaching of the soil and we propose a master plan to evacuate those waters.

Photo 2: *Stagnation of water and destruction of the palms.*

Photo 3: *Erosion of drain.*

Photo 4: *State of the ground and the formation of salt.*

Based on the quality of soil and irrigation water, we estimated the amount of water needed for the leaching of soil to reduce its salinity. The waters of the drainage basin of Ouargla are characterized by a conductivity of more than 5 mS/cm; they have therefore a high salinity (Servant, 1975).Their classification according to the SAR, shows that 50% of samples are classified S4 ie: water with a high concentration of sodium, therefore use in irrigation is not recommended. (US Salinity Laboratory Staff 1954). The study shows clearly that the re-use of drainage water in irrigation requires demineralization.

The flow of drainage water (IHAB 1984) (see Tab.2).

For drainage water, we estimated values for two conductivities:

- electrical conductivity: E.C.=8 mS/cm (average value of tolerance of the date palm).
- electrical conductivity: E.C.=15 mS cm (maximum value of tolerance of the date palm).

Tab. 2: *Determination of drainage flow of the palm plantation of Ouargla.*

N°	Zone	Surface (ha)	electrical conductivity (mS/cm)		Drainage flow (m^3/d) E.Cd. = 8.00 mS/cm		Drainage flow (m^3/d) E.Cd.=15.00 mS/cm	
			winter	summer	winter	summer	winter	summer
1	ENFSAS	32.00	3.63	3.63	685.29	548.23	507.16	405.73
2	Bamendil	84.59	2.08	2.08	1406.17	1124.94	872.92	698.34
3	Mekhadma	307.20	3.55	3.58	6551.54	5249.89	4794.97	3858.26
4	Beni Brahim	322.44	3.58	3.68	6887.92	5536.10	5062.08	4126.33
5	Said Otba	67.10	5.84	5.85	1142.68	911.47	1378.36	1103.37
6	Beni Ouaguine	124.34	6.14	5.99	1917.02	1616.80	2597.43	2061.50
7	Beni Sessine	179.87	4.33	4.28	3858.75	3092.92	3191.11	2535.24
8	Beni Thour	110.87	4.41	4.49	2369.63	1887.08	1988.29	1607.25
9	Rouissat	437.57	4.50	4.50	9303.83	7443.07	7939.27	6351.42
10	Ain Bieda	163.10	6.20	6.20	2457.26	1965.81	3417.11	2733.69
11	Adjadja	179.65	5.80	5.80	3094.65	2475.72	3681.07	2944.86
12	Chott	308.74	6.00	6.00	5001.59	4001.27	6402.03	5121.63
	TOTAL	2317.47			**44676.32**	**35853.31**	**41831.83**	**33547.62**

Perfecting the master plan:

According to the survey on the ground and bearing in mind the type of palm plantation (traditional) and its topography, we find that the only disadvantaged areas are the palm plantation of Ain Bieda and part of the palm plantation of Rouissat which are situated in an area where low pumping is necessary. The master plan is to make a reprofiling of former drains and direct their discharges to the main drain. We found it necessary to verify conditions for disposing of main drains and make recommendations to ensure the proper functioning of drains (see Tab.3). The relationship used is that of Chezy, considering that the flow is uniform. (Hullin, 1983)

Tab. 3: *Checking flow conditions.*

ZONES	Width (m)	Slope Coefficient	Depth (m)	Slope %	Observations
ENFSAS	2.40	0.80	1.10	0.04	Sufficiently wide, this drain is used to evacuate wastewater
Bamendil	-				There is no drain in this area
Mekhadma	4.20 3.30	0.86 0.93	1.10 1.30	0.02 0.02	Drain is sufficiently wide
Beni brahim	3.50	1.14	1.10	0.02	Drain is insufficient; drain depth must be increased to 30 cm
Said Otba					There is no drain for this zone
Beni Ouaguin	1.30	0.57	0.90	0.02	Drain is insufficient; the drain depth must be increased to 30 cm
Beni Sessine	1.20 1.30	0.3 0.57	1.10 0.9	0.02 0.02	Drain is insufficient; the drain depth must be increased to 20 cm
Beni Thour	4.20	1.43	1.30	0.02	Sufficient drain
Rouissat	3.60	1.00	1.50	0.01	Drain is insufficient; the problem of pumping needs to be resolved
Adjadja	3.20	0.75	1.80	0.02	Sufficiently wide
Chott	2.30	0.50	2.30	0.03	Sufficient drain

DOI 10.4409/Am-022-10-0023

Broadly speaking, the existing drainage system is adequate in terms of width and layout (see Fig. 4). But a reprofiling is necessary in some areas, to increase the depth and improve the condition of drains (in the cases of Beni Brahim, Beni Sessine and Beni Ouaguine).

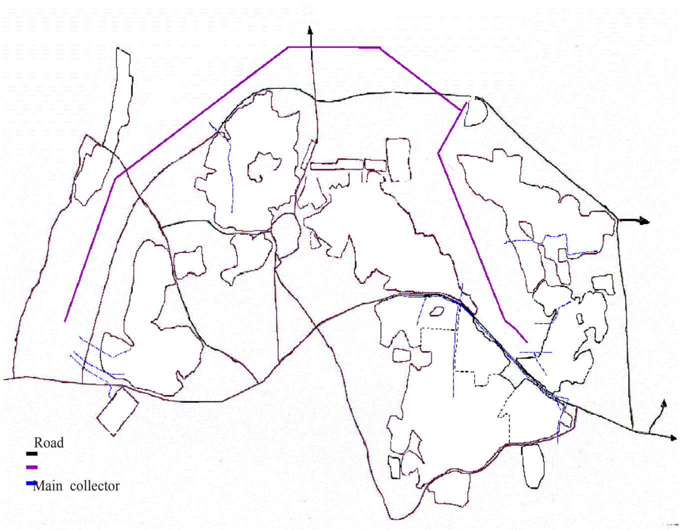

Fig. 4: *Location of main drains in palm plantations.*

For other regions (Bamendil, Said Otba) the drainage system is non-existent and it is therefore necessary to provide for the realization of drains after a thorough study. On the West (Rouissat, Ain Bieda), the existing discharge station must be strengthened and its modus operandi be reviewed. (This station discharges wastewater and part of the drainage from Rouissat and Ain Beida). By improving drainage conditions, a capacity of 37,689.72 m^3/d could be achieved which will supply the groundwater, resulting in a rise of the latter, of 14 mm/year. To avoid this we need to re-use some of the drainage water for irrigation.

Re-Use of Drainage Water after Desalination

The characteristics of drainage raw water:

The size of our station is based on the quality water drain of Ain Beida, representing an electrical conductivity of 15 mS/cm (Table 4).

The technique used (Reverse Osmosis):

The molality is determined by the following relation: (Dupont, 1977a)

$$m_i = \frac{C_i \cdot 1000}{\left[M_i\left(10^6 - TDS\right)\right]} \qquad TDS = \sum C_i$$

Ci: Concentration of the element i (mg/l)
Mi: molecular weight of the element i (g)
TDS: Total dissolved salts (mg/l) (show Table 4)

In our case, we opted for two stages, each of which works with a conversion of 50% (Dupont, 1977b). To increase the system recovery, we opted for a configuration rejection staging.

Reverse Osmosis plant design:

Calculations were performed for three different arrangements: 2/1, 3/2 and 5/3. The results of calculations are shown in Table 5.

To increase the volume of water produced, the desalinated water can be mixed with a quantity of raw water. The flow of raw water and the total flow are determined by the following relationships: (Ammour and Touil, 2008b)

$$Q_t.C_t = Q_p.C_p + Q_b.C_b \qquad Q_t = Q_b + Q_p$$

Qt: The total flow after dilution
Ct: The salinity of water, after dilution, which is taken as 4000 mg/l TDS;
Qp: Flow of desalinated water
Cp: The salinity of desalinated water
Qb:. Raw water flow
Cb: The salinity of raw water

Tab. 4: *Characteristics of drainage raw water.*

Parameters	Concentration (mg/l)	Molality (mol/Kg)
pH	7.8	-
E.C. (mS/cm)	15.	-
Ca^{++} (mg/l)	832.0	0.02098
Mg^{++} (mg/l)	439.0	0.01806
Na^{+} (mg/l)l	1580.0	0.06870
K^{+} (mg/l)	120.0	0.00307
Cl^{-} (mg/l)	3350.0	0.09450
SO_4^{--} (mg/l)	3750.0	0.03904
HCO_3^{-} (mg/l)	268.0	0.00439
Total	TDS = 10339.0	$\sum m_i = 0.25090$

Tab. 5: *The results of calculations of various permeators arrangements.*

Type of arrangement	**2/1**	**3/2**	**5/3**
The feed rate (m^3/d)	5000	5000	5000
The total salinity (mg/l)	10339	10339	10339
The molarity (moles/Kg)	0.2509	0.2509	0.2509
The production rate of the 1st stage (m^3/d)	27.98	29.25	28.83
The rejection rate of the 1st stage (m^3/d)	14.75	18.13	16.80
The product salinity, 1st stage (mg/l)	1210	1065	1117
The rejection salinity, 1st stage (mg/l)	27656	25304	26163
The production rate of 2nd stage (m^3/d)	7.73	9.44	9.01
The rejection rate of 2nd stage (m^3/d)	20.30	17.80	19.06
The salinity of the product 2nd stage (mg/l)	5752	4985	5233
The salinity of rejection 2nd stage (mg/l)	35998	36082	36058
The conversion	0.756	0.751	0.750
The conversion of 1st Stage	0.6590	0.6172	0.6316
The conversion of 2nd Stage	0.2669	0.3469	0.3214
The total number of permeators	177	176	176
The number of permeators in 1st Stage	118	106	110
The number of permeators in 2nd stage	59	70	66
The total production rate (m^3/d)	3757.71	3761.30	3765.96
The total rejection rate (m^3/d)	1197.7	1246	1257.96
The total product salinity (mg/l)	1761	1754	1767

The results are summarized in Table 6.

The values of key parameters for the three variants of arrangements (Tables 5 and 6), differ insignificantly.

It is worth noting that the water flow mobilized after desalination and dilution, is equivalent to two wells operated continuously.

Tab. 6: *Comparison of production rates after dilution, for different arrangements.*

Type of arrangement	2/1	3/2	5/3
The flow of raw water (m^3/d)	1342.04	1332.68	1326.61
The total production rate (m^3/d)	5045.64	5093.98	5092. 57

Conclusion

Through this study, we find that the misuse of water resources has contributed significantly to the destruction of the palm grove. To resolve this problem, we recommend:

•Improving the existing drainage system according to the master plan proposed, in order to remove excess water and reduce areas of stagnant water.

•The use of sand dunes as biological filters may solve the problem of sewage currently mixed with drainage water without treatment and contaminating the groundwater.

•Desalination of drainage water for re-use in irrigation or in the groundwater recharge, reducing the rising groundwater and conserving drinking water.

All proposed solutions must take into account the specificities of the region.

We wanted, through the example of Ouargla, to sound the alarm about the degradation of oases in Algeria. We hope that the message is transmitted and we want concrete actions to be undertaken in the short and medium term to stop this environmental disaster.

Bibliography

Ammour F., Touil Y., Kettab A. (2008) - Use of sands of the dunes like biofilter in the purification of waste water of the town of Ouargla, Proceedings of the 4th Water Resources in the Mediterranean Basin Conference(Watmed4), vol.II, ENPA, Algeria, pp.851-588.

Ammour F., Touil Y. (2008) - Study of opportunities for drainage water reuse in the basin of Ouargla (South of Algeria), Proceedings of EUROMED Desalination conference, Dead Sea, Jordan, p.34.

CNERIB (National Centre for Integrated Studies and Research Building) 1993, autonomous sanitation and semi collective.

Cornet A. (1964) Introduction to Saharan hydrogeology. Rev. Géogr.Phys. & Géol. Dyn., Vol.VI, pp. 5-72.

Dupont Company (1977) - Factors influencing the capacity of reverse osmosis devices, technical bulletin. 501,

Dupont Company (1977) - Predicting the salt passage of the B-9 permeator, technical bulletin, 510.

Gougoussi C. (1979) - Individual sanitation and soil's ability for elimination and purification of sewage effluents, PhD thesis, Polytechnic National Institute of Lorraine, France.

Hullin M. (1983) - Course of drainage, National School of Agricultural Sciences, vol.III, El Harrach, Algeria.

IHAB A. (1984) - Contribution to the determination of the effectiveness of leaching of soil salt, Master, ENGGREF Montpellier, France.

Rouvilois B.M. (1975) - The town of Ouargla (Algerian Sahara). Univ. Public. Sorbone. Paris, France, 52.

Servant J. (1975) - Contribution to the study of halomorphic soils; PhD thesis, Montpellier University, France.

DOI 10.4409/Am-022-10-0023