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Determination of Total Selenium Content in Salty Soils in Lower Cheliff (Algeria)

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ABSTRACT

This work deals with the determination of total selenium content in salty soils perimeter H'madéna located in Lower Cheliff. This work focuses on the analysis and exploitation of the data obtained on the solution of 36 samples from 7 profiles. The main results show that the salinity of soils studied is variable. It covers a wide range of salinity varying between 0.72 dS/m and 51.7 dS/m. Selenium has a specific and independent evolution of salinity and pH variation. The levels of Se are between 0.971 mg/kg to 7.08 mg/kg. These levels are considered high compared to agricultural land use. The change in selenium levels in soil is not related to land use and water stagnation areas.

INTRODUCTION

Salinization is a frequent pedogenic process in soils of Algeria (Daoud 1993, Halitim 1988). The evolution of soil salinity causes a change in the chemical composition of the soil solution. The variation of the concentration of the soil solution is proportional to the electrical conductivity for certain ions, it can be particular for other ions involved in the precipitation of the mineral or the ion exchange phenomenon (Laoufi 2010, Ait Mechedal 2011, Boussoussa 2012).

The soils of the Lower Cheliff are generally affected by salinization (Durand 1956, Daoud 1993, Douaoui 2005, Hadj Miloud 2010). This salinity is related to the nature of relatively rich alluvium of soluble salts, the quality of irrigation water and low water table depth (Durand 1956).

With geochemical standpoint, trace elements are metals whose total content in the soil does not exceed 0.1% (Zovko & Romic 2011).

Selenium (Se) is a non-metallic element. It is in the form of elementary selenium (Se(0)), selenide (Se^{2-}) selenite (Se^{4+}), selenate (Se^{6+}), and organic selenium. Selenium speciation in soils is regulated by redox conditions, pH, availability of absorbent surfaces, and biological processes. Selenium is nutritionally essential in small amounts, but at higher doses it causes diseases and potential adverse effects in humans (Santos et al. 2015). The maximum allowable concentration in soils used in agriculture is about 5 mg Se/kg (Hazelton & Murphy 2007). Its total average content in soils is in the order of 0.44 mg/kg. Selenium soil can be inherited from the parent material, it can come from atmospheric deposition from anthropogenic sources such as foliar sprays, seed treatment and fertilizers (Kabata-Pendias 2011). The levels of selenium in soil of Algeria range from 2.21 mg/kg in the region of Tiaret and 6.23 in the region of Khroub (Beladel et al. 2013).

In saline soils, selenium speciation does not seem related to the salinity status (Tuttle et al. 2014). However, according to Bañuelos et al. (2013), the increase in the level of soil salinity leads to the increase of the selenium level. Moreover, irrigation with saline water causes an increase of the selenium content in the soil (Centofanti & Banuelos 2015).

This work deals with the determination of total selenium content in salty soils of Lower Cheliff (Algeria).

MATERIALS AND METHODS

Soil samples

This work was performed on samples from soil perimeter H'madéna which is located in the plains of Lower Chéliff. The latter part of the valley of Wadi Chéliff, is located in the northwest part of Algeria.

The scope of H'madéna has an area of about 252 hectares. The 36 studied samples coming from 7 profiles were selected to cover a wide range of salinity (Fig. 1).

The profiles A503, A573, A570, A567 and B217 are located in a cultivated area in barley. The profiles A495, A922 are located in a fallow area.

Methods of Study

Samples of soil taken were first dried in the open air and then sieved to 2 mm.

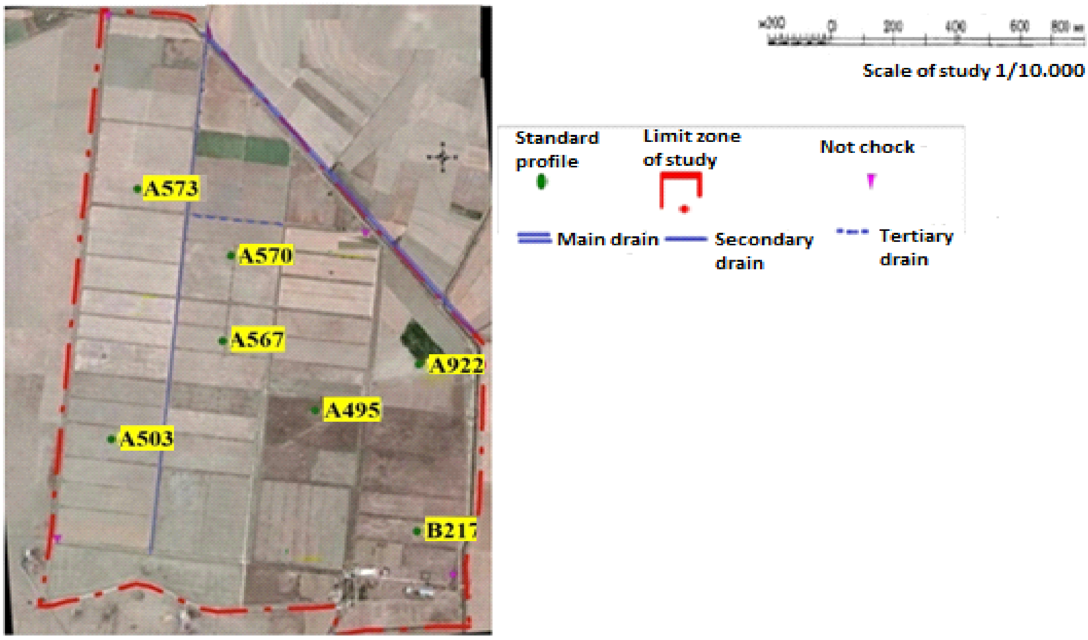

Fig. 1: Map of the location of the profiles in the H'madéna station.

The soil solution was obtained from the extract of saturated paste (USSL 1954). The following analysis were performed on the soil solution using the methods recommended by the USSL (1954). The electrical conductivity was measured by electrical conductivity meter and the pH by pH meter.

Analysis of the total selenium is performed according to the method recommended by EPA (1998). The method consists on a test sample of 0.5 g of soil, digestion assisted by microwaves is carried out by a mixture of nitric acid (HNO_3) and hydrochloric (HCl) (a ratio of 3: 1 (HNO_3: HCl)) and aqua regia. The samples analysis was made by Agilent Technology SAA 240Fs/240Z with a graphite furnace Zeeman correction.

RESULTS

Characterization of Soil Solution

Soil solution is characterized by an electrical conductivity that covers a wide range of salinity. The values obtained were between 0.72 dS/m for the sample B217 H1, and 51.7 dS/m for the sample A495 H5. Increasing salinity is accompanied by a sodification of the clay-humus complex. The pH values ranged from 7.03 for the sample H3 A573 and 8.36 for the sample H1 A567. The pH values show an alkalinity of the soil reaction (Table 1).

The Total Contents of Selenium

The content of selenium ranges from 0.971 mg/kg to 7.08 mg/kg (Table 2). These levels are high compared to a level of 1 mg/kg recommended by CCME (2009). According to the standards reported by Tan et al. (1994), soil with total Se equal to or < 0.15 mg/kg is deficient soil, grading 0.75-0.40 mg/kg is an average soil, a content >0.40 mg/kg is high soil, and excessive soil with a content of >3.0 mg/kg. The samples in this study were ranked between high and excessive.

Distribution of Salinity and Selenium in Profiles

The study of salt distribution profiles reveals the existence of two types of saline profiles. Fig. 2 shows a distribution of the salts according to a descending gradient, and the salinity increases with depth. This type of distribution, out of five profiles, corresponds to a saline profile type D (Servant 1976). Fig. 2 also shows another type of salts distribution. This type of profile has a maximum concentration of salts in medium depth, which concerns two profiles (A503, A570). According to Servant (1976), this distribution corresponds to a convex profile salt type B.

The distribution of selenium is heterogeneous. This distribution does not follow the distribution of salinity except for the B217 profile.

Statistical Analysis

Descriptive statistics: The value of EC ranged between 0.725 dS/m and 51.7 dS/m, with an average of 17.614 dS/m. The minimum of Se value is equal to 0.971 mg/kg, and the maximum value of Se equal to 7.083 mg/kg, with an average of

Table 1: Characterization of the soil solution.

Profile	Horizon	EC (dS/m)	pH
A 495	H1	4.95	8.3
	H2	11.18	7.45
	H3	26.1	7.95
	H4	32	7.97
	H5	51.7	7.5
A503	H1	8.66	8.29
	H2	16.82	8.15
	H3	31.5	7.49
	H4	25.9	8.01
	H5	24.4	8.15
	H6	23	8.17
A567	H1	1.55	8.36
	H2	7.27	7.73
	H3	20.3	7.65
	H4	29.7	7.51
	H5	30.5	7.47
A570	H1	3.14	8.34
	H2	14.38	7.41
	H3	25.6	7.98
	H4	25.3	7.87
	H5	23.9	7.92
A573	H1	1.63	7.91
	H2	4.76	7.7
	H3	10.26	7.03
	H4	11.87	7.82
	H5	12.78	7.73
	H6	14.88	7.15
A922	H1	5.1	8.38
	H2	13.3	8.29
	H3	20.4	7.79
	H4	41.2	7.67
	H5	37.7	7.53
B217	H1	0.72	8.24
	H2	3.57	8.04
	H3	8.43	7.53
	H4	9.63	7.47

Table 2: The content of selenium in soil.

Profiles	Horizons	EC (dS/m)	Se (mg/kg)
A 495	H1	4.95	2.34
	H2	11.18	5.43
	H3	26.1	1.22
	H4	32	0.97
	H5	51.7	7.08
A503	H1	8.66	4.8
	H2	16.82	1.42
	H3	31.5	4.65
	H4	25.9	2.11
	H5	24.4	1.98
	H6	23	1.87
A567	H1	1.55	1.45
	H2	7.27	5.23
	H3	20.3	2.34
	H4	29.7	5.74
	H5	30.5	2.13
A570	H1	3.14	5.43
	H2	14.38	1.87
	H3	25.6	1.98
	H4	25.3	1.11
	H5	23.9	1.78
A573	H1	1.63	1.56
	H2	4.76	4.67
	H3	10.26	2.53
	H4	11.87	2.67
	H5	12.78	5.46
	H6	14.88	2.87
A922	H1	5.1	4.97
	H2	13.3	1.64
	H3	20.4	4.03
	H4	41.2	5.79
	H5	37.7	2.82
B217	H1	0.73	1.37
	H2	3.57	4.34
	H3	8.43	5.17
	H4	9.63	5.54

Table 3: Descriptive statistics of the variables.

Variable	Observations	Obs. missing data	Obs. without missing data	Minimum	Maximum	Average	Standard deviation
EC (dS/m)	36	0	36	0.730	51.700	17.614	12.465
Se (mg/kg)	36	0	36	0.970	7.080	3.288	1.770
pH	36	0	36	7.030	8.380	7.832	0.355

3.288 mg/kg. The maximum of pH value is 8.38 and the minimum value is 7.03, with an average of 7.83 (Table 3).

Correlation matrix: For DOF equal to 34 and α equal to 0.5, there are no correlations between the variables (EC, pH, Se) (Table 4).

The best fit model: The recourse to a nonlinear regression makes it possible to give the following model (Fig. 3), whose equation is $Se = 4.34 - 0.16 \times EC + 3.97 - 0.3 \times EC^2$. Coefficients of adjustment of the model are presented in Table 5.

DISCUSSION

Soil solution is characterized by a variable electrical conductivity. It covers a wide range of salinity with unsalted level (EC < 2 dS/m) to a very salty level (EC > 16 dS/m) according to the norms of USSL (1954). The pH reveals a relatively alkaline soil.

The salts distribution profile revealed the presence of two types of saline profiles. Both types of salt profiles were characterized by a descending salt gradient, only the loca-

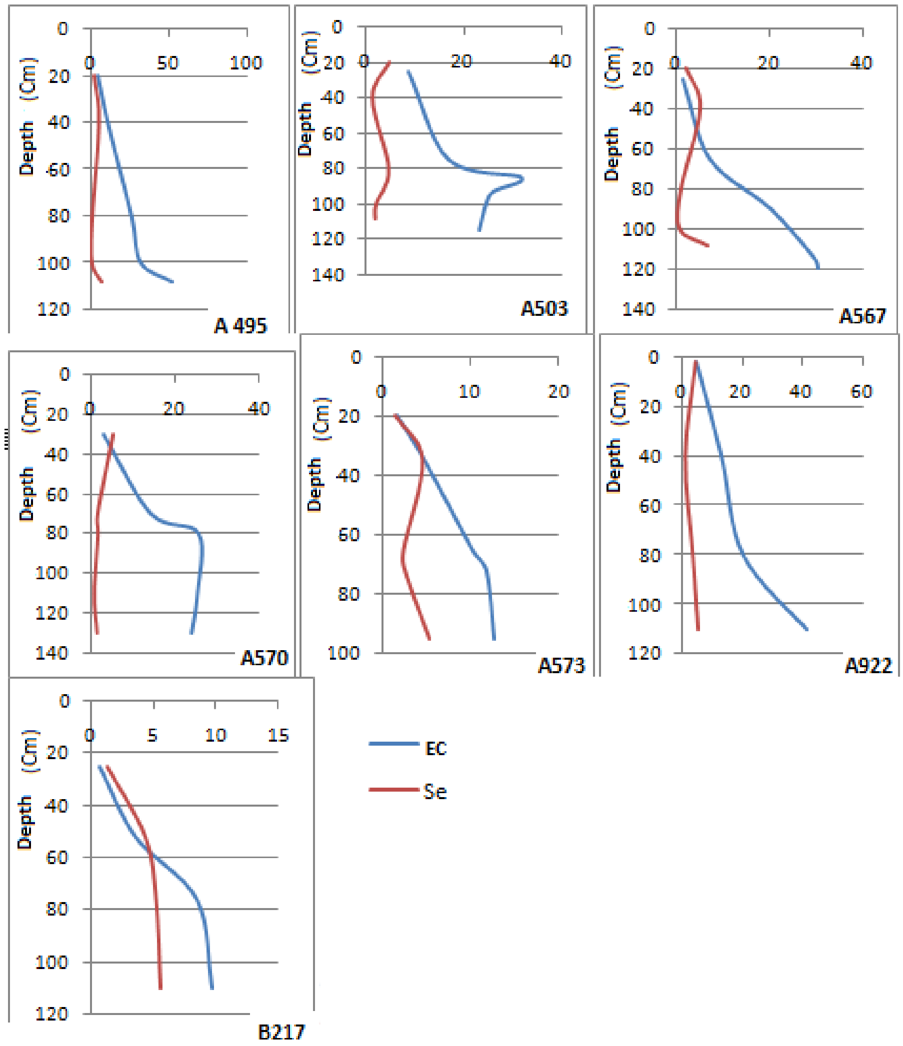

Fig. 2: Distribution of salinity and selenium in profiles.

tion of the maximum salinity level differs. The distribution of Se in the profiles does not follow the gradient of salinity.

The increase in salinity with depth is due to partial leaching of salts in surface horizons during the rainy period (Servant 1976). The inefficiency of the drainage system prevents the removal of soluble salts and cause accumulation in average depth or base profile (Daoud 1993). The intensity of leaching depends on soil infiltration properties that would be conditioned by the relatively fine texture and structure affected by sodicity of the clay-humus complex (Saidi et al. 2004, Douaoui et al. 2004). The distribution of Se in the profiles appear to be controlled by different parameters other than salinity.

The content of Se in soil is higher for agricultural soils (CCME 2009), while soil which contains over 3ppb of the total Se can be defined as excessive for human nutrition (Hawkesford & Zhao 2007). The total selenium indicates the bioavailable selenium in soil (Statwick & Sher 2017). Fallow land or cultivated land does not control the variation of selenium levels in the soil. Water stagnation zones have a relationship with the salinity, but do not have it with selenium content.

Salinity and pH variation does not control the distribution of Se. This result confirms the work of Tuttle et al. (2014) and Matos et al. (2017), and contradictory to the work of Rodriguez et al. (2005). Selenium does not seem to be controlled by precipitation phenomena, although it has an affinity to the sulphate salts other than gypsum (Gerla 2011), while Hmadana soils are undersaturated vis-a-vis the gypsum (Ait Mechedal 2014). Selenium might be control-

Table 4: Correlation between variables.

Variables	EC dS/m	Se mg/kg	pH
EC (dS/m)	1	0.059	-0.323
Se (mg/kg)	0.059	1	-0.289
pH	-0.323	-0.289	1

Table 5: Goodness of fit statistics.

Observations	36.000
DF	33.000
R^2	0.177
SSE	90.334
MSE	2.737
RMSE	1.655

led by the oxidation-reduction which increases the mobility of Se. While hydroxides and clay fraction decreases its mobility (Kabata-Pendias 2011).

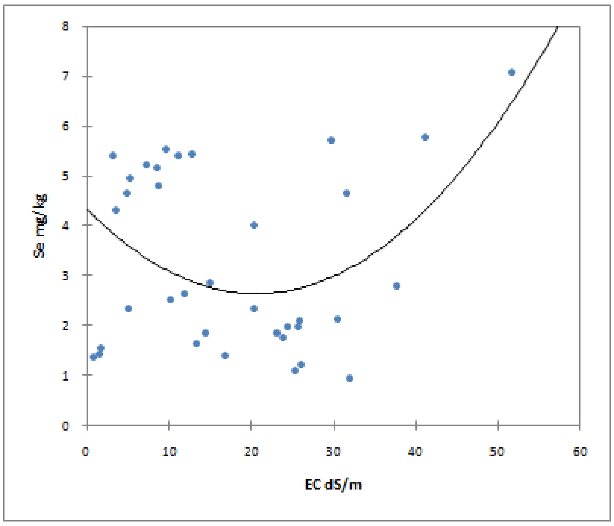

Fig. 3: Nonlinear regression (Se mg/kg).

CONCLUSION

This work focuses on the characterization of soil salinity status perimeter Hmadena located in Lower Cheliff, and the determination of the total selenium content. This work focuses on the analysis and exploitation of data obtained from 36 samples from 7 profiles.

The main results show that the salinity of soils studied is variable. It covers a wide range of salinity varying between 0.72 dS/m and 51.7 dS/m. The pH reveals a relatively alkaline soil. The evolution of selenium concentration is specific and independent on salinity and pH variation.

The salts distribution profile revealed the presence of two types of saline profiles. These profiles are characterized by a descending salt gradient, only the location of the maximum salinity level differs.

The levels of Se are between 0.971 mg/kg and 7.08 mg/kg. These levels are considered high compared to the agricultural land use. The change in selenium levels in soil is not related to land use and water stagnation areas.

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