Laboratory Percolation Experiments with Saline Soils from Syria

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In general, it can be said that irrigation water of low or moderate salinity having a low sodium adsorption ratio [SAR $= Na^{+}.(Ca^{2+} + Mg^{2+})^{-1/2}$, where Ca^{2+}, Mg^{2+} and Na^{+} represent the concentration of the cations in me.] can safely be used for the irrigation of plants of moderate salt tolerance on soils of moderate permeability. However, the situation becomes complicated when the soils are not only extremely saline, but also contain a high content of water soluble sodium in relation to calcium and magnesium (high SAR-value). In the course of soil analyses carried out on behalf of irrigation and drainage projects in the Euphrates Basin of Syria such conditions were found in several areas.

When enough water is available and the soils are sufficiently permeable, high salinity can be lowered. However, it is difficult to predict what will happen with the exchangeable sodium percentage (ESP) in the deeper layers when the irrigation water, having originally a low SAR value, is mixed with the salts present in the soil and percolates through the lower horizons.

To study this problem percolation experiments were conducted in the laboratory with saline soils and water of the same composition as Euphrates water collected during the dry season.

Materials and methods

Materials

Artificial "Euphrates water" of the composition shown in Table 1 was used. Due to some hydroxide present in the carbonates used to prepare this water, the pH of the solution was 8.3 as compared to 7.8 for the Euphrates water. Soil samples from 4 sampling sites in an experimental field near the Euphrates west of Raqqa in Syria were used. The samples were numbered: 1/2, 3/4, 5/6 and 7/8 representing respectively topsoils (0—20 cm), subsoils (20—40 cm). The composition of the water soluble salts in these samples is presented in Table 2.

Methods

40 grams of each sample were put in percolation tubes, the topsoils on top of the subsoil and separated by a disc of nylon cloth. In order to obtain a more or less uniform packing of the soil, all the tubes were placed

Table 1

Ionic composition of Euphrates water (m.e./liter)

pH	EC mmhos/cm	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^{2-}	SAR
7.8	0.51	2.20	1.48	0.13	1.39	3.03	1.07	1.08	0.01	1.0

in a reciprocating shaker for 10 minutes. Subsequently, they were leached with "Euphrates water", keeping a constant head of 10 cm above the soil columns.

The amount of water leaching from the tubes was checked and the decrease in the electrical conductivity (EC) of the leachates was registered. When the EC had decreased to about 4 mmhos/cm or lower, which in most cases took approximately 70 hours, the percolation was stopped (short percolation).

In a second series the percolation was continued for about 100 hours (long percolation).

After completion of the leaching experiment the soil was pressed out of the tubes and the topsoil and subsoil samples separated. After drying at 40 °C they were analyzed for texture, % $CaCO_3$, exchangeable bases, cation exchange capacity (CEC.), ESP and the electrical conductivity of the 1 : 5 water extracts (EC_5).

Short description of the analytical methods

Texture

To get rid of excess salts, the soil was shaken with water for two hours, centrifuged with a superspeed centrifuge and the supernatant solution discarded. This was repeated twice. Subsequently, the soil was shaken for two hours with a dispersing agent containing sodium-pyrophosphate and sodium carbonate. The suspension was sieved over a 200 micron sieve and a 50 micron sieve, respectively for the separation of the coarse and fine sand fractions. The material passing through the 50 micron sieve was collected in glass cylinders and the coarse silt, fine silt and clay fractions determined by the conventional pipette method.

With this method any free carbonates present in the soil remained in the various fractions. Other investigations have shown that, these particular soils contain "pseudosilt", which means that clay minerals are present in the silt fraction as aggregates or coatings which are difficult to disperse.

% $CaCO_3$

The well-known Scheibler method was used. The soil was treated with hydrochloric acid and the volume of the resulting CO_2 measured.

Table 2

Soluble constituents of soil samples as determined with 1 : 5 water extracts m.e./100 g

Sample no.	EC_5 mmhos/cm	Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^{2-}	SAR
1	14.80	22.80	13.00	0.31	39.2	tr	0.21	75.4	0.18	1.65	9.3
2	6.78	8.04	4.77	0.17	20.8	tr	0.19	33.5	tr	0.63	8.2
3	13.80	23.50	16.30	0.47	31.7	tr	0.30	70.9	0.24	1.48	7.1
4	6.18	8.14	4.96	0.20	16.9	tr	0.25	30.5	tr	0.41	6.6
5	16.20	36.20	17.60	0.34	32.5	tr	0.21	84.6	1.96	1.22	6.3
6	4.82	4.61	3.94	0.17	14.2	tr	0.25	20.6	0.44	0.17	6.9
7	7.17	11.70	9.74	0.07	17.1	tr	0.22	33.3	5.15	0.12	5.2
8	8.37	10.10	9.52	0.16	23.7	tr	0.26	39.6	2.85	0.34	7.6

Exchangeable bases and CEC

Excess salts were washed out with water—alcohol and subsequently the soil was leached with ammonium acetate—alcohol of pH 8.2. In the leachate exchangeable Ca, K and Na were determined with the flamephotometer and Mg with the atomic absorption method.

The same aliquots of soil were saturated with sodium acetate, the excess of which was removed with pure ethyl alcohol. Subsequently, the adsorbed sodium was extracted with ammonium acetate of pH 8.2 and and in the leachate sodium was determined flamephotometrically. The content of Na expressed in me/100 g oven-dry soil represented the CEC. From this value and the exchangeable sodium content the ESP was calculated.

Electrical conductivity 1 : 5 water extracts (EC_5)

The soil was shaken with water at a 1 : 5 soil-water ratio for two hours. In the filtrate the EC was measured with a conductivity meter.

Results

The experimental results are graphically presented in Figs. 1—4 A and B. The Figs. 1 A to 4 A showing the change in percolation rates during the experiment. These percolation rates are expressed in terms of hydraulic conductivity which can be calculated from:

$$K_w = \frac{Q \cdot L}{A \cdot H}$$

in which K_w — hydraulic conductivity (mm/hr).
Q = volume of water moving through the soil column per unit of time (mm³/hr).
L = height of the water satured soil column (mm).
A = surface area of the column (mm²).
H = height of water soil column (mm).

Figs 1 B to 4 B show the decrease in electrical conductivity (mmhos/cm) of the leachates during the experiment.

The results of the analyses of soil samples before and after the experiments are presented in the Table 3.

Discussion

As shown in Fig. 1(1A--4A), the graphs for the two series (short and long percolation) run fairly close especially for the fine-textured soils 1/2 and 7/8. This indicates that the packing was rather uniform. For the more sandy soils 3/4 and 5/6 it was less regular.

In all cases the initial hydraulic conductivity (permeability, percolation rate) was higher than at the end of the experiment, the only exception being samples 5/6 (Fig. 1/3A) where the initial percolation rate was relatively high. It remained more or less constant during the first 20 to 30 hrs. and declined only slowly afterwards. The higher initial permeability was most probably due to the flocculating action of the high content of the salts present in the soil. After the greater part of the salts had been leached, the soil became more dispersed.

The difference in hydraulic conductivity between the two fine-textured soils 1/2 (Fig. 1/1A) and 7/8 (Fig. 1/4A) is interesting. The low permeability in soils 1/2 was as expected for a soil with a high content of silt and clay, only a small amount of fine sand and practically no coarse sand, especially in the subsoil (see Table 3). In the other fine-textured soil 7/8 (Fig. 1/4A) the high initial percolation rate was very surprising.

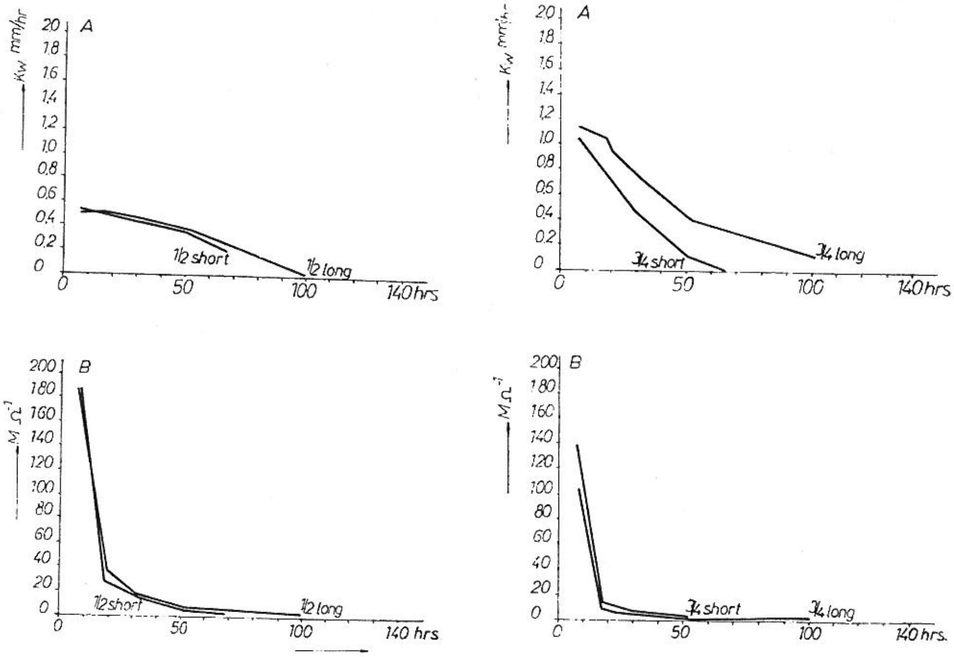


Fig.

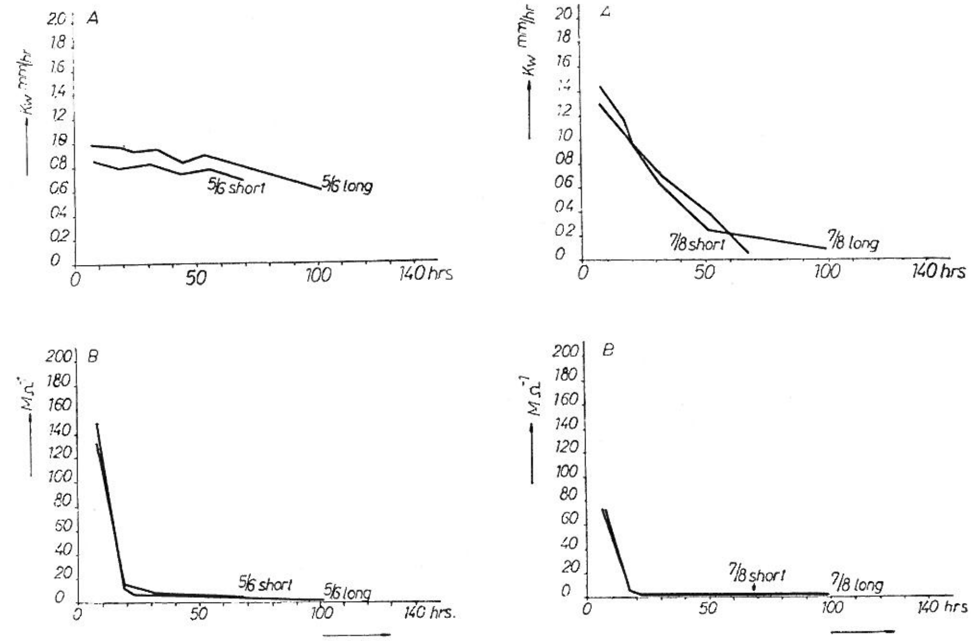
Changes in both hydraulic (A) and electrical (B) conductivity

The Fig. 1(1B—4B) show that in all cases the EC values of the leachates decreased rapidly during the first 20 hrs. Apparently, the greater part of the salt was leached during this period, whereas the removal of the remaining salt took place at a much slower rate.

Insufficient material was available to determine the EC_e (saturation extract) in the samples after the experiment, but the EC_5 values (1 : 5 extracts) in Table 3 show that in all cases the soluble salts decreased to a low level, both in topsoil and subsoil. The topsoils show little or no differences in the EC_5 values between long and short percolation periods indicating that after percolation periods practically all of the salts had been removed. In the subsoil, however, the contrast was greater. In the finer-textured samples 2 and 8 it seems that, even with long percolation, not all the salts had been leached. In Table 3 it is shown that in all topsoils the ESP had decreased strongly. As already mentioned, during the first 20 hours of the experiment a large part of the salts were leached out of the topsoil + subsoil samples and it can be safely assumed that after this period the topsoils were treated with pure "Euphrates water". Because of its low SAR value, the decrease of the ESP in the topsoils was expected.

With regard to ESP the subsoils behaved differently. Only for sample 6 did this percentage decrease greatly and only after long percolation. In other cases ESP increased (sample 2) or remained practically the same (sample 8). In sample 4 it increased after short percolation, but long percolation resulted in a somewhat lower value than short percolation.

In connection with both percolation rate and ESP the samples 5/6



1.
with time. From left to right graphs 1, 2, 3, 4

Table

Analytical data of soil samples

Sample no	Texture, %					% $CaCO_3$	% $CaSO_4$
	2 mm—200 mμ	200—50 mμ	50—20 mμ	20—2 mμ	< 2 mμ		
1 B.P.	0.4	1.5	15.0	51.0	32.1	18.6	—
1 A.P. short	0.4	1.6	11.1	48.7	38.2	21.4	—
1 A.P. long	0.4	1.5	8.6	53.2	36.3	23.9	—
2 B.P.	0.1	0.7	11.1	56.2	31.9	21.5	—
2 A.P. short	0.0	0.7	15.3	50.2	33.8	23.8	—
2 A.P. long	0.0	0.8	12.5	51.3	35.4	23.7	—
3 B.P.	4.2	13.6	15.7	37.8	28.7	20.5	—
3 A.P. short	4.1	14.4	13.2	40.8	27.5	20.5	—
3 A.P. long	4.2	12.9	11.2	49.5	22.2	19.9	—
4 B.P.	1.6	8.2	15.5	44.3	30.4	20.0	—
4 A.P. short	1.2	7.1	12.7	48.5	30.5	21.0	—
4 A.P. long	1.3	7.2	17.2	42.4	31.9	21.3	—
5 B.P.	0.3	2.3	14.4	48.9	34.1	19.1	0.62
5 A.P. short	0.2	2.1	11.8	49.3	36.6	21.1	—
5 A.P. long	0.2	2.5	11.6	47.8	37.9	21.8	—
6 B.P.	0.1	4.9	15.0	47.5	32.5	19.3	—
6 A.P. short	0.1	5.0	14.8	45.0	35.1	21.4	—
6 A.P. long	0.1	5.8	15.6	44.0	34.5	22.3	—
7 B.P.	0.6	1.0	8.3	64.4	25.7	23.0	0.33
7 A.P. short	0.0	0.5	3.5	62.6	33.4	23.3	—
7 A.P. long	0.0	0.4	3.6	63.7	32.3	23.9	—
8 B.P.	0.8	1.7	11.0	64.2	22.3	23.6	0.17
8 A.P. short	0.0	0.7	8.4	61.4	29.5	21.2	—
8 A.P. long	0.1	0.7	9.5	56.0	33.7	21.9	—

B.P. = before percolation

behaved quite differently from the others. The deviating conduct cannot have been exclusively due to the more sandy character of these soils or samples 3/4 with even higher sand contents would have shown the same characteristics. An explanation of the divergence in behaviour may be found in the presence of gypsum (0.62% $CaSO_4$) in topsoil sample 5 (Table 3). The gypsum content of these sand-containing soils would seem to be sufficient to maintain permeability at a relatively high level even after long percolation. Apparently, the higher percolation rate prevented the preferential adsorption of sodium from the salt solution. Moreover, the calcium released by the slowly dissolving gypsum probably had a favourable influence on the composition of the salt solution, decreasing its SAR value in such a way that the exchangeable sodium originally present was partly exchanged for other cations.

In all other cases the percolation rate was so low that during long contact with a salt solution having a high SAR value, preferential adsorption of sodium took place. This process was not most conspicuous in sample 2 which had an ESP twice as high as the original, even after long percolation.

The surprisingly high initial hydraulic conductivity in the fine textured samples 7/8 may have been due to a combined flocculating action of a high salt content and the presence of gypsum (Table 3). It seems that in these soils the gypsum content was not sufficient to maintain the original permeability, but on the other hand it prevented further adsorption of sodium and the ESP did not change.

3

before and after percolation

Exchangeable bases, m.e./100 g						ESP	EC_e mmhos/cm	EC_s mmhos/cm
Ca^{2+}	Mg^{2+}	K^+	Na^+	sum	CEC.			
16.0	7.99	0.40	0.76	25.15	23.70	3.2	104	14.80
21.9	6.68	0.89	0.23	29.70	30.29	0.8	—	0.27
21.1	6.86	0.84	0.26	29.06	29.83	0.9	—	0.21
13.2	8.27	0.34	1.24	23.05	24.1	5.2	62	6.78
18.3	4.77	0.81	3.21	27.09	29.10	11.0	—	0.40
18.3	5.81	0.78	2.98	27.87	29.10	10.2	—	0.34
12.3	6.36	0.30	0.44	19.40	21.80	2.0	126	13.80
16.9	5.39	0.95	0.08	23.32	22.71	0.4	—	0.22
16.7	6.00	0.89	0.08	23.67	22.71	0.4	—	0.20
14.6	6.05	0.22	1.07	21.94	24.60	4.4	60	6.18
16.3	5.87	1.02	1.87	25.04	28.04	6.7	—	0.36
16.8	6.82	1.00	0.90	25.52	26.67	3.4	—	0.25
20.6	9.83	0.25	0.59	31.27	29.20	2.0	126.0	16.20
20.9	6.25	0.91	0.08	27.98	28.61	0.3	—	0.18
20.9	6.34	0.82	0.10	28.16	29.54	0.3	—	0.18
15.5	6.42	0.25	1.99	24.16	26.00	7.7	45.4	4.82
18.8	7.46	0.95	0.43	27.64	29.07	1.5	—	0.31
18.5	7.63	0.95	0.14	27.22	29.07	0.5	—	0.19
15.9	8.15	0.12	1.10	25.27	26.60	4.1	50.0	7.17
19.4	7.35	0.55	0.19	27.49	28.74	0.7	—	0.21
18.8	7.43	0.52	0.21	27.01	29.21	0.7	—	0.19
13.4	7.01	0.17	1.67	22.25	24.70	6.8	62.0	8.37
17.2	7.17	0.73	1.65	26.68	29.01	5.7	—	0.33
16.8	7.18	0.67	1.56	26.21	28.10	5.6	—	0.29

A.P. = after percolation

In Table 3 interesting facts are shown. In the first place it seems that percolation resulted in an increase in the clay content and an increase in the CEC in the fine-textured soils 1/2 and 7/8. In the more sandy soils 5/6 the difference in clay content and CEC before and after percolation was negligible. In the other, coarser-textured, samples 3/4 there was not much difference in CEC in the topsoil, but after long percolation an accumulation took place in the fine silt fraction (20—2 micron) due to a dispersion of coarse silt (50—20 micron) on the one hand and aggregation of clay on the other hand. In the subsoil sample the clay content remained more or less the same, but there was a redistribution within the coarse and fine silt fractions, which was accompanied by an increase of CEC especially after short percolation.

These changes in particle distribution had an influence on the percolation rate. This change is shown in Fig. 1(1A – 4A).

A second interesting fact is the conspicuous increase of exchangeable potassium that occurred in all samples after percolation. A comparison of the data on exchangeable bases shows that Ca and K were preferentially adsorbed during percolation at the expense of Mg and/or Na.

Conclusions

Although the results of this laboratory experiment cannot be directly extrapolated to field conditions, the assumption is warranted that when sufficient water of medium salinity is available the salt content of highly saline soils can be lowered, provided the excess salts are drained off. However, the danger exists that during this operation ESP will increase, even when water with a low SAR value is used. This occurs mainly under conditions of low soil permeability. The presence of gypsum has a favourable effect, but in fine-textured soils more gypsum will be needed to exert the same influence as in sandy soils.

Summary

Percolation experiments were conducted to study the effect of the salts present in highly saline soils on salinity and exchangeable sodium percentage (ESP), especially in the lower horizons, when the soil was leached with water of moderate salinity and a low sodium adsorption rate (SAR).

It was shown that under experimental conditions the total salt content could be decreased in topsoil and subsoil. However, the ESP was only decreased when the permeability remained relatively high during percolation. The presence of gypsum in the soil was favourable for increasing permeability and lowering ESP.