Salt-Liberation Capacity of Sodic Soils of the Karabakh Plain in Azerbaijan

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The relationship between the salt composition of a soil and its capacity to give up salts is now sufficiently clear. Yet the processes of salt liberation in sodic-alkaline soils still await further clarification.

In order to find out how separate salts and their mixtures are liberated from different soils, tests with sodium salts were conducted with quartz sand as follows:

1. Sand + 5% solution of NaCl
2. Sand + 5% solution of Na_2SO_4
3. Sand + 5% solution of Na_2CO_3
4. Sand + 5% solution of NaCl + Na_2SO_4
5. Sand + 5% solution of NaCl + Na_2CO_3
6. Sand + 5% solution of Na_2SO_4 + Na_2CO_3
7. Sand + 5% solution of NaCl + Na_2SO_4 + Na_2CO_3

Quartz sand with a particle size of 0.25 – 0.50 mm was poured into meter-long glass tubes 3.7 cm in diameter, thereupon, the tubes were saturated with salt solutions. After leaching the salt-saturated columns successively for five times it was found that (Table 1):

a) Most of the salts were removed from the soil in the first two or three leachings.

b) Because of the uniform texture of the sand, the process of salt removal proceeded in a more or less regular way.

c) In all cases a certain amount of salts remained in the columns probably due to a surface-tension effect in pellicular water.

Thus leaching at field moisture capacity removed from 90.9 to 97.8 per cent of the added salt. The addition of alkali (soda) to chloride had no effect on salt-liberation, but the addition of sulphates did affect it slightly. The addition of soda to sulphates appreciably decreased salt liberation. A similar test was conducted using river clay from the Kura. The total content of water soluble salts in the clay was equal to 0.095 per cent. Chlorides and normal carbonates were absent. The clay contained 0.035 per cent calcium and magnesium sulphates (0.73 me.), 61.8 per cent physical clay and as little as 23 per cent of heavy fraction. The content of bicarbonate was to 3.0 per cent. Total exchangeable bases were equal to 12.4 me./100 g including 68 per cent exchangeable calcium and 31 per cent exchangeable sodium. The columns filled with this clay were saturated with salts and leached. During the test the clay liberated salts in a somewhat different manner (Table 2), than did the quartz sand.

Table 1

Salt leaching from a homogeneous medium (quartz sand)

	Cl^-	SO_4^{2-}	$CO_3^{2-} + HCO^-$	$Cl^- + SO_4^{2-}$	$Cl^- + CO_3^{2-} + HCO_3^-$	$SO_4^{2-} + CO_3^{2-} + HCO_3^-$	$Cl^- + SO_4^{2-} + CO_3^{2-} + HCO_3^-$
	%/ g						
Initial content of salt ions	$\frac{100}{3.42}$	$\frac{100}{4.66}$	$\frac{100}{6.56}$	$\frac{100}{4.01}$	$\frac{100}{4.84}$	$\frac{100}{5.88}$	$\frac{100}{4.73}$
Salts removed							
On 1st leaching	$\frac{20.5}{0.71}$	$\frac{20.6}{0.94}$	$\frac{19.8}{1.30}$	$\frac{21.2}{0.85}$	$\frac{20.8}{1.01}$	$\frac{26.2}{1.54}$	$\frac{22.4}{1.06}$
On 2nd leaching	$\frac{20.0}{0.68}$	$\frac{22.0}{1.03}$	$\frac{21.1}{1.39}$	$\frac{21.2}{0.85}$	$\frac{20.4}{0.99}$	$\frac{19.3}{1.13}$	$\frac{24.8}{1.17}$
On 3rd leaching	$\frac{20.0}{0.68}$	$\frac{23.0}{1.07}$	$\frac{19.8}{1.30}$	$\frac{19.9}{0.80}$	$\frac{22.5}{1.09}$	$\frac{19.7}{1.16}$	$\frac{19.3}{0.91}$
On 4th leaching	$\frac{18.8}{0.64}$	$\frac{19.8}{0.92}$	$\frac{17.7}{1.16}$	$\frac{17.8}{0.71}$	$\frac{19.3}{0.93}$	$\frac{14.4}{0.85}$	$\frac{19.1}{0.90}$
On 5th leaching	$\frac{16.5}{0.57}$	$\frac{12.7}{0.60}$	$\frac{14.2}{0.93}$	$\frac{12.7}{0.51}$	$\frac{12.4}{0.60}$	$\frac{11.3}{0.67}$	$\frac{10.1}{0.50}$
Total	$\frac{95.8}{3.28}$	$\frac{98.1}{4.56}$	$\frac{92.6}{6.08}$	$\frac{92.8}{3.72}$	$\frac{95.3}{4.62}$	$\frac{90.9}{5.34}$	$\frac{96.2}{4.55}$
Retained in test columns	$\frac{4.2}{0.14}$	$\frac{1.9}{0.10}$	$\frac{7.4}{0.48}$	$\frac{7.2}{0.29}$	$\frac{4.7}{0.22}$	$\frac{9.1}{0.54}$	$\frac{3.8}{0.18}$
Amount of water in excess of total field capacity millilitres	120	127.5	115.0	122.0	120.0	122.0	118.0

Table 2

Salt liberation by clay (leaching dose — 2 total field moisture capacities)

Treatments	Total of salts, g	Amount of salts leached in successive portions, %					Total of salts leached	
		1st	2nd	3rd	4th	5th	g	%
Clay + NaCl	7.28	54.5	7.0	11.1	6.6	4.1	6.07	83.3
Clay + Na_2SO_4	6.76	59.1	16.0	7.3	4.6	2.8	6.06	89.8
Clay + Na_2CO_3	5.24	46.9	10.4	6.4	4.4	3.3	3.74	71.4
Clay + NaCl + Na_2SO_4	6.83	38.5	23.3	11.5	7.2	4.8	5.83	85.4
Clay + NaCl + Na_2CO_3	4.89	36.6	14.7	9.3	4.6	4.8	3.42	70.0
Clay + Na_2SO_4 + Na_2CO_3	5.11	41.6	12.5	7.8	4.9	3.5	3.59	70.3
Clay + NaCl + Na_2SO_4 + + Na_2CO_3	4.82	51.5	17.0	10.7	7.3	4.5	4.38	90.0

Clay liberated less salt than sand and retained from 9 to 30 per cent of that added. Soda decreased the salt-liberation capacity of the clay (71 per cent total), and decreased its salt-liberation capacity for sodium chloride and sulphate (by 13—19 per cent). The clay liberated 37—59 per cent of the total salts in the first leaching thus sharply differing from the sand.

These preliminary tests provided grounds for our experimental study of salt-liberation from sodic soils of the Karabakh Plain of Azerbaijan.

Five varieties of meadow-alkaline sodic soils were selected for the experiment:

1. a soda-sulphate solonetz-solonchak (profile pit 244);
2. a sulphate-soda medium-saline solonetz (profile pit 337);
3. a chloride-soda slightly saline solonetz (profile pit 850);
4. a strongly alkaline, medium-saline, soda-sulphate meadow soil (profile pit 468);
5. a slightly alkaline, slightly saline meadow soil (profile pit 236).

Table 3 shows data for some of the properties of these soils.

Samples from the arable layer of the soils were passed through a 2 mm-mesh sieve and poured into tubes. The soils were wetted to field moisture

Table 3

Certain properties of soils under study

Soil	$CaCO_3$ %	Physical clay %	Total of salts %	CO_3^{2-}	HCO_3^-	Total of exchange bases, me	% of total	
				%/me			Mg^{2+}	Na^+
Solonetz-solonchak	10.1	61.8	0.87	0.038 / 0.28	0.149 / 2.44	25.4	3.5	89.4
Medium-saline solonetz	23.2	48.3	0.36	0.012 / 0.40	0.120 / 1.96	30.6	35.4	64.3
Slightly-saline solonetz	11.6	48.4	0.19	none	0.076 / 1.24	18.5	16.5	29.1
Strongly-alkaline, medium-saline meadow soil	12.1	60.0	0.28	none	0.081 / 1.32	40.4	64.7	15.4
Slightly-alkaline, slightly-saline meadow soil	8.3	61.3	0.11	none	0.044 / 0.72	27.9	32.0	9.7

Table 4

Changes in the mineralisation of filtrates in process of leaching soda-saline alkaline soils

Soil and profile	Initial salinity %	Mineralisation of filtrates, grams per litre									
		1	2	3	4	5	6	7	8	9	10
Medium-saline solonetz, 337	0.403	19.6	7.8	5.8	4.9	4.7	4.9	4.5	3.5	—	—
Slightly-saline solonetz, 850	0.185	13.5	2.3	2.1	2.1	2.1	2.3	2.2	1.9	1.8	1.7
Strongly-alkaline medium-saline meadow soil, 468	0.348	20.4	4.7	4.0	3.6	3.5	3.7	3.6	3.7	2.8	3.3
Slightly-alkaline, slightly-saline meadow soil, 236	0.124	9.3	1.9	1.1	1.0	1.1	1.2	1.5	1.1	1.1	1.0

capacity and then the columns were leached 5 times successively with water to equal 1/5 of the total field moisture capacity. Each successive portion of water was poured in after the previous one had drained. Each portion of the filtrate was subjected to analysis. The results of the analyses show that most of the salts were leached out by the first portion of water. On subsequent leachings the outflow of salts became steady and no special changes were observed in the mineralisation of the filtrates (Table 4).

The sample from profile pit 244 would not accept the quantities of water applied to the other soils. In the initial, most heavily mineralised portions of filtrates from this soil there was little or no concentration of carbonates. On further leaching, as the mineralisation of the filtrates went down, the concentration of alkali appreciably increased and normal carbonates appeared in the filtrates. The liberation of different salts upon leaching was uneven. Chlorides were leached out completely and ahead of all other salts. Sulphates followed chlorides in being leached out. The leaching of carbonates and bicarbonates (alkali salts) was not completed in our experiments. Of the cations, calcium was most poorly leached, while magnesium was leached almost completely. Sodium was less effectively leached than magnesium. This is illustrated in tabular form (Table 5).

According to the rate at which they were removed by leaching, ions may be arranged in the following descending order $Cl > Mg > SO_4 > Na > CO_3 > HCO_3 > Ca$. Thus, sodium and magnesium chlorides are leached out most readily (96—100 per cent), followed by magnesium and sodium sulfates. Even sodium and magnesium were not completely leached out, while calcium was retained quite strongly. Maximum soda occurred in the filtrates by the time chlorides and sulphates had been almost completely leached out. On further leaching, alkalinity in the filtrates failed to disappear and their chemism changed from sulphate- and chloride-soda, at the beginning of leaching, to purely soda chemism, at the end. Calculations made by a method proposed by Morozov and Vernikovskaya (1954) showed the salt balance on leaching to be positive. Despite the vigorous removal of soda with leaching water, the total content of soda in the soil was not reduced by leaching (Table 6).

The way salts are liberated from sodic soils is clarified by the data

Table 5

Salt liberation upon leaching solonetz-solonchak

	Amount of leaching water m^3/m^2	Solid residue	Total of salts	Salts removed, %						
				CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+
Initial soil	—	1.66	1.46	0.049	0.494	0.082	0.382	0.008	0.008	0.436
On 1st leaching	0.043	0.760 21.4	0.773 22.1	none	0.156	0.060	0.330	0.001	0.034	0.191
On 2nd leaching	0.085	0.276 7.8	0.355 10.2	0.040	0.198	0.006	0.005	0.0007	0.006	0.100
On 3rd leaching	0.128	0.171 4.8	0.253 7.3	0.036	0.135	0.001	0.002	0.0006	0.004	0.073
On 4th leaching	0.171	0.185 5.2	0.277 8.0	0.034	0.160	none	0.001	0.0004	0.004	0.079
On 5th leaching	0.213	0.171 4.8	0.248 7.1	0.013	0.166	none	none	0.0003	0.004	0.065
On 6th leaching	0.256	0.171 4.8	0.212 6.1	0.028	0.120	none	none	0.0003	0.003	0.060
On 7th leaching	0.299	0.144 4.1	0.186 5.4	0.027	0.103	none	none	0.0003	0.001	0.055
On 8th leaching	0.342	0.102 2.9	0.160 4.6	0.021	0.090	none	none	0.0002	0.002	0.046
Total	—	1.980 55.7	2.464 70.8	0·199 69.1	0.128 64.1	0.067 100.0	0.338 89.3	0.004 15.8	0.058 95.9	0.668 74.4
Salts retained in column	—	1.571 44.3	1.015 29.2	0.089 30.9	0.632 35.9	none	0.041 10.7	0.020 84.2	0.002 4.1	0.230 25.6
Total of salts in column	—	3.551 100.0	3.479 100.0	0.288 100.0	1.760 100.0	0.067 100.0	0.379 100.0	0.024 100.0	0.061 100.0	0.898 100.0

Table 6

Salt balance of a medium-saline sulphate-soda solonetz (profile 337) in a soil-sample column (h = 40 cm), leaching dose being equal 3,411 m³/ha

Characteristics of balance	Total salts	tons per hectare						
		CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ + K^+$
Initial content of salts (water-extract data)	9.5	0.32	3.21	0.53	2.49	0.05	0.05	2.84
Salts removed with leaching water	16.0	1.28	7.33	0.44	2.20	0.02	0.37	4.34
Salts retained in soil after leaching (water-extract data)	6.6	0.58	4.11	none	0.26	0.13	0.02	1.50
Total salts	22.6	1.86	11.44	0.53	2.46	0.15	0.39	5.34

collected: their leaching is accompanied by the intensive formation of "secondary salts" (soda) on the evolution of exchangeable sodium. The leaching of soluble soda from the soil is completed only by the time exchangeable sodium has been completely removed from the adsorbing complex (A. P. Rozov, 1936). The leaching doses used in our experiment were insufficient to meet this requirement. In order to completely remove a 0.22 per cent content of soda from a 10 cm-deep layer of soil, it is necessary to leach with 102 thous. m³ of water per hectare (Rozov, 1956). In order to leach out a metre-deep layer of soil containing 7.4 per cent humus, 0.167 per cent of HCO_3 and 5.8–14.3 me. of exchangeable sodium it is necessary to leach with 130 thous. m³ of water per hectare. This amount of leaching considering the drainage available, would take at least 10 years to accomplish.

It follows from the above that the leaching of a meadow-alkali solonetz to be brought under cultivation would be impossible without chemical reclamation. The test applications of reclamative chemicals (alum crushed in the raw state), which we carried out, resulted in vigorous salt liberation and more effective leaching (Table 7).

Table 7

Salt liberation upon leaching a 15 cm-deep layer of solonetz-solonchak soil pre-treated with alum

	No reclamative chemicals	Water at 4000 m³/ha			No reclamative chemicals	Water at 8000 m³/ha		
		alum, to/ha				alum, to/ha		
		10	30	50		10	30	50
Total salts	11.76	22.77	33.96	157.50	14.22	133.09	108.68	554.02
HCO_3^-	0.45	0.56	0.46	1.74	1.23	23.07	8.53	11.76
Cl^-	0.97	1.53	1.78	5.37	1.17	8.27	5.08	16.66
Na^+	3.54	7.34	10.50	52.82	4.56	40.18	33.96	137.77

The results of similar field tests have been published before by the author of this paper (AGAEV, 1968).

Thus, salt liberation from sodic soils involves a slow leaching of the carbonates and bicarbonates of alkalis and a rapid removal of chlorides and sulphates. The application of reclamative chemicals improves the seepage capacity of the soil and salt liberation from the soil thus reducing the time of leaching.