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SALINITY APPRAISAL IN SOME SOILS OF SUKKUR DISTRICT, WEST PAKISTAN*

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This paper deals with some characteristics of salt-affected soils of Sukkur District in West Pakistan. The electrical conductivity, saturation percentage, sodium adsorption ratio and exchangeable sodium percentage of some of these soils have been discussed.

Introduction

In West Pakistan the injudicious use of irrigation water in the field without having any suitable arrangement for drainage has ultimately caused a gigantic problem of salinity and waterlogging, which at present looks very difficult, if not impossible, to solve. The ground water table at the beginning of irrigation agriculture was at a depth far below the danger limit. Every year new water used to be added to the soil, but there was no provision for this water to be drained out. This water moved downward and started to accumulate year after year and caused the ground water table to come near the root zone of the growing plants. The main trouble is that this ground water table brings with it the soluble salts which can easily affect plant growth both directly and indirectly. Hausenbuiller *et al.*[1] worked with ground water in some Punjab soils and determined the extent of sodium accumulation in the 0–6- in layer of soils in the field which had been irrigated for several years. Their work showed that because of irrigation with Punjab ground water there was accumulation of high amount of exchangeable Na^+ in the soil and the amount of Na^+ accumulation was highly correlated with the "residual Na_2CO_3" content of the irrigation water. Bower and Maasland[2] also worked with the ground water in the Punjab and predicted the bad effect of using such water for irrigation for a long time.

Since the soluble salts present in the saline and sodic soils determine the properties of these soils, it is essential to find out the amount of soluble constituents, such as, sodium, calcium, magnesium, potassium, chlorides, bicarbonates, carbonates and sulphates to characterize these soils. A vast literature exists regarding the reclamation of saline and sodic soils in West Pakistan but very few works have been done purely to charatcerize these soils from pedogenic point of view.[3] In this paper a number of chemical and physicochemical features of few soils from West Pakistan, which were affected by salts and do not grow any plant, have been discussed.

Material and Methods

Nine soil samples from the Ghulam Muhammad Barrage area in the Sukkur district of West Pakistan were collected for this study. All the soil samples were from the surface covering an area of 10 square miles. Soil Nos. 3, 4 and 5 did not grow any crop in living memory and were barren for a long time. Other soils were from fields which used to be cultivated in the past but at present have gone out of cultivation.

The parent materials of the soils were alluvia carried by the river Indus and deposited on the floodplain on the two sides of the river channel. The parent materials were deposited by the floodwaters probably during the recent time.[4]

There is no mineralogical study of the soils in this area, but from the X-ray diffraction study of the present soils it seems that mica, quartz and felspars are the dominant minerals. In the clay fraction there is kaolinite, mica and a small amount of 2:1 expanding lattice secondary silicate. The mineralogy of the parent materials of the present soils probably depends on their provenance.[5]

For most of the chemical analyses the methods described in the USDA handbook No. 60 (USSL Staff 1954) were used. Electrical conductivity and pH were determined from the saturation extract of the soils. Exchangeable sodium percentage (ESP) was determined by the method given by Bower and Hatcher.[6] In calculating ESP of the soils the following formula was used:

$$ESP = \frac{\text{Exch. } Na^+}{CEC} \times 100$$

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The cation exchange capacity (CEC) was determined by N NaOAc solution buffered at pH 8.2. The amount of Ca, Mg, K, and Na was determined from the saturation extracts as well as from N NH_4OAc extracts. Exchangeable Ca^{++}, Mg^{++}, K^+ and Na^+ were obtained by subtracting these ions in the saturation extracts from those soluble in N NH_4OAc solution. The anions, such as, CO_3, HCO_3, Cl and SO_4 were determined from the saturation extracts. Sodium adsorption ratio (SAR) was calculated according to the following formula:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Mineralogical analysis was made with a Norelco X-ray diffraction unit using a Geiger Muller counter and a chart recorder.

Results and Discussion

Saturation Percentage of the Soils.—Saturation percentage in the present soils ranges from 38 to 68 (Table 1). The saturation percentage may be regarded as a measure of the moisture absorbing capacity of the soils, which in turn is guided by the percentage of clay present in them. The large range of saturation percentage is an indication that the present study includes soils which have varying amount of clays present in them. Some of the soils are heavy while others are sandy or light-textured.

Soil Reaction.—Although the saturation percentage of the soils varies within wide limits, the pH values of them are quite uniform. The pH values range from 7.0 to 7.5 (Table 1), which means that the reaction of the soils are neutral to slightly alkaline. This near-neutral pH values of these soils is probably due to the high salt content in them. It is interesting to note that although the soils have a wide range of EC_e, the range of pH is comparatively low. Bower and Maasland[3] determined pH values of a large number of tube-well and drainage waters in the soils of the Punjab and found more or less similar result as the present one. Another point that comes out of the present pH values of these soils is that the soils under the present study are probably saline and not sodic.

Electrical Conductivity.—Electrical conductivity ($EC_e \times 10^3$), which is a measure of the total salt content of the soils ranges from 3.7 to 189.2 mmhos cm^{-1} at 25°C (Table 1). From the electrical conductivity data it appears that except soil No. 2, all the soils under the present study are saline, i.e., all the soils have electrical conductivity higher than 5 mmhos cm^{-1} at 25°C. Soil No. 2 has an electrical conductivity of 3.7 mmhos cm^{-1} at 25°C which is quite close to 4.0. Soils Nos. 3, 4, and 5 have very high electrical conductivity in the saturation extracts.

Sodium is the dominant cation in the saturation extracts of all the soils except soils Nos. 1 and 2 (Table 2). The amount of calcium and magnesium present in the saturation extracts is also high, and that of potassium is comparatively low. Among the anions present in these soils chloride and sulphate are the dominant ones. There is a small amount of HCO_3 in all the soils. Since the pH values in the present soils are lower than 7.5, there is no soluble carbonate in them.

An X-ray diffraction analysis of the soluble salts present in the soils under study shows that sodium chloride, gypsum and magnesium sulphate are the important salts in them.

TABLE 1.—RESULTS OF CHEMICAL ANALYSES OF SOME SALT-AFFECTED SOILS FROM SUKKUR DISTRICT, WEST PAKISTAN.

Soil. No	Depth in in.	SP	pH	$EC_e \times 10^3$	ESP	SAR	CEC me%	Clay %
1	0–6	64.8	7.4	5.0	4.4	5.3	24.5	40
2	0.6	67.7	7.4	3.7	3.5	4.6	20.4	44
3	0.6	37.6	7.1	180.0	1483.0	96.9	6.3	24
4	0.6	44.9	7.0	90.0	27.4	44.2	9.7	26
5	0.6	47.5	7.1	189.0	2044.0	95.2	9.2	25
6	0.6	49.4	7.4	31.3	20.4	28.8	12.0	28
7	0–6	47.8	7.4	24.2	21.8	28.6	10.0	27
8	0–6	54.9	7.4	37.6	23.4	25.9	11.9	32
9	0–9	58.8	7.5	34.6	22.2	32.9	14.5	35
Mean	—	51.4	—	—	—	—	12.0	31

TABLE 2.—DISTRIBUTION OF SOLUBLE SALTS IN SOME SALT-AFFECTED SOILS OF SUKKUR DISTRICT, WEST PAKISTAN.

Soil No.	Depth in in.	Ca^{++} me/l	Mg^{++} me/l	Na^{+} me/l	K^{+} me/l	Cl me/l	SO_4 me/l	HCO_3 me/l
1	0.6	26.7	8.8	22.5	0.6	28.8	25.1	3.0
2	0–6	9.3	3.5	6.5	0.4	7.0	5.8	5.3
3	0–6	144.3	2039.3	3200.0	40.0	5710.3	136.0	8.1
4	0–6	376.5	279.7	800.0	28.0	1345.3	38.6	9.6
5	0–6	589.6	1888.0	3350.0	27.5	6036.7	312.0	10.4
6	0–6	97.5	68.8	262.5	1.9	346.5	47.9	6.0
7	0–6	77.0	31.9	210.0	3.0	246.8	44.9	7.2
8	0–6	145.1	102.3	286.9	3.5	443.5	40.9	3.5
9	0–6	90.9	104.2	325.0	2.3	378.8	57.9	3.7

Cation Exchange Capacity.—The cation exchange capacity (CEC) of these soils ranges from 6.3 to 24.5 me/100 g of soil. This may be due to the presence of different amounts and kinds of clay minerals present in the soils. Similar conclusions have been drawn from the saturation percentage results of these soils. Bower, Reitemeier and Fireman[8] reported the CEC of a number of saline and alkali soils. Their CEC values ranged from 6.2 to 39.1 me/100 g of soils. The present result, therefore, falls well within the limit of the CEC values obtained by the above authors.

The average CEC of the soils is 12 me/100 g of soil. The CEC of the present soils bears a positive correlation with percent clays in them.

Exchangeable Sodium Percentage (ESP).—The exchangeable sodium percentage of the soils under study ranges from 3.5 to 2044.0. In any soil, the exchangeable sodium percentage can never exceed 100, because when the ESP is 100, it will mean that in the exchange complex of the soils all the positions are occupied by Na^{+} alone. The exceedingly high ESP in the present soils as is encountered in soil Nos. 3 and 5 is, therefore, puzzling.

In the beginning it was thought that soils Nos. 3 and 5 possibly contain some sodium-bearing minerals like analcime, which has the capacity of holding sodium in a way. that remains undissolved in water at saturation point but gradually comes into solution on continuous washing with N NH_4OAc solution.[9] An extensive X-ray examination of the soils indicated that there is no analcime mineral in the soils that could give such a high ESP result.

Babcock[10] studied some Fresno soils in California and found that some saline soils gave ESP values more than 100. In explaining his results he noted that the soils in the arid region contain fixed sodium which is not soluble in distilled water at saturation point, but on continuous washing with N NH_4OAc, the fixed sodium is slowly released. This, he said was the main reason for the unusually high ESP values of some desert soils. Bower and Hatcher[6] also encountered fixed sodium in some desert soils and observed that this sodium is not equally extractable with all salt solutions. According to their data $(Mg(OAc)_2$ extracted less sodium from soils than NH_4OAc. Bower and Hatcher[6] although admitted that NH_4OAc has the capacity of extracting some extra amount of sodium from soils, they expressed doubts as to whether the additional sodium extracted by NH_4OAc should be considered as exchangeable and in equilibrium with the cations in the soil solution. These authors further suggested that the ESP in the salt-affected soils should be checked with sodium adsorption ratio (SAR) because there is a close relation between them. In the present study it appears that excepting soils Nos. 3 and 5 other soils show a good correlation between ESP and SAR.

Reitemeier[11] in a study of six desert soils found that the soluble sodium content in the soils increased with dilution. He noted that in the saturation extract the amount of moisture is limited, and not all sodium may be released, but when the extraction is made with a N NH_4OAc solution, dilution increases with more washings and more sodium comes into solution.

From the above discussion it may be concluded here that the high ESP of soils Nos. 3 and 5 is due probably to the presence of fixed sodium in the present soils, which issoluble in N NH_4OAc solution but not in distilled water at saturation point.

In their study of some soils in the Punjab area, Bower and Maasland[2] recognised that the determination of ESP in the soils which have high sodium salts, by the usual NH_4OAc -method may give erroneous results. They, therefore, established an empirical equation to calculate ESP from the SAR of the soils as follows:

$$ESP = 2\ SAR + 2\ SAR\ (8.4 - pH_c).$$

in which the term $(8.4 - pH_c)$ is modified Langelier's[12] saturation index. They found a close correlation between ESP, calculated according to the above equation, and ESP experimentally determined in the traditional way.

Classification of the Soils.—The soils under the present study show some confusing properties. With respect to pH of the saturation extract the soils show pH values of less than 7.5 which indicates that all the soils are saline in character. The electrical conductivity of the soils show that except soil No. 2 all other soils have EC_e higher than 4 mmhos cm^{-1} at 25°C. All the soils, with the exception of soil No. 2 may, therefore, be regarded as saline.

Exchangeable sodium percentage of all the soils except soils No. 1 and 2 are higher than 15.0. Therefore, all the soils under the present study, except the above two show the characteristics of an alkali soil. According to the Classification System of the USSL Staff (1954) the present soils may be characterized as follows: (1) soil No. 1 is saline, (2) soil No. 2 is non-saline, (3) the rest of the soils are saline-sodic.

Summary

Salinity status of nine salt-affected soils from Sukkur district in West Pakistan has been studied. All the soils were collected from barren fields and all were surface soils. pH values of the soils ranged from 7.0 to 7.5 which gave an indication that all the soils were probably saline. Electrical conductivity of the saturation extract showed that all the soils, except one, had an EC_e higher than 4.0 mmhos cm^{-1} at 25°C. Exchangeable sodium percentage of the soils ranged from 3.5 to 2044.0. Two soils were found to have an ESP of higher than 100. This was due to the fact that these soils have probably some fixed sodium in them which was not dissolved in distilled water at saturation point but was dissolved on continuous washing with N NH_4OAc solution. Excepting two soils, which showed very high ESP, all other soils showed a close correlation between ESP and SAR. Among the nine soils one was classified as non-saline, another one saline, and the rest of the soils were saline-sodic.

References

1. R. L. Hausenbuiller, M. A. Hoque and A. Wahab, Soil Sci., **90,** 357(1960).
2. C.A. Bower and M. Maasland, *Sodium Hazard of Punjab Ground Water,* Symp. of "Waterlogging and Salinity in West Pakistan". Golden Jubilee Session of West Pak. Engg. Cong. (1963), pp. 49-61.
3. R.E. Clark, *Recent Soil Reclamation Research* (Paper presented in 20th All Pakistan Sci. Con. Seminar in Agriculture and Forestry Section, 1969).
4. M.S. Krisnan, *Geology of Burma and India,* Madras, 1960.
5. B.L. McNeal, Soil Sci., **102,** 53(1966).
6. C.A. Bower, and J.T. Hatcher, Soil Sci., **93,** 275 (1962).
7. USSL Staff, *USDA Handbook No.* 60 (1954), pp. 160.
8. C.A. Bower, R.F. Reitemeier and M. Fireman, Soil Sci., **73,** 251 (1952).
9. W.P. Kelley, Soil Sci., **84** (1957).
10. K.L. Babcock, Soil Sci. Soc. Am. Proc., **24,** 85(1960).
11. R.F. Reitemeier, Soil Sci., **61,** 195 (1946).
12. W.F. Langelier, J.Am. Water Works Assoc., **28,** 1500 (1936).