

Effect of Brackish Water on Atterberg Limits of Different Soil Series

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ABSTRACT

Undisturbed soil columns of the Rasulpur (sandy loam), Bhalwal (silty clay loam) and Bhalike (clay loam) were collected from the field and were treated with varying levels of salt solutions until steady-states were achieved. Then, Atterberg limits (liquid, plastic and shrinkage limits) were determined. It was found that in both Bhalwal and Bhalike soil series liquid limit increases with increase in salts especially by exchangeable sodium percentage (ESP). There was no effect of TSS or ESP on plastic limits. Shrinkage limit decreased with increasing amount of TSS and ESP. However, this trend was not visible in Rasulpur soil series.

Key Words: Atterberg limits; Brackish water; Soil consistency

INTRODUCTION

Various physical states depending upon soil consistency are important properties of soil for manipulation. These consistency states are used both in construction (buildings and roads) and agriculture (Archer, 1972), and are evaluated on the basis of different criteria like plastic, shrinkage and liquid limits. Although, Pakistan has a large saline/sodic area, but no effort has been made to study the effect of brackish water on Atterberg limits on these soils.

This study, therefore was planned to investigate the effect of brackish water (salts) on Atterberg limits of different in soil series of Pakistan.

MATERIALS AND METHODS

The undisturbed columns of the Rasulpur (sandy loam), Bhalwal (silty clay loam) and Bhalike (clay loam) soil series were collected. These soil series are classified as Ustic Haplocambids, Ustic Calciargids and Ustic Haplocambids, respectively.

Development of salinity/sodicity. To these columns, brackish water having EC 0.64, 2.00, 4.00 and 7.35 dS m⁻¹

and SAR 3.95, 9.65, 18.00, 26.35 and 32.00 (mmol L⁻¹)^{1/2} was applied until steady-states were achieved, i.e. EC and SAR of outflow water was nearly same as that of applied brackish water. At steady-state, samples were taken from the undisturbed columns. They were air-dried, ground and passed through a 2 mm sieve and well mixed. The EC_e and SAR levels achieved at steady-state are presented in Table I. The Exchangeable sodium percentage (ESP) was calculated from SAR and TSS from EC_e levels achieved using the formula given by Franklin and Schmehl (1973).

$$ESP = \{100 (0.0063 + 0.0124 SAR)\} / 1 + (0.0063 + 0.0124 SAR) \times 100$$

Particle-size analysis was carried-out by the hydrometer method (Moodie *et al.*, 1959). The pH of the saturated soil paste (pH_s) and the electrical conductivity of the soil paste extract (EC_e) were measured by the methods described by Page *et al.* (1982). The CaCO₃ was determined by the procedure described by Moodie *et al.* (1959). Liquid, plastic and shrinkage limits were determined by using the Jack (1987) methods.

Statistical analysis of data was carried-out following the simple and multiple correlation tests (Steel & Torrie, 1980).

Table I. Observed SAR and EC_e of the soils at steady-states

Tr. No.	Sandy loam		Silty clay loam		Clay loam	
	SAR (mmol L ⁻¹) ^{1/2}	EC _e (dS m ⁻¹)	SAR (mmol L ⁻¹) ^{1/2}	EC _e (dS m ⁻¹)	SAR (mmol L ⁻¹) ^{1/2}	EC _e (dS m ⁻¹)
1.	1.71	1.57	2.88	3.66	2.57	1.67
2.	5.59	1.16	8.37	2.68	9.26	1.23
3.	9.03	1.40	8.52	1.72	13.97	2.81
4.	9.33	1.24	16.52	3.60	14.77	3.31
5.	9.76	1.04	16.79	3.42	17.60	2.39
6.	10.25	1.07	27.61	3.38	19.82	3.83
7.	14.09	2.26	27.65	4.21	33.87	4.33
8.	17.39	1.77	57.55	9.87	34.66	4.41
9.	28.44	2.99	62.44	8.30	34.86	3.73

RESULTS AND DISCUSSION

The physical and chemical characteristics of the original soils are given in Table II. The clay content of the soils ranges 7.50 to 27.82 and silt 21.50 to 53.50% representing a considerable variation in their particle-size distribution. All the soils are calcareous with 3 to 7% CaCO_3 . The liquid, plastic and shrinkage limits data of the soils having different TSS and ESP levels are given in Tables III, IV and V. The liquid limit and plastic limits are slightly higher in the case of silty clay loam than in the clay loam soil. This difference in these limits may be attributed to the amount and nature of clay and sand contents. Liquid and plastic limit increase with increasing clay, silt and organic matter (Archer, 1972). Sandy loam soil has no liquid and plastic limit. It occurs mostly with the soils having small amount of fine particles, i.e. 7.5% clay in it. So, it can be interpreted that coarse textured soils have good traffic load bearing capacity, hence will be less compacted under mechanized farming. While fine textured soils will be compacted more due to less traffic load bearing capacity. Jumikis (1968) reported that coarse textured soil possess a good foundation or traffic load bearing capacity while fine textured soils possess a poor foundation or traffic load bearing capacity.

It is evident from Tables III, IV and V that the shrinkage limit of clay loam soil is low as compared to

Table II. Physical and chemical properties of the original soils

Determinant	Unit	Rasulpur series	Bhalwal series	Bhalike series
Sand	%	71.00	19.50	33.49
Silt	%	21.50	53.50	38.70
Clay	%	7.50	27.00	27.82
Textural class	-	Sandy loam	Silty clay loam	Clay loam
Bulk density	g cm ⁻³	1.85	1.53	1.57
Particle density	g cm ⁻³	2.67	2.66	2.65
Saturation	%	16.40	39.44	44.80
CaCO_3	%	3.42	6.49	6.84

Table III. Atterberg limits of the Rasulpur series (sandy loam) having different TSS and ESP levels

Tr. No.	ESP (%)	TSS (me L ⁻¹)	Liquid limit	Plastic limit	Shrinkage limit
1.	2.16	16.00			20.88
2.	7.04	11.80			20.67
3.	10.56	14.50			20.31
4.	10.87	13.00	Non liquid	Non plastic	20.14
5.	11.29	10.50			19.97
6.	11.77	10.80			19.91
7.	15.33	24.00			19.27
8.	18.16	19.00			19.53
9.	26.41	33.00			19.27

sandy loam soil. The silty clay loam has the shrinkage limit value slightly lower than sandy loam soil. Shrinkage behavior is difficult to predict quantitatively as it depends upon the nature of the clay and its percentage, salt contents and their nature and moisture changes. In general, the lower the shrinkage limit, the greater the potential shrinkage of soil (Sowers & Sowers, 1970). According to this criterion, sandy loam and silty clay loam soil will have smaller volume changes on repeated wetting and drying. Cracks formed due to shrinkage in agricultural soils may be beneficial in promoting aeration of plant roots or harmful in breaking roots and allowing extreme drying. The cracks in clay soil may play an important role in water infiltration and movement, although not good for nutrient/moisture retention.

The numerical difference between the liquid limit and the plastic limit is known as the plasticity index and indicate the water content range over which a soil is plastic. The friability index is a measure of the range of the friable consistency state. It is the numerical difference between the plastic limit and shrinkage limit. This is the optimum water range for cultivation. Thus, larger the index the longer the period when cultivation operations can be carried out, especially during soil drying in spring. If the index is small, the soil will pass quickly from being too wet to being too dry for good cultivation.

Table IV. Atterberg limits of the Bhalwal series (silty clay loam) having different TSS and ESP levels

Tr. No.	ESP (%)	TSS (me L ⁻¹)	Liquid limit	Plastic limit	Shrinkage limit
				%	
1.	2.96	39.00	20.93	16.64	20.41
2.	9.92	29.00	21.68	16.96	19.78
3.	10.07	18.00	21.78	16.57	19.77
4.	17.43	38.00	22.66	17.04	19.41
5.	17.66	37.00	22.42	16.59	19.39
6.	25.84	35.00	23.07	16.79	18.49
7.	25.88	46.00	23.14	16.48	18.47
8.	41.86	120.00	22.54	16.92	17.53
9.	43.84	99.00	24.78	16.60	17.50

Table V. Atterberg limits of the Bhalike series (clay loam) having different TSS and ESP levels

Tr. No.	ESP (%)	TSS (me L ⁻¹)	Liquid limit	Plastic limit	Shrinkage limit
				%	
1.	2.76	11.50	17.98	14.16	16.81
2.	10.80	12.50	18.61	13.64	16.86
3.	15.22	31.00	19.23	14.13	15.64
4.	15.92	37.00	19.29	13.47	15.55
5.	18.34	26.00	19.63	13.94	15.33
6.	20.13	43.00	19.73	14.21	15.42
7.	29.88	50.00	20.31	13.91	15.07
8.	30.36	50.00	20.84	14.39	14.97
9.	30.49	41.00	20.87	13.54	15.11

Table VI. The simple and multiple correlation coefficients between liquid limit and TSS and/or ESP

Soil type	Dependent variable	Independent variable	Correlation coefficient (r)
Silty clay loam	Liquid limit	TSS	0.85**
		ESP	0.99**
		TSS x ESP	0.99**
Clay loam	Liquid limit	TSS	0.88**
		ESP	0.99**
		TSS x ESP	0.98**
Sandy loam	Non liquid	-	-

* = Significant; ** = Highly significant

Table VII. The simple and multiple correlation coefficients between plastic limit and TSS and/or ESP

Soil type	Dependent variable	Independent variable	Correlation coefficient (r)
Silty clay loam	Plastic limit	TSS	0.11
		ESP	0.01
		TSS x ESP	0.21
Clay loam	Plastic limit	TSS	0.16
		ESP	0.01
		TSS x ESP	0.31
Sandy loam	Non plastic	-	-

Table VIII. The simple and multiple correlation coefficients between shrinkage limit and TSS and/or ESP

Soil type	Dependent variable	Independent variable	Correlation coefficient (r)
Silty clay loam	Shrinkage limit	TSS	-0.83**
		ESP	-0.99**
		TSS x ESP	-0.99**
Clay loam	Shrinkage limit	TSS	-0.94**
		ESP	-0.90**
		TSS x ESP	-0.95**
Sandy loam	Shrinkage limit	TSS	-0.14
		ESP	-0.87**
		TSS x ESP	-0.86**

* = Significant; ** = Highly significant

Table VI shows the relationship for silty clay loam soil between liquid limit, TSS and ESP. The liquid limit is positively and highly significantly correlated with TSS ($r = 0.85^{**}$) and ESP ($r = 0.99^{**}$). The value of correlation coefficient is more in the case of ESP. However, the value of multiple correlation of TSS x ESP ($r = 0.99^{**}$) is the same as of ESP. Similar results are obtained for clay loam soil. Sandy loam soil has no liquid limit. Thus, it can be concluded that the values of liquid limit are influenced by salts significantly especially by ESP. El-Swaify *et al.* (1970) reported that liquid limit is dependent on the nature of saturating cation, with Na^+ giving the highest values.

Table VII indicates non-significant correlation of plastic limit with TSS (0.11) and ESP (0.01) in case of silty

clay loam soil. The multiple correlation is also non-significant. Similar is the case for clay loam soil. Sandy loam soil has no plastic limit. Thus, it reflects that plastic limit is independent of both TSS and ESP but significantly dependent upon clay type and its percentage. Ahmed *et al.* (1969) noted that plastic limits are independent of the saturating cations but significantly dependent upon clay type. It is evident from Table VIII that highly significant negative correlations are found between shrinkage limit and TSS and ESP in all the cases except for sandy loam soil where TSS has no significant correlation while ESP has a significant correlation with shrinkage limit. Shrinkage limit decreases with increase in TSS and ESP and this may be due to increase in swelling and shrinkage, which increase with salinity/sodicity (Waller & Wallender, 1993).

CONCLUSIONS

It is concluded that more swelling and shrinkage of a soil would correspond to low shrinkage limit. Thus, soils having high salinity/sodicity will have high swelling and shrinkage, which may affect their structural stability adversely.

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