Effect of total electrolyte concentration and sodium adsorption ratio on physical properties of salt affected soils in purna valley, Maharashtra, India

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ABSTRACT

The present investigation was carried out in the Purna valley of Vidarbha region of Maharashtra to study the effect of sodium adsorption ratio with total electrolyte concentration and on physical properties of salt affected soils in Purna valley of Maharashtra. The sampling was done in the month of October, 2013. The soil samples were taken from two sites; at the depth of 0-20 cm (surface soil) and 20- 40 cm (sub-surface soil) respectively. For equilibration of soil samples the synthetic waters were prepared with 4 levels of total electrolyte concentrations (TEC) i.e.10, 20,40,80 meL^{-1} with three levels of SAR viz., 5, 10 and 15 mmol$^{1/2}$L$^{-1/2}$. With SAR, MWD decreases due to the increase in dispersion. In case of COLE and VSP with increasing SAR they used to increase but with TEC they inversely related. Total electrolyte concentration and SAR significantly affect the MWD.

Introduction

Black soils (Vertisols and their Vertic intergrades) occur widely in many parts of the world, and in India particular. It occupies an area of 72.9 M.ha in India, 35.5 per cent of which is in the state of Maharashtra (Sharma *et al.* 2004).

The poor structural stability of Vertisols particularly during monsoon season renders the agricultural activities very difficult. The soil of Purna valley is mainly derived from basaltic alluvium and has clay texture with synthetic clay mineralogy. They have swell shrink potential, slow permeability with very low hydraulic conductivity and imperfect drainage. The soils are classified as sodic Haplusterts and Sodic Calciusterts (Padole *et al.*1998).

The swelling of Vertisols is influenced by the initial water content, associated soil moisture suction, CEC, nature and amount of clay and composition of soil solution, ESP, lime and organic matter content.

The swell shrink potential of Vertisols in relation to clay content and ESP and soils are found to be dominantly smectitic with minor amounts of kaolinite and illite. At same levels of clay and ESP, the increase in electrolyte concentration would decrease the swelling Nayak *et al.* (2006)

Materials and methods:

The present laboratory investigation entitled "Effect of Total Electrolyte Concentration and Sodium Adsorption ratio on Swelling Percentage of Salt Affected Soils in Purna Valley" was carried out during 2013-14 in Purna valley of Vidarbha region of Maharashtra state. The materials and methods are discussed in this chapter.

Site Description and Collection of Soil

The study area comprises parts of Purna valley of Vidarbha region of Maharashtra state. Soil samples were collected from Ramagar village under Daryapur tashil of Amravati district (latitude: 20° 55' 19.452 " N, longitude: 77° 19' 36.40 " E).The sampling was done in the month of October, 2013. The soil samples were taken from two sites, the samples were collected up to the depth of 0-20 cm (surface soil) and 20- 40 cm (sub-surface soil) respectively.

Preparation of different qualities of synthetic water

For equilibration of soil samples the synthetic waters were prepared with 4 levels of total electrolyte concentrations (TEC) i.e.10, 20, 40, 80 meL^{-1} with three levels of SAR viz., 5, 10 and 15 mmol$^{1/2}$ L$^{-1/2}$. The Ca: Mg ratio were kept at 1 : 1.5 in these solutions. Pure AR grade chloride salts of calcium magnesium and sodium were used to prepare different quality waters.

Each quality of waters is prepared as below. As per definition

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

Soil reaction (1:2)

Soil pH was determined in soil suspension (1:2 soil: water) by a glass electrode pH meter after equilibrating soil water for 30 min with occasional stirring (Jackson, 1973)

Electrical conductivity (1:2)

The soil water suspension prepared for measuring pH was also used for measuring electrical conductivity. It was measured by ELICO conductivity bridge meter (Jackson, 1973)

Organic carbon

Organic carbon was determined by Walkely and Black (1934) rapid titration procedure. Soil samples were oxidized by Potassium dichromate (1N) and the concentrated H_2SO_4 was used to generate the heat of dilution. The amount of unutilized dichromate was determined by back titration with Standerd ferrous ammonium sulphate solution (0.5N).

Free calcium carbonate

The free calcium carbonate was determined by rapid titration method. The soil was treated with a known volume of 0.5 N HCl to neutralize all the carbonates. The unutilized HCl was back titrated with Standard NaOH of 0.25N using phenolphthalein as an indicator.

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Exchangeable cations

The exchangeable Ca^{2+} and Mg^{2+} were determined by leaching the soils in 1N KCl TEA, buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using mureoxide and EBT as an indicator (Jackson.1973)

Exchangeable sodium and potassium were determined by leaching the soil with 1N ammonium acetate (pH7) solution, Na^+ and K^+ from the leachate were estimated by using Flame photometer given by Page *et al.* (1982).

Cation exchange capacity (CEC)

Soil was saturated with 1N NaOAC (sodium acetate pH 8.2), after removal of excess, sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1N NH_4OAC (ammonium acetate pH7) and the leachate was made up to known volume. Na^+ present in the leachate was determined with flame emission spectrophotometer (Jackson, 1973) and Percent Base saturation, Exchangeable sodium percentage (ESP) was derived by using following equations:

$$PBS = \frac{\text{Exchangeable base}}{\text{CEC}} \times 100$$

$$ESP = \frac{\text{Exchangeable sodium}}{\text{CEC}} \times 100$$

Where, Exchangeable cations and CEC of soils were expressed in c mol (p+) kg^{-1}

Saturation extracts analysis

The saturated paste was prepared and the extract was obtained. The method described by Richards (1954) was followed for the saturation extract preparation. The saturation extracts of the soil samples were analyzed for pHs, electrical conductivity (ECe) and cations and anions as per the methods outlined by Richards (1954). Saturation percentage was determined from a volume of water required to prepare the paste of known weight of the soil.

Exchangeable sodium ratio (ESR)

The exchangeable sodium ratio determined by

From extract ESR = (-0.0126 + 0.01475 SAR) developed by U.S. Salinity Laboratory Staff (1954).

$$\text{From soil ESR} = \frac{\text{Ex Na}}{\text{CEC} - \text{Ex Na}} \times 100, \text{ developed by}$$

Jurinak *et al.* (1984).

Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage from the paste extract was determined by

$$ESP = \frac{100(-0.0126 + 0.01475 \text{ SAR})}{1 + (0.0126 + 0.01475 \text{ SAR})}$$

The above equation was developed by U.S. Salinity Laboratory Staff (1954).

Chemical composition of different quality of synthetic solutions

Equilibration of soil samples

Soil samples passed through 2 mm sieve were kept on the Buchner funnels and allowed to leach with the equilibrating solution. About 300 g soils were taken in the Buchner funnel. After addition of the solution the leaching were facilitated by the application of suction to Buchner funnel using a vacuum pump. The leaching process was continued till effluent attains nearly the constant composition. For certain estimations such as organic carbon, samples were further ground and passed through a 0.2 mm (80 mesh) sievs, as suggested by Jackson, (1973). The soil samples thus prepared were air dried and after appropriate

grinding, sieved the samples were used for the determination of different properties viz. swelling, degree of dispersion, hydraulic conductivity and aggregate stability and as well as coefficient of linear extensibility.

Swelling Percentage

The metallic cylinders (constant head device) prepared for measuring HC are allowed be saturated overnight with the same solution from downward to upward movement by which it was equilibrated. Since these swelling type of soils take much time to attain equilibrium, the samples were allowed to saturated for 16 hrs. and the same sample were used for swelling and saturated Hydraulic Conductivity. After 16 hrs duration, the increase in volume in each cylinder was measured from top at 4 sites and average increase was recorded as percent swelling.

$$\text{Percent Swelling} = \frac{\text{Increase in volume}}{\text{Original volume}} \times 100$$

Mean weight diameter

The Mean weight diameter was determined by Yoder's apparatus method described by Kemper and Rosenau, (1986)

Coefficient of linear extensibility (COLE)

The determination of Coefficient of linear extensibility (COLE) was done as per the method of Schafer and Singer (1976). The COLE has been defined as the ratio of the difference between moist length and dry length of clod to its dry length. It is expressed as

$$\frac{Lm - Ld}{Ld}$$

Where, Lm- Length of soil clod at saturation and
Ld- Length of soil clod when oven dry.

Volumetric shrinkage potential (VSP)

The volumetric shrinkage potential (VSP) was computed from measured (COLE) and using the relationship given by

$$VSP = \left[(COLE + 1)^3 - 1 \right] 100$$

Statistical analysis

Statistical analysis was carried out by analysis of variance technique for two way classification as suggested by Panse and Sukhatme (1985) and multiple linear regression as suggested by Darlington (1973).

$Y = a + b_1X_1 + b_2X_2.$

Where,

X_1= TEC

X_2= SAR

Y= Hydraulic conductivity

Results And Discussion:

The results presented in Table 1 revealed that the swelling percentage was 10.80 per cent (surface soil) and 12.41 per cent (sub-surface soil) in first site and in second site 11.80 per cent (surface soil) and 18.40 per cent (sub-surface soil). McNecl and Coleman, (1966) had found similarly results. They showed that with increase in the ESP of the soil, a very sharp increase in macroscopic swelling was observed.

Table 1: Initial physical properties of soil

Depth	Swelling (%)
Site I(0-20 cm)	10.8
Site I(20-40 cm)	12.4
Site II(0-20cm)	11.8
Site II(20-40cm)	18.4

The data presented in Table 2 revealed that the pH (1:2) was recorded 8.53 (surface soil) to 8.6 (sub-surface soil) for first site and for second site it was 8.31(surface soil) and 8.37(sub-

surface soil) which was increased with depth. This may be due to the alkaline hydrolysis of bicarbonates which is predominant in these soils. The electrical conductivity ranged from 0.17 dSm^{-1} (surface soil) and 0.23 dSm^{-1}(sub-surface soil) for the first site, and for second site it was 0.16 dSm^{-1} (surface soil) and 0.25 dSm^{-1}(sub-surface soil). The electrical conductivity in subsoil was observed more. The calcium carbonate was 9.4 % (surface soil) and 11.6 % (sub-surface soil) for the first site, and for second site it was 8.37 % (surface soil) and 10.2 per cent (sub-surface soil).Calcium carbonate concentration is increased in sub soil layers. The organic carbon was recorded 4.0 g kg^{-1}(surface soil) and 2.7 g kg^{-1}(sub-surface soil) in first site, and for second site it was 4.3 g kg^{-1}(surface soil) and 2.5 gkg^{-1}(sub-surface soil). In general the organic carbon observed low in the sub soil which is due to dispersion of organic matter caused by exchangeable Na^{+}.

Table 2: Initial chemical properties of soil

Depth	pH (1:2)	EC (1:2) dSm-1	CaCO$_3$ (%)	Organic Carbon (g kg-1)
Site I (0-20 cm)	8.53	0.17	9.4	4
Site I (20-40 cm)	8.6	0.23	11.6	2.7
Site II (0-20 cm)	8.31	0.16	8.37	4.3
Site II (20-40 cm)	8.37	0.25	10.2	2.5

Ion exchange analysis

The exchange complex of studied soil was observed in Table 3 to be dominated by calcium, magnesium and sodium. The calcium ion (Ca^{2+}) and magnesium ion (Mg^{+2}) in general showed decreasing trend with depth in soil where sodium (Na^{+}) showed increasing trend. The base saturation percentage was 96.77 per cent (surface soil) and 87.44 per cent (sub-surface soil) in the first site and 94.61 per cent (surface soil) and 85.16 per cent (sub-surface soil) in the second site, which was highly base saturated.

Effect of total electrolyte concentration on the mean weight diameter

The results presented on Table 4 that mean weight diameter of site I (surface soil) was 0.48, 0.53, 0.66 and 0.73 mm at 10, 20, 40 and 80 meL^{-1} of total electrolyte concentration of equilibrating solution respectively, irrespective of SAR level.

As the same SAR levels, the mean weight diameter was found to increase by 52.08 per cent with increase in different total electrolyte concentration levels of equilibrating solution.

Similarly in site I for the sub-surface soil the mean weight diameter was 0.41, 0.46, 0.50 and 0.52 mm at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR level. The MWD was found to increase by 36.08 % with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of equilibrating solution.

With the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the first depth of the second site (0-20 cm) mean weight diameter was 0.48, 0.54, 0.63 and 0.72 mm which was increase up to 50 % with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of the equilibrating solution.

In the site II (sub-surface soil) the mean weight diameter was 0.42, 0.46, 0.49 and 0.54 mm at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR level. Here we can observe that significant relationship between total electrolyte concentration and mean weight diameter of the soil. The mean

weight diameter was found to increase by 28.57 % with increase total electrolyte concentration levels from 10 to 80 of the equilibrating solution.

Effect of SAR on the mean weight diameter

The results (Table 4) indicated that the mean weight diameter of site I (surface soil) was 0.63, 0.60 and 0.57 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level.

Similarly in site I for sub-surface soil the mean weight diameter was 0.50, 0.47 and 0.44 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level. In both soils, at the same total electrolyte concentration levels the MWD was found to decrease by 10.52 % and 13.63 % respectively with increase in SAR level 5 to 15 of the equilibrating solution.

In site II (surface soil) the percent mean weight diameter of equilibrated samples were 0.62, 0.58 and 0.56 respectively, whereas, in site II of sub-surface soil, the MWD of equilibrated samples were 0.50, 0.48 and 0.44. In both soils, at the mean weight diameter was decrease up to 10.71% and 13.63 % respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

Relationship between total electrolytes concentration and sodium adsorption ratio with MWD in different sites

The results recorded in Table 4 showed that with increase in total electrolyte concentration level from 10 to 80 meL^{-1} mean weight diameter increase. There is a significant relationship between TEC and MWD at 5% level of significance.

The results showed that the increase in SAR, MWD of the equilibrated soil was decreased. So, there is significant relation between SAR and MWD of the equilibrated soil at 5% level of significance.

Similar finding were mentioned by Emerson and Bakker (1973). They observed that the dispersion of clay from a wet aggregate of low ESP immersed in water depends on the gradient of the soluble salt concentration at the boundary of the intact portion of the aggregate as well as the actual concentration. Similar results were obtained by Gupta and Verma (1983). They found that the proportion and mean weight diameter of the water stable aggregate decreased considerably at ESP more than 10. They found 10 as a critical ESP value for Montmotillonite black clay soil.

The results with respect to total electrolytes concentration and sodium adsorption ratio with aggregate stability of equilibrated samples for multiple regressions are presented in Table 5.

As results revealed (Table 5) that in the site I surface soil the total electrolytes concentration positively significant at 0.05 % level of significance and sodium adsorption ratio negatively significant at 0.01 % level of significance. It showed that the coefficient of determination was 0.91. Similarly in the site I sub-surface soil, the total electrolytes concentration positively significant and sodium adsorption ratio negatively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.80) significant at 0.01 % level of significance.

In the site II surface soil the total electrolytes concentration positively significant and sodium adsorption ratio negatively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.94) significant at 0.01 % level of significance. Similarly in the site II sub-surface soil, the total electrolytes concentration positively significant and sodium adsorption ratio negatively significant at 0.01 % level of

significance. It showed that the coefficient of determination was (0.96) significant at 0.01 % level of significance.

Coefficient of linear extensibility (COLE) of the equilibrated soil

The Coefficient of linear extensibility (COLE) of the equilibrated samples treated with different TEC and SAR are presented in Table 30 for site I and site II soils.

Effect of total electrolyte concentration on the coefficient of linear extensibility

The results presented on Table 6 indicated that the COLE value of site I (surface soil) was 0.21, 0.19, 0.17 and 0.15 cmcm^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. As the same SAR levels, the COLE value was found to decrease by 40 per cent with increase in different total electrolyte concentration levels of equilibrating solution.

Similarly in site I (depth 20-40 cm) the COLE value was 0.25, 0.22, 0.21 and 0.18 cmcm^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The COLE was found to decrease by 38.88 % with increase in total electrolyte concentration level of equilibrating solution. As per the results presented in Table 6 with the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the first depth of the second site (0-20 cm) COLE was 0.22, 0.20, 0.18 and 0.17 cmcm^{-1} which was decreased up to 29.41 % with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of the equilibrating solution.

In the 2nd depth of the site II (sub-surface soil) the COLE was 0.25, 0.23, 0.21 and 0.20 cmcm^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively irrespective of SAR levels. Here we can observe that significant relationship between total electrolyte concentration and coefficient of linear extensibility of the soil. The coefficient of linear extensibility was found to decrease by 25.00 % with increase total electrolyte concentration levels from 10 to 80 of the equilibrating solution.

Effect of SAR on the coefficient of linear extensibility

The results Table 6 presented that the coefficient of linear extensibility value of site I (surface soil) was 0.16, 0.17 and 0.21 cmcm^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentration levels. In site I (sub-surface soil) the coefficient of linear extensibility value was 0.19, 0.21 and 0.23 cmcm^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte levels. In both soils, at the same total electrolyte concentration levels the coefficient of linear extensibility value was found to increase by 31.25 % and 21.05 % respectively with increase in SAR level 5 to 15 of the equilibrating solution. In site II (surface soil) the percent coefficient of linear extensibility was 0.15, 0.19 and 0.22 cmcm^{-1} respectively, whereas, in site II of sub-surface soil, the COLE of equilibrated samples were 0.20, 0.22 and 0.24 cmcm^{-1}. At the same Level of concentration the COLE was found to increase up to 46.66% and 20.00 % respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

Relationship between total electrolytes concentration and sodium adsorption ratio with COLE in different sites

The results (Table 6) obtained that with increase in total electrolyte concentration level from 10 to 80 meL^{-1} coefficient of linear extensibility decrease. There is a significant relationship between TEC and COLE at 5% level of significance.

The results showed that the increase in SAR, COLE of the equilibrated soil was increased. So, there is a significant relation between SAR and COLE of the equilibrated soil at 5% level of significance.

The results with respect to total electrolytes concentration and sodium adsorption ratio with COLE of equilibrated samples for multiple regressions are presented in Table 7.

As results revealed in the Table 7 showed that in the site I surface soil the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.92) significant at 0.01 % level of significance. Similarly in the site I sub-surface soil, the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.92) significant at 0.01 % level of significance.

In the site II surface soil the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.94) significant at 0.01 % level of significance. Similarly in the site II sub-surface soil, the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was 0.83.

Volumetric shrinkage potential (VSP) of the equilibrated soil

The Volumetric shrinkage potential (VSP) of the equilibrated samples treated with different total electrolyte concentration and SAR are presented in Table 8 for site I and site II soils.

Effect of total electrolyte concentration on the volumetric shrinkage potential

The volumetric shrinkage potential of site I (surface soil) was 78.78, 68.68, 61.68 and 53.56 per cent at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. Similarly in site I of sub-surface soil, the volumetric shrinkage potential was 93.91, 83.13, 78.73 and 65.75 per cent at 10, 20, 40 and 80 meL^{-1} total electrolyte concentrations of equilibrating solution respectively, irrespective of SAR levels.

As the same SAR levels, the volumetric shrinkage potential was found to decrease by 47.08% and 42.82 % respectively with increase in different total electrolyte concentration levels of equilibrating solution.

With the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the first depth of the second site (surface soil) volumetric shrinkage potential was 80.40, 71.66, 65.92 and 59.01 per cent respectively, irrespective of SAR levels and in site II of sub-surface soil, the volumetric shrinkage potential was 95.64, 87.66, 78.68 and 74.35 per cent at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution.

At the same SAR level, the VSP was found to decrease by 36.24% and 28.63% respectively with increase in total electrolyte concentration level of the equilibrating solution.

Effect of SAR on the volumetric shrinkage potential

The results Table 8 presented that the volumetric shrinkage potential of site I (surface soil) was 56.26, 63.43 and 77.34 per cent at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentration levels.

In depth sub-surface soil of site I the volumetric shrinkage potential was 71.85, 80.69 and 88.60 per cent at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level.

SAR $mmol^{1/2}$ $L^{-1/2}$	TEC 10 meL^{-1}					TEC 20 meL^{-1}					TEC 40 meL^{-1}					TEC 80 meL^{-1}				
	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	Total	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	Total	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	Total	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	Total
5	6.4	1.8	1.8	10	10	11	3.5	5.7	20	20	17	8.9	14	40	40	27	22	31	80	80
10	8.7	0.5	0.9	10	10	15	1.8	2.7	20	20	26	6	8.1	40	40	43	15	22	80	80
15	9	0.5	0.5	10	10	18	1.1	1.1	20	20	31	3.4	5	40	40	54	10	16	80	80

Table 3: Ion exchange analysis data of initial soil

Site/ Depth	Extractable bases c mol (P+) Kg^{-1}				Total Cations	CEC Cmol (p+) kg^{-1}	Base saturation (%)	ESP (%)	ESR
	Ca^{2+}	Mg^{2+}	Na^+	K^+					
Site I(0-20 cm)	33.4	12.6	4.2	1.3	51.58	53.3	96.77	7.87	0.08
Site I(20-40 cm)	30.4	11.8	5.1	0.97	48.27	55.2	87.44	9.23	0.1
Site II(0-20 cm)	33	12.4	4.6	1.28	51.28	54.2	94.61	8.48	0.09
Site II(20-40 cm)	31.4	10.8	5.7	0.9	48.8	57.3	85.16	9.94	0.11

Table 4: Effect of total electrolyte concentration and SAR on MWD

Depth (cm)	SAR ($mmol^{1/2} L^{-1/2}$)	MWD (mm) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I (0-20)	5	0.51	0.55	0.69	0.77	0.63
	10	0.48	0.53	0.67	0.73	0.60
	15	0.46	0.50	0.63	0.70	0.57
	Mean	0.48	0.53	0.66	0.73	
	TEC : SE (m) = 0.003		CD at 5 % = 0.012		SAR: SE (m) = 0.003 CD at 5 % = 0.011	
Site I (20-40)	5	0.43	0.49	0.53	0.55	0.50
	10	0.41	0.46	0.51	0.52	0.47
	15	0.39	0.44	0.47	0.49	0.44
	Mean	0.41	0.46	0.50	0.52	
	TEC : SE (m) = 0.003 CD at 5 % = 0.012			SAR: SE (m) = 0.003 CD at 5 % = 0.010		
Site II (0-20)	5	0.53	0.58	0.66	0.74	0.62
	10	0.46	0.54	0.63	0.72	0.58
	15	0.44	0.51	0.60	0.71	0.56
	Mean	0.48	0.54	0.63	0.72	
	TEC : SE (m) = 0.008 CD at 5 % = 0.028			SAR: SE (m) = 0.007 CD at 5 % = 0.024		
Site II (20-40)	5	0.45	0.48	0.52	0.57	0.50
	10	0.42	0.46	0.50	0.54	0.48
	15	0.40	0.43	0.45	0.51	0.44
	Mean	0.42	0.46	0.49	0.54	
	TEC : SE (m) = 0.003 CD at 5 % = 0.013			SAR: SE (m) = 0.003 CD at 5 % = 0.011		

Table 5: Multiple linear regression of TEC and SAR with MWD in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	0.52	0.47	0.52	0.47
b_1 (TEC)	0.003**	0.001**	0.003**	0.001**
b_2 (SAR)	-0.005*	-0.005**	-0.006**	-0.005**
R^2	0.91**	0.80**	0.94**	0.96**

**Significant at 0.01 % level of significance
*Significant at 0.05 % level of significance

Table 6: Effect of total electrolyte concentration and SAR on coefficient of linear extensibility

Depth (cm)	SAR (mmol$^{1/2}$ L$^{-1/2}$)	COLE (cmcm-1) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I (0-20)	5	0.19	0.17	0.15	0.13	0.16
	10	0.21	0.18	0.17	0.15	0.1775
	15	0.24	0.22	0.20	0.18	0.21
	Mean	0.21	0.19	0.17	0.15	
	TEC : SE (m) = 0.001 CD at 5 % = 0.005			SAR: SE (m) = 0.001 CD at 5 % = 0.004		
Site I (20-40)	5	0.22	0.21	0.19	0.17	0.1975
	10	0.25	0.22	0.22	0.18	0.2175
	15	0.27	0.24	0.23	0.20	0.235
	Mean	0.25	0.22	0.21	0.18	
	TEC : SE (m) = 0.003 CD at 5 % = 0.012			SAR: SE (m) = 0.003 CD at 5 %= 0.011		
Site II (0-20)	5	0.18	0.16	0.15	0.14	0.1575
	10	0.22	0.20	0.19	0.16	0.1925
	15	0.25	0.23	0.21	0.20	0.2225
	Mean	0.22	0.20	0.18	0.17	
	TEC : SE (m) = 0.003 CD at 5 % = 0.011			SAR: SE (m) = 0.002 CD at 5 % = 0.009		
Site II (20-40)	5	0.21	0.22	0.20	0.18	0.2025
	10	0.26	0.23	0.21	0.21	0.2275
	15	0.28	0.25	0.23	0.22	0.245
	Mean	0.25	0.23	0.21	0.20	
	TEC : SE (m) = 0.006 CD at 5 % = 0.022			SAR: SE (m) = 0.005 CD at 5 % = 0.019		

Table 7: Multiple linear regression of TEC and SAR with COLE in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	0.16	0.21	0.15	0.21
b_1 (TEC)	-0.0007**	-0.0008**	-0.0006**	-0.0007**
b_2 (SAR)	0.005**	0.003**	0.006**	0.003**
R^2	0.92**	0.92**	0.94**	0.83**

**Significant at 0.01 % level of significance
*Significant at 0.05 % level of significance

Table 8: Effect of total electrolyte concentration and SAR on volumetric shrinkage potential

Depth (cm)	SAR (mmol$^{1/2}$ L$^{-1/2}$)	VSP (%) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I (0-20)	5	68.52	60.16	52.09	44.29	56.26
	10	77.16	64.30	60.16	52.09	63.43
	15	90.66	81.58	72.80	64.30	77.34
	Mean	78.78	68.68	61.68	53.56	
	TEC : SE (m) = 0.75 CD at 5 % = 2.62			SAR:SE (m) = 0.65 CD at 5 % = 2.27		
Site I (20-40)	5	81.58	77.16	68.52	60.16	71.85
	10	95.31	81.58	81.58	64.30	80.70
	15	104.84	90.66	86.09	72.80	88.60
	Mean	93.91	83.13	78.73	65.75	
	TEC : SE (m) = 1.77 CD at 5 % = 6.13			SAR: SE (m) = 1.53 CD at 5 % = 5.31		
Site II (0-20)	5	64.30	56.09	52.09	48.15	55.16
	10	81.58	72.80	68.52	56.09	69.75
	15	95.31	86.09	77.16	72.80	82.84
	Mean	80.40	71.66	65.92	59.01	
	TEC : SE (m) = 1.52 CD at 5 % = 5.26			SAR: SE (m) = 1.31 CD at 5 % = 4.56		
Site II (20-40)	5	77.16	81.58	72.80	64.30	73.96
	10	100.04	86.09	77.16	77.16	85.11
	15	109.72	95.31	86.09	81.58	93.17
	Mean	95.64	87.66	78.68	74.35	
	TEC : SE (m) = 3.03 CD at 5 % = 10.48			SAR: SE (m) = 2.62 CD at 5 % = 9.08		

Table 9: Multiple linear regression of TEC and SAR with VSP in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	56.83	79.32	51.90	81.51
b_1 (TEC)	-0.32**	-0.37**	-0.27**	-0.32**
b_2 (SAR)	2.10**	1.56**	2.76**	1.58**
R^2	0.92**	0.92**	0.94**	0.82**

At the same total electrolyte concentration levels the volumetric shrinkage potential was found to increase by 37.46 % and 23.3 % respectively with increase in SAR level 5 to 15 of the equilibrating solution. In site II (surface soil) the percent volumetric shrinkage potential was 55.16, 69.75 and 82.84 per cent respectively, whereas, in site II of sub-surface soil, the volumetric shrinkage potential of equilibrated samples were 73.96, 85.11 and 93.17 per cent at 5, 10 and 15 SAR level respectively, irrespective of different electrolyte levels. At the same level of concentration the volumetric shrinkage potential was found to increase about 50.18 % and 25.97 % respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

Relationship between total electrolytes concentration and sodium adsorption ratio with VSP in different sites

The results obtained that with increase in total electrolyte concentration level from 10 to 80 meL^{-1} volumetric shrinkage potential decrease. There is a significant relationship between total electrolyte concentration and volumetric shrinkage potential at 5% level of significance. The results showed that the increase in SAR, VSP of the equilibrated soil was increase. So, there is significant relation between SAR and VSP of the equilibrated soil at 5% level of significance. The results with respect to total electrolytes concentration and sodium adsorption ratio with volumetric shrinkage potential of equilibrated samples for multiple regressions are presented in Table 9.

As results revealed in the Table 9 showed that in the site I surface soil the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.92) significant at 0.01 % level of significance. Similarly in the site I sub-surface soil, the total electrolytes concentration negatively significant and sodium adsorption ratio positively significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.92) significant at 0.01 % level of significance.

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Conclusions:

Total electrolyte concentration and SAR significantly affect the MWD. With increasing TEC, MWD increased. It due to the suppression of the double layer thickness.

With SAR, MWD decreases due to the increase in dispersion. In case of COLE and VSP with increasing SAR they used to increase but with TEC they inversely related.

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