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Effect of total electrolyte concentration and sodium adsorption ratio on degree of dispersion of salt affected soils in 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 degree of dispersion of salt affected soils in 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 mmol1/2L-1/2. Electrolyte concentrations significantly affect the degree of dispersion. With increasing electrolyte concentration degree of dispersion decreases which usually increase the permeability of the soil. Dispersed clay particles clogged the micro pores which ultimately affect the hydraulic conductivity of the soil.

Key words: Total electrolyte concentration, Sodium adsorption ratio, Swelling Percentage, Mean weight diameter

Soil salinity and sodicity is the major threat to the agriculture, which not only seriously harm the agricultural productivity but also cause soil degradation. 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).Salt affected soils consists of saline, saline-sodic and sodic soils. Millions of hectares (955 M.ha) of land throughout the world are affected by salinity and sodicity and this area is increasing year after year because of salt accumulation (Lal *et al.,* 1993). In India these soils occupy an area about 12 M.ha (Sharma and Gupta, 1986). In Maharashtra about 0.54 M.ha of swell-shrink soils are initially reported to be salt affected (Abhange *et al.*, 1986) which has been increased to 1.06 M.ha (3.4 %) of the total geographical area (Gaikwad and Challa, 1996).The Purna valley of Vidharbha region is an East – West elongated basin with slight curving to south, occupying part of Amravati (1738 sq.km), Akola (1939 sq.km) and Buldhana (1015 sq.km) district of Vidharbha and extends from 20045' to 21051' N latitude and 75025' to 77045' E longitude with east west length 100-150 km (Balpande, 1993). The tract spreads both sides of Purna River influencing about 894 villages, covering area about 4692 sq.km. The land form is nearly plain. The soils are fine textured with imperfect poor drainage and high water holding capacity. The clay content ranges from 52-70 %, the pH, ECe and ESP ranges from 7.7 to 9.4, 0.90 to 5.20 dSm-1 and 2.57 to 33.78 respectively. The soils are mostly normal at surface horizons and problem of salinity / sodicity increase with depth (Padole *et al.*, 1998). 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 SodicCalciusterts (Padole *et al.,* 1998).The major causes of formation of salt affected Vertisols under Purna Canal Command are excess and unscientific irrigation, topographic situation, arid climate, unlined canal above the ground water, poor permeability of Vertisols, use of saline ground water for irrigation and blocking of natural drains. (Abhange *et al.,* 1986).

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 Daryapurtashil 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

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

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 0.25 N using phenolphthalein as an indicator.

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:

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

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

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)

(U.S. Salinity Laboratory Staff, 1954)

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

(Jurinak *et al.*, 1984)

Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage from the paste extract was determined by

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

(U.S. Salinity Laboratory Staff, 1954)

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) sieves, 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.

Degree of dispersion

The Degree of Dispersion measured in the equilibrated soils with removal of the excess soluble salts with ethanol, and was carried out with the method suggested by Hamid and Mustafa (1985) with some modification. 5gm (<0.25 mm) of soil were shaken for 30 minutes on a mechanical shaker and transferred to a 1000 ml cylinder. After keeping the soil suspension overnight as such the volume were made up to the mark and shaken for 1 minute. The suspensions wereallowed to settle for the specified time for the clay at the given temperature. Suitable aliquot of the suspension were taken out with the help of pipette from a depth of 10 cm, dried and weighed. The degree of dispersion was calculated as.

$$\text{DD}(\%) = \frac{\text{Water dispersed clay }(\%)}{\text{Total clay}} \times 100$$

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.

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 (20-40cm)	8.6	0.23	11.6	2.7
Site II (0-20 cm)	8.31	0.16	8.37	4.3
Site II (20-40cm)	8.37	0.25	10.2	2.5

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^+.

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.

Degree of Dispersion of the equilibrated soil

The results with respect to the degree of dispersion of the equilibrated samples treated with different total electrolyte concentration and SAR solution are presented in Table 4 for site I and site II soil

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

Effect of total electrolyte concentration on the degree of dispersion

The results (Table 4) presented that the per cent degree of dispersion of site I (surface soil) was 14.86, 13.66, 11.99 and 10.52 at 10, 20, 40 and 80 meL^{-1} TEC of equilibrating solution respectively, irrespective of SAR level. The degree of dispersion was found to decrease by 41.25 % with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of equilibrating solution. Similarly in site I for the sub-surface soil the degree of dispersion was 14.99, 13.93, 13.45 and 11.96 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The degree of dispersion was found to decrease by 25.33% with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of equilibrating solution. In 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) degree of dispersion was 14.57, 13.63, 11.97 and 10.44, which was decreased up to 39.55 % with total electrolyte concentration level from 10 to 80 meL^{-1} of the equilibrating solution.

Table 4. Effect of total electrolyte concentration and SAR on degree of dispersion

Depth (cm)	SAR (mmol$^{1/2}$ L$^{-1/2}$)	Degree of Dispersion (%) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I(0-20)	5	14.45	13.35	11.30	10.05	12.29
	10	14.84	13.53	11.88	10.35	12.65
	15	15.30	14.09	12.80	11.15	13.34
	Mean	14.86	13.66	11.99	10.52	
	TEC : SE (m) = 0.10 CD at 5 % = 0.35			SAR: SE (m) = 0.08 CD at 5 % = 0.30		
Site I(20-40)	5	14.72	13.44	12.86	11.29	13.08
	10	15.02	13.82	13.53	12.03	13.60
	15	15.24	14.53	13.97	12.57	14.08
	Mean	14.99	13.93	13.45	11.96	
	TEC : SE (m) = 0.10 CD at 5 % = 0.36			SAR: SE (m) = 0.09 CD at 5 % = 0.31		
Site II(0-20)	5	14.29	13.29	11.46	10.00	12.26
	10	14.41	13.44	11.90	10.20	12.49
	15	15.01	14.17	12.55	11.11	13.21
	Mean	14.57	13.63	11.97	10.44	
	TEC : SE (m) = 0.06 CD at 5 % = 0.22			SAR: SE (m) = 0.05 CD at 5 % = 0.19		
Site II(20-40)	5	14.66	13.65	12.33	11.45	13.02
	10	15.29	14.21	12.67	12.12	13.57
	15	16.61	14.44	13.23	12.35	14.15
	Mean	15.52	14.1	12.74	11.97	
	TEC : SE (m) = 0.18 CD at 5 % = 0.62			SAR: SE (m) = 0.15 CD at 5 % = 0.53		

In 20-40 cm depth of the site II for the depth of sub-surface soil, the degree of dispersion was 15.52, 14.1, 12.74 and 11.97 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 degree of dispersion of the soil. The degree of dispersion was found to decrease up to 29.65 % with increase total electrolyte concentration levels from 10 to 80 of the equilibrating solution.

Effect of SAR on the degree of dispersion

The results Table 4 presented that the degree of dispersion of site I (surface soil) was 12.29, 12.65 and 13.34 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level. At the same total electrolyte concentration levels the degree of dispersion was found to increase by 8.55 % with increase in SAR level 5 to 15 of the equilibrating solution. Similarly in 20-40 cm depth soil of the first site the degree of dispersion was 13.08, 13.6 and 14.08 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level. At the same total electrolyte concentration levels the degree of dispersion was found to increase by 7.64 % with increase in SAR level 5 to 15 of the equilibrating solution. In site II (surface soil) the percent degree of dispersion of equilibrated samples were 12.26, 12.49 and 13.21 respectively, whereas, in site II of sub-surface soil, the degree of dispersion of equilibrated samples were 13.02, 13.57 and 14.15. In both soils, at the same total electrolyte concentration levels the degree of dispersion was found to increase about 7.74% and 8.67 % respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

Relationship between total electrolyte concentration and SAR with degree of dispersion in different site

The results showed (Table 4) that with increase in total electrolyte concentration level from 10 to 80 meL^{-1} degree of dispersion decreased. There is a significant relationship between TEC and degree of dispersion at 5% level of significance. The results showed that with the increase in SAR degree of dispersion of the equilibrated soil was also increased. So, there is significant relation between SAR and degree of dispersion of the equilibrated soil at 5% level of significance (Table 5). In the site I, surface soil the electrolytes concentration was negatively significant at 0.01 % level of significance and sodium adsorption ratio was significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.93) significant at 0.01 % level of significance. Similarly in the site I, sub-surface soil the electrolytes concentration was negatively significant at 0.01 % level of significance and sodium adsorption ratio was significant at 0.01 % level of significance. It showed that the coefficient of determination was (0.94) significant at 0.01 % level of significance. In the site II, surface soil the electrolytes concentration was negatively significant at 0.01 % level of significance and sodium adsorption ratio was significant at 0.01 % level of significance. It showed that the coefficient of determination was 0.94. Similarly in the site II, sub-surface soil the electrolytes concentration was negatively significant at 0.01 % level of significance and sodium adsorption ratio was significant at 0.05 % level of significance. It showed that the coefficient of determination was (0.89) significant at 0.01 % level of significance.

Table 5. Multiple linear regression of TEC and SAR with degree of dispersion 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)	13.93	14.07	13.86	14.18
b_1 (TEC)	- 0.05**	- 0.03**	- 0.05**	- 0.04**
b_2 (SAR)	0.10**	0.10**	0.09**	0.08*
R^2	0.93**	0.94**	0.94**	0.89**

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

The decrease in the degree of dispersion with increase in total electrolyte concentration was observed in this study was also reported by Van (1977), he observed that in a stable clay suspension, dispersed particles colloide frequently because of their Brownian movement but separate again because of diffuse double layer repulsion forces. When salt is added to the clay suspension, the particles stick together upon collision, forming flocks which settle down.

In this study, because of high clay content in both of these soils, they are subjected to susceptibility for the degree of dispersion. The higher decrease in degree of dispersion led to the increase in hydraulic conductivity at high salt concentration range. Giridhar and Yadav (1980) found similar findings that the increase in Mg/Ca ratio and SAR and the decrease in the total electrolyte concentration of the leaching water increased the dispersion.

CONCLUSION

Electrolyte concentrations significantly affect the degree of dispersion. With increasing electrolyte concentration degree of dispersion decreases which usually increase the permeability of the soil. Whereas with increasing SAR degree of dispersion increases by adversely affecting the soil structure. Dispersed clay particles clogged the micro pores which ultimately affect the hydraulic conductivity of the soil.

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