Effect of Total Electrolyte Concentration and Sodium AdsorptionRatioon Swelling Percentage of Salt Affected Soils in Purna Valley of Maharashtra

Abstract

The present investigation was carried out in the Purna valley of Vidarbha region of Maharashtra to study the effect of total electrolyte concentration and sodium adsorptionratio on swelling percentage 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 $mmol^{1/2}L^{-1/2}$. The increase in swelling percentage was due to the increase in SAR, ESP, levels and also decreases with increasing total electrolyte concentration.The swelling percentage was found to decrease by 27.74 % with increase in TEC levels from 10 to 80meL^{-1} similarly the swelling percentage was found to increase about 8.94 to 7.81% respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

(Keywords: Swelling percentage, Total electrolyte concentration, Sodium adsorption ratio)

1.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 is dominant with montmorillonite expanding type of mineral which shrinks in low moisture and swells with high moisture which hampers field capacity of soil and disturb soil aeration, hydraulic conductivity and infiltration rate. 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).

Swelling was observed as an important mechanism in reducing hydraulic conductivity in these soils. Also the clay contents a major cause for reduction in hydraulic conductivity. Hence it is needed to study the suitable irrigation water for such soil for its improvement and better crop productivity.

2.MATERIALS AND METHODS

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

2.1 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 Ram nagar village under Daryapur Tahasil 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.

2.2 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

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

Table 1. Chemical composition of different quality of synthetic solutions

SAR mmol1/2 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

2.3 Physicochemical Properties

The physicochemical properties of experimental soil samples were determined by using the standard methods. The Soil pH was determined by a glass electrode pH meter in 1:2 soil : water suspension as given by Jackson, 1973. The Electrical conductivity (1:2) measured by measured by ELICO conductivity bridge meter (Jackson, 1973). The organic carbon was determined by Walkley 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 Standardferrous ammonium sulphate solution (0.5N). The free calcium carbonate was determined by rapid titration method (Pipper, 1966). 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. 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 murexide 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). For the determination of 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:

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

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

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

2.4 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).

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

X 100,developed by Jurinak*et al*. (1984).

2.5 Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage from the paste extract was determined by

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

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

2.6 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.

2.7 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.

Table 2: 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

2.8 Swelling Percentage:

The metallic cylinders (constant head device) prepared for measuring Hydraulic Conductivity are allowed be saturated overnight with the same solution from downward to upward movement by which it was equilibrated. Since these swelling types 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.

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

Table 1: Initial swelling percentage 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

2.9 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*et al.* (1973).

$Y= a + b_1X_1 + b_2X_2.$

Where,

X_1= TEC

X_2= SAR

Y= Hydraulic conductivity

3. RESULTS AND DISCUSSION

3.1Effect of total electrolyte concentration on swelling percentage

The swelling percentage of equilibrated soil of site I at the depth of 0-20 cm was 12.43, 10.50, 10.27 and 9.73 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels(Table 4). The swelling percentage was found to decrease by 27.74% with increase in the TEC levels from 10 to 80 meL^{-1}.Where as at the depth of 20-40 cmthe swelling percentage was 14.50, 13.67, 11.53 and 10.87 at 10, 20, 40 and 80 meL^{-1} at total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The swelling percentage was found to decrease by 33.39% with increase in the total electrolyte concentration levels from 10 to 80 meL^{-1} of the equilibrating solution.

The increase in total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} at the depth of 0-20 cm second site (surface soil) swelling percentage was 14.77, 12.63, 10.90 and 9.80 which was decrease up to 50.71 % with increase in total electrolyte concentration level from 10 to 80 meL^{-1} of the equilibrating solution (Fig. 1). Similarly at the depth of 20-40 cm of the site II (sub-surface soil) swelling percentage was 15.53, 14.87, 12.60 and 11.70 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of the equilibrating solution respectively, irrespective of SAR level. Here, we can observe that significant relationship between total electrolyte concentration and swelling percentage of the soil. The swelling percentage was found to decrease by 32.73 % with the increase total electrolyte concentration levels from 10 to 80 meL^{-1} of the equilibrating solution.

Table 4: Effect of total electrolyte concentration and SAR on swelling percentage

Depth (cm)	**Initial Swelling (%)**	**SAR ($mmol^{1/2}$ $L^{-1/2}$)**	**Swelling (%)**				Mean
			Total electrolyte concentration (meL^{-1})				
			10	20	40	80	
Site I (0-20)	10.8	5	12.00	10.00	9.80	9.30	10.28
		10	12.30	10.50	10.20	9.90	10.73
		15	13.00	11.00	10.80	10.00	11.20
		Mean	12.43	10.50	10.27	9.73	
		TEC : SE (m)= 0.07 CD at 5 % = 0.26			SAR: SE (m)= 0.06 CD at 5 % = 0.23		
Site I (20-40)	12.4	5	14.00	13.00	11.00	10.60	12.15
		10	14.50	13.80	11.60	10.80	12.68
		15	15.00	14.20	12.00	11.20	13.10
		Mean	14.50	13.67	11.53	10.87	
		TEC : SE (m)= 0.08 CD at 5 % = 0.29			SAR: SE (m)= 0.07 CD at 5 % = 0.25		
Site II (0-20)	11.8	5	14.50	12.30	10.00	9.50	11.58
		10	14.80	12.50	11.20	9.90	12.10
		15	15.00	13.10	11.50	10.00	12.40
		Mean	14.77	12.63	10.90	9.80	
		TEC : SE (m)= 0.16 CD at 5 % = 0.56			SAR: SE (m)= 0.14 CD at 5 % = 0.48		
Site II (20-40)	18.4	5	15.30	14.50	12.00	11.30	13.28
		10	15.50	15.00	12.50	11.80	13.70
		15	15.80	15.10	13.30	12.00	14.05
		Mean	15.53	14.87	12.60	11.70	
		TEC : SE (m)= 0.11 CD at 5 % = 0.40			SAR: SE (m) = 0.10 CD at 5 % = 0.35		

3.2 Effect of SAR on swelling percentage

The results (Table 4) presented that the swelling percentage of equilibrated soil of site I in the surface soil was 10.28, 10.73 and 11.20 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level.

Similarly in site I in the sub-surface soil, the swelling percentage was 12.15, 12.68 and 13.10 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentration level.

In both soils, at the same total electrolyte concentration levels the swelling percentage was found to increase about 8.94 and 7.81 per cent respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

The swelling percentage of site II of surface soil the equilibrated samples were 11.58, 12.10, 12.40 respectively. Whereas in site II of sub-surface soil, the swelling percentage was 13.28, 13.70 and 14.05.
In both soils, at the same total electrolyte concentration level the swelling percentage was found to increase about 7.08% and 5.79 % respectively in SAR level from 5 to 15 of the equilibrating solution (Fig. 1).

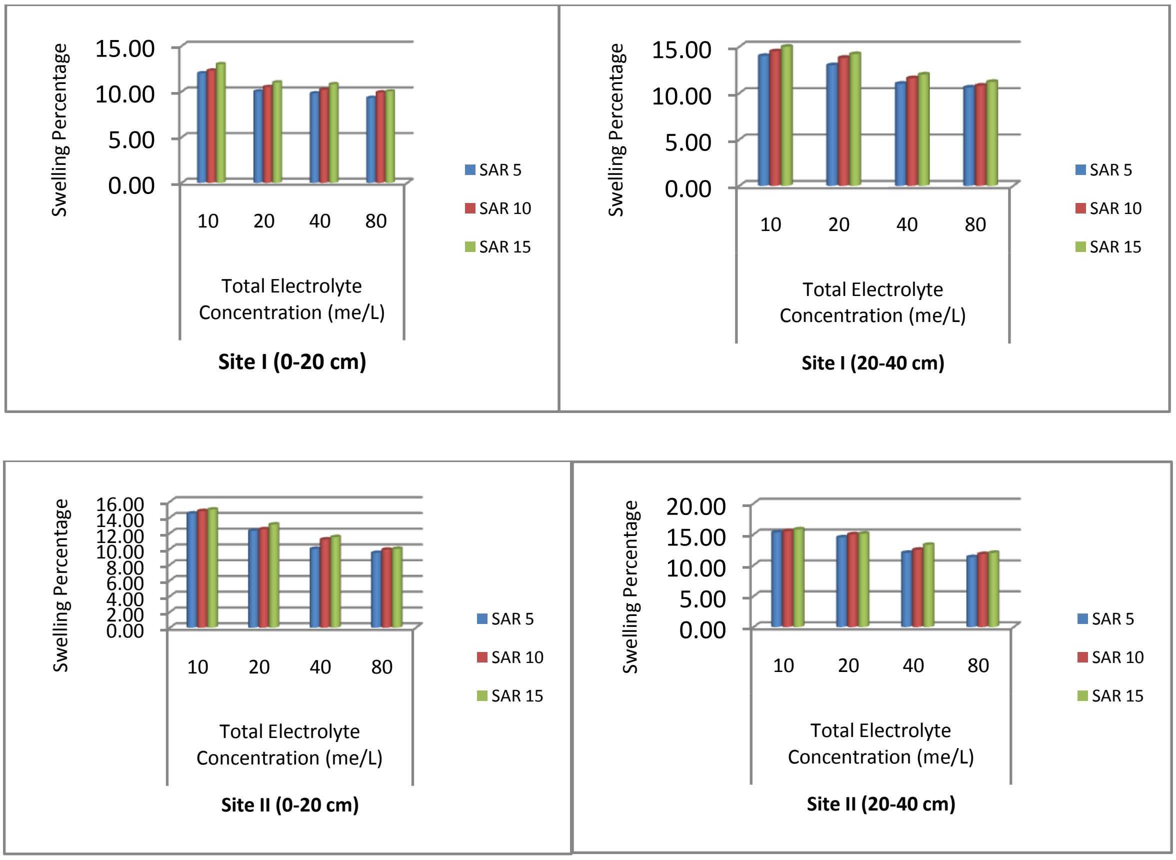

Fig. 1: Relationship between total electrolyte concentration and SAR with swelling percentage in different site

3.3 Relationship between total electrolyte concentration and SAR with swelling percentage in different site

We can observe that there is a significant relationship between TEC and swelling, with increase in total electrolyte concentration levels from 10 to 80 meL^{-1} at 5% level of significance.

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

Table 5: Multiple linear regression of TEC and SAR with swelling percentage 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)	10.93	13.61	13.59	14.96
b_1 (TEC)	- 0.03**	-0.05**	- 0.06**	- 0.05**
b_2 (SAR)	0.09	0.09*	0.08	0.07
R^2	0.66**	0.85**	0.82**	0.87**

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

The results with respect to electrolyte concentration and sodium adsorption ratio with swelling percentage of equilibrated samples for multiple regressions are presented in Table 5, indicates that in the site I, at the depth of 0-20 cm the electrolytes concentration was negatively significant at 0.01 % level of significance. Whereas the coefficient of determination was (0.66) significant at 0.01 % level of significance. Similarly, in the site I, at the depth of 20-40 cm 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 (0.85) 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. It showed that the coefficient of determination was (0.82) significant at 0.01 % level of significance. Similarly, in the site II, sub-surface soil the electrolytes concentration was negatively significant at 0.05 % level of significance. It showed that the coefficient of determination was (0.87) significant at 0.01 % level of significance.

The higher swelling percentage may be due to the more clay content. In general increase in ESP increases swelling percentage, similar results are found by Klages (1966) who observed that under sodic conditions the clay swells when wet and swelling pressure causes it to reorient in the direction of least resistance.

The increase in the swelling percentage was due to the increase in SAR, ESP levels and also decreases with increasing electrolyte concentration due to compression of double layer thickness of clay minerals. McNeal and Coleman (1966) had found similar results. They showed that with increase in the ESP of the soil, a very sharp increase in macroscopic swelling was observed.

4. CONCLUSION

The significant relationship was observed between TEC and swelling percentage, the results showed that with increase in SAR, swelling percentage of the equilibrated soil was increased, also higher the clay content higher the swelling percentage similarly increase in ESP increases swelling percentage

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