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## Impact of irrigation on soil properties in Purna valley of Vidarbha region of Maharashtra

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### Abstract

To study the impact of irrigation on soil properties in Purna valley of Vidarbha region of Maharashtra an experiment was conducted during 2014-2015 at Department of Science and Agril. Chemistry Dr. PDKV, Akola. The water samples from ten bore wells were collected in the month of October 2014 and the soil samples were taken during and after irrigation.

The bore well water samples were found to be in high salinity and low sodicity class ( $S_1C_3$ ). Amongst the cations, sodium was dominant cation which was above permissible limit followed by calcium, magnesium and potassium, anions in irrigation water with respect to bicarbonate it was dominant anion followed by chloride and sulphate. The sodium adsorption ratio was within the permissible limit and Mg:Ca ratio of water falls in acceptable range, in most of the samples whereas the adjusted sodium adsorption ratio was higher than the recommended guidelines.

The irrigation water affects the physical and chemical properties of soil to a considerable extent where hydraulic conductivity was decreased and bulk density showed increasing trend after irrigation, whereas particle density and porosity of soil was decreased after irrigation. The pHs varied from 8.65 to 8.94 before irrigation and 8.76 to 8.96 after irrigation whereas ECe 1.87 to 2.28 dSm<sup>-1</sup> before irrigation and 1.95 to 2.30 dSm<sup>-1</sup> after irrigation while among the cations the concentration of sodium, calcium, magnesium and potassium was increased over the initial value and sodium was the dominant cation found in soil. Bicarbonate is dominated among the anions in between 7.1 to 8.5 before irrigation and 7.9 to 8.9 meL<sup>-1</sup> before irrigation and 7.5 to 8.9 meL<sup>-1</sup> after irrigation followed by chloride and sulphate.

**Keywords:**  $S_1C_3$ , cation, anion, ECe, pH, bulk density, particle density

### Introduction

Irrigated agriculture is depend on adequate water supply of usable quality concerns have often been neglected because of lack of knowledge about it (Shamsad and Islam, 2005; Islam *et al.*, 1999) [21-43, 33-11]. In India large parts of the arable land are still uncultivated due to either excessive salinity or sodicity. India covers an area of salt affected soils to the tune of 6.73 Mha (Sharma *et al.*, 2004) [44-22]. In Maharashtra the area under these soils has been increased to 1.06 Mha (Gaikwad and Challa, 1996) [32-10].

Irrigation water quality is related to its effects on soils and crops and its management. High quality crops can be produced only by using high-quality irrigation water keeping other inputs optimal. Characteristics of irrigation water that define its quality vary with the source of the water. There are regional differences in water characteristics, based mainly on geology and climate. There may also be great differences in the quality of water available on a local level depending on whether and the source is from surface water bodies (rivers and ponds) or from groundwater aquifers with varying geology. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency or indirectly by altering availability of nutrients (Ayers and Westcot, 1985; Rowe *et al.*, 1995) [2-24, 42-20].

The purpose of study was to know the physico-chemical properties to assess the extent and intensity of salinity or sodicity problem as per standard method. The saturation soil paste was prepared and saturation paste extract was obtained as described by Richard (1954) [41-19] and analyzed for various quality parameters the farmers in Purna valley of Vidarbha now a day's giving protective irrigation by using bore well as source (water). Presence of monovalent cations in the soil solution or in the percolating leaching water causes dispersion of the soil colloids. To avoid the adverse effect of salts present in water and to find out the suitability of different quality of water present research was carried out.

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Saline irrigation water contains dissolved substances known as salts. In much arid and semi-arid regions, most of the salts present in irrigation water are chlorides, sulphates, carbonates, and bicarbonates of calcium, magnesium, sodium and potassium. While, salinity can deteriorate soil structure, it can also negatively affect plant growth and crop yields. Sodicity refers specifically to the amount of sodium present in the irrigation water. Irrigation with water that has excess amounts of sodium can adversely impact soil structure making it difficult for plant growth. Highly saline and sodic water qualities can cause problems for irrigation, depending on the type and amount of salts present under field conditions, irrigated soils are exposed to sequential periods of rapid wetting followed by drying. Soils which are subject to these wetting and drying cycles have been found to exhibit low aggregate stability (Caron *et al.*, 1992)<sup>[27-51]</sup>.

## Material and Methods

The ten bore well water samples were collected in the month of October 2014, from the Devri and Raundala village in Purna valley. Simultaneously, soil samples were taken before irrigation and after irrigation of chickpea in the month of January 2015. The samples were collected in closed air tight polyethylene bottles and transported to laboratory for analysis. The water samples were analyzed for various parameters

### Analysis of soil sample

#### A. Physical properties of soil

##### 1. Hydraulic conductivity

Saturated hydraulic conductivity of disturbed samples was determined by constant head method as described by Richard (1954)<sup>[41-19]</sup>.

##### 2. Bulk density

The bulk density was determined by clod coating method as described by Black and Hergte (1986).

##### 3. Particle density

The particle density was determined by Pycnometer method.

##### 4. Porosity

The porosity was determined by 1-(BD/PD) X100 method as described by Baver (1949)<sup>[25-3]</sup>.

#### B. Chemical properties of soils

Saturated soil paste and saturation extracts were prepared as per procedure outlined by Richards (1954)<sup>[41-19]</sup>. pHs and E<sub>c</sub>e of saturation extract were determined by using ELICO pH

meter and ELICO conductivity bridge respectively. Saturation extracts were analyzed for composition of cations and anions by the methods outlined by Richards (1954)<sup>[41-19]</sup>.

#### 1. Sodium adsorption ratio (SAR)

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

All the cations are expressed in meL<sup>-1</sup>.

#### 2. Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage from the paste extract was determined by

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

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

#### 3. 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).

#### Statistical analysis

The data was analyzed for statistical computations as suggested by Panse and Sukhatme (1985)<sup>[38-7]</sup>.

## Result and Discussion

### Effect of irrigation on physical properties of soil.

#### Hydraulic conductivity (cm hr<sup>-1</sup>)

The data in relation to hydraulic conductivity of soil in Devri and Raundala village are presented (Table 1).

The hydraulic conductivity of soil was observed in range of 0.55 to 0.69 cm hr<sup>-1</sup> before irrigation and 0.39 -0.57 cm hr<sup>-1</sup> after irrigation of soil which indicates that the decreases in the hydraulic conductivity after irrigation of soil was mainly due to dispersion, saline irrigation water, suspended solids present in water which accumulate and physically block water conducting pores, thereby leading to a sharp decrease in soil hydraulic conductivity, the blocking of the pores occurs mostly in the upper soil layer.

**Table 1:** Effect of Irrigation on soil physical properties

Particulars	Bulk density (Mgm <sup>-3</sup> )		Particle density (Mgm <sup>-3</sup> )		Porosity (%)		Hydraulic conductivity (cm hr <sup>-1</sup> )	
	BI	AI	BI	AI	BI	AI	BI	AI
S <sub>1</sub>	1.49	1.59	2.32	2.27	35.78	29.96	0.58	0.41
S <sub>2</sub>	1.43	1.69	2.94	2.4	51.36	29.58	0.61	0.49
S <sub>3</sub>	1.53	1.63	2.17	2.27	29.49	28.19	0.55	0.45
S <sub>4</sub>	1.35	1.54	2.32	2.38	41.81	35.29	0.65	0.51
S <sub>5</sub>	1.36	1.49	2.56	2.12	46.88	29.72	0.58	0.55
S <sub>6</sub>	1.43	1.59	2.77	2.32	48.38	31.47	0.55	0.49
S <sub>7</sub>	1.49	1.59	2.12	2.56	29.72	37.89	0.57	0.41
S <sub>8</sub>	1.54	1.62	2.84	2.17	45.77	25.35	0.59	0.39
S <sub>9</sub>	1.43	1.63	2.56	2.12	44.14	23.11	0.63	0.55
S <sub>10</sub>	1.54	1.64	2.41	2.12	36.10	22.64	0.69	0.57

BI- Before irrigation AI- After irrigation

Ahmed and Swaity (1969) [23-1] found that hydraulic conductivity was affected by the four cations in the order  $\text{Ca} = \text{Mg} > \text{K} > \text{Na}$  and was also significantly affected by clay type.

Emerson and Bakker (1973) [29-7] Frenkel *et al.* (1978) [31-9] Pupisky and Shainberg (1979) [39-17] found that blocking of soil pores was a major mechanism in the reduction of hydraulic conductivity.

Quirk and Schofield (1955) [40-18] reported that the presence of divalent ions such as  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  generally stabilizes or increase soil hydraulic conductivity, while the presence of  $\text{Na}^{+}$  in the percolating solution or on the ion exchange complex frequently decreases the hydraulic conductivity, particularly at low salt concentration.

Marshall (1968) [35-13] found that whenever particles are detached from aggregates, they tend to migrate to other locations with water. In the process, the particles may block some macropores and decrease the hydraulic conductivity of the soil.

McNeal *et al.* (1966) [36-14] working with various types of soil, noted a decrease in hydraulic conductivity of soil under sodic conditions.

### Bulk density

The bulk density of soil varied from 1.49 to 1.69  $\text{Mgm}^{-3}$  before irrigation and after irrigation, it was in between 1.36 to 1.54  $\text{Mgm}^{-3}$  which showed increasing trend after irrigation (Table 2).

Magesan (2001) [34-12] reported that bulk density increased in topsoil because suspended solids present in saline water may accumulate and physically block water conducting pores, thereby leading to increase of the bulk density of soil.

Emdad *et al.* (2006) [30-8] also reported that Irrigation water quality has been found to significantly affected soil physical properties. These changes occurred in the presence of high solute concentrations normally associated with maintaining soil aggregate stability and continued throughout the irrigation season. Soil dispersion causes clay particles to plug the soil pores and increase bulk densities.

### Particle Density

The data in concern to particle density of soil is presented in Table 2, which shows that, it was varied from 2.12 to 2.56  $\text{Mgm}^{-3}$  before irrigation and was 2.12 to 2.94  $\text{Mgm}^{-3}$  after irrigation of soil which might be due to the irrigation with saline water.

### Porosity

The Porosity of soil varied from 24.62 to 48.38% before irrigation and 22.64 to 37.89% after irrigation (Table 2), which was decreased after irrigation of soil due to saline irrigation water and accumulation of salt which results the sealing of pores.

### Effect of irrigation on soil chemical properties

**Table 2:** Effect of irrigation water on soil pH<sub>s</sub> and EC<sub>e</sub>

Particulars	pH <sub>s</sub>		EC <sub>e</sub> (dSm <sup>-1</sup> )	
	BI	AI	BI	AI
S <sub>1</sub>	8.65	8.76	1.91	2.1
S <sub>2</sub>	8.88	8.91	2.03	2.1
S <sub>3</sub>	8.69	8.75	2.12	2.23
S <sub>4</sub>	8.88	8.95	2.00	2.15
S <sub>5</sub>	8.94	8.96	1.87	1.95
S <sub>6</sub>	8.75	8.8	2.13	2.14
S <sub>7</sub>	8.85	8.91	2.12	2.2
S <sub>8</sub>	8.86	8.89	2.2	2.4
S <sub>9</sub>	8.86	8.96	2.25	2.27
S <sub>10</sub>	8.89	8.93	2.28	2.30

BI-Before irrigation AI-After irrigation

### pH<sub>s</sub>

The saturation paste extract analysis of soil indicated that the pH<sub>s</sub> varied from 8.65 to 8.94 before irrigation and 8.76 to 8.96 after irrigation (Table 3). It was increased after irrigation up to 8.96 due to soluble salt present in irrigation water. This might be due to high proportion of bicarbonate ions which dissociates more hydroxyl ions on dilution (Dubey *et al.*, 1983) [28-6] also reported similar result.

### Electrical Conductivity (EC<sub>e</sub>)

The electrical conductivity of saturation paste extract (EC<sub>e</sub>) was in the range of 1.87 to 2.28  $\text{dSm}^{-1}$  before irrigation, which was considerably increased after irrigation up to 1.95 to 2.30  $\text{dSm}^{-1}$  (Table 3). The highest increase in the EC<sub>e</sub> indicated the

process of salinization is operative in the soils and soils are facing irrigation induced hazards.

### Cations

The data regarding cationic concentration in saturation paste extract is mentioned in Table 3, which reveals that the sodium was dominant cation ranging from 9.67 to 11.75  $\text{meL}^{-1}$  before irrigation and 9.71 to 11.92  $\text{meL}^{-1}$  after irrigation in Devri and Raundala village soils, the concentration of calcium was 5.1 to 6.2  $\text{meL}^{-1}$ , magnesium was 3.8 to 6.2  $\text{meL}^{-1}$  whereas the potassium content was 0.78 to 1.00  $\text{meL}^{-1}$  which increased after irrigation. The dominance of  $\text{Na}^{+}$  over  $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$  and  $\text{K}^{+}$  ions in the saturation extract of the salt affected soils was also reported by More *et al.* (1988) [37-15d].

**Table 3:** Cationic concentration in soil before and after irrigation

Particular	Soluble Cations (meL <sup>-1</sup> )							
	Ca <sup>+2</sup>		Mg <sup>+2</sup>		Na <sup>+</sup>		K <sup>+</sup>	
	BI	AI	BI	AI	BI	AI	BI	AI
S <sub>1</sub>	5.8	5.9	3.6	3.8	10.3	10.56	0.88	0.95
S <sub>2</sub>	5.6	5.9	4.3	4.8	10.55	10.76	0.85	0.88
S <sub>3</sub>	5.9	6.2	4.8	5.2	9.78	10.55	0.53	0.78
S <sub>4</sub>	4.9	5.1	4.3	4.8	11.6	11.9	0.73	0.93
S <sub>5</sub>	5.5	5.9	5.9	6.2	9.67	9.71	0.75	0.95
S <sub>6</sub>	5.5	5.8	5.3	6.2	11.54	11.75	0.80	0.90
S <sub>7</sub>	5.6	5.8	4.9	5.2	10.9	11.2	0.80	0.85
S <sub>8</sub>	5.9	5.5	4.9	5.2	11.4	11.92	0.79	0.95
S <sub>9</sub>	5.1	5.9	4.3	6.3	11.7	11.92	0.95	1.00
S <sub>10</sub>	5.4	5.8	4.0	5.7	11.3	11.8	0.81	0.95

BI= before irrigation AI= after irrigation

It is interesting to note that the soils with sodium as a dominant cation in the saturation extract showed relatively high pHs. Thus, there was direct and positive relation between pHs and soluble sodium content. Similar observations were also reported earlier (More *et al*, 1988)<sup>[37-15]</sup>.

### Anions

The data presented in Table 4, reveals that among the anions bicarbonate was dominant and ranged from 7.3 to 8.4 meL<sup>-1</sup> before irrigation and 7.5 to 8.9 meL<sup>-1</sup> after irrigation of soil where as chloride concentration of soil was in the range of 4.8 to 7.2 meL<sup>-1</sup> before irrigation and 5.2 to 8.00 meL<sup>-1</sup> after irrigation which might be due to the increase in electrical conductivity of irrigation water.

**Table 4:** Anionic concentrations in soil before and after irrigation

Particular	Soluble anions (meL <sup>-1</sup> )					
	HCO <sub>3</sub> <sup>-</sup>		Cl <sup>-</sup>		SO <sub>4</sub> <sup>-</sup>	
	BI	AI	BI	AI	BI	AI
S <sub>1</sub>	8.5	8.9	6.00	6.6	2.62	4.76
S <sub>2</sub>	8.4	8.6	5.2	5.6	3.05	4.18
S <sub>3</sub>	8.1	8.3	6.2	6.6	2.54	4.39
S <sub>4</sub>	7.92	8.9	5.6	6.6	2.58	4.32
S <sub>5</sub>	7.3	7.8	4.8	5.2	2.59	3.36
S <sub>6</sub>	7.1	7.9	4.8	5.8	2.88	4.56
S <sub>7</sub>	7.19	8.2	7.8	8.6	2.89	3.25
S <sub>8</sub>	7.3	7.5	7.2	7.8	2.85	3.02
S <sub>9</sub>	7.7	8.2	5.4	6.45	2.66	3.58
S <sub>10</sub>	7.5	8.3	7.2	8.00	3.89	3.96

BI= before irrigation AI= after irrigation

Sulphate concentration observed in the range of 2.54 to 3.89 meL<sup>-1</sup> before irrigation of soil and 3.02 to 4.76 meL<sup>-1</sup> after irrigation.

**Table 5:** Effect of irrigation water on soil SAR, ESP and ESR

Source	SAR		ESP		ESR	
	BI	AI	BI	AI	BI	AI
S <sub>1</sub>	6.71	6.78	7.77	7.87	0.086	0.087
S <sub>2</sub>	6.70	6.57	7.31	7.66	0.086	0.088
S <sub>3</sub>	5.97	6.24	6.85	7.18	0.075	0.079
S <sub>4</sub>	7.64	7.56	8.92	8.75	0.10	0.098
S <sub>5</sub>	5.72	5.58	6.57	6.39	0.071	0.069
S <sub>6</sub>	7.15	6.66	8.36	7.71	0.092	0.085
S <sub>7</sub>	6.72	6.75	7.79	7.82	0.086	0.086
S <sub>8</sub>	6.93	7.28	8.07	8.53	0.089	0.094
S <sub>9</sub>	7.63	6.82	8.91	7.91	0.099	0.087
S <sub>10</sub>	7.37	6.95	8.58	8.01	0.096	0.089

BI= before irrigation AI= after irrigation

The sodiumization and sodification processes owing to the continuous irrigation of these soils. Exchangeable Sodium Percentage in soil saturation paste extract before irrigation was in the range of 6.57 to 8.91% and 7.18 to 8.75% after irrigation and exchangeable sodium ratio of soil in Devri and Raundala Village was ranging from 0.071 to 0.10 before irrigation and 0.069 to 0.098 after irrigation.

### Conclusion

The irrigation water collected from various bore well falls in C3S1 i.e. high salinity and low sodicity class which can use for irrigation with caution.

The irrigation water affects the physical and chemical properties of soil to a considerable extent where hydraulic conductivity was decreased and bulk density showed increasing trend after irrigation, whereas particle density and porosity of soil was decreased after irrigation. The pHs varied from 8.65 to 8.94 before irrigation and 8.76 to 8.96 after irrigation whereas ECe 1.87 to 2.28 dSm-1 before irrigation and 1.95 to 2.30 dSm-1 after irrigation while among the cations the concentration of sodium, calcium, magnesium and potassium was increased over the initial value and sodium was the dominant cation found in soil. Bicarbonate is dominated among the anions in between 7.1 to 8.5 before irrigation and 7.9 to 8.9 meL-1 before irrigation and 7.5 to 8.9 meL-1 after irrigation followed by chloride and sulphate.

### References

- Ahmed S, Swait SA. Effect of adsorbed cations on physical properties of tropical red earths and tropical black earth. I. Plastic limit percentage of stable aggregates and hydraulic conductivity. *J Soil Sci.* 1969; 20(2):255-268.
- Ayers RS, Westcot DW. Water quality for agriculture FAO irrigation and drain. 1985; 29(1):1-109.
- Baver LD. Practical value from physical analysis of soil soil sci. 1949; 68:1-14.
- Blake GR, Hartge KH. Bulk density, in method of soil analysis Part I, Physical and mineralogical methods (A. Klute Ed.) Agronomy Monograph. 1986; 9(12):363-375.
- Caron J, Kay B, Stone J. Improvement of structural stability of a clay loam with drying. *Soil Science Society of America Journal.* 1992; 56:1583-1590.
- Dubey DD, Verma GP, Sharma OP. Differences in the nature and properties between salt affected and normal Vertisols. *Current Agric.* 1983; 7:129-137.
- Emerson WW, Bakker AC. The composition effect of exchangeable Ca, Mg and Na on some physical

- properties of red brown earth subsoil's. The spontaneous dispersion of aggregates in water. *Aust. J Soil Res.* 1973; 11:151-157.
8. Emdad MR, Shahabifar M, Fardad H. Effect of Different Water Qualities on Soil Physical Properties. Tenth International Water Technology Conference, Iwtc10 2006, Alexandria, Egypt, 2006, 647.
  9. Frenkel H, Goertzen JO, Rhoades JD. Effect of clay type and content exchangeable sodium percentage and electrolyte concentration on clay dispersion and soil hydraulic conductivity. *Soil Sci. Am. J.* 1978; 43:32-39.
  10. Gaikwad ST, Challa O. Soils of Maharashtra, their problems and potentials. Paper presented at state level Seminar Indian Soc. Soil Sci. Akola Chapter, Akola, Dec, 1996, 12-13.
  11. Islam MS, Hassan MQ, Shamsad SZKM. Ground water quality and hydrochemistry of Kushtia District, Bangladesh. *J Asiat. Soc. Bangladesh Sci.* 1999; 25(1):1-11.
  12. Magesan GN. Changes in soil physical properties after irrigation of two forested soils with municipal waste water. New Zealand Forest Research Institute. Number 2767, 2001.
  13. Marshall TJ. Some effects of drag on structure and hydraulic conductivity of soil. *Inter. Congr. Soil Sci. Trans. 9th (Adelaide, Austr.).* 1968; 1:213-221.
  14. McNeal BL, Norvell WA, Coleman NT. Effect of solution composition on the swelling of extracted soil clays. *Soil Sci. Soc. Am. Proc.* 1966; 30:313-317.
  15. More SD, Shinde JS, Malewar GU. Characterization of some salt affected soils of Purna command area of Maharashtra. *J Indian Soc. Soil. Sci.* 1988; 36:146-150.
  16. Panse VG, Sukhatme PV. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi, 1985.
  17. Pupisky H, Shainberg I. Salt effect on the hydraulic conductivity of a sandy soil. *Soil Sci. Soc. Am. J.* 1979; 43:429-433.
  18. Quirk JP, Schofield RK. The effect of electrolytes concentrations on soil permeability. *J Soil Sci.* 1955; 6:163-178.
  19. Richards LA. *Diagnosis and improvement of saline and alkali soils USA Handbook No. 60*, Oxford and IBH Publishing Co. Calcutta, 1954, 160.
  20. Rowe DR, Abdel-Magid IM. *Handbook of Wastewater Reclamation and Reuse*. CRC Press, Inc, 1995, 550.
  21. Shamsad SZKM, Islam MS. Hydrochemical behaviour of the water resource of Sathkhira Sadar of southwestern Bangladesh and its impact on environment. *Bangladesh J of Water Resource Research.* 2005; 20:43-52.
  22. Sharma RC, Mandal AK, Saxena RK, Verma KS. Characteristics, formation and reclamability of sodic soils under different geomorphic plains of Ganga basin. *UP Council of Agricultural Research, Lucknow.* 2004; 1:168-170.
  23. Ahmed S, Swaity SA. Effect of adsorbed cations on physical properties of tropical red earths and tropical black earth. I. Plastic limit percentage of stable aggregates and hydraulic conductivity. *J Soil Sci.* 1969; 20(2):255-268.
  24. Ayers RS, Westcot DW. *Water quality for agriculture FAO irrigation and drain.* 1985; 29(1):1-109.
  25. Baver LD. Practical value from physical analysis of soil soil sci. 1949; 68:1-14.
  26. Blake GR, Hartge KH. Bulk density, In *method of soil analysis Part I, Physical and mineralogical methods (A. Klute Ed.) Agronomy Monograph, 9,12nd Ed.* 1986, 363-375.
  27. Caron J, Kay B, Stone J. Improvement of structural stability of a clay loam with drying. *Soil Science Society of America Journal.* 1992; 56:1583-1590,
  28. Dubey DD, Verma GP, Sharma OP. Differences in the nature and properties between salt affected and normal Vertisols. *Current Agric.* 1983; 7:129-137.
  29. Emerson WW, Bakker AC. The composition effect of exchangeable Ca, Mg and Na on some physical properties of red brown earth subsoil's. The spontaneous dispersion of aggregates in water. *Aust. J Soil Res.* 1973; 11:151-157.
  30. Emdad MR, Shahabifar M, Fardad H. Effect of Different Water Qualities on Soil Physical Properties. Tenth International Water Technology Conference, Iwtc10 2006, Alexandria, Egypt, 2006, 647.
  31. Frenkel H, Goertzen JO, Rhoades JD. Effect of clay type and content exchangeable sodium percentage and electrolyte concentration on clay dispersion and soil hydraulic conductivity. *Soil Sci. Am. J.* 1978; 43:32-39.
  32. Gaikwad ST, Challa O. Soils of Maharashtra, their problems and potentials. Paper presented at state level Seminar Indian Soc. Soil Sci. Akola Chapter, Akola, Dec, 1996, 12-13.
  33. Islam MS, Hassan MQ, Shamsad SZKM. Ground water quality and hydrochemistry of Kushtia District, Bangladesh. *J Asiat. Soc. Bangladesh Sci.* 1999; 25(1):1-11.
  34. Magesan GN. Changes in soil physical properties after irrigation of two forested soils with municipal waste water. New Zealand Forest Research Institute. Number, 2001, 2767.
  35. Marshall TJ. Some effects of drag on structure and hydraulic conductivity of soil. *Inter. Congr. Soil Sci. Trans. 9th (Adelaide, Austr.).* 1968; 1:213-221.
  36. McNeal BL, Norvell WA, Coleman NT. Effect of solution composition on the swelling of extracted soil clays. *Soil Sci. Soc. Am. Proc.* 1966; 30:313-317.
  37. More SD, Shinde JS, Malewar GU. Characterization of some salt affected soils of Purna command area of Maharashtra. *J Indian Soc. Soil. Sci.* 1988; 36:146-150.
  38. Panse VG, Sukhatme PV. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi, 1985.
  39. Pupisky H, Shainberg I. Salt effect on the hydraulic conductivity of a sandy soil. *Soil Sci. Soc. Am. J.* 1979; 43:429-433.
  40. Quirk JP, RK Schofield. The effect of electrolytes concentrations on soil permeability. *J Soil Sci.* 1955; 6:163-178.
  41. Richards LA. *Diagnosis and improvement of saline and alkali soils USA Handbook No. 60*, Oxford and IBH Publishing Co. Calcutta, 1954, 160.
  42. Rowe DR, Abdel-Magid IM. *Handbook of Wastewater Reclamation and Reuse*. CRC Press, Inc, 1995, 550.
  43. Shamsad SZKM, Islam MS. Hydrochemical behaviour of the water resource of Sathkhira Sadar of southwestern Bangladesh and its impact on environment. *Bangladesh J of Water Resource Research.* 2005; 20:43-52.
  44. Sharma RC, Mandal AK, Saxena RK, Verma KS. Characteristics, formation and reclamability of sodic soils under different geomorphic plains of Ganga basin. *UP Council of Agricultural Research, Lucknow.* 2004; 1:168-170.