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Performance evaluation of subsurface drainage system in upper Krishna command

■ **RAHUL PATIL AND P. BALAKRISHNAN**

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See end of the Paper for authors' affiliation

Correspondence to :

RAHUL PATIL
Department of Soil and Water Engineering, College of Agricultural Engineering, RAICHUR (KARNATAKA) INDIA
Email : rahul1235110@gmail.com

■ **ABSTRACT :** The study was conducted in an area of 10.65 ha at Agricultural Research Station, Malnoor under UKP command during 2014. The drain discharge was observed with an weighted average discharge of mains was 0.50 mm d^{-1} and 0.44 mm d^{-1} in the laterals this magnitude could be categorized as low drain discharge and attributed to lower rate of hydraulic conductivity (0.067 m d^{-1}) and sodic nature of the soil. The ionic composition of leachate was dominated by sodium, while the anionic concentration of leachate was dominated by chlorides and bicarbonates.The pH ranged from 7.10 to 9.10 in the outlets and 6.20 to 8.50 in the laterals and salinity of leachate with mean EC of 9.68 dS m^{-1} in collector mains and 9.44 dS m^{-1} in laterals implied that it was 9 to 14 times higher than the canal water (0.70 to 1.10 dS m^{-1}) and not good for irrigation. Groundwater reaction was neutral with a mean pH of 7.64, while the mean salinity of groundwater was very high with the EC of 9.47 dS m^{-1} as compared to canal water. The total amount of salt removes was observed to be 3.22 and 5.20 t during the study period, This outgoing salt load over a period of time depending of cropping and irrigation practices would help in reducing the soil salinity and thereby facilitate restoration of soil production capabilities.

■ **KEY WORDS :** Drain discharge, EC, pH, Carbonate, Bicarbonates

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Soil, land and water are essential resources for the sustained quality of human life and foundation of agricultural development. Efficient management of land and water resources is a major challenge for the scientist, planners, administrators and farmers to ensure food, water and environmental security for the present and future generations (Das *et al.*, 2009). Irrigation development is largely responsible for making India self sufficient in food grains production but the negative aspect is drainage has not been given importance as much as irrigation. Productive agricultural land is going out of cultivation because water logging and salinity caused by the raise of water table due to lack of proper drainage are the major problem in the canal command areas. Adoption of sub surface drainage technology is probably one of the best ways to increase resource use efficiency in order to increase crop production and sustain natural resources like soil and water in severely water logged saline soils. So there is a great demand for the research and developmental efforts to reclaim all the salt affected and water logged soils by providing drainage and bring them back to non saline productive soils.

To produce required food of the increasing population of the world, it is necessary to increase the cultivated land productivity or more lands to be cultivated. Predictions show that food production in the next 25 years should be doubled (Ritzema, 2007). Drainage projects are faced with challenges in the various stages of research, design and implementation that their negligence led to the ineffectiveness of such projects. Prevention of particles entrance into subsurface drains is done by using porous materials called drainage envelopes. The main goal of these materials is infiltration improvement around drains (Ministry of Agriculture, 2000 and Stuyt *et al.*, 2000). In addition, the drainage envelopes can improve the bed conditions (Bybordi, 1999) and reduce resistance against entrance flow into drains (Stuyt and Dierickx, 2006). Drainage discharge plays a very vital role in the reclamation of the waterlogged and the saline soils, as the drainage discharge found to be increased the reclamation will take place in a fast way.

METHODOLOGY

Study area and climate :

The area selected for the present study comes under the command of Narayanapur Left Bank Canal (NLBC) of UKP and is located in the Agricultural Research Station (ARS) Farm, Malnoor of the University of Agricultural Sciences Raichur at a distance of about 7 km from Hunasagi in Shorapur taluk, Yadgir district, Karnataka. The project area lies at 17^0 03’ N latitude and 76^0 15’ E longitude at an elevation of 460 m above the mean sea level. The annual average rainfall of the nearest raingauge station at Hunasagi is 547.1 mm, of which 340.6 mm occurs during June-September, which is about 60.62 per cent of the average annual rainfall. The soils present in the study area are predominantly *vertisols* shallow to medium black soils and the texture of top soil is sandy clay loam, while the lower soils are clay loam.

Observations recorded :

The drain discharge was collected at main drain outlets and also at the laterals from the inspection chambers weekly during the study period. The discharge from the SSDs was measured using a bucket, stop watch and a graduated cylinder on volume basis. Taking the area of influence of each drain, the drain discharge was converted and expressed in the form of mm d^{-1}.The leachate water samples were collected fortnightly during the study period in all the outlets and all the laterals in the inspection chambers and were analyzed for water quality parameters of EC, pH, cations, anions, SAR and RSC. The total amount of salt removed was done using the EC of the drain discharge.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Monitoring of discharge in SSD system :

The standard week wise weighted average discharge and the overall weighted average discharge data in two SSD main drains (collector main I and main II) are presented in Table 1. The discharge in collector main I and II ranged from 0.17-0.54 and 0.23-0.80 mm d^{-1}, respectively. It was observed that the discharge was maximum in main II (0.80 mm d^{-1}) during 46^{th} week (November) while the minimum was observed to be 0.17 mm d^{-1} in main I during 3^{rd} week of January. Among the mains, the average discharge was 0.38 mm d^{-1} in main I and 0.62 mm d^{-1} in main II, which was higher than that of the main I. Considering overall area the weighted discharge observed to be 0.50 mm d^{-1}.

The standard week wise weighted average discharge and the overall weighted average discharge data in three lateral drains (LLII, RLII and RRII) are presented in Table 2. Drain discharge in laterals ranged from ranged from 0.13-0.54, 0.17-0.89 and 0.15-0.59 mm d^{-1} in laterals LLII, RLII and RRII, respectively. It was observed that the discharge was maximum in RLII (0.89 mm d^{-1}) during 46 and 51^{st} week and minimum was (0.13 mm d^{-1}) during 3^{rd} week of January. Among the laterals, the average discharge was 0.34, 0.60 and 0.44 mm d^{-1} in LLII, RLII and RRII with overall mean of 0.44 mm d^{-1}.

This magnitude of drain discharge could be categorized as low drainage discharge / co-efficient. The drain discharge was low due to lower rate of hydraulic conductivity and sodic nature of the soil (0.067 mm d^{-1}). The discharge could be increased in the following seasons by application of gypsum and organic manure to the soil. Manjunath *et al.* (2004) noticed that, after the transplanting of the paddy crop, the higher drain discharge was recorded with maximum of 0.60 mm d^{-1} during the September month in 1998 and 1999, which coincided with the monsoon season and the paddy crop in the fields.

Table 1 : Average weekly discharge of SSD mains in the study area

		Drain discharge, mm d^{-1}		
Sr. No.	Standard week	Main I, mm d^{-1}	Main II, mm d^{-1}	Overall weighted weekly average discharge, mm d^{-1}
1.	37	0.42	0.79	0.61
2.	38	0.35	0.60	0.48
3.	39	0.35	0.69	0.53
4.	40	0.33	0.61	0.48
5.	41	0.44	0.73	0.59
6.	42	0.32	0.74	0.54
7.	43	0.33	0.65	0.50
8.	44	0.37	0.58	0.48
9.	45	0.49	0.68	0.59
10.	46	0.43	0.80	0.62
11.	47	0.47	0.75	0.61
12.	48	0.44	0.65	0.55
13.	49	0.54	0.58	0.57
14.	50	0.49	0.65	0.58
15.	51	0.50	0.79	0.65
16.	52	0.31	0.52	0.42
17.	1	0.23	0.42	0.33
18.	2	0.21	0.28	0.25
19.	3	0.17	0.23	0.21
	Average	0.38	0.62	0.50

Table 2 : Average weekly discharge of SSD lateral drains in the study area

		Drain discharge, mm d^{-1}			
Sr. No.	Standard week	LLII	RLII	RRII	Overall weighted weekly average discharge
1.	37	0.45	0.58	0.59	0.53
2.	38	0.35	0.43	0.49	0.42
3.	39	0.41	0.63	0.56	0.52
4.	40	0.26	0.50	0.43	0.38
5.	41	0.19	0.71	0.49	0.43
6.	42	0.26	0.78	0.40	0.44
7.	43	0.35	0.65	0.56	0.50
8.	44	0.41	0.58	0.44	0.46
9.	45	0.45	0.84	0.45	0.54
10.	46	0.54	0.89	0.56	0.63
11.	47	0.50	0.84	0.51	0.58
12.	48	0.45	0.58	0.49	0.50
13.	49	0.41	0.52	0.43	0.44
14.	50	0.37	0.63	0.49	0.48
15.	51	0.35	0.89	0.54	0.55
16.	52	0.26	0.54	0.49	0.41
17.	1	0.19	0.41	0.26	0.27
18.	2	0.19	0.35	0.20	0.23
19.	3	0.13	0.17	0.15	0.15
	Average	0.34	0.60	0.44	0.44

Analysis of leachate water quality :

Salinity of the leachate water at the laterals and the outlets :

The leachate water samples collected from the subsurface collector main drain outlets and the inspection chambers of different laterals were subjected to fortnightly analysis of salinity (EC) from September 2014 till January 2015 and the data are presented in Table 3. Considering all the laterals, the mean leachate salinity (dS m^{-1}) ranged from 7.20 dS m^{-1} during October in lateral RLII to 12.50 dS m^{-1} during November. Individually, the mean leachate salinity (dS m^{-1}) varied from 7.80 to 11.1 in case of LLII, from 7.2 to 11.30 in RLII and from 8.30 to 12.50 in RRII, with their mean salinities of 9.18, 9.20 and 9.94 dS m^{-1}, respectively. The overall leachate mean salinity of the laterals was 9.44 dS m^{-1}.

Similarly, the maximum leachate salinity was observed in the month of January, 2015 (11.50 dS m^{-1}) in the subsurface collector main drain outlet I and the lowest observed was (7.60 dS m^{-1}) during September, 2014 in the subsurface collector main drain outlet II. Individually, the leachate salinity in the subsurface collector main drain outlet I varied from 8.90 to 11.50 dS m^{-1} with a mean of 10.00 dS m^{-1} while that of the subsurface collector main drain II outlet ranged from 7.60 to 9.60 dS m^{-1} with a mean of 9.36 dS m^{-1}. In comparison, the EC of canal water was very low during the study period with 0.70 dS m^{-1} in September, 2014 and 1.10 dS m^{-1} in January, 2015. Thus, the leachate salinity was nearly more than 12 times during September, 2014 and nearly 8-9 times during January, 2015 compared to that of the canal water (Table 4).

The results of mean EC of 9.68 dS m^{-1} in the collector mains and 9.44 dS m^{-1} in the laterals implied that the reclamation process might take few seasons or couple of years so that the leachate quality would come in equilibrium with the canal water. It was observed that EC of groundwater was found to be much more as compared to canal water. The concentration of the leachate was found to be nearer to severe conditions or of highly poor quality, hence it was not good for utilization for the purpose of irrigation.

Ionic composition of leachate water :

The results on ionic composition of leachate samples collected fortnightly during the study period from the laterals and the outlets are presented in Table 5. Analysis of the same revealed that the cationic concentration of leachate water collected at the outlets ranged from 19.50-36.50 (Ca^{2+}), 5.00-15.00 (Mg^{2+}), 24.50 to 51.00 (Na^{+}) and 0.30 to 1.10 meq/l (K^{+}) and at the laterals varied from 14.50-42.50 (Ca^{2+}), 6.50-16.50 (Mg^{2+}), 25.50 to 48.50 (Na^{+}) and 0.12 to 1.50 meq/l (K^{+}).

Thus, the ionic composition of leachate was dominated by sodium followed by calcium, magnesium and potassium among the cations. The sodium adsorption ratio (SAR) for outlets and laterals was moderate and pH ranged from 7.10 to 9.10 in the outlets and 6.20 to

Table 3 : Salinity of leachate from SSD main outlets and laterals during September 2014- January 2015

SSD main outlet / lateral	Salinity of leachate (EC, dS m^{-1})					
	September	October	November	December	January	Mean
Main outlet						
I	8.90	9.00	9.90	11.00	11.50	10.0
II	7.60	7.70	11.00	10.90	9.60	9.36
Mean	8.20	8.30	10.50	10.90	10.60	9.68
Laterals						
LLII	8.10	8.20	7.80	10.70	11.10	9.18
RLII	7.80	7.20	11.30	9.90	9.80	9.20
RRII	8.30	8.90	12.50	9.70	10.30	9.94
Mean	8.10	8.10	10.50	10.10	10.40	9.44

Table 4 : EC and pH of the canal water and groundwater

Source of water	September, 2014		December, 2014	
	EC, dS m^{-1}	pH	EC, dS m^{-1}	pH
Groundwater	9.50	7.70	9.43	7.58
Canal water	0.58	7.10	0.63	7.15

8.50 in the laterals. The anionic concentration of leachate water collected was dominated by chlorides and bicarbonates followed by sulphates. The anionic concentration of leachate water collected in the outlets ranged from 7.30 to 15.10 (HCO_3^-), 26.47 to 44.50 (Cl^-) and 2.10 to 6.30 (SO_4^-) and in the laterals varied from 7.50 to 13.50 (HCO_3^-), 24.50-37.50 (Cl^-) and 2.50 to 6.50 (SO_4^-), respectively.

The average cationic composition during the entire cropping period for subsurface collector main drain outlet I and outlet II consisted of 27.95 and 27.46 (Ca^{2+}), 11.72 and 10.29 (Mg^{2+}), 32.30 and 31.10 (Na^+) and 0.65 and 0.56 (K^+) meq/l, respectively. Similarly, the mean anionic composition for outlet I and outlet II contained 12.24 and 11.50 (HCO_3^-), 34.64 and 37.55 (Cl^-) and 4.10 and 4.86 (SO_4^-), respectively. The SAR values at the outlets ranged from 5.60 to 10.90 and at the laterals varied from 5.60 to 11.90. The residual sodium carbonate (RSC) values ranged from -34.50 to -19.00 meq/l at the outlets and -34 to -22 meq/l in laterals.

The ionic composition of the leachate collected from the outlets of the collector mains and the manholes of the laterals was dominated by sodium followed by calcium, magnesium and potassium among the cations and by chlorides followed by bicarbonates sulphates in case of anions. Further, that the ionic concentration of leachate was much more than the canal water. The mean pH of leachate reduced from 8.01 to 7.67 due to SSD system during November 1998 to May, 1999 in the Upper Krishna Project command area (Barker, 2000). Tahir and Nasir (2008) noticed that the average pH of drain outflow was in the range of 8.10-8.11, whereas irrigation water was slightly alkaline in the range of 7.38.

Leaching and removal of salts :

The month wise quantities of salts removed from the fields in the study area by the influence of subsurface drainage system are presented in Table 6. The results revealed that under the main drain I, the maximum salts removed was 0.94 t ha^{-1} during December month, while the minimum was 0.44 t ha^{-1} in the month of January. Similarly, in case of main II, the maximum removal of salts (1.36 t ha^{-1}) was observed during November month and the minimum (0.63 t ha^{-1}) was noticed in January. Average salt removed was 0.64 and 1.04 t in main I and main II. Further, the total amount of salts removed from the main drains I and II were 3.22 and 5.20 t, respectively. This outgoing salt load over a period of time depending of cropping and irrigation practices would help in reducing the soil salinity and thereby facilitate restoration of soil production capabilities. Srikanth *et al*. (2004) in their study of salt and water balance in SSD executed area in Upper Krishnan Project (UKP), Karnataka assessed the salt loads as 0.98 and 1.09 t during *Kharif* and *Rabi* seasons, respectively which were disposed through the drainage system. The total quantity of salts disposed through subsurface drainage systems during the three consecutive years during 1999 to 2002 as 567.21 and 197.92 t at the rate of 81.03 and 39.58 t ha^{-1} through pipe and open drainage systems, respectively (Srinivasulu

Table 5 : Ionic composition of leachate from SSD main outlets and laterals during late *Kharif* season 2014

Outlets	pH	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Ca^{2+}	Mg^{2+}	K^+	Na^+	RSC	SAR
Main I	8.06	0.00	12.24	34.64	4.10	27.95	11.72	0.65	32.3	-30.57	7.75
Main II	7.94	0.00	11.51	37.55	4.86	27.46	10.29	0.56	31.10	-30.90	7.20
Range	7.1-9.1	0.00	7.3-15.1	26.47-44.5	2.1-6.3	19.5-36.5	5-15	0.3-1.10	24.5-51	-19-(-34.5)	5.6-10.9
Laterals											
LLII	7.56	0.00	9.38	28.05	3.52	26	9.72	0.81	37.27	-27.33	9.06
RLII	8.10	0.00	8.27	33.13	3.8	19.50	10.04	0.76	38	-28.5	8.5
RRII	7.16	0.00	10.13	32.4	3.61	25.10	12.24	0.78	33.27	-27.24	8.81
Range	6.2-8.5	0.00	7.5-13.5	24.5-37.5	2.5-6.5	14.5-42.5	6.5-16.5	0.12-1.5	25.5-48.5	-22-(-34)	5.6 to 11.9

Table 6 : Average salts removed in SSD system during September 2014-January 2015

	Month wise total salts removed (t ha^{-1})						
Drain no.	September	October	November	December	January	Monthly average	Total
Main I	0.52	0.54	0.78	0.94	0.44	0.64	3.22
Main II	1.08	0.97	1.36	1.15	0.63	1.04	5.20
Total	1.60	1.51	2.14	2.09	1.07	1.68	8.42

et al., 2006).

Conclusion :

The drain discharge was observed with an weighted average discharge of mains was 0.50 mm d^{-1} and 0.44 mm d^{-1} for the laterals. The ionic composition of leachate was dominated by sodium, while the anionic concentration of leachate was dominated by chlorides and bicarbonates. The salinity of leachate was 9 to 14 times higher than the canal water, outgoing salt load over a period of time depending of cropping and irrigation practices would help in reducing the soil salinity

Authors' affiliations:
P. BALAKRISHNAN, Department of Soil and Water Engineering, College of Agricultural Engineering, RAICHUR (KARNATAKA) INDIA

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