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CM Pradeep
Ph.D Scholar (Agri. Engg.)
SWE, UAS, Raichur,
Karnataka, India

P Balakrishnan
Professors, University of Agricultural Sciences, Raichur, Karnataka, India

U Satishkumar
Professors, University of Agricultural Sciences, Raichur, Karnataka, India

AT Dandekar
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

H Lokesh
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

MA Bellakki
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

Correspondence
CM Pradeep
Ph.D Scholar (Agri. Engg.)
SWE, UAS, Raichur,
Karnataka, India

Performance evaluation of subsurface drainage system on drain discharge, leachate quality, salt load and crop yield improvement in waterlogged saline areas in UKP command area, Karnataka

CM Pradeep, P Balakrishnan, U Satishkumar, AT Dandekar, H Lokesh and MA Bellakki

Abstract

The study was carried out to check the performance of subsurface drainage system on soil quality parameters, land and crop performance in the UKP command Area, Karnataka. The study area is located between 16°43’34.18” N to 16°44’10.52” N and longitude of 76°34’10.02” E to 76°34’43.13” E at an elevation of 458 m above the mean sea level. The lowest and highest of weekly overall weighted average discharge considering all the drains together has been observed that 0.18 mm d^{-1} in 10^{th} week and 1.55 mm d^{-1} in 38^{th} week respectively. Among the mains, the average discharge was 0.49, 0.43, 0.39, 1.19 and 1.30 mm d^{-1} in main I, II, III, IV and V respectively. Further, considering the whole area for the entire period of study, the overall weighted average discharge of the SSD system was found to be 0.76 mm d^{-1}. The minimum and maximum salinity were observed in the month of September-2014 (*i.e.* 1.80 dS m^{-1}) and December-2014 (5.67 dS m^{-1}) in main drain outlet V and I respectively. The values of pooled mean salinity of the outlets were 3.99, 3.22, 4.09, 3.79, 4.20, 4.29 and 4.42 dS m^{-1} during August, September, October, November, December, January and February respectively, with the overall leachate mean salinity of the outlets was 4.04 dS m^{-1}. The mean EC, SAR and RSC values observed to be 4.04, 7.95 and -24.56 respectively.

Keywords: Electrical conductivity, pH, SAR, RSC and crop yield

1. Introduction

Inter-basin transfer of water has been a major thrust area such that canals networks are now a major source of irrigation in the arid and semiarid regions. It is now well established that seepage from the canals and other distribution structures and inefficient use of irrigation water has led to the development of waterlogging and soil salinity in many irrigation commands. The problem is quite widespread and it is assessed that about 5.6 million ha of land has gone out of cultivation in irrigation commands (Tyagi and Minhas, 1998) [6]. To reclaim and manage waterlogged salt affected lands, drainage seems to be most appropriate intervention. Besides many advantages, drainage helps to maintain edaphic environment that is favorable to crop production.

The state of Karnataka is no exception to these phenomena as the command areas of its many irrigation projects are suffering from waterlogging and salinity problems. About 4 lakh ha has been affected by waterlogging and salinity in the state. The Upper Krishna Project (UKP) is the most prestigious and an ongoing major irrigation project in the state, that aims to irrigate the chronically drought hit areas of Kalaburagi, Yadgiri, Raichur, Koppal and Vijayapura districts in northern Karnataka. Under the UKP, irrigation water was first let out in September, 1982 and about 6 lakh ha irrigation potential has been created till date. The project on its full development envisages bringing 1 M ha under irrigation in three stages I, II, III and beyond. The predominant soils of the UKP command areas are black soils with fine texture and poor water transmission properties. Therefore, the problems of waterlogging and salinity are unavoidable processes in vertisols (black cotton soils) and they are increasing at alarming rate because of their inherent poor drainage property coupled with potential evapotranspiration rates that are much higher than the annual rainfall.

In order to expedite adoption of land reclamation by subsurface drainage technology, many demonstrations need to be undertaken in farmers’ fields in different parts of the command areas in order to convince them. Further, these reclamation projects need to be taken up on community basis in larger contiguous areas by the concerned (CADAs) and the farmers together with funding from the state/central Government(s).

Thus, adopting the recommendations of the Indo-Dutch Network Project, a project was taken up with the funding under the RKVY for demonstration of the subsurface drainage with the objectives of reclaiming the agricultural lands affected by waterlogging and salinity to restore the crop productivity and to serve as a model drainage demonstration for promoting the drainage activities in the UKP command area for the benefit of the farming community.

Materials and methods

Description of study area

The study area selected for the present study comes under the command of Jevargi Branch Canal (JBC) of the Narayanpur Left Bank Canal (NLBC) taking off from the Narayanapur dam under the UKP. The study area is located at Malla-Buzurg (B) village in Shorapur taluk, Yadgiri district within 16°43’34.18” N to 16°44’10.52” N and longitude of 76°34’10.02” E to 76°34’43.13” E at an elevation of 458 m above the mean sea level. In and around the study area also, considerable area was affected by the problems of waterlogging and salinity. The total area of the NLBC command was 180 ha of which about was affected by these problems and the area of the study site was 50 ha. The study area falls under the Northern Dry Zone (Zone-2) of Karnataka state agro-climatic zones. The study area is part of semi-arid region with average annual rainfall of 711.2 mm. The evaporation values ranged from 697 to 1522 mm, minimum and maximum temperature is ranged from 13.81ºC to 27.46 ºC and 28.67ºC to 42.29 ºC respectively, the relative humidity (RH) values are ranged from 24.19 to 83.04 per cent, wind velocity ranged from 3.98 to 11.05 km day^{-1} and the average sunshine hour of the study area is 6.25 h.

Drainage planning of the study area

The SSD layout of study area at Malla-B is given in Figure 1. The SSD system was laid out using PVC perforated and corrugated drain pipe laterals of 10 cm dia in composite systems with herringbone or grid iron patterns and in singular systems directly leading to the nala. The collector mains consisted of blind PVC corrugated pipes of 12 cm dia installed at a depth of 1.20 m. The overall SSD system in the study area (only cropped area was considered here) consisted of 5 composite systems with collector drains and 51 laterals connected on either side of the collector drains and 30 inspection chambers (manholes) and also 12 singular system (SS) direct line drains. The drain discharge was monitored, collected and measured in 5 main outlets located within the cropped area.

Observations recorded for performance of SSD system

The drain discharges were monitored 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. In order to assess the impact of the SSDs on water table, the water levels were monitored fortnightly in observation wells, which were installed in the study area. The leachate water samples were collected mothly 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

Monitoring of Drain Discharge in SSD System

The Table 1 reveal that the standard week wise weighted average discharge and the overall weighted average discharge of five main drain outlets. The analysis of data revealed that the drain discharge were ranged from 0.01 to 1.03, 0.01 to 0.96, 0.01 to 0.91, 0.34 to 2.32 and 0.37 to 2.51 mm d^{-1} in the collector main I, main II, main III, main IV and collector main V respectively. The lowest and highest of weekly overall weighted average discharge considering all the drains together (on pipe drained area basis) has been observed that 0.18 mm d^{-1} in 10th week and 1.55 mm d^{-1} in 38th week respectively. Among the mains, the average discharge was 0.49, 0.43, 0.39, 1.19 and 1.30 mm d^{-1} in main I, II, III, IV and V respectively. Further, considering the whole area for the entire period of study, the overall weighted average discharge of the SSD system was found to be 0.76 mm d^{-1}. The standard week wise weighted average discharge and the overall weighted average discharge data in five lateral drains are presented in Table 2. In the study period of August-2014 to February-2015 minimum discharge has been observed that 0.01 mm d^{-1} and maximum was 2.46 mm d^{-1}. The weekly overall weighted average discharge considering all the laterals together indicating a range of 0.18 to 1.47 mm d^{-1}. Among the laterals, the average discharge was 0.31, 0.42, 0.37, 1.18 and 1.25 mm d^{-1} in M1LL1, M2RL1, M3RL1, M4LL1 and M5RL1 respectively with overall mean of 0.71 mm d^{-1}.

The discharge was maximum in some of the outlets and laterals drains because those areas have the cropping practice of paddy and remaining have the practice of cotton and fallow. As in the paddy fields, more water was there as compared to cotton field, the discharge was more in paddy cultivated area as compare to cotton sown and fallow area. The drain discharge in cotton cultivated area was more as compared to fallow land because the cultivated area was less compact and has better porosity. The drain discharge was also influenced by soil texture, infiltration rate, hydraulic conductivity and cropping practice. Therefore, the discharge was rated as medium due to medium rate of hydraulic conductivity and saline and sodic nature of the soil. The discharge could be increased by application of gypsum and organic manure to the soil in the subsequent seasons. Manjunath *et al.* (2004) [2] 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 and these results also supported by the findings of Wright and Sands (2009) [8] and Valipour (2012) [7].

Analysis of Leachate Water Quality during the period from August- 2014 to February-2015

The water quality aspects in respect of salinity and ionic composition of the leachate from the outlets of the SSD collector main drains, laterals (at manholes) and singular system direct line drains collected during period 2014 and 2015 are presented in the following sections.

Salinity of the leachate water at the laterals and the outlets of main drains

The Table 3 revealed that the monthly analysis of salinity (EC) of leachate water samples collected from the subsurface collector main drain outlets and the inspection chambers of different laterals during the period from August 2014 till February 2015. Considering all the laterals, the leachate salinity (dS m^{-1}) ranged from 1.81 dS m^{-1} during December in lateral M5LL1 to 5.36 dS m^{-1} during February in lateral M41LL1. Individually, the mean salinity of laterals M1LL1, M2RL1, M3RL1, M4LL1 and M5RL1 were 4.08, 4.21, 3.75, 4.37 and 3.77 dS m^{-1} respectively. The values of pooled mean salinity of the laterals were 4.19, 3.52, 4.29, 3.99, 3.26, 4.43 and 4.55 dS m^{-1} during August, September, October, November, December, January and February respectively, with the overall leachate mean salinity of the laterals was 4.03 dS m^{-1}.

Similarly, the minimum and maximum salinity were observed in the month of September-2014 (*i.e.* 1.80 dS m^{-1}) and December-2014 (5.67 dS m^{-1}) in main drain outlet V and I respectively. The values of pooled mean salinity of the outlets were 3.99, 3.22, 4.09, 3.79, 4.20, 4.29 and 4.42 dS m^{-1} during August, September, October, November, December, January and February respectively, with the overall leachate mean salinity of the outlets was 4.04 dS m^{-1}. The highest mean leachate salinity was found in the outlet IV (4.49 dS m^{-1}) followed by outlets of I, III, V and II. Further, it could be noticed that the mean salinity in the outlets increased over the months from August to February (Table 3). The EC of canal water was very low during the study period with 0.80 dS m^{-1} in September, 2014 and 0.93 dS m^{-1} in February, 2015. Thus, the leachate salinity was higher by 4 times during September, 2014 and nearly 5 times during February 2015 compared to that of 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 leachate ionic composition of the cations was dominated by sodium followed by calcium, magnesium and potassium and anions dominated by chlorides followed by bicarbonates and sulphates. The mean values of cations of Na^+, Ca^{2+}+ Mg^{2+} and K^+ were ranged from 31.00 to 36.02, 31.73 to 36.17 and 0.30 to 0.42 meq/l respectively. Similarly, the mean values of anions of Cl^-, HCO_3^- and SO_4^{-2} were ranged from 27.63 to 33.75, 8.80 to 10.42 and 2.82 to 4.47 meq/l respectively. The ionic composition of the leachate from the laterals and mains drains indicated that the ionic concentrations were higher than that of the canal water. However, the leachate water quality was found to be not good and couldn't be used for irrigation. These results were in confirmation with findings of Mathew *et al*. (2001) [3], Shakya and Singh (2010) [5] and Jadhao *et al.* (2009) [1].

The salinity and alkalinity is generally measured in terms of the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). The mean minimum and maximum SAR values observed during the study period were 7.53 and 8.57 respectively, with their overall average value for the study area as 8.11. Similarly, the RSC values were ranged from -26.32 to -19.37 with overall average value as -23.92. The leachate water from arid and semi-arid areas always has a higher salinity than the supply water, a higher proportion of Na^{2+} and Cl^- an increased hardness and a higher sodium adsorption ratio (SAR) and also it depicts a clear trend that SAR and RSC of leachate water has increased after sowing of the crops. It is recommended that leachate water of this area must be treated or mixed with canal water before being used for irrigation because direct use of such water may increase the carbonates and bicarbonates concentrations in soil. The present results obtained are in line with the findings of Shakya and Singh (2010) [5].

Leaching and Removal of Salts

The month wise quantities of salts removed from the collector mains in the study area by the influence of subsurface drainage system during the period of 2014-'15 was presented in Table 4. The minimum and maximum salts removed under the main drains was 0.11 t ha^{-1} in main III and 11.66 t ha^{-1} in main IV respectively. The total amount of salt removed from main drain I, II, III, IV and V were 13.83, 18.29, 11.19, 53.23 and 13.21 t with their monthly average salts removed as 1.98, 2.61, 1.60, 7.60 and 1.89 t ha^{-1} respectively. In all the mains, a total of 109.75 t of salt load was removed out from the entire study area during the cropping period in 2014-'15. For the same period, the total amount of salt load removed from the total study area was 142.81 t. The salt removed was more in main IV because the discharge was more as compared to other mains. This might be due to the fact that the removal of salt load mainly depends on EC_e of the soil, EC of the drain discharge and amount of drain water, therefore salt removal might be more.

Crop yield

It was observed that annual cropping intensity before the installation of subsurface drainage was 25.12 per cent which were improved to 146.2 per cent after the installation of subsurface drainage system. Before the installation of SSDs the average paddy and cotton yield of the study area was ranging between 25 to 29 and 10.0 to 11.25 q ha^{-1} respectively. After installation of SSDs the paddy yield was range between the 45.90 to 50.89 q ha^{-1} and the yield of cotton was ranged between 19.23 to 23.21 p ha^{-1} during the period 2014-'15 (Table 5). Therefore, there is a 45.59 and 49.77 per cent increase in of paddy and cotton yields as compare to pre-drainage condition. Naftchali and Shahnazari (2014) [4] reported the introduction of the subsurface drainage resulted in an increase in both crop yield and cropping intensity in the study area.

Summary and conclusions

The SSD layout for reclamation planning using the perforated and corrugated PVC pipes was laid out during 2012-'13. The performance and the impact of the SSDs were monitored during 2014-'15 for improvement in the soil physical, chemical and hydraulic parameters as well as the cropping intensity and yield response of the crops in the post-drainage scenario compared to the pre-drainage conditions. The lowest and highest of weekly overall weighted average discharge considering all the drains together (on pipe drained area basis) has been observed that 0.18 mm d^{-1} in 10^{th} week and 1.55 mm d^{-1} in 38^{th} week respectively and the overall weighted average discharge of the SSD system was observed to be 0.76 mm d^{-1}. The highest mean leachate salinity was found in the outlet IV (4.49 dS m^{-1}) followed by outlets of I, III, V and II. Further, it could be noticed that the mean salinity in the outlets increased over the months from August to February. 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. During the study period the total amount of salt removed was observed to be 109.75 t from the entire study area. The cropping intensity and crop yield was observed to be increased by 146.20 and 47.68 per cent respectively as compare to pre drainage condition.

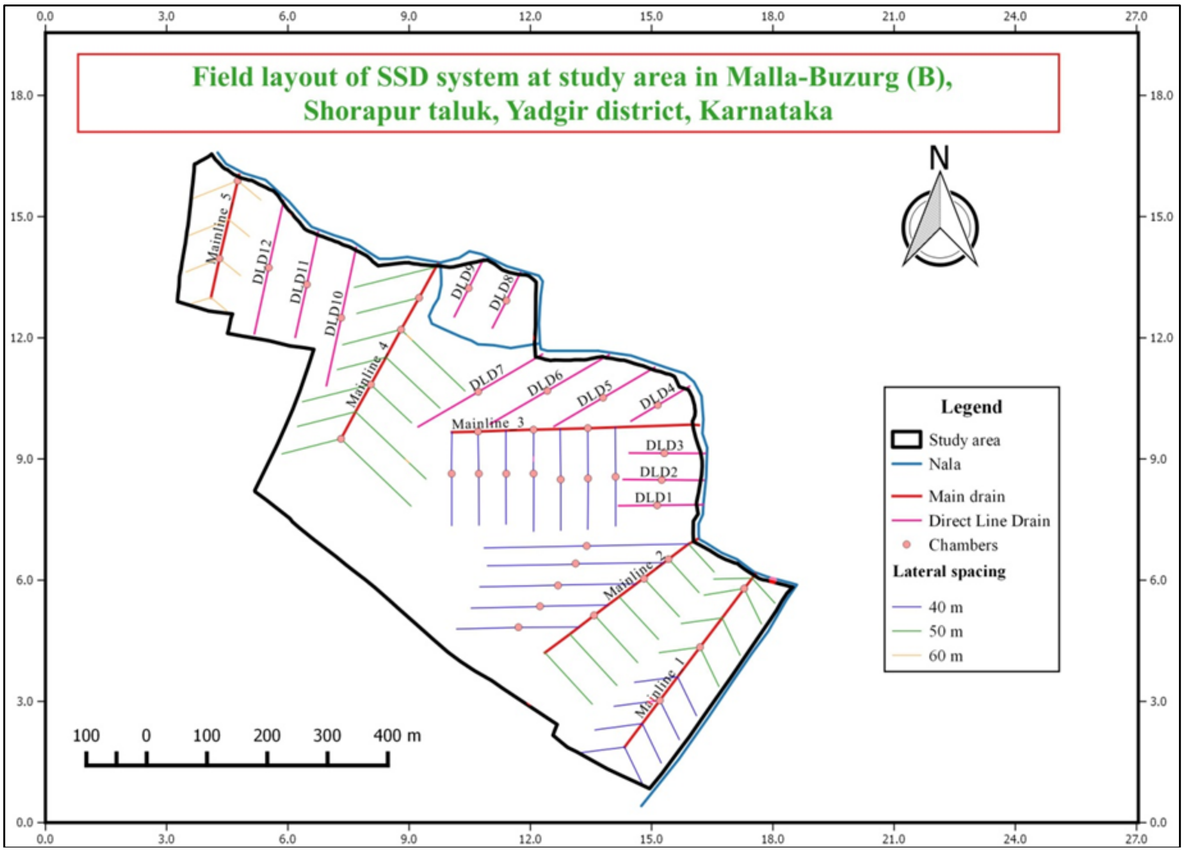

Fig 1: Subsurface drainage system layout of study area at Malla B

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

		Drain discharge, mm d^{-1}					
Sl. no.	**Standard week**	**Main I, mm d^{-1}**	**Main II, mm d^{-1}**	**Main III, mm d^{-1}**	**Main IV, mm d^{-1}**	**Main V, mm d^{-1}**	**Overall weighted weekly average discharge, mm d^{-1}**
1	32	0.42	0.39	0.36	0.83	0.91	0.58
2	33	0.58	0.48	0.43	0.98	1.03	0.70
3	34	0.85	0.72	0.67	1.86	2.15	1.25
4	35	0.93	0.86	0.82	2.21	2.45	1.45
5	36	0.87	0.82	0.79	1.96	2.16	1.32
6	37	0.97	0.88	0.84	2.08	2.26	1.41
7	38	1.03	0.96	0.91	2.32	2.51	1.55
8	39	0.92	0.81	0.75	1.83	1.97	1.26
9	40	0.85	0.79	0.74	1.71	1.87	1.19
10	41	0.88	0.82	0.77	1.83	1.94	1.25
11	42	0.81	0.76	0.72	1.75	1.82	1.17
12	43	0.94	0.86	0.78	1.86	2.07	1.30
13	44	0.87	0.81	0.69	1.69	1.89	1.19
14	45	0.80	0.74	0.62	1.48	1.53	1.03
15	46	0.64	0.53	0.46	1.26	1.36	0.85
16	47	0.51	0.42	0.38	0.85	0.92	0.62
17	48	0.34	0.29	0.26	0.74	0.79	0.48
18	49	0.31	0.22	0.19	0.52	0.61	0.37
19	50	0.27	0.20	0.18	0.34	0.37	0.27
20	51	0.26	0.18	0.17	0.67	0.84	0.42
21	52	0.23	0.16	0.14	0.87	0.92	0.46
22	1	0.19	0.15	0.12	0.88	0.94	0.46
23	2	0.16	0.13	0.10	0.92	1.03	0.47
24	3	0.14	0.11	0.08	0.86	0.99	0.44
25	4	0.13	0.09	0.06	0.87	0.96	0.42
26	5	0.10	0.07	0.04	0.83	0.92	0.39
27	6	0.08	0.05	0.02	0.73	0.76	0.33
28	7	0.06	0.03	0.02	0.69	0.71	0.30
29	8	0.03	0.02	0.01	0.61	0.69	0.27
30	9	0.01	0.01	0.01	0.54	0.58	0.23
31	10	0.01	-	-	0.42	0.49	0.18
Average		0.49	0.43	0.39	1.19	1.30	0.76

Table 2: Average weekly discharge of SSD lateral drains

		Drain discharge, mm d^{-1}					
Sl. no.	Standard week	M1LL1 mm d^{-1}	M2RL1 mm d^{-1}	M3RL1 mm d^{-1}	M4LL1 mm d^{-1}	M5LL1 mm d^{-1}	Overall weighted weekly average discharge, mm d^{-1}
1	32	0.29	0.37	0.34	0.82	0.88	0.54
2	33	0.42	0.46	0.41	0.97	0.98	0.65
3	34	0.46	0.70	0.65	1.85	2.08	1.15
4	35	0.58	0.84	0.80	2.20	2.39	1.36
5	36	0.60	0.80	0.77	1.94	2.13	1.25
6	37	0.70	0.86	0.82	2.07	2.23	1.34
7	38	0.76	0.94	0.89	2.31	2.46	1.47
8	39	0.65	0.79	0.73	1.82	1.90	1.18
9	40	0.58	0.77	0.72	1.70	1.81	1.12
10	41	0.61	0.80	0.75	1.81	1.91	1.18
11	42	0.54	0.74	0.70	1.74	1.77	1.10
12	43	0.67	0.85	0.77	1.85	2.00	1.23
13	44	0.60	0.79	0.67	1.68	1.83	1.11
14	45	0.53	0.73	0.61	1.46	1.50	0.97
15	46	0.37	0.52	0.45	1.25	1.33	0.78
16	47	0.24	0.40	0.36	0.83	0.87	0.54
17	48	0.20	0.28	0.25	0.73	0.72	0.44
18	49	0.17	0.21	0.07	0.51	0.55	0.30
19	50	0.13	0.19	0.05	0.33	0.34	0.21
20	51	0.12	0.17	0.07	0.65	0.79	0.36
21	52	0.09	0.15	0.05	0.86	0.85	0.40
22	1	0.05	0.14	0.11	0.87	0.88	0.41
23	2	0.30	0.12	0.09	0.91	1.00	0.48
24	3	0.02	0.09	0.07	0.84	0.96	0.40
25	4	0.01	0.09	0.05	0.86	0.91	0.38
26	5	0.01	0.07	0.07	0.82	0.85	0.36
27	6	0.01	0.05	0.04	0.72	0.70	0.30
28	7	0.01	0.02	0.03	0.67	0.68	0.28
29	8	0.01	0.01	0.01	0.60	0.62	0.25
30	9	0.01	0.01	0.01	0.53	0.52	0.22
31	10	0.01	-	-	0.41	0.46	0.18
Average		0.31	0.42	0.37	1.18	1.25	0.71

Table 3: Salinity of leachate from SSD main outlets and laterals during August- 2014 to February-2015

SSD main outlet/lateral			Salinity of leachate (EC, dS m^{-1})					
Main outlet	August	September	October	November	December	January	February	Mean
I	3.99	3.80	4.20	3.57	5.67	4.42	4.52	4.31
II	3.10	3.78	3.18	2.94	4.65	3.35	3.55	3.51
III	4.20	2.50	4.25	4.10	3.67	4.40	4.60	3.96
IV	4.51	4.21	4.59	4.35	3.96	4.87	4.93	4.49
V	4.16	1.80	4.25	3.99	3.03	4.39	4.48	3.73
Mean	3.99	3.22	4.09	3.79	4.20	4.29	4.42	4.04
Laterals								
M1LL1	4.00	4.40	4.05	3.90	3.80	4.16	4.25	4.08
M2RL1	4.15	5.20	4.24	3.98	3.02	4.38	4.47	4.21
M3RL1	3.90	2.30	3.96	3.78	4.15	4.03	4.13	3.75
M4LL1	4.90	1.90	4.99	4.73	3.52	5.16	5.36	4.37
M5LL1	4.00	3.81	4.21	3.58	1.81	4.43	4.53	3.77
Mean	4.19	3.52	4.29	3.99	3.26	4.43	4.55	4.03

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