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RESEARCH PAPER

Assessment of spatial and temporal changes in salinity and alkalinity of natural streams/nala water in Sindhanur taluk of Tungabhadra command area in Karnataka

HARSHAWARDHAN RATHOD, J. VISHWANATH, H. V. RUDRAMURTHY, H. VEERESH AND N. ANANDA

Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur
University of Agricultural Sciences, Raichur - 584 104, Karnataka, India
E-mail: vishwa110931@rediffmail.com

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Abstract: The feasibility of quality of canal and natural stream/nala water for irrigation over the cropping season was assessed from August 2019 to February 2020 in Sindhanur taluk of TBP command area. Water samples from twelve different sampling stations along natural streams revealed that, EC of nala water varied from 0.14 to 0.30 dS m^{-1} as against 0.44 to 7.39 dS m^{-1} of canal water respectively. Among cations, Na^+ was the dominant followed by Ca^{2+}, Mg^{2+} and K^+. The relative proportion of anions was in the order of $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{2-}$. In general, the maximum variations in EC, concentrations of cations/anions and the SAR and RSC values in nala water among the sampling stations were observed particularly in the months of December and February. Across the sampling stations, the mean EC(3.66 to 24.80), SAR (4.11 to 19.41) and RSC (0.46 to 1.30) of nala were, higher compared to canal water over the cropping season. The EC, Cl/SO_4 ratio and SSP values are the major constraints in majority of nala water samples as far as their irrigation feasibility is concerned.

Key words: Irrigation, Natural stream, Water quality

Introduction

The Tungabhadra Irrigation Project (TBP) in Karnataka has been adversely affected due to the development of irrigation induced waterlogging and soil salinization in the command area. As per TBP-CADA report (2012), it is estimated that about 26.5 per cent (96,215 ha) of the command area (3.62 lakh ha) is affected due to waterlogging and salinity in TBP command area. As per the guidelines, it was proposed to allocate 8 per cent (29,032 ha) and 4 per cent of TBP command area under paddy and sugarcane, respectively, to avoid development of waterlogging and soil salinity. However, at present actual area under paddy is more than 40 per cent of the command area and in addition, the crop is being cultivated by majority of farmers in upstream area of the command as against downstream farmers as suggested in the guidelines. At the mid-reach and downstream of the command, farmers are not only compelled to grow paddy but also forced to use natural streams/drain/ underground poor quality water for irrigation because of the limited canal water availability. Nala water is being used for land preparation, raising paddy nursery and over the cropping season as and when canal water supply is limited. It has added a new dimension to the problem of waterlogging and soil salinization in the command. In a recent study, Manjunath (2019) revealed that EC, Cl/SO_4 ratio and RSC values appear to be the major constraints in majority of water samples collected from natural stream in Gangavathi taluk (TBP command area). Hence, the present investigation was carried out to document spatial and temporal changes of nala water in comparison to canal water in Sindhanur taluk of TBP command area.

Material and methods

Based on the GPS, toposheet (1:50,000 scale) and satellite image, major natural stream/nala existing under canal distributary 36 of the TBP command in Sindhanur taluk, Karnataka was located. It is the fourth of the 9 major natural streams present across Left Bank Main Canal (LBMC) of TBP command area. A total of twelve sampling stations were located along the natural stream (approx. 34.7 km in length) from the start of distributary (15°40'04.9" N and 76°35'48.0" E) to the end of the stream (15°40'04.8" N and 76°51'57.2" E) leading to Tungabhadra river as depicted in Fig.1. The twelve sampling stations along natural stream were at 0.50, 1.63, 0.86, 2.15, 2.02, 4.82, 5.50, 0.83, 3.17, 4.01, 2.09 and 1.37 km away from the start of the distributary based on the accessibility to the sampling stations. Water samples from the distributary-36 and different sampling stations were collected from August, 2019 to February, 2020 at an interval of 10-14 days over twelve times. A total of 156 samples were collected for irrigation water quality appraisal. After measuring pH and EC, these samples were stored for further analysis after adding 1ml toluene to arrest the microbial growth.

The pH and EC of water samples was determined by using glass electrode and conductivity meter (Jackson, 1973). The cationic concentrations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anionic concentrations (Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-) were measured following standard procedures outlined by Richards (1968). The values obtained were used to compute for sodium adsorption ratio (SAR), residual sodium carbonate (RSC), magnesium to calcium ratio (Mg/Ca), divalent cation ratio (DCR), Cl/SO_4, soluble sodium percentage (SSP) and magnesium hazard (MH) as under:

$$SSP = \frac{Na^+ \times 100}{Ca^{2+} + Mg^{2+} + Na^+}$$

$$MH = \frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} \times 100$$

$$DCR = \frac{Ca^{2+} + Mg^{2+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$$

$$RSC\ (me\ L^{-1}) = (CO_3^{2-} + HCO^{3-}) - (Ca^{2+} + Mg^{2+})$$

$$SAR\ (mmol/L)^{1/2} = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

The criteria (EC, SAR and RSC) used for the classification of irrigation water are based on the classification diagram proposed by Richards (1968). The ICAR-CSSRI, Karnal also proposed three broad categories of classification of ground water viz., good, saline, and alkali (Minhas *et al*., 1998) based on EC, RSC and SAR values wherein the values set in for good category water are not as conservative as compared to Richards (1968) classification. Irrigating with the good quality Tungabhadra river water (EC 0.10-0.20 dS m^{-1}) for paddy-paddy cultivation in shallow and medium black soil of this region over the decades has resulted in the development of waterlogging and secondary salinization @ 3000 ha per annum (Manjunatha *et al*., 2004), classification proposed by Richards (1968) is considered in this article.

Results and discussion

The water quality parameters viz., pH, EC, cation/anion concentrations, SAR, RSC, DCR, NO_3-N, PO_4-P, Mg/Ca, SSP, MH and Cl/SO_4 ratios in water samples collected from distributaries and natural stream is presented in Table 1 and in Fig 2 to 6.

pH

Temporally, the pH of canal water collected from distributary 36 varied from 7.42 to 8.49 with a mean value of 7.91.The standard deviation (SD) and coefficient of variation (CV) values over the sampling period were 0.35 and 4.36% respectively. Similarly, the temporal values of water pH at 12 different sampling stations over the sampling period ranged from 7.75 to 8.47, 7.22 to 8.27, 7.17 to 7.99, 7.17 to 7.83, 7.15 to 8.05, 7.09 to 8.22, 7.20 to 8.04, 7.22 to 7.94, 7.01 to 7.95, 7.08 to 8.83, 6.98 to 8.36 and 7.50 to 8.01 with a mean value of 8.18 , 7.74 , 7.57 , 7.51, 7.59, 7.60, 7.67, 7.69, 7.66, 7.96, 7.92and 7.84, respectively. The SD ranged from 0.20 to 0.44 with a mean of 0.27 and CV ranged from 2.55 to 4.36 with a mean of 3.55% at over the sampling period at 12 different sampling stations.

Spatially, across the 12 sampling stations, water pH ranged from 6.98 to 8.83 with a mean of 7.74 over the sampling period. The SD ranged from 0.16 to 0.40 with a mean of 0.29. Similarly, the CV ranged from 2.0 to 5.45 with a mean of 3.7%.

The results are in conformity with the findings of Manjunath (2019) wherein pH of water samples collected from natural

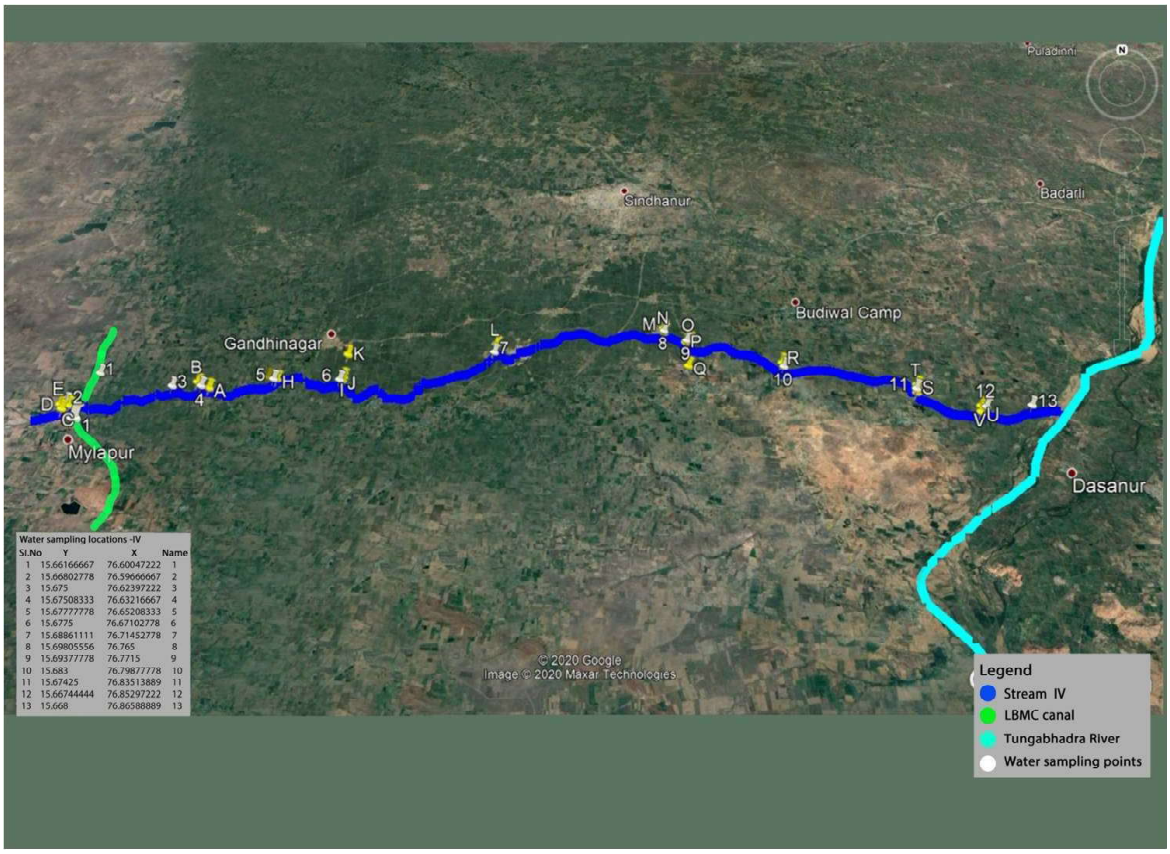

Fig. 1. Water sampling points of LBMC in TBP command area.

streams in Gangavathi taluk of TBP command area during *Kharif* 2019 ranged from 7.50 to 8.00 and 8.0 to 8.50.

Electrical conductivity (EC)

Temporally, the EC of canal water samples collected at distributary 36 varied from 0.14 to 0.30 with a mean value of 0.21 dS m^{-1}. The standard deviation (SD) and coefficient of variation (CV) values over the sampling period were 0.35 and 4.36% respectively .Similarly, EC of water samples collected from natural stream of LBMC in TBP command area at different sampling stations over the sampling period ranged from 3.35 to 7.39, 0.44 to 1.20, 0.49 to 1.06, 0.70 to 1.28, 0.72 to 2.65, 0.61 to 4.18, 0.65 to 3.77, 0.64 to 1.84, 0.60 to 5.16, 0.59 to 4.02, 0.58 to 5.16 and 0.60 to 4.33 dS m^{-1} with a mean value of 5.21 , 0.77 , 0.80 , 0.92 , 1.13 , 1.14, 1.22 , 1.07 , 1.41, 1.65 , 1.87 and 1.77dS m^{-1} respectively. The SD ranged from 0.18 to 1.48 with a mean of 0.79 and CV ranged from 26.5 to 85.2 with a mean of 51.9% at over the sampling period at 12 different sampling stations.

Spatially, across the 12 sampling stations, water EC ranged from 0.44 to 7.39 with a mean of 1.58 over the sampling period. The SD ranged from 0.78 to 2.11 with a mean of 1.31. Similarly, the CV ranged from 54.8 to 135 with a mean of 84.7%.

The mean EC values of nala water were 3.66 to 24.80 times higher compared to canal water of distributary 36. The maximum EC values observed at each of the sampling stations were in the months of December and February. Occurrence of higher EC values in the beginning of the season could be attributed that the water flowing in the natural stream was poor quality seepage water from the upper and adjacent fields as there was no release of canal water from the Tungabhadra reservoir. Consequent to the release of canal water in late September, the EC values declined. However, as per classification of irrigation water by Richards (1968), majority of water samples in stream at all sampling stations fall under category C3 (EC 0.75 to 2.25 dS m^{-1}) which indicate high salinity hazard and hence not feasible for irrigation.

Similar findings were reported by Manjunath (2019) wherein the mean EC of majority of water samples of natural streams of LBMC in TBP command area were under category of C3 (EC 0.75 to 2.25 dS m^{-1}) which indicate high salinity hazard and hence not feasible for irrigation. The canal water which passes through waterlogged saline soil and discharged into the natural stream (nala) would be of poor quality as it carries salts present in the soil profile. Hence, depending on the soil properties through which canal water passes through the quality of natural stream water is expected to be different than the canal water with respect to salinity so also the ionic composition (Prasanna *et al.,* 2011).

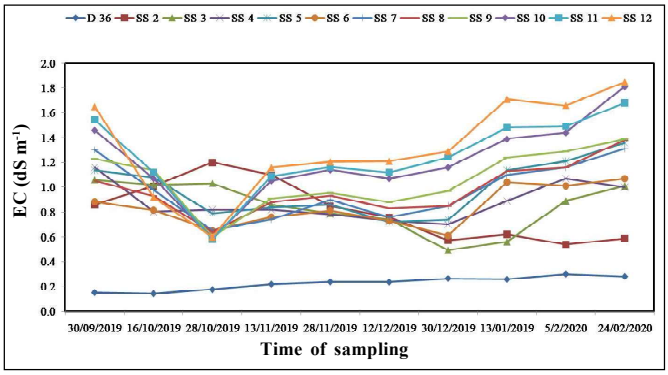

Fig. 2. Spatial and temporal variations in EC (dS m^{-1}) of water samples collected at different sampling stations of natural stream and distributary 36 of LBMC in TBP command area

Calcium, magnesium, sodium and potassium

Temporally, the Ca^{2+} concentrations of canal water collected at distributary 36 varied from 0.44 to 1.12 me L^{-1} with a mean value of 0.73 me L^{-1}. The SD and CV over the sampling period were 0.17 and 23.6%. Similarly, the Ca^{2+} concentrations in water samples collected from 12 natural stream ranged from 1.52 to 5.16, 0.60 to 1.92, 0.60 to 2.88, 0.64 to 2.68, 0.84 to 2.80, 0.64 to 3.28, 1.16 to 3.08, 1.12 to 3.12, 1.00 to 3.20, 0.56 to 3.20, 1.24 to 3.36 and 0.32 to 4.40 me L^{-1} with a mean value of 3.39, 1.45, 1.82, 1.84, 1.99, 2.01, 2.05, 1.98, 2.12, 2.10, 2.34 and 2.24 me L^{-1} respectively. The SD ranged from 0.42 to 1.13 with a mean of 0.69 and CV ranged from 27.3 to 50.4 with a mean of 32.5% at over the sampling in 12 different sampling stations. The mean Ca^{2+} concentrations values of nala water were 1.98 to 4.64 times higher compared to canal water flowing in distributary 36. Similarly, Prasanna *et al.* (2011) observed that the Ca^{2+} concentrations in surface and sub-surface water in and around Perumal Lake, Tamilnadu ranged from 0.8 to 2.2 me L^{-1} with an average of 1.45 me L^{-1}.

Spatially, across the 12 sampling stations, the Ca^{2+} content in natural stream ranged from 0.32 to 5.16 with a mean of 2.11 me L^{-1}. The SD ranged from 0.17 to 0.98 with a mean of 0.61. Similarly, the CV ranged from 10.3 to 42.0 with a mean of 29.1%.

Temporally, the Mg^{2+} concentrations of canal water collected at distributary 36 ranged from 0.14 to 1.32 me L^{-1} with a mean value of 0.59 me L^{-1}. The SD and CV across the sampling period were 0.36 and 60.8%. Similarly, the Mg^{2+} concentrations in water samples collected from 12 natural stream ranged from 3.28 to 8.68, 0.64 to 2.08, 0.48 to 2.04, 0.92 to 2.40, 0.88 to 6.60, 0.56 to 6.44, 0.88 to 6.64, 0.88 to 3.28, 0.84 to 6.84, 0.92 to 6.24, 0.76 to 7.64 and 1.04 to 9.12 me L^{-1} with a mean value of 5.41, 1.21, 1.23, 1.59, 2.25, 1.98, 2.26, 1.71, 2.41, 2.63, 3.04 and 3.64 me L^{-1} respectively. The SD ranged from 0.41 to 2.62 with a mean of 1.36. Similarly, the CV ranged from 27.8 to 77.4 with a mean of 54.3%. The mean Mg^{2+} concentrations values of nala water were 2.05 to 9.16 times higher compared to canal water. Similar findings were reported by Manjunath (2019) wherein the mean Mg^{2+} concentrations values of nala water were 5.0 to 11.3 times higher compared to canal water.

Spatially, across the 12 sampling stations, the Mg^{2+} content in natural stream ranged from 0.48 to 9.12 with a mean of 2.30 me L^{-1}. The SD ranged from 0.66 to 2.91 with a mean of 1.49. Similarly, the CV ranged from 40.6 to 98.0 with a mean of 65.2%.

Temporally, the Na^{+} concentrations of canal water samples varied from 0.32 to 1.12 me L^{-1} with a mean value of 0.70 me L^{-1}. The SD and CV over the sampling were 0.23 and 32.7%. Similarly,

Table 1. Quality parameters of canal water in distributary and natural stream water samples collected in Sindhanur taluk of TBP command area, Karnataka

Parameters		Distributary	Natural stream water sampling stations											
		36	1	2	3	4	5	6	7	8	9	10	11	12
pH	Max.	8.49	8.47	8.27	7.99	7.83	8.05	8.22	8.04	7.94	7.95	8.83	8.36	8.01
	Min.	7.42	7.75	7.22	7.17	7.17	7.15	7.09	7.20	7.22	7.01	7.08	6.98	7.50
	Avg.	7.91	8.18	7.74	7.57	7.51	7.59	7.60	7.67	7.69	7.66	7.96	7.92	7.84
	SD	0.35	0.24	0.31	0.22	0.22	0.27	0.33	0.22	0.20	0.30	0.44	0.34	0.20
	CV	4.36	2.97	4.02	2.93	2.98	3.51	4.36	2.90	2.57	3.86	5.55	4.34	2.55
EC (dS m^{-1})	Max.	0.30	7.39	1.20	1.06	1.28	2.65	4.18	3.77	1.84	5.16	4.02	5.16	4.33
	Min.	0.14	3.35	0.44	0.49	0.70	0.72	0.61	0.65	0.64	0.60	0.59	0.58	0.60
	Avg.	0.21	5.21	0.77	0.80	0.92	1.13	1.14	1.22	1.07	1.41	1.65	1.87	1.77
	SD	0.06	1.38	0.24	0.21	0.18	0.52	0.97	0.83	0.31	1.20	1.05	1.48	1.11
	CV	27.98	26.51	30.95	26.45	19.72	46.02	85.25	68.14	29.22	85.21	63.85	79.14	62.64
Ca^{2+}	Max.	1.12	5.16	1.92	2.88	2.68	2.80	3.28	3.08	3.12	3.20	3.20	3.36	4.40
	Min.	0.44	1.52	0.60	0.60	0.64	0.84	0.64	1.16	1.12	1.00	0.56	1.24	0.32
	Avg.	0.73	3.39	1.45	1.82	1.84	1.99	2.01	2.05	1.98	2.12	2.10	2.34	2.24
	SD	0.17	0.99	0.42	0.59	0.53	0.54	0.68	0.57	0.58	0.75	0.81	0.67	1.13
	CV	23.6	29.2	28.9	32.3	28.8	27.3	33.4	27.3	29.3	35.4	38.7	28.6	50.4
Mg^{2+}	Max.	1.32	8.68	2.08	2.04	2.40	6.60	6.44	6.64	3.28	6.84	6.24	7.64	9.12
	Min.	0.14	3.28	0.64	0.48	0.92	0.88	0.56	0.88	0.88	0.84	0.92	0.76	1.04
	Avg.	0.59	5.41	1.21	1.23	1.59	2.25	1.98	2.26	1.71	2.41	2.63	3.04	3.64
	SD	0.36	1.86	0.41	0.44	0.44	1.53	1.53	1.53	0.62	1.57	1.54	2.28	2.62
	CV	60.8	34.3	34.1	35.6	27.8	68.0	77.4	67.5	36.1	65.3	58.4	75.0	72.0
Na^{+}	Max.	1.12	56.80	7.52	6.30	7.37	16.74	29.62	25.38	13.12	38.74	27.41	37.60	28.20
	Min.	0.32	24.22	1.78	2.17	3.83	3.95	3.30	3.75	3.45	3.30	2.88	3.40	3.45
	Avg.	0.70	38.35	4.53	4.51	5.19	6.54	6.92	7.41	6.38	8.76	10.52	11.94	10.94
	SD	0.23	11.3	1.91	1.57	1.11	3.50	7.20	5.81	2.47	9.55	8.08	11.3	7.36
	CV	32.7	29.5	42.2	34.9	21.3	53.5	104.0	78.4	38.8	109.0	76.8	94.6	67.3
K^{+}	Max.	0.10	0.35	0.10	0.10	0.31	0.19	0.17	0.20	0.66	0.18	0.35	0.30	0.17
	Min.	0.01	0.08	0.03	0.02	0.06	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07
	Avg.	0.06	0.17	0.07	0.07	0.11	0.10	0.09	0.12	0.15	0.10	0.13	0.13	0.10
	SD	0.02	0.09	0.03	0.03	0.07	0.05	0.04	0.04	0.17	0.04	0.08	0.08	0.03
	CV	39.2	52.7	40.2	37.8	61.8	45.4	40.3	34.4	110.2	37.0	65.3	58.9	29.0
CO_3^{2-}+HCO_3^{-}	Max.	2.12	12.40	4.20	5.00	4.40	9.20	7.20	4.90	5.40	6.40	10.60	7.60	7.40
	Min.	0.70	5.80	2.00	2.33	2.60	3.10	2.80	3.40	3.00	2.80	3.00	2.95	3.10
	Avg.	1.24	7.95	3.14	3.80	3.70	4.48	4.16	4.16	4.22	4.34	5.50	5.18	5.42
	SD	0.43	1.86	0.69	0.85	0.53	1.67	1.14	0.56	0.68	1.10	1.99	1.34	1.20
	CV	34.8	23.4	22.1	22.4	14.2	37.4	27.4	13.4	16.2	25.2	36.2	25.9	22.2
Cl^{-}	Max.	0.84	39.50	5.82	4.40	6.20	10.80	21.90	21.20	10.90	30.90	20.60	30.80	23.50
	Min.	0.50	16.80	2.00	1.80	2.40	2.40	2.00	2.20	1.80	2.40	2.20	2.20	2.10
	Avg.	0.67	26.06	3.26	2.79	3.50	4.25	4.58	5.09	4.21	6.21	6.49	8.55	7.70
	SD	0.11	8.89	1.05	0.85	1.11	2.38	5.52	5.23	2.35	7.91	5.66	9.84	6.78
	CV	16.4	34.1	32.2	30.4	31.8	56.0	120.5	102.7	55.7	127.2	87.2	115.0	88.0
SO_4^{2-}	Max.	0.43	19.80	2.42	1.96	2.84	5.61	10.45	7.86	3.29	11.39	10.28	11.66	9.65
	Min.	0.02	8.20	0.35	0.48	0.60	0.58	0.53	0.71	0.67	0.55	0.64	0.65	0.64
	Avg.	0.24	13.17	1.15	1.17	1.55	1.96	2.09	2.17	1.88	2.63	3.32	3.62	3.38
	SD	0.13	4.09	0.73	0.50	0.61	1.27	2.67	1.89	0.73	2.84	2.81	3.29	2.49
	CV	52.4	31.0	63.9	42.4	39.0	64.8	127.8	87.1	38.8	108.0	84.8	91.0	73.6
NO_3-N (mg L^{-1})	Max.	0.84	3.92	1.40	1.40	1.96	2.24	1.96	2.80	2.52	2.52	1.68	3.36	2.24
	Min.	0.14	0.28	0.14	0.28	0.14	0.28	0.14	0.28	0.14	0.28	0.28	0.28	0.28
	Avg.	0.37	1.26	0.61	0.82	0.90	0.91	0.86	1.31	1.13	1.28	0.96	1.42	1.19
	SD	0.18	1.00	0.43	0.44	0.62	0.59	0.58	0.85	0.75	0.69	0.56	0.88	0.60
	CV	49.6	79.5	70.7	53.4	69.0	64.4	67.5	64.7	66.6	53.9	58.3	62.0	50.3
PO_4-P	Max.	0.01	2.62	1.19	2.04	3.60	2.76	2.90	2.81	2.91	2.80	2.67	2.71	2.48
	Min.	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Avg.	0.01	1.20	0.40	0.78	1.19	1.12	1.11	1.00	1.05	1.05	0.99	1.00	0.95
	SD	0.01	0.84	0.43	0.76	1.16	1.00	1.00	1.00	1.02	1.00	0.84	0.86	0.79
	CV	52.2	69.6	106.6	97.9	97.2	88.0	88.8	99.8	97.4	95.5	85.3	86.0	82.7

Contd....

SAR (mmol L^{-1})$^{1/2}$	Max.	1.82	37.21	8.41	7.00	7.19	11.31	19.00	16.66	12.18	24.45	23.77	23.45	16.45
	Min.	0.64	19.18	2.44	2.61	4.32	4.88	4.26	4.66	4.21	4.23	3.75	4.46	4.45
	Avg.	1.30	25.24	5.72	5.35	5.45	6.34	6.39	6.84	6.42	7.52	8.14	8.13	7.92
	SD	0.32	5.83	2.03	1.58	0.89	1.87	3.98	3.18	2.06	5.40	5.74	6.15	3.55
	CV	24.8	23.1	35.5	29.6	16.4	29.5	62.3	46.5	32.0	71.9	70.5	75.6	44.8
RSC	Max.	2.20	5.04	1.56	2.04	1.48	1.20	2.08	1.80	4.76	2.26	5.28	1.84	2.04
	Min.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Avg.	1.07	0.50	0.78	1.00	0.69	0.69	1.07	0.90	1.40	0.84	1.39	0.77	0.78
	SD	0.62	1.45	0.52	0.62	0.51	0.46	0.67	0.68	1.27	0.81	1.38	0.60	0.69
	CV	57.8	289.7	67.3	62.4	74.5	66.3	63.0	75.3	90.5	96.0	99.0	78.4	88.6
Mg/Ca	Max.	2.36	5.13	2.27	2.73	3.19	3.06	2.75	2.52	2.41	2.56	8.50	3.08	10.63
	Min.	0.19	0.92	0.33	0.24	0.40	0.39	0.30	0.35	0.28	0.35	0.53	0.25	0.36
	Avg.	0.91	1.96	0.97	0.91	1.11	1.15	1.01	1.05	1.03	1.17	2.07	1.32	2.84
	SD	0.64	1.20	0.55	0.67	0.73	0.78	0.72	0.56	0.59	0.71	2.23	0.90	2.86
	CV	70.8	61.3	56.7	73.6	66.2	67.5	71.3	52.9	57.3	60.3	107.7	68.4	100.6
Cl/SO_4	Max.	49.73	2.07	6.22	3.57	2.75	3.11	3.89	3.09	3.31	4.71	3.44	3.36	3.75
	Min.	1.58	0.51	1.07	1.64	1.48	1.50	0.78	1.26	1.55	1.43	1.20	1.29	1.30
	Avg.	6.99	1.37	2.65	2.34	2.19	2.05	2.05	2.11	2.17	2.07	1.87	1.98	2.10
	SD	13.53	0.35	1.41	0.60	0.44	0.39	0.75	0.58	0.60	0.94	0.54	0.68	0.68
	CV	193.6	25.6	53.4	25.5	20.1	19.2	36.6	27.4	27.5	45.4	29.0	34.2	32.2
DCR	Max.	0.73	0.24	0.54	0.55	0.47	0.45	0.46	0.43	0.43	0.46	0.44	0.43	0.44
	Min.	0.55	0.14	0.30	0.31	0.35	0.31	0.25	0.27	0.25	0.21	0.16	0.21	0.29
	Avg.	0.63	0.19	0.39	0.41	0.40	0.38	0.38	0.37	0.37	0.37	0.34	0.34	0.35
	SD	0.06	0.03	0.09	0.08	0.04	0.04	0.05	0.04	0.05	0.06	0.08	0.07	0.05
	CV	9.0	15.2	23.8	18.6	9.0	9.9	13.5	11.4	13.7	17.2	22.4	19.2	13.4
MH	Max.	70.21	83.69	69.39	73.21	76.12	75.34	73.33	71.55	70.69	71.91	89.47	75.49	91.40
	Min.	16.00	47.83	25.00	19.67	28.72	28.21	22.95	25.88	22.00	25.77	34.82	20.21	26.67
	Avg.	41.02	60.87	44.85	41.21	46.86	47.42	43.82	47.13	45.86	48.48	52.80	49.68	57.08
	SD	17.6	10.7	13.1	14.7	12.2	14.0	14.7	11.6	13.5	15.5	17.0	16.7	22.6
	CV	42.9	17.5	29.3	35.6	26.0	29.6	33.6	24.6	29.5	32.0	32.1	33.7	39.6
SSP	Max.	42.42	86.07	70.15	68.35	64.88	68.00	75.29	73.23	73.87	79.42	83.75	78.53	70.57
	Min.	24.26	76.17	45.64	44.00	52.06	53.85	53.28	55.77	56.28	53.64	54.96	56.77	55.16
	Avg.	35.01	81.11	60.91	58.27	59.92	61.26	61.55	62.60	62.77	62.61	65.67	65.31	64.41
	SD	5.86	2.84	9.38	7.73	3.68	3.89	5.34	4.44	4.92	6.62	7.77	6.63	4.97
	CV	16.7	3.50	15.4	13.3	6.20	6.35	8.70	7.10	7.83	10.6	11.8	10.2	7.71

the Na^+ concentrations in natural stream water samples varied from 24.22 to 56.80, 1.78 to 7.52, 2.17 to 6.30, 3.83 to 7.37, 3.95 to 16.74, 3.30 to 29.62, 3.75 to 25.38, 3.45 to 13.12, 3.30 to 38.74, 2.88 to 27.41, 3.40 to 37.60 and 3.45 to 28.20 me L^{-1} with a mean value of 38.35, 4.53, 4.51, 5.19, 6.54, 6.92, 7.41, 6.38, 8.76, 10.52, 11.94 and 10.94 me L^{-1} respectively. The SD ranged from 1.11 to 11.3 with a mean of 5.93 and CV ranged from 213 to 104 with a mean of 62.5% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the Na^+ content in natural stream ranged from 1.78 to 56.8 with a mean of 10.2 me L^{-1}. The SD ranged from 5.9 to 15.9 with a mean of 9.0. Similarly, the CV ranged from 70.0 to 162 with a mean of 106%.

The Na^+ concentration of water samples particularly at sampling station 1 was consistently higher compared to other stations over the sampling period which could be due to the presence of salinized area around the sampling station contributing Na^+ to the surface water. The mean Na^+ concentrations values of nala water were 6.44 to 54.78 times higher compared to canal water and generally the maximum Na^+ concentrations were observed in August and December-February. Direct toxicity effect of sodium is expected when sodium concentration in water is >3.0 me L^{-1}. Further, moderate to severe effects could be noticed if the concentration ranges from 3.0 to 9.0 me L^{-1}. The results are in conformity with findings of Manjunath (2019) who also observed maximum concentrations of Na^+ in the month of December – January.

Temporally, not much fluctuation was observed with respect to K^+ concentrations. The K^+ concentrations in canal water samples varied from 0.01 to 0.10 me L^{-1} with a mean

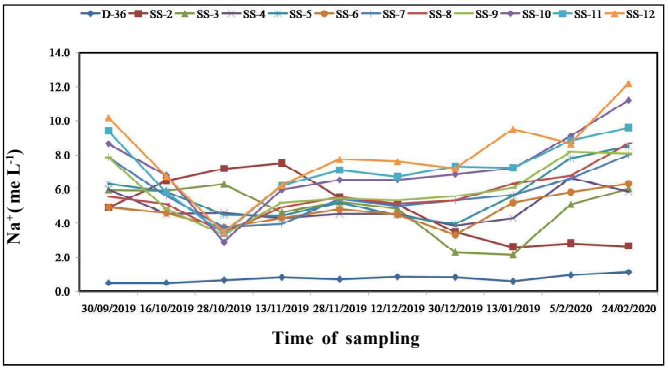

Fig. 3. Spatial and temporal variations of Na^+ (me L^{-1}) in water samples collected at different sampling stations of natural stream and distributary 36 of LBMC in TBP command area

value of 0.06 me L^{-1}. The SD and CV over the sampling were 0.02 and 39.2%. Similarly, the K^+ concentrations in natural stream water samples varied from 0.08 to 0.35, 0.03 to 0.10, 0.02 to 0.10, 0.06 to 0.31, 0.05 to 0.19, 0.05 to 0.17, 0.06 to 0.20, 0.06 to 0.66, 0.06 to 0.18, 0.07 to 0.35, 0.07 to 0.30 and 0.07 to 0.17 me L^{-1} with a mean value of 0.17, 0.07, 0.07, 0.11, 0.10, 0.09, 0.12, 0.15, 0.10, 0.13, 0.13 and 0.10 me L^{-1} respectively. The SD ranged from 0.03 to 0.17 with a mean of 0.06 and CV ranged from 34.4 to 110.2 with a mean of 51.1% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the K^+ content in natural stream ranged from 0.0 to 0.66 with a mean of 0.11 me L^{-1}. The SD ranged from 0.01 to 0.17 with a mean of 0.05. Similarly, the CV ranged from 9.1 to 82.2 with a mean of 38.8%.

Kumar (2014) also reported lower K^+ concentrations compared to other cations in all stream, bore well and canal water samples analyzed.

Carbonates, bicarbonates, chloride and sulphate

Generally, carbonate (CO_3^{2-}) ions were absent in majority of water samples analyzed over the cropping season. The CO_3^{2-} + HCO_3^- concentrations in canal water samples varied from 0.70 to 2.12 me L^{-1} with a mean value of 1.24 me L^{-1}, respectively. The SD and CV over the sampling were 0.43 and 34.8%. Similarly, the CO_3^{2-} + HCO_3^- concentrations in water samples collected from natural stream varied from 5.80 to 12.40, 2.00 to 4.20, 2.33 to 5.00, 2.60 to 4.40, 3.10 to 9.20, 2.80 to 7.20, 3.40 to 4.90, 3.00 to 5.40, 2.80 to 6.40, 3.00 to 10.60, 2.95 to 7.60 and 3.10 to 7.40 me L^{-1} with a mean value of 7.95, 3.14, 3.80, 3.70, 4.48, 4.16, 4.16, 4.22, 4.34, 5.50, 5.18 and 5.42 me L^{-1} respectively. The SD ranged from 0.53 to 1.99 with a mean of 0.06 and CV ranged from 14.2 to 37.4 with a mean of 23.8% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the CO_3^{2-} + HCO_3^- content in natural stream ranged from 2.0 to 12.4 with a mean of 4.67 me L^{-1}. The SD ranged from 0.74 to 3.26 with a mean of 1.45. Similarly, the CV ranged from 16.6 to 50.7 with a mean of 30.3%.

The mean CO_3^{2-} + HCO_3^- concentrations values of nala water were 2.53 to 6.41 times higher compared to canal water. The CO_3^{2-} + HCO_3^- concentration of water samples of both streams were similar to the findings of Kumar *et al.* (2016) wherein the HCO_3^- concentration in the surface water samples of current nala ranged from 1.0 to 8.3 me L^{-1} and 91 per cent of samples were within the permissible limit and 9 per cent of samples exceeded the limit (8.3 me L^{-1}) as per WHO guidelines.

Temporally, the Cl^- concentrations of canal water samples varied from 0.50 to 0.84 me L^{-1} with a mean value of 0.67 me L^{-1}. The SD and CV over the sampling were 0.11 and 16.4%. Similarly, the Cl^- concentrations in natural stream water samples varied from 16.80 to 39.50, 2.00 to 5.82, 1.80 to 4.40, 2.40 to 6.20, 2.40 to 10.80, 2.00 to 21.90, 2.20 to 21.20, 1.80 to 10.90, 2.40 to 30.90, 2.20 to 20.60, 2.20 to 30.80 and 2.10 to 23.50 me L^{-1} with a mean value of 26.06, 3.26, 2.79, 3.50, 4.25, 4.58, 5.09, 4.21, 6.21, 6.49, 8.55 and 7.70 me L^{-1}, respectively. The SD ranged from 0.85 to 9.84 with a mean of 4.8 and CV ranged from 30.4 to 127 with a mean of 73.4% at over the sampling in 12 different sampling stations.

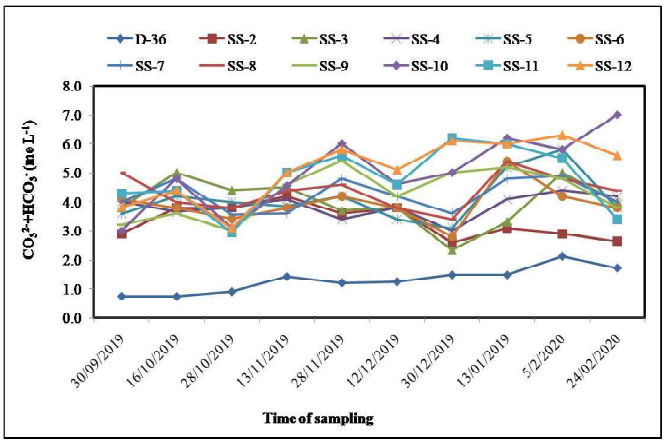

Fig. 4. Spatial and temporal variations of CO_3^{2-}+HCO_3^- (me L^{-1}) in water samples collected at different sampling stations of natural stream and distributary 36 of LBMC in TBP command area

Spatially, across the 12 sampling stations, the Cl^- content in natural stream ranged from 1.80 to 39.5 with a mean of 6.89 me L^{-1}. The SD ranged from 4.0 to 12.2 with a mean of 7.1. Similarly, the CV ranged from 57.2 to 168 with a mean of 110%.

The mean Cl^- concentrations values of nala water were 4.16 to 38.89 times higher compared to canal water. Similarly, Manjunath (2019) observed that the Cl^- concentrations of stream water were 0.65 to 20.4 times higher compared to that of canal water. As per classification of irrigation water given by US salinity laboratory (1954), nearly 63 per cent of stream water samples fall under excellent water category (<4 me L^{-1}) as far as Cl^- concentration is concerned.

Temporally, the SO_4^{2-} concentrations of canal water samples varied from 0.02 to 0.43 me L^{-1} with a mean value of 0.24 me L^{-1}. The SD and CV over the sampling were 0.13 and 52.4%. Similarly, the SO_4^{2-} concentrations in natural stream water samples varied from 8.20 to 19.80, 0.35 to 2.42, 0.48 to 1.96, 0.60 to 2.84, 0.58 to 5.61, 0.53 to 10.45, 0.71 to 7.86, 0.67 to 3.29, 0.55 to 11.39, 0.64 to 10.28, 0.65 to 11.66 and 0.64 to 9.65 me L^{-1} with a mean value of 13.17, 1.15, 1.17, 1.55, 1.96, 2.09, 2.17, 1.88, 2.63, 3.32, 3.62 and 3.38 me L^{-1} respectively. The SD ranged from 0.50 to 4.09 with a mean of 4.8 and CV ranged from 31.0 to 128 with a mean of 73.4% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the SO_4^{2-} content in natural stream ranged from 0.35 to 19.8 with a mean of 3.17 me L^{-1}. The SD ranged from 2.15 to 5.45 with a mean of 3.48. Similarly, the CV ranged from 65.7 to 191 with a mean of 116%.

The mean SO_4^{2-} concentrations values of nala water were 4.79 to 54.87 times higher compared to canal water. The results are in conformity with the findings of Prasanna *et al.* (2011) who observed that the SO_4^{2-} ranged from 0.07 to 1.86 me L^{-1} (average 0.56 me L^{-1}) in surface water.

Nitrate nitrogen

Temporally, the NO_3-N concentrations of canal water samples varied from 0.14 to 0.84 mg L^{-1} with a mean value of 0.37 mg L^{-1}. The SD and CV over the sampling were 0.18 and 49.6%. Similarly, the NO_3-N concentrations in natural stream

water samples varied from 0.28 to 3.92, 0.14 to 1.40, 0.28 to 1.40, 0.14 to 1.96, 0.28 to 2.24, 0.14 to 1.96, 0.28 to 2.80, 0.14 to 2.52, 0.28 to 2.52, 0.28 to 1.68, 0.28 to 3.36 and 0.28 to 2.24 mg L^{-1} with a mean value of 1.26, 0.61, 0.82, 0.90, 0.91, 0.86, 1.31, 1.13, 1.28, 0.96, 1.42 and 1.19 mg L^{-1}, respectively. The SD ranged from 0.43 to 1.0 with a mean of 0.67 and CV ranged from 53.4 to 79.5 with a mean of 63.4% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the NO_3-N content in natural stream ranged from 0.14 to 3.92 with a mean of 0.94 me L^{-1}. The SD ranged from 0.25 to 1.0 with a mean of 0.56. Similarly, the CV ranged from 30.5 to 107 with a mean of 64.8%.

Manjunath (2019) also reported that the mean NO_3-N content of all the water samples in natural stream were less than 5 mg L^{-1} and the maximum NO_3-N concentrations were observed in January.

Phosphate phosphorus

Temporally, the PO_4-P concentrations of canal water samples varied from 0.00 to 0.01 mg L^{-1} with a mean value of 0.01 mg L^{-1}. The SD and CV over the sampling were 0.01 and 52.2%. Similarly, the PO_4-P concentrations in natural stream water samples varied from 0.01 to 2.62, 0.01 to 1.19, 0.01 to 2.04, 0.01 to 3.60, 0.01 to 2.76, 0.01 to 2.90, 0.01 to 2.81, 0.01 to 2.91, 0.01 to 2.80, 0.01 to 2.67, 0.01 to 2.71 and 0.01 to 2.48 mg L^{-1} with a mean value of 1.20, 0.40, 0.78, 1.19, 1.12, 1.11, 1.00, 1.05, 1.05, 0.99, 1.00 and 0.95 mg L^{-1} respectively. The mean PO_4-P values of stream water across sampling times were < 2 mg L^{-1} indicating feasibility for irrigation in terms of PO_4-P content. The SD ranged from 0.43 to 1.16 with a mean of 89 and CV ranged from 69.6 to 107 with a mean of 91.2% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the PO_4-P content in natural stream ranged from 0.01 to 3.60 with a mean of 0.78 me L^{-1}. The SD ranged from 0.06 to 0.70 with a mean of 0.29. Similarly, the CV ranged from 19.5 to 212 with a mean of 79.8%.

The findings corroborates the results of Prasanna *et al.* (2011) who reported that the PO_4-P concentrations varied from 0.04 to 6.04 mg L^{-1} (average 1.92 mg L^{-1}) in surface water.

Sodium adsorption ratio (SAR)

Temporally, the SAR values of canal water samples varied from 0.64 to 1.82 $(mmol/L)^{1/2}$ with a mean value of 1.30 $(mmol/L)^{1/2}$. The SD and CV over the sampling were 0.32 and 24.8%. Similarly, the SAR of natural stream water samples varied from 19.81 to 37.21, 2.44 to 8.41, 2.61 to 7.00, 4.32 to 7.19, 4.88 to 11.31, 4.26 to 19.00, 4.66 to 16.66, 4.21 to 12.18, 4.23 to 24.45, 3.75 to 23.77, 4.46 to 23.45 and 4.45 to 16.45 $(mmol/L)^{1/2}$ with a mean value of 25.24, 5.72, 5.35, 5.45, 6.34, 6.39, 6.84, 6.42, 7.52, 8.14, 8.13 and 7.92 $(mmol/L)^{1/2}$ respectively. The SD ranged from 0.89 to 6.15 with a mean of 3.52 and CV ranged from 16.4 to 75.6 with a mean of 44.8% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the SAR content in natural stream ranged from 2.44 to 37.20 with a mean of 8.66 $(mmol/L)^{1/2}$. The SD ranged from 3.91 to 9.21 with a mean of 6.05. Similarly, the CV ranged from 55.0 to 112.0 with a mean of 70.7%.

The mean SAR values of nala water were 4.11 to 19.41 times higher compared to canal water and generally the maximum SAR values were observed in December - February. However, the mean SAR values at all sampling stations (SAR<10) indicate water is safe for irrigation. The result are in conformity with Manjunath (2019) who confirmed that most of the stream water did not show any threat to cause sodicity based on its critical value (SAR<10). Based on classification of irrigation waters by Richards (1968), most of the water samples of the streams fall under category C3S1 (C3- EC 0.75 to 2.25 dS m^{-1}, S1- <10 SAR) and C2S1 (C2- EC 0.25 to 0.75 dS m^{-1}, S1- <10 SAR) which are fit for irrigation.

Residual Sodium Carbonate (RSC)

Temporally, the RSC values of canal water samples varied

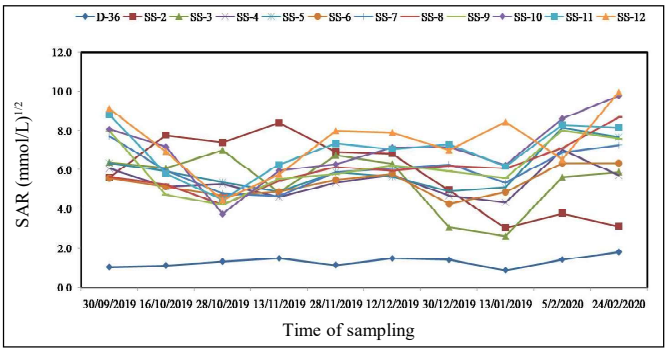

Fig. 5. Spatial and temporal variations of SAR $(mmol/L)^{1/2}$ in water samples collected at different sampling stations of natural stream and distributary 36 of LBMC in TBP command area

from 0.00 to 2.20 me L^{-1} with a mean value of 1.07 me L^{-1}. The SD and CV over the sampling were 0.62 and 57.8%.Similarly, the RSC values of natural stream water samples varied from 0.00 to 5.04, 0.00 to 1.56, 0.00 to 2.04, 0.00 to 1.48, 0.00 to 1.20, 0.00 to 2.08, 0.00 to 1.80, 0.00 to 4.76, 0.00 to 2.26, 0.00 to 5.28, 0.00 to 1.84 and 0.00 to 2.04 me L^{-1} with a mean value of 0.50, 0.78, 1.00, 0.69, 0.69, 1.07, 0.90, 1.40, 0.84, 1.39, 0.77 and 0.78 me L^{-1} respectively. The SD ranged from 0.46 to 1.45 with a mean of 0.81 and CV ranged from 62.4 to 290 with a mean of 96.0% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the RSC content in natural stream ranged from 0.0 to 5.28 with a mean of 0.76 $(mmol/L)^{1/2}$. The SD ranged from 0.05 to 1.98 with a mean of 0.66. Similarly, the CV ranged from 40.0 to 280 with a mean of 115%.

Richards (1968) based on the values of RSC classified water into safe (<1.25 me L^{-1}), moderately safe (1.25 to 2.5 me L^{-1}) and unsafe (>2.5 me L^{-1}) for irrigation. Among 144 water samples analyzed from stream, about 80, 18 and 2 per cent samples are safe, moderately safe and unsafe for irrigation respectively. With one-time sampling, Prasanna *et al.* (2011) and Kumar (2014) reported that the RSC values of the majority surface/stream/bore well water samples were under good category (<1.25 me L^{-1}) indicating feasibility for irrigation purpose.

Magnesium to Calcium ratio (Mg/Ca)

Temporally, the Mg/Ca ratio of canal water samples collected varied from 0.19 to 2.36 with a mean value of 0.91. The SD and CV over the sampling were 0.64 and 70.8%. Similarly, the Mg/Ca of natural stream water samples varied from 0.92 to 5.13, 0.33 to 2.27, 0.24 to 2.73, 0.40 to 3.19, 0.39 to 3.06, 0.30 to 2.75, 0.35 to 2.52, 0.28 to 2.41, 0.35 to 2.56, 0.53 to 8.50, 0.25 to 3.08 and 0.36 to 10.63 with a mean value of 1.96, 0.97, 0.91, 1.11, 1.15, 1.01, 1.05, 1.03, 1.17, 2.07, 1.32 and 2.84, respectively. The SD ranged from 0.55 to 2.23 with a mean of 1.04 and CV ranged from 52.9 to 108 with a mean of 70.3% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the Mg/Ca content in natural stream ranged from 0.24 to 10.6 with a mean of 1.24. The SD ranged from 0.21 to 2.91 with a mean of 0.83. Similarly, the CV ranged from 27.9 to 205 with a mean of 62.2%.

Based on ratio of Mg to Ca, waters are categorized as safe (<1.5), moderately safe (1.5 to 3.0) and unsafe (>3.0) for irrigation (Tandon, 2017). Among 144 water samples analyzed from stream, about 80, 14 and 6 per cent samples are safe, moderately safe and unsafe for irrigation, respectively. Manjunath (2019) also reported the feasibility of majority of natural stream water for irrigation in LBMC of TBP command area.

Chloride to Sulphate ratio (Cl/SO4)

Temporally, the Cl/SO_4 ratio of canal water samples varied from 1.58 to 49.73 with a mean value of 6.99. The SD and CV over the sampling were 13.5 and 194%. Similarly, the Cl/SO_4 concentration of natural stream water samples varied from 0.51 to 2.07, 1.07 to 6.22, 1.64 to 3.57, 1.48 to 2.75, 1.50 to 3.11, 0.78 to 3.89, 1.26 to 3.09, 1.55 to 3.31, 1.43 to 4.71, 1.20 to 3.44, 1.29 to 3.36 and 1.30 to 3.75 with a mean value of 1.37, 2.65, 2.34, 2.19, 2.05, 2.05, 2.11, 2.17, 2.07, 1.87, 1.98 and 2.10, respectively. Generally the maximum Cl/SO_4 values were observed in October. The SD ranged from 0.35 to 1.41 with a mean of 0.66 and CV ranged from 20.1 to 45.4 with a mean of 31.3% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the Cl/SO_4 content in natural stream ranged from 0.51 to 6.22 with a mean of 2.08. The SD ranged from 0.13 to 1.24 with a mean of 0.54. Similarly, the CV ranged from 8.80 to 48.9 with a mean of 24.9%.

The Cl/SO_4 ratios were much higher than 3.0 which is considered to be unsafe as far as their effect on crop yield is concerned. Similar results were reported by Vishwanath *et al.* (2016), wherein groundwater samples of Dharwad had Cl/SO_4 ratio >2.0 indicating the potential chloride injury of these waters in sensitive crops.

Divalent Cation Ratio (DCR)

Temporally, the divalent cation ratio of canal water samples varied from 0.55 to 0.73 with a mean value of 0.63. The SD and CV over the sampling were 0.06 and 9.0%. Similarly, the DCR values of natural stream water varied from 0.14 to 0.24, 0.30 to 0.54, 0.31 to 0.55, 0.35 to 0.47, 0.31 to 0.45, 0.25 to 0.46, 0.27 to 0.43, 0.25 to 0.43, 0.21 to 0.46, 0.16 to 0.44, 0.21 to 0.43 and 0.29 to 0.44 with a mean value of 0.19, 0.39, 0.41, 0.40, 0.38, 0.38, 0.37, 0.37, 0.37, 0.34, 0.34 and 0.35 respectively. The SD ranged from 0.03 to 0.09 with a mean of 0.06 and CV ranged from 9.0 to 23.8 with a mean of 15.6% at over the sampling in 12 different sampling stations.

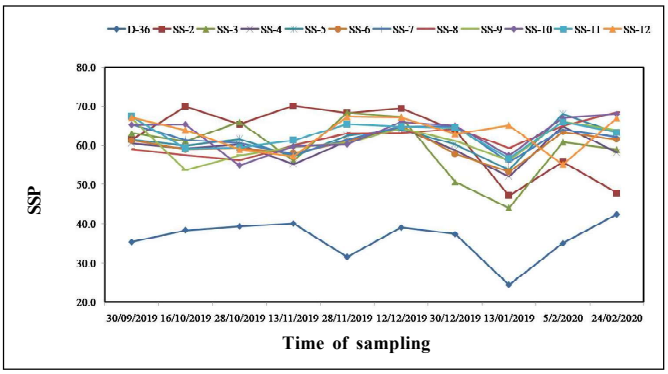

Fig. 6. Spatial and temporal variations in soluble sodium percentage (SSP) of water samples collected at different sampling stations of natural stream and distributary 36 of LBMC in TBP command area

Spatially, across the 12 sampling stations, the DCR in natural stream ranged from 0.14 to 0.55 with a mean of 0.36. The SD ranged from 0.05 to 0.11 with a mean of 0.07. Similarly, the CV ranged from 14.8 to 35.6 with a mean of 20.4%.

The mean DCR of nala water were 0.30 to 0.65 times higher compared to canal water. In the present investigation, about 88 per cent of water samples of stream had DCR >0.25 indicating feasibility of water for irrigation. Similar results were reported by Manjunath (2019) wherein the mean divalent cation ratio was >0.25 in majority of water samples of the natural stream studied suggesting that the quality of water is suitable for irrigation.

Magnesium Hazard (MH)

Temporally, the magnesium hazard of canal water samples varied from 16.00 to 70.21 with a mean value of 41.02. The SD and CV over the sampling were 17.6 and 42.9%. Similarly, the MH values of natural stream water varied from 47.83 to 83.69, 25.00 to 69.39, 19.67 to 73.21, 28.72 to 76.12, 28.21 to 75.34, 22.95 to 73.33, 25.88 to 71.55, 22.00 to 70.69, 25.77 to 71.91, 34.82 to 89.47, 20.21 to 75.49 and 26.67 to 91.40 with a mean value of 60.87, 44.85, 41.21, 46.86, 47.42, 43.82, 47.13, 45.86, 48.48, 52.80, 49.68 and 57.08, respectively. The SD ranged from 10.7 to 22.6 with a mean of 14.7 and CV ranged from 17.5 to 39.6 with a mean of 30.2% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the magnesium hazard in natural stream ranged from 19.7 to 91.4 with a mean of 48.3. The SD ranged from 6.93 to 17.8 with a mean of 11.0. Similarly, the CV ranged from 10.3 to 43.6 with a mean of 23.8%.

Nearly 41 per cent of natural streams water samples had MH more than 50 per cent and were found unsuitable for irrigation. If the value of magnesium hazard is more than 50 per cent, the soil becomes alkaline and its opposite impact on crop yield can be observed (Singh *et al.,* 2020)

Soluble Sodium Percentage (SSP)

Temporally, the soluble sodium percentage of canal water varied from 24.26 to 42.42 with a mean value of 35.01. The SD and CV over the sampling were 5.86 and 16.7%. Similarly, the SSP values of natural stream water samples varied from 76.17 to 86.07, 45.64 to 70.15, 44.00 to 68.35, 52.06 to 64.88, 53.85 to 68.00, 53.28 to 75.29, 55.77 to 73.23, 56.28 to 73.87, 53.64 to 79.42, 54.96 to 83.75, 56.77 to 78.53 and 55.16 to 70.57 with a mean value of 81.11, 60.91, 58.27, 59.92, 61.26, 61.55, 62.60, 62.77, 62.61, 65.67, 65.31 and 64.41 respectively. The SD ranged from 2.84 to 9.38 with a mean of 5.68 and CV ranged from 3.5 to 15.4 with a mean of 9.1% at over the sampling in 12 different sampling stations.

Spatially, across the 12 sampling stations, the SSP in natural stream ranged from 44.0 to 86.1 with a mean of 63.9. The SD ranged from 5.1 to 10.6 with a mean of 7.30. Similarly, the CV ranged from 7.6 to 16.5 with a mean of 11.5%.

As per the guidelines, irrigation water having SSP value of 60 and above are considered as harmful Sathyanarayana *et al.* (2020). Nearly 79 per cent of water samples analyzed from natural stream had soluble sodium percentage values above 60 which are considered as harmful for soils and crops.

Conclusion

About seventy per cent of stream water samples had high salinity hazard and hence not feasible for irrigation. The Na^+ and HCO_3^- ions are the dominant cation and anion, respectively observed in the stream water samples analyzed. Among different sampling stations along the natural stream, higher spatial variations in stream water quality parameters viz., EC, Cl/SO_4 ratio and SSP were observed particularly in the first (close to the distributary) and the last two (towards the river) sampling stations. Overall, it is evident that EC, Cl/SO_4 ratio and SSP are the major constraints in majority of stream water samples collected in Sindhanur taluk as far as their irrigation feasibility is concerned especially for use at the crop grand-growth stage (December-January) of the cropping season. Further, monitoring the resultant build-up of soil salinity status would also help the feasibility of stream water for irrigation in such soil-water-cropping system.

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