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Assessment of Sarda Sahayak Canal water quality for irrigation using different indices

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ABSTRACT

Suitability of canal water for irrigation is a useful tool for careful management of canal water resources that can impact soils and thereby effect agricultural production. The present work was conducted at Kunda Tehshil in Pratapgarh district of Uttar Pradesh, India for the assessment of variation in water quality of Sarda Sahayak Canal. Canal water samples were collected and important parameters deciding irrigation water quality were analysed viz., pH, electrical conductivity (EC), chloride, calcium, magnesium, carbonate, bicarbonate, sodium, potassium and sodium, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index levels (PI) and Irrigation Water Quality Index (IWQI). Correlations between studied parameters were deduced to derive at relationships existent between different water quality parameters. Results showed that monthly variation of water quality of the Sarda Sahayak Canal were under permissible limits and classified as good for irrigation with respect to pH, Na%, SAR, RSC and Cl parameters. EC values ll water samples were under medium /good range for irrigation whereas irrigation water quality index of 50% of water samples were under no restriction category and the rest 50% samples showed low restriction category, and hence canal water could be satisfactorily used for irrigation purposes. Further, soils of the studied area were saline, and hence canal water could be safely used for leaching the excess salts out from root zone to achieve high yields without risking and any other soil related problems that could arise out of the use of canal water.

Key words: Canal Water, Quality, Suitability, Irrigation,

INTRODUCTION

Irrigation with good quality water at different critical stages of crop growth is one of the most important inputs required for enhancing the productivity of various crops and increasing production. Sarda Sahayak Pariyojana was an intervention in 1968 providing irrigation to unserved areas falling under the command area of Sarda Sahayak Canal Project (SCP) commissioned in 1926. Five major canals, viz. Dariyabad, Barabanki, Pratapgarh, Allahabad and Hydergarh arose from the feeder channel that provide irrigation to lakhs of farmers in 150 development blocks of 16 districts in Uttar Pradesh. The quality of irrigation water is a crucial factor for maintaining long term soil productivity. Use of poor-quality water in the long term makes the soil less productive depending on the amount and type of chemical constituent's present in the irrigation water. Increasing demand for freshwater with a rapid increase in population has contributed to over exploitation of several aquifers that has become unsustainable for use (*Maurya, et. al. 2020*). Many areas in country are facing a serious problem of poor water quality. Supply of poor-quality irrigation water is expect to decrease sustainability of future agriculture because excessive concentrations of dissolved ions in the ground water affects soil physically and chemically soil properties and alters plant growth through lowering of osmotic pressure in the plant structural cells (*Rao, et.al. 2012*) and negatively impacts agricultural productivity. Hence, assessment of canal water quality for irrigation is very important because poor quality irrigation water not only affects soil health but also adversely impacts human health.

High quality grain and fodder crops can be produced only using good-quality irrigation water and keeping inputs at optimal level. The main objective of this research was to evaluating the irrigation water quality parameters of the Sarda Sayak cannal at Kunda in Pratapgarh district of Uttar Pradesh, India and using the Irrigation Water Quality Index (IWQI) model (*Meireles et. al. 2010*).

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METHODS AND MATERIALS

The study was conducted in northern part of India in Kusuvapur village, Kunda of Pratapgarh District, Uttar Pradesh situated at 25° 51' 49.9314"N latitude and 81° 25' 19.092"E longitude (Fig. 1). Pratapgarh district enjoys tropical climate with mild winter and long summer days. The area receive rainfall from majorly south-west monsoon with mean annual rainfall of 1180 cm, 85-90 % of which received during June to September and potential evapotranspiration is about 1400 mm. The major agricultural crops in the area are rice, wheat, mustard, barley, onion, tomato, potato, onion, moong, urd, mentha and carrot etc.

Canal water sampling and physicochemical analysis

Water samples were collected in acid washed and distilled water rinsed plastic bottles from middle stream of the canal at different times of the year during 1st and 15th date of each month. The water samples were stored at 4 ^{0}C until laboratory analysis. The water samples were analyzed for pH, electrical conductivity (EC), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) chloride (Cl^-) and sulphate ($SO4^{2-}$) ions by standard methods. Soluble sodium percentage, residual sodium carbonate, sodium adsorption ratio, permeability index and Kelley's ratio were calculated using the following formulae:

Soluble sodium percentage $(Na\ \%) = \frac{Na}{Na+Ca+Mg+K} \times 100$ (*Rao, et. al. 2012*)

Residual Sodium Carbonate (RSC) = (CO_3 + HCO_3) – (Ca + Mg)…Eaton (*Rao et. al. 2012*)

Sodium Adsorption Ratio $(SAR) = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$.........Richards (*Rao et. al. 2012*)

Permeability index $(PI) = \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} \times 100$.oneen (*Rao et. al. 2012*)

Kelley's Ratio $(KI)\ (meq/L) = \frac{Na}{Ca+Mg}$ ……… …………Kelley (*Dhembare, 2012*)

Irrigation water quality index (IWQI) model

We used the IWQI model developed by Meireles (2010) to evaluate the canal water quality. In the first step, those parameters were identified for more irrigation potential which were considered more relevant to the irrigation use. In the second step, a definition of quality measurement values (qi) and parameter weights (wi) were established. Values (qi) were estimated based on each parameter value, according to irrigation water quality parameters proposed by the University of California Committee of Consultant and by the criteria established by the Ayers and Wescot (*Khalaf, et. al. 2013*) as shown in Table 1. Water quality parameters were presented by a non-dimensional number, with higher value denoting better water quality.

Table (1): Parameter limiting value for quality measurement (qi) calculation Ayers and Wescot (*Khalaf, et. al. 2013*)

Qi	EC (µs/cm)	SAR	Na (meq/l)	Cl meq/l	HCO3 (meq/l)
100-85	200≤EC<750	2 ≤SAR< 3	2 ≤ Na < 3	1 ≤ Cl < 4	1≤ HCO3<1.5
85-60	750≤EC<1500	3 ≤SAR< 6	3 ≤ Na < 6	4 ≤ Cl < 7	1.5≤ HCO3<4.5
60-35	1500≤EC<3000	6≤SAR<12	6 ≤ Na < 9	7 ≤ Cl < 10	4.5≤ HCO3<8.5 0
35-0	EC<200 or EC≥3000	SAR<2 or SAR≥12	Na<2 or Na≥9	Cl < 1 or Cl ≥10	HCO3<1 or HCO3≥8.5

Values of qi were calculated using equation (a), based on the tolerance limit show in Table (1) and water quality results determined

$$qi = qi_{max} - \left\{\frac{[(x_{ij} - x_{inf}) \times qi_{amp}]}{x_{amp}}\right\} \ldots\ldots\ldots\ldots\ldots (a)$$

Where qi_{max} is the maximum value of qi for the class, X_{ij} is the observed value for the parameter; X_{inf} is the corresponding value to the lower limit of the class to which the parameter belongs; qi_{amp} is the class amplitude to which the parameter belongs. In order to evaluate Xamp, of the last class of each parameter, the upper limit was considered to be the highest value determined in the analysis of the water samples. Each parameter weight used in the IWQI was obtained by *Meireles et al., (2010)* as shown in Table (2).

Table (2): Weights assigned to the water quality parameters of the IWQI model (*Meireles et al.,* 2010)

Parameters	Wi
Electrical conductivity (EC)	0.211
Sodium (Na+)	0.204
Chloride (Cl^-)	0.194
Bicarbonate (HCO3-)	0.202
Sodium Absorption ratio (SAR)	0.189
Total	1.00

The Wi values were normalized such that their sum equals one. The irrigation water quality index (IWQI) was calculated as:

$IWQI = \sum_{i=1}^{n}(\mathrm{qi} * \mathrm{wi})$............ (b)

RESULTS AND DISCUSSION

pH and EC

The pH of the canal water samples ranged from 8.09 to 8.37 with a mean value of 8.22 pH (Table 3). According to FAO classification, all water sample suitable for irrigation purpose (Table 4). The EC value of canal water samples ranged between 0.3 to 0.44 dS m^{-1} with a mean value 0.33 dS.m^{-1} (Table 3). Irrigation water has good quality rating of EC range with respect to soluble salts for irrigation purpose (Table 4). However there was no significant variation of pH and EC with time of sampling. The salinity hazard is measured by EC, whereby high concentration reduces the osmotic pressure of plants and thus interferes with the adsorption of water and nutrients from the soil. High salt content forms saline soils, which is the major cause of crop loss (*Rao, et. al. 2012*).

Chloride

The chloride content of the water samples ranged from 0.16 to 0.65 me/l with a mean value 0.37 me/l (Table 3). All water samples excellent for irrigation purposes (Table 4). Chloride ions are mostly dominant in very high salinity water. However, chloride ions neither effect the physical properties of the soil and are not absorbed by soil.

Table 3: Canal water chemical parameters and Irrigation Water Quality Index for assessment of irrigation water quality

Month	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	SAR	RSC	Na%	PI	IWQI
		dS/m	me/q	me/q	me/q	me/q	me/q	me/q	me/q	me/q	me/q		me/q	me/q	me/q	
1th July	8.26	0.30	0.13	0.05	2.00	3.85	NIL	2.80	0.16	0.22	0.14	0.06	-3.05	2.12	30.14	87.70
15th July	8.18	0.30	0.13	0.05	2.20	3.44	NIL	2.90	0.33	0.42	0.21	0.06	-2.74	2.20	31.73	84.39
1th August	8.09	0.32	0.13	0.05	2.20	4.05	NIL	2.80	0.33	0.31	0.64	0.06	-3.45	1.99	28.24	84.78
1th Sept.	8.32	0.40	0.15	0.14	1.60	4.46	NIL	3.20	0.65	0.15	0.20	0.08	-2.86	2.36	31.25	89.65
15th Sept.	8.37	0.38	0.15	0.13	1.90	3.44	NIL	2.80	0.49	0.16	0.63	0.07	-2.54	2.65	33.19	88.75
1Oth Oct.	8.23	0.30	0.13	0.07	1.90	4.66	NIL	2.60	0.49	0.31	0.28	0.06	-3.96	1.89	26.03	88.48
15th Oct.	8.23	0.30	0.13	0.07	1.90	4.66	NIL	2.80	0.16	0.27	0.48	0.06	-3.76	1.89	26.94	87.70
1th Nov.	8.3	0.44	0.15	0.14	1.60	7.29	NIL	3.50	0.49	0.37	0.44	0.08	-5.39	1.63	22.35	88.25
15th Nov.	8.15	0.30	0.13	0.07	1.80	4.15	NIL	3.00	0.33	0.21	0.12	0.06	-2.95	2.08	30.59	84.22
1th Dec.	8.16	0.30	0.13	0.07	2.00	3.34	NIL	2.70	0.33	0.72	0.32	0.06	-2.64	2.31	32.38	84.72
15th Dec.	8.3	0.30	0.13	0.06	1.70	3.85	NIL	2.60	0.33	0.15	0.16	0.06	-2.95	2.25	30.68	84.87
1th Jan.	8.09	0.31	0.15	0.06	2.20	3.54	NIL	2.80	0.33	1.12	0.14	0.07	-2.94	2.50	30.92	84.55
Mean	8.22	0.33	0.135	0.08	1.92	4.23	NIL	2.875	0.37	0.37	0.31	0.07	-3.27	2.16	29.54	86.51
Max	8.37	0.44	0.15	0.14	2.2	7.29	NIL	3.5	0.65	1.12	0.64	0.075	-2.54	2.65	33.19	89.65
Min	8.09	0.3	0.13	0.05	1.6	3.34	NIL	2.6	0.16	0.153125	0.13	0.064	-5.39	1.63	22.35	84.22

Bicarbonate

The bicarbonate (HCO_3^-) concentration in water samples ranged between 2.6 to 3.5 me/l with a mean value 2.88 me/l. Bicarbonate generally occurs in low salinity water and its concentration usually decrease with increase in electrical conductivity.

Soluble sodium percentage (Na %)

Sodium percentage have crucial role in classifying irrigation water because sodium react with soil to reduce its permeability. The role of sodium percentage classification for irrigation is emphasised because of the fact that sodium reacts with soil and as a result clogging of

Table 4: Irrigation water quality classes of canal water parameter for irrigation purpose

Parameter and reference of class	Classes of water	Value of classification	Remark	Total No. of Sample 12 sample	Percentage
pH		6.5-8.5	Suitable	12	100
FAO	No Class	8.6-9.5	Moderate suitable	-	-
		>9.5	Not Suitable	-	-
EC (dS/m)	Class 1	<0.25	Low/ Excellent	-	-
Ayers &Westcot	Class 2	0.25-0.75	Medium/Good	12	100
(Balachandar, D., *et al.*	Class 3	0.76-2.25	High/ Permissible	-	-
2010)	Class 4	>2.25	Very high/ Unsuitable	-	-
	S1	0-10	Excellent	12	100
SAR	S2	10 -.18	Good	-	-
Ayers &Westcot	S3	18 – 26	Doubtful	-	-
(Rao, N.S., *et al.*2012)	S4	>26	Unsuitable	-	-
RSC (me/l)	Low	<1.25	Suitable	12	100
USSLS	Medium	1.25-2.50	Moderate suitable	-	-
(Rao, N.S., *et al.*2012)	High	> 2.5	Not Suitable	-	-
	very Low	< 20	Excellent	12	100
Na %	Low	20-40	Good	-	-
Wilcox	Medium	40-60	Permissible	-	-
(Rao, N.S., *et al.* 2012)	High	60-80	Doubtful	-	-
	Very High	> 80	Unsuitable	-	-
PI (me/l)	Class 1	25-75	Good	11	91.67
Doneen	Class 2	> 75	Permissible	-	-
(Rao, N.S., *et al.* 2012)	Class 3	< 25	Unsuitable	1	8.33
	Class 1	<4	Excellent	12	100
Cl^-	Class 2	4-7	Moderately Good	-	-
Ayers &Westcot	Class 3	7-10	Slightly Usable	-	-
(Khalaf, R.M. *et al.* 2013)	Class 4	>10	Unsuitable	-	-

particles takes place, thereby reducing the permeability (*Brhane, 2016*). The ranges of sodium percentage were between 1.63 to 2.65 % with a mean value 2.16% (Table 3). According to the classification of Wilcox (*Rao, et. al. 2012*), all the water samples were good for irrigation purposes (Table 4). However there was no significant seasonal variation observed during our sampling.

Sodium Adsorption Ratio (SAR)

SAR is an important parameter for determining suitability of irrigation water because it determines the sodium hazard (*Brhane, 2016*). The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio (*Rao, et. al. 2012*). Sodium can replace calcium and magnesium from the soil exchange complex and its causes damage to the soil structure. Sodium saturated soils become compact and impervious. The SAR values of canal water collected seasonally ranged between 0.06 to 0.08 with a mean value 0.07 (Table 3) and hence all canal water were good for irrigation as per the classification of Ayers and Wescot (*Rao, et. al. 2012*) (Table 4).

Residual Sodium Carbonate (RSC)

The RSC values of canal water were ranged from -5.39 to -2.54 me/l with a mean value -3.27 me/l (Table 3) and hence is safe as per the classification of Eaton (*Rao, et. al. 2012*)

Permeability index (PI)

Permeability is greatly influenced by Na^+, Ca^{2+}, Mg^{2+}, HCO_3^- and Cl^- contents of soil and hence is affected by long-term use of irrigation water, with high salt content (*Rao, et. al. 2012*). Permeability index ranged between 22.35 to 33.19 me/l with a mean value 29.54 me/l (Table-3). According to Doneen’s classification 11 out of the 12 collected water samples were good and only one sample collected in November were unsuitable for irrigation purpose (Table 4).

Table 5: Classes of Irrigation Water Quality Index (*Meireles et al., 2010*). for Canal water classification in Pratapgarh District of UP India

Classes of IWQI	Water use restriction	Recommendation		No. of sample	%
		Soil	Plant		
85≤100	No restriction	May be use for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability.	No toxicity risk for most plant.	6	50
70≤85	Low restriction	The recommended for use in irrigated soils with light texture of moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay levels 2:1.	Avoid salt sensitive plants.	6	50
55≤70	Moderate restriction	May be used in soils with moderate to high Permissibility values, being suggested moderate leaching of salt.	Plant with moderate tolerance to salt may be grown	-	-
40≤55	High restriction	May be used in soils with high Permissible without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2.000dS m-1 and SAR above 7.0.	Should be used for irrigation of plants with moderate to high tolerance to salt with special salinity control practice, except water with low Na, Cl and HCO3 values	-	-
0≤40	Sever restriction	Should be avoided its use for irrigation under normal conditions. In social cases, may be used occasionally. Water with low salt levels and high SAR require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.	Only plant with high salt tolerance except for waters with extremely low values of Na, Cl and HCO3.	-	-

Irrigation Water Quality Index (IQWI)

The IWQI model is based on parameters i.e.: electrical conductivity (EC), concentration of sodium (Na^+), concentration of chloride (Cl^-), concentration of bicarbonate (HCO_3^-), sodium adsorption ratio (SAR) and its model reflects soil salinity risk to plants. The irrigation water quality index of canal water samples were ranges from 84.22 to 89.65 with a mean value of 86.51 (Table 3). According to Meireles (2010) 50 % water sample come under “no restriction”, whereas rest of the 50 % samples felt just below “Low restriction” for irrigation purpose (Table 5).

Table 6: Classification of Canal water quality for Irrigation on the basis of U.S. Salinity Laboratory Staff in Pratapgarh District of UP India

Groups of USSSL (1954)	USDA Classes	Irrigation water classes	Number of Sample	% of Sample
C1-S1, C2-S1	I	Suitable to use	12	100
C1-S2, C2-S2, C3-S1, C3-S2,	II	Conditionally suitable	-	-
C1-S3, C1-S4, C2-S3, C2-S4, C3-S3, C3-S4, C4-S1, C4-S2, C4-S3, C4-S4	III	Unsuitable	-	-

Irrigation water classification

The classification given by U.S. Salinity Laboratory Staff (Rao, et. al. 2012) and salinity diagram were used to classify suitability of canal water for irrigation (Fig. 2). EC is taken as salinity hazard (C) and SAR as alkalinity hazard (S) for the purpose of irrigation water classification. All water samples (100 %) were in the suitable range for irrigation purposes (Table 6). This is a pointer that canal water used for irrigation was of good quality.

Table 7: Degree of risk of water quality for irrigation, USSLS (Rao, *et al.* 2012)

Zone Description	Zone Description
C1 Low-salinity water (EC, <250 μS/cm) can be used for irrigation of most crops on most soils, with little likelihood of soil salinity development. Some leaching is required, but this occurs under normal irrigation practices, except in soils of extremely low permeability	S1 Low-sodium water (SAR, <10) can be used for irrigation on almost all soils, with little danger of the development of harmful levels of exchangeable sodium
C2 Medium-salinity water (EC, 250 to 750 μS/cm) can be used if a moderate amount of leaching occurs. Crops of moderate salt tolerance can be irrigated with this water without special practices for salinity control	S2 Medium-sodium water (SAR, 10 to 18) will be present an appreciate sodium hazard in fine-textured soils, especially poorly leached soils. Such water may be used safely on coarse textured or organic soils that have good permeability
C3 High-salinity water (EC, 750 to 2,250 μS/cm) cannot be used on soils of restricted drainage. Even with adequate drainage, special management for salinity control may be required and crops of good salt tolerance can be selected	S3 High-sodium water (SAR, 18 to 26) may produce harmful levels of exchangeable sodium in most soils and will require a special soil management like good drainage and leaching, and addition of organic matter
C4 Very-high-salinity water (EC, >2,250 μS/cm) is not suitable for irrigation under ordinary conditions. It can be used only on crops that are very tolerant of salt and only if special practices are followed, including provision for a high degree of adverse effects	S4 Very-high-sodium water (SAR, >26) is generally unsatisfactory for irrigation, unless special action is taken, such as addition of gypsum to the soil

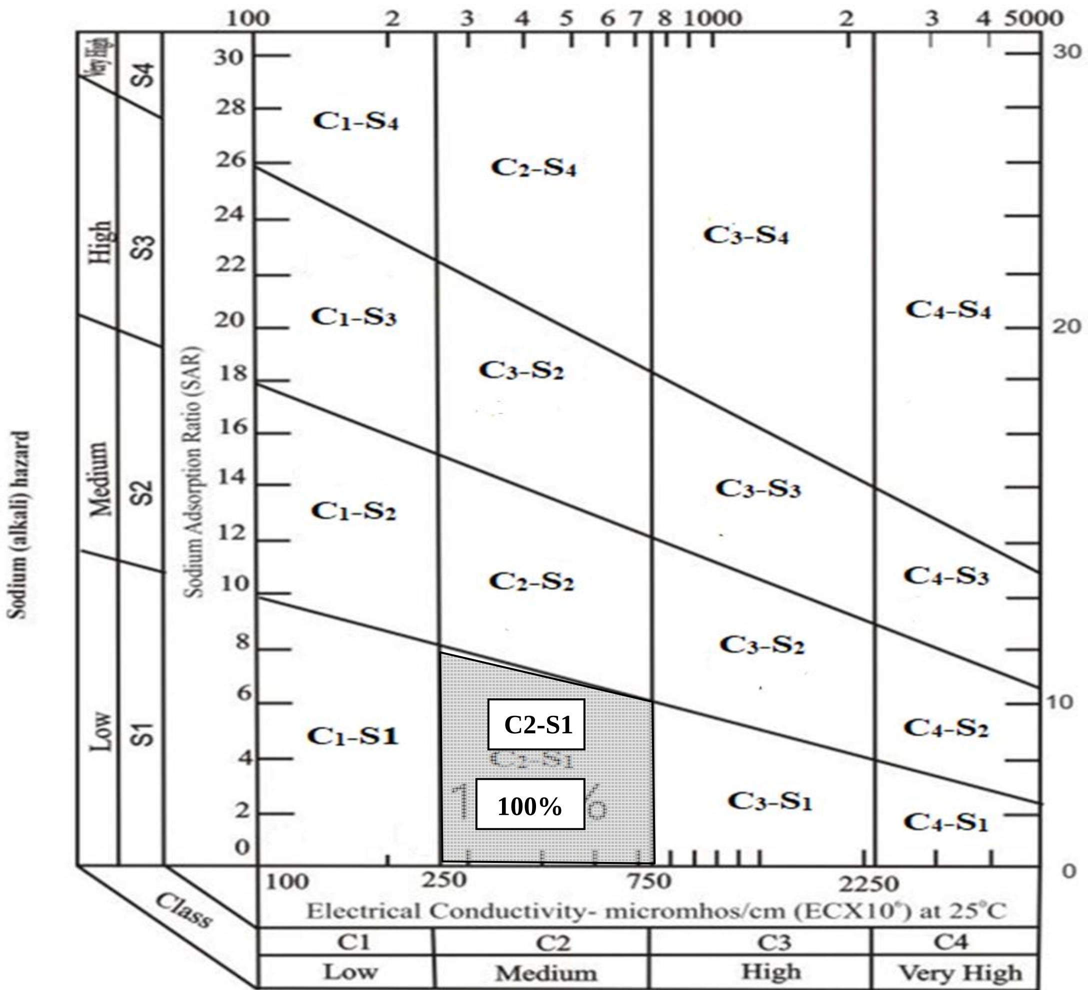

Fig. 2: Classification of irrigation water quality with respect in salinity hazard and sodium hazard USSLS (*Rao, et. al. 2012*) of Sarda Sahayak Command in pratapgarh district of UP, India

Correlation and its significance of chemical Parameter

Correlation is a statistical measure that expresses the extent to which variables are linearly related. It was observed that (Table no. 8) pH was negatively correlated with Ca^{2+} (r= -0.72^{**}) and SO_4^{2-} (-0.63^{*}) indicating that salinity decrease with increases calcium and sulphate content and it has positively correlation with EC (0.58^{*}) and K^{+}(0.70^{*}), Na^{+}(0.40), and Cl^{-}(0.44) indicating that salinity increases with increase in these parameters. EC was negatively correlated with Ca^{2+} (r= -0.59^{*}) indicating that salinity decrease with increases calcium content and it were positively correlation with $HCO^{3\ -}$(0.81^{**}), K^{+}(0.94^{**}), Na^{+}(0.82^{**}), Mg^{2+}(0.66^{*}), $SO4^{2-}$ (0.71^{*}) and Cl^{-}(0.71^{*}) indicating that salinity increases with increase in $HCO^{3\ -}$, K^{+}, Na^{+}, Mg^{2+}, SO_4^{2-} and Cl^{-} content in canal water. Na^{+} have positively correlated with HCO^{3-}(0.58^{*}), K^{+}(0.82^{**}) and Cl^{-}(0.65^{*}) indicating that sodium increases with increase HCO^{3-}, K^{+} and Cl^{-} content in canal water. Ca^{2+} have negatively correlated with $HCO^{3\ -}$(-0.50), Mg^{2+}(-0.60^{*}), and Cl^{-}(-0.51) indicating that Ca^{2+} decreased with increases HCO^{3-}, Mg^{2+}, and Cl^{-} content and it has positively correlation with SO_4^{2-} (0.54) indicating that Ca^{2+} increases with increase in $SO4^{2-}$content in canal water. Mg^{2+} has positively correlation with HCO^{3-} (0.74^{**}) indicating that Mg^{2+}increases with increase in HCO^{3-}content in canal water.

Table 8: Correlation coefficients and significance among different water quality parameters

	pH	EC	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	HCO^{3-}	Cl^{-}	$SO4^{2-}$	No^{3-}
pH	1.00									
EC	0.58^{*}	1.00								
Na^{+}	0.40	0.82^{**}	1.00							
K^{+}	0.70^{*}	0.94^{**}	0.82^{**}	1.00						
Ca^{2+}	-0.72^{**}	-0.59^{*}	-0.34	-0.68^{*}	1.00					
Mg^{2+}	0.29	0.66^{*}	0.33	0.52	-0.60^{*}	1.00				
HCO^{3-}	0.25	0.81^{**}	0.58^{*}	0.68^{*}	-0.50	0.74^{**}	1.00			
Cl^{-}	0.44	0.71^{*}	0.65^{*}	0.79^{**}	-0.51	0.31	0.44	1.00		
$SO4^{2-}$	-0.63^{*}	0.71^{*}	0.20	-0.27	0.54	-0.19	-0.11	-0.16	1.00	
No^{3-}	0.30	0.35	0.13	0.29	0.10	0.20	0.06	0.10	-0.21	1.00

*** - Highly significance, *-Significance*

CONCLUSION

Water quality of the Sarda Sahayak Canal at place Kusuvapur, Kunda in Pratapgarh district of Uttar Pradesh were investigated and it were found that pH, Na%, SAR, RSC and Cl content was within permissible limits and can be use as good for irrigation. EC values indicated that all water samples were under medium /good range for irrigation. Irrigation Water Quality Index indicated that 50% of water samples came under no restriction category and the rest 50% under low restriction category, and hence could be satisfactorily used for irrigation purposes. Further, soils of the area were saline in nature and canal water could be used for leaching the excess salts out of the root zone to achieve high yields without risk to aggravate any other soil related problems that could arise out of the use of canal water.

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