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Research Paper

Irrigation Water Quality Assessment in Vanivilas Sagar Reservoir Catchment

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ABSTRACT : *The water quality of Vanivilas Reservoir and borewells in the catchment was monitored and assessed for irrigation water use in a semiarid climate experiencing water scarcity. Surface Water and borewell water samples were collected for the pre-monsoon period at interval of 4 years. Physico-chemical analysis indicates that pH of surface waters was found to have increased alkalinity and salinity. Surface waters categorized as C2S1(medium salinity and low sodium hazard) and deteriorating water quality index (32.92 for (April-2015) and WQI>76 for 2019). Surface waters have increase in cations like Magnesium. Similarly, the same trend is observed in groundwater also. Groundwaters categorized as C3S1(high salinity low sodium) have poor water quality. Kelly's ratio for groundwater is greater than 1 indicates more sodium concentration which results in salt formation. The presence of high HCO_3 content can increase soil pH. Furthermore, high bi-carbonate ions HCO_3 decreases the quality of production. The water stored in the reservoir has high magnesium concentrations due to interactions with the underlying strata such as lime stone (rock dominance).*
KEYWORDS: *Irrigation water quality, USSL, Gibb's equation, Water Quality Index (WQI).*

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I. INTRODUCTION

The knowledge of water quality status as well as the process affecting water quality is vital for Integrated Water Resource Management (IWRM) within the catchment, especially in water scare Semi-Arid Tropics (SAT) [1]. Water quality monitoring is important for the various water allocation activities i.e water resource planning and supply projects. Rapid increase in the world inhabitants demands improved crop yield per unit of surface water and groundwater used up for irrigated agriculture [2]. Yield generation is a component of the soil management and nature (of which water accessibility and quality are significant lists) [3]. Irrigation is one of preliminary systems conditioned rise crop yield to meet crop water requirement [CWR] especially in dry and semi-arid tropics (SAT) [4]. Water intended for irrigation remains obtained from both surface and groundwater sources (conjunctive use). The fitness of an aquatic source used for irrigation is a function of the quality of the water and the ability of the source to supply the total irrigation requirements periodically [5]. In semi-arid tropics (SAT), where surface water is scarce, there is a need to map the aquifers to estimate the significant and excellence of groundwater sources (replenishable as well as non-replenishable) in the country [6]. Thus, the objective of this paper is to assess the surface and borewell water quality for irrigation in a semiarid environment.

II. STUDY AREA

The Rivers, Veda and Avathi originate from on the eastern part of Sahyadri hills and flow east and further tributary Suvarnamukhi confluences with Vedavathi at Koodalahalli, Hiriyurtaluk. The River then flows down to the southeastern state of Andhra Pradesh, where the River is named as Hagari. The Vedavathiis a tributary to the Tungabhadra and joins the Tungabhadra near Siruguppa. VanivilasSagar Reservoir is built across the Vedavathi River, near Vanivilaspura, Chitradurga district. The Reservoir catchment area encompasses four taluks Chickmagalur, Arsikere, Belur and Kadur and is located between $13^{\circ}10'$ to $14^{\circ}\ 0'$ N latitude and $75^{\circ}\ 40'$ to $76^{\circ}\ 30'$ E longitudes.

2.1 Soil, Geology and Climate

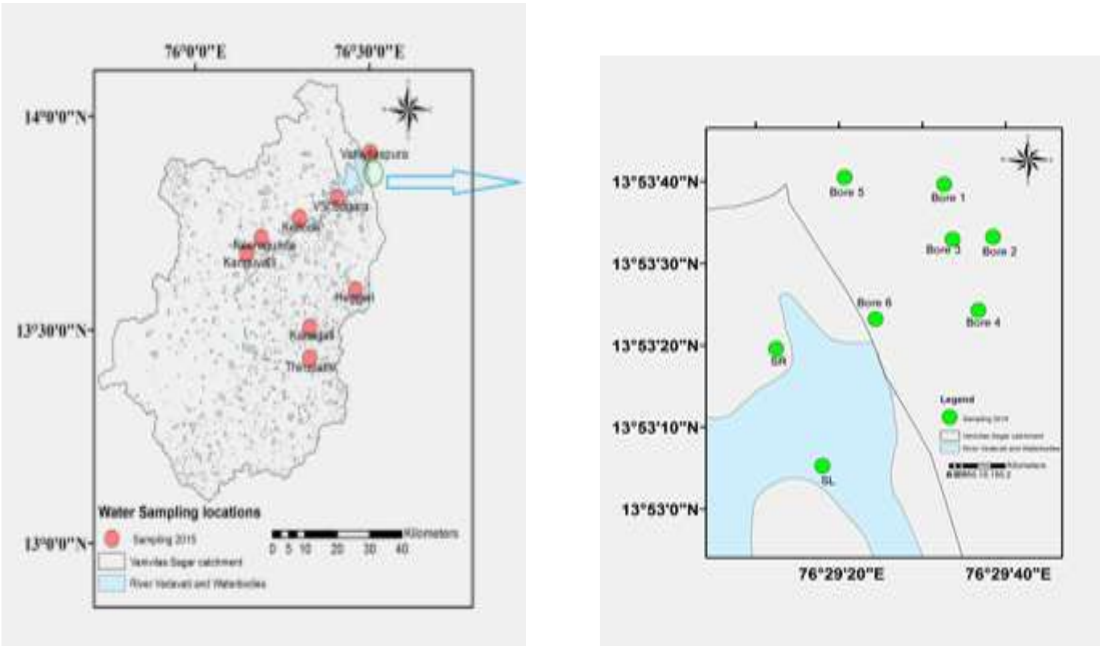
Red loamy, sandy soil, mixed red, Clayey, mixed clayey, Clayey skeletal, and Black cotton soils are dominant in the Reservoir catchment. Soils are moderately fertile and have potential for agriculture yield. Groundnut, Maize and sorghum are major crops grown in the catchment. Agriculture plantations like Coconut and banana are also grown in the area.

Geologically, Vanivilas Reservoir catchment is dominated by magmatite and tonalite Gneiss. It is a mixture of igneous and metamorphic rock, which was formed when metamorphic rock such as gneiss partially melted, and then recrystallizes as igneous rock. Plutonic rock of felsic composition, with phaneritic texture, have more than 20% quarts is present. Genies and Schist are major water bearing formations. The catchment experiences average annual rainfall of 1090mm. major portion of rainfall occurs in the duration of 4 months (July to October). Mean monthly maximum temperature is 33º C in month of April and monthly mean minimum temperature is month of January 14.1º C.

III. WATER QUALITY MONITORING

The samples were collected in the period of April 2015 (Fig 1a.) and January 2019 (Fig 1b). Both surface and groundwater were collected in Vanivilas sagar catchment. The samples were analyzed in the laboratory and the result is compared with the both the period.

Groundwater samples were collected by bore well. The total 7 numbers of samples were collected by borewell for ground water analysis around the study area of Vanivilas Sagar (Fig 1a) during the period of April-2015. Surface water is collected at Vanivilaspura in April-2015 as reservoir water (Fig 1a). Water samples were collected in cleaned polythene bottles of 2 liters capacity for physicochemical analysis after pumping out sufficient quantity of water from the tube wells such that, the sample collected served as a representative sample. Water sample were completely sealed and named before transport.



(a) **(b)**

Fig 1. Sampling locations of Surface water and Groundwater in study area.

The surface water of Vanivilas sagar is collected during the period of April-2015. Surface water is collected from the reservoir of Vanivilas sagar. The total 2 number of surface water samples are collected from left and right side of reservoir (Fig 1b) during the period of January 2019. Samples were collected in 2 liters of polythene bottles which had been thoroughly washed and filled with distilled water, and then taken to the sampling site. The bottles were emptied and rinsed several times with the water to be collected.

Groundwater samples were collected by bore well. The total 6 numbers of samples were collected by borewell for ground water analysis around the study area of Vanivilas Sagar (Fig 1b). Groundwater samples were collected in cleaned polythene bottles of 2 liters capacity for physicochemical analysis after pumping out sufficient quantity of water from the tube wells such that, the sample collected served as a representative sample. Water sample were completely sealed and named before transport.

IV. WATER QUALITY ANALYSIS.

The laboratory test is carried for the samples to check the water quality. Bicarbonate analysis was carried out using acid titration method; chloride concentration was measured by $AgNO_3$ titration method. Sodium and Potassium were measured using flame photometer, calcium and magnesium by titration method. Monitoring of major cations and anions namely calcium, sodium, magnesium, potassium, bicarbonate, chloride, sulphate, nitrate and fluoride in the groundwater Reservoir Catchment Karnataka state. Global Positioning System (GPS) was used for identifying longitude and latitude of each Sampling location there are 4 talukas are taken for assessment of ground water quality aspects.

Table 1 Surface water analysis for the water sample of Vanivilas Reservoir catchment

Location	Ph	Ca	Na	Mg	K	CO_3	HCO_3	Cl	NO_3	SO_4	F	TDS
Surface water sample of sampling period April-2015.												
V.V Sagar	7.61	20	-	16	-	60	232	102	-	30	0.34	305
Surface water sample of sampling period January-2019.												
Reservoir (left)	8.67	7.2	73	23.04	4	60	134.2	90	-	60	-	307.9
Reservoir (right)	8.67	6.4	63	22.56	4.2	60	122	86	-	48	-	307.3
BIS Limits	6.5-8.5	200	200	100	10	-	-	1000	-	400	-	2000

Table 2 Groundwater analysis for the water sample of Vanivilas Reservoir catchment

Location	pH	Ca	Na	Mg	K	CO_3	HCo_3	Cl	NO_3	SO_4	F	TDS
Hydro chemical data for groundwater in Vanivilas Reservoir catchment (April-2015)												
Vanivilasapur	7.42	64	123	156	8	0	414	114	20	20	0.36	387
Kellode	7.48	136	153	90	10	28	444	220	28	190	0.62	622
Heggare	7.58	190	145	36	9	40	568	168	30	110	1.90	636
Neeragunda	7.54	100	212	104	20	32	714	438	37	180	0.99	1080
Kanguvalli	7.19	284	167	36	6	0	694	430	35	340	1.92	1105
Thirupati	7.88	114	87	812	8	0	384	60	33	110	1.44	745
Kanagati	7.33	198	153	162	144	0	600	146	33	220	1.77	1075
Hydro chemical data for groundwater in Vanivilas Reservoir catchment (January- 2019).												
Bore-1	7.26	60.8	213.5	70.56	6.2	0	549	342	-	96	-	1410
Bore-2	7.37	76.8	201.5	75.35	8.3	0	671	382	-	144	-	1500
Bore-3	7.35	46.4	202	69.12	5.3	0	573.4	338	-	98	-	1400
Bore-4	7.55	15.2	201	45.6	6	0	427	170	-	52	-	1020
Bore-5	7.95	25.6	155	42.24	4.3	24	244	144	-	28	-	790
Bore-6	7.47	16	167	42.24	4	0	439.2	124	-	32	-	850
BIS Limits	6.5-8.5	200	200	100	10	-	-	1000	-	400	-	2000

Ca=Calcium, Mg= Magnesium, Na=sodium, K=Potassium, HCO_3=Bicarbonate, Cl=Chloride, NO_3=Nitrate, SO_4=Sulphate, F=Flouride, TDS=Total Dissolved solids, EC=Electrical conductivity

Note: All concentrations are mg/l except for pH, EC in micro mho/cm

4.1 HYDRO CHEMICAL ANALYSIS

pH: The pH of water sample is determined by method of pH meter test. Surface water (reservoir water) is found to be alkaline in nature (pH>7) (Table 1). The value of Ph of surface water during sampling period April-2015 is 7.61 is alkaline in nature. As values of pH of both left and right side of the reservoir is 8.67 (Table 1). The comparison of both period of samples shows that, there is increase in the pH value of the surface water from April-2015 to January-2019(Table 1). Obtained pH of surface water is not in optimal range (6.5-8.5). High pH in irrigation waters results in deficiency of micronutrients like Mn, Zn, Cu and B. The groundwater samples were alkaline (7.26 to 7.95) in nature (pH>7) i.e, pH of groundwater samples is in optimal range (6.5-8.5) (Table 2). The groundwater samples during the period of April-2015 shows pH of 7.42 and the pH of groundwater samples during sampling period of Jan-2019 shows 7.26 to 7.95 in Vanivilaspura. The result of groundwater indicates there is an increase in the pH of the water sample. High absorptions of HCO_3^-in water cause the increase in the pH of the water. This increase of pH in water is eventually affects the plant growth by interpretation of micronutrients (e.g., iron and zinc) insoluble.

EC (Electrical conductivity): Temperature, type and concentration of various ions are functions for Electrical conductivity. The EC of water samples is tested from electrical conductivity meter method. During the sampling period of April-2015 the EC of surface water sample is 550 micro mho/cm. The EC of surface water sample of left side and right side of the reservoir is 860 micro mho/cm and 870 micro mho/cm respectively during the period of Jan-2019. The EC of the surface water is safe for irrigation (Table 1). The samples of both the period were compared and found that the EC of the surface water is increases. The groundwater samples values of EC are varied from 677 micro mho/cm to 2145 micro mho/cm and are within permissible limits (Table 2) for the sampling period of April 2015. The groundwater samples values of EC are varied from 820 micro mho/cm to 1640 micro mho/cm and are within permissible limits (Table 2) for the sampling period of January 2019. The EC values of groundwater in Vanivilaspura is compared on both the period and observed that there is increase of salinity in groundwater.

Calcium: Calcium content of water tested in laboratory by method of titration. For the sampling period of April-2015, the concentration of calcium in surface water is found 20 mg/l (Table 1). Calcium attention of surface water varies from 6.4-7.2 mg/l (Table 1) for the sampling period of January-2019. The observed values show there is decrease in concentration of calcium in surface water of Vanivilas sagar catchment. For the sampling period of April-2015, the calcium concentration varies from 64-284 mg/l (Table 2). The groundwater samples show the calcium concentration varies from 15.2-76.8 mg/l (Table 2) for the sampling period of January-2019. The results show that there is decrease in the calcium content in groundwater in Vanivilaspura as compared with both the sampling period. Sufficient supply of exchangeable calcium of water, soil is allowed water to drain easily with it. The low transpiration rates are observed in soil by water stress of deficiency of calcium in water supply, this deficiency of calcium in plants affects the leaves curling, poor plant growth [7].

Magnesium: In plants, Mg is powerhouse behind photosynthesis. Without magnesium, chlorophyll cannot capture sun energy required for photosynthesis. The magnesium content of water analysed in the laboratory by the method of titration. For the sampling period of April-2015, the concentration of magnesium in surface water is found 156 mg/l (Table 1). The surface water shows the magnesium ion concentration varies from 22.56-23.04 mg/l (Table 1) for the sampling period of January-2019. The observed values show there is decrease in concentration of magnesium in surface water of Vanivilas sagar catchment. For the sampling period of April-2015, the magnesium concentration varies from 36-812 mg/l (Table 2). The groundwater sample with magnesium concentration varies from 42.24-75.35 mg/l (Table 2). The results show that there is decrease in the magnesium content in groundwater in Vanivilaspura as compared with both the sampling period. If Mg becomes more than Ca, it results in soil dispersion and decreased infiltration rate [8] excess amounts of Magnesium is toxic for soil properties and crop growth.

Chlorides: The chloride content of water is analyzed in the laboratory by the method of titration. For the sampling period of April-2015, the chloride concentration found to be 102 mg/l. The chloride concentration found in the study area for surface water is varies from 86-90 mg/l which is less (Table 1) for the period of January-2019. The results show that there is decrease in the chloride content in surface water as compared with both the sampling period. The more concentration of chloride content of water for irrigation may affect the plant growth which caused by chloride toxicity. The chloride content in groundwater varies from 60-438 mg/l (Table 2) for sampling period of April-2015 and the chloride content in groundwater varies from 124-382 mg/l (Table 2) for sampling period of January-2019. The results show that there is increase in the chloride content in groundwater in Vanivilaspura as compared with both the sampling period. Chloride content is necessary for plant growth in small amounts, while high concentration will inhibit plant growth. The plant roots are taken up the chloride content from water and accumulate in the plant leaves. The burning of leaf tips, bronzing and premature yellowing of the leaves are caused by excessive chloride accumulation.

Sulphates: For the sampling period of April-2015, the surface water shows the sulphate concentration is 30 mg/l (Table 1). The sulphate concentration for surface water varies from 48-60 mg/l and (Table 1) for the sampling period of January 2019. Obtained value of sulphate for both the period shows there is increase of sulphate concentration in surface water. For the sampling period of April-2015, the groundwater shows the sulphate concentration varies from 20-340 mg/l (Table 2). The sulphate values for groundwater varies from 28-144 mg/l (Table 2) for the sampling period of January-2019. The sulphate concentration in groundwater of Vanivilaspura is observed to be increased in concentration for the 4 years periodic time (April-2015 to January-2019). Presence of sulphate in water has no major impact on the soil.

Sodium: The sodium content of water is analysed in the laboratory by flame photometer method. The surface water shows the sodium value varies from 63-73 mg/l within permissible limits (Table 1) for sampling period of January-2019. For the sampling period of April-2015, the groundwater shows sodium concentration varies from 87-212 mg/l. The groundwater shows the sodium value varies from 155-213.5mg/l (Table 2) for the period of January-2019. The obtained result of both the period is compared and found that Vanivilaspura shows there is increase in sodium concentration in groundwater for the 4 years periodic time. If the excess leaching of calcium and magnesium from the growing media is due high sodium which inhibits the plant uptake of nutrients. If water with high sodium levels is used continually in irrigation it affects the soil physical properties.

Potassium: The potassium content of water is analyzed in the laboratory by flame photometer method. The surface water shows the potassium value varies from 4-4.2 mg/l. Potassium in study area is within permissible limits (Table 1) for the period of January-2019. For the sampling period of April-2015, the concentration of potassium in groundwater is varied from 8-144 mg/l (Table 2). The groundwater shows the potassium value varies from 4-8.3 mg/l (Table 2) for the period of January-2019. The obtained result of potassium in groundwater of Vanivilaspura shows there is decrease in the potassium concentration by comparison of both the sampling period. Potassium is found in natural water with small in amounts and behaves similarly to sodium in the soil.

Carbonates: The carbon dioxide dissolves in water, carbonic acids are formed. These carbonic acids further produce the salts called Carbonates. The carbonates in the water are tested in the laboratory by the method of titration. The carbonates are the anionic salts ranged in the surface water 60 mg/l for both the sampling period (Table 1). The result shows there is no change in the carbonate concentration in surface water of Vanivilas sagar catchment for the period time of 4 years (April-2015 to January-2019). For the sampling period of April-2015, the groundwater shows varies in carbonate from 0-40 mg/l (Table 2) and for the sampling period of January-2019, it is varying from 0-24 mg/l (Table 2). Hence, the result obtained shows there is increase in the carbonate values in groundwater of Vanivilaspura.

Bicarbonates: Bicarbonates are carbonic salts formed by carbonic acids in natural waters. The irrigation operation system and quality production are mainly influenced by bicarbonate (HCO_3) value. For the sampling period of April-2015, the bicarbonates value is 232 mg/l (Table 1) in surface water. The bicarbonate value in surface water is ranged between 122-134.2 mg/l (Table 1) for the sampling period of January-2019. The result shows there is decrease in the carbonates content in surface water for the periodic time of 4years. For the sampling period of April-2015, concentration of bicarbonates in groundwater varies from 414-600 mg/l. Bicarbonate concentration varies from 244-671 mg/l (Table 2) in groundwater for the sampling period of January-2019. Obtained result shows there is increase in the bicarbonate concentration in groundwater of Vnivilaspura for the periodic time of 4years. Over use of more concentrated bicarbonate in irrigation water can contribute to a soil dominant in sodium, as the result in decrease in water filtration rates and exchange of soil gas. And also, reduction in soil moisture, calcium and magnesium bicarbonates can separates calcium from clay colloid. Detrimental effect of drip tube irrigation system and nozzles of pesticide sprayer can clog by carbonates and bicarbonates present in irrigation water.

4.2 Water Quality Indices

The assessment of water quality suitability for irrigation was carried with the help of indices like Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), MH (Magnesium Hazard), Permeability index (PI), percentage sodium (%Na), Kelly's Ratio (KR).

Table 3. Representation of different water quality indices of groundwater sample for Vanivilas catchment area

Location	SAR	RSC	MH	% Na	PI	KR (meq/l)
Surface water samples for sampling period of January 2019.						
Reservoir (left)	2.96	1.92	84.21	-	85.38	1.390
Reservoir (right)	2.6	1.32	85.45	-	84.06	1.24
Groundwater samples for sampling period of April 2015.						
Vanivilasapura	**1.87**	**-9.42**	**80.09**	**37.32**	**40.83**	**-**
Kellode	1.75	-5.92	52.28	41.90	44.83	-
Heggare	2.52	-1.87	23.81	40.52	187.63	-
Neeragunda	3.53	-0.79	63.18	53.21	54.74	-
Kanguvalli	2.93	-5.9	17.21	35.29	39.21	-
Thirupati	0.62	-66.43	92.00	9.30	10.44	-
Kanagati	1.92	-13.40	57.45	44.00	27.00	-
Groundwater samples for sampling period of January 2019.						
Bore-1	5.39	0.08	65.91*	-	67.47+	1.04
Bore-2	3.89	1.12	61.86*	-	64.13+	0.869
Bore-3	4.36	1.32+	71.28*	-	70.26+	1.08
Bore-4	5.78	2.44	83.34*	-	85.59	1.91
Bore-5	4.34	0.8	73.34*	-	75.51	1.40
Bore-6	4.93	2	81.48*	-	85.58	1.68

NOTE: +Medium suitable, *Unsuitable (exceeding permissible limits) [17]

Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium Hazard (MH), Sodium percent (%Na) and Permeability Index (PI), Kelly's Ratio (KR), Index Base Exchange (CAI- 1 and CAI-2) for Vanivilas Reservoir catchment

Sodium Adsorption Ratio

The sodium adsorption ratio of water gives the measure of suitability of water for irrigation with respect to sodium (alkali) hazard. Higher salinity reduces the osmotic activity of plants and prevents water from reaching the branches and leaves of plants resulting in inferior production [9]. The SAR is computed by the formula.

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

With the cations expressed in milliequivalents per litre. As per IS: 11624-1986, irrigation water quality rating can be based on SAR (Table 3). Entire sample show SAR < 10(Table 3) indicating water class to be low (excellent). The surface water of the period January-2019 shows excellent water quality (SAR<10) and groundwater also shows the excellent water quality (SAR<10).

Residual Sodium Carbonate

The sum of carbonate and Bicarbonate over the sum of calcium and magnesium in water influences the fit of ground water for irrigation purpose. An excess sodium bicarbonate and carbonate influence the physical properties of soil by dissolution of organic matter in the soil that leaves a black stain on its surface on drying [10]. Parameter RSC is computed by $RSC=(CO_3^{-}+HCO_3^{-}) - (Ca^{2+}+Mg^{2+})$ And its units in mill equivalents per litre. As per IS: 11624-1986, the irrigation water quality rating based on residual sodium carbonate is shown in Table 4. Water class is considered low for RSC< 1.25, medium for RSC range 1.25-2.5, and >2.5 high (Table 3). The surface water samples of January-2019 observed to be RSC of the surface water is medium suitable (1.32-1.92 meq/l) in nature. RSC value of groundwater of Vanivilas Reservoir catchment shows negative, Varies from -0.79 to-66.43 (Table 3) for the sampling period of April -2015. The groundwater samples show RSC of water is varies from 0.08-2.24 meq/l (Table 3). during the sampling period of January 2019.

Magnesium Hazard Ratio

The magnesium hazard (MH) ratio values are calculated by using the equation proposed by [11] for irrigation water where

$$MH = \frac{Mg^{+2}}{(Ca^{+2}+Mg^{+2})}*100$$

The units are in milliequivalents per litre and where MH> 50 the effects are considered to be harmful. The presence of more magnesium in water than calcium increases the degree of magnesium saturation and deteriorates the soil structure and decrease soil productivity Generally, in the groundwater, high pH soils are equilibrium state. There is a reduction in crop yield if soils have more alkaline [12]. It is observed that 57.14 % samples have MH ratio values greater than 50 percent during the sampling period of April - 2015. The groundwater samples show the MH value varies from 61.86% to 83.34% (>50) (Table 3) for the sampling period of January 2019.

Sodium percent (%Na)

Sodium concentration is important in classifying irrigation water because sodium reacts with the soil to reduce its permeability (Todd, 1980). The sodium % can be calculated by

$$\%Na = \frac{(Na^{+}+K^{+})}{(Ca^{+2}+Mg^{2+}+Na^{+}+K^{+})}*100$$

High sodium in irrigation water tends to be absorbed by clay particles displacing Ca^{2+} and Mg^{2+} ions. According to Wilcox (1955) the sodium percent for 42.84% sites is between 20-40 (good), 57.16% sites with permissible value between 40 and 60 suitable for use.

Permeability Index

The soil permeability is influenced by long term use of irrigation water containing sodium and bicarbonates and also influences the quality of irrigation water on long term use. Permeability index is calculated using the formula

$$PI = \frac{(Na^{+}+\sqrt{HCO3})}{(Ca^{2+}+Mg^{2+}Na^{+}+K^{+})}*100$$

The surface water shows permeability index value varies from 84.06-85.38 meq/l. For the study area the permeability index of groundwater ranges from 10.44 to 187.63 for samples of April-2015. The groundwater samples ranged with the PI value from 64.13 -85.59 meq/l (Table 3), for the sampling period of January 2019.

Kelly's Ratio (KR)

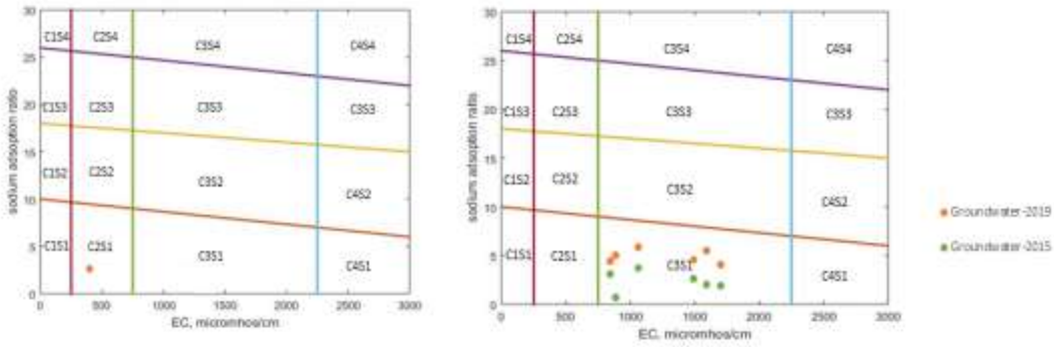
In contradiction of Mg^{2+} and Ca^{2+}, sodium measured and is used to calculated by following formula, the concentration of ion is expressed in meq/l. If Kelly's Ratio (KI>1) greater than 1 indicates an additional level of sodium in waters. Hence, irrigation water with a KI<1 is suitable for irrigation, while greater ratio is unsuitable [2].

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

The KR value of surface water in Table 3.3 shows that the water is not in the permissible limit (>1). The Table 3 indicates unsuitable of water quality of surface water. The KR value for groundwater varies from 0.869-1.91 meq/l. All borewells remain not in the permissible limits (KR>1), but the Bore-2 shows the suitable of water for irrigation (KR=0.869<1).

Irrigation water USSL Diagram

A graphical classification by the U.S. Salinity Laboratory [13] is used for classification of irrigation water in Vanivilas Reservoir catchment. It is based on SAR and Electrical conductivity. For the study area in Vanivilas Reservoir catchment it is found that 85% water samples are categorized high salinity and low sodium hazard(C3S1), 15% water samples are categorized medium salinity and low sodium hazard (C2S1) (Fig 2).



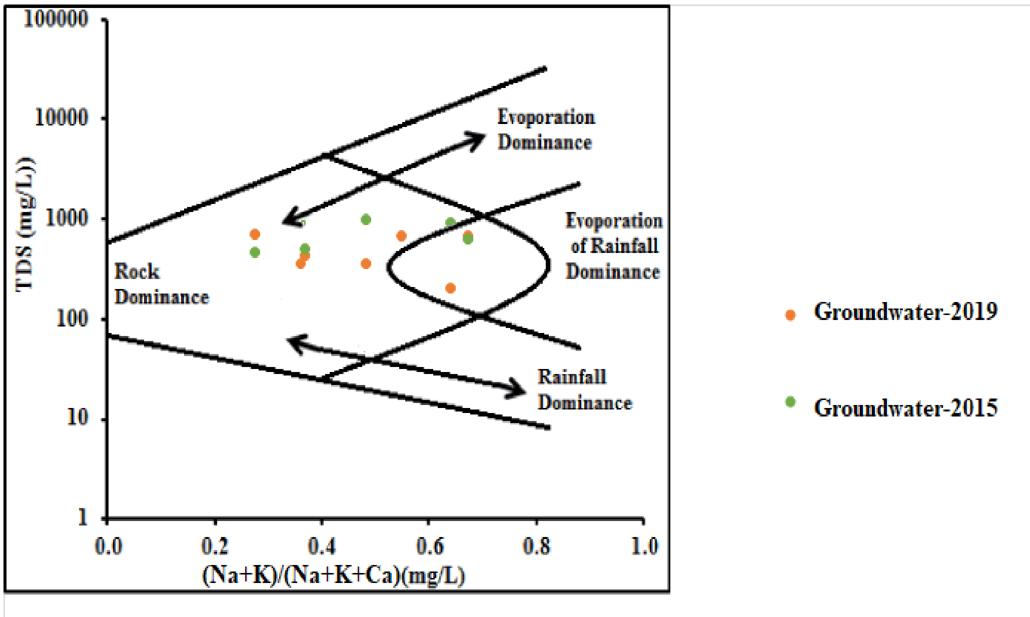
a. Surface water-2019. **b. Groundwater**

Fig 2. Classification of Surface and groundwater based on SAR and EC for Irrigation purposes (After U.S. Salinity Laboratory, 1954).

From the above figure we observed that the surface water in the catchment area falls under C2S1 category which indicate lesser in salinity and medium in sodicity. This results in percolation of irrigation water (less amount of water retained, low moisture content in soil). In groundwater it found that the water samples are falls under class of C3S1 (both April-2015 and January-2019). Lumps formed in the soil due to alkaline groundwaters results in percolation of waters resulting low salinity in soil.

4.3 Aquifer lithological characteristics

Water quality parameters in Gibb's diagram the water samples have pollutant dominant owing to rock-water interaction as well as evaporation (Fig 4). This suggests chemical weathering of rock forming minerals and evaporation is the main process that contributes to the ion's concentrations in the water [14]. High salinity in the groundwater it is due to mineral decomposition.



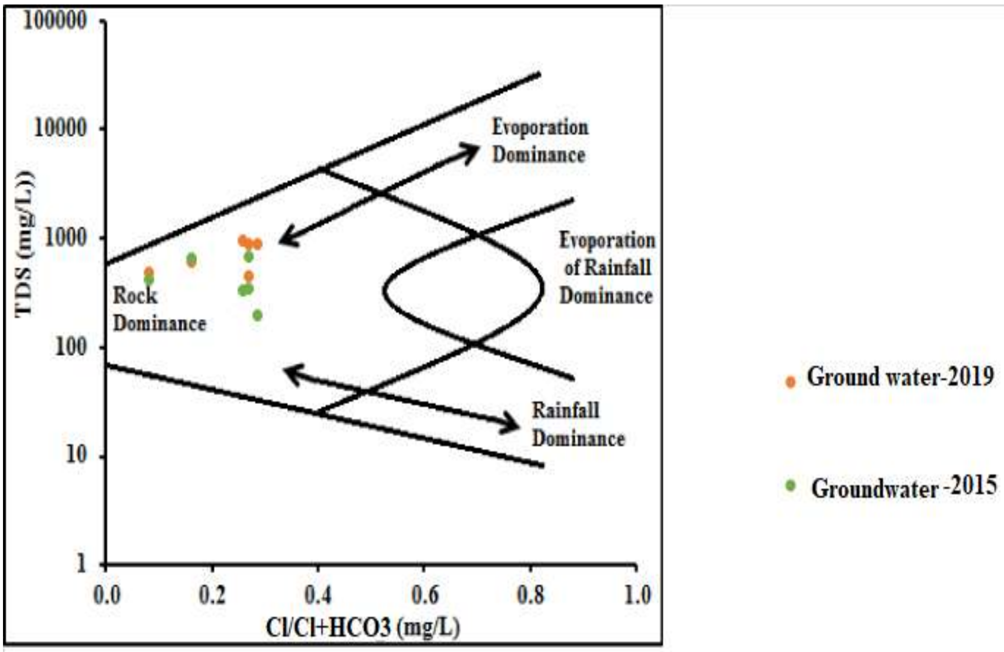


Fig 3. Rock water relationship using Gibbs diagram for ground water samples [weight ratio of (Na+K)/(Na+K+Ca) and ($Cl/Cl+HCO_3$)].

The above Gibb's diagram shows that rock dominance in groundwater samples. This has contributed to increase in cations like Magnesium and Sodium and their concentration are found to be increasing in surface waters. Cations released in the prevailing conditions further react with anions like Cl and HCO_3 to forms the salts resulting in saline groundwaters.

4.4 Water quality index

Water quality index (WQI) is one of the utmost operative tools to interconnect evidence on quality of water to concerned citizens and policy makers. WQI is defined as rating that reflects complex impact of different quality parameters. A water quality index is incomes to review large quantities of water quality data into simple terms for broadcasting to management and the public in consistent manner [15]. Water quality indicates suitability of the resource aimed at different uses, because each kind of water use needs certain biological, chemical and physical characteristics. Several water quality indices have been proposed, taking into account: nutrients, pollutants, dissolved ions, physicochemical parameters, physical stream conditions and/or ecological characteristics. Using method of weighted arithmetic index, WQI is calculated [16].

Let (n) be quality of water parameters and that can be calculated from the following equation:

$$WQI = \frac{\Sigma q_n W_n}{\Sigma W_n}$$

Where,

q_n= quality rating for the n^{th} water quality parameter.

W_n= unit weight for the n^{th} water quality parameter.

Calculation of unit weight (W_n) for various water quality parameters is inversely proportional to the recommended standards S_n for the corresponding parameters.

$$Wn = \frac{K}{S_n}$$

Where,

K= constant for proportionality.

S_n= standard permissible value of n^{th} parameter.

'q_n' quality rating or sub-index corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standards permissible value). The q_n value of is calculated using the following expression.

$$q_n = 100\left[\frac{Vn - Vio}{Sn - Vio}\right]$$

Where,

V_n= estimated value of the n^{th} parameter at a given sampling station.

V_{i0}= ideal value of n[th] parameter (V_{i0}=0 for all the other parameters except pH and DO. Where it is 7.0 and dissolved oxygen =16.6 mg/dm^3) [16].

Table 4 Water quality index of water sample collected in Vaniilas Sagar catchment area.

Water sample	WQI	*Water quality status
Surface water		
Surface water (April-2015)	32.92	Good
Surface water sample (January-2019)		
Reservoir water(left)	89.879	Very poor
Reservoir water(right)	91.878	Very poor
Groundwater		
Groundwater (April-2015)	78.56	Very poor
Groundwater sample (January-2019)		
Bore -1	31.337	Good
Bore -2	62.501	Poor
Bore -3	70.794	Very poor
Bore -4	98.210	Very poor
Bore -5	44.116	Good
Bore -6	88.363	Very Poor

*water quality status with WQI range (0-25 excellent water quality, 26-50 good water quality, 51-75 poor water quality, 76-100 very poor water quality and above 100 unsuitable) [16].

The above Table 4 shows the WQI of both surface and groundwater. The surface water in the period of April-2015 found good water quality (WQI is between 26-50). The surface water of reservoir catchment area in both left and right side collected sample demonstrated that water is very poor in class (WQI is between 51-75) (January-2019). This shows the surface water is deteriorate in the period of 4 years. The groundwater of April-2015 samples shows very poor water quality (WQI>76). The groundwater illustrates the water quality with good, poor and very poor in quality. The Bore-1 and Bore-5 shows the good water quality and used for irrigation. The Bore-2 and Bore-3 shows the poor water quality. Bore-4 and Bore-6 shows the very poor water quality (January-2019). From the above results of WQI, the surface and groundwater of catchment area is originated near continue very poor water quality.

V. IMPACT ON CROPS

Surface waters categorized as C2S1(medium salinity low sodium) having water quality index greater than 76 indicate poor water quality and are alkaline in nature. Alkaline waters (High pH) and high residual carbonate (carbonate greater than Ca and Mg) in irrigation waters results in deficient nutrients and segregation of soil forming lumps. This results in percolation of irrigation water (less amount of water retained, low moisture content in soil). High MAR in irrigation waters results in more alkaline soil (pH> 8). Kelly's ratio more than 1 designates extra sodium concentration which results in salt formation. Ground waters categorized as C3S1(high salinity low sodium) has poor water quality (WQI> 76) for more than 50% of borewell samples. Lumps formed in the soil due to alkaline groundwaters results in percolation of waters resulting low salinity in soil. MAR and Kelly's ratio exceed the permissible limits indicating sodium ion concentration. This is reflected by moderate sodic soils. Saline Waters of soil affect the plant growth like root zone, leaf damage and decrease in yield. The increase in the salt content in soil is toxic to plant. High EC in soil is affects plant due to high osmotic pressure, water uptake and root zone. The high salinity in soil is due to more concentration of salt in soil, this results in less water available for uptake by the plants, increasing water stress and root dehydration which lead to reduce the crop growth. High concentrations of HCO_3^- in groundwater causes the increase in the pH of the water. This increase of pH in water is eventually affects the plant growth by interpretation of nutrients insoluble.

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List of figures

List of tables

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