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Ground Water Quality Assessment of Different Villages of Chikkamagalur Block in Chikkamagalur District of Karnataka

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Quality of the irrigation water is one of the important aspects for plant growth and it has been a major global concern in developing and developed countries. There has been a regular increase in the irrigated area in the country in the last decade that led to a higher yield potential. If poor quality of irrigation water is used it results in decreased yield. So there is a need to assess quality of the irrigation water before its use on the crops. An attempt was made to assess the ground water quality of different villages in Chikkamagalur block of Chikkamagalur district in Karnataka using various water quality parameters. The values of pH ranged from 6.3 to 8.0, while electrical conductivity ranged from 0.10 to 1.10 dS m^{-1}. Sodium and potassium content in the irrigation water ranged from 0.13 to 3.83 and 0.10 to 5.12 meq L^{-1}, respectively. Calcium and magnesium contents which indicate the hardness of the water and are the important cations was recorded between 0.60 and 5.85 meq L^{-1}. Chloride concentration varied from 4.40 to 11.2 meq L^{-1}, while bicarbonate ranged from 0.4 to 8.8 meq L^{-1}. Based on irrigation water quality index (IWQI), it was found that 87.5% of the water samples of the study area was poor in quality and slightly unsustainable for irrigation, while 8.3% was very poor and only ~4.2% was good in quality for irrigation.

Key words: Water quality, yield potential, sustainable and irrigation water quality index

Groundwater is a dynamic and rechargeable precious natural resource of fresh water source for almost all the purposes including domestic, irrigation and industrial uses. Quality of the irrigation water is one of the important aspects for crop production and it has been a major global concern in developing and developed countries. There has been a regular increase in the irrigated area in the country in the last decade that led to a higher yield potential. Irrigation plays a very important role to increase agricultural production. If poor quality of irrigation water is used in the irrigation it results in decreased yield. So, there is a need to assess quality of the irrigation water before its use on the crops. The quality of irrigation water plays a crucial role in long-term productivity of the soil. The quality of water refers to the characteristics of the water which affects its suitability for a specific use. The quality of water primarily depends on the concentration and composition of soluble salts present in it and the proportion of sodium (Na^+) to other cations and other parameters in respect to their sources. The quality of the water decides the salinity or alkalinity status of the soils of the irrigated area. Keeping the above facts, an investigation was carried out to assess the groundwater quality of Chikkamagalur block in Chikkamagalur District, Karnataka used for the irrigation purposes by assessing different water quality parameters.

Materials and Methods

Study area

Chikkamagalur is situated in the south-western part of the Karnataka, India. It is famous for its coffee cultivation and is known as the coffee land of Karnataka. It has a geographical area of 7,22,075 hectares, lies between 12°54′ and 13°53′ N latitude, 75°04′ and 76°21′ E longitude. The district comprises seven *talukas* with Chikkamagalur being the headquarters of the district. Twenty four representative irrigation water samples were collected from four different villages of Chikkamagalur block.

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These villages include Mugtihalli, Shirgunda, Dambadahalli and Mattavara. The collected samples were analyzed for different water quality parameters.

Analysis of water quality parameters

Twenty four irrigation water samples from each of the identified locations of different villages of Chikkamagalur block were collected in the polythene bottles during the pre-monsoon period (April) in the year 2018. To prevent the microbial growth 2-3 drops of toluene was added and capped and brought to the laboratory for further analysis. The physicochemical analysis was performed following standard methods (APHA 1992). The pH was measured by a digital pH meter. Electrical conductivity (EC) of the water samples was measured by a digital EC meter and expressed in dS m^{-1}. Estimation of chloride (Cl^-) in the water samples was done by Mohr's titration method with the help of 0.02 *N* silver nitrate ($AgNO_3$) and potassium chromate (K_2CrO_4) as indicator. The carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) in the water samples were determined by simple acidimetric titration method (Richards 1954). The water soluble sodium (Na^+) and potassium (K^+) present in the water samples was determined using flame photometer. The total calcium and magnesium (Ca^{2+}+Mg^{2+}) was determined by complexometric titration, involving ethylene diamine tetra acetic acid (EDTA). The secondary water quality parameters include sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP), Kelly's ratio (KR) and permeability index (PI) were computed for irrigation water quality index (IWQI).

Sodium adsorption ratio (SAR)

The SAR measures the alkali/sodium hazard level to the crops which is used as the Na toxicity indicator. The SAR was calculated using the following formula where the concentration of all ions were expressed in meq L^{-1}.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots(1)$$

Residual sodium carbonate (RSC)

The RSC can be referred as the difference between the sum of the CO_3^{2-} plus HCO_3^- concentrations and sum of the Ca^{2+} plus Mg^{2+} concentration and expressed (Richards 1954) as:

$$RSC\ (meq\ L^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad \ldots(2)$$

Soluble sodium percentage (SSP)

Wilcox (1955) has proposed classification scheme for rating irrigation water on the basis of soluble sodium percentage (SSP). The SSP was calculated by using following formula where the concentration of all ions are expressed in meq L^{-1}.

$$SSP = \frac{Na^+}{(Ca^{2+} + Mg^{2+} + Na^+)} \times 100 \quad \ldots(3)$$

The values of SSP <50 indicate good quality of water while higher values (SSP >50) indicate that the water is unsafe for irrigation (Richards 1954).

Permeability index (PI)

Permeability index is calculated by using the following formula:

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad \ldots(4)$$

Where, all the values of concentrations ions are expressed in meq L^{-1}. The PI values >75 indicate excellent quality of water for irrigation. When the values of PI fall between 25 and 75, they indicate good irrigation water quality. However, if the PI values are <25, they reflect their unsuitable nature of water used for irrigation.

Kelly's ratio (KR)

Kelly's ratio as given by Kelly (1963) was calculated by using the following formula:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \quad \ldots(5)$$

Where, all concentrations of ions are expressed in meq L^{-1}. If the value of KR is <1, it indicates good quality of water for irrigation, whereas KR>1 suggests its unsuitability of irrigation water for agricultural purposes due to alkali hazards (Karanth 1987).

Results and Discussion

Quality parameters of irrigation water

Results on quality parameters of irrigation water samples from different villages of Chikkamagalur block are given in table 1. It is observed that pH values ranged from 6.3 to 8.0 in different water samples, which falls in relatively neutral condition, indicating good suitability for the irrigation purpose and suitable for almost all the agriculture crop. The EC values ranged between 0.10 and 1.10 dS m^{-1}. Higher the EC values, higher was the concentration of the salts and hence higher the salinity. According

Table 1. Water quality parameters of different villages of Chikkamagalur block of Chikkamagalur district in Karnataka

Sample	pH	EC (dS m^{-1})	Concentration (meq L^{-1}) of					SAR	RSC	PI	KR	SSP	IWQI
			K^+	Na^+	Ca^{2+}+Mg^{2+}	HCO_3^-	Cl^-						
W_1	6.9	0.66	3.22	1.83	2.90	5.6	5.6	1.52	2.80	88.7	0.63	38.6	132.3
W_2	6.9	0.23	0.49	0.70	1.35	2.8	6.8	0.85	1.45	115.8	0.52	34.0	152.6
W_3	6.6	0.23	0.13	0.96	1.75	4.4	5.2	1.02	2.75	112.8	0.55	35.3	152.5
W_4	6.3	0.49	0.10	2.74	1.85	3.2	8.8	2.85	1.65	98.7	1.48	59.7	164.3
W_5	7.3	1.07	5.12	3.83	3.85	8.8	4.8	2.76	5.15	88.5	0.99	49.8	147.2
W_6	6.3	0.57	0.18	1.43	2.85	3.2	6.8	1.20	0.75	75.2	0.50	33.5	111.2
W_7	6.5	0.52	0.23	1.39	2.50	4.8	5.6	1.24	2.40	92.1	0.56	35.8	132.0
W_8	6.5	0.78	0.18	3.26	3.60	5.2	6.8	2.43	1.70	80.8	0.91	47.5	133.3
W_9	7.0	0.39	0.15	1.26	2.00	4.4	6.8	1.26	2.50	103.0	0.63	38.7	146.1
W_{10}	6.5	0.17	0.10	0.87	0.60	3.2	9.2	1.59	2.90	180.9	1.45	59.2	246.0
W_{11}	7.0	0.54	0.38	1.70	3.00	4.4	6.8	1.38	1.60	80.8	0.57	36.1	120.4
W_{12}	6.7	0.81	0.36	2.74	3.15	2.8	4.4	2.18	-0.25	74.9	0.87	46.5	124.2
W_{13}	8.0	0.32	0.15	1.17	1.45	4.8	4.8	1.38	3.45	128.2	0.81	44.7	178.6
W_{14}	7.1	0.14	0.18	0.39	1.50	2.0	9.2	0.45	0.90	95.5	0.26	20.7	117.8
W_{15}	7.7	0.10	0.10	0.13	0.85	3.2	11.2	0.20	3.15	195.8	0.15	13.3	212.6
W_{16}	6.6	1.10	1.05	2.96	5.85	8.0	6.8	1.73	2.45	65.7	0.51	33.6	104.0
W_{17}	7.1	0.35	0.13	1.22	1.75	3.2	6.4	1.30	1.55	101.3	0.70	41.0	145.9
W_{18}	6.9	0.28	0.43	0.70	1.45	1.2	8.4	0.82	-0.25	83.5	0.48	32.4	116.9
W_{19}	7.1	0.28	0.20	0.96	1.05	2.8	5.6	1.32	1.85	131.1	0.91	47.7	182.8
W_{20}	7.2	0.37	0.18	1.22	2.45	6.0	4.4	1.10	3.75	100.0	0.50	33.2	138.5
W_{21}	6.8	0.41	0.26	1.22	2.25	6.4	4.4	1.15	4.45	108.1	0.54	35.1	149.3
W_{22}	7.2	0.19	0.31	0.43	1.30	0.4	8.8	0.54	-0.90	61.5	0.33	25.1	86.6
W_{23}	7.5	0.69	0.49	2.57	3.50	8.4	5.2	1.94	5.30	90.1	0.73	42.3	140.4
W_{24}	7.0	0.21	0.43	0.65	0.95	2.0	7.2	0.95	1.15	129.0	0.69	40.7	172.5
Mean	6.95	0.45	0.61	1.51	2.24	4.22	6.67	1.38	2.18	103.4	0.68	38.5	146.2
Range	6.3-8.0	0.1-1.1	0.10-5.12	0.13-3.83	0.60-5.85	0.4-8.8	4.40-11.2	0.20-2.85	-0.9 to 5.3	61.5-195.8	0.15-1.48	13.3-59.7	86.6-246.0
SD±	0.42	0.28	1.15	0.99	1.20	2.18	1.82	0.67	1.59	32.2	0.32	10.6	34.8
CV (%)	6.06	61.7	189.7	65.6	53.7	51.7	27.3	48.6	73.0	31.2	46.7	27.6	23.8

Note: SAR = Sodium adsorption ratio; RSC = Residual sodium carbonate; KR = Kelly's ratio; SSP = Soluble sodium percentage; PI = Permeability index; IWQI = Irrigation water quality index

Table 2. Water quality classification based on irrigation water quality index (IWQI) value

Water value range	Water quality	No. of samples (IWQI)	% of water samples	Sustainable state
<50	Excellent	0	0	Sustainable
51-100	Good	1	4.2	Sustainable
101-200	Poor	21	87.5	Slightly unsustainable
201-300	Very poor	2	8.3	Unsustainable
>301	Very bad	Nil	Nil	Highly unsustainable

to FAO (1994), the water samples which do not cause any damage to the crops can be used. It was observed that Na^+ content in the irrigation water ranged from 0.13 to 3.83 meq L^{-1}, while K^+ content ranged from 0.10 to 5.12 meq L^{-1}. The sum of Ca^{2+}+Mg^{2+} content which indicates the hardness of the water and are the important cations, recorded between 0.60 and 5.85 meq L^{-1}. A harmful effects on soil appeared when Ca:Mg ratio declined below 50. The Cl^- concentration ranged from 4.40 to 11.20 meq L^{-1}. It is reported that Cl^- concentration with 4-10 meq L^{-1} is considered as good quality water as per the FAO guidelines for irrigation water. The results on the collected samples having moderately good quality water can be used for agriculture purpose. The HCO_3^- values ranged from 0.4 to 8.8 meq L^{-1}. Geological location is one of the most important factors affecting ground water quality (Becket *et al.* 1985).

The calculated values of SAR in the study area were found to be 0.20-2.85, indicating that these samples are falling in the water class of S_1 (SAR 0-10) with no or low Na hazard and suitable for all the crops. The higher the SAR values in the water, the greater the risk of Na which leads to the development of an alkaline soil. Similarly, higher the concentration of the salts, higher will be the salinity. The RSC values ranged from -0.90 to 5.30 meq L^{-1}. It is reported that RSC >2.5 meq L^{-1} is unsuitable for irrigation purpose. Based on this, 37.5% of the samples showed high RSC and relatively not good for agriculture purpose. The values of SSP <50 indicate good quality of water and higher values (SSP>50) show that the water is unsafe for irrigation (Richards 1954). According to this classification, the majority of the water samples in the present study area had SSP values <50, and graded as suitable water quality for irrigation. The PI values ranged between 61 and 196%. If the PI value >75, it indicates excellent quality of water for irrigation while, the PI values between 25 and 75 indicate good quality of water for irrigation. Based on PI values, these water samples were found good for irrigation. The value of Kelly's ratio of unity with <1 indicates good quality of water for irrigation whereas, KR >1 suggests unsuitability for agricultural purpose due to alkali hazards (Karanth 1987). The present water samples showed that KR values ranged between 0.15 and 1.48. Only about 2 samples had little hazard of alkali. But majority of the water samples showed KR <1, indicating that they can be used safely for agriculture purpose.

In order to assess the quality of groundwater used for irrigation purpose of different villages of Chikkamagalur block, an attempt was made to develop a model on irrigation water quality index (IWQI) using different indices of water quality for irrigation such as SAR, SSP, RSC, PI and KR. The indices values were summed and then classified into excellent to unfit groundwater quality (Table 2). The results showed that 87.5% of water was found poor in quality and slightly unsustainable for irrigation, 8.3% was very poor and only about 4.2% of water samples was found good in quality. These findings are in close conformity with those reported by Anbazhagan (2014).

Correlation coefficients

The correlation coefficients among the water quality parameters are given in table 3. The pH of the water had negatively significant relationship with Ca^{2+} (r = -0.438*) and positively non-significant relationship with K^+ (r = 0.129), HCO_3^- (r = 0.110) and negatively with Na^+ (r = -0.248) and Ca^{2+}+Mg^{2+} (r = -0.224). The EC of the samples had shown positively and highly significant relationship with Na^+ (r = 0.929**), K^+ (r = 0.574**), Ca^{2+}+Mg^{2+} (r = 0.936**) and HCO_3^- (r = 0.712**). The HCO_3^- had shown highly significant and positive relationship with Na^+ (r = 0.674**), K^+ (r = 0.510*) and Ca^{2+}+Mg^{2+} (r =0.733**). The Na^+ content showed highly and positively significant with SAR (r = 0.921**) but positively non-significant with RSC (r = 0.306).

Table 3. Correlation coefficients among water quality parameters of Chikkamagalur block of Chikkamagalur district in Karnataka

Parameters	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	Ca^{2+}+Mg^{2+}	HCO_3^-	Cl^-	SAR	RSC	PI	KR
EC	-0.228												
Na^+	-0.248	0.929**											
K^+	0.129	0.574**	0.514*										
Ca^{2+}	-0.438*	0.788**	0.617**	0.217									
Mg^{2+}	0.009	0.855**	0.793**	0.493*	0.547**								
Ca^{2+}+Mg^{2+}	-0.224	0.936**	0.809**	0.416*	0.858**	0.899**							
HCO_3^-	0.110	0.712**	0.674**	0.510*	0.557**	0.720**	0.733**						
Cl^-	-0.039	-0.465*	-0.420*	-0.273	-0.335	-0.406*	-0.424*	-0.563**					
SAR	-0.310	0.746**	0.921**	0.409*	0.407*	0.550**	0.550**	0.517**	-0.370				
RSC	0.338	0.264	0.306	0.375	0.121	0.308	0.252	0.839**	-0.402	0.279			
PI	0.299	-0.581**	-0.484*	-0.210	-0.525**	-0.603**	-0.644**	-0.169	0.378	-0.304	0.306		
KR	-0.324	0.231	0.486*	0.125	-0.009	-0.008	-0.010	0.130	-0.109	0.776**	0.167	0.152	
SSP	-0.317	0.331	0.553**	0.171	0.073	0.089	0.093	0.214	-0.316	0.814**	0.188	0.017	0.967**

Note: '*' represents significant at 0.05 level and '**' represents significant 0.01 level

Conclusions

The present investigation clearly showed that the groundwater used for irrigation in different villages of Chikkamagalur block was found good for its use in irrigation. The results showed that it was good with respect to soluble salts concentration and could be used safely for wide range of crops and varieties. But the results on the irrigation water quality index showed that 87.5% of the water samples were found poor in the quality and slightly sustainable. About 8.3% of the samples were very poor in quality and unsustainable and about 4.2% of the samples were good and sustainable for use in irrigation.

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