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Evaluation of groundwater quality for irrigation purpose in Rediyarchatram block of Dindigul district, Tamil Nadu, India

S. **Samahajira and C. Florence Annal***
Department of Geography, M.V. Muthiah Government Arts College for Women, Dindigul, Tamil Nadu, India
florenceannal@rediffmail.com

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Abstract

In the present study the quality of groundwater for irrigation purpose in Rediyatchatram Block of Dindigul District, Tamil Nadu was assessed. Twenty four groundwater samples from the study area randomly collected and analyzed for important chemical parameters such as EC (Electrical conductivity), Ca (Calcium), Mg (Magnesium), Na(sodium), CO_3 (carbonate), HCO_3 (bicarbonate), SO_4 (sulphate), and Cl (chloride). To evaluate the groundwater quality for irrigation purpose, the important water quality criteria such as SAR (Sodium Absorption ratio) EC (Salinity Hazard), SSP (Sodium soluble Percentage), KR (Kelley Ratio), MR (Magnesium ratio), Na (Sodium Percentage), and RSC (Residual Sodium Carbonate) value have been computed from the chemical parameters. The computed result showed that based on SAR and MR ratio the quality of groundwater is excellent for irrigation purpose in the study area. In respect of other criteria the quality ranged from excellent to unsuitable category for agricultural purposes.

Keywords: Groundwater Quality, Agriculture, Irrigation, SAR, Salinity, Kelley ratio.

Introduction

The quality groundwater varies from region to region with climatic changes and based on the depth of water table. The presence of dissolved solids in the groundwater governed its quality. The large-scale disposal of industrial and urban wastes, domestic, municipal wastes and use of pesticides and chemicals in the agricultural fields deteriorate the quality of groundwater. The growth of crops could adversely affect if the groundwater consists above the permissible limit of ions[1]. The sustainable agricultural production of an area depends upon the judicious management and monitoring of water and soil resources. Periodical monitoring of groundwater quality would minimize the occurrence of salinity in groundwater[2]. About one third of the world population depend groundwater for drinking purpose. In arid and semiarid regions of India due to non availability of surface water and erratic monsoon rainfall the demand for water become a crucial problem. Groundwater constitutes about 53 percent of the total irrigation potential and about 50 percent of the total irrigated area is dependent on groundwater in India (Central Water Commission- 2006). It is important to determine the groundwater quality to observe its suitability for a particular use. In densely populated and thickly industrialized areas the groundwater quality is more acute. The geochemistry of groundwater determined its suitability for irrigation purpose[3]. In recent years the competition for water resources has gained importance not only in India but also in many parts of the world. Groundwater is the clean water source which serves the water requirements of semi urban and rural populations[4]. About 96 percent of the global fresh water is þn the form of groundwater but it is not evenly distributed. Both in urban and rural areas groundwater has been tremendously used for irrigation and industries all over the world. But the occurrence of groundwater is restricted in areas underlain by crystalline rock of Precambrian age, because they area igneous and metamorphic rocks characterized by low porosity and permeability. The natural composition of groundwater can alter by human activities through the disposal or dissemination of chemical and microbial matter on land surface. Hence the evaluation of groundwater chemistry is needed to obtain the suitability of water for different uses particularly for irrigation purposes[5]. The study area is located between 10^0 20' N – 10^0 30' N latitude and 70^0 40' E – 70^0 50' E longitude and covers 279 sqkms. Geologically the block is covered by crystalline metamorphic rock types of calcareous, cal gneisses and ferruginous gravels. Geomorphologically the block is composed of buried and shallow pediments. There are a number of residual and inselbergs found in the block. There is a sudden increase in the slope of the area from central plain towards south west and western part. Red soil and calcareous soil are important soil group of the study area. In the study area climate is very hot in summer and it experienced mild climate during monsoon season. The highest amount of the rainfall received by the study area is 710mm during southwest monsoon season. Groundwater is the important source of water here. There are 115 tanks, 6 dams and 9583 wells and bore wells used for irrigation. The total cropped area of the region is 20139 hectare. Nearly 50 percent of the cropped area is under irrigation. Very few studies had been conducted relating groundwater in the study area. There was no special study about groundwater quality evaluation for irrigation purpose. Hence the present study planned to assess the quality of groundwater for irrigation

purpose which would serve as useful input for formulating efficient management plans.

Materials and methods

Groundwater in the study area is polluted by various sources. To assess the quality of groundwater for irrigation purpose twenty four groundwater samples were collected randomly from the study area. One liter polythene bottles were used for sampling, which were carefully washed with the sampling water before collecting the sample water. The collected samples will be analyzed in the laboratory for major chemical parameters and the obtained data will be interpreted to delineate the study area into suitable and unsuitable regions for irrigation purposes[6]. Assessment of groundwater suitability for irrigation purpose was carried out by obtaining Sodium Adsorption ratio (SAR), Salinity hazard, (EC) Percent Sodium (% Na), Magnesium Ratio (MGR), Potential salinity, (PS) , Kelly's Ratio (KR), Residual Sodium Carbonate (RSC) and Soluble Sodium Percent (SSP). The obtained chemical data were interpreted by using various techniques and methods.

Results and discussion

The chemical parameters analyzed for the present study were presented in Table-1. For agricultural purpose, the quality of irrigated water and types of soil in the region determined the suitable irrigation practices. The presence of excessive content of dissolved ions in the irrigation water affects the growth and productivity of the crops and also the soil properties of the agricultural fields physically and chemically.

Table-1: Chemical Parameters for Reddiyarchatram Block.

Sl.No	Name of the Sample Locations	SAR	NA%	MAR	PS	KR	SSP	PH	EC	TDS	RSC
1.	Adalur	1.45	37.3	16.6	3.3	0.5	33.3	7.6	0.67	0.42	3.9
2.	Alagupatti	0.52	22.9	38.2	3.15	0.17	14.5	7.6	0.61	0.39	2.6
3.	Ammapatti	6.3	64.2	28.5	11.7	1.62	63.5	8.2	2.10	1.34	15
4.	Chatirapatti	0.52	47.9	13.38	10.55	0.10	9.2	7.4	2.44	1.56	10.1
5.	Gurunathanayakanur	1.1	12.8	18.18	7.15	0.26	20.7	7.5	1.15	0.73	8.3
6.	K.pudhukottai	3.76	49.1	17.6	14.4	0.75	42.9	6.8	2.46	1.57	4.5
7.	Kamachipuram	0.21	11.76	20	4.45	0.05	5.06	7.3	0.85	0.54	5
8.	Kannivadi hills	2.96	55.4	24.3	10.25	0.73	42.2	7.7	1.84	1.17	10.5
9.	Kasavanampatti	5.43	71.7	27.2	10.6	1.63	62.0	7.8	1.95	1.24	9.85
10.	Kodalvavi	0.32	9.41	20.7	9.4	0.05	5.5	7.4	1.70	1.08	2
11.	Kothapuli	1.96	25.5	30.3	16.85	0.30	23.5	8.0	2.70	1.72	18.7
12.	Kuttathupatti	0.46	8.78	19.9	10.9	0.05	5.6	7.9	3.30	2.11	23.7
13.	Mangarai	1.84	19.1	39.5	11.95	0.22	18.2	7.5	1.94	1.24	19.7
14.	Nilamalaikottai	1.66	61.1	23.8	5.45	0.57	36.3	7.7	1.08	0.69	4
15.	Palakanathu	0.19	8.6	16.0	7.65	0.036	3.52	7.9	1.50	0.96	8.6
16.	Palayakannivadi	3.26	46.5	15.5	8.45	0.83	45.3	6.9	1.44	0.92	11.9
17.	Pandrimalai	0	0	34.4	1.2	0	0	7.9	0.29	0.18	0.9
18.	Silvarpatti	1.96	29.6	15.66	6.4	0.34	25.8	8.2	1.18	0.75	7.9
19.	Siraggadu	2.83	60	25	5.65	1	50	8.0	1.0	0.64	5.8
20.	Sindalagundu	4.82	67.6	19.7	15.4	1.23	55.2	7.5	2.35	1.50	14.5
21.	Sulerumbu	3.08	41.8	14.28	41.9	0.39	28.2	7.2	5.30	3.39	37.1
22.	Tamaraikulam	2.97	33.5	12.5	24.9	0.47	31.9	7.4	3.01	1.92	24
23.	Tetthupatti	2.53	32.0	35.8	17.7	0.40	28.8	7.8	2.87	1.83	19.1
24.	Thonimalai	1.08	17.0	5.88	12.85	0.18	15.8	7.4	2.05	1.31	18

Sodium Absorption Ratio (SAR): Sodium absorption ratio (SAR) is the important measure used to find out the presence of sodium in the soil. It is considered to be a better yardstick than sodium percentage to measure the alkaline hazard in irrigation water. The property and permeability of the soil changed due to high concentration of sodium in irrigation water[7]. The following formula used to calculate the SAR ratio.

$SAR = Na+ K/ \sqrt{Ca + Mg / 2}$

Table-2: Classification of irrigation water based on sar ratio.

SAR in epm	Water class	Total samples	% of total samples
Less than 10	Excellent	24	100
10-18	Good	-	
18-26	Permissible	-	-
More then 26	Unsuitable	-	-

The SAR values ranged from 0 to 6.3 in the study area. The lowest SAR value is found in Pantimalai area and highest of 6.3 is found in Ammapatti village. The result of the analysis showed that 100 percent of the sample locations fall in excellent water category with SAR value of less than 10 and indicated the suitability for irrigation purpose in all agricultural fields.

Electrical Conductivity (EC) or Salinity Hazard: The total dissolved slats in groundwater can be determined by specific conductance (EC) or salinity Index or salinity hazard. The groundwater samples are expressed as excellent quality to brain water based on EC values. The quality of groundwater for irrigation is primarily determined by salinity hazard. Based on salinity hazard Richard, 1954 classified the irrigation water in to four categories. In the study area all the sample locations falls from excellent to poor water classes based on salinity value. The presence of higher salinity in the soil restricted the availability of water to the plants. The EC value of less than 250µS/cm is considered good for irrigation and EC value of more than 3000µS/cm is unsuitable for irrigation. Irrigation water with high salinity converts the soil in to saline and affects the production of crops. Physiological drought condition is occurred due to high concentration of salt in the soil[8].

Table-3: Classification of irrigation water based on salinity ratio.

Salinity ratio (EC) µS/cm	Water Class	Total Number samples	% of total samples
<250	Excellent	-	-
250-750	Good	3	13
750-2000	Permissible	11	45
>2000	Unsuitable	10	42

The assessment of quality of irrigation water based on EC indicated that 13 percent of the sample locations have good quality water for irrigation with the EC value of 250 to 750 µS/cm. Whereas 45 percent of the sample locations come under permissible limit with EC value of 750 µS/cm to 2000 µS/cm. Nearly 42 percent of the sample locations have unsuitable water for irrigation and indicate EC value of more than 2000 µS/cm.

Percent Sodium (Na%): The important water quality criteria used to analyzing the irrigation water is the determination of Sodium Percent because the hardness of the soil increased by absorption of sodium by the clay particles and displaying magnesium and calcium ions. It reduces the soil permeability and affects the poor soil internal drainage[9]. Sodium percentage in groundwater is determined by using the following formula

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

Where all the ions are expressed in epm.

Table–4: Classification ground water for irrigation based on na%

Sodium %	Water class	Total Number samples	% of total samples
<20	Excellent	8	33
20-40	Good	6	25
40-60	Permissible	6	25
>60	Unsuitable	4	17

The quality of groundwater in the sample locations was classified on the basis of sodium percentage as excellent quality with Na % of <20 , as good quality water with the Na % of 20 – 40, as permissible quality with Na% of 40 – 60 and unsuitable water class for irrigation with Na % of more than 60. Out of the collected 24 ground water samples 33 % comes under excellent category for irrigation purpose. About 23 % of the sample locations have good quality irrigation water. Nearly 25 % of the sample locations come under permissible water class and the remaining 7% have unsuitable water for irrigation the fields.

Residual Sodium Carbonate (RSC): When the concentration of bicarbonate and carbonate ions exceeds the presence of cations such as calcium and magnesium it results in the occurrence of residual sodium carbonate in the irrigation water. Sodium ions accumulated in the soil when the agricultural fields are irrigated with the water of high RSC content.

This continuous irrigation process causes soil salinity and poor plant growth performance, toxicity to crops and loss of soil structure and associates decrease in the permeability would occur. The following table shows the classification of groundwater sample locations based on RSC values.

Table-5: Classification of irrigation water based on residual carbonate

RSC in epm	Water class	Total samples	% of total samples
<1.25	Safe	1	4
1.25-2.5	Marginally suitable	1	4
>2.5	Unsuitable	22	92

The values of RSC value in the study area ranged from 0.9 to 37.1. Out of the 24 sample locations 4 percent of the locations come under safe water class which will use for irrigation purpose and indicates RSC value of < 1.25 epm). About 4 percent of water sample locations come under marginally suitable water category with the RSC value of 1.25 to 2.5 epm for agricultural purpose. The remaining 92 percent of the sample locations have unsuitable water for irrigation with the RSC value of more than 2.5 epm. The following formula used to calculate the RSC values

$RSC = (CO^{3} + HCO^{3}\text{-}) - (Ca^{+2} + Mg^{+2})$

Table-6: Groundwater Quality for Irrigation Purpose based on EC, Na% and RSC.

Water Quality Parameters	Excellent	Good	Permissible	Unsuitable
EC µS/cm	-	13	45	42
Na%	33	25	25	17
RSC in epm	-	4	4	92

Kelly's Index: The Kelley Index is used to find out the presence of sodium level in the irrigation water. When the Kelley index exceeds the value of 1, which shows that more content of sodium in irrigation water. If the result of the analysis showed <1 one value of Kelley ratio the water is suitable for irrigation purpose and when it showed >1 value of Kelley Index, the water is unsuitable for irrigation purpose. The problem of excess sodium in irrigation water would determined by assessing the values of the Kelley's ratio[10].

The following formula is used to calculate Kelley Ratio

Kelly ratio = NA/Ca+Mg.

Table-7: Classification of irrigation water based on Kelly's ratio

KR	Water class	Total Number of samples	% of total samples
<1	Good	21	88
>1	Unsuitable	3	12

In the present study the Kelley ratio for all water sample locations has been find out. The Index varies from 0 to 1.63 epm (Table-1). The analysis of the above shows that nearly 88 % of the sample locations have Kelley Index of < 1 and have suitable water for irrigation purpose. The remaining 12 % have > 1 Kelley Index value and are not suitable for irrigation.

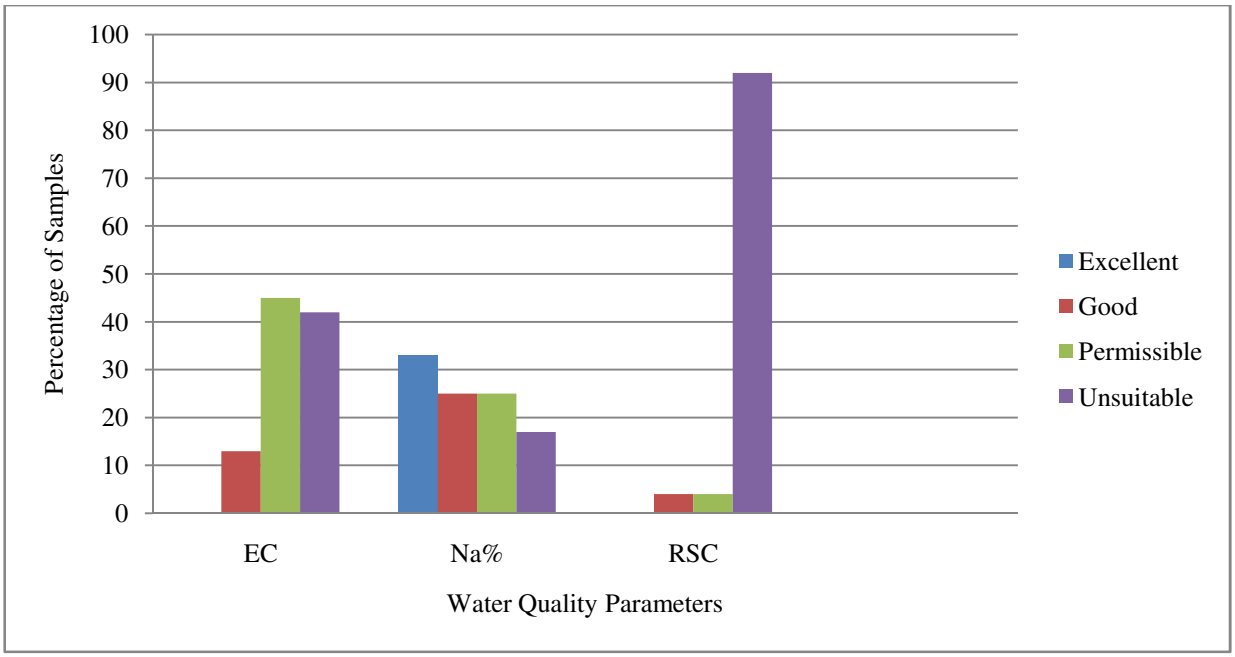

Figure-1: Assessment of quality of ground water for orrigation purpose based on EC, NA% and RSC.

Soluble Sodium Percentage (SSP): Soluble Sodium Percentage (SSP) is used to evaluate sodium hazard. For the calculation of SSP all the cations are expressed in mille equivalents per liter (epm). The physical properties of the soil would breakdown if the SSP values are greater than 60%. When the calculated SSP value is high it showed that sodium ion in presented more in the irrigation water. As a result it decrease the content of calcium and magnesium in the soil and increase the concentration of sodium in the soil[11]. The presence of sodium in irrigation water s calculated by using the following formula

SSP = [Na + / (Ca + Mg + Na] xl00

Table-7: Classification of irrigation water based on SSP

SSP In epm	Water class	Total Number of samples	% of total samples
<50	Good	22	92
>50	Bad	2	8

The calculated range of SSP is l<50 or equal to 50 shows suitable water for irrigating the agriculture fields. If the arrived value of SSP is higher than 50 it showed unsuitable water for irrigation. In the study area the range of SSP varies from 0 to 63.5. The interpretation of the Table-7 showed that about 92 % of the sample locations have SSP value of <50 and come under suitable water class for irrigation. The remaining 8% of the sample locations have higher than 50 SSP value and unsuitable for irrigation purpose.

Magnesium Hazard: The determination of MG ratio is the important parameter to identify the quality of irrigation water. The presences of cations are needed for the growth of plants. When water running along the rocks it bring magnesium by solution processes. The hydrogen ion concentrations (pH) in the soil particles increased by more content of magnesium. Like that the amount of phosphorous in the soil is reduced by it. In the study area the value of Mg ranges from 9 – 322 mg/l. The water with Mg ratio of < 50 is suitable for irrigation and >50 is unsuitable for irrigation[4]. Mg ratio can be calculated by using the following formula.

MR ratio {Mg / (Mg+ Ca2)} 100

Table–8: Classification of ground water for irrigation based on MG ratio

MG Ratio	Water class	Total samples	% of total samples
<50	Suitable	24	100
>50	unsuitable	-	-

The magnesium ratio in the ground water samples varies from 5.88 – 39.5 epm (Table-1). In the study area about 100% of the groundwater sample shows less than 50% of magnesium ratio and indicates suitable water for irrigation.

Table-9: Groundwater Quality for Irrigation Purpose based on Kelly Index, SSP and MG ratio.

Water Quality Parameters	Suitable	Unsuitable
Kelly Index	88	22
SSP	92	8
MG Ratio	100	-

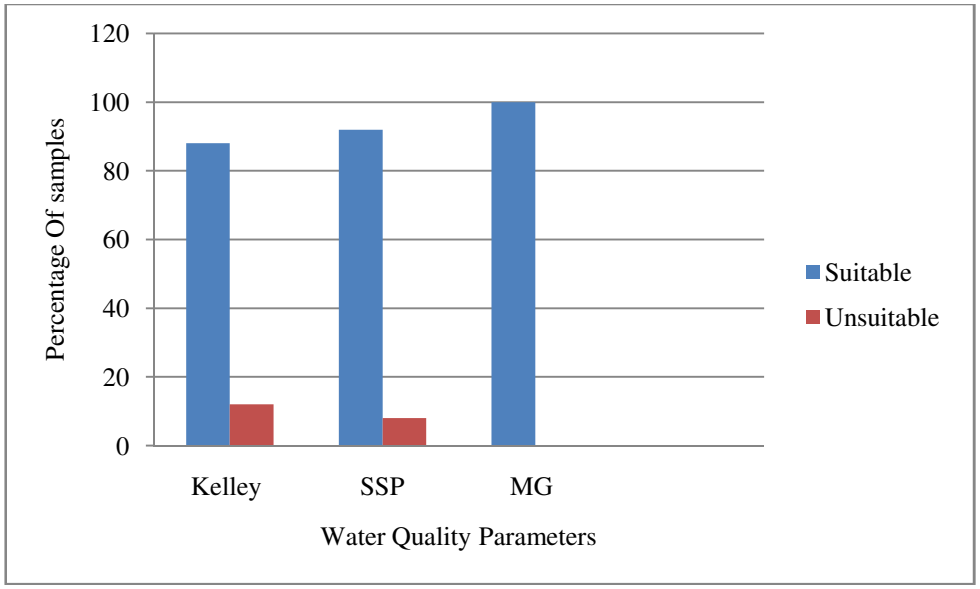

Figure-2: Assessment of quality of groundwater for irrigation purpose based on Kelley, SSP and Mg ratio.

Conclusion

The present study about the suitability of groundwater for irrigation purpose in Reddiyarchatram Block of Dindigul District was evaluated by using important water quality parameters. The analysis showed that based on SAR ratio and Magnesium Ratio 100 percent of the water samples locations comes under excellent category and indicate suitable water for irrigation purpose. Based on other parameters the quality for water varied from excellent to unsuitable categories for irrigation purpose[12].

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