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Study of Groundwater Quality using GIS in Hirehalla Sub-basin of Koppal District, Karnataka, India

Sreenivasa A. and Ajay Kumar N. Asode

Department of Studies in Geology, Karnatak University, Dharwad, Karnataka, India

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Abstract Water quality problems were reported in the groundwaters of Hirehalla Sub-basin, Koppal district, Karnataka, India. 21 representative samples were collected and subjected to hydrochemical investigations. Major cations- Ca, Mg, Na, K and anions- CO_3, HCO_3, Cl, SO_4 were analysed. Physical parameters such as pH, EC, TDS, H were also determined. Piper hill trilinear diagram were plotted to study the hydrochemical characters of groundwater and it was found the groundwater to be of class- NaCl and CaMgCl type. Fluoride ion concentration was found to be in the range 0.26 to 6.42 mg/lit. Based on EC values it was found that 61% of water samples fall in excellent category. Drinking use suitability was determined by comparing the analysis results of water samples with BIS and WHO standards and it was found that 65% of the water samples are safe and fit for drinking purposes. Parameters like SAR and Na% were calculated to evaluate the suitability of waters for irrigational purposes. USSL and Wilcox diagram were plotted to determine agriculture suitability. It was found that 90% of the water samples are fit for irrigation. Different spatial variation maps were generated in GIS environs. Thus GIS based approach was efficient tool in assessment of water quality of Hirehalla Sub-basin.
Keywords *Hirehalla Sub-Basin; Hydrogeochemistry; Water Quality; Fluoride; SAR; GIS*

1. Introduction

The quality of water is one of the major concern and problem of almost all nations of the world. Not all of the available water resources on the globe can be used directly for drinking, agriculture and industrial purposes. While of the available limited direct resources many have the problem of water quality some are due to natural processes (geogenic) and others due to anthropogenic activities. Thus making mankind to explore other source of water such as groundwater to fulfil and meet his demand for different purposes.

In this quest of finding water resources, suitable groundwater potential sites are being located and explored. Due to this over-exploitation the water table levels are slowly lingering deeper and deeper. And with the irregular trend of monsoons and no other source of recharge the groundwaters are depleting at faster rates.

The quality of water resources is governed by many factors such as climate, topography, soil characters, sub-surface litho-units, groundwater flow, anthropogenic activities (Rajesh et al., 2002; Lakshmanan et al., 2003; Srivastava, 2005; Das Brijraj and Kaur, 2007; Cloutier et al., 2008; Prasanna et al., 2010). The study area in particular being a typical hard rock terrain of Peninsular India consisting predominantly granites and gneiss here it is mainly controlled by factors such as weathering and its features and impact of anthropogenic activities.

Many researchers and scientists from different parts of the world have studied the water quality in different geologic regimes with both conventional methods and GIS approach (Sreedevi, 2002; Anbazhagan and Archana, 2003; Subbarao and John Devdas, 2003; Subbarao, 2006; Subramani et al., 2010).

Thus in the present study an attempt has been made to assess the water quality of Hirehalla Sub-basin with the help of GIS. Further suggest the respective authorities for proper planning, management and development of groundwater resources.

2. Study Area

The present study area Hirehalla Sub-basin of Koppal district, Karnataka, India is geographically located between 15^{0}23’ to 15^{0}32’ N latitude and 75^{0}45’ to 76^{0}07’ E longitude and is covered in Survey of India (SOI) toposheets numbered 48M/14, 48M/15 and 57A/03 and spread over an area of 389 km^{2}. It is a tributary of Tungabhadra River.

Physiographically major portion is covered by plains with shallow troughs and mounds at some places. The highest and lowest elevations are 625 and 552 meters respectively. The major rock types include granitic gneiss and schist. These rocks are highly weathered and the resulting fractures, joints act as conduit for storage of water. The waters are found to be in phreatic conditions. The study area experiences semi-arid type of climate which is characterized by hot summer where maximum temperature reaches upto 45^{0}C in the month of April and May while coolest month is December and January where temperature drops upto 16^{0}C (Figure 1).

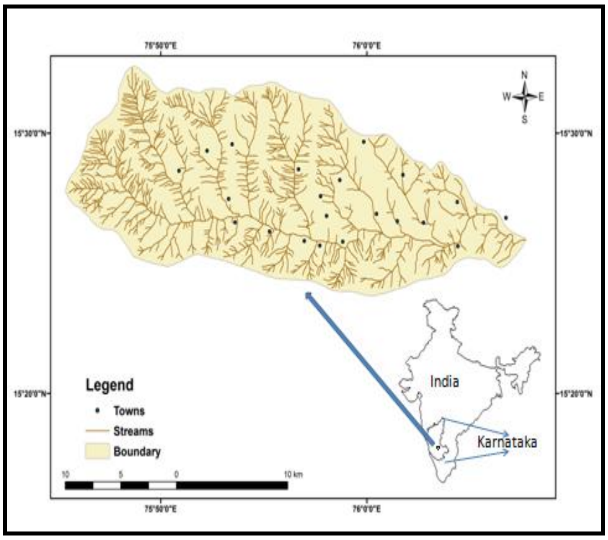

Figure 1: *Location Map of Hirehalla Sub-basin*

3. Materials and Methods

Water samples were collected in one litre polyethylene cans which were pre-rinsed and washed in the laboratory using proportionate distilled water and dil. HCl and later in the field it was washed using representative sample. Standard procedure of analysis was followed that of APHA (APHA, 1995). Table 1 depicts the list of parameters the samples were subjected for analysis and the methodology/instrument applied for same. Table 2 shows the results obtained after physico-chemical analyses. All the thematic and variation maps were generated in GIS environ using different tools of arcGIS v10 such as spatial analyst, interpolation.

Table 1: *List of Physico-Chemical Parameters and Analytical Methods*

Sl. No.	Parameters	Analytical Methods/Instruments
1	pH	Elico LI120
2	Electrical Conductivity (EC)	Elico CM180
3	Total Dissolved Solids (TDS)	EC*0.65 (Todd 1980)
4	Hardness (H)	Trimetric
5	Calcium (Ca)	Trimetric
6	Magnesium (Mg)	Calculation
7	Sodium (Na)	Atomic Absorption Spectrophotometer (AAS)
8	Potassium (K)	Atomic Absorption Spectrophotometer (AAS)
9	Carbonate (CO_3)	Trimetric
10	Bicarbonate (HCO_3)	Trimetric
11	Chloride (Cl)	Trimetric
12	Sulphate (SO_4)	Colorimeter
13	Fluoride (F)	Ion Selective Method

Table 2: *Physico-Chemical Analyses Results*

Sl No	LOCATION	TDS	EC	H	pH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F
1	HIREHANCHIHALLA	320	490.61	120	7.9	24.04	14.61	109.53	2.19	0	180	63.9	60	1.1
2	BINNALA	2860	443.41	1752	8.11	352.7	212.46	415.72	1.86	0	250	1356.1	710	0.69
3	CHIKENAKOPPA	3030	460.97	2128	7.58	432.86	255.34	494.96	1.77	0	225	2157.3	380	0.26
4	SHIDNEKOPPA	1920	297.67	1260	7.5	192.38	190.04	476.21	15	0	365	1262.6	700	0.43
5	SOMPUR	7840	124.8	3220	7.16	838.47	274.83	845	2.38	0	350	3494	380	0.35
6	MALEKOPPA	5370	102.32	2640	7.28	585.16	287.5	820	1.94	0	325	3061.2	380	0.36
7	MANNAPUR	2090	324.03	1060	7.49	157.11	162.75	656.7	7.87	0	375	1704.22	560	1.98
8	LINGAPUR	1620	251.16	680	7.61	128.25	87.71	421.15	7.51	0	280	681.6	550	2.29
9	LINGAPUR	1180	182.94	404	7.93	64.12	59.44	392.54	6.5	0	320	731.3	430	2.33
10	ITAGI	1100	170.54	720	7.64	128.25	97.45	179.57	7.88	0	300	546.7	450	0.44
11	MANDALGERI	1380	213.95	1260	7.55	264.52	146.18	226.18	9.25	0	205	1072.1	600	0.51
12	BETAPANAHALLI	5570	863.56	2440	7.6	689.37	175.42	746	9.01	0	355	2350	380	0.47
13	GORLEKOPPA	620	960.12	320	7.77	40.08	53.6	196.04	5.31	0	360	79.52	170	1.89
14	KUKNUR	1150	178.29	940	7.29	272.54	63.34	134.39	5.2	0	275	809.4	268	0.44
15	GAVARHALLA	600	930.02	300	7.83	64.12	64.11	155.92	2.36	0	265	191.7	70	0.59
16	CHENDURU	1390	215.5	960	7.32	173.14	128.64	301.37	5.15	0	460	898.86	275	1.08
17	VIRAPUR	970	150.38	212	7.83	48.09	22.41	383.66	2	0	525	156.2	312	6.42
18	MUDLAPUR	370	570.36	100	8.2	19.23	12.66	151.2	1.59	0	210	107.92	80	2.02
19	BENAKAL	2100	325.58	200	8.28	40.08	24.36	651.03	2.21	0	775	866.2	350	5.94
20	NITALLI	2350	364.34	1760	7.27	288.57	253.39	434.02	6.21	0	335	1830	600	1.15
21	MOSOBAHANCHINALA	1460	226.35	980	7.3	296.59	58.47	269.3	4.42	0	350	781	400	0.57

4. Results and Discussion

4.1. Water Quality

4.1.1. *Electrical Conductivity (EC)*

EC value in the study area range from 102 to 960 µS/cm. Water samples are classified based on Sarma et al. (1982) (Table 3) and accordingly it was found that approximately 62% of water samples fall in excellent category followed by 19% each falling in good and permissible category. Figure 2 shows the EC distribution in the study area.

Table 3: *EC Classification based on Sarma et al.*

Class	EC range in µS/cm	No. of Samples	Percentage
Excellent	0-333	13	61.90
Good	333-500	04	19.04
Permissible	500-1000	04	19.04
Brackish	1000-1500	-	-
Saline	1500-10,000	-	-

4.1.2. *Total Dissolved Solids (TDS)*

TDS can be defined as the different types of mineral present in water in the dissolved state. To ascertain the suitability of groundwater for any purpose, TDS is an important factor. Thus the waters of the study area were classified based on Freeze and Cherry (1979) (Table 4). It suggests that 76% of the water samples in the Hirehalla Sub-basin are brackish while 24% are fresh waters. Figure 3 shows the distribution of TDS in the study area.

Table 4: *Classification of TDS based on Freeze and Cherry*

TDS (mg/lit)	Nature of Water	No. of Samples	%
<1000	Fresh	05	23.80
1000-10000	Brackish	16	76.19
10000-100000	Saline	-	-
>100000	Brine	-	-

4.1.3. *Hardness (H)*

The classification of water samples of Hirehalla Sub-basin based on Sawyer and McCarthy (1967) (Table 5) shows that 85% of the water samples fall in water class hard while 9.52% fall in moderately hard and 4.76% fall in very hard class. Figure 4 shows the distribution of hardness in the study area.

Table 5: *Classification of Waters Based on Hardness*

Hardness ($CaCO_3$) in ppm	Water Class	No. of Samples	%
0-75	Soft	-	-
75-150	Moderately Hard	02	9.52
150-3000	Hard	18	85.71
>3000	Very Hard	01	4.76

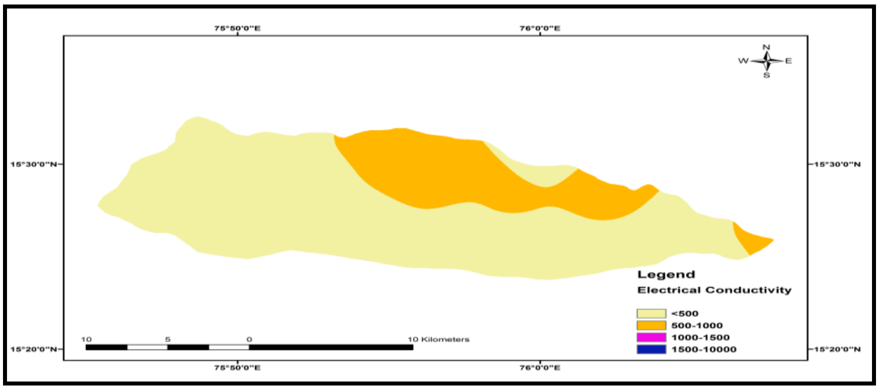

Figure 2: *Spatial distribution of Electrical Conductivity (EC)*

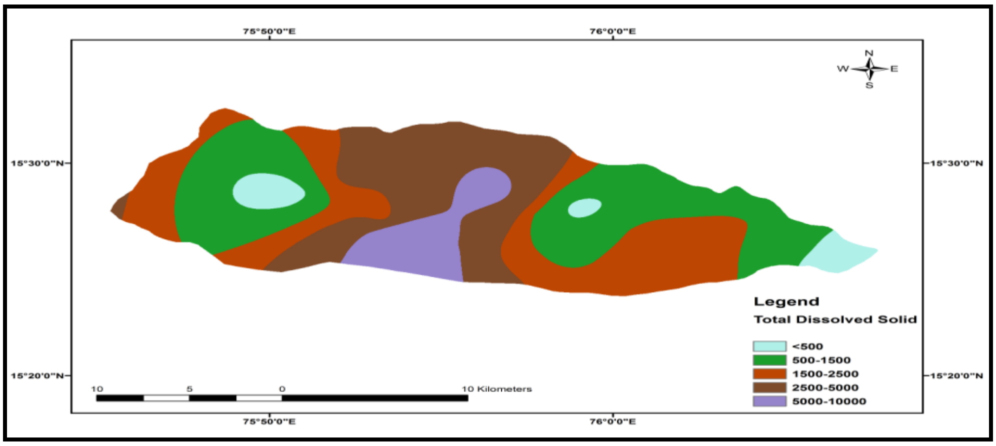

Figure 3: *Spatial distribution of Total Dissolved Solids (TDS)*

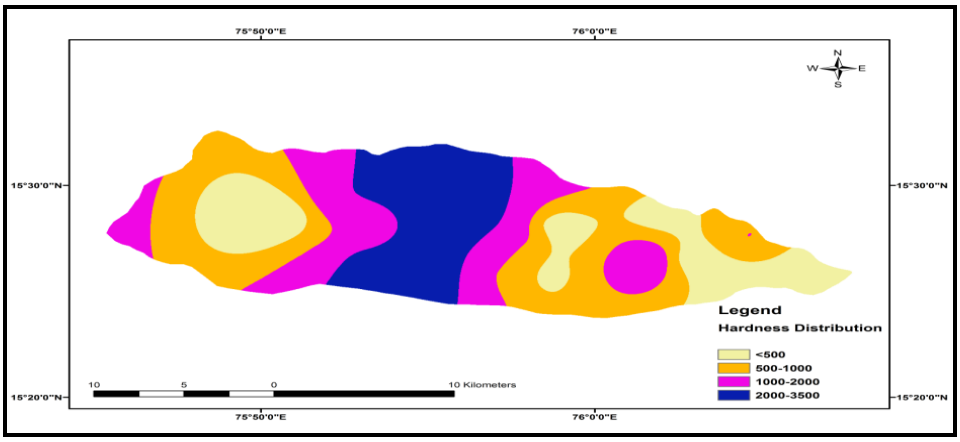

Figure 4: *Spatial distribution of Hardness (H)*

4.2. Hydrochemical Facies (Piper Hill Tri-linear Diagram)

The chemical processes and the evolution of the groundwater in the aquifer due to prolonged presence and flow may be assessed using the hydrochemical facies. This can be best illustrated and interpreted using Hill Piper plot wherein plot of cations mainly Ca, Mg, Na+K versus anions HCO_3, Cl, SO_4 is plotted. From the plot (Figure 5) it was found that the groundwaters of Hirehalla Sub-basin falls in field 2 & 4 and are categorized as –NaCl and Mixed CaMgCl type. This indicates strong acid exceeding weak acid and alkali exceeding alkaline.

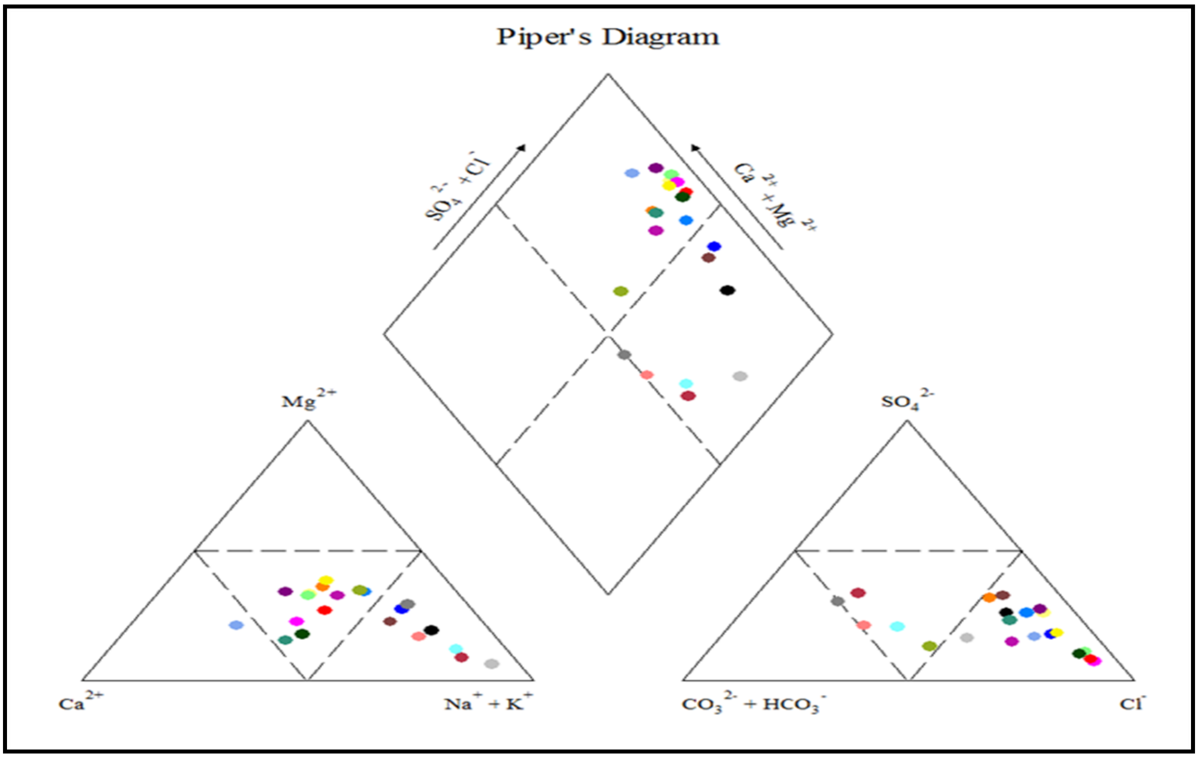

Figure 5: *Piper's Diagram for the waters of Hirehalla Sub-basin*

4.3. Drinking Quality

Physico-chemical analyses results of the Hirehalla Sub-basin were compared with Bureau of Indian Standards (BIS, 2003) and World Health Organisation (WHO, 2005) to decipher the quality of water for drinking purpose (Table 7). The comparison study revealed that on an average 65% of the water samples for all parameters except TDS fall in allowable limits and is safe for drinking purpose while 76% of the water samples exceed allowable limit based on TDS. Thus there is need to check the water quality and necessitate appropriate actions for supply of safe drinking water.

Table 7: *Drinking Water Standards of BIS (2003) and WHO (2005)*

Parameters	Drinking Water Standards				Samples exceeding allowable limit	%
	BIS (2003)		WHO (2005)			
	Permissible	Allowable	Permissible	Allowable		
pH	7.0-8.5	6.5-9.2	7-8.5	6.5-9.2	-	-
TDS	NS	NS	500	1000	16	76.19
TH	300	600	-	1000	09	42.85
Ca	75	200	75	200	08	38.09
Mg	50	150	50	150	08	38.09
Cl	250	1000	200	600	09	42.85
SO_4	200	400	200	400	08	38.09
F	1.0	1.50	-	1.50	07	33.33

4.4. Irrigational Quality

4.4.1. *Sodium Absorption Ratio (SAR)*

SAR is considered a better measure of sodium/alkali hazard in irrigation as it is directly related to the adsorption of sodium by soil and is an important criterion in determining the suitability of water for irrigation. The SAR is classified as shown in Table 8 and is calculated using:

$$SAR = \frac{Na^{+}}{(\sqrt{Ca^{2+} + Mg^{2+}})/2}$$ all values are in epm

According to classification (Table 8), it shows that 90% of water samples in the study area fall in excellent category while 5% each fall in good and fair category. Groundwater samples were also plotted in United States Salinity Laboratory diagram (Richard, 1954) to study its suitability for irrigation where plot of SAR vs EC is plotted (Figure 6) and it was found that, 42.85% of water samples fall in field of C1S1, indicating low salinity and low sodium, 23.80% of water samples fall in field of C2S1, indicating medium salinity and low sodium, 14.28% samples falling in field of C3S1, indicating high salinity and low sodium and 9.52% samples falling in field of C2S2, indicating medium salinity and medium sodium. Figure 8 shows the spatial distribution of SAR.

Table 8: *Classification based on SAR*

Class	SAR Range	No. of Samples	Percentage
Excellent	<10	19	90.47
Good	10-18	01	4.76
Fair	18-26	01	4.76
Poor	>26	-	-

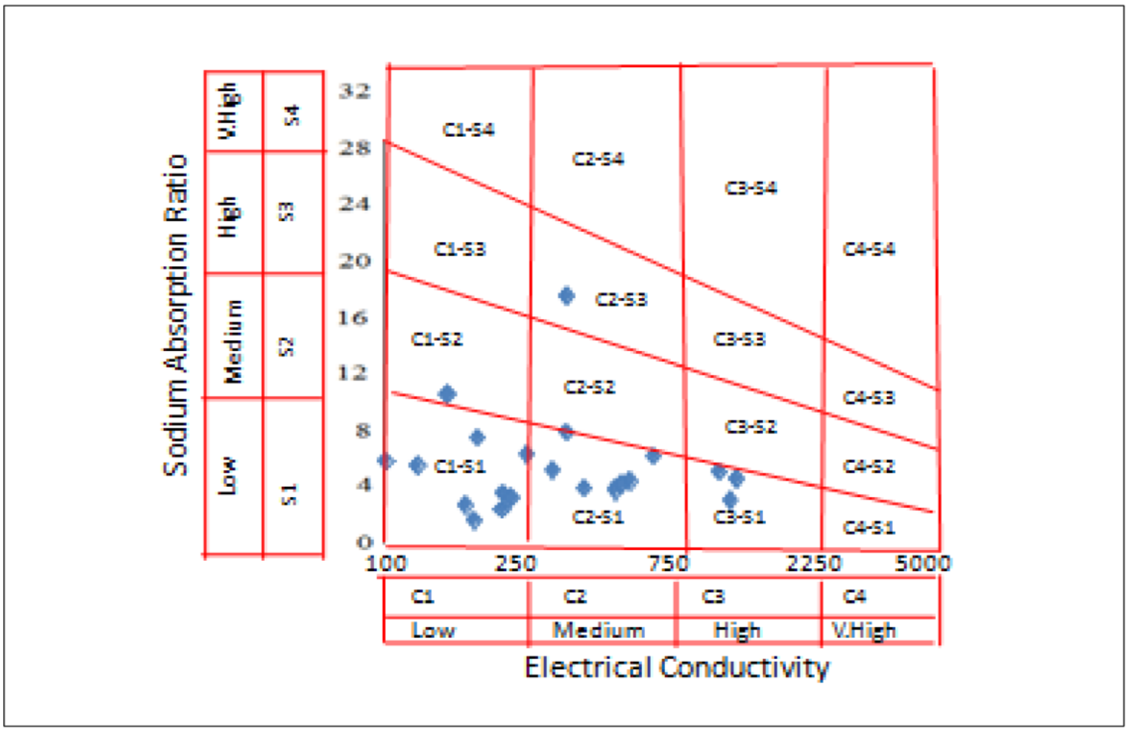

Figure 6: *USSL Diagram for Classification of Irrigation Waters, 1950*

5.4.2. *Sodium Percent (Na%)*

The suitability of the groundwater for irrigation depends on the minerals and its interaction present in water and its effect on plants and soil. When the concentration of sodium is high in irrigation water, sodium ions tend to be absorbed by clay particles which reduce soil permeability (Saleh, 1999; Arumugam and Elangovan, 2008). This can be computed using:

$$\%Na = \frac{(Na^{+} + K^{+}) \times 100}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}$$ all values are in epm

The classification for irrigation suitability based on sodium percent (Table 9) revealed that 66.66% of water samples from the study area fall in category excellent while 33.33% fall in good category. Similar comparison study to know the suitability of water for irrigation is done by plotting the plot of sodium percent vs EC i.e., Wilcox diagram (Wilcox, 1954) (Figure 7) which indicate 85% of the water samples falling in range excellent to good category and 15% of water samples fall in good to permissible category. Figure 9 shows the spatial distribution of sodium percent.

Table 9: *Sodium Percent Classification for Irrigation Water*

Class	Na%	No. of Samples	Percentage
Excellent	< 20%	14	66.66
Good	20-40	07	33.33
Permissible	40-60	-	-
Doubtful	60-80	-	-
Unsuitable	>80	-	-

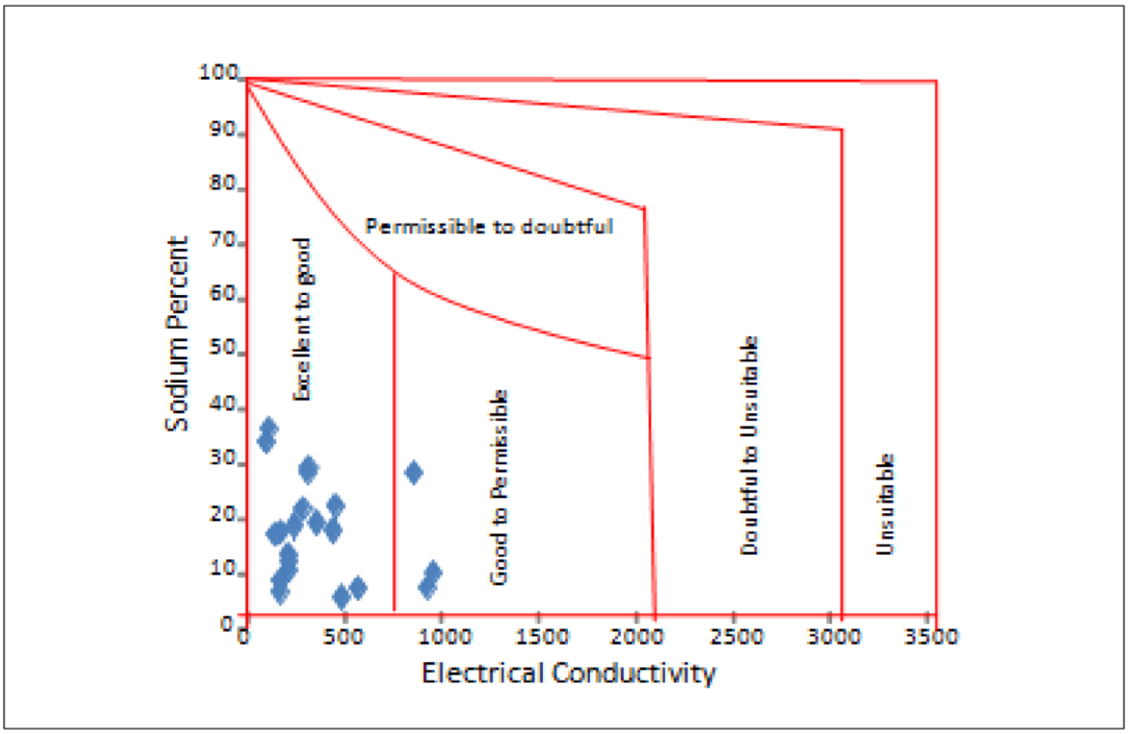

Figure 7: *Classification of Irrigated Waters based on Wilcox, 1955*

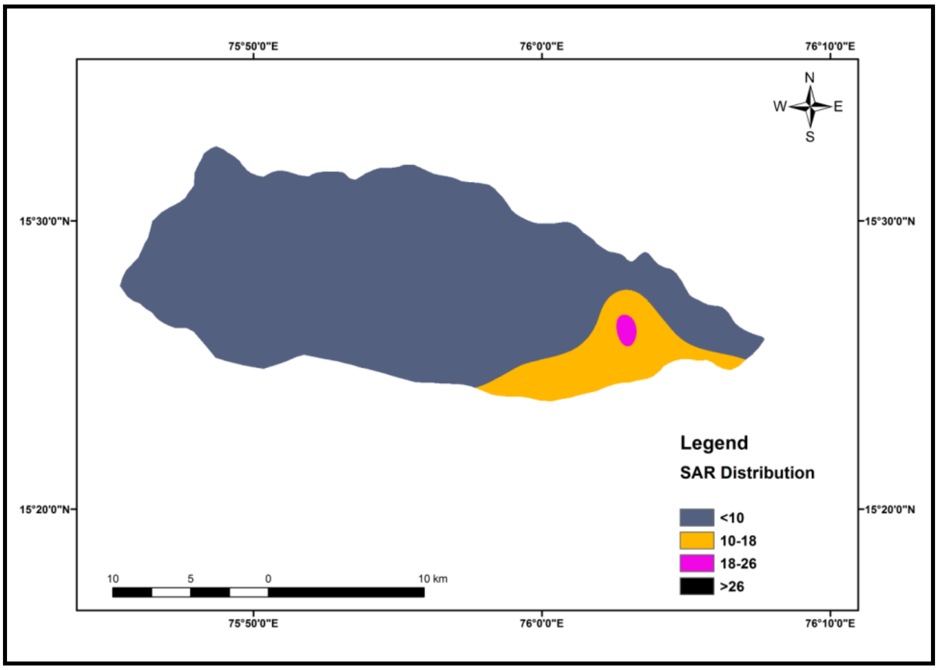

Figure 8: *Spatial Distribution of Sodium Absorption Ratio (SAR)*

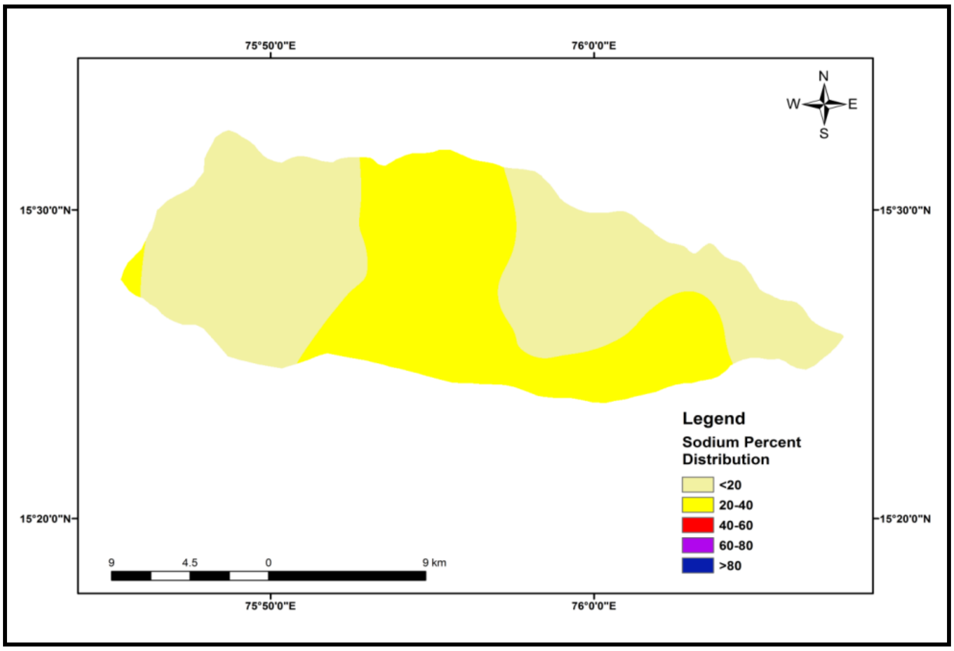

Figure 9: *Spatial distribution of Sodium percent*

6. Conclusion

GIS based approach has turned out to be very effective and efficient tool in determining the water quality of hard rock Hirehalla Sub-basin, Koppal district, Karnataka were water quality issues has been reported. Physico-chemical analyses result obtained revealed that, based on TDS 76% of the water samples are brackish and 85% hard based on hardness. Comparison of water samples with BIS and WHO standards for suitability for drinking purpose indicated approximately 35% of the water samples having water quality problem with respect to domestic use.

SAR classification for irrigational suitability showed 90% of the water samples in excellent category. Plot of SAR vs EC (USSL diagram) indicated the water samples to be in the field C1S1, C2S1 & C3S1. Based on sodium percent classification for irrigated waters it was found that 66.66% of water samples range in water class excellent and 33.33% in good. Wilcox diagram revealed the water samples to be ranging from excellent to permissible. Fluoride incidence was reported at some places which are due to geogenic processes. Further it is suggested to the authorities to keep a check on the water quality at regular intervals and necessitate actions for providing safe drinking water. Furthermore plan and manage for sustainable development of water resources.

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