Physico-Chemical Characteristics of Shalmala River Sub-Basin, Dharwad District, Karnataka

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Abstract : A hydro chemical study has been carried out to assess the groundwater quality in Shalmala river sub-basin Dharwad district, Karnataka. About 45 groundwater samples from different locations in study area are collected. The aim of the study is to determine the suitability of water for drinking and domestic purposes. The physico-chemical parameter such as hydrogen ion concentration (pH), Total dissolved solids (TDS), Electrical conductivity (EC), Total hardness (TH), Cations like Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Potassium (K^{+}) and Anions like Carbonate (CO_3^{--}), Bi-carbonates (HCO_3^{-}), Chloride (Cl^{-}), Sulphate (SO_4^{-}) and Nitrate (NO_3^{-}). The pH value ranges from 7.13 to 8.12 and average is 7.59. Therefore, all the groundwater samples are indicating faintly alkaline in nature and are suitable for drinking and domestic purposes. 96% of total hardness (TH) in the study area showing hard category consequently softening of water is recommended. The piper diagram illustrates that the 96% of groundwater samples in the study area are belonging to area 1 suggesting that water samples are alkaline earths exceeds alkalis. According to Gibbs (1970) classification it is illustrated that all the groundwater samples in the study area are representing rock dominance. All the groundwater samples are within the permissible limits as per WHO (2017).

IndexTerms **- Hydrochemical, Groundwater, Shalamla river sub-basin,Karnataka.**

I. INTRODUCTION

Water is a colourless, odourless and tasteless natural resources and that is essential for the survival of the living things. About 71% of earth's surface is covered with water. The sources of water have been characterized into two categories – Surface water and Ground water. The surface water means the water that collects on the surface of the earth such as rivers, lakes, reservoirs etc. The Ground water found beneath the land that is surface water seeps into the cracks or crevices of rocks and reaches the ground.

The physio chemical analysis of water plays a vital role to determine the quality of water whether it is good for drinking or agricultural purposes. The Ground water contains dissolved mineral ions which may results on the quality of water. If the dissolved mineral ions content is above the permissible standard limits, then it hazards to human health. Therefore, an attempt made to evaluate the various hydro chemical parameters of ground water of Shalmala river sub-basin Dharwad district, Karnataka.

II. STUDY AREA

The Shalmala river sub-basin is situated at Survey of India toposheet no. D43D3 and D43D4 lies in between North latitudes 15º 06' 21.6" to 15º 24' 50.4" and East longitudes 75º 00' 3.6" to 75º 11' 49.2". The total geographical area is 363.39 km^2. Geologically, the study area is covered by quartz-mica schist of Chitradurga group of Archean age, greywacke and argillites. And also, the study area consists of intrusions of dolerite dyke and banded ferruginous quartzite. The elevation ranges from 498 to 772 above mean sea level (MSL).The study area receives 772mm of average annual rainfall and annual average temperature is around 24.3ºC.

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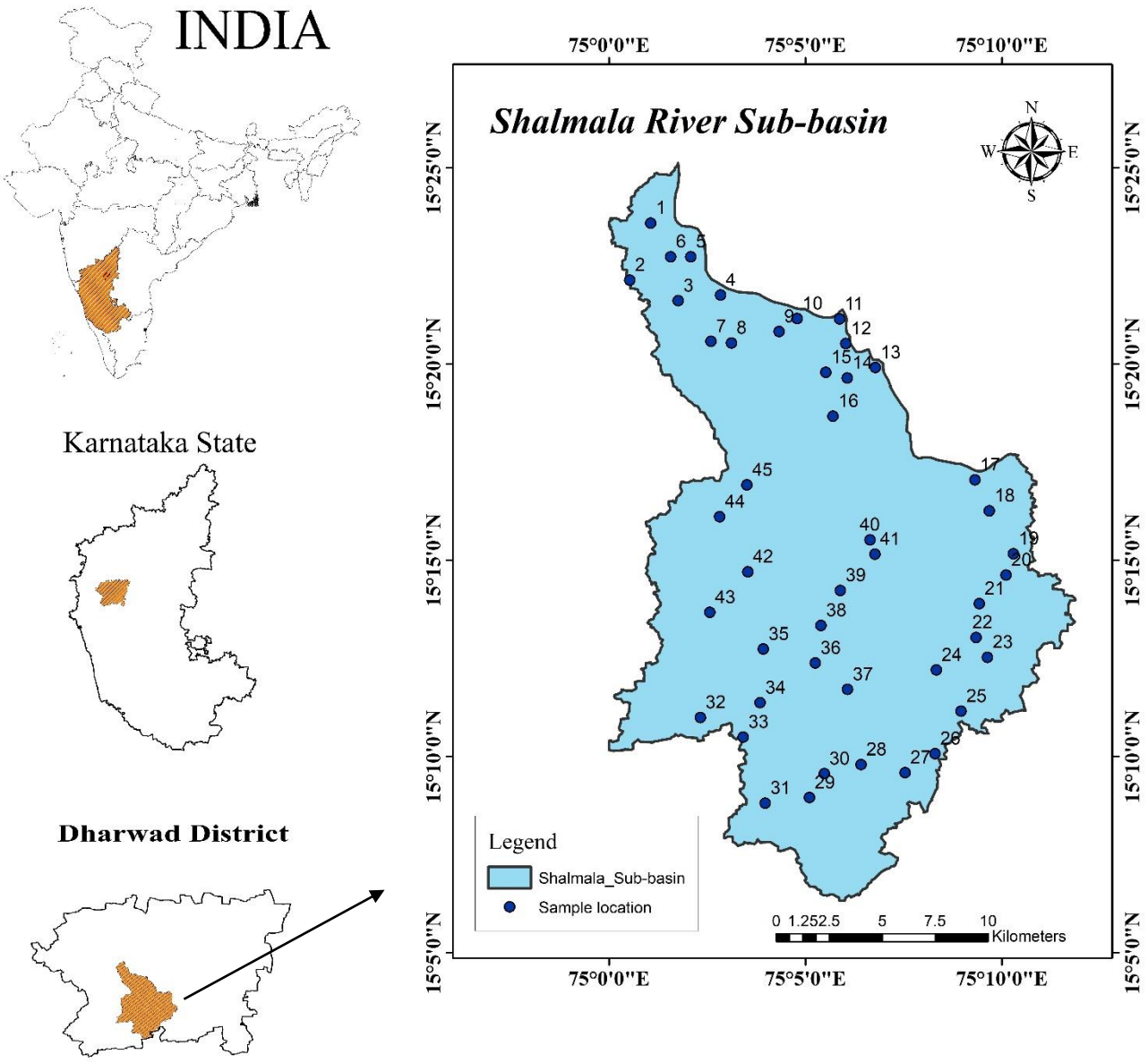

Figure 1: Location of the study area

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III. MATERIALS AND METHODS

Ground water samples are collected in one-liter polyethylene cans which were pre-rinsed and washed in the laboratory by using proportionate dilute HCl and distilled water. 45 groundwater samples from different locations in study area are collected. The physico-chemical analyses were carried by standard methods (APHA, 2017). The results of physio-chemical analysis of groundwater for Shalmala river sub-basin were shown on table 1.

IV. RESULTS AND DISCUSSIONS

Table 1: Physico-chemical data of Shalmala river sub-basin

Sample no.	Location	Longitude	Latitudes	Elevation	pH	EC	TDS	TH	Cations				Anions				
									Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{-}	NO_3^{-}
1	Joga yellapur	75°01'36"	15°23'35.52"	714	7.22	1321	467	440	104.1	43.74	60.36	1.2	20	266	159.48	24.71	6.89
2	Kanvihonnapur	75° 0' 31.64"	15° 22' 8.4"	694	7.82	858.3	305	240	55.26	24.9	71.71	1.23	14	236	87.08	11.62	4.08
3	Vajpayee nagar,Tarihal	75° 1' 45.59"	15° 21' 36.79"	669	7.45	1218	344	272	64.07	27.22	89.39	1.99	24	252	91.97	10.14	58.94
4	Gamanagatti road, Tarihal	75° 2' 50.28"	15° 21' 45.43"	696	7.83	1806	581	452	96.1	51.52	103.4	3.94	10	250	262.22	8.03	17.2
5	Ittigatti road	75° 2' 4.67"	15° 22' 44.11"	696	7.31	1233	414	288	72.07	26.24	102.66	1.13	10	262	138.94	7.18	17.73
6	Ittigatti village	75° 1' 34"	15° 22' 43.9"	707	7.32	1393	527	452	94.49	52.49	100.6	2.31	18	296	202.53	17.74	18.63
7	Revadihal	75° 2' 35.7"	15° 20' 34.7"	655	7.25	1439	496	312	73.67	31.1	150.35	1.9	20	430	127.19	5.28	19.65
8	Devaragudihal road	75° 3' 6.804"	15° 20' 32.316"	647	7.28	1622	544	440	106.51	42.28	105.26	1.73	20	326	144.81	59.35	68.9
9	Gokul road hubli	75° 4' 19.596"	15° 20' 49.668"	650	7.81	1260	401	328	72.87	35.48	76.43	1.6	26	280	129.15	7.6	11.48
10	Airport Hubli	75° 4' 47.28"	15° 21' 9.468"	672	7.13	1686	593	304	65.67	34.02	159.92	1.91	20	290	241.67	5.7	15.57
11	Nehru nagar, hubli	75° 5' 52.08"	15° 21' 9.072"	668	8.12	801.6	279	170	42.44	15.55	80.15	1.62	18	212	69.47	10.98	7.85
12	Manjunath nagar, Hubli	75° 6' 1.512"	15° 20' 31.2"	650	7.3	1531	584	310	84.08	24.3	164.28	2.96	16	238	269.28	2.85	30.49
13	Mehboob nagar, Hubli	75° 6' 46.62"	15° 19' 54.66"	635	7.51	1170	417	306	74.4	29.16	85.15	1.88	16	270	136.98	14.26	17.35
14	Gangival	75° 6' 3.816"	15° 19' 38.784"	630	7.97	1236	460	360	81.68	37.91	83.43	1.53	26	272	154.59	10.45	11.99
15	Rayanal	75° 5' 31.128"	15° 19' 47.424"	631	7.47	2181	880	810	212.21	68.04	83.16	3.48	26	298	369.84	52.27	83.89
16	Anchatageri	75° 5' 42.072"	15° 18' 40.284"	613	7.52	2282	970	576	147.35	50.54	214.19	1.15	30	384	323.86	52.8	77.83
17	Adaragunchi	75° 9' 18.828"	15° 17' 3.12"	626	7.68	1884	764	640	171.37	51.52	100.7	0.84	18	238	279.83	87.66	116.1
18	Nulvi	75° 9' 40.968"	15° 16' 15.636"	622	7.74	1469	542	464	113.71	43.74	76.1	0.87	20	204	147.74	51.58	104.9
19	Sherevada	75° 10' 17.616"	15° 15' 9.864"	628	7.54	1055	358	180	32.03	24.3	115.73	0.86	32	342	30.33	14.36	32.15
20	Chabbi road	75° 10' 6.528"	15° 14' 37.5"	636	7.86	485.5	136	124	34.43	9.23	23.01	0.7	10	112	10.76	2.85	30.36
21	Chabbi	75° 9' 25.704"	15° 13' 53.652"	608	7.76	1376	534	372	91.29	34.99	97.31	0.8	10	224	89.04	54.7	33.43
22	Aralikatti road	75° 9' 20.772"	15° 13' 1.92"	628	7.24	2002	804	174	48.78	32.9	56.64	13.73	12	268	142.65	77.72	141.94
23	Aralikatti	75° 9' 37.944"	15° 12' 31.68"	643	7.36	2137	882	766	205.81	61.24	79.69	2.72	12	280	314.07	71.17	146.08
24	Varur	75° 8' 19.932"	15° 12' 12.312"	633	7.64	1748	644	520	130.53	47.14	93.57	6.77	6	228	226.02	147	120.89
25	Aghadi	75° 8' 57.768"	15° 11' 9.276"	654	7.96	917.3	329	234	55.26	23.33	82.93	4.14	18	228	80.23	26.4	14.23
26	Tirumalakoppa	75° 8' 18.096"	15° 10' 4.476"	658	7.98	917.3	322	254	52.85	29.65	65.79	3.3	8	232	87.08	18.59	8.1
27	Guddad hulikatti	75° 7' 32.196"	15° 9' 35.316"	643	7.97	1457	556	486	106.51	53.46	57.66	2.29	10	176	207.43	63.46	53.33
28	Parasapur	75° 6' 24.804"	15° 9' 47.736"	613	7.44	975.4	334	340	72.07	38.88	45.85	1.76	12	294	66.53	19.01	13.84
29	Bullanaikana hulikatti	75° 5' 6"	15° 8' 57.228"	628	7.2	548.6	180	174	44.04	15.55	26.86	0.58	12	143	42.07	6.97	16.84
30	Solar koppa	75° 5' 28.644"	15° 9' 33.768"	616	7.33	1246	475	480	102.5	54.43	44.81	0.58	20	260	174.16	26.93	15.31
31	Tabkad honnalli	75° 3' 58.464"	15° 8' 48.624"	599	7.78	748.2	268	256	44.04	35.48	42.37	1.45	26	244	46.96	6.23	0.19
32	Bagadgeri	75° 2' 19.32"	15° 10' 59.556"	579	7.78	861.6	302	274	58.46	31.1	47.19	2.85	16	382	71.42	15	11.67
33	Sutagatti	75° 3' 24.768"	15° 10' 29.676"	576	7.3	771.3	258	226	40.04	30.62	55.79	1.54	22	250	31.31	17	0.03
34	Ganjigatti	75° 3' 50.652"	15° 11' 22.2"	561	7.93	428.4	136	130	29.63	13.61	24.59	2.65	8	124	24.46	7.29	2.93
35	Bhogenagar koppa	75° 3' 55.584"	15° 12' 44.208"	574	7.49	924.1	323	330	70.47	37.42	53.08	0.87	20	314	63.6	7.92	24.82
36	Surashetti koppa	75° 5' 15.036"	15° 12' 22.968"	574	7.62	812.3	300	190	384.38	106.92	74.07	1.51	18	224	69.56	21.42	11.48
37	Naganur	75° 6' 4.32"	15° 11' 42.648"	598	7.89	808.9	289	240	49.65	28.19	45.02	1.2	14	170	68.49	21.96	23.99
38	Kurdikeri	75° 5' 23.676"	15° 13' 20.316"	583	7.74	947.9	333	260	58.46	27.7	55.59	0.86	6	200	105.67	16.4	18.31
39	Kardikoppa	75° 5' 53.1564"	15° 14' 13.8084"	605	7.73	771.7	278	280	57.66	33.05	28.38	1.63	4	220	45.99	8.24	15.63
40	Giriyal road	75° 6' 38.628"	15° 15' 31.32"	568	7.33	1539	570	268	56.06	31.1	72.8	2.03	32	380	163	19.32	14.3
41	Inam veerapur	75° 6' 46.044"	15° 15' 9.288"	576	7.6	1857	689	384	80.08	44.71	195.64	4.1	18	352	266.13	34	1.21
42	Mishrikoti	75° 3' 31.86"	15° 14' 42.396"	565	7.65	1220	428	460	78.48	64.15	49.61	0.69	20	292	144.81	18.8	0
43	Kamadhenu	75° 2' 33.756"	15° 13' 40.332"	560	7.78	1860	703	648	124.92	81.65	77.62	1.23	18	232	301.35	124.61	5.42
44	kadankoppa	75° 2' 48.876"	15° 16' 6.636"	593	7.92	1322	485	412	88.09	46.66	94.25	0.86	14	336	151.66	8.03	6.25
45	Chalamatti	75° 3' 30.564"	15° 16' 55.128"	590	7.24	901.6	328	320	76.08	31.59	46.39	0.53	12	170	145	11.62	1.79

4.1 Hydrogen ion concentration (pH)

The pH of pure water is 7, if the pH values are less than 7 then it should be acidic and if the pH values are greater than 7 then it is alkaline. The neutral value of pH depends on the temperature. In the study area the pH value ranges from 7.13 to 8.12. Hence, all the samples are indicating faintly alkaline in nature and are suitable for drinking purpose as per WHO (2017) and BIS (2012) standards.

4.2 Total dissolved solids (TDS)

Total dissolved solids represent the presence of chemical constituents in water. TDS indicates the salinity of ground water. Higher the value of TDS impacts on taste, hardens and corrosive property of ground water. In the study area TDS value of ground water is ranges from 136 mg/l to 927 mg/l.

According to Bucks and Gilbert (1979); Nakayama and Bucks (1991), about 62% of water samples are in good condition and 38% of water samples are in moderate condition, as shown in table 2.

Table 2: TDS classification based on Bucks and Gilbert (1979); Nakayama and Bucks (1991)

Sl No	Water Classification	TDS range	No. of samples	Percentage (%)
1	Good	< 500 mg/l	28	62%
2	Moderate	500-2000 mg/l	17	38%
3	Poor	>2000mg/l	00	00%

4.3 Total hardness (TH)

Total hardness is very useful for determining the groundwater whether it is good for drinking or domestic purpose. Hardness is mainly due to the presence of calcium and magnesium concentration in water. The hardness of groundwater in the study area is ranges from124 mg/l to 810mg/l.

According to Sawyer and McCarthy (1967), illustrates that 4% of groundwater samples of the study area found at moderate category and 96% of groundwater samples found at hard category as shown in table 3. Hence softening of water is recommended.

Table 3: TH classification based on Sawyer and McCarthy (1967)

Sl. No	Hardness range (CaCO3) in mg/l	Water classification	No. of Samples	Percentage (%)
1	0-75	Soft	00	00%
2	75-150	Moderate	02	4%
3	150-3000	Hard	43	96%
4	>3000	Very Hard	00	00%

4.4 Electric Conductivity (EC)

Electric Conductivity is an important parameter in groundwater quality assessment for drinking and irrigation purposes. It is used to determine the total amount of dissolved ions in the water. The EC values in the study area ranges from 428.4 µS/cm to 2282 µS/cm.

According to Sarma et al. (1992), 4% of groundwater samples are arises at good category, 33.33% each of groundwater samples are arises at permissible and Brackish category. Similarly, 29% of water samples are located at saline category, as shown in table 4.

Table 4: Electric Conductivity Classification based on Sarma et al. (1992)

Sl. No	Water Classification	EC range in µS/cm	No. of samples	Percentage (%)
1	Excellent	0-333	00	00%
2	Good	333-500	02	4%
3	Permissible	500-1000	15	33.33%
4	Brackish	1000-1500	15	33.33%
5	Saline	1500-10,000	13	29%

4.5 Cation geochemistry

The major cations found in the groundwater of Shalmala river sub-basin are Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}) and Potassium (K^{+})

4.5.1 Calcium (Ca^{++})

The calcium (Ca) concentration in groundwater are from rain, fertilizers and soil amendment. The calcium concentration in the study area ranges from 29.63 mg/l to 384.38 mg/l. According to WHO (2017) classification, 53% of groundwater samples of the study area are at desirable category, 40% of groundwater samples at permissible limits and 7% are at undesirable category respectively (Table 5). Therefore, almost all the groundwater samples are within the permissible limits. Hence suitable for drinking and domestic purposes.

Table 5: Ca^{++} classification based on WHO (2017)

Sl. No	Ca^{++} range (mg/l)	Water classification	No. of samples	Percentage (%)
1	< 75	Desirable	24	53
2	75-200	Permissible	18	40
3	>200	Undesirable	03	7

4.5.2 Magnesium (Mg^{++})

Magnesium (Mg^{++}) is abundant in groundwater as it commonly associated with calcium and causes hardness of water. The magnesium concentration in the study area is in between 9.23 mg/l to 106.92 mg/l. Around 76% of groundwater samples are in desirable category and 24% are in permissible limits as per WHO classifications (2017) as shown in table 6. Hence, suitable for drinking and domestic purposes.

Table 6: Mg^{++} classification based WHO (2017)

Sl. No	Mg^{++} range in mg/l	Water classification	No. of samples	Percentage (%)
1	< 50	Desirable	34	76
2	50-150	Permissible	11	24
3	>150	Undesirable	00	00

4.5.3 Sodium (Na^{+})

Sodium (Na^{+}) is commonly found in soils and rocks and are always associated with chloride and bromide. Sodium is readily dissolving in groundwater. The Sodium concentration in groundwater from the study area varies from 23.01 mg/l to 214.19mg/l and average value is 81.32 mg/l. Hence, all the samples are suitable for drinking and domestic purposes except one sample as shown in table 1

4.5.4 Potassium (K^{+})

Potassium (K^{+}) is an important fertilizer, is strongly held by clay particles in soil. Like sodium, potassium also easily dissolves in groundwater. The potassium concentration in the study area is varies from 0.53 mg/l to 13.73 mg/l and average value is 2.12 mg/l. Therefore, all the samples are suitable for drinking purposes except one sample as shown in table 1.

4.6 Anions geochemistry

The major anions found in the ground water of the study area are Chloride (Cl^{-}), Sulphate (SO_4^{-}), Nitrate (NO_3^{-}), Carbonates (CO_3^{-}) and Bicarbonates (HCO_3^{-}).

4.6.1 Chloride (Cl^{-})

Chloride (Cl^{-}) is one of the foremost anions found in water and are generally associated with cations like calcium, magnesium, or sodium. The chloride content in study area is ranges from 10.76 mg/l to 369.84 mg/l.

According to classification of World Health Organization (WHO) Standards (2017),73% of groundwater samples are situated at desirable category and 27% at permissible limit respectively (Table 7). Hence, groundwater from the study area are suitable for drinking purposes.

Table 7: Cl^{-} classification based on WHO (2017)

Sl. No	Cl^{-} range in mg/l	Water classification	No. of samples	Percentage (%)
1	< 200	Desirable	33	73
2	200-600	Permissible	12	27
3	>600	Undesirable	00	00

4.6.2 Sulphate (SO_4^{-})

Sulphates (SO_4^{-}) are the combination of Sulphur and oxygen and are part of naturally occurring minerals in soils and rock formations that contain groundwater. The mineral dissolves gradually and is released into groundwater. The sulphate concentration in study area are ranges from 2.85 mg/l to 124.61 mg/l. Based on the classification of World Health Organization (WHO) Standard (2017), all the groundwater samples are at desirable category (Table 8). Hence, suitable for drinking and domestic purposes.

Table 8: SO_4^{-} classification based WHO (2017)

Sl. No	SO_4^{-} range in mg/l	Water classification	No. of samples	Percentage (%)
1	< 200	Desirable	45	100
2	200-400	Permissible	00	00
3	>400	Undesirable	00	00

4.6.3 Nitrate (NO_3^{-})

Nitrate (NO_3^{-}) concentration in groundwater is due to the presence of industrial wastes, sewage, animal wastes and agricultural activities. In the study area nitrate value varies from 0 mg/l to 146.08 mg/l.

Based on classification of World Health Organization (WHO,2017), Standards concluded that about 27% of groundwater samples from the study area found at desirable classification, 51% at permissible limit and 22% found at poor condition respectively (Table 9). Hence, the processes such as ion exchange, distillation and reverse osmosis is recommended for ten samples.

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Table 9: NO_3^- classification based on WHO (2017)

Sl. No	Nitrate in mg/l	Water classification	No. of samples	Percentage (%)
1	< 10	Desirable	12	27
2	10-45	Permissible	23	51
3	>45	Poor	10	22

4.6.4 Carbonates (CO_3^-) and bicarbonates (HCO_3^-)

The alkalinity of water depends on the concentrations of carbonates and bi-carbonates. Most of the carbonates and bicarbonates ions in the groundwater are obtained from the carbon dioxide in the atmosphere, soil and soluble carbonate rocks. Usually, the concentration of bi-carbonate in groundwater is between 10mg/l to 800 mg/l and carbonate concentrations is less than 10mg/l. The bicarbonate content of study area is ranges from 112mg/l to 430 mg/l and carbonates ranges from 4 to 32 mg/l (Table 1).

V. HYDRO-CHEMICAL FACIES

The term hydro-chemical facies are described as the bodies of groundwater in an aquifer that differs in their chemical composition and highlight the significant ions in the groundwater. Piper's (1944) and Back's (1966) have studied the hydro chemical facies in the same manner as lithofacies in geology and used to identify the various chemical types by using trilinear diagram.

Table 10: Piper's trilinear chart for chemical classification of water Shalmala river sub-basin, Dharwad district, Karnataka.

Sample no.	Cations			Anions		
	Mg^{++}	Ca^{++}	$Na^+ + K^+$	Cl^-	SO_4^-	$CO_3^{--} + HCO_3^-$
01	3.65	5.21	2.66	4.56	0.51	5.03
02	2.08	2.76	3.15	2.49	0.24	4.34
03	2.27	3.20	3.94	2.63	0.21	4.93
04	4.29	4.81	4.60	7.49	0.17	4.43
05	2.19	3.60	4.49	3.97	0.15	4.63
06	4.37	4.72	4.43	5.79	0.37	5.45
07	2.59	3.68	6.59	3.63	0.11	7.72
08	3.52	5.33	4.62	4.14	1.24	6.01
09	2.96	3.64	3.36	3.69	0.16	5.46
10	2.84	3.28	7.00	6.90	0.12	5.42
11	1.30	2.12	3.53	1.98	0.23	4.08
12	2.03	4.20	7.22	7.69	0.06	4.43
13	2.43	3.72	3.75	3.91	0.30	4.96
14	3.16	4.08	3.67	4.42	0.22	5.33
15	5.67	10.61	3.70	10.57	1.09	5.75
16	4.21	7.37	9.34	9.25	1.10	7.30
17	4.29	8.57	4.40	8.00	1.83	4.50
18	3.65	5.69	3.33	4.22	1.07	4.01
19	2.03	1.60	5.05	0.87	0.30	6.67
20	0.77	1.72	1.02	0.31	0.06	2.17
21	2.92	4.56	4.25	2.54	1.14	4.01
22	2.74	2.44	2.81	4.08	1.62	4.79
23	5.10	10.29	3.53	8.97	1.48	4.99
24	3.93	6.53	4.24	6.46	3.06	3.94
25	1.94	2.76	3.71	2.29	0.55	4.34
26	2.47	2.64	2.95	2.49	0.39	4.07
27	4.46	5.33	2.57	5.93	1.32	3.22
28	3.24	3.60	2.04	1.90	0.40	5.22
29	1.30	2.20	1.18	1.20	0.15	2.74

30	4.54	5.13	1.96	4.98	0.56	4.93
31	2.96	2.20	1.88	1.34	0.13	4.87
32	2.59	2.92	2.12	2.04	0.31	6.80
33	2.55	2.00	2.47	0.89	0.35	4.83
34	1.13	1.48	1.14	0.70	0.15	2.30
35	3.12	3.52	2.33	1.82	0.17	5.81
36	8.91	19.22	3.26	1.99	0.45	4.27
37	2.35	2.48	1.99	1.96	0.46	3.25
38	2.31	2.92	2.44	3.02	0.34	3.48
39	2.75	2.88	1.28	1.31	0.17	3.74
40	2.59	2.80	3.22	4.66	0.40	7.30
41	3.73	4.00	8.61	7.60	0.71	6.37
42	5.35	3.92	2.17	4.14	0.39	5.45
43	6.80	6.25	3.41	8.61	2.60	4.40
44	3.89	4.40	4.12	4.33	0.17	5.97
45	2.63	3.80	2.03	4.14	0.24	3.19

All the values are in meq/l or epm.

5.1 Piper's trilinear diagram

Piper's diagram consists of three components: a ternary diagram in the lower left representing cations (Magnesium, Calcium and Sodium plus Potassium), a ternary diagram in the lower right representing anions (Chloride, Sulphate and Carbonate plus Bi-carbonate) and a diamond plot at the center representing matrix transformation of two ternary diagrams figure 2. The values are representing as absolute concentration of water in (meq/l or epm).

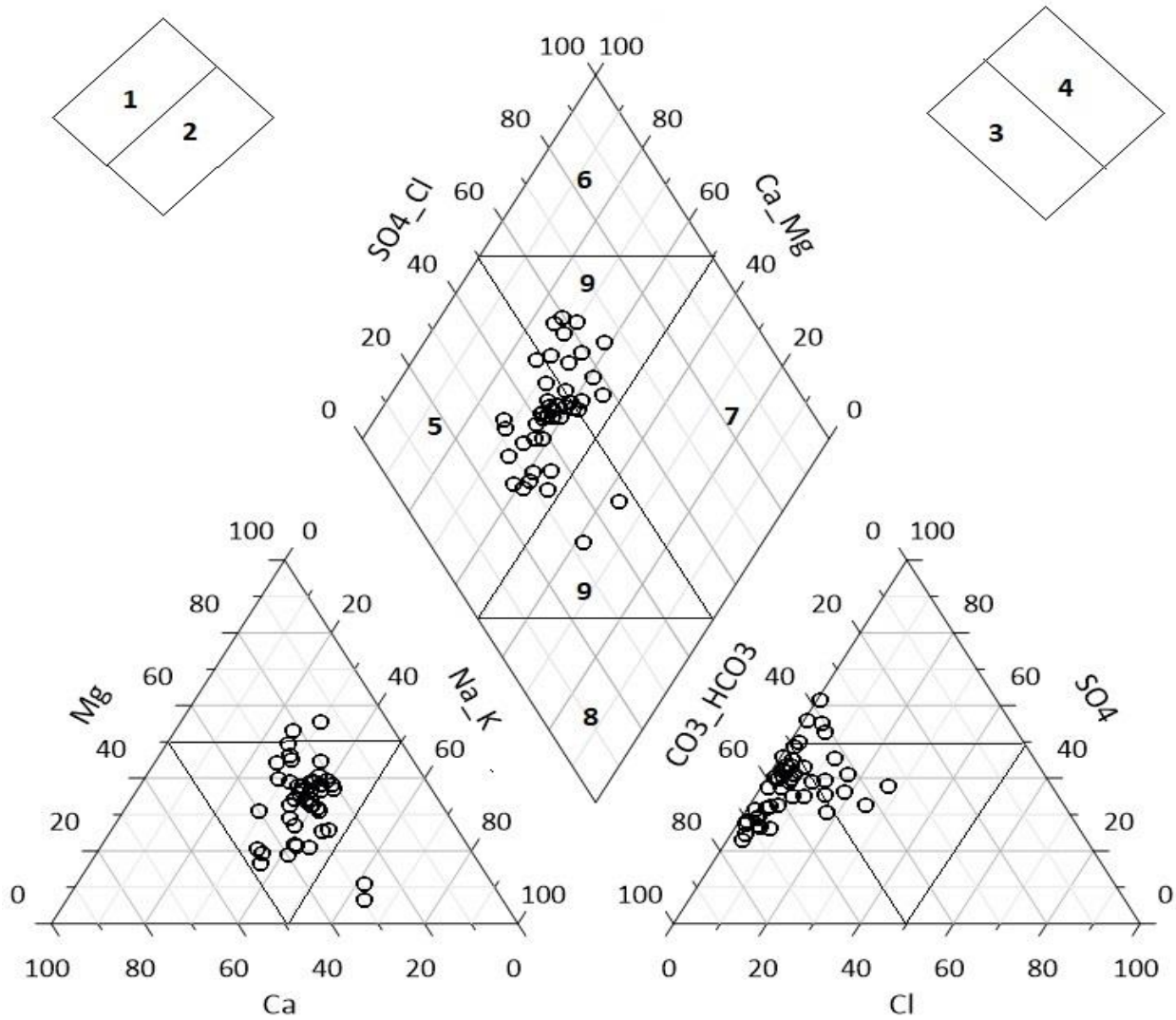

Figure 2: Piper trilinear diagram (1944) for chemical classification of water Shalmala river sub-basin, Dharwad district, Karnataka.

Table 11: Classification of central diamond shaped plot based on Piper's trilinear diagram.

Sub-division number of diamond shaped plot	Characteristics of corresponding self-division of diamond plot	Number of samples in the study area	Percentage of samples in the study area
Area 1	Alkaline earths exceed alkalis (Ca, Mg>Na+ K)	43	96%
Area 2	Alkalis exceeds alkaline earths (Na+ K>Ca, Mg)	02	04%
Area 3	Weak acids exceed strong acids (HCO_3, CO_3>SO_4, Cl)	34	76%
Area 4	Strong acids exceed weak acids (SO_4, Cl> HCO_3, CO_3)	11	24%
Area 5	Carbonate hardness (secondary alkalinity) exceeds 50%	32	71%
Area 6	Non-carbonate hardness (secondary salinity) exceeds 50%	00	00%
Area 7	Non-carbonate alkalis (primary salinity) exceeds 50%	00	00%
Area 8	Carbonate alkalis (primary alkalinity) exceeds 50%	00	00%
Area 9	No one cation and anion pair exceed 50% (Mixed type)	13	29%

The piper's trilinear diagram (Table 11), depicts that the 96% of groundwater samples in the study area are belonging to area 1 suggesting that water samples are alkaline earths exceeds alkalis. 76% of groundwater samples are belonging to the area 3 reveals that weak acids exceeds strong acids. 24% of groundwater samples belongs to area 4 which shows that strong acids exceed weak acids. 71% of groundwater samples are situated at area 5 reveals that secondary alkalinity exceeds 50%. 29% of groundwater samples are belonging to area 9 illustrates that the no one cation and anion pair exceed 50% respectively.

VI. GIBBS CLASSIFICATION

Gibbs (1970) has proposed a graphical representation for assessing the mechanisms controlling groundwater chemistry. It comprises the plotting of TDS vs Na+K/Na+K+Ca for cations and TDS vs Cl/Cl+HCO_3 for anions as shown in figure 3 and 4, whereas TDS is plotted on the Y-axis on a logarithmic scale. The Gibbs has suggested two mechanisms and they are evaporation dominance and precipitation dominance. If the plots are locating at the top then it represents the evaporation dominance and if the plots situated at the bottom which represents the precipitation dominance. A third mechanism was suggested by Vishwanathiah (1978) that is the rock dominance for the plots locating at the middle of the diagram. The values of anions and cations are representing as absolute concentration of water in (meq/l or epm) except TDS (Mg/l or ppm).

Table 12: Gibbs classification for assessing the mechanisms controlling groundwater chemistry.

Sample no	TDS	Cations	Anions
		Na+K/Na+K+Ca	Cl/Cl+HCO_3
01	467	0.3378	0.5110
02	305	0.5327	0.3914
03	344	0.5514	0.3888
04	581	0.4889	0.6464
05	414	0.5549	0.4803
06	527	0.4841	0.5439
07	496	0.6413	0.3402
08	544	0.4646	0.4364
09	401	0.4801	0.4456
10	593	0.6808	0.5922
11	279	0.6243	0.3635
12	584	0.6320	0.6635
13	417	0.5020	0.4693
14	460	0.4731	0.4976
15	880	0.2588	0.6838
16	970	0.5591	0.5951
17	764	0.3393	0.6720
18	542	0.3694	0.5580
19	358	0.7594	0.1339
20	136	0.3717	0.1434
21	534	0.4822	0.4093
22	804	0.5358	0.4812
23	882	0.2557	0.6616
24	644	0.3939	0.6334

25	329	0.5733	0.3801
26	322	0.5271	0.3955
27	556	0.3251	0.6726
28	334	0.3613	0.2828
29	180	0.3494	0.3389
30	475	0.2770	0.5386
31	268	0.4605	0.2512
32	302	0.4209	0.2458
33	258	0.5518	0.1792
34	136	0.4342	0.2558
35	323	0.3981	0.2609
36	300	0.1450	0.3512
37	289	0.4447	0.4125
38	333	0.4549	0.4794
39	278	0.3068	0.2670
40	570	0.5344	0.4278
41	689	0.6826	0.5685
42	428	0.3566	0.4636
43	703	0.3529	0.6936
44	485	0.4833	0.4403
45	328	0.3480	0.5978

All the values are in meq/l or epm except TDS (Mg/l or ppm).

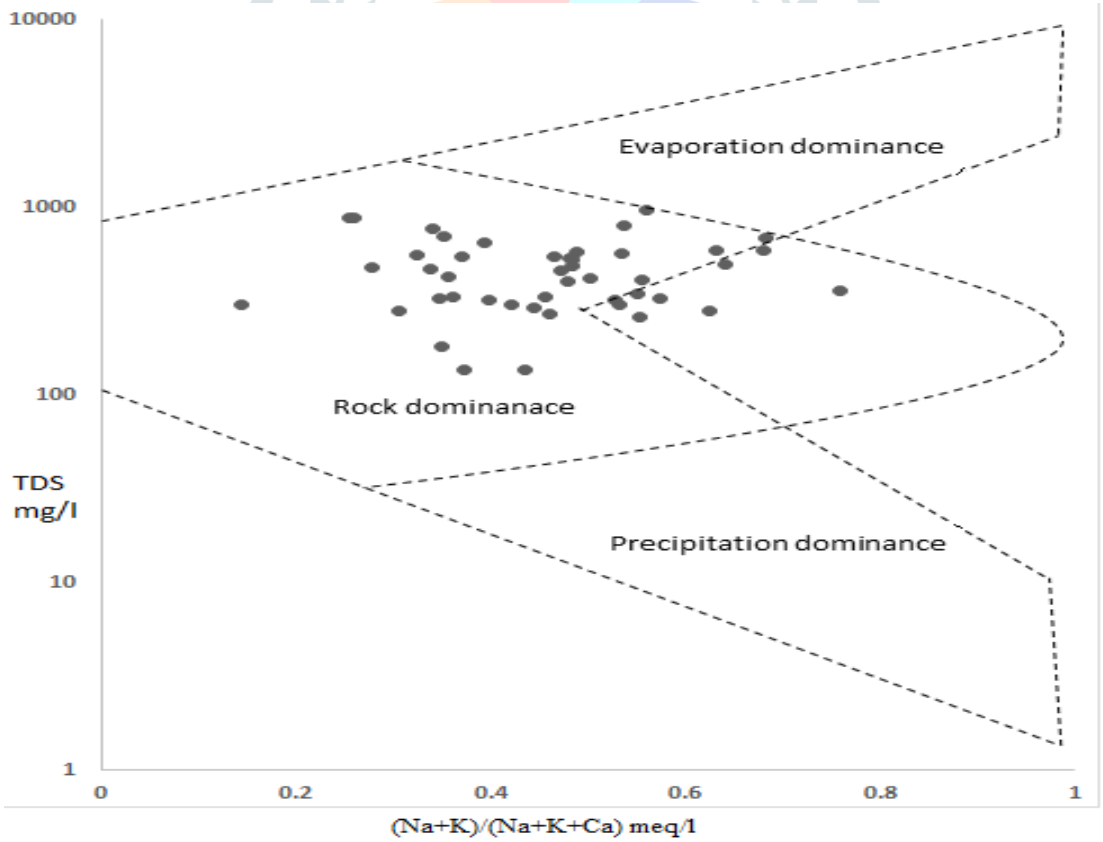

Figure 3: Mechanism controlling chemistry of groundwater for cations (Gibbs,1970).

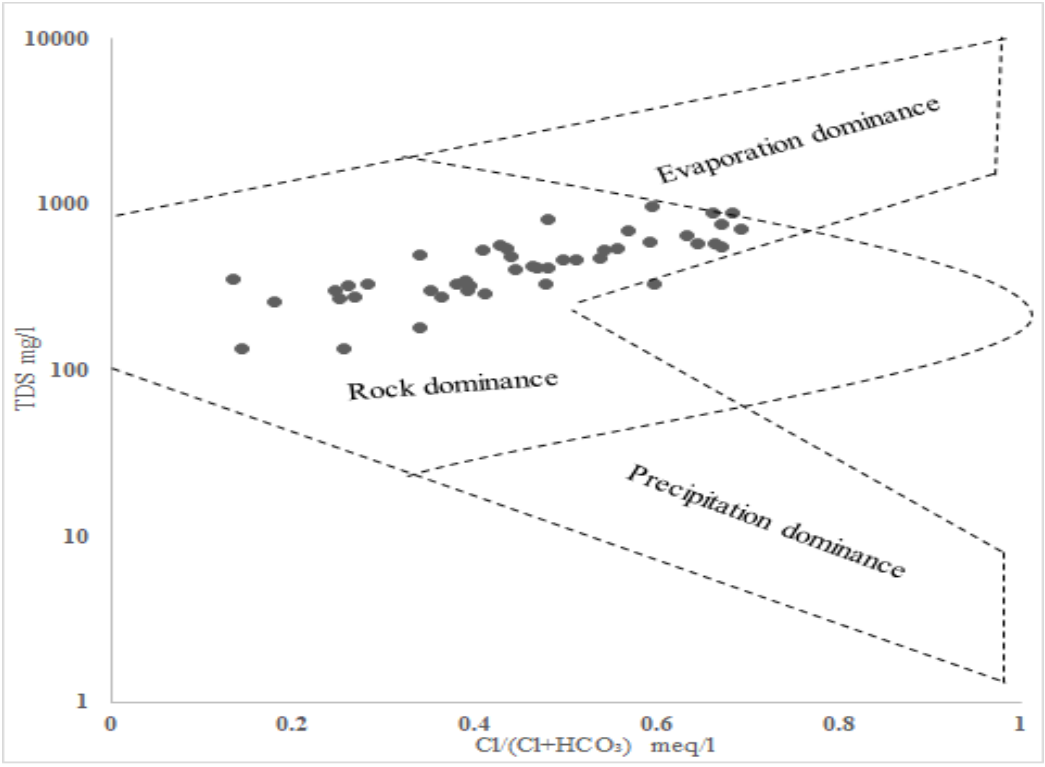

Figure 4: Mechanism controlling chemistry of groundwater for anions (Gibbs,1970)

From the figure 3 and 4, it is concluded that all the groundwater samples in the study area are found at middle of the diagram which represents the rock dominance in nature.

VII. Conclusion

The assessment of groundwater quality carried out in the study area. The pH value ranges from 7.13 to 8.12 and average is 7.59. Therefore, all the groundwater samples are indicating faintly alkaline in nature and are suitable for drinking and domestic purposes. According to Bucks and Gilbert (1979); Nakayama and Bucks (1991), the TDS value of all the groundwater samples are in good to moderate category respectively. 96% of total hardness (TH) in the study area showing hard category consequently softening of water is needed otherwise human may face cardiovascular diseases. According to world Health Organization (WHO, 2017), the major cations such as calcium, magnesium, sodium and potassium concentration in the study area are within the permissible limits similarly the major anions like chloride, sulphate, nitrate, Carbonates and bi-carbonates are also within the permissible limits except a few samples. Hence suitable for drinking and irrigation purposes. The piper diagram illustrates that the 96% of groundwater samples in the study area are belonging to area 1 suggesting that water samples are alkaline earths exceeds alkalis. 76% of groundwater samples are belonging to the area 3 reveals that weak acids exceeds strong acids. 71% of groundwater samples are situated at area 5 reveals that secondary alkalinity exceeds 50%. According to Gibbs classification it is illustrated that all the groundwater samples in the study area are representing rock dominance.

VIII. Acknowledgment

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