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Research Article

Evaluation of Geochemical Parameter Studies in Chamarajanagar Taluk, Chamarajanagar District, South Karnataka, India

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Abstract

The present paper is an attempt to make a classification of the groundwater of the Chamarajanagar Taluk , which falls under Chamrajanagara District, Karnataka, India using various methods, having an area of 1222.50 sq.km. The water field of hydrogeochemistry has been created for the analysis of the quality, contamination, chemical properties and its reactions in the groundwater. The quality of groundwater for various purposes largely depends on the chemical nature and behavior of the various chemical constitutes present in the groundwater. The groundwater samples are analyzed for the major cations and anions such as Ca, Mg, Na, K, Fe, HCO_3 CO_3, SO_4, NO_3, Cl and SAR,$CaCO_3$ water facies and hardness etc. with the standard values of bureau of Indian standard (BIS).The chemical quality of groundwater in any area is influenced by various factors such as climate, hydrological conditions, chemical properties and physical characteristics of soil and geology etc. The sources of groundwater contamination is either natural or anthropogenic or both. According to World Health Organization ((WHO), about 80% of the diseases in human beings are caused by water. Hence, proper knowledge and understanding of the quality and chemical constituents of groundwater becomes very important.

Keywords: *Groundwater quality, BIS, Geochemistry, hydrogeochemistry*

Introduction

Hydrogeochemical studies involves a description of the existence of different constituents in groundwater, the connection of these constituents to water purposes, proof of geochemical patterns and the evaluation of hydrogeochemical models of the study area. The quality and availability of groundwater is described by their physical, chemical, and bacteriological/biological characteristics. The relation between chemical properties of water and environment in which it exists is observed.

Some of the chemical parameters which can suggest different methods signify as follows:

Location of recharge, discharge areas, the long time stay of water in the aquifer (Indices of base exchanges, (IBE) $CaCO_3$ saturation indices and groundwater types).

Availability of groundwater that may be suitable for domestic, irrigation, and industrial purposes (salinity and sodium hazards and USSL classification).

The distinction between water from the various places. Directions of flow and Movements.

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The mechanisms controlling the groundwater chemistry (Gibbs Ratio).

Water quality is described analytically by calculation of concentration and the effects of characteristic reason by the occurrence of the ionic substances.

Study area

To check the groundwater quality, 50 groundwater samples have been collected from the various villages of the study area. The groundwater samples are analyzed for the major cations and anions such as Ca, Mg, Na, K, Fe, HCO_3 CO_3, SO_4, NO_3, Cl (**Table.1).** The chemical concentration of groundwater is expressed in the ppm (parts per million, mg/L) concentration.

Reliability Check

On an equivalent basis, the total cations in a water sample should be equal to the total anions. However, in reality there is usually a small discrepancy because of all dissolved constituents are not analyzed or because of analytical errors. The discrepancy is determined as:

$$Discrepancy(\%) = \frac{Total\ cations - \text{Total anions}}{Total\ cations + Taotal\ anioms} X100$$

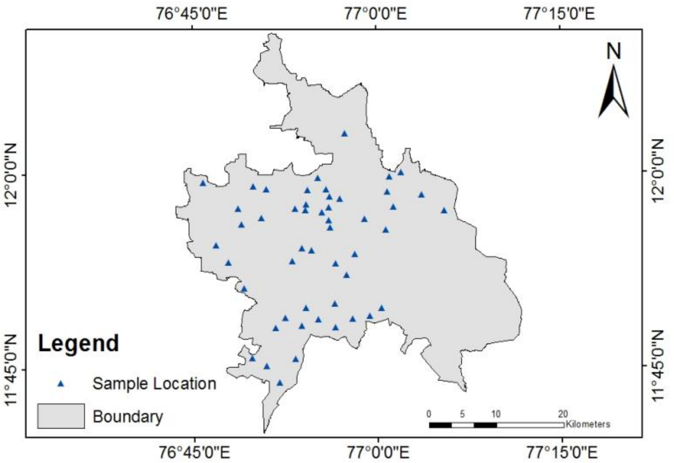

Fig. 1 Sample analysis of study area

Table 1. Geochemical analysis report of study area 2013-14 (ppm)																
A type of Cation(mg/L)								B. Type of Anions(mg/L)								
SL.No.	Village Name	Ca	Mg	Na	K	Na+K	Fe	HCO_3	CO_3	Cl	NO_3	SO_4	TDS	EC	P^H	Remarks
1	Boodamballi	204	23	183	3	186	0.25	649	0	252	129	40	1260	600	6.67	Not potable
2	kanchanahalli	120	28	71	2	73	0.72	392	0	133	39	32	601	1147	7.42	Not potable
3	Malmala	212	93	98	6	104	2.48	789	0	210	125	92	1336	900	6.65	Not potable
4	Devalapur	24	12	52	4	56	2.48	260	0	20	17	9	296	521	8.17	Not potable
5	Bandigere	134	79	197	13	210	2.25	603	0	283	139	90	1267	2197	7.7	Not potable
6	Gangavadi	124	120	112	5	117	1.85	624	0	268	125	63	1184	2102	7.09	Not potable
7	Kethepura	80	88	119	11	130	2.02	453	0	224	115	60	957	1683	7.8	Not potable
8	Mariyala	111	55	192	9	201	1.99	538	0	266	100	47	1192	1850	7.29	Not potable
9	Masagapur	61	77	275	4	279	2.22	887	0	151	105	45	1193	2148	8.08	Not potable
10	Doddamole	139	65	199	23	222	2.5	590	0	210	200	105	1336	2128	7.43	Not potable
11	Nanjahalli	102	67	116	11	127	2.08	557	0	168	71	60	864	1355	7.34	Not potable
12	Yelachagere	124	63	89	2.4	91.4	1.99	521	0	154	78	65	896	1545	8.23	Not potable
13	Bokkepura	140	38	81	6	87	2.05	588	0	77	36	86	738	1387	6.95	Not potable
14	Achattipura	110	94	156	5	161	1.85	554	0	193	208	95	1163	1984	8.17	potable
15	Bommanahalli	29	70	75	5	80	2.21	135	24	132	80	130	645	1075	9.45	Not potable
16	Boodittittu	71	187	259	14	273	2.51	882	0	413	190	81	1856	3270	7.3	Not potable
17	Basthipura	51	28	69	4	73	1.97	407	0	28	6	14	434	783	8.27	Not potable
18	Haradanahalli	134	79	192	18	210	1.22	603	0	283	139	90	1267	2197	7.7	Not potable
19	Kiragasur	93	45	193	11	204	2.43	496	0	210	100	80	1076	1733	7.54	Not potable
20	Kagalavadi	102	79	246	25	371	2.14	779	0	241	285	62	1606	3043	7.86	Not potable
21	Chandakavadi	122	51	144	19	163	1.56	539	0	123	182	60	1001	1646	8.02	Not potable
22	Voddagalpura	84	92	88	2	90	1.98	576	0	154	72	40	841	1577	7.65	Not potable
23	Shivapura	119	36	68	5	78	2.02	529	0	76	42	36	68	1222	7.87	potable
24	Honnahalli-1	29	70	76	4	80	2.42	135	24	132	80	130	645	1075	9.45	Not potable
25	Sagade	12	25	102	19	121	2.15	137	0	45	25	195	565	890	8.78	Not potable
26	Uthavalli	74	50	69	6	75	1.66	211	5	106	102	130	680	1070	9.18	Not potable
27	Yadapura	171	33	154	22	178	1.48	505	0	174	276	68	1188	1903	7.61	Not potable
28	Yanagumba	32	105	104	38	142	2.48	784	18	84	15	46	876	1617	8.6	Not potable
29	Kellambali	148	83	89	11	100	2.39	526	0	264	85	46	1043	1840	7.36	potable
30	Masagapur-1	104	48	69	6	75	1.15	350	0	140	105	41	727	1221	7.44	Not potable
31	Bogapura	160	75	92	9	101	1.76	551	0	261	60	50	1032	1837	7.76	Not potable
32	Hosahalli	56	83	32	12	44	0.22	539	0	49	42	18	625	1153	8.21	Not potable
33	Aralikate	180	8	88	4	92	1.28	478	0	154	30	43	804	1355	7.62	Potable
34	Madapura	36	28	12	3	15	0.96	195	0	56	0	0	250	471	7.15	Not potable
35	Honganur	32	35	44	1	45	2.25	318	0	49	0	0	1572	950	6.6	Not portable
36	Kotamballi	208	108	141	10	151	2.2	698	0	315	240	80	1572	950	6.6	Not potable
37	Bedarapura	9	48	56	6	62	1.26	218	46	25	22	53	406	710	8.01	Not potable
38	Narasamangala	116	63	104	23	127	2.26	613	0	175	55	34	942	1677	6.7	Not potable
39	Chamarajanagar	126	56	118	6	124	2.2	524	0	140	161	51	950	1617	8	Not potable
40	Govindavady	106	74	27	9	36	1.96	292	7	95	177	135	805	1148	8.94	Not potable
41	Muthige	76	63	89	5	94	1.56	538	0	70	66	51	723	1297	8.15	Not potable
42	Heggavady	120	63	96	6	102	1.56	462	0	175	125	45	914	1551	7.48	Not potable
43	Kadahalli	120	105	96	20	116	1.46	613	0	205	105	65	1087	1942	6.26	Not potable
44	Channappanpur	128	38	188	6	194	2.76	676	0	168	54	35	1043	1753	6.85	Not potable
45	Gulipura	196	48	104	19	123	1.22	637	0	189	128	20	1102	1820	7.56	Not potable
46	Harve	115	104	203	14	217	1.28	559	0	249	348	80	1423	2345	7.89	Not potable
47	Kilagere	4	69	169	5	174	1.05	311	0	84	5	289	974	1695	8.18	Not potable
48	Bisalvadi*	51	28	62	11	73	2.38	407	0	28	6	14	434	783	8.27	Not potable
49	Attigulipur	35	95	79	5	84	1.35	137	0	185	124	155	79	1310	9.3	Not potable
50	Kesthur	100	50	108	14	122	1.02	433	0	182	78	0	776	1350	8.3	Not potable

Table 2 - A different parameters of 2013-2014 at study area

SL.No.	Village name	Indices of baseExachange		scho water types	RSC	SAR	PI Field	Ca CO3Saturation Indices		Handa's Class	**Stuyfzand's Classification**				Gibbs Plot	USSL Classification	Corrosivity Ratio
		IBE-1	IBE-2					Equi. Ca	Equi.pH		Water Facies	**WaterType.(Based on Cl)**	**Sub -Type (Based on Alk)**	Sig			
1	Boodamballi	-0.14	-0.07	III	-1.4363	3.2915	C2	-3.032	0.504	A1C3S1	Ca HCO_3	F	ALK - HIGH	Static and Dissolution regimes	Evaporation	C2S1	0.611
2	Kanchanahalli	0.154	0.075	III	-1.8679	1.5587	C2	-0.135	0.805	A1C3S1	Ca HCO_3	F	ALK-MOD-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.5629
3	Malmala	0.237	0.083	III	-5.301	1.4976	C2	-2.191	0.585	A1C4S1	Ca HCO_3	F	ALK - HIGH	Static and Dissolution regimes	Evaporation	C3S1	0.4963
4	Devalapur	-3.32	-0.4	IV	1.4175	2.042	C4	0.144	0.677	B1C2S1	Mg HCO_3	G-Oli	ALK-MOD-HIGH	Dissolution andMixing	Rock Interaction	C2S1	0.1444
5	Bandigere	-0.14	-0.08	III	-3.3055	3.555	C3	0.3393	1.32	A1C3S2	Ca HCO_3	F	ALK--HIGH	Static and Dissolution regimes	Rock Interaction	C2S1	0.8165
6	Gangavadi	0.327	0.182	III	-5.8359	1.795	C2	0.31	6910	A1C3S1	Mg Mixed	F	ALK--HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.7101
7	Kethepura	0.105	0.063	III	-3.8095	2.3849	C2	-0.473	1.072	A2C3S1	Mg Mixed	F	ALK-MOD-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.8344
8	Mariyala	-0.16	-0.11	III	-1.2479	3.895	C3	0.106	0.778	A1C3S1	Ca Mixed	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.7874
9	Masagapur	-1.85	-0.46	IV	5.1561	5.6013	C3	0.9013	1.526	B2C3S2	Na+Kmixed	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S2	0.6854
10	Doddamole	-0.63	-0.25	III	-2.6158	3.8945	C3	0.349	1.056	A1C3S2	Ca Mixed	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C3S2	0.6867

11	Nanjahalli	-0.17	-0.07	IV	-1.4749	2.3981	C3	0.0603	0.807	A1C3S1	Mg HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S2	0.537
12	Yelachagere	0.085	0.033	III	-2.8335	1.666	C3	0.917	1.752	A1C3S1	Ca HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.5463
13	Bokkepura	-0.74	-0.13	III	-0.4767	1.6821	C3	-5.485	0.578	A1C3S1	Ca HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.3368
14	Achattipura	-0.29	-0.11	III	-4.145	2.725	C3	0.9124	1.667	A1C3S1	Mg Mixed	F	ALK-IGH	Static and Dissolution regimes	Evaporation	C3S1	0.6693
15	Bommanahalli	0.066	0.035	III	4.1948	1.8322	C3	0.8636	1.755	A2C3S1	Ca HCO_3	F	ALK - HIGH	Water contaminated with Gypsum	Rock Interaction	C3S1	2.021
16	Boodittittu	-0.02	-0.01	III	-4.4763	3.858	C3	0.1475	0.809	A1C5S2	Mg Mixed	B	ALK-HIGH	Static and Dissolution regimes	Evaporation	C4S2	0.7552
17	Basthipura	-3.02	-0.34	III	1.8209	2.038	C4	0.7428	1.3	B1C3S1	Ca HCO_3	G-Ligo	ALK-MOD-HIGH	Dissolution andMixing	Rock Interaction	C3S1	0.1327
18	Haradanahalli	-0.14	-0.08	III	-3.3053	3.5557	C_2	0.3393	1.32	A1C3S2	Cahco3	F	ALK-MOD-HIGH	Static and Dissolution regimes	Rock Interaction	C3S2	0.8165
19	Kiragasur	-0.5	-0.26	III	-0.2151	4.3424	C_3	-0.157	0.916	A1C3S1	Na+K Mixed	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.7643
20	Kagalavadi	-1.02	-0.37	IV	1.1757	5.7071	C_3	0.3284	1.473	B2C5S2	Cahco3	F	ALK-HIGH	Dissolution andMixing	Evaporation	C5S2	0.5186
21	Chandakavadi	-1.04	-0.28	III	-1.4513	3.1252	C_2	0.9188	1.55	A1C3S1	$Cahc0_3$	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C3S1	0.4337
22	Voddagalpura	0.095	0.036	III	-2.3225	1.6207	C_2	-0.103	1.047	A1C3S1	Mg HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.4459

23	Shivapura	-0.48	-0.1	III	-0.2311	1.5045	C_2	0.1519	1.381	A1C3S1	Ca HCO_3	F	ALK-HIGH	Recent dolomitic	Precipitation	C3S1	0.2736
24	Honnahalli-1	0.066	0.035	III	-4.1948	1.8322	C_2	0.8636	1.755	A2C3S1	Cahco3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.5996
25	Sagade	-3.14	-0.6	II	-0.4108	4.5651	C_3	-2.247	0.709	A3C3S1	Mghco3	F	ALK-HIGH	Water contaminated with Gypsum	Rock Interaction	C3S1	1.9453
26	Uthavalli	-0.29	-0.11	III	-4.145	2.7222	C_2	0.9124	1.667	A1C3S1	Mg Mixed	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C3S1	1.3181
27	Yadapura	-0.58	-0.2	III	-2.9724	3.2633	C_2	0.3818	1.259	A1C3S1	Ca Mixed	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C3S1	0.6256
28	Yanagumba	-1.61	-0.26	III	3.2112	2.7289	C_2	0.7872	1.712	B1C3S1	Cahco3	F	ALK-HIGH	Dissolution and Mixing	Evaporation	C3S1	0.2073
29	Kellambali	0.416	0.283	III	-5.5949	1.6308	C2	0.3142	0.964	A1C3S1	Ca Mixed	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.798
30	Masagapur-1	0.174	0.083	III	-3.4035	1.5254	C_2	-0.467	0.714	A1C3S1	Ca Mixed	F	ALK MOD HIGH	Dissolution and Mixing	Rock Interaction	C3S1	0.6854
31	Bogapura	0.404	0.269	III	-5.1257	1.6506	C_2	0.3944	1.418	A1C3S1	Ca Mixed	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.7617
32	Hosahalli	-0.38	-0.04	III	-0.7911	0.872	C_2	0.8231	1.402	A1C3S1	Mg HCO_3	F	ALK-HIGH	Recent dolomitic	Rock Interaction	C3S1	0.1628
33	Aralikatte	0.079	0.037	III	-1.8068	1.8219	C_2	0.3795	1.267	A1C3S1	Ca HCO_3	F	ALK MOD HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.5475
34	Madapura	0.587	0.29	I	-0.9047	0.4554	C_2	-6.605	-0.29	A1C2S1	Mg HCO_3	F	ALK-MODERATE	Static and Dissolution regimes	Rock Interaction	C2S1	0.4045

35	Honganur	-0.42	-0.11	I	0.7345	1.3077	C_3	0.4754	1.12	B1C2S1	Mg HCO_3	F	ALK-MOD-HIGH	Dissolution and Mixing	Rock Interaction	C2S1	0.217
36	Kotamballi	0.261	0.137	III	-7.8274	2.1152	C_2	-2.677	0.474	A1C5S1	Ca-Mixed	B	ALK-HIGH	Static and Dissolution regimes	Evaporation	C5S1	0.755
37	Bedarapura	-2.82	-0.3	I	0.7069	1.8176	C_2	-1.721	0.005	B1C2S1	Mg HCO_3	G-Olig	ALK-MOD-HIGH	Dissolution and Mixing	Rock Interaction	C2S1	0.3425
38	Narasamangal a	-0.12	-0.05	III	-0.9266	2.3574	C_2	-6.508	0.264	A1C3S1	Ca HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.4599
39	Chamarajanag a	-0.37	-0.12	III	-2.3081	2.3098	C_2	0.9191	1.532	A1C3S1	$Cahco_3$	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.4777
40	Govidavady	0.828	2.143	II	-6.36	0.6562	C_2	0.8275	2.143	A2C3S1	$Mghco_3$	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.6115
41	Muthige	-1.07	-0.19	III	-0.1597	1.9291	C_2	0.8694	1.474	A1C3S1	Mg HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.2821
42	Heggavady	0.102	0.048	III	-3.6001	1.8763	C_2	0.037	0.936	A1C3S1	Ca Mixed	F	ALK MOD HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.6352
43	Kadahalli	0.128	0.056	III	-4.5823	1.8648	C_2	-6.258	-0.16	A1C3S1	Mg HCO_3	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.5815
44	Channappanpur	-0.78	-0.29	III	1.5641	3.8672	C_3	-5.17	0.5	B1C3S1	Ca HCO_3	F	ALK-HIGH	Dissolution andMixing	Evaporation	C3S1	0.4041
45	Gulipura	-0	-0	III	-3.29	2.04	C_2	0.57	1.36	A1C3S1	$Cahco_3$	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C4S1	0.4506
46	Harve	-0.34	-0.15	IV	-5.1354	3.5288	C_2	0.1695	1.411	A1C4S2	Mg Mixed	F	ALK-HIGH	Static and Dissolution regimes	Evaporation	C4S1	0.7765

47	Kilagere	-2.19	-0.46	II	-0.7807	4.413	C_2	-3.292	-0.01	A3C3S1	$Cahco_3$	F	ALK-HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	1.3484
48	Bisalvadi*	-3.02	-0.34	III	1.8209	2.0383	C_3	0.7428	1.3	B1C3S1	Ca HCO_3	G-Olig	ALK-MOD-HIGH	Dissolution andMixing	Rock Interaction	C3S1	0.1327
49	Attigulipur	0.3	0.21	III	-7.3186	1.6701	C_2	0.8887	1.693	A2C3S1	Cahco3	F	ALK-MOD-HIGH	Water contaminated with Gypsum	Rock Interaction	C3S1	3.0805
50	Kesthuru	-0.03	-0.02	I	-2.0083	2.4861	C_2	0.8767	1.649	A1C3S1	Ca HCO_3	F	ALK MOD HIGH	Static and Dissolution regimes	Rock Interaction	C3S1	0.592

The discrepancy is analyzed based on TDS content. The permissible error of different ranges of TDS content (Reported by the Groundwater Cell, Department of Mines and Geology Government of Karnataka in their publication GWS No. 102.(1973) is as:

TDS(ppm)	50	100	200	500	1000	2000
Permissible Error in %	>7	7	5	4	3	2

All the samples reliable with respect to their determined TDS. The maps for all the chemical constituents have been prepared in the geoinformatic environment with the help of ArcGIS 10.2 software. The study area of groundwater samples tested by mines and geology department, Karnataka and also following tables are generated by the HYCH PROGRAMME software done.

Results and discussion

Methods of interpretation

Balasubramanian (op cit), Prasad (1984), Subramanian (Opcit) have followed a series of methods to interpret and classify the hydrochemistry of groundwater.

Calcium (Ca^{2+})

Calcium concentrations in normal potable groundwater generally range between 75 (desirable) to 200 ppm (permissible) (BIS, 2009) Ca within this range has no effect on the health of humans and animals (Davis and Dewiest, 1966). The bureau of Indian Standards (BIS, 2009) has set forth a desirable limit of 75 mg/L for drinking purpose. The range value of Ca in the study area lowest in Kiligereis(4Mg/L) and highest in Malmala (212 mg/L)of seasons. Ca^{2+} can be measured using either ion chromatography (IC) or inductively coupled plasma optical emission spectroscopy (ICP- OES).

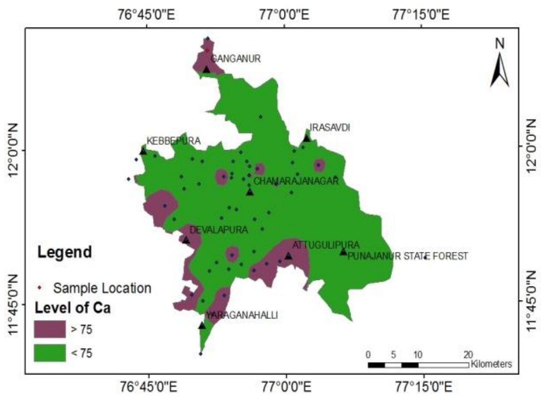

Fig.2 Calcium of the study area

Table 1 Distribution of Calcium of Chamarajanagar taluk of area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 75	15	189.01	15.46
> 75	35	1033.49	84.54
50		1222.50	100.00

Magnesium (Mg^{2+})

The behavior of magnesium is very similar to that of calcium. Magnesium is the major constituent causing hardness in water. The common sources of magnesium in the hydrosphere are dolomite in sedimentary rocks; olivine, biotite, hornblende and augite in igneous rocks and serpentine, talc, diopside and trimolite in metamorphic rocks. Although the solubility of magnesium is more as compared with that of the calcium, magnesium is generally found in lesser concentrations in natural water. This is probable due to slow dissolution of dolomite and the greater abundance of calcium in the earth's crust. The common concentration of magnesium is 30 (desirable) to 100 ppm (permissible) (BIS, 2009). The range value of magnesium concentration in the study area lowest in Aralikate is (8 Mg/L)and higest in Booditittu(187Mg/L) of seasons. Magnesium usually occurs in less concentration in groundwater than calcium (Frederic Gladstone Bell, 2004). Mg^{2+} can be measured using either ion chromatography (IC) or inductively coupled plasma optical emission spectroscopy (ICP- OES) **Fig.3**

Table 2 Distribution of Mg of Chamarajanagar taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 30	9	55.53	4.54
30 -100	35	1146.54	93.79
> 100	6	20.43	1.67
50		1222.50	100.00

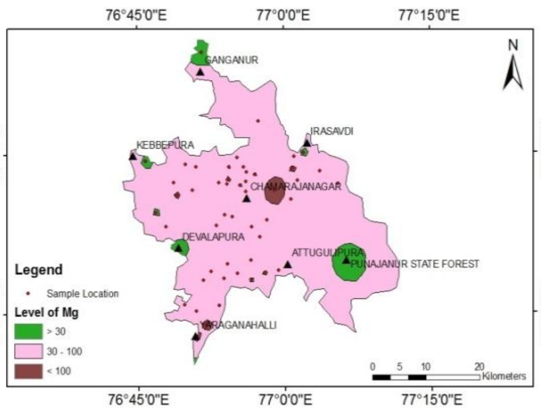

Fig.3 Magnesium of the study area

Sodium (Na^+)

Sodium unlike calcium and magnesium is not found as an essential constituent of the rock-forming minerals. The primary source of sodium in natural water is from the release of soluble products during weathering of plagioclase feldspars, clay minerals, nephiline, soda-bearing pyroxenes and amphiboles. Certain clay minerals and zeolites can increase the sodium content in groundwater by Base Exchange reaction. The normal content of sodium in the natural water is 1 to 200 ppm and in the study area the varies values are lowest in madapur (12Mg/L) and (275Mg/L) of seasons. Majority of the area has high Na concentration in seasons indicating the higher rate of weathering in the study area. These anomalies are due to lithologiesviz, granites, gneisses, laterites and also due to agricultural practices that is, applying of various chemical fertilizers. Sodium has medical effect on human health. If it's concentration is high in blood, it may lead to hypertension **Fig.4**

Table 3 Distribution of Na of Chamarajanagar taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
>100	26	313.86	25.67
< 100	24	908.64	74.33
50		1222.50	100.00

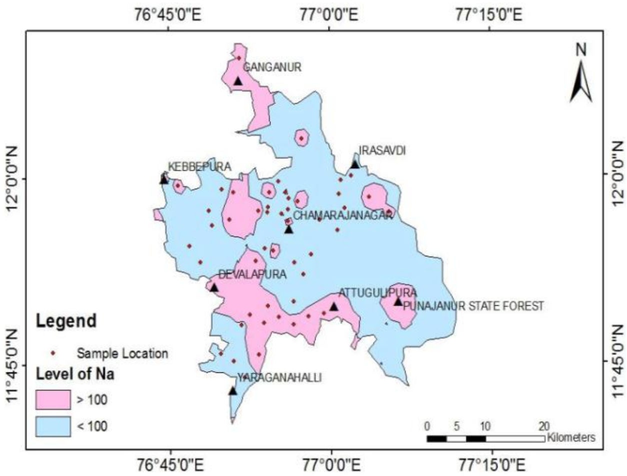

Fig.4 Sodium of the study area

Potassium (K^+)

Potassium in groundwater is due to the weathering of orthoclase, microcline, biolite, leucite and nephiline in igneous and metamorphic rocks. Although the abundance of potassium in the earth's crust is about the same as Na, potassium is commonly less than one-tenth of the concentration of Na in natural water. This relative immobility of potassium is due to higher resistance to weathering as compared to the sodium minerals. Some amount of potassium is also extracted by plants in the soil zone. The concentration of potassium ranges from 1 to 12 ppm in potable water. The range value of potassium in the study area lowest in honganur (1mg/L) and highest in 38Mg/L for seasons of respectively, which is slightly higher than the permissible limits (Satish and Vajrappa, 2013b). Potash feldspar-rich rocks contribute potassium to groundwater fig.5.

Table 4 Distribution of K of Chamarajanagar Taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
>10	28	760.56	62.21
< 10	22	461.94	37.79
50		1222.50	100.00

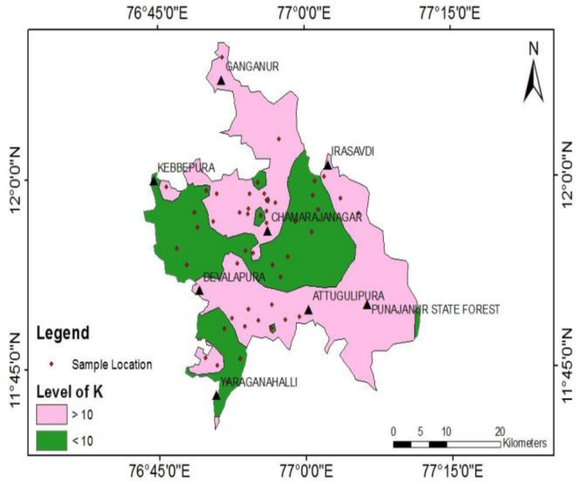

Fig.5 Potassium of the study area

Chloride (Cl^-)

The principle sources of chloride and sodalities, orthoclase, apatite and micas which are minor constituents from source rocks is only insignificant. It is presumed that chloride in groundwater is either from atmosphere or seawater contamination. Sodium chloride has little effect on the suitability of water for use unless it is present in such concentration has to make the water highest in 413Mg/L for seasons respectively. Chloride in surface and groundwater from the both natural and anthropogenic sources such as irrigation drainage, inorganic fertilizer etc, The sources of chloride in the study area could be atmospheric source, anthropogenic effect (the infiltration of domestic wastes) and to some extent weathering of host rocks. Groundwater having concentration of chloride more than 1000 mg/L not suitable for drinking water purposes unpotable or corrosive. Chlorine in water is a stronger oxidizing agent than oxygen. The presence of chlorine in water is harmful for bacteria and it improves the quality of water. The permissible range of chloride in water is 250 (desirable)to 100 (permissible) ppm (BIS, 2009). The range value of chloride in the study area is lowest in Devalapur20Mg/L and highest in Booditittu Fig .6

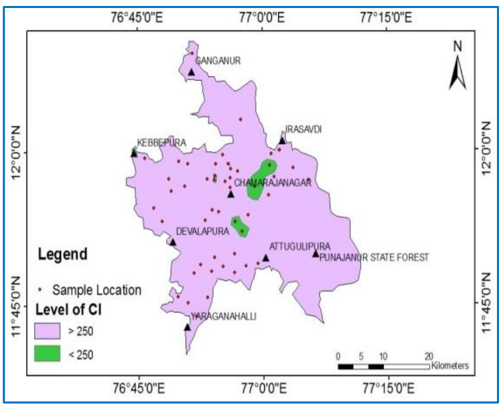

Fig.6 Chloride of the study

Table 5 Distribution of Cl of chamarajanagar taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 250	41	1188.48	97.22
> 250	9	34.02	2.78
50		1222.50	100.00

Nitrate (NO_3)

Occurrence of nitrate in groundwater is normally anthropogenic in nature. The possible source of contamination include domestic wastes, septic systems, human waste lagoons and animal feed-lots as point sources and manure applied to land, agriculture fertilizers, industrial effluents, native soil organic matter, etc. as nonpoint sources. Nitrate present in excess in drinking water could cause the *"Blue baby syndrome"* in children. Nitrate may be fixed by plants before the rain water infiltrates below the root zone. Although for the contribution of nitrate in groundwater, it is from decaying organic matter, and sewage waste. The source of nitrate in the study area is from soil where fertilizers NPK and other chemical compounds are used in excesses of agricultural practices (Agrawal *et al.,* 1999). Nitrate up to 45 mg/L in groundwater is permissible according to BIS (2009), but polluted water contains up to 100 ppm. The range value of nitrate in the study area is lowest in Madapura and Honganur zero (0) to highest in Harve (348Mg/L) for seasons respectively Fig.7.

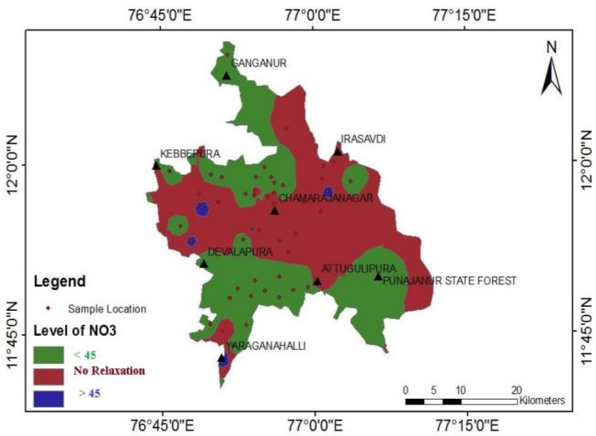

Fig.7 NO3 of the study area

Table 6 Distribution of NO3 of Chamarajanagar Taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 45	27	560.21	45.82
No Relaxation	11	648.61	53.06
> 45	04	13.69	1.12
50		1222.50	100.00

Alkalinity

Alkalinity is the acid neutralizing capacity of water. In general, the alkalinity of groundwater is measured as the values of bicarbonate. Most bicarbonate ions in the groundwater are derived from the carbon dioxide in the atmosphere, soils and solution of carbonate rocks. The permissible range of bicarbonate is 100 and 400 ppm, respectively (BIS, 2009). The range value of bicarbonate in the study basin lowest in Bommanahalli is135 and higest in Masagapur 887Mg/L of seasons. The range value of carbonate in the study basin is Zero in (expect Yanagumba, Uthavalli and Bommanahali remains all the samples) to 46Mg/L in Bedarapura.Bicarbonate in bottled water is ranging up to about 1800 mg/L with very view waters (Apollinaris, Gerolsteiner, Borsek,) and most waters contain between 50 - 200mg/L. High concentrations of bicarbonates are reported in water flowing through carbonate soils and aquifers as Na-HCO_3. (Ritcher B. Chrsitan and Charles W., Kreitler, 1993).Usually, bicarbonates increase as pH lowest and it is play a central role in maintaining the body's internal acid-base balance, in stomach secretions and it is essential to the process of digestion **Fig. 8 and Fig. 9**

Table 8 Distribution of CO3 of Chamarajanagar Taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
>30	45	1123.12	91.87
30 – 60	04	97.02	7.94
< 60	01	2.36	0.19
50		1222.50	100.00

Table 7 Distribution of HCO3 of Chamarajanagar Taluk at area sq.in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 400	13	153.72	12.57
400 -800	35	1064.20	87.05
> 800	2	4.58	0.37
50		1222.50	100.00

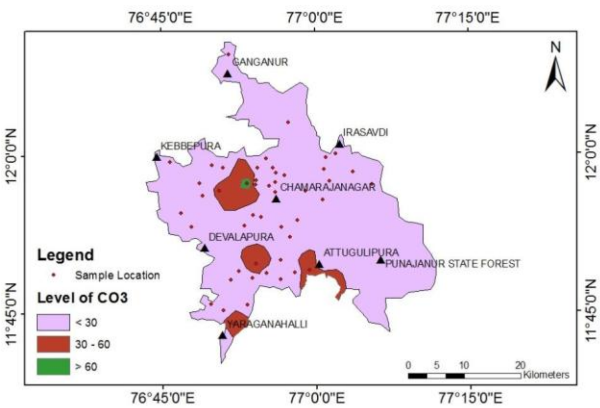

Fig.8 CO3 of the study area

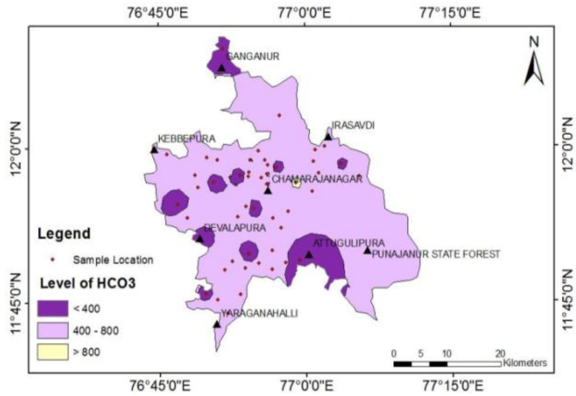

Fig.9 HCO3 of the study area

Total Dissolved Solids

TDS can be defined as the material remaining in solution after filtration of the suspended solids (Rayamahashay, 1996). On the basis of TDS classification of Davis and Dewiest (1966), most of the samples ore suitable for irrigation and drinking purposes. The TDS in water samples include all salts in solution, but does not include suspended sediments, colloids or dissolved gases. TDS and specific electrical conductance are interdependent. The permissible TDS ranges from 500 (desirable) to 2000 ppm (permissible) (BIS, 2009). The range the values of TDS is lowest 68 (Shivapura) and Highest 1856 Boodittitu. The values are well within the permissible range except in a few isolated cases. Different limits of TDS content are fixed foe different purpose by various organizations and individuals (Davis and Dewiest, 1966) as tabulated below.

Table 10 Water quality based on TDS concentration

Water type	**Concentration of TDS ppm**
Fresh water	0-1000
Brackish water	1000-10,000
Salty water	10,000-100,000
Brine water	100,000-100,0000

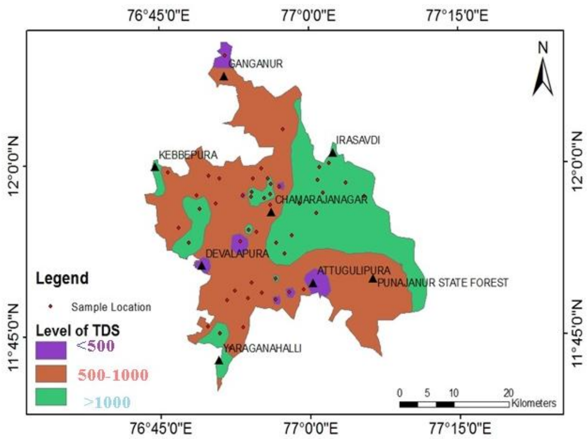

Fig.10 Total dissolved solids of the study

Table 9 Distribution of TDS of Chamarajanagar Taluk at area in sq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)
< 500	07	44.39	3.63
500 - 1000	23	754.80	61.74
> 1000	20	423.31	34.63
50		1222.50	100.00

Based on TDS Davis and Dewiest (1966) classified the groundwater for various uses like general household, drinking, irrigation and industry, using the same concentration limits proposed by them. FIG10

It could be seen from the above (table 9) that a majority of the portion is occupied by <500 ppm (3.63%) of the sample are permissible for drinking and TDS followed by > 1000 ppm (34.63%) of the samples are useful for irrigation observed in sample numbers etc. It has been noticed by Freeze and Cherry (1979) that the groundwater in the recharge areas have low TDS than discharges areas.

The higher concentration of the TDS indicates that a longer stay of the groundwater in the water bearing formation and dissolution coefficients of the minerals present in the rocks is high and hence gives a higher dissolved solid concentration.

Electrical Conductivity

The EC is an index of degree of mineralization and usually expressed in µ-mhos/cm at 25ºC. This property varies with concentration and degree of ionization of the constituents and with temperature. The specific conductance of groundwater varies from a few tens of µ-mhos to over 10,000 µ-mhos/cm. An approximate relation exits between specific conductance and ionic concentration in water. The range EC value of the study basin is 521 and 2345 µ-mhos/cm the iso-concentration maps of EC indicate that the anomalies are in and around northern, northeastern, central and southern parts of the study area **Fig. 11.**

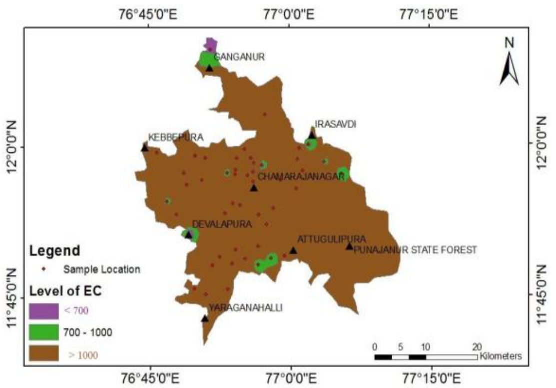

Fig.11 Electrical conductivity of study area

Electrical Conductivity is an index of the degree of mineralization which various with temperature. A major part of the area containing water with an EC 0-700micro mhos/cm at 25ºC covers the 0.70% observed in the study area .The second horizon with 700-1000micro mhos/cm at 25ºC observed in the study area are 3.08% of the area coverage (Table 5.17) >1000micro mhos/cm at 25⁰C covers the 96.22% observed the samples. it's indicates that doubtful but in the case of this recently soil fertility may be changes because using of the not limited nitrate, sulphate,(expressly urea).

Table 11 Distribution of EC of Chamarajanagar Taluk at area insq.km

Classes	No. of Samples	Area in sq.km.	Area in Percentage (%)	Water quality
700	3	8.61	0.70	Desirable
700-1000	7	37.62	3.08	Permissible
>1000	40	1176.27	96.22	Not potable
Total	50	1222.50	100.00	

Index of Base Exchange

The control on the dissolution of undesirable constituents in water is impossible during the subsurface runoff but it is essential to know the various changes undergone by water during the travel (Pojasek, 1977; Johnson, 1977). The ion exchange between the groundwater and its host environment during residence or travel can be understood by studying the chloro-alkaline indices and expressed as follows (Schoeller, 1965 and 1967; Hegde, 2006).The chloro-alkaline indices can be either positive or negative depending on the exchange of sodium and potassium from water with magnesium and calcium in rock or vice versa. If the values of chloro-alkaline indices are positive, it indicates a direct exchange. In case of reverse exchange the indices are negative. These values indicate that 65.82%of the area water samples are negative and 34.18% of the area samples are positive. This explains that the groundwater in major portions of the study area do not have long residence time in the aquifers (Freeze and Cherry, 1979; Fetter, 1980).

Table 12 Distribution Index Base Exchange (IBE) of Chamarajanagar Taluk at area in sq.km

IBE- 1 Values	Value Ranges	Area in sq.km	percentage
1	-3.31 to -1.43	81.72	6.70
2	-1.43 to -0.49	336.06	27.50
3	0.49 to 0.82	804.72	65.80
		1222.50	100.00

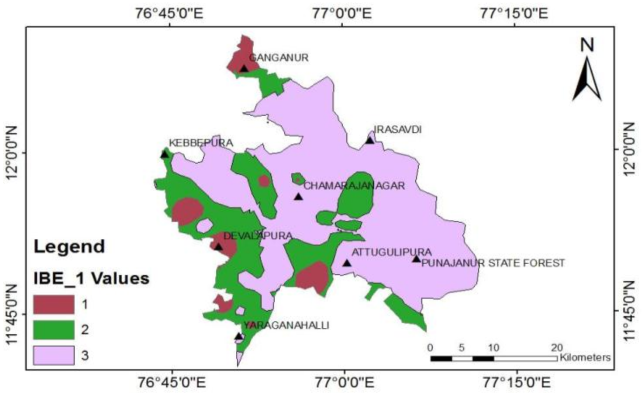

Fig.12 IBE-1 of the study area

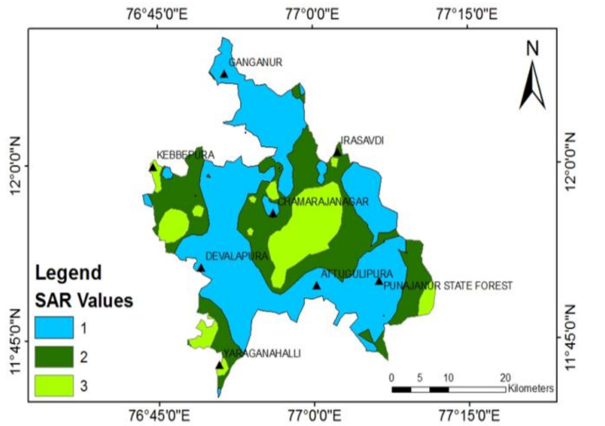

Fig.13 Sodium adsorption ratio of the study area

Sodium Adsorption Ratio (SAR)

(Fig.13) depicts the study area, based on SAR values 52.98% the groundwater of the area belonging to excellent irrigational water quality and 31.86% very good and also remaining area good Table 13.Since the urban area is growing very fast the utility of the water for irrigation is out of question.

A high salt concentration in water leads to formation of saline soil and high sodium leads to development of an alkali soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium absorption ratio (SAR). If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is less. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil (CGWB, 2009). If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. According to Richerds (1954) SAR is calculated as

$$SAR=[Na^+] / \{([Ca^{2+}] +[Mg^{2+}]) / 2\}^{1/2}$$

Where $[Na^+]$, $Ca^{2+}]$ and $[Mg^{2+}]$ are the concentrations in meq/L of sodium, calcium and magnesium ions in the soil solution. Concentration of sodium, calcium, and magnesium are determined by first extracting the ions from the soil into solution. Na^+, Ca^{2+}, and Mg^{2+} concentrations are commonly using atomic absorption spectrometry (AA).

Table 13 Distribution of SAR of Chamarajanagar at area in sq.km

SAR Values	Value ranges	Area in sq.km	Area in %	Water class
1	0.45 - 2.39	647.69	52.98	Excellent
2	2.39 - 3.09	389.45	31.86	Very good
3	3.09 - 5.69	185.36	15.16	good
TOTAL		1222.50	100.00	

Groundwater hardness

Hardness is an important criterion for determining the solubility of water for domestic, drinking and industrial purposes. Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulphate in water. It is expressed as the equivalent quantity of calcium carbonate. Water hardness is divided into permanent hardness and temporary hardness, the sum of two being total hardness. The carbonate hardness or temporary hardness, is caused by Ca and Mg carbonates. The hardness is computed by multiplying the sum of meq/L of Ca and Mg by 50 and expressed as equivalent amount of $CaCO_3$. The resultant hardness value is generally indicated as hardness of $CaCO_3$ or Ca+Mg hardness or total hardness. Carbonate hardness includes only that portion of the hardness equal to the HCO_3+CO_3.

If the hardness exceeds alkalinity, the excess is turned as noncarbonated hardness. Sulphates and chlorides of Ca and Mg cause the non-carbonate hardness or permanent hardness. It can be calculated by the formula:

$$NCH = (Ca+Mg) – (CO_3+HCO_3) \times 50$$

The normal range is 300 (desirable) to 600 ppm (permissible). The values of the total hardness not determine the available in the laboratory.

Table 14 Distribution of Groundwater hardness of Chamarajanagar at area in sq.km

Ranking	Area	%
1	0.03	0.003
2	224.85	18.392
3	223.43	18.277
4	338.50	27.689
5	244.19	19.975
6	107.17	8.766
7	72.46	5.927
8	11.09	0.907
9	0.78	0.064
Total	1222.50	100.000

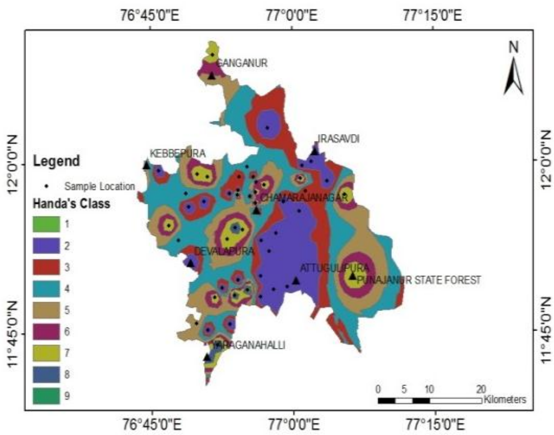

Fig.14 Handa's class of the study

Utilizing Handa's classification the groundwater of the study area have been classified into permanent (A_1, A_2, A_3) and temporary hard water (B_1, B_2, B_3) areas respectively. It is found that water belonging to temporary hardness occupies a small part of the study area and there is a gradual change of hardness from permanent to temporary hardness depending upon the time of residency of groundwater in the subsurface. It is of interest to note that 82% of the groundwater of the area belonging to permanent hard water indicating that the water can be used with happiness in the domestic or industrial sectors and 18% of the samples occupies the temporary water cannot be used with domestic or industrial sector of samples numbers 4,9,17,20,28, 35 etc

Groundwater Types

All the four types of the groundwater elucidated by schoellers (op cit) exists in the study area.

Table 15 Statistical data of Groundwater's types of the study area

Type	Hardness	No. of samples		Percentage	
A_1	Permanent	1,2,3,5,6,8,10,11,12,13, 14,16,18,19,21,22,23,26, 27,29,30,31,32,33,34,36, 38,39,41,42,43,45,46,50 =34	41	68.00	82.00
A_2		7,15,24,40,49=05		10.00	
A_3		25,47=02		04.00	
B_1	Temporary	4,9,17,20,28,35,37,44 48=09	09	18.00	18.00
B_2		NIL			
	Total	**50**		**100.00**	**100.00**

(Condensed Table 2)

Table16 Distribution of Schoeller of Chamarajanagar at area in sq.km

Ranking	Area	%
1	0.03	0.003
2	22.11	1.809
3	687.24	56.216
4	513.12	41.973
Total	1222.50	100.000

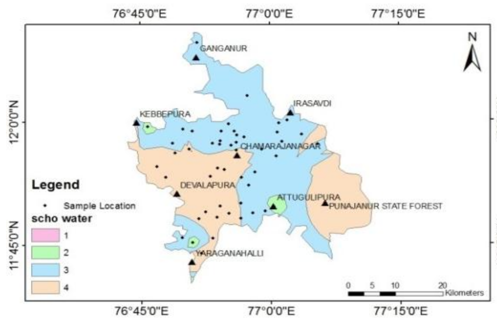

Fig.14 Schoeller water types of study area

The above (**Table 15)** it is clear that groundwater type III predominates in the indicating a larger residence time of water in the subsurface and more time for the base exchange to take place.

Scheoller (1961) pointed out that the first and fore-most waters are those in which

γ CO3> γ SO4 Type I

As the total concentration increases, it becomes rSO_4 (Type I)

γ SO4> γ CL Type II

With still more increase in residence time the chemistry changes to

γ Cl>r SO4>**γ** CO3 Type III

And in the final stages the ionic concentrations reach a stage where

γ Cl>r SO_4> **γ** CO_3 and

(Na+K)>Mg>Ca Type IV

Where r is the epm concentration of the different ions.

Groundwater Salinity – Sodium Hazard

Based on the degree of salinity - sodium hazard the groundwater of the area gets divided into 7 horizons (C2S1, C3S1,C3S2, C4S2, C4S1, C5S2 and C5S1), with a maximum predomination of C3S1class (37) and among these all the water upto C_3 type could be suitably used for crops, similarly S_2 category water is suitable for soils with good drainage.

Table 17 Statistics data of salinity sodium hazard of study area

Quality Parameter	No. of Samples	Percentage
C2S1	4,34,35,37=04	08.00
C3S1	1,2,6,7,8,11,12, 13,14,15, 17,19,21,22,23, 24,25,26, 27,28,29,30,31 ,32,33,38 39,40,41,42,43 ,44,45,47 48,49,50=37	74.00
C3S2	5,9,10,18=04	08.00
C4S2	46=01	02.00
C4S1	3=01	02.00
C5S2	16,20=02	04.00
C5S1	36=01	02.00
Total	**50**	**100**

(*condensed Table 2)

$CaCO_3$ saturation Index ($CaCO_3$ SI)

From table 2, following data is extracted to show that the groundwater of the study area have equally distributed of positive and negative $CaCO_3$ SI values.

Table 18 $CaCO_3$ Saturation indices of the study area

$CaCO_3$ S.I	Saturation of index No. of samples	Percentage
Negative	1,2,3,7,13,20 ,23,25,30,34 36,37,38,43 ,44,47=16	32.00
Positive	4,5,6,8,9,10,11 ,12,14,15,16,17, 18,19,21, 22,24,26,27,28 ,29,31,32,33,35, 39,40,41,42,45, 46,48,49,50=34	68.00
Total	**50**	**100.00**

(*Condensed Table 2)

Table 18 the $CaCO_3$ saturation indices of the groundwater of the study area. The table could be divided into two portions positive and negative areas. Sharma, Prasad, Indira (Op cit) in their works clearly indicated that the $CaCO_3$ saturation indices have to be positive in the discharge areas and negative in the recharge areas. But such behavior is not reflected in this area confirming that (i)The groundwater have stayed for a longer time in the aquifers and (ii) the released calcite due to retrograde metamorphism has contributed more CO_3 to the groundwater of the area as was the case referred to by Balasubramanians; Venugopal, Chandrashekar, Siddaraju and Nagaraju in their doctoral thesis.

Stuyfzand's Water types

Based on this classification the groundwater of the water types have been sorted out to know the various implications.

Table 19 Groundwater main water types of study area

Main type	Code	No. of samples	Percentage
Oligohaline	G	4,17,37,48=04	08.00
Fresh	F	2,13,15,18, 19,20,21,22 ,23,24,25,26 ,27,30,31,32, 33,34,35,38,39, 40,41,42,43,44, 45, 46,47,49, 50=31	62.00
Fresh – brackish	f	1,3,5,6,7,8,9 ,10,11,12,14, 28,29=13	26.00
Brackish	B	16,36=02	04.00
Total		**50**	**100**

(*condensed Table 2)

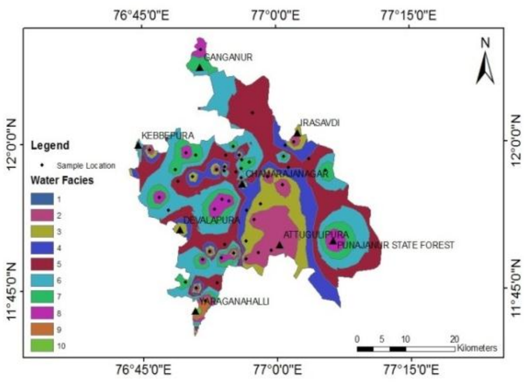

Fig.15 Groundwater facies of the study area

Table 20 Distribution of water facies of Chamarajanagar at area in sq.km

Ranking	Area	%
1	0.03	0.003
2	102.19	8.359
3	119.15	9.747
4	147.50	12.065
5	360.34	29.476
6	297.44	24.331
7	128.75	10.531
8	56.80	4.646
9	7.99	0.653
10	2.32	0.190
Total	1222.50	100.000

As per Stuyzand's style of classification majority of the area groundwater (62%) belong to the fresh quality type of water and followed by oligohaline type of water (8%) brackish type of water around 4% and fresh-brackish type of water 26% are noticed.

Mechanism controlling groundwater chemistry

It is interest to note that from **Table 22** that majority of rock interaction occupying the major areal extent of 70.00% and followed by evaporation is around 28.00% of the area and area 2% of the precipitation.

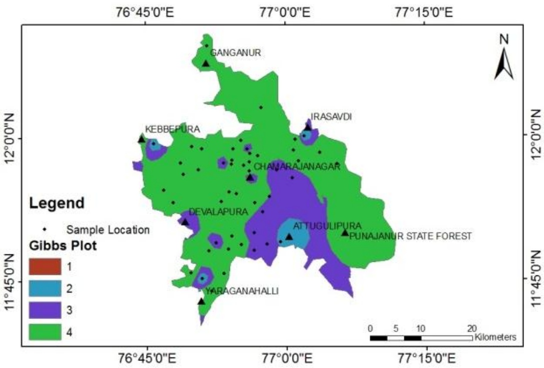

Fig.16 GIBB'S plots of the study area

Table 21 Distribution of Gibb's plots Chamarajanagar at area in sq.km

Ranking	Area	%
1	0.03	0.003
2	39.69	3.247
3	275.94	22.572
4	906.84	74.179
Total	1222.50	100.000

Table 22 Statistics data of Gibb's plot of the study area

Gibb's ratio	No. of Samples	Percentage
Evaporation	1,3,10,14, 16,20,21, 26,27,28, 36,44,45, 46 =14	28.00
Rock interaction	2,4,5,6,7, 8,9,11, 12,13,15, 17,18, 19,22,24, 25,29, 30,31,32, 33,34, 35,37,38, 39,40, 41,42,43, 47,48, 49,50=35	70.00
Precipitation	23=01	02.00
Total	50	100.00

(*Condensed Table 2)

The point scatter for the area on a majority fall into rock dominance area followed by precipitation dominance horizon. This is clearly shows and confirms the hydrometerological parameters maps are not much of rainfall dominance on the chemistry.

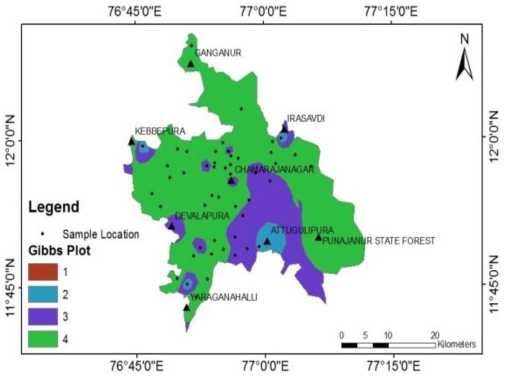

Fig.17GIBB'S plot of study area

Evaluation for Irrigation Purpose

Irrigation water quality refers to its suitability for agricultural use. The suitability of water for agricultural use depends on many factors such as water quality, soil type, cropping pattern, etc. of these factors, water quality is very important as excessive amount of dissolved ions in irrigation water limit plant growth physically, by restricting the uptake of water through modification of osmotic processes and by the effects of toxic substances on metabolic processes. Quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area. Good quality water has the potential to cause maximum yield under good soil and good water management practices.

Conclusion

The study area is facing the problem of exploitation and deterioration of groundwater quality due to rapid use of ground water for irrigation, domestic and industrial purpose. In the absence of perennial source of surface water and inadequate rainfall the problems are increasing year after year. Water quality has deteriorated considerably due to unscientific disposal of domestic, industrial and agricultural waste. Change in land use pattern resulted in the degradation of hydrogeochemical environment. From the foregoing account of ground water quality studies carried out in study area, the salient features are emerged out are as follows:

1. The ground water is Na-Mg and HCO3 facies dominant.
2. Scholler's ground water type-III is dominant.
3. The majority of the area falls under permanent hardness followed by a Temporary hardness
4. Sodium adsorption ratio is – excellent

6. Salinity sodium Hazard- C3S1 is predominant
7. Based on alkalinity Stuyfzand's water type-is High

Result

(a) Measure must be taken to prevent pollution from agricultural and sewage effluents which are due to anthropogenic activity
(b) Priority must be given for conservation of rain water through various rain water harvesting measures
(c.) More concentration is necessary towards ground water recharge by constructing various artificial recharge structures
(d)Create awareness among the public towards judicious use of available potable water resources
(e)Bring awareness among the public towards Change in land use pattern.

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