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Evaluation of Groundwater Quality and Its Suitability for Drinking and Agriculture Use in Dodda-Halla Sub-Basin, Belgaum and Bagalkot District, Karnataka State.

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Abstract : *The problems of water quality have become more important than the quantity, as the environmental problems are getting more serious in different parts of the world. A number of factors like Geology, soil, effluents, sewage disposal and other environmental conditions in which the water happens to stay or move and interact with ground and biological characteristics. These influence greatly on the groundwater quality of an area. This study is made to evaluate the status of groundwater quality and its suitability for drinking and agricultural purposes. For this study, 60 water samples of pre-monsoon and post-monsoon seasons were collected. The chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) and the concentration of ions such as Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Bicarbonate (HCO_3), Sulphate (SO_4) and Chloride (Cl) were analysed in order to understand the different geochemical processes. The chemical characteristics were determined as per the standard methods for examination of water and waste water proposed by APHA (2002) and Trivedi & Goel (1984). All the results were compared with the standard limits recommended by the Bureau of Indian Standards (BIS, 1991) and the World Health Organization (WHO,1993), which indicate that the majority of the groundwater samples are within the limits prescribed. Besides, suitability of water for irrigation is evaluated based on SAR, RSC, Sodium percent, Salinity hazard and USSL diagrams. The results reveal that, the water has moderate to high salinity and low to medium alkalinity is suitable for irrigation.*

Keywords: *Dodda-Halla sub-basin, Drinking and Irrigation water quality, Ground water in hard rocks*

I. Introduction

Groundwater is an important source of drinking water for many people around the world. The resource in several places becomes contaminated from natural source or numerous human activities. Residential, municipal, commercial, industrial and agricultural activities affect groundwater quality. Contamination of groundwater results in poor drinking water quality, loss of water supply, high cleanup costs, high costs alternative water supplies and potential health problems. This study is related to both water quality and quantity. Exploitation of groundwater is a must and it is the main source for agricultural, industrial, drinking and domestic purposes. Water quality data are utilized in the present study to analyse the groundwater chemistry for pre-monsoon and post-monsoon seasons. Hydrogeochemical data are used in the analysis, including Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) and Sodium Adsorption Ratio (SAR).

II. Study Area

The study area, Dodda-Halla sub-basin, is a typical hard rock terrain covering an area of approximately 365 sq. kms. and lies between the latitudes N 16^0 03' 40" to 16^0 19' 50" and longitudes E 75^0 05' 10" to 75^0 16' 45" in Belgaum and Bagalkot district of Karnataka. The region is one of the draught prone areas receiving low rainfall and is classified as arid to semi arid region. Geologically, the area comprises of lime stones and quartzites of Kaladgi series belonging to Bagalkot group of proterozoic age and Deccan traps of Cretaceous – tertiary age. The Deccan trap sequence consists of multiple layers of solidified lava flows of dark grey colour with intertrappean beds. The groundwater occurs under water table conditions and is mainly controlled by the extent of its secondary porosity i.e. thickness of weathered rocks and spacing of joints and fractures in both the litho units. The highly weathered trap and underlying weathered, jointed and fractured massive trap and the lime stones constitutes the main water yielding zones.

III. Materials and methods

Survey of India (SOI) topo-sheets (1:50000 scale) were used for the preparation of the base map. GIS software package ArcGIS 9.2 is used to map and analyze the data for the evaluation of groundwater quality. In order to assess the ground water quality, a total of 60 representative samples were collected for pre and post monsoon periods of 2013 covering the entire study area. Samples were stored in polythene bottles and analysed for major and minor cations and anions using standard procedures. EC, pH and TDS were measured on spot by

pH and conductivity meters. The chemical results are compared with standard limits recommended by the Bureau of Indian Standards (BIS, 1991) and the World Health Organization (WHO,1993).The chemical characteristics were determined as per the standard methods for examination of water and waste water proposed by APHA (2002) and Trivedi&Goel (1984).

IV. Results And Discussion

A. Groundwater Quality Assessment :

Groundwater quality assessment was carried to determine its suitability in terms of drinking and Agricultural purposes. The hydro chemical analysis of groundwater samples of both the seasons are presented in Table 1 and 2 and the statistical analysis of chemical parameters of the Pre and post monsoon water samples are presented in Table 3 and 4 (a&b). The hydrochemical parameters of groundwater are compared with the limits prescribed by the Bureau of Indian Standards (BIS,1991), and the World Health Organization (WHO,1993). The pH of a water sample measures its hydrogen ion concentration and indicates whether the water is acidic, neutral or basic. The pH value of absolute pure water is 7. If the pH value is less than 7, the water is said to be acidic in nature and if it is more than 7, the water is called an alkaline. The pH values of ground water ranged from 7 to 8 showing that, the groundwater of the study area is mostly alkaline in nature.

B. Statistical Analysis for Post and pre monsoon water chemistry :

The statistical analyses of the chemical data of the groundwater samples of Post&Pre- monsoon have been undertaken. Important Statistical parameters such as maximum, minimum, mean, Standared deviation have been calculated and presented in table-.3 .Correlation matrix of 13 hydrochemical parameters reveals the good correlations of both monsoons and is given in table 4(a) & 4(b). The results points out that, the mean values of all the chemical quality characteristics are within permissible limits for drinking as well as irrigation purpose. Pre and Post Monsoon Chemical analysis results are compared with the ISI standards table-5.

C. Electrical Conductivity (EC) :

Electrical Conductivity is the measure of capacity of a substance to conduct the electric current. It depends upon the presence of various ionic species in the water. The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and other mineral contamination (Jain *et. al*,2009). The value of EC varied between 7730 μmhos to 530 μmhos during the pre-monsoon period and was observed to be maximum in Hosur (7730 μmhos/cm) and minimum in Timmapur (530 μmhos/cm). In post-monsoon period, higher concentration was observed in Hosur (7880 μmhos/cm) and lower in Kunnal (170 μmhos/cm).During the pre-monsoon period, results show that 45% of the samples fall under permissible category, 40% under doubtful category while the remaining 15% under good category. The results of post-monsoon period show that 33% of the samples fall under permissible category, 45% under doubtful category, 15% under good category and 7% of samples under excellent category (Table 6).

D. Total Dissolved Solids (TDS) :

The determination of total dissolved solids is a measure of all salts in solution. Since EC of water is a function of the concentration of dissolved constituents, an estimate of total dissolved solids in ppm, in a fresh water sample can be made using the relationship, specific conductance of micro mhos at 25 0 C x A = dissolved solids in ppm. 'A' has a value between 0.55 and 0.75, if the value is higher than this value, indicates that the water is a saline one. If the value is lower than the value indicating that the water will be in acid condition. For irrigation and most other natural waters, milli mhos are customarily taken as equal to 640 mg. per liter of water and can be classified according to its TDS content (Hem, 1970). But Davis and De Wiest (1996) classified the water with TDS content of 1,000 to 10,000 mg/l as brackish, 10,000 to 100,000 mg/l as salty and more than 100,000 mg/l as brine (Table 7).

During pre-monsoon period, the TDS was observed to be maximum in Hosur, minimum in Timmapur and in post-monsoon period higher concentration was observed in Hosur and lower in Kunnal. The results show that 45% and 38% of the samples fall under fresh water category, 50% and 54% under slightly saline category while the remaining 5% and 8% fall under moderately saline category, for pre and post monsoon seasons respectively.

E. Total Hardness (TH) :

Hardness of water refers to the soap neutralizing power of water. Since soap is precipitated primarily by calcium and magnesium ions, hardness is defined as the sum of concentration of these ions expressed as mg/l of CaCO3. Generally water with a hardness of less than 50 ppm is rated as a soft water. The hardness below 500

ppm is recommended for drinking purpose. But for agricultural purpose, more than 1000 ppm of hardness is also accepted (Rao, 1975).

During pre-monsoon period, the TH was observed to be maximum in Hosur, minimum in Timmapur and in post-monsoon period higher concentration was observed in Hosur and lower in Kunnal. During both the seasons, result shows 43% and 60% of samples fall under very very hard category, 43% and 30% of samples fall under very hard category while the remaining 14% and 7% of samples fall under slightly hard category and the 3% of post-monsoon samples fall under the soft category (Table 8).

F. Residual Sodium Carbonate :

The result revels that 97% and 27% Samples fall in good category of both the monsoons respectively, 3% and 25% of pre and post monsoon samples fall in the medium category and the remaining 48% of the post-monsoon samples fall under the bad category (Table 9).

G. Sodium Adsorption Ratio (SAR) :

During pre-monsoon period, the SAR was observed to be maximum in Hosur and minimum in Timmapur. In post-monsoon period, higher concentration was observed in Hosur and lower in Kunnal. During pre-monsoon period, results show that 95% of the samples fall under excellent category and 5% under good category. The results of post-monsoon period show that 97% of the samples fall under the excellent category and 3% under good category (Table 10). The sodium or alkali hazard in the use of water for irrigation is expressed by determining the Sodium Adsorption Ratio (SAR). The Sodium Adsorption Ratio of the samples from the study area ranges between 1.63 to 11.64 and 0.52 to 12.26 in pre monsoon and post monsoon respectively. There is no much variation in SAR concentrations, the value being less than 10 in most of the samples except a few.

The plot of the data on the US Salinity diagram (1954) (Fig.2) in which the EC is taken as salinity hazard and SAR as sodium (alkali) hazard shows that 48% and 33% of the samples of both the seasons in the study area falls in C3S1; 23% and 22% of the samples of pre and post monsoon fall in C4S2; 12% and 22% of the pre and post monsoon samples fall in C4S1 ; 12% and 10% of the samples of both the season fall in C2S1; 5% and 3% of the samples of pre and post monsoon fall in C5S3 ;3% of the samples fall in C1S1 and C5S2 of post monsoon and 2% of the post monsoon fall in the C3S2 and C5S1, indicating Moderate to High salinity and low to medium alkalinity water suitable for irrigation. (Table11).

H. Mechanisms controlling water chemistry:

Gibb's diagram that represent the ratios of Na+: (Na++Ca2+) and Cl-: (Cl-+HCO3-) as a function of TDS are widely employed to understand the functional sources of dissolved chemical constituents such as precipitation-dominance, rock dominance and evaporation dominance (Gibbs, 1970), Viswanathaiah et al. (1978) emphasized the mechanism of controlling the chemistry of groundwater of Karnataka. The chemical data of the water samples are plotted on the Gibbs diagram (Fig.3). The majority of the samples from both pre- and post-monsoon fall in the rock dominance area indicating the interaction between the rock and water in the sub surface and few samples fall in the Evaporation dominance.

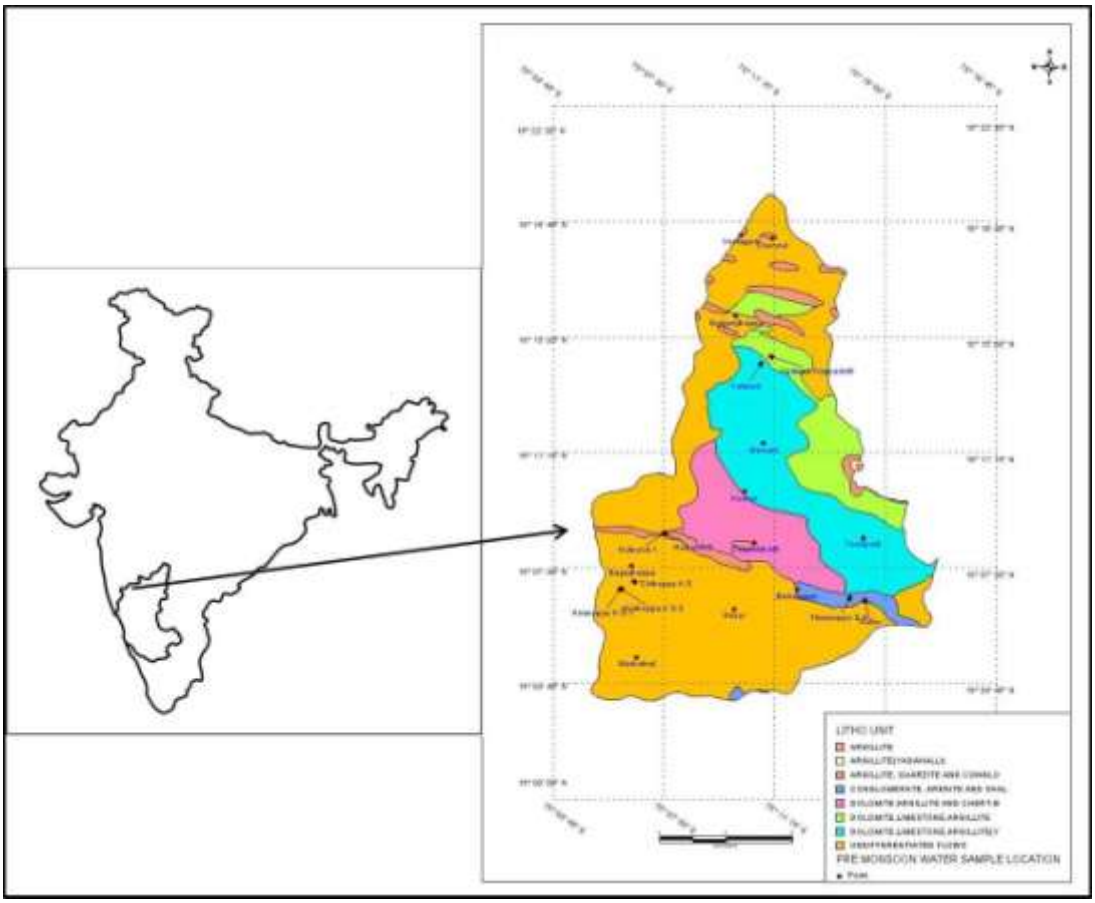

Figure 1: Location and Geological Map of Dodda-halla Sub-Basin

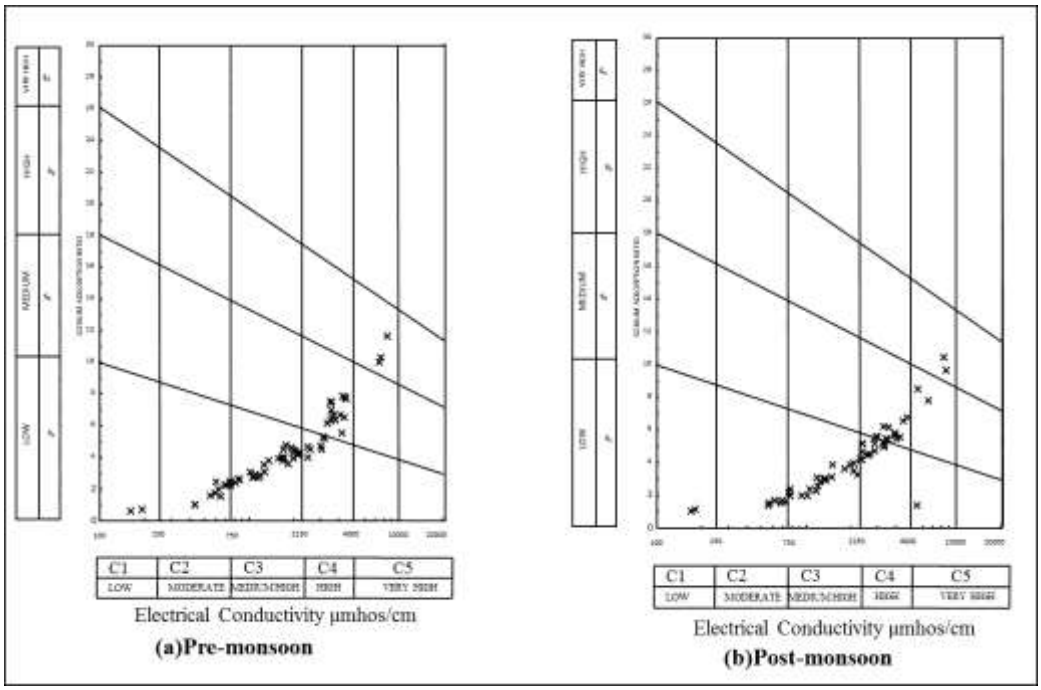

Figure 2: USSL Classification of Irrigation Water

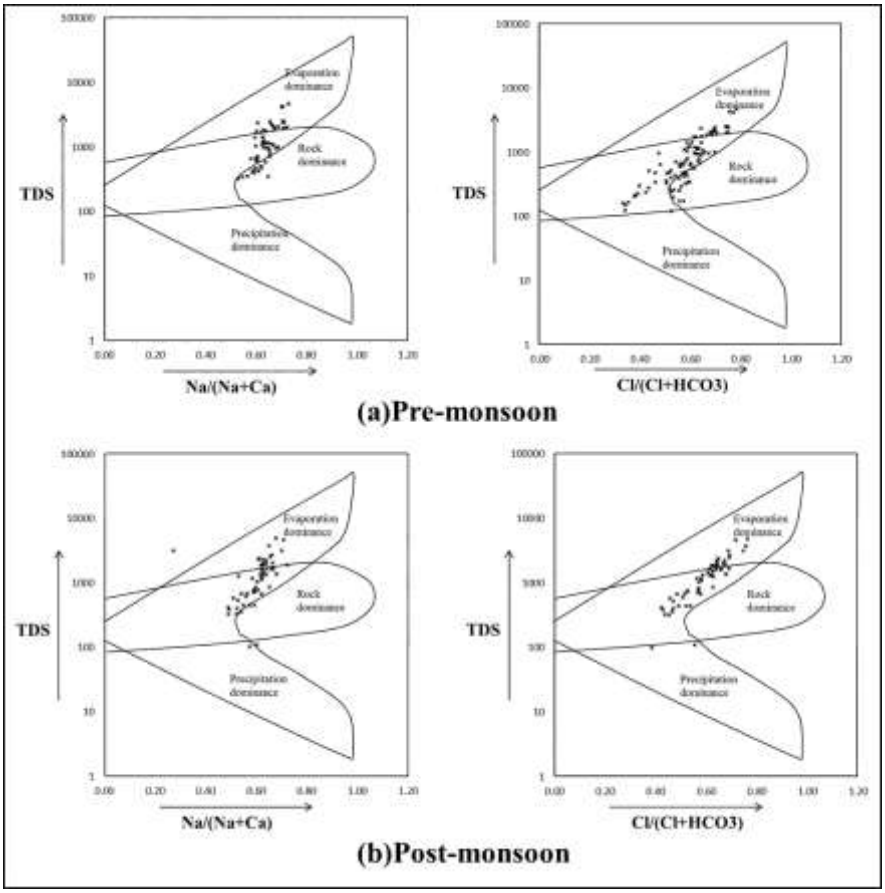

Figure3: Gibb's Classification diagram

Table 1: Chemical parameters of the Pre-monsoon water samples

Sample ID	Sample type	Location	Easting	Northing	Ca	Mg	Na	K	Fe	HCO3	Cl	F	NO3	SO4	TDS	EC	TH	pH
1	BW	Murkatnal	16.076	75.109	94	46	220	2	0.3	314	336	0.76	62	120	1084	1810	420	7.76
2	BW	Murkatnal	16.076	75.109	106	52	224	5	0	343	342	0.84	38	170	1160	1940	472	7.62
3	BW	Murkatnal	16.076	75.109	112	55	220	2	0	363	336	0.9	72	150	1183	1970	500	7.52
4	BW	Chikkoppa.k.s	16.117	75.108	61	30	106	0	0	220	162	0.58	28	70	600	1010	272	7.92
5	BW	Chikkoppa.k.s	16.117	75.108	64	30	114	0	0	201	174	0.72	32	92	636	1060	280	7.8
6	BW	Chikkoppa.k.s	16.117	75.108	54	26	110	2	0	181	168	0.56	27	75	580	970	240	7.72
7	BW	Hirekoppa.k.s	16.114	75.1	62	30	108	1	0	225	165	0.61	28	72	614	1030	276	7.88
8	BW	Hirekoppa.k.s	16.114	75.1	67	33	116	4	0	235	176	0.68	28	92	670	1120	300	7.7
9	BW	Hirekoppa.k.s	16.114	75.1	69	32	110	2	0	245	188	0.7	28	82	650	1090	300	7.82
10	BW	Bagojikoppa	16.125	75.107	72	35	128	3	0	245	196	0.61	38	94	725	1210	320	7.77
11	BW	Bagojikoppa	16.125	75.107	70	32	154	2	0	225	227	0.72	32	110	774	1290	304	7.66
12	BW	Bagojikoppa	16.125	75.107	64	32	140	4	0	216	213	0.73	32	84	720	1200	288	7.8
13	BW	Hulkund	16.143	75.125	90	43	186	4	0.2	304	286	0.36	40	220	970	1620	396	7.68
14	BW	Hulkund	16.143	75.125	83	40	212	2	0	245	325	0.4	40	138	1000	1670	368	7.58
15	BW	Hulkund	16.143	75.125	82	40	200	2	0	260	308	0.48	36	124	960	1610	364	7.62
16	BW	Kunnal	16.166	75.169	168	85	330	12	0	441	504	0.98	210	250	1846	3000	760	7.4
17	BW	Kunnal	16.166	75.169	147	72	440	12	0	392	672	1.02	184	210	1992	3270	656	7.42
18	BW	Kunnal	16.166	75.169	149	72	450	12	0	402	678	1	182	220	2024	3320	660	7.44
19	BW	Chippalakatti	16.138	75.175	230	110	410	10	0.3	613	634	0.54	240	330	2362	3860	1016	7.32
20	BW	Chippalakatti	16.138	75.175	184	90	520	12	0	451	784	0.82	220	310	2413	3950	820	7.23
21	BW	Chippalakatti	16.138	75.175	187	98	530	14	0.3	470	798	0.78	230	330	2493	4080	860	7.34
22	BW	Bichaguppi	16.113	75.2	85	43	182	1	0	284	280	0.28	40	120	936	1570	384	7.84
23	BW	Bichaguppi	16.113	75.2	90	44	176	6	0	377	196	0.4	40	170	970	1590	400	7.78
24	BW	Bichaguppi	16.113	75.2	80	40	174	2	0	260	266	0.38	35	124	890	1490	360	7.14
25	BW	Kullur	16.107	75.238	43	19	78	0	0	152	118	0.66	24	44	425	710	184	8.05
26	BW	Kullur	16.107	75.238	48	22	82	1	0	167	126	0.62	20	53	466	780	209	7.88
27	BW	Kullur	16.107	75.238	45	21	74	1	0	157	106	0.52	22	62	433	720	196	7.9
28	BW	Tondikatti	16.141	75.238	163	80	330	5	0.2	480	504	0.32	92	270	1760	2920	728	7.62
29	BW	Tondikatti	16.141	75.238	168	90	292	5	0.3	470	448	0.56	176	260	1744	2860	780	7.5
30	BW	Tondikatti	16.141	75.238	160	86	300	4	0.2	490	448	0.8	132	260	1709	2820	744	7.42
31	BW	Timmapur	16.109	75.23	32	15	68	0	0	118	101	0.36	20	34	346	580	140	7.92
32	BW	Timmapur	16.109	75.23	38	18	53	0	0	147	73	0.4	19	45	342	570	168	7.74
33	BW	Timmapur	16.109	75.23	37	17	48	0	0	118	70	0.36	28	48	321	530	160	7.68
34	BW	Hosur	16.103	75.165	323	160	880	30	0.2	696	1344	1.74	340	650	4180	6830	1448	7.31
35	BW	Hosur	16.103	75.165	336	170	1050	34	0.3	784	1624	1.68	342	630	4700	7730	1520	7.28
36	BW	Hosur	16.103	75.165	328	160	910	24	0.2	784	1400	1.72	330	580	4242	6970	1460	7.24
37	BW	Yadwad	16.235	75.179	203	90	456	18	0	529	700	2.3	142	340	2206	3780	868	7.38
38	BW	Yadwad	16.235	75.179	192	100	530	14	0	490	812	2.18	160	370	2497	4120	880	7.32
39	BW	Yadwad	16.235	75.179	214	110	470	10	0	544	728	2.24	240	340	2466	4040	976	7.28
40	BW	Yadwad-Koppadatti	16.234	75.185	43	20	78	0	0	147	120	0.34	24	48	430	720	188	7.92
41	BW	Yadwad-Koppadatti	16.234	75.185	48	24	90	1	0	172	137	0.44	26	58	496	830	216	7.84
42	BW	Yadwad-Koppadatti	16.234	75.185	46	24	88	0	0	167	134	0.54	24	58	483	810	212	8
43	BW	Vantagodi	16.304	75.168	160	78	382	12	0.4	466	588	1.4	140	260	1890	3130	712	7.45
44	BW	Vantagodi	16.304	75.168	168	83	400	8	0.4	500	616	120	114	260	1974	3280	752	7.4
45	BW	Vantagodi	16.304	75.168	154	80	430	10	0.2	490	672	1.32	88	230	1982	3320	704	7.48
46	BW	Manami	16.191	75.18	194	90	440	16	0	519	672	1.14	140	330	2220	3360	844	7.42
47	BW	Manami	16.191	75.18	182	90	420	10	0	510	672	1.2	116	280	2102	3500	816	7.68
48	BW	Manami	16.191	75.18	168	87	428	6	0	539	658	1.18	120	240	2058	3430	768	7.7
49	BW	Gulganjikoppa	16.261	75.165	134	60	260	10	0	392	409	1.32	94	180	1402	2320	576	7.62
50	BW	Gulganjikoppa	16.261	75.165	138	72	234	6	0	441	361	1.28	120	180	1398	2310	632	7.52
51	BW	Gulganjikoppa	16.261	75.165	131	65	254	4	0	441	392	1.14	96	200	1429	2400	588	7.44
52	BW	Chennal	16.303	75.186	108	50	220	6	0.3	343	336	1.06	38	158	1135	1900	460	7.69
53	BW	Chennal	16.303	75.186	114	60	226	3	0	407	350	1.04	80	128	1225	2050	524	7.7
54	BW	Chennal	16.303	75.186	112	58	218	2	0.2	402	336	1.08	60	138	1185	1990	512	7.88
55	BW	Hirekoppa	16.114	75.1	42	18	70	0	0	147	106	0.82	22	40	395	660	176	8.02
56	BW	Hirekoppa	16.114	75.1	40	17	60	0	0	157	92	0.52	20	24	355	600	168	8
57	BW	Hirekoppa	16.114	75.1	43	19	71	0	0	172	109	0.42	18	30	402	680	184	7.98
58	BW	Hulkund1	16.143	75.125	104	50	180	2	0	343	280	0.98	62	130	1030	1720	460	7.84
59	BW	Hulkund1	16.143	75.125	99	50	220	3	0	343	336	1	70	120	1121	1870	448	7.78
60	BW	Hulkund1	16.143	75.125	104	55	200	4	0	392	308	0.92	60	116	1102	1850	480	7.74

Note: EC=Electrical conductivity in micro mhos/cm, all other values except pH are in ppm, TH= Total hardness, TDS= Total Dissolved Solids

Table 2: Chemical parameters of the Post-monsoon water samples

Sample ID	Sample type	Location	Easting	Northing	Ca	Mg	Na	K	Fe	HCO3	Cl	F	NO3	SO4	TDS	EC	TH	pH
1	BW	Hosur	16.103	75.165	323	162	690	28	0.2	588	1064	1.68	280	770	3700	6020	1456	7.44
2	BW	Hosur	16.103	75.165	245	125	660	20	0	593	1008	1.34	220	480	3143	5170	1112	7.34
3	BW	Hosur	16.103	75.165	392	205	950	42	0	784	1456	1.48	330	940	4825	7880	1800	7.33
4	BW	Hosur	16.103	75.165	352	190	980	24	0	1029	1512	1.38	240	626	4593	7640	1640	7.28
5	BW	Kullur	16.107	75.238	48	20	80	0	0	196	123	0.68	20	23	442	750	200	7.81
6	BW	Kullur	16.107	75.238	48	22	74	0	0	167	112	0.72	28	51	444	740	208	7.9
7	BW	Kullur	16.107	75.238	50	24	70	0	0	191	106	0.52	24	47	445	750	220	7.94
8	BW	Tondikatti	16.141	75.238	112	58	272	8	0.2	343	420	0.54	74	180	1347	2240	512	7.74
9	BW	Tondikatti	16.141	75.238	144	70	330	12	0.2	392	504	0.44	122	240	1677	2760	640	7.68
10	BW	Tondikatti	16.141	75.238	146	70	330	16	0.2	451	504	0.52	120	204	1683	2780	644	7.72
11	BW	Tondikatti	16.141	75.238	131	65	254	4	0.2	441	392	0.6	96	200	1429	2400	588	7.62
12	BW	Bichaguppi	16.113	75.2	66	32	124	0	0	240	190	0.34	34	70	672	1130	292	7.71
13	BW	Bichaguppi	16.113	75.2	72	36	120	2	0	245	185	0.86	41	92	707	1180	324	7.62
14	BW	Bichaguppi	16.113	75.2	280	150	120	22	0.2	686	868	1.02	210	580	3116	5120	1300	7.34
15	BW	Chippalakatti	16.138	75.175	78	38	128	4	0	304	196	0.6	33	80	755	1270	348	7.66
16	BW	Chippalakatti	16.138	75.175	208	100	400	20	0.2	519	616	0.82	220	340	2242	3650	920	7.44
17	BW	Chippalakatti	16.138	75.175	187	88	360	14	0	539	560	0.9	120	290	1970	3260	820	7.54
18	BW	Hulkund	16.143	75.125	104	49	182	2	0	363	280	0.82	60	115	1028	1720	456	7.7
19	BW	Hulkund	16.143	75.125	107	55	200	2	0	382	308	0.94	60	130	1110	1860	488	7.58
20	BW	Hulkund	16.143	75.125	61	30	78	0	0	230	118	0.32	22	70	528	890	272	8.03
21	BW	Kunnal	16.166	75.169	11	5	17	0	0	69	25	0.32	4	6	100	170	48	8.04
22	BW	Kunnal	16.166	75.169	11	5	19	0	0	39	28	0.16	9	11	109	180	48	7.98
23	BW	Kunnal	16.166	75.169	128	65	236	8	0.2	441	361	0.8	90	160	1335	2220	580	7.64
24	BW	Manami	16.191	75.18	224	105	400	20	0.2	583	616	1.18	230	340	2314	3770	980	7.35
25	BW	Manami	16.191	75.18	202	102	410	8	0.2	613	630	1.04	140	310	2200	3650	912	7.4
26	BW	Manami	16.191	75.18	227	106	410	20	0.2	588	624	1.16	240	350	2360	3940	992	7.62
27	BW	Manami	16.191	75.18	178	90	330	7	0	539	510	1.1	110	280	1855	3080	804	7.54
28	BW	Yadwad	16.235	75.179	176	88	360	14	0.3	466	560	2.32	160	290	1951	3200	792	7.26
29	BW	Yadwad	16.235	75.179	181	90	336	6	0.3	539	518	220	120	280	1881	3120	812	7.18
30	BW	Yadwad	16.235	75.179	40	20	54	0	0	167	84	0.42	18	30	355	600	180	8.06
31	BW	Yadwad	16.235	75.179	48	22	53	0	0	186	81	0.54	22	38	385	650	208	7.84
32	BW	Yadwad	16.235	75.179	77	36	128	2	0	304	196	0.82	24	73	734	1240	336	7.66
33	BW	Yadwad	16.235	75.179	75	38	132	3	0	265	204	0.78	40	94	760	1270	340	7.7
34	BW	Gulganginkop	16.261	75.165	227	120	510	24	0.2	608	784	1.08	250	380	2690	4400	1048	7.28
35	BW	Gulganginkop	16.261	75.165	221	110	480	10	0.4	564	728	1.2	218	380	2514	4120	992	7.4
36	BW	Gulganginkop	16.261	75.165	123	63	234	4	0	387	358	0.78	80	186	1300	2160	560	7.77
37	BW	Gulganginkop	16.261	75.165	125	59	254	3	0	412	392	0.8	92	140	1332	2220	548	7.68
38	BW	Channal	16.303	75.186	144	73	270	7	0.4	436	420	1.02	108	210	1515	2510	652	7.38
39	BW	Channal	16.303	75.186	142	68	320	4	0.2	441	490	1.1	110	186	1607	2670	628	7.52
40	BW	Channal	16.303	75.186	150	80	290	12	0.2	490	448	1.12	110	220	1630	2700	696	7.32
41	BW	Channal	16.303	75.186	150	73	310	4	0.3	480	493	1.18	110	172	1625	2710	668	7.4
42	BW	Vantagodi	16.304	75.168	187	88	360	14	0	539	560	1.44	120	290	1970	3260	820	7.44
43	BW	Vantagodi	16.304	75.168	176	83	400	12	0	539	622	1.38	120	240	2003	3330	772	7.38
44	BW	Vantagodi	16.304	75.168	178	84	340	10	0.2	519	518	1.38	114	280	1861	3080	780	7.42
45	BW	Vantagodi	16.304	75.168	121	80	360	5	0.3	539	560	1.36	118	210	1855	3090	748	7.58
46	BW	Hirekoppa	16.114	75.1	74	38	100	2	0	284	154	0.64	26	86	665	1120	336	7.62
47	BW	Hirekoppa	16.114	75.1	40	18	44	0	0	147	70	0.52	18	35	320	540	172	7.89
48	BW	Hirekoppa	16.114	75.1	38	18	48	1	0	157	70	0.4	24	27	328	550	168	7.92
49	BW	Hirekoppa	16.114	75.1	74	36	110	0	0	274	168	0.38	34	78	678	1140	328	7.7
50	BW	Chikkoppa	16.117	75.108	46	23	58	0	0	176	90	0.56	20	46	398	670	208	7.06
51	BW	Chikkoppa	16.117	75.108	66	32	96	1	0	245	146	0.62	22	78	600	1010	292	7.78
52	BW	Chikkoppa	16.117	75.108	69	33	82	0	0	260	126	0.5	32	66	577	970	304	7.88
53	BW	Chikkoppa	16.117	75.108	51	24	56	1	0	206	87	0.42	24	38	415	700	224	7.98
54	BW	Murkatnal	16.076	75.109	112	57	210	4	0.2	402	319	0.94	62	140	1165	1950	508	7.66
55	BW	Murkatnal	16.076	75.109	147	62	190	4	0.3	343	336	0.84	70	220	1252	2080	616	7.47
56	BW	Murkatnal	16.076	75.109	118	64	190	2	0.2	392	291	0.88	72	178	1170	1950	552	7.68
57	BW	Bagojikoppa	16.125	75.107	85	42	144	2	0	294	224	0.4	36	110	834	1400	380	7.58
58	BW	Bagojikoppa	16.125	75.107	78	37	168	2	0	260	252	0.5	40	110	856	1430	344	7.7
59	BW	Thimmapur	16.109	75.23	112	58	272	8	0.2	343	420	0.54	74	180	1347	2240	512	7.74
60	BW	Thimmapur	16.109	75.23	131	65	254	4	0.2	441	392	0.6	96	200	1429	2400	588	7.62

Note: EC=Electrical conductivity in micro mhos/cm, all other values except pH are in ppm, TH= Total hardness, TDS= Total Dissolved Solids

Table 3: Statistical analysis of Chemical parameters of the Pre-monsoon water samples

Chemical Variables	Post monsoon				Premonsoon			
	Min	Max	Mean	std.Dev	Min	Max	Mean	Std.Dev
Ca	28	300	79	45.964	18	240	75	47.14
Mg	12	316	72	56.602	24	199	70	36.01
Na	21	644	217	142.267	5	621	199	115.039
K	1	246	16	37.622	2	196	15	31.161
HCO3	134	781	375	149.469	238	946	468	143.778
SiO2	29	648	147	115.564	7	394	126	77.687
Cl	46	1383	313	263.04	25	1170	266	211.091
NO3	1	129	20	24.04	0	46	11	10.331
F	0	2	1	4.44	0	3	1	0.732
TDS	368	3518	1125	669.865	388	2686	1033	485.261
TH	155	1900	493	325.914	145	1080	477	217.088
EC	550	6290	1887	1124	670	4210	1628	743.094
pH	7	9	8	0.314	7	9	8	0.278

Table 4(a): Correlation Matrix for Post-monsoon

Chemical Variables	Ca	Mg	Na	K	HCO3	SiO2	Cl	NO3	F	TDS	TH	EC	pH
Ca	1												
Mg	0.321	1											
Na	0.369	0.54	1										
K	0.036	0.002	0.189	1									
HCO3	0.114	0.362	0.598	0.439	1								
SiO2	0.486	0.654	0.698	0.086	0.397	1							
Cl	0.666	0.719	0.799	0.08	0.235	0.646	1						
NO3	0.259	0.292	0.439	0.234	0.364	0.354	0.281	1					
F	0.276	0.286	0.05	0.289	0.255	0.276	0.149	0.062	1				
TDS	0.618	0.731	0.914	0.248	0.556	0.799	0.912	0.493	0.011	1			
TH	0.763	0.857	0.57	0.022	0.309	0.711	0.853	0.34	0.045	0.836	1		
EC	0.651	0.75	0.883	0.217	0.49	0.778	0.938	0.47	0.033	0.991	0.867	1	
pH	0.424	0.106	0.15	0.002	0.013	0.11	0.284	0.246	0.374	0.249	0.302	0.279	1

Table 4(b): Correlation Matrix for Pre-monsoon

Chemical Variables	Ca	Mg	Na	K	HCO3	SiO2	Cl	NO3	F	TDS	TH	EC	pH
Ca	1												
Mg	0.631	1											
Na	0.545	0.561	1										
K	0.029	0.036	0.089	1									
HCO3	0.319	0.381	0.611	0.448	1								
SiO2	0.484	0.548	0.751	0.099	0.361	1							
Cl	0.773	0.862	0.813	0.005	0.398	0.636	1						
NO3	0.637	0.622	0.513	0.019	0.27	0.299	0.617	1					
F	0.066	0.284	0.353	0.072	0.425	0.199	0.262	0.093	1				
TDS	0.763	0.821	0.903	0.146	0.584	0.757	0.944	0.69	0.3	1			
TH	0.819	0.962	0.607	0.018	0.394	0.576	0.91	0.684	0.233	0.876	1		
EC	0.756	0.842	0.889	0.127	0.564	0.746	0.957	0.674	0.3	0.996	0.889	1	
pH	0.494	0.183	0.172	0.049	0.056	0.176	0.308	0.219	-0.03	0.268	-0.31	0.278	1

Table 5: Range in concentration of chemical parameters of the study area and Indian Standards for drinking water

Sl.No	**Parameters**	**Range in Concentration**		**Indian Standard (ISO 10500,1991)**		**Undesirable Effects Out side Highest**
		Pre Monsoon	**Post Monsoon**	**Highest Desirable**	**Minimum Permissible**	
1	**pH**	7.14-8.05	7.06 - 7.60	6.5 - 8.5	No relaxation	Water will affect the mucous membrane
2	**TDS**	321 - 4700	100 - 4825	500	2000	May Cause gastro-intenstinal irritation
3	**Ca**	32 - 336	11 - 392	75	200	Encrustation in water supply structure, adverse effects on domestic use
4	**Mg**	15 - 170	5 - 205	30	100	…..
5	**Na**	48 - 1050	17 - 980	…..	…..	…..
6	**Fe**	0 -0.4	0 - 0.4	0.3	1	Taste, appearance are affected, promotes Fe Bacteria
7	**HCO3**	118 - 784	39 - 1029	…..	…..	…..
8	**Cl**	70 - 1624	25 - 1512	250	1000	Taste,Corrosion and poratability are affected
9	**SO4**	24 - 650	6 - 940	200	400	Causes gastro-intestinal irritation when Mg or Na are present
10	**NO3**	18 - 342	4 - 330	45	100	Methaemoglobinemia takes place
11	**F**	0.28 - 2.3	0.16 - 2.32	1	1.5	High fluoride may cause fluorosis
12	**TH**	140 - 1520	48 - 1800	300	600	Encrustation in the water supply structure

Table 6: Classification of Irrigation Water Based on Electrical Conductivity

Water Class	EC (micro mhos/cm)	Salinity Significance	Pre-Monsoon	Post-Monsoon
Excellent	<250	Water of low salinity is generally composed of higher proportions of calcium, magnesium and bicarbonate ions.	0	04
Good	250-750	Moderately saline water, having varying ionic concentrations	9	09
Permissible	750-2250	High saline waters consist mostly of sodium and chloride ions	27	20
Doubtful	>2250	Water containing high concentration of sodium, bicarbonate and carbonate ions have high pH	24	27

Table 7: Condition of Water Quality with Reference to Concentration

Sl.No	Water Class	Values in ppm	Pre-Monsoon	Post-Monsoon
1	Fresh Water	Less than, 1,000	27	23
2	Slightly Saline	1,000 to 3,000	30	32
3	Moderately Saline	3,000 to 10,000	03	5
4	Very Saline	10,000 to 35,000	00	00
5	Brine	More than 35,000	00	00

Source: Davis and De Wiest, (1996)

Table 8: Recommended Range of Hardness

Total Hardness by Ragunath, 1987		$TH = (2.497Ca + 4.115Mg)$ • ppm value	
Classification		Pre Monsoon	Post Monsoon
Soft	0-55	0	2
Slightly Hard	56-100	0	0
Moderately Hard	101-200	8	4
Very Hard	201-500	26	18
Very Very Hard	>500	26	36

Table 9: Classification of RSC

Residual Sodium Carbonate by Richards, 1954		$RSC = (CO_3 + HCO_3) - (Ca + Mg)$ • epm values	
Classification		Pre Monsoon	Post Monsoon
Good	<1.25	58	16
Medium	1.25-2.50	02	15
Bad	>2.50	00	29

Table 10: Irrigation Water Classification based on Sodium Adsorption Ratio

Sodium Absorption Ratio	**Water Class**	**No. of Water Samples**	
		Pre-monsoon	**Post-monsoon**
Less than 10	Excellent	57	58
10 to 18	Good	3	2
18 to 26	Permissible	0	0
More than 26	Unsuitable	0	0

Table 11: USSL Classification of Irrigation Water

Classification by US Salinity diagram			**Number of Samples**	
Salinity	**SAR**		**Pre Monsoon**	**Post Monsoon**
Low	Low	$C_1 S_1$	0	2
Low	Medium	$C_1 S_2$	0	0
Low	High	$C_1 S_3$	0	0
Low	Very-High	$C_1 S_4$	0	0

Moderate	Low	$C_2 S_1$	7	6
Moderate	Medium	$C_2 S_2$	0	0
Moderate	High	$C_2 S_3$	0	0
Moderate	Very-High	$C_2 S_4$	0	0
Medium High	Low	$C_3 S_1$	29	20
Medium High	Medium	$C_3 S_2$	0	1
Medium High	High	$C_3 S_3$	0	0
Medium High	Very-High	$C_3 S_4$	0	0
High	Low	$C_4 S_1$	7	13
High	Medium	$C_4 S_2$	14	13
High	High	$C_4 S_3$	0	0
High	Very-High	$C_4 S_4$	0	0
Very High	Low	$C_5 S_1$	0	1
Very High	Medium	$C_5 S_2$	0	2
Very High	High	$C_5 S_3$	3	2
Very High	Very-High	$C_5 S_4$	0	0

V. Conclusion

In general, the groundwater of the Dodda-halla sub-basin is hard and alkaline in nature, but in some places, the water is relatively soft and falls within the safety limits as prescribed by the WHO and Indian Standards. The values of total dissolved solids show that 45% and 38% of the samples fall under fresh water category, 50% and 54% under slightly saline category while the remaining 5% and 8% fall under moderately saline category, for pre and post monsoon seasons respectively. The Correlation matrix of the hydrochemical parameters reveals the good correlations of the both monsoons. The values of TDS, SAR, EC and TH and the concentration of Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, SO_4^{-} and Cl^{-} of the samples do not exceed the safety limits for drinking and for irrigation water and hence the water is fit for agricultural utility. Gibbs Classification reveals rock dominance and evaporation dominance holds good for irrigation purpose.

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