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CHEMICAL CHARACTERISTICS AND GROUNDWATER QUALITY ASSESSMENT IN MANGALORE BLOCK, CUDDALORE DISTRICT, TAMIL NADU, INDIA.

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Abstract - *Groundwater is the prime source of drinking water supply for many of the Indian rural and urban habitats. Water quality plays an important role in promoting agricultural production and standard of human health. Study on chemical characteristics of groundwater and influence on human health is necessary to study in every part of the country. An elaborate hydrogeochemical study was carried in Mangalore Block, Cuddalore District, Tamil Nadu. The present study mainly focused on chemical characteristics of groundwater with respect to the hydrogeochemical facies, genetic geochemical evolution of groundwater, and hydrogeochemical signatures. Thirty nine groundwater samples were collected from dug wells and hand pumps during pre monsoon season (2014). These water samples were analysed for major cations and anions. The water analysis data was processed using a computer programme HYCH. In this program, numerical steps are adopted for the hydrochemical facies classification using the criteria of Schoeller, Stuyfzand and USSL schemes, etc. According to Sawyer and MC Carthy around 61% of area is covered by very hard water and hard water. Based on Schoeller's water type, the type III water dominates the area. The Stuyfzand classification reveals that fresh brackish water dominates in the study area. The USSL classification exhibits that C3S2 category for 49%, which indicates high salinity-medium sodium water occupies half of the study area. Non corrosive water covers around 75%. Gibbs plot reveals that evaporation process is more dominating than rock water interaction. The overall studies indicate that the groundwater quality in the study area is not encouraging for drinking and other purposes. Further to develop the quality and quantity of groundwater in the study area, a detailed scientific study including rejuvenation of surface water resources is necessary for groundwater development.*

1. INTRODUCTION

Having a safe drinking water is an internationally accepted human right [1] Groundwater is the prime source of drinking water supply for many of the Indian rural and urban habitats, like in other parts of the world [2]. Due to inadequate supply of surface water, demand for groundwater resource has increased in many folds in recent times for drinking, irrigation, and industrial purposes in the world. It is estimated that approximately one third of the world's population use groundwater for drinking [3]. Because of the over-exploitation of groundwater, it has detrimentally affected its quantity and quality. The chemical quality of groundwater can influence the chemical composition of soils and rocks through which the water flows, depending upon the mineral dissolution, mineral solubility, ion exchange, oxidation, reduction, etc., [4]. Water quality is a term used to describe the chemical, physical and biological characteristics of water, usually in respect to its suitability for a particular purpose [5]; [6]. Researchers show that the hydrogeochemical characteristics of groundwater and groundwater quality in different aquifers over space and time are important parameters in solving the groundwater management issues [7]; [8]; [9]; [10]; [11]. The problems of groundwater quality are more acute in areas of which dense populated and thick industrialized area have shallow groundwater tube wells [12]. In hard rock terrain, availability of groundwater is limited and its occurrence is essentially confined

to fractures and weathered zones [13]. At the start, it should be pointed out that the quality of groundwater depends on the chemical composition of recharge water, the interaction between water and soil, soil–gas interaction, the types of rock with which it comes into contact in the unsaturated zone, the residence time of groundwater in the subsurface environment and the reactions that take place within the aquifer [14]; [15]; [16]. The present study mainly focused on chemical characteristics of groundwater with respect to the hydrogeochemical facies, genetic geochemical evolution of groundwater, and hydrogeochemical signatures. [17].

2. STUDY AREA

The study area falls in Mangalore Block of Cuddalore District, Tamil Nadu, South India (location map shown in Fig. 1). The study area lies between the latitudes North 11°21'80" to 11°30'11" and the longitudes East 78°40'57" to 79°03'11" in the Survey of India Toposheet numbers 58 $\frac{M}{3}$ & 58 $\frac{M}{15}$. The study area covers about 100 sq. km; the relief ranging from 62 to 121 m above MSL. The average annual rainfall is about 1100 mm, of which more than 80% is received during NE monsoon. The temperature of the study area ranges from 20° C in the month of January to 34°C in the month of May. The river Vellar flows in the southern part of the study area which originates in shevroy hills and finally joins in the Bay of Bengal. The drainage pattern is of mostly dendritic. The geomorphology of the area consists of the old flood plains, pediments, duricrust and covered by forest land. [18].

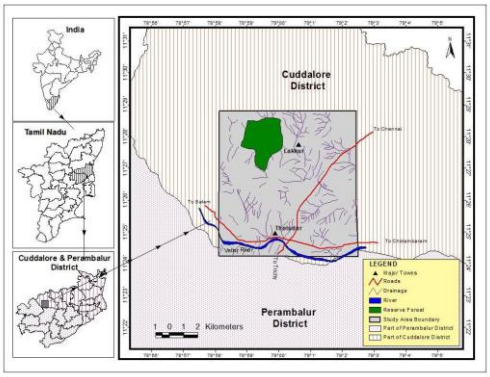

Fig-1: Location map of the study area

3. GEOLOGICAL SETTING

The study area rock types belong to early to mid Precambrian period represented by charnockite and charnockitic gneiss, indicating the oldest and subjected to granulite facies of metamorphism. The charnockites are intermediate to acid in composition, coarse to medium grained and form the high land topography. The charnockitic rocks are massive to foliated and the foliations usually trending ENE – WSW with an average dip of 45° towards South. The charnockite shows different depth of weathered zones. In the study area groundwater occurs under water table conditions in the joints, fractures and weathered rocks. Generally the charnockite of the study area is highly massive and compact and devoid of joints and fractures making it impervious, which in turn result in poor potential.

4. MATERIALS AND METHODS

The groundwater in the study area has been classified using various geochemical parameters in the following manner. In order to cover the entire study area, thirty nine groundwater samples were collected during the pre-monsoon period (July 2014). The location's coordinates were recorded with GPS receiver. The Electrical Conductivity (EC) and pH were measure immediately on collection of water samples in the field using portable consort C-425 digital pH meter. The collected samples were chemically analysed by standard analytical method. [19] at Tamil Nadu Water and Drainage, (TWAD), Cuddarole. The analytical results have been processed by using a computer program *HYCH* [20]. This program is capable of providing most of the needed output using the major ion chemistry data. It aids in the interpretation of water quality based on water chemistry, facies, mechanisms of origin, type, suitability and usage factors like corrosivity and permeability. *HYCH* Program data processing flow chart is shown in Figure 2. with the output result. GIS technique has been used for preparation of thematic maps and the following maps have been generated and discussed in detail.

i) Total Dissolved Solids, ii) Total Hardness, iii) Schoeller water type Classification, iv) Stuyzand water Classification, v) USSL Classification, vi) Corrosivity ratio and vii) Gibbs plot.

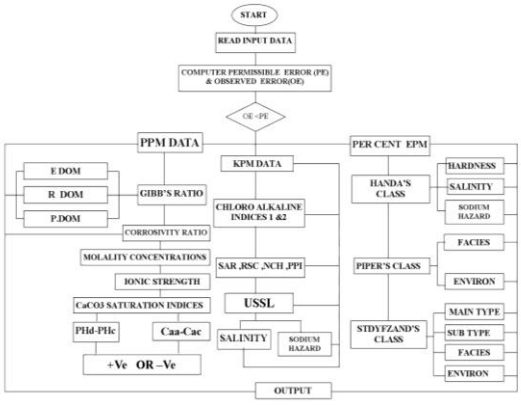

Fig-2: Flow chart shows *HYCH* program hydrochemical data processing method.

5. RESULTS AND DISCUSSION

The study area pre-monsoon groundwater characteristics are shown in Table 1. The computer software *HYCH* processed output data of the study area for pre-monsoon groundwater is shown in Table 2.

5.1. pH and EC

The various physico-chemical parameters of ground water sample of Mangalore block are present in table 1. The pH value of pre-monsoon groundwater samples varies from 6.8 to 8.3 with an average of 7.45. However the pH falls in the recommended limit (6.5 to 8.5) for human consumption. The electrical conductivity (EC) values range from 540 to 5200 µmhos/cm at 25 ºC. High EC value arise from the zone of high mineralisation in the phreatic zone due to heavy leaching of Ca, SO_4, HCO_3, CO_3, NO_3, Fe and F [15]. Maximum EC of 5200 µmhos/cm was noted in a dug well of Pudukulam village (loc. 25) dug well. This is a clear indication that the aquifer in question has been subjected to salinization processes either naturally or anthropogenically [21]. Saline samples are mostly from the plain and from the wells. A high salt content (high EC) in irrigation water leads to formation of saline soil. This affects the salt intake capacity of the plants through their roots.

5.2. TDS (Total Dissolved Solids)

From the analytical results, Total Dissolved Solids (TDS) spatial distribution map has been prepared for the pre-monsoon period of the study area (Figure 3). TDS is one of the governing factors to determine the suitability of water for various uses. [22], proposed a classification for Total Dissolved Solids present in groundwater. According to his classification TDS up to 100 mg/l is fresh water, 1,000-10,000 mg/l is brackish water, above 10,000 mg/l is saline water and above 1,00,000 is brine water. TDS of the study area ranges from 378 mg/l at Thachchur (Location No.23) to 3640 mg/l at Pudukulam (Location No. 25). The pre-monsoon period aquifer exhibits that the TDS values less than 1000 mg/l which is about 51% of the study area falls in fresh water category, TDS values between 1000-1500 mg/l falls in 11 locations (28 %) near to fresh water category. The remaining 21 % samples falls in brackish category according to Carroll's classification. Fresh water (TDS<1000 mg/l) occurs a half of the study area during pre-monsoon period. Region around Pudukulam (Location No. 25) is found to be having groundwater with high TDS above 3000 mg/l, which indicates that the location having effluent. Groundwater of moderate quality occurs in the rest of the study area. High concentration of TDS has been added on the rainwater through interactions with soils and rocks [23]. During the slow movement of groundwater in subsurface the TDS concentration is slowly enriched. Groundwater has low TDS in recharge areas than in discharge areas [14].

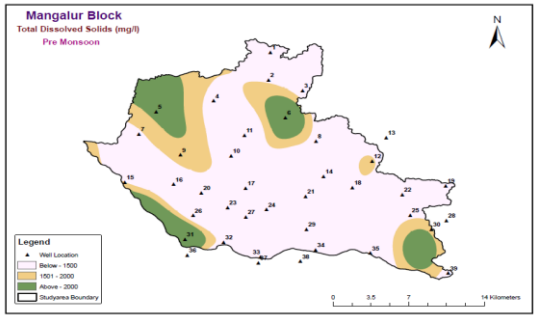

Fig.-3: Pre-monsoon TDS map of the study area.

5.3. (TH) Total Hardness

Hardness of water is not a specific constituent but variable and is a complex mixture of cations and anions. The degree of hardness of drinking waters has been classified in terms of equivalent $CaCO_3$ concentration. [24] have made a classification of water based on total hardness present in their classes details of groundwater. The study area hardness of groundwater is classified into soft water, moderate hard water, hard water and very hard water. Total Hardness (TH) spatial map has been prepared and shown in Figure 4. In the pre-monsoon period, very hard water and hard water occupies more areal extent and contributes about 61% share. Moderate hard water covers about 21% of the area. Soft water occurs in very less areal extent. Water hardness is the

traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather and increases the boiling point of the water.

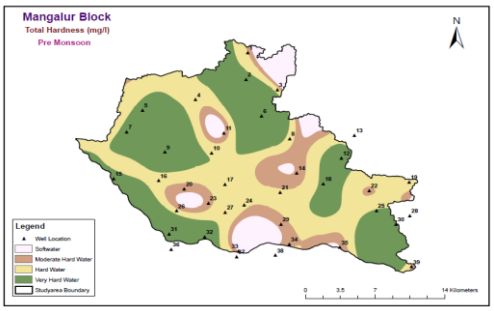

Fig-4: Total Hardness map of the study area.

5.4. Groundwater Type (Schoeller's Water Type)

From the *HYCH* output the groundwater types of the study area have been found according to [25] water type classification. Schoeller has described that the first and foremost waters are those in which:

$r\ CO_3 > r\ SO_4$ ----------Type – I

as the total concentration increases, the above relation becomes

$r\ SO_4 > r\ Cl$ ---------- Type – II,

still at higher concentration, the water may change to

$rCl > r\ SO_4 > r\ CO_3$ ---------- Type – III

and in the final stages, the relation would be $rCl > r\ SO_4 > r\ CO_3$ and

$r\ Na > r\ Mg > r\ Ca$ ----- Type - IV

The spatial map of Schoeller water types is shown in Figure 5. The study area pre-monsoon period groundwater samples falls in Type II and Type III. The Type III water dominates (about 90%) the study area during pre-monsoon season. Type II water is found in four locations (Locations No. 17, 20, 22, and 33). Type I and Type-IV water does not occur in the area during pre-monsoon period. As per the Schoeller's water type mode, Chloride and Carbonate ions are the dominant constituents of the water samples of the study area.

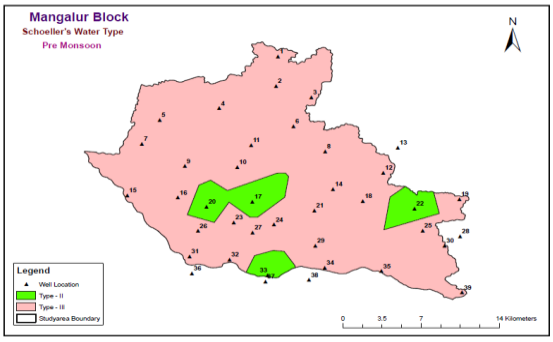

Fig-5: Groundwater Type (Schoeller) of the study area.

5.5. Groundwater classification (Stuyfzand's classification)

Stuyfzand, 1989 [26] classification of groundwater has been studied for pre- monsoon period. Stuyfzand has classified groundwater and identified main types based on Chlorine concentration as given below:

Table-1: Stuyfzand(1989) classification of groundwater

Sl.No	Main Type	Cl in mg	Location No
1	Oligohaline	5-30	8
2	Fresh	30-150	8
3	Fresh-Brackish	150-300	12
4	Brackish	$300\text{-}10^3$	1

From the prepared thematic map (Figure 6) the pre-monsoon groundwater samples of the study area falls in the categories of Oligohaline; Fresh, Fresh-Brackish, Brackish and Brackish salt nature. During the pre - monsoon period only one location (25) exhibits brackish salts. During pre-monsoon period fresh-brackish water dominates.

Table-2: Chemical analysis results of groundwater samples collected from Mangalore Block.

S. No.	Habitation	EC (µmhos/cm)	TDS	pH	Ca	Mg	Na+K	HCO_3	Cl	NO_3	SO_4
1	Kulavay	835	585	6.8	43	12	80	304.2	43	19	7
2	Rettakurichi	2000	1400	7.7	89	44	343	728	216	5	260
3	Kalattur	1350	945	7.3	53	19	219	378	173	15	121
4	Sirupakkam	1785	1250	7.5	51	23	244	500	184	2	82
5	Vadapadi	3100	2170	7.7	97	31	580	868	475	20	230
6	Poyinappadi	3800	2660	8.1	252	70	615	1064	670	0	426
7	Panaiyandur	2000	1400	7.7	81	40	360	700	216	5	260
8	Sirukarambalur	1610	1127	7.1	49	23	241	541	173	12	49
9	Orangur	2500	1750	8.0	149	46	428	840	508	14	124
10	Pudur	1725	1208	7.5	64	28	202	604	119	15	43
11	Mangalur	745	522	6.9	17	7	72	208.8	22	19	15
12	Pullur	2200	1540	8.0	96	36	337	770	227	10	159
13	Lakshmanapuram	1260	882	7.4	48	9	169	352.8	119	16	55
14	Avatti	965	676	7.1	23	7	112	324.5	22	19	20
15	Korakkavadi	2200	1540	7.4	116	35	293	693	292	2	90
16	Kandamattan	1285	900	7.2	66	14	135	432	86	7	38
17	Lekkur	1825	1278	7.5	67	19	304	511.2	302	7	58
18	Meladanur	1860	1302	7.4	79	34	219	520.8	205	0	99
19	Nidinattam	1285	900	7.6	55	25	166	432	130	15	52
20	Nangur	1330	931	7.3	28	7	119	372.4	11	22	21
21	Alambadi	1395	977	7.4	38	17	195	390.8	162	9	35
22	Nedungulam	1175	823	7.2	44	8	90	329.2	22	9	33
23	Thachchur	540	378	7.0	28	10	23	151.2	11	15	14
24	Venganur	1175	823	7.7	45	15	148	329.2	97	8	84
25	Pudukulam	5200	3640	8.3	244	80	1173	1456	1166	18	615
26	Vaidhiyanathapuram	1350	945	7.3	53	19	219	378	173	15	121
27	Eluttur	1440	1008	7.1	60	22	200	403.2	194	18	60
28	Adamangalam	985	690	7.1	35	11	116	276	86	12	31
29	Korukkai	1000	700	7.2	36	3	102	280	43	13	29
30	Vaiyangudi	2600	1820	7.8	154	34	445.9	873.6	454	5	184
31	Alattur	1900	1330	7.8	70	36	291	665	238	7	69
32	Tholudur	1890	1323	7.8	131	35	277	635	313	13	101
33	Arangur	1225	858	7.2	25	5	117	343.2	11	19	29
34	Edaicheruvai	1140	798	7.4	32	11	111	319.2	43	21	31
35	Tittagudi	625	438	7.3	26	0	64	175.2	22	6	29
36	Paraiur	2400	1680	7.9	80	36	402	672	421	1	76
37	Labbaikudikadu	850	595	7.0	58	17	95	285.6	97	15	42
38	Nathamedu	1190	833	7.5	32	19	40	160	43	12	47
39	Neyvasal	1625	1138	7.4	48	9	219	455.2	130	12	69

Table-3: Hych software processed output chemical results of pre-monsoon groundwater samples.

S.No	Habitation	HANDA'S Classification	CR	SCHOELLER'S Classification	STUYFZAND'S Classification	USSL Classification	GIBB'S	SAR	RSC	PI
1	**Kulavay**	Temporary	0.2231	III	Fresh	C3S1	Rock interaction	2.547728	0.488911	81.97802
2	**Rettakurichi**	Temporary	0.7899	III	Fresh-brackish	C3S2	Evaporation	6.296372	2.19975	75.71763
3	**Kalattur**	Temporary	0.9781	III	Fresh-brackish	C3S2	Rock interaction	7.960897	4.4645	120.3493
4	**Sirupakkam**	Temporary	0.6891	III	Fresh-brackish	C3S2	Evaporation	6.855066	3.842773	87.53668
5	**Vadapadi**	Temporary	1.0468	III	Brackish	C4S4	Evaporation	7.757607	0.100095	74.57131
6	**Poyinappadi**	Permanent	1.304	III	Brackish	C4S3	Evaporation	8.372424	1.850854	76.48103
7	**Panaiyandur**	Temporary	0.8215	III	Fresh-brackish	C3S2	Evaporation	9.014836	4.317123	91.50814
8	**Sirukarambalur**	Temporary	0.5448	III	Fresh-brackish	C3S2	Evaporation	4.719502	1.34058	79.37727
9	**Orangur**	Temporary	1.0055	III	Brackish	C4S2	Evaporation	5.521208	20.75238	70.07251
10	**Pudur**	Temporary	0.3517	III	Fresh	C3S2	Evaporation	5.05089	0.217806	73.53422
11	**Mangalur**	Temporary	0.2232	III	Oligohaline	C2S1	Rock interaction	2.67825	1.561495	91.88831
12	**Pullur**	Temporary	0.6303	III	Fresh-brackish	C3S2	Evaporation	7.402952	2.184733	81.01413
13	**Lakshmanapuram**	Temporary	0.6375	III	Fresh	C3S2	Rock interaction	4.318545	0.65471	79.21706
14	**Avatti**	Temporary	0.1597	III	Oligohaline	C3S1	Evaporation	3.618196	2.19749	108.3602
15	**Korakkavadi**	Temporary	0.7287	III	Fresh-brackish	C3S2	Evaporation	4.899491	2.0422	73.57209
16	**Kandamattan**	Temporary	0.372	III	Fresh	C3S1	Evaporation	4.4753	2.224477	86.46765
17	**Lekkur**	Temporary	0.9503	II	Oligohaline	C3S2	Evaporation	5.639642	1.355165	76.53994
18	**MelAdanur**	Temporary	0.7524	III	Fresh-brackish	C3S2	Evaporation	14.74765	6.556938	113.6776
19	**Nidinattam**	Temporary	0.5492	III	Fresh	C3S1	Rock interaction	4.901252	1.85533	85.64595
20	**Nangur**	Temporary	0.1003	II	Oligohaline	C3S2	Evaporation	10.73535	6.658252	119.9992
21	**Alambadi**	Temporary	0.6771	III	Fresh-brackish	C3S2	Rock interaction	4.467491	0.594121	71.17519

22	**Nedungulam**	Temporary	0.1985	II	Oligohaline	C3S1	Evaporation	3.455622	1.291386	78.10714
23	**Thachchur**	Temporary	0.1989	III	Oligohaline	C2S1	Rock interaction	1.82976	0.692233	83.21867
24	**Venganur**	Temporary	0.6808	III	Fresh	C3S1	Rock interaction	4.230556	2.911594	102.5359
25	**Pudukulam**	Temporary	1.5679	III	Brackish-salt	C5S4	Evaporation	12.66277	6.290869	81.01012
26	**Vaidhiyanathapuram**	Temporary	0.9781	III	Fresh-brackish	C3S2	Rock interaction	10.73535	6.658252	119.9992
27	**Eluttur**	Temporary	0.8327	III	Fresh-brackish	C3S2	Rock interaction	7.666335	3.738946	88.51708
28	**Adamangalam**	Temporary	0.5559	III	Fresh	C3S1	Rock interaction	4.081508	1.85356	94.57262
29	**Korukkai**	Temporary	0.3242	III	Fresh	C3S1	Rock interaction	3.207664	1.578008	89.43692
30	**Vaiyangudi**	Temporary	0.9514	III	Brackish	C4S3	Evaporation	3.454474	1.682685	87.15123
31	**Alattur**	Temporary	0.6122	III	Fresh-brackish	C3S2	Evaporation	6.675169	2.524149	77.73061
32	**Tholudur**	Temporary	0.8599	III	Brackish	C3S2	Rock interaction	6.82957	4.053886	92.71568
33	**Arangur**	Temporary	0.1332	II	Oligohaline	C3S2	Evaporation	4.115627	0.741108	79.54324
34	**Edaicheruvai**	Temporary	0.2909	III	Fresh	C3S1	Evaporation	4.577618	2.590887	105.2619
35	**Tittagudi**	Temporary	0.3493	III	Oligohaline	C2S1	Rock interaction	3.573656	1.343755	105.6659
36	**Paraiur**	Temporary	1.0002	III	Brackish	C4S3	Evaporation	6.706645	2.56884	81.12629
37	**Labbaikudikadu**	Temporary	0.6315	III	Fresh	C3S1	Rock interaction	4.483724	1.970461	94.98067
38	**Nathamedu**	Permanent	0.6845	III	Fresh	C3S1	Rock interaction	5.559577	3.286144	106.9538
39	**Neyvasal**	Temporary	0.5601	III	Fresh	C3S2	Evaporation	5.088911	2.2991	84.74886

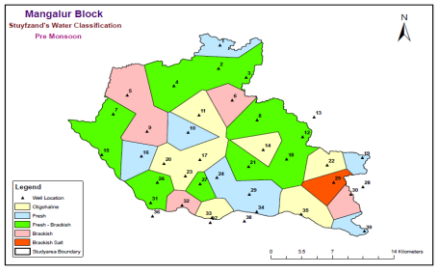

Fig-6: Water classification (Stuyfzand)

5.6. USSL Classification

Based on the United States Salinity Laboratory (USSL) classification a thematic map was prepared for pre-monsoon groundwater (Figure 7). This classification is based on salinity and sodium hazard classification [27]. The classes C2S1 (medium salinity-low sodium water), C_3S_2 (high salinity-low sodium water), C_3S_3 (high salinity-medium sodium water), C_4S_2 (very high salinity-medium sodium water), C_4S_3 (very high salinity-high sodium water), C_4S_4 (very high salinity-very high sodium water), and C_5S_4 (extremely high salinity – high sodium). Among these orders, C_4S_2, C_4S_4 and C_5S_4 types are present in one location each Location No. 5 Vadapathi (C_4S_4), Location No. 9 Orangur (C_4S_2) and Location No. 25(C5S4) Pudukulam. C_4S_3 type occurs each in two places (Location No. 6. Poyinapadi, and Location No. 30 Vaiyangudi). Mostly C_3S_2 dominates (49%) the study area in the pre-monsoon period. C_3S_1 occupies eight locations: Location No.1 (Kulavai), Location No.14 (Avatti), Location No.16 (Kandamattan), Location No.19 (Nidinattam), Location No.22 (Nedungulam), Location No.24 (Venganur), Location No.29 (Korukkai) and Location No.34 (Edaicheruvai). C_2S_1 occupies three locations: Location No.11 (Mangalur), Location No.23 (Thachchur) and Location No.35 (Tittagudi). the class C3S2 (High salinity - medium sodium) is spread all over the study area extent and dominates by 49% of all locations

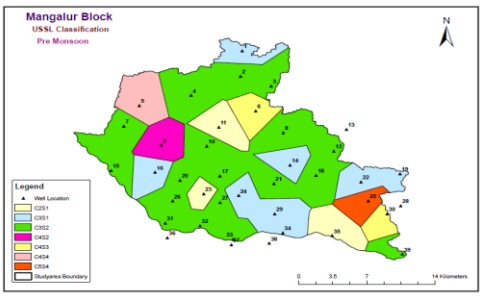

Fig-7: USSL classification

5.7. Corrosivity Ratio (CR)

In the Figure 8, the distribution of the corrosivity ratio of groundwater in the pre monsoon period is displayed. Corrosive water (CR >1) is noticed in areas around Vadapadi (Location No. 5), Poyinappadi (Location No. 6), Orangur (Location No. 9) and Alattur (Location No. 31). The rest of the area is occupied by non-corrosive water (CR<1) and it dominates with 74% of the study area. Corrosive water can be transported only through the PVC pipes, as it corrodes the metal pipes. Non corrosive water may be transported through metal pipes as it does not corrode them.

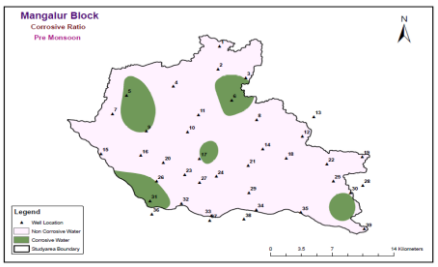

Fig-8: Corrosivity Ratio

5.8. Gibbs Plot

From the *HYCH* output, the mechanism controlling water chemistry [28] in the study area has been evaluated based on Gibb's ratio and a spatial distribution map have been prepared (Figure 9). From the map it is inferred that the pre-monsoon period water dominates in water evaporation. Water evaporation category samples occupy the southern, central, northern and northeastern parts of the study area. During pre-monsoon period in the study area, water evaporation is the main process that influences the quality of groundwater.

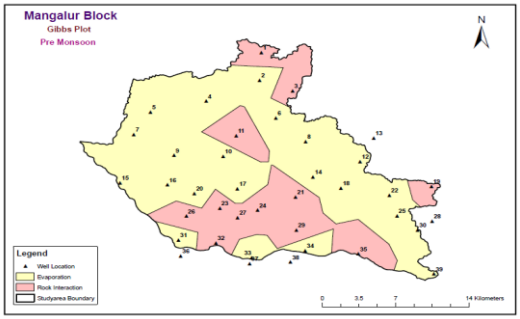

Fig-9: Gibbs Plot

6. SUMMARY AND CONCLUSION

The groundwater quality assessment done in Mangalore Block, Cuddalore District, Tamil Nadu, South India during the pre-monsoon period of 2014. From the overall assessment of the study reveals that physical parameters in the groundwater are almost within the desirable limit. Regarding TDS, 51% of groundwater samples falls in freshwater category. According to Sawyer and MC Carthy (1967) [24] around 61% of the area is covered by very hard water and hard water. Based on Schoeller's (1967) [25] water type, the type III water dominates the area. Stuyfzand classification elucidates that, the fresh brackish water dominates in pre monsoon period. The USSL classification manifests 49% of C3S2 category and cover with high salinity-medium sodium water. Non corrosive water spreads about 75% in the area. Gibbs plot reveals that evaporation process is more dominating than rock water interaction. The overall studies indicate that the groundwater quality in the study area is not encouraging with quality drinking water. Further the study suggest that the area needs some scientific developments including rainwater harvesting, constructing of check dams in the suitable places, creation of ponds, etc, is necessary for groundwater development.

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