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STUDIES OF GROUNDWATER QUALITY AND ITS IMPACT ON ENVIRONMENT OF KANCHUGARAKOPPLU WATERSHED KRISHNARAJANAGARA TALUKU, MYSORE DISTRICT, KARNATAKA, SOUTH INDIA.

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ABSTRACT

The quality of water is a little concern for mankind since it is directly linked to human health. The present work is carried out with an objective to assess and map the spatial variability in the groundwater quality parameters in Kanchugarakoppalu Watershed. Total 12 respective groundwater samples from different bore wells has been collected and analyzed for major cations and anions with concentration for the water quality. Groundwater in the region is found alkaline with presence of bicarbonate in nature and very hard.

KEYWORDS: Spatial Variability, Major Cations, Water quality, bore wells, Groundwater.

1. INTRODUCTION

Chemical quality of water is as important as the quantity. Groundwater movement in the water bearing formation contains chemical ions in solution and is carried along with groundwater flow and hence groundwater never occurs in its purest form. The chemical ions concentrations in groundwater depend on the environment on the surface as well as subsurface rate of groundwater movement, ion exchange capacity and the source of groundwater itself. Utilizing the chemical parameters hydro-geologists could successfully and effectively discuss. The suitability of groundwater for domestic, irrigation and industrial uses and areas of recharge and discharge, residence time of water within the water bearing formation (Indices of Base exchange, water types and $CaCO_3$ saturation indices) and Corrosive tendency of groundwater within the pipeline used for transport to different consumer points (Corrosivity ratio). Water quality is determined by measuring the concentration of the solid particles and their effect caused by the presence of the ionic substances.

According to Mercado et.al (1977) a “hydrogeochemical system” is a complex natural framework of liquid, gaseous and mineral phases. In Kanchugarakopplu micro watershed area, the aquifers are mostly considered to be open geochemical systems, in which the chemical composition of groundwater is controlled by the inflow and outflow of solutes across the boundaries and by the rock water interaction with in the aquifers during the time of residence.

Geographical setting

The micro level watersheds area located in and around Kanchugarakopplu area, western parts of Krishnarajanagar taluk, Mysore District, Karnataka, India; with the latitude 12˚24′30″ to 12˚32′45″ north and longitude 76˚16′15″ to 76˚21′30″ east consisting an area of 4847.325 hectares and covered by survey of India topo sheet Nos. 57D/7 and 57D/6 of 1:50,000 scale is detailed in **Fig. 1.**

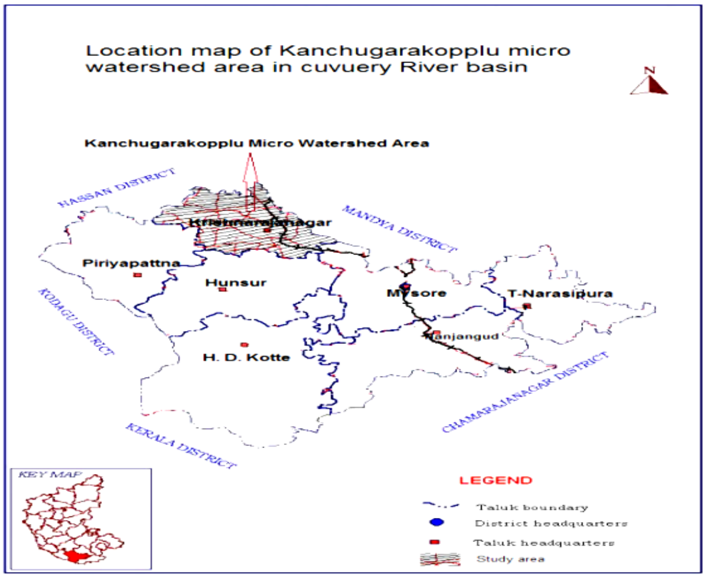


Fig. 1: Location Map of Kanchugarakopplu Micro Level Watershed Area.

Geology of the area

Cauvery river basin is exposed around Krishnarajanagara taluk, Mysore District and Kanchugarakopplu micro level watershed area are represented by typical hard rock terrain belongs to the Precambrian of south India. The major portion of the rock is peninsular gneissic complex and schists. These are mixed up with granodiorite, tonalite migmatite gneiss and some patches of amphibolite, hornblende Schist and traces of garnet are noticed in the region. Numerous younger basic dykes invaded gneisses and schistose. These banded gneisses show evidences of multiple deformations. The following geological column gives a general succession of the rocks exposed in the area (**Fig.2**).

Fig. 2: Field photographs at Gowdanahalli village.

2. MATERIALS AND METHODS

Twelve representative groundwater samples consisting of pre and post monsoon were collected from the area by adopting standard techniques (Palmquist; 1973) shown in **Fig 3**. All the samples have been analyzed by following the standard procedures of water analysis (ISI, 1991; Indian Council of Medical Research 1975 and WHO 1971). The parameters like electrical conductivity, pH and total dissolved solids have been determined along with the major ions including Ca, Mg, Na, K, HCO_3, CO_3, Cl, NO_3 and SO_4 given in **Table 1 and 2**.

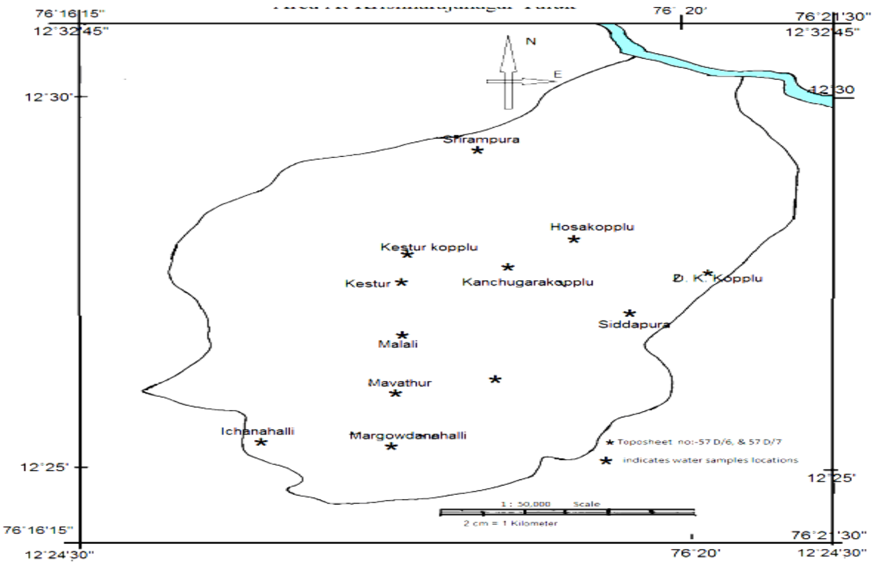


Fig. 3: Ground Water sample location map of the study area.

Table 1: Chemical analysis data of Pre-monsoon (ppm) groundwater in the study area.

Location	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS
Sri Rampura	380	6.6	26	14	28	75		66	9.8	24	247
Kestur	260	6.7	19	19	32	98	-	58	16	20	169
Malali	150	6.7	11	9	18	78	-	18	0.3	12	98
Dodda betta	670	7	16	48	45	234	-	63	0.7	29	436
Mavathur	310	7	26	19	20	162	-	27	0.14	14	202
Margowdanahalli	1120	7.8	47	20	55	159	-	82	11.1	60	728
Aichanahalli	570	7.8	38	33	23	174	-	48	16	54	371
Gowdanahalli	720	7.3	52	35	37	200	-	110	10.1	26	468
Siddapura	850	7.7	51	34	41	224	-	86	3.3	46	553
Kanchugarakopplu	880	8	30	18	13	120	-	44	8.9	10	572
Hosakopplu	790	7.2	5	9	26	103	-	10	-	8	514
D.K.Kopplu	240	7.5	15	11	23	60	-	56	0	4	156

Table 2: Chemical analysis data of Post-monsoon (ppm) groundwater in the study Area.

Location.	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	Cl	NO_3	SO_4	TDS
Sri Rampura	390	6.9	36	19	19	133	-	48	0.79	33	254
Kestur	540	6.6	48	29	19	150	-	75	1.8	45	351
Malali	200	6.8	16	17	7	123	-	14	0.17	4	130
Dodda betta	1350	6.7	164	92	32	512	-	223	2.1	72	878
Mavathur	460	6.5	56	29	11	239	-	40	3.86	8	229
Margowdanahalli	1050	7.2	132	65	29	465	-	110	27	88	683
Aichanahalli	440	6.9	36	36	7	193	-	53	5.6	13	286
Gowdanahalli	670	6.9	46	21	15	200	-	36	0.3	18	436
Siddapura	740	7.2	104	36	20	331	-	87	10.4	55	481
Kanchugarakopplu	560	6.8	164	17	18	403	-	106	0.4	36	369
Hosakopplu	950	6.9	96	77	27	393	-	167	1.68	18	618
D.K.Kopplu	610	7.6	96	14	17	250	-	40	2.3	68	397

Study Techniques

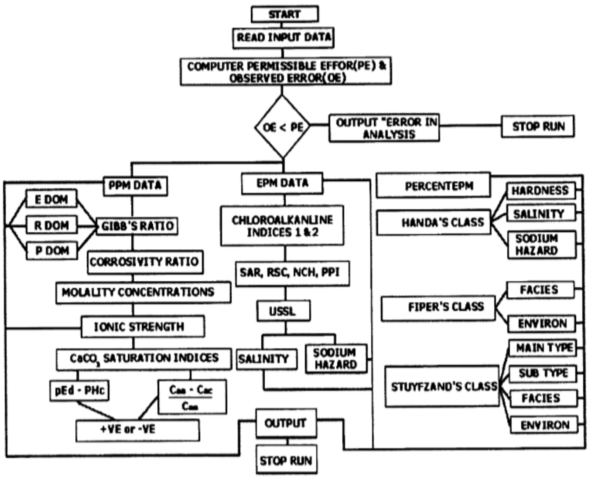


Fig. 4: Flow Chart of the Programme "HYCH" (After Balasubramanian 1986).

The concentration of ground water is often expressed in two different modes:

- PPM (parts per million, mg/L) concentration.
- EPM (equivalents per million, mg/L) concentration.

The results of chemical analysis of ground water samples are processed and classification of hydrogeochemical facies of the groundwater is done using a computer program "HYCH" (Balasubramanian et al., 1991). Fig 4 shows the flow chart of the program. The sources of basic criteria used for the preparation of HYCH program are given in **Table 3**.

Table 3: Sources of Basic Criteria for HYCH program.

Sl. No.	Parameter of study	Source
1.	Percentage permissible error:	Richards (1954), Palmquist (1973)
2.	Piper's classification:	Piper (1973)
3.	USSL classification:	Wilcox (1953)
4.	Honda's classification:	Honda (1964a, 1965)
5.	Indices of base exchange and water types:	Schaller (1965a, 1967)
6.	Residual sodium carbonate:	Eaton (1950)
7.	Sodium adsorption ratio:	Richards
8.	Permeability index:	Doneen (1948)
9.	Non carbonate hardness:	Raghunath (1987)
10.	Corrosivity index:	RYZNER1944, Badrinath etal. (1984)
11.	CaCO3 saturation index:	Baronet et al., (1975) Back, (1961, 1963) Etal;(1942) Robertson (1964).
12	Mechanism controlling groundwater: Chemistry	Gibbs (1942) Viswanathaiah et al., (1978c)
13	Stuyfzard's classification and water types:	Stuyfzard (1989)

The sequence of computations involved in this data processing as follows:

- Checking the precision and accuracy of analysis.
- Computation of ionic strength and $CaCO_3$ saturation indices.
- Hydrochemical classification of water characteristics with reference to its hardness, salinity and sodium hazards as postulated through a graphical representation by Handa`s section.
- Facies classification by piper and Stuyfzand's approaches section.
- Identification of the mechanism controlling the chemistry as explained by Gibbs's section.
- Classification of water using USSL scheme.

Precision and Accuracy of Water Analysis

Precision and accuracy of the analysis have to be determined. Minor errors unavoidable in analytical works mainly due to reagents employed, limitations of methods, instruments used, impurities in distilled water and finally the human error during analysis. Richards (1954) has worked out a procedure to check the precision and accuracy of chemical analytical data. Groundwater Wing, Department of Mines and Geology (GW-MGD), Karnataka State has fixed permissible limits to check the quality of the analytical data. Summers (1972) suggested that the total weight of the cation approximately should be equal to the anion and the weight of two should be verified with TDS to find the precision and accuracy of the sample. In the present study the relation between permissible percentage errors to the Total dissolved solids (TDS) of water sample is evaluated as follows.

$$\text{Calculated \% error of the analysis (PEc)} = \frac{(100) \times (\text{Difference between cations and anion epm})}{\text{Sum of total epm cations and anions}}$$

The criteria for verifying the accuracy is given below**:**

TDS (ppm)	**50**	**100**	**200**	**500**	**1000**	**2000**
Percentage permissible error **(PEt)**	15	8	5	4	3	2

If PEc is less than the PEt then the analysis is accepted to unravel the geo-chemical evolution of the ground water and used for further processing, otherwise rejected. The epm analysis is tabulated in **Table 4 and 5**.

Table 4: Chemical analysis of groundwater of Kanchugarakopplu microlevel watershed (epm) in Pre-monsoon.

Location	Ca	Mg	Na+K	TSC	HCO_3	CO_3	Cl	NO_3	SO_4	TSA
Sri Rampura	1.8	1.6	0.8	4.185	2.2	-	1.4	-	0.7	4.233
Kestur	2.4	2.4	0.8	5.607	2.5	-	2.1	-	0.9	5.539
Malali	0.8	1.4	0.3	2.501	2	-	0.4	-	0.1	2.496
Dodda betta	8.2	7.6	1.4	17.145	8.4	-	6.3	-	1.5	16.313
Mavathur	2.8	2.4	0.5	5.659	3.9	-	1.1	0.1	0.2	5.273
Margowdanahalli	0.6	2.1	0.7	3.477	2	-	1	-	0.3	3.368
Aichanahalli	1.8	3	0.3	5.063	3.2	-	1.5	0.1	0.3	5.018
Gowdanahalli	2.3	1.7	0.7	4.675	3.3	-	1	-	0.4	4.672
Siddapura	5.2	3	0.9	9.021	5.4	-	2.5	0.2	1.1	9.191
Kanchugarakopplu	8.2	1.4	0.8	10.365	6.5	-	3	-	0.7	9.663
Hosakopplu	4.8	6.3	1.2	12.3	6.4	-	4.7	-	0.4	11.552
D.K.Kopplu	1.1	1.7	1.4	4.217	3.3	-	0.9	-	-	4.31

Table 5: Chemical analysis of groundwater of Kanchugarakopplu microlevel watershed (epm) in Post monsoon.

Location	Ca	Mg	Na+K	TSC	HCO_3	CO_3	Cl	NO_3	SO_4	TSA
Sri Rampura	1.3	1.2	1.2	3.666	1.2	-	1.9	-	0.5	3.606
Kestur	0.9	1.6	1.4	3.902	1.6	-	1.6	0.3	0.4	3.916
Malali	3.4	2.6	2	8.032	5	-	1	0.1	2	8.028
Dodda betta	1.9	2	1.3	5.181	3.6	-	0.9	0.1	0.5	5.09
Mavathur	1.7	1.7	1.9	5.344	3.2	-	1.1	-	1	5.292
Margowdanahalli	4.8	2.5	2.7	9.998	4.7	-	3.4	0.2	1.7	9.991
Aichanahalli	0.2	0.6	1.3	2.129	1.3	-	0.8	-	0.1	2.18
Gowdanahalli	2.1	2.2	1.7	6.063	2.5	-	2.3	-	1.2	6.032
Siddapura	1.3	-	2.4	3.732	1.9	-	0.8	0.1	1	3.743
Kanchugarakopplu	2.6	2.1	1.5	6.13	2.1	-	2.2	0.1	1.8	6.108
Hosakopplu	2.3	2.9	1.3	6.479	3.2	-	1.8	0.1	1.2	6.469
D.K.Kopplu	0.2	0.7	1.1	2.12	1.7	-	0.3	-	0.2	2.136

Specific electrical conductivity (Ec)

The ability of a substance to conduct an electrical current is termed as electrical conductivity. In ionized or mineralized water current flows easily because the ions are electrically charge and move towards a current source that will neutralize them. Specific electrical conductance can be defined as the conductance of a cube centimeter of water at 25o C. It is measured in microsiemens / cm (μs/cm) or mhos (micro ohms). Several factors influence the conductivity amongst them is temperature, mobility of ions and ionic valences.

The quality of water can be easily determined from the electrical conductivity value. Higher the value indicates higher mineralisation. Water with relatively high specific conductance can corrode iron and steel even though other properties of the water may not indicate a corrosion problem. Electrical conductivity value of the area is given in Table 6 (a&b) and shown in Fig. 3. for pre-monsoon and post-monsoon respectively.

Electrical conductivity in groundwater of the area ranges from 200 to 1350 microsiemens /cm (µs/cm) in pre-monsoon and 150 to 1120 microsiemens /cm (µs/cm) in post-monsoon with a mean value of 775 & 635 microsiemens /cm (µs/cm) respectively, which is detailed in Table 6 as follow:

Table 6: Electrical conductivity in groundwater of Kanchugarakopplu micro level watershed Area.

Range Ec (Mhos/Cm at 25 c)	No. of Samples		Percentage		Water Quality
	Pre monsoon	Post monsoon	%	%	
< 250	1	2	8	17	Excellent
250-750	8	6	67	50	Good
750-2000	3	4	25	33	Permissible
> 2000	0	0	0	0	Doubtful
Total	**12**	**12**	**100**	**100**	**Unsuitable**

It is interesting to note that majority of water samples belong to (250-750) microsiemens /cm (µs/cm) followed by (750-2000) microsiemens /cm (µs/cm), (< 250) micro mhos and (> 2000) microsiemens /cm (µs/cm).

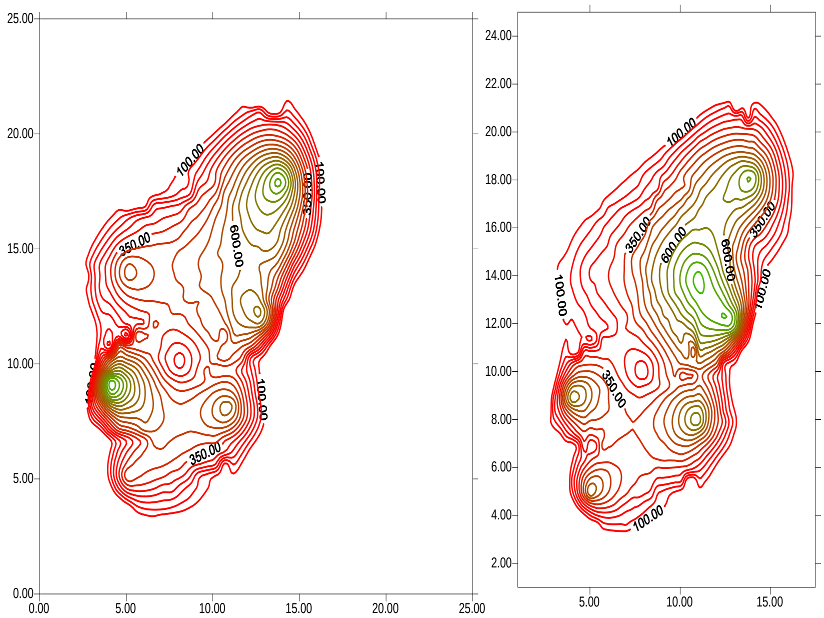


Fig. 5: Distribution Map of Electric Conductivity at Pre and Post-Monsoon in Kanchugarakopplu Micro Watershed Area.

Potential Hydrogen Ion Concentration (pH**)**

The hydrogen ion concentration is expressed as pH and it is the negative logarithm of the hydrogen ion concentration. pH measurements provide quick and easy to obtain appraisal of the acid-base equilibrium in an ecological system (Abbasi, 1998). A water sample with pH less then 7 indicates that the samples has acidic character, while pH higher than 7 indicates an alkaline character. Lithology and anthropogenic activity also controls the pH of water. The pH of groundwater of the area ranges from 6.5 to 7.6 (**Table 1 and 2**) in pre monsoon and 6.6 to 8 ppm in post monsoon thus showing the character of feeble acidic to base.

3. Interpretation Methods

Graphical techniques are commonly used to portray the chemical analysis of natural water. Collins (1923) presented the first graphical method in which the concentration of individual ions both cations and anions were indicated by colour or pattern on a bar graph. Hem (1970) proposed Pie and Vector diagrams and Stiff (1951) proposed the pattern diagram, which are widely used for representing the analysis. Schoeller (1962) used semi logarithmic diagram to compare the groundwater analysis. Hydrochemical diagrams are aimed at facilitating interpretation trends particularly in a groundwater system when they are interpreted with spatial distribution map. Trilinear diagrams were proposed independently by Hill (1940) and later by Piper (1944) are widely used to depict chemical data, which is given in **Fig. 6(a and b)**.

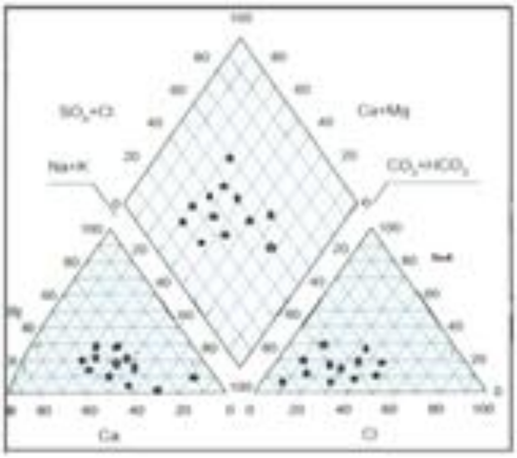


Fig. 6a: Piper Diagram (Post Mansoon).

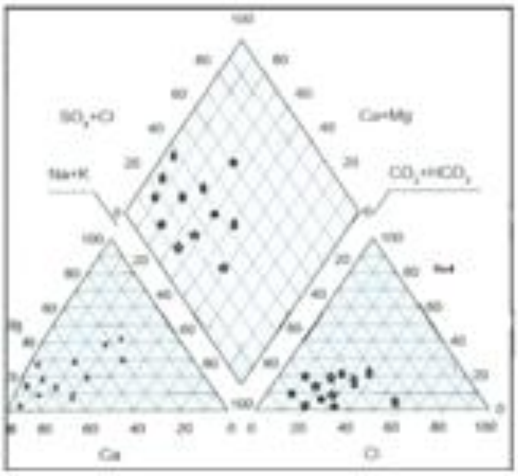


Fig. 6b: Piper Diagram (Pre Mansoon).

The method shows the relative concentrations of major cations and anions. Cations are plotted on the left triangle and anion on the right triangle. The diamond shape diagram above the cations and anion triangle are used to present both cation and anion groups as a percentage of samples, which explains the hydrogeochemical facies classification (Back et.al., 1965). Durov (1948) proposed a rectangular field instead of diamond, which has advantage of splitting the triangles (Burdon, 1958) for better representation. Handa (1965) modified the diagram proposed by Hill and Piper adding U.S. salinity research lab diagram with modification. Sodium concentration is plotted against salinity instead of sodium adsorption ratio and water is classified. Chadha (1999) proposed a new diagram after modifying the Hill-Piper diagram. The difference is the omission of two equilateral triangular diagrams and diamond shape projected into rectangle which projects total ion concentration.

The hydrochemical data have been interpreted using the following methods:

- Physico-chemical properties and major constituent of ground water.
- Classification of water with reference to its Hardness, Salinity and sodium hazard using Handa’s classes (1965)
- Identification of water types using based on Schoeller’s method (1967).
- Determination of the hydrogeochemical facies using Piper’s trilinear plot (Piper, 1944).
- $CaCO_3$ saturation Indices of groundwater using pH method (Hem, 1961; Handa, 1964) and equilibrium Ca method (Larson and Boswell, 1942).
- Identification of the mechanisms controlling the chemistry of water using Gibbs diagram (Gibbs, 1970).

In addition to this, parameters like Index of Base exchange, corrosivity ratio (Ryzner, 1944), Isochlor Map, Sodium Adsorption ratio, Permeability index, and Isolines of Na+ K% Map of Groundwater were determined.

The suitability of groundwater for different purposes has also been assessed based on the amount of Total Dissolved solids (TDS). The dominant hydrochemical facies are being correlated with the ion-evolution sequence of Chebatorev (1955). The spatial and time variant of groundwater quality has been assessed through graphical representations. Ionic ratio computed from ionic concentration expressed in epm or (r-values) are calculated for classifying the water bodies.

Physico-chemical properties and major constituent of ground water

In the area the major constituents and physico-chemical properties of groundwater are explained as follows.

Calcium (Ca)

Calcium is one of the eight most abundant rocks forming elements (O, Si, Al, Fe, Ca, Na, Mg, and K) (Krauskopf, 1979) and it is freely dissolving ion from many rock types and soils. In igneous metamorphic high-grade terrains, weathering and presence of CO_2 releases calcium from minerals like gypsum, apatite, wollastinite and other various members of feldspars, amphibole and pyroxenes groups. Along with magnesium, calcium causes hardness in water. The permissible level of calcium is 200 ppm. In the groundwater of the area Ca ranges from 16 to 164 ppm in pre monsoon and in post monsoon it ranges from 5 to 54 ppm.

Magnesium (Mg)

Like calcium, the solubility of magnesium is influenced by the presence of CO_2. Magnesium commonly associated with calcium contributes to hardness of water. The maximum permissible level for magnesium is 200 ppm and the highest desirable is 30 ppm. In pre monsoon it ranges from 14 to 92 ppm and in post monsoon ranges from 9 to 48 ppm.

Sodium (Na)

Sodium is also a most abundant and important element. It is highly mobile and nearly all sodium compounds are readily soluble. Ground water is readily polluted by sodium chloride, which is a byproduct of anthropogenic activates like disposal of industrial and urban wastes.

In the area, pre monsoon ranges from 19 to 40 ppm and in post monsoon ranges from 5 to 26 ppm.

Potassium (K)

Potassium is the most abundant next to Na. Like sodium the solubility of potassium is also very high. Main sources of potassium are feldspars, micas and feldspathoids. The potassium content of groundwater in the area in pre monsoon ranges from 4 to 15 ppm and 1to 6 ppm in post monsoon.

Sulphate (SO_4)

Sulphate is found in small concentrations than chloride in water. The major sources of Sulphate in fresh water are evaporates, mainly gypsum, decaying organic matter and weathering of some magmetic rocks. In the area the Sulphate concentration of groundwater in pre monsoon ranges from 4 to 88 ppm and in post monsoon ranges from 4 to 60 ppm. The highest desirable level is 200 ppm and maximum permissible level is 400 ppm.

Chloride (Cl)

Chloride is present in all types of water, in most of rocks and minerals. The important sources are sodalite, apatite, connate water and hot springs. Chloride does not enter into ion exchange process and in water it is a strong oxidizing agent. The chloride content in groundwater of the area varies from 14 to 223 ppm in pre monsoon and varies from 10 to 110 ppm in post monsoon.

Nitrate (NO_3)

Nitrate is the most common form of nitrogen species in groundwater. Nitrate gets released into the groundwater by disassociation (oxidizing by aerobic bacteria) of organic materials. In ground water of the area, it ranges from 4 to 88 ppm (average 46) in pre monsoon and from 0 to 11.1 ppm (average 5.55) in post monsoon. In the area of investigation no samples contain nitrate greater than 45 ppm, which is not harmful for anthropogenic purpose.

Bicarbonate (HCO_3) and Carbonate (CO_3)

These two constituents along with hydroxides are responsible for the alkalinity of water. Solubility of carbonate mineral in pure water is very low, but they get dissolved and form bicarbonate compounds in water containing carbon dioxide CO_2. The bicarbonate in the groundwater of the area ranges from 123 to 512ppm in pre -monsoon (average 311.5 ppm) and 60 to 234 ppm in post-monsoon (average 141 ppm). The carbonate level variation is 19.2 to 86.4 ppm.

Groundwater metasomatisum

Groundwater quality changes during courses of flow from the point of its entry to the point of its exit due to rock-water interaction. For proper interpretation, it is obvious to note that the chemical changes take place in the water bearing formations. Various thematic maps are prepared in order to illustrate the spatial distribution of groundwater of the area.

Total dissolved solids (TDS)

As ground water moves and stays for a longer time along its flow path, increases in total dissolved concentrations and major ions normally occur (Norris et. al., 1992). Higher TDS shows that water has stayed for a longer period in the aquifer to get the present quality (Davis and Deviest, 1966). TDS content is usually the main factor, which limits or determines the use of groundwater for any purpose (Nordstrom, 1987) and he classified the water based on TDS is given in **Table 7**. as follows:

Table 7: Nordstrom Classification of Water Based on TDS.

Description	Dissolved Solid Content (ppm)
Fresh	Less than 1000
Slightly saline	1000 to 3000
Moderately saline	3000 to 10000
Very saline	10000 to 35000
Brine	More than 35000

The TDS of ground water in the area ranges from 130 ppm to 878 ppm in pre-monsoon and 98 to728 ppm in post monsoon. The analysis of samples for the two seasons has shown that there is increase in TDS in the post monsoon period. The only samples No. 04, & 6 have little higher mineralization in the area. It could be due to the geo chemical process-taking place in the subsurface. The quality of water along the course of its underground movement is thus dependent upon the chemical and physical properties of the surrounding rocks. All other samples are found to be fresh with TDS less than 1000 ppm and spatial distribution is shown in **Figs. 7.**

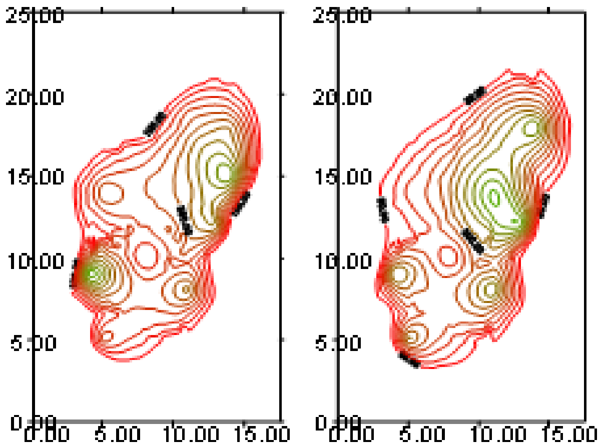


Fig. 7: Distrubution Map of Total Dissolved Solids at Pre and Post-Monsoon in Kanchugarakopplu Micro Watershed Area.

Handa`s Classification

The hydrochemical data are plotted over the modified Hill-Piper diagram of Handa (1965) Figs.6a and 6b. This diagram provides a better picture of hardness, salinity and alkalinity. By considering the major dissolved constituents and grouping together certain dissolved ions whose properties are to some extent similar to the natural water chemistry can be represented as three cationic constituents Ca, Mg, Na+K and three anionic constituents SO_4, $Cl+NO_3$, CO_3+HCO_3. These compositions are plotted on trilinear diagram. This diagram is a useful tool for characterizing the water types and to evaluate the suitability of water for domestic, industrial and irrigational purposes. In addition to the identification of hydrogeochemical facies, this diagram can also be used for indicating the sequential geochemical modifications and evolution of a water quality during its mobility in the surface systems.

Water can be classified into A1, A2, A3 and B1, B2, B3, (based on hardness), C1, C2, C3 and C4 (based on salinity) and S1, S2 and S3 (based on sodium hazard). The different chemical characters of each field are given in Table 8a, 8b and 8c as follows: -

Table 8a: Classification of water based on hardness.

A	Ca+Mg	Ca+Mg	Cl+SO4	RSC	Remarks
A1	>HCO3	>Na+K	<HCO3	Nil	Permanent hard water
A2	>HCO3	>Na+K	<HCO3	Nil	Permanent hard water
A3	>HCO3	>Na+K	<HCO3	Nil	Permanent hard water
B1	>HCO3	>Na+K	<HCO3	Present	Temporary hard water
B2	>HCO3	>Na+k	<HCO3	Present	Temporary hard water
B3	>HCO3	>Na+K	<HCO3	Present	Temporary hard water

Table 8b: Classification of water based on salinity.

Salinity	EPM TSC OR TSA	
C1	Low	< 2.5
C2	Low-Medium	2.5-7.5
C3	Medium-High	7.5-22.5
C4	High-Very high	>22.5

Table 8c: Classification of water based on sodium hazard.

	Type	Percentage Sodium hazard
S1	Low sodium water	0-30.0
S2	Low medium sodium water	30.0-57.5
S3	Medium high water	57.5-100.0

Groundwater hardness (GWH)

Hardness mainly due to the presence of carbonates of calcium and magnesium and is expressed as an equivalent amount of calcium carbonate. Temporary hardness is caused by calcium carbonate, which is only sparingly soluble in pure water but gets dissolved rapidly in presence of carbon dioxide. The highest desirable level of $CaCO_3$ is 300 ppm and the maximum permissible level is 600 ppm. Based on hardness the region can be divided into four zones as A1 and A2 (Permanent hardness) and B1and B2 (Temporary hardness) (Handa, 1965). The spatial variation of ground water hardness is detailed in **Table 9**.

The analysis has shown that the permanent hardness has increased during the post monsoon season.

Table 9: Groundwater Hardness in Kanchugarakopplu microlevel watershed Area.

Ground water hardness	No. of samples		Percentage	
	Pre monsoon	Post monsoon	%	%
Permanent	9	10	75	83
Temporary	3	2	25	17
Total	**12**	**12**	**100**	**100**

Groundwater Salinity – Sodium Hazard: The groundwater for irrigation needs could be gauged by salinity - sodium hazards (Wilcox, 1955; Balasubramanian, 1986, Sastri and Lawrence, 1988). Based on this the aquifers of the area has classified into 3 class namely C1S1, C2S1, C3S1, with a predomination class C2S1 which is detailed in **Table 10**. Wilcox diagram is plotted in **Figs. 8 (a&b)** of salinity - sodium hazard as follows:

Table 10: Classification of Salinity-Sodium Hazards Of Kanchugarakopplu microlevel watershed Area.

Salinity-Sodium Hazards	No. of Samples		Percent	
	Pre monsoon	Post monsoon	%	%
C1S1	0	2	0	17
C2S1	8	8	67	67
C3S1	4	2	33	16
Total	**12**	**12**	**100**	**100**

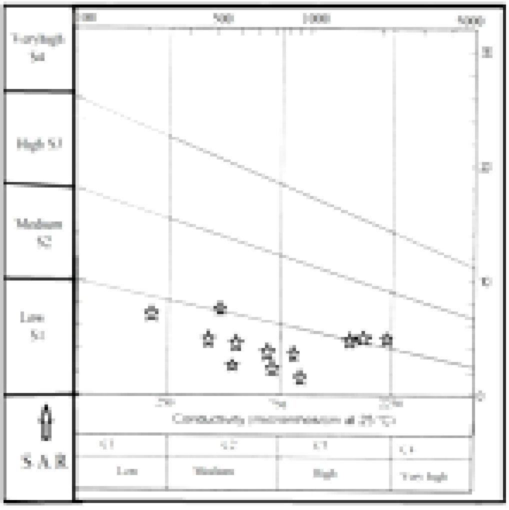


Fig. 8a: Wilcox Diagram (Pre Mansoon).

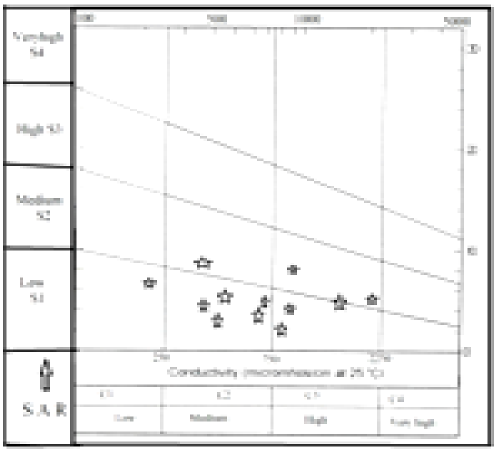


Fig. 8b: Wilcox Diagram (Post Mansoon).

Stuyfzand's Classification of Water

Stuyfzand (1986, 1989) in her classification determined eight main water types, 27 sub types and 3 classes. Theoretically she formulated a maximum number of water types amounting to 7128. Further, she explained that many water types do not exist in nature, which reduces the total number to a few hundreds. The main type of water is determined based on chloride concentration is detailed in Table 11. as follows:

Table 11: Groundwater Classification Based on Chloride Concentration (Stuyfzand's Classification).

Main type	Code	Cl mg/t
Very oligohaline	G	<5
Oligohaline	g	5-30
Fresh	F	30-150
Fresh-Brackish	f	150-300
Brackish	B	300-1000
Brackish-Salt	b	1000-1000
Salt	S	1000-2x104
Hyper Saline	H	>2x104

Based on this classification, the groundwater of the area has been sorted out to know the various implications, which is detailed in **Table 12**. as follows:

Table 12: Stuyfzand's Classification of Groundwater in the area.

Code	No. of Samples		Percent	
	Pre-monsoon	**Post-monsoon**	**%**	**%**
g - Oligohaline	01	03	08	25
F-Fresh-Brackish	10	09	84	75
F-Fresh	01	00	08	00
Total	**12**	**12**	**100**	**100**

From the above results, the majority of the ground water sample belongs to the (F-Fresh-Brackish) quality followed by Oligohaline.

Schoeller`s Groundwater Classification

According to Schoeller (1967) water type is related to the evolution of ground water with respect to chemistry. He proposed two Indices of Base Exchange capacity of water. There are some substances in ground water, which absorb and exchange cat ions with the cat ions of natural water. Ionic ratios computed from ionic concentration expressed in epm or r-values are calculated for classifying the water bodies. These hydrogeochemical parameters are useful for comparing different water bodies and for tracing the geochemical evolution of ground water. Schoeller (1956) pointed out its significance with regard to formation of water. Rosenthal (1987) has computed a set of ratios for classification. Ionic ratios computed for ionic concentration expressed in epm or r-values are calculated for classifying the water bodies. Schoeller (1967) pointed out the first and foremost water is those in which.

$rCO_3 > rSO_4$ Type I.

The increase in total concentration makes a change to

$rSO_4 > rCl$ Type II

still at higher concentration

$rCl > rSO_4 > rCO_3$ Type III

and in the final stages

$rCl > rSO_4 > rCO_3$ and

$rNa > rMg > rCa$ Type IV.

Where r represents the concentration of ion in epm.

From the **Table 13 (a&b)**, three types of water are noticed in the area. The statistical seasonal change of groundwater in the area is detailed in Table 14. as follows:

Table 13a: Chemical characteristics of Pre-monsoon groundwater in Kanchugarakopplu micro level watershed.

Location	Honda's Class	Schoeller's Water Type	Index of Base Exchange		$CaCO_3$ Saturation Indices		Corrosivity Ratio
			Cal I	Cal II	CaA-CaC	pHd-pHc	
Sri Rampura	A2C2S1	III	0.3461	0.3693	-20.2669	-1.3973	1.5728
Kestur	A2C2S1	III	0.1496	0.1073	-21.5447	-1.3173	1.046
Malali	B1C1S1	III	-0.5414	-0.179	-41.5564	-1.6537	0.4853
Dodda betta	A1C2S1	III	-0.101	-0.04	-0.293	-0.714	0.5083
Mavathur	A1C2S1	III	-0.1418	-0.037	-0.1418	-0.0366	0.3248
Margowdanahalli	A2C2S1	IV	-0.0339	-0.019	0.3554	0.3861	1.1195
Aichanahalli	A1C2S1	III	0.2614	0.0836	0.2838	0.3329	0.7118
Gowdanahalli	A2C2S1	III	0.4815	0.3752	0.5207	0.0296	0.9101
Siddapura	A1C2S1	III	0.2651	0.1374	0.5614	0.4704	0.7547
Kanchugarakopplu	A1C2S1	III	0.4275	0.171	0.8929	0.3004	0.4629
Hosakopplu	B2C1S1	IV	-3.0077	-0.458	-6.0331	-1.3754	0.2176
D.K.Kopplu	A2C2S1	IV	0.3669	0.5434	-3.2373	-0.833	1.384

Table 13b: Chemical characteristics of Post-monsoon groundwater in Kanchugarakopplu micro level watershed Area.

Locations	Honda's Class	Schoeller's Water Type	Index of Base Exchange		$CaCO_3$ Saturation Indices		Corrosivity Ratio
			Cal I	Cal II	CaA-CaC	pHd-pHc	
Sri Rampura	**A1C2S1**	**III**	0.3898	**0.**1833	-8.1012	-0.7072	**0.7668**
Kestur	**A2C2S1**	**III**	0.6095	0.3766	-5.5695	-0.8301	**1.0167**
Malali	**A1C2S1**	**III**	0.2293	0.0431	-18.5154	-1.1933	**0.1942**
Dodda betta	**A1C3S1**	**III**	0.7788	0.4936	0.1875	0.3365	**0.7599**
Mavathur	**A1C2S1**	**III**	0.5761	0.1568	-2.499	-0.6609	**0.2706**

Margowdanahalli	**A1C2S1**	**III**	0.2721	0.1174	-26.4189	-1.4112	0.5223
Aichanahalli	**A1C3S1**	**III**	0.9154	0.5606	0.9392	1.0695	0.6356
Gowdanahalli	**A1C2S1**	**III**	0.5119	0.2104	0.6297	-0.1802	0.6309
Siddapura	**A1C3S1**	**III**	0.738	0.1645	0.9591	1.2184	0.2986
Kanchugarakopplu	**A1C3S1**	**III**	0.7382	0.2999	0.1348	0.3326	0.4635
Hosakopplu	**A1C3S1**	**III**	0.6259	0.2495	0.7428	0.3562	0.4713
D.K.Kopplu	**B1C2S1**	**II**	-0.5414	-0.1434	0.0249	0.0539	0.2631

Table 14: Groundwater Types of Kanchugarakopplu micro level watershed area.

Groundwater Types	No. of Samples		Percentage	
	Pre-monsoon	Post-monsoon	%	%
I	00	00	00	00
II	00	01	00	08
III	09	11	75	92
IV	03	00	25	00
Total	**12**	**12**	**100**	**100**

It is observed that groundwater type varies with season. Type II dominates in the area and changes observed with the seasonal variation. Decrease trend noted in type I and increasing in III**.** The residence of water on the subsurface and extent of rock - water interaction is the dominant factor that controls the change in type.

Indices of Base Exchange (IBE)

Indices of Base Exchange helps to identify recharge discharge zones (Sharma 1982). Schoeller (1965a) was proposed the IBE (Chloro-alkaline indices-CA11 and CA12) and it could be determined as follows;

$$CA_{11} = \frac{Cl - (Na+K)}{Cl}$$

And

$$CA_{12} = \frac{Cl - (Na+K)}{(SO_4 + HCO_3 + CO_3 + NO_3)}$$

All the ions are expressed as epm values. The substances which exchange ions are called permutolites, in clay minerals e.g. kaolinite, halisite, illite, chlorite with low capacity exchange of ions, where as in montmorillonite and vermiculite, the exchange capacity of ions is high. IBE has given in **Table 13 (a&b)**, **Figure 8a and 8b** and it could be observed that

07samples have positive in pre monsoon and 05 samples have negative. In post monsoon 11 samples have positive and the remaining 01 samples have negative indices.

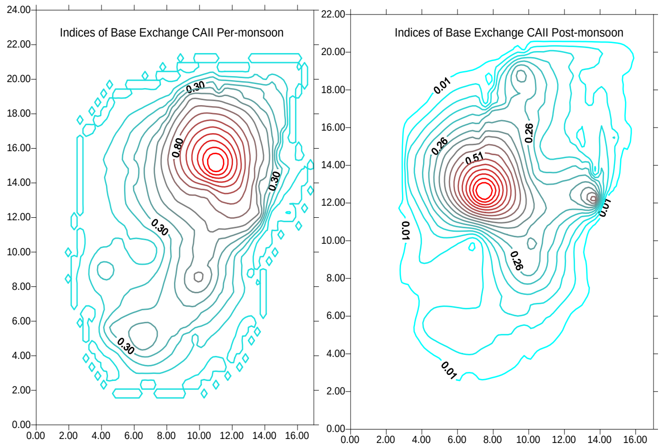


Fig 8a: Distribution Map of Indices of Base Exchange at Pre -Monsoon in Kanchugarakopplu Micro Watershed Area.

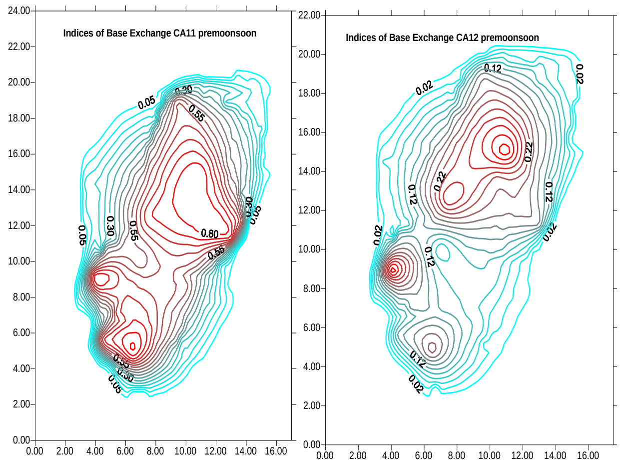


Fig 8b: Distribution Map of Indices of Base Exchange at Post – Monsoon in Kanchugarakopplu Micro Watershed Area

Corrosivity Index (CI)

The corrosivity ratio is important to know whether the water can be transported in metallic pipes or not. The groundwater with corrosivity ratio less than one is considered to be safe for transporting of water in any pipe (Balasubramanian, 1986). If the corrosivity ratio is more than one, only non-corrosive pipe have to be used for transporting of water. The rate at which corrosion proceeds depends upon certain physical factors like temperature, pressure and velocity of flow of water (Ayer and Westcot, 1985). Raman (1983) reported that, in the absence of carbonate minerals maximum concentration of Cl and SO_4 is noted which in tern increases the corrosion rate. Corrosivity ratio proposed by Ryzner (1944) is been widely used by many scientists (Badrinath et.al 1984, Balasubramanian 1986, Rangarajan 1996) to evaluate the corresivity ratio of various basins. The equation used for calculating the ratio is

$$\text{Corresivity ratio} = \frac{\dfrac{Cl}{35.5} + \dfrac{2SO_4}{96}}{0.02 \text{ X } (HCO_3+CO_3)}$$

The corresivity ratio of the area is given in **Table 15**, where all ionic values are expressed in ppm concentration.

Table 15: Corrosivity Index of Kanchugarakopplu microlevel watershed Area.

Corrosivity Index	No. of Samples		Percentage	
	Pre-monsoon	Post-monsoon	%	%
< 1	08	11	67	92
> 1	04	01	33	08
Total	12	12	100	100

About 67% of groundwater in pre-monsoon & 92% in post-monsoon have less than one corrosivity index, indicating that ground water could be transported using metallic pipes without corrosion problems. **Figures 9 (a&b)**. gives the spatial distribution of the corrosivity index in the area.

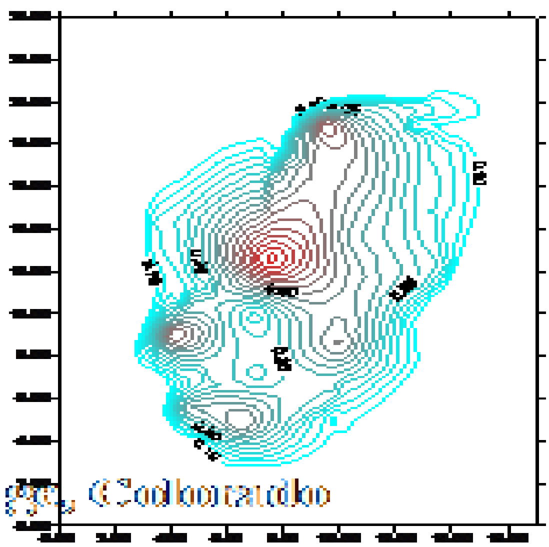


Fig 9a: Distribution Map of Corrosivity index at Pre Monsoon in Kanchugarakopplu Micro Watershed Area.

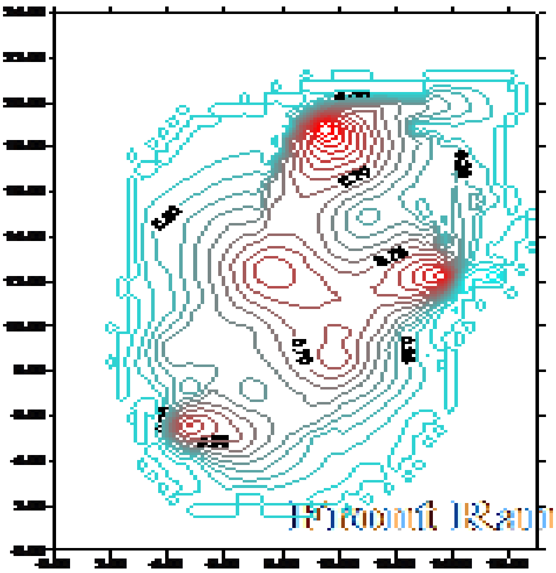


Fig. 9b: Distribution Map of Corrosivity index at Post – Monsoon in Kanchugarakopplu Micro Watershed Area.

Calcium carbonate saturation index ($CaCO_3$ SI)

The rainwater Percolating gets enriched in CO_2 and becomes weak acid and act as powerful weathering cum dissolution agents, decompose the country rock and leach away the soluble salts**.** $Ca(HCO_3)$ is formed when solution is passing through these rocks. The solubility of Ca is greatly influenced by CO_2 in groundwater, temperature, pH, ionic strength of solutions and organic content in the water. Groundwater passes through different stages like under saturation, saturation and over saturated stages.

$CaCO_3$ saturation index was calculated using equilibrium pH method and equilibrium Ca method. The saturation index in 07 samples have negative and 05 samples have positive is given in **Table 14 and 12**. **Figure 10 (a&b).** Water with positive saturation index has a tendency of incrustation and negative saturation index has the tendency of corrosion (Tamatha, 1993). No variation is observed with seasonal variation.

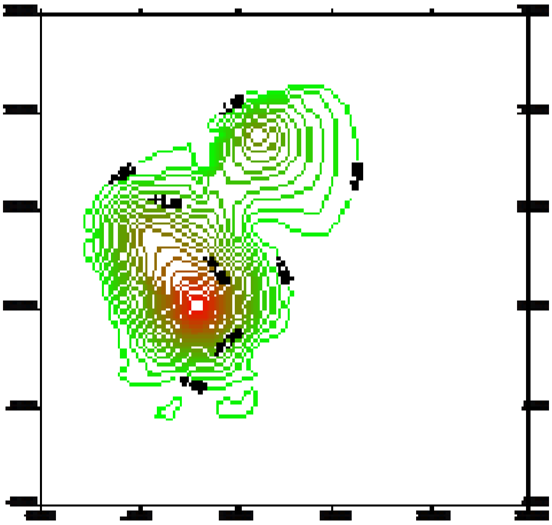


Fig 10a: Distribution Map of $CaCO_3$ saturation index at Pre Monsoon in Kanchugarakopplu Micro Watershed Area.

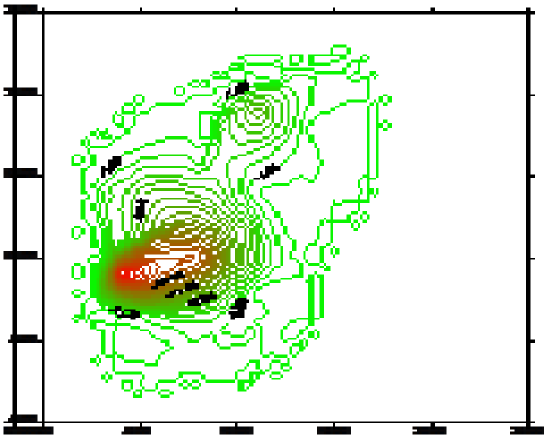


Fig 10b: Distribution Map of $CaCO_3$ saturation index at Post - Monsoon in Kanchugarakopplu Micro Watershed Area.

Mechanism Controlling the Groundwater Chemistry

In all hydrogeochemical studies and interpretations it is essential to know the possible mechanisms controlling the groundwater chemistry and facies. To identify the mechanisms controlling the chemistry of water, a set of following standards and widely used procedures has been followed.

Gibb's Plot

The Conway (1967); Gorham (1961); Mackenzie et al. (1965, 1966) and Sullen (1967), Gibbs (1970) has worked to find the mechanism controlling the chemical composition of major ions in the natural water. Hydrogeochemical studies of water quality on a large area of Karnataka state, India, have been attempted by Viswanathiah et al., (1973), Sastri (1974, 75 & 76) and established the relationship of water composition to aquifer lithology. Balasubramanian et al., (1991) made an attempt to unravel the hydrochemical facies of the southern Tamilnadu. Gibbs's (1970) has proposed the method to find the mechanism controlling the chemistry of surface water of the earth by plotting. This plot is used here for finding the factors controlling the groundwater chemistry. The mechanism controlling the water chemistry of the area during pre monsoon and post monsoon are shown in **Figures 11**. Based on this, it could be confirmed that the chief mechanisms controlling the chemistry of groundwater of the domain during pre-monsoon is rock water interaction and in post-monsoon is due to both evaporation and rock-water interaction. In one or two places it is extreme by depicting the presence of more dissolved solids.

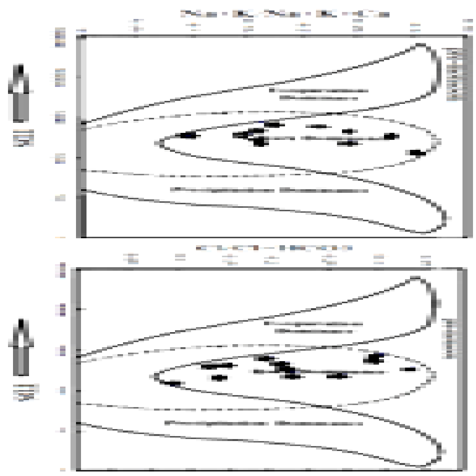


Fig. 11a: Gibbs Plot of (TDS Vs Na+K / (Na+K+Ca) and (TDS Vs Cl/ Cl+ HCO_3) at Pre-monsoon in the study area.

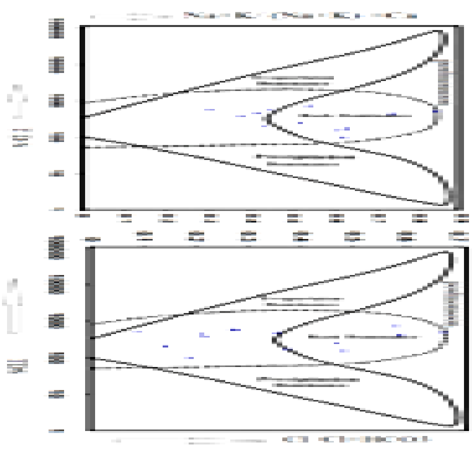


Fig. 11b: Gibbs Plot of (TDS Vs Na+K / (Na+K+Ca) and (TDS Vs Cl/ Cl+ HCO_3) at Post-monsoon in the study area.

Sodium Adsorption Ratio (SAR)

SAR is defined as Na / Ca+Mg / 2 where all the ionic concentration is expressed in epm. This has a direct relation to the adsorption of sodium by soil. Todd (1959) recommended a water classification based on SAR is detailed in **Table 16**. as follows:

Table 16: Todd's Water Classification Based on SAR.

SAR	Water Class
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

All the groundwater samples of the area fall within the range of (<10).

Isochlor map

The permissible limit of Cl in natural ground water is up to 250 ppm. The excess presence of Cl in water improves water quality. Isoline of Cl concentration of the area of pre monsoon and post monsoon are shown in **Figure 12**. Based on results the area could be divided into four divisions as follows: < 100, 100-200, 200-300 & >300. Majority of the water samples have less than 100-ppm Cl is been detailed.

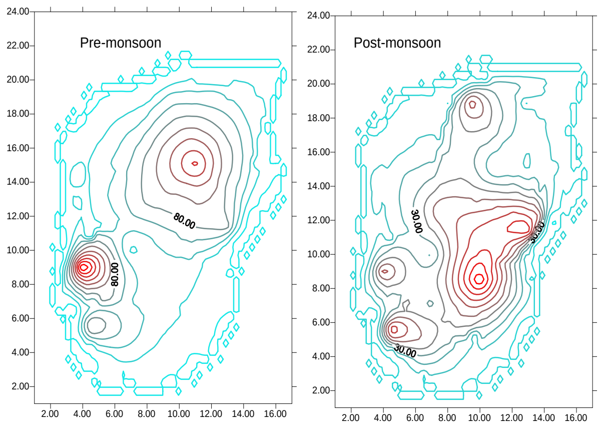


Fig. 12: Distribution Map of Isochlor at Pre and Post-Monsoon in Kanchugarakopplu Micro Watershed Area.

Permeability Index (PI)

Doneen (1948) gave the Permeability Index (P.I) formula using epm ionic values as;

$$P.I = \frac{(Na + HCO_3)}{(Ca + Mg + Na)} \times 100$$

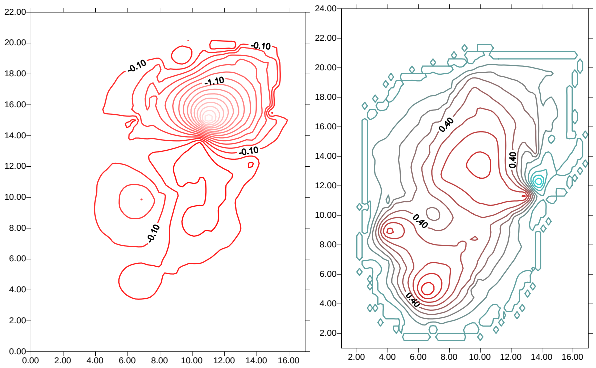
According to Doneen water is of good quality if P.I plot falls in class I or class II and if the plot falls in class III, the soils have very low permeability. Higher the P.I, lower is the permeability of the soil.

In the area, major part of the P.I falls in class-III and class-IV which is detailed in **Table 17**. as follows:

Table 17: Permeability Index of Kanchugarakopplu microlevel watershed Area Based on Doneen's Classification.

Doneen's Class	No. of samples		Percentage	
	Pre-monsoon	Post-monsoon	%	%
I	00	00	00	00
II	00	01	00	08
III	09	11	75	92
IV	03	00	25	00
Total	**12**	**12**	**100**	**100**

From the above results it is very clear that a major part of the area indicating a lower permeable horizon and less to accept infiltration, which is given in **Fig 13**.



Pre – Monsoon **Post Monsoon**

Fig. 13: Distribution Map of Permeability Index of Kanchugarakopplu micro level watershed Area.

Hydrogeochemical significance

- Twelve representative pre and post monsoon water samples were collected from the area by adopting standard techniques.
- Electrical conductivity of groundwater ranges from 200 to 1350 microsiemens /cm (µs/cm) in pre-monsoon and 150to 1120 microsiemens /cm (µs/cm) at post-monsoon.

- It is interesting to note that majority of water samples belong to Ec range of 250-750 microsiemens /cm (µs/cm) followed by 750-2000 microsiemens /cm (µs/cm), < 250 micro mhos and > 2000 microsiemens /cm (µs/cm). These results show relatively good correlation with the mineralization of groundwater.
- The pH in groundwater ranges from 6.5 to 7.6 in pre monsoon and 6.6 to 8 ppm at post monsoon thus having the character of liter acidic to base.
- Nitrate content ranges from 0.17 to 10.4 ppm with an average of 5.28 ppm in pre monsoon and 0 to 11.1 ppm with an average of 5.55 ppm at post monsoon. Hence ground water could be used for anthropogenic utility.
- Bicarbonate ranges from 123 to 512 ppm (average: 317.5) in pre-monsoon and 60 to 234 ppm (average 147ppm) at post-monsoon. Since the maximum pH value is less than 8, the carbonate level variation is neglected.
- TDS of ground water range from pre-monsoon 130 ppm to 878 ppm and post-monsoon 98 to 728ppm. The analysis of samples for the two seasons has shown that there is increase in TDS in the post monsoon period. The samples are moderate higher mineralization and it could be due to the geochemical process taking place in the subsurface and they are found to be fresh with TDS less than 1000ppm.
- Based on Stuyfzand's classification, groundwater facies in the area are prepared and it is clear that $MgHCO_3$ facies in post-monsoon and $CaHCO_3$ facies in pre-monsoon are predominated.
- Groundwater type (III) dominates and indicates larger residence time of water in the sub-surface and more time for Indices Base Exchange to take place and obliterate the original chemistry to the present state. 7 samples have positive indices and 5 samples have negative indices in pre monsoon, where as 11 samples have positive indices and the remaining 01 samples have negative indices at post monsoon.
- In the area about 67% of groundwater in pre-monsoon & 92% in post-monsoon belongs to less than one corrosivity index, indicating that the majority of the area could be supplied with groundwater using metallic pipes without corrosion problems.
- Based on Gibbs plot, it could be confirmed that the chief mechanisms controlling the chemistry of groundwater of the domain during pre-monsoon is rock water interaction and in post-monsoon it is due to both evaporation and rock-water interaction. The groundwater system has contributed much for the surface water flow and in one or two places it is extreme by depicting the presence of more dissolved solids.

- Majority of the water samples have less than 100 ppm Cl. It is also observed that isolated samples 4 have greater than 200 ppm in pre monsoon and in post monsoon all samples are <200 ppm.
- A major part of the area indicating a moderately high permeable horizon and are moderate to accept infiltration.

CONCLUSION

Groundwater is an important source of global potable water supply. In hardrock terrain, occurrence of groundwater depends mainly on Geological, Structural and hydrogeological conditions.

An integrated approach has been made in the present study to understand the surface and groundwater potentiality in the Kanchugarakopplu micro level water shed area in Cauvery river basins based on detailed analysis of geology, structure, hydro-geomorphology, hydro-geology, Hydro-meteorology and hydro-geochemistry.

Geology of Karnataka has been considered to assess the lithological features and structural pattern of the area and it is bearing on the available groundwater resources have been identified. The structural features are mainly lineaments and these are due to tectonic impact.

Cauvery river basin is exposed around Krishnarajanagara taluk. The major portion of the rock is peninsular gneissic complex and schists and these are mixed up with granodiorite, tonalite migmatite gneiss and some patches of amphibolites, hornblende and traces of garnet are noticed in the region. Numerous younger basic dykes invaded gneisses and schistose. These banded gneisses show evidences of multiple deformations. The general trend of the gneiss is NNW-SSE with a westerly dip ranging from 52^o to 76^o.

Soils of the area occur in different physiographic units, such as hilly region, hillocks, undulating to rolling lands, gently sloping pediments, and valleys. Three orders of soil (Alfisols, Inciptisols, and Entisols) are noticed in the area, the soil in the area in general is very deep, loamy skeletal, clayey skeletal, where Aslfisols dominate occupying 34.4% followed by Entisols 28.9% and Inceptisols 5.5%. Soils are well drained but poor in moisture retention capacity and are highly leach able, however poor in bases. They are suitable for crops like paddy, sugarcane, coconut, and vegetables under irrigated condition and coffee, areca, potato, ragi, millets, groundnut and cotton under rain fed conditions

In Cauvery river basins in and around Kanchugarakopplu is found that the streams in granitic gneisses are consequent and the streams developed over schistose rocks are subsequent**.** The drainage system is dendritic and sub-dendritic drainage pattern.

Twelve representative pre and post monsoon water samples were collected from the area by adopting standard techniques. Electrical conductivity of groundwater ranges from 200 to 1350 microsiemens /cm (μs/cm) in pre-monsoon and 150to 1120 microsiemens /cm (μs/cm) at post-monsoon. It is interesting to note that majority of water samples belong to EC range of 250-750 microsiemens /cm (μs/cm) followed by 750-2000 microsiemens /cm (μs/cm), < 250 micro mhos and > 2000 microsiemens /cm (μs/cm). These results show relatively good correlation with the mineralization of groundwater.

The pH in groundwater ranges from 6.5 to 7.6 in pre monsoon and 6.6 to 8 ppm at post monsoon thus having the character of liter acidic to base. Nitrate content ranges from 0.17 to 10.4 ppm with an average of 5.28 ppm in pre monsoon and 0 to 11.1 ppm with an average of 5.55 ppm at post monsoon. Hence ground water could be used for anthropogenic utility. Bicarbonate ranges from 123 to 512 ppm (average: 317.5) in pre-monsoon and 60 to 234 ppm (average 147ppm) at post-monsoon.

Since the maximum pH value is less than 8, the carbonate level variation is neglected.

The development has to be made in stages with continuous monitoring of groundwater levels for observing the effects of development on groundwater regime.

The methodologies followed, computer programs developed can be used as a positive and predictive tool for the future developmental schemes of the micro level studies, in similar hard rock terrains. Groundwater development will be successful while an integrated hydrogeological approach is employed.

Groundwater development will be successful while an integrated hydrogeological approach is employed.

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