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HYDROGEOCHEMICAL STUDY OF GROUNDWATER OF MADARAGALLI VILLAGE, MYSORE TALUK, MYSORE DISTRICT, KARNATAKA, INDIA

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Abstract

Hydrogeochemical studies are carried out for the groundwater of Madaragally village using a computer technique. The analysed groundwater data is processed using the HYCH program. HYCH is capable of providing the required output using the major ion chemistry data for classifying and identify the suitability of the groundwater for agricultural purposes. The suitability of the groundwater for irrigation is based on water chemistry, facies, mechanism of origin, type, suitability and usage factors such as corrosivity and permeability. The present study revealed that the groundwater is fresh with high salinity and low sodium hazard, belongs to MgHCO3 facies and of both permanent and temporary hardness category. The chief mechanism controlling the chemistry of groundwater of this area is rock interaction. In overall, the quality of the groundwater is good and is suitable for agricultural purposes.

Key words: *Groundwater, Madaragalli, Hydrogeochemistry, Mysore, Hydrochemistry.*

INTRODUCTION

Groundwater is extensively used all over the world as an alternate source in the absence or scarcity of surface water. Groundwater may be exploited for multiple purposes such as industrial, agricultural and domestic utilization that includes drinking purposes. The quality of groundwater is directly dependent on number of natural and anthropogenic factors. The quality and suitability of the groundwater for domestic consumption and agricultural utilization is dependent on the following factors. The physical, chemical and bacteriological characteristics are the one which decides the quality and suitability of the groundwater [1,2]. The elements present in the groundwater are derived through the interaction of rain water with soil and rock bodies during percolation. The concentration of these elements are depends on the minerals present, the length of residence time and the amount of dissolved carbon dioxide in water [1,2]. Some of the anthropogenic activities increase the concentration of these elements at times. The increase in concentration of these elements may change the quality and make the groundwater unsuitable for drinking and agricultural purposes. In rural areas some of the groundwater sources may be utilised for both domestic and irrigation purposes. Therefore, the present study is focused on the quality and suitability of the groundwater for irrigation and domestic activities in the study area.

STUDY AREA

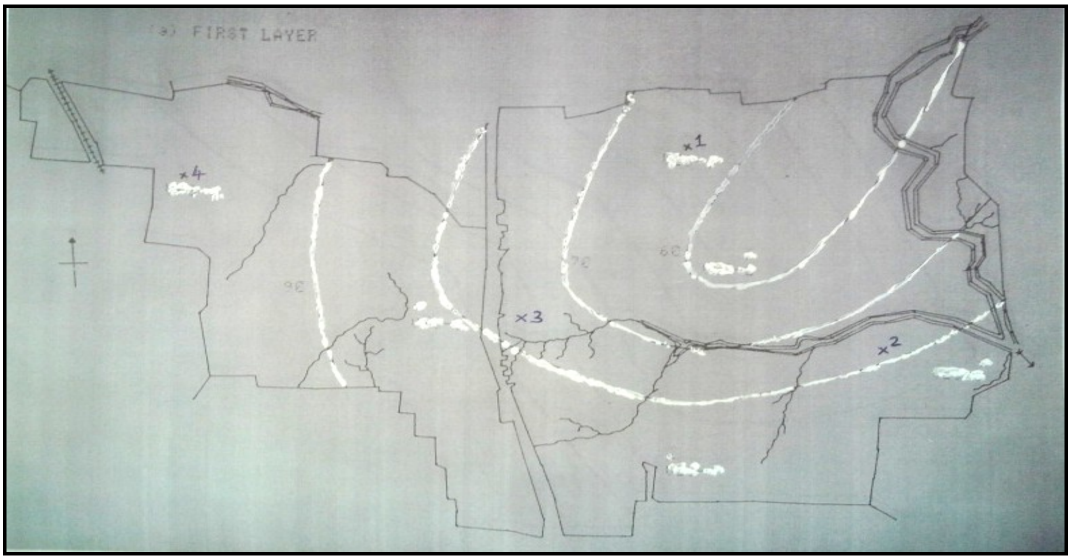
The Madaragalli village belongs to the Mysore Taluk and District, Karnataka, India. Madaragalli village is nearly 9 km away from Mysore city situated between 12^{O}13' North latitude and 76^{O}40' East longitude having a total area of 311.6 hectares. The Madaragalli village is covered by the survey of India topographic sheet 57 D/12. Map 1, shows the location of the study area. The average elevation of the study area is 680 meters above mean sea level. The average annual rainfall in the study area is 798 mm where most of the precipitation is received from the southwest monsoon. The annual average maximum temperature in the study area is 33.4^{O}C and the minimum temperature is 20.9^{O}C.

The most dominant rock types in the study area are the peninsular gneisses. The general trend of the gneisses is $N5^{O}W$ – $S5^{O}E$ with a dip of 75^{O} towards southwest. The gneisses are traversed by thin bands of quartzite with varying thickness.

Map 1. Location map of the study area; Madaragalli Village, Mysore District.

METHODOLOGY

A total of 4 samples are collected from bore wells from different locations such that they are spatially distributed in the study area. Standard procedures of the sample collection are followed for the collection of groundwater samples. Samples are collected in 1 litre PVC bottles. The bottles are thoroughly washed and rinsed twice with the water of sample collecting wells before filling to the brim. Care has been taken to avoid presence of any air gap in the sample bottles. Sample bottles are properly sealed first with airtight cork and then closed with a cap. Samples are properly labelled and date and location are mentioned on it for future reference. Such collected water samples are sent to the laboratory for the groundwater quality analysis immediately and are analysed within 24 hours. The water samples are analysed for major cations and anions such as Ca, Mg, Na, K, CO_3, HCO_3, Cl. SO_4, NO_3 and other physicochemical parameters. Map 2, shows the locations of the sampling points in the study area; Madaragalli village map. Table 1, shows the sampling locations along with the groundwater quality parameters of the study area with its acceptable and permissible limits as per BIS standards [3].



Map 2. Locations of the sampling points in the Madaragalli village.

Table 1. Groundwater quality parameters of the study area with its acceptable and permissible limits.

Parameters	Acceptable Limit	Permissible Limit	Sample 1	Sample 2	Sample 3	Sample 4
EC			900	830	1600	1000
pH	6.5-8.5	6.5-8.5	8.55	8.11	7.99	7.86
CO_3 mg/L	250	1000	48	38.4	38.4	28
HCO_3 mg/L	200	400	436.1	392	485.1	387.1
Cl mg/L	250	1000	50.4	58.8	218.4	140
SO_4 mg/L	200	400	14	4	16	16
Ca mg/L	75	200	19.2	65.6	59.2	49.6
Mg mg/L	30	100	64.3	54.7	120.9	83.5
TH	200	600	312.92	389.36	646.11	468.02
Na+ K			122	50	109	67
TDS	500	2000	585	517	949	642
NO_3 mg/L	45	45	25.3	25.3	110	35.2

The classification and suitability assessment of the groundwater obtaining manually through graphical method is tedious. The computer software / programs make these studies simple and fast. One such simple utility oriented computer program is

HYCH, which is capable of providing the required output using the major ion chemistry data [4]. It provides the interpretation of water quality based on water chemistry, facies, mechanism of origin, type, suitability and usage factors such as corrosivity and permeability.

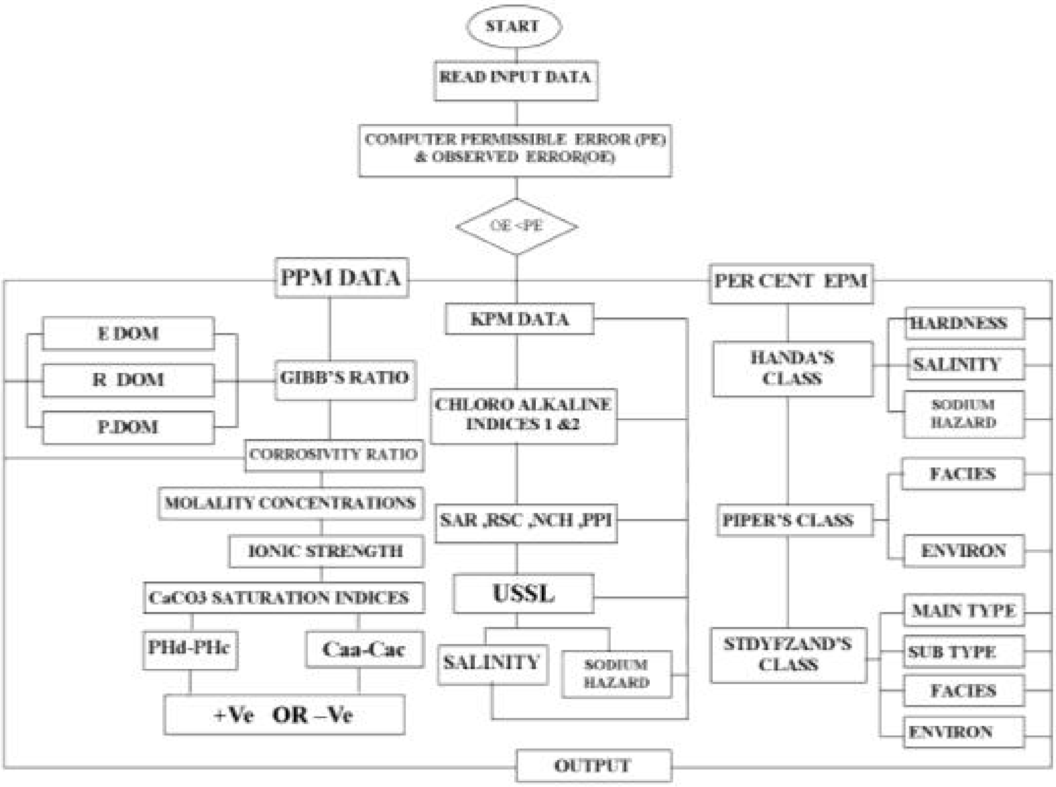


Figure 1. Flowchart of the HYCH program data processing method.

The HYCH program performs the hydrogeochemical facies classification using the criteria of Handa (1964), Piper (1944), Schoeller (1967), Stuyfzand (1989) and USSL (Wilcox, 1955) schemes [5,6,7,8,9]. The other parameters such as permeability index (Doneen, 1962), sodium absorption ratio (Todd, 1959), Residual Sodium Carbonate (Richards, 1954), Corrosivity Ratio, CR (Ryzner, 1944), indices of Base Exchange (Schoeller, 1967), Gibbs' plot (1970) [2,4,7,10,11,12,13,14,15,16]. The flow chart for the data processing in HYCH is shown in figure 1.

RESULTS AND DISCUSSION

The groundwater quality analysis data is processed using the HYCH program. Table

2, shows the HYCH program processed output data of the groundwater quality and classification for the study area.

Table 2. Output of the HYCH program showing the groundwater quality and classification.

Parameters		1	2	3	4
SAR		3	1.1	1.87	1.35
RSC		2.50	-0.07	-3.67	-2.04
PI		69.05	47.33	42.85	44.31
CR		0.177	0.202	0.619	0.514
IBE		-2.731	-0.311	0.231	0.262
		-0.411	-0.063	0.125	0.126
Gibb's Classification		ROCK INTERACTION	ROCK INTERACTION	ROCK INTERACTION	ROCK INTERACTION
Handa's Classification		B1C3S1	B1C3S1	A1C3S1	A1C3S1
SWT		IV	I	III	III
Piper's Facies		Ca+Mg, Na+K HCO_3+CO_3	Ca+Mg, Na+K HCO_3+CO_3	Ca+Mg, Na+K HCO_3+CO_3, Cl+SO_4	Ca+Mg, Na+K HCO_3+CO_3, Cl+SO_4
Stuyfzand's Classification	**Main TYPE**	FRESH	FRESH	FRESH BRACKISH	FRESH
	SUB TYPE	ALK-HIGH	ALK-MOD-HIGH	ALK-HIGH	ALK-MOD-HIGH
	FACIES	Mg HCO_3	Mg HCO_3	Mg HCO_3	Mg HCO_3
USSL		C3S1	C3S1	C3S1	C3S1

Groundwater quality

The pH, the concentration of carbonate, bicarbonate, chloride, magnesium, total hardness and total dissolved solids of the groundwater in the study area are within the permissible limits for all the samples where sample number 3 shows marginally higher values for bicarbonate, magnesium, nitrate and total hardness than the permissible limits. The concentration of calcium and sulphate are within the acceptable limits. The quality of the groundwater in the study area is very hard as reported earlier by the author [1].

Groundwater classification

In rural areas, it has been observed that the groundwater from wells is utilized for both domestic as well as agricultural purpose. Therefore, it is necessary to find the suitability of the groundwater for irrigation irrespective of the type of well. Following criteria is used for the classification and suitability study of the groundwater for irrigation in the study area.

i. Sodium absorption ratio (SAR)

The alkali (sodium) hazard is expressed as sodium absorption ratio. The SAR can be defined as the expression of the equilibrium between exchangeable cations in the soil and cations in the irrigation water. The SAR is calculated using the formula $SAR = Na/[(Ca+Mg)/2]^{1/2}$. A high concentration of sodium concentration leads to development of alkali soil and tends to become deflocculated, relatively impermeable and restricts the aeration which is very difficult to cultivate [10,16]. A low SAR is desirable for irrigation water. Irrigation water quality can be classified as follows [10].

SAR	Quality of GW
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Based on this criteria, all the samples are having the SAR values less that 10 and thus fall under the excellent category with respect to the use of groundwater for irrigation.

ii. Residual sodium carbonate (RSC)

When the sum of carbonate and bicarbonate is in excess of calcium and magnesium, there will be a residue of $NaHCO_3$ and on evaporation the pH of the soil increases which is caustic to plant life [17]. The RSC is calculated using the formula $RSC = (CO_3+HCO_3) - (Ca+Mg)$. Irrigation water should contain excess (CO_3+HCO_3) than (Ca+Mg) and can be classified as follows [11,17].

RSC	Quality of GW
<1.25	Safe
1.25-2.5	Marginal
>2.5	Not suitable

In the present study, three samples fall under the safe regime and sample number 1 is of marginal quality.

iii. Permeability index (PI)

Long term use of irrigation water containing sodium and bicarbonate contents influences the permeability of the soil. Higher the PI lower will be the permeability of the soil and hence, greater the drainage problem. Based on the index of the permeability irrigation water is classified as class I (PI>75), class II (PI 25-75) and class III (PI <25) based on the formula PI = $[(Na+(HCO_3)^{1/2})/Ca+Mg+Na]x100$ [18]. Water grouped in class I and class II are having higher permeability value and is of good quality where as water grouped in class III is of poor quality for agricultural activity. All the samples of the study area fall under the class II indicating the good quality of groundwater.

iv. Corrosivity ratio (CR)

Corrosion is a process where water interacts with the metals and deteriorates the quality of metals. CR is an index to evaluate corrosive tendency of groundwater calculated using the formula CR = $(0.028\ Cl+0.021SO_4)/\ 0.02\ (HCO_3+CO_3)$ [12]. Water with CR>1 cannot be transported through metallic pipes as it corrodes it. The CR for groundwater of the present study area is less than 1 and can be transported by metallic pipes.

v. Indices of base exchange (IBE)

There may be a mutual exchange of ions between the groundwater and rocks during its stay and/or travel at subsurface. An indices of base exchange called chloro-alkaline indices (CAI) is used to indicate the exchange of ions. These indices are determined based on the exchange phenomenon of Cl, Na, K, CO_3, HCO_3 and NO_3 and calculated using the following formula [7]. CAI1 = [Cl-(Na+K)]/Cl and CAI2 = $[Cl-(Na+K)]/[CO_3+HCO_3+Cl+NO_3]$.

Positive values indicate a direct exchange where exchange of Na and K from water with Ca and Mg in the rock; negative values indicate a reverse exchange where Ca and Mg of the rock exchanging with the Na and K of water. Negative values indicate that the water samples do not have long residence time in the aquifers and vice-versa [16]. In the present study area, sample number 1 and 2 shows the reverse exchange whereas sample number 3 and 4 shows the direct exchange indicating a long residence time suggesting a potential zone for exploitation of groundwater.

vi. Schoeller's water type

Schoeller classified the groundwater based on the percolation of water into the soil and changes in the anion concentration [7]. Schoeller has pointed out that the first and foremost type of water is one in which;

$rCO_3 > rSO_4$ -- Type I,

As the total concentration increases, the following types are obtained.

$rSO_4 > rCl$ -- Type – II,

$rCl > rSO_4 > r\,CO_3$ -- Type – III

And in the final stages, $rCl > rSO_4 > rCO_3$ and $rNa > rMg > rCa$ -- Type - IV

Where r represents the epm (equivalents per million) concentration of ions.

Two samples of the study area shows type III and one sample each shows type I and type IV water types.

vii. Handa's classification

Handa proposed a classification based on the hardness and salinity-sodium hazard [5]. In this method the groundwater is classified into permanent (A1, A2, A3) and temporary hardness (B1, B2, B3) based on the concentration of calcium and magnesium and its relation to bicarbonates. Based on the degree of salinity-sodium hazard, the groundwater is classified into categories (C1, C2, C3, C4, C5) and (S1, S2, S3, S4, S5). Among these, all the waters up to C3 could be suitably used for crops, where as C4 type could be used to some extent for salt-tolerant crops and the extreme salinity class C5 is not suitable for any crop cultivation [5,16]. In the present study area, two samples each belong to permanent hardness and temporary hardness and all the four samples are belonging to the safe category for agricultural activity.

viii. Stuyfzand classification

Stuyfzand has classified groundwater and identified main types based on Chlorine concentration [8]. In this classification the groundwater is divided into main type and subtype along with facies. In the present study area, three samples belong to fresh water type and one sample is fresh-brackish type in the main water type category and two samples each for alkali-high and alkali-moderately-high types under sub water type. All the samples indicate a $MgHCO_3$ facies in the present study.

ix. USSL classification

United States Salinity Laboratory (USSL) classification is based on salinity and sodium hazard [11]. In this classification, salinity in categorised into C1, C2, C3, C4 and sodium hazard is classified into S1, S2, S3, S4 categories as low, medium, high and very high category. In the present study, all the samples fall under C3S1 category indicating high salinity with low sodium hazard.

x. Gibbs' plot

The mechanism controlling the groundwater chemistry is indicated by the Gibb's plot. In this classification method, Gibb's ration is obtained using the expressions (Na+K)/(Na+K+Ca), $Cl/Cl+HCO_3$ and Ca+Mg+Na+K and is classified into rock dominant, evaporation dominant and precipitation dominant types [13]. The chief mechanism controlling the chemistry of groundwater of this area is rock interaction.

CONCLUSION

The quality of the groundwater in the present study area is very hard but almost all the physicochemical parameters are within permissible limits.

In the present study the suitability of the groundwater for domestic as well as agricultural purposes has been studied under different classification methods.

- Based on the SAR criteria, all the samples fall under the excellent category with respect to the use of groundwater for irrigation.
- Based on the RSC three samples fall under the safe regime and one sample is of marginal quality.
- Permeability index indicated the good quality of groundwater as all the samples of the study area fall under class II category of PI.
- The CR indicated that the groundwater of the study area can be transported by metallic pipes.
- According to IBE studies, the groundwater in the study area belongs to both direct and reverse exchange regime.
- Two samples of the study area shows type III and one sample each shows type I and type IV water types under the Schoeller's classification.
- According to Handa's classification, two samples each belong to permanent hardness and temporary hardness; and all the four samples are belonging to the safe category for agricultural activity.
- In the stuyfzand's classification three samples belong to fresh water type and one sample is fresh-brackish type in the main water type category and two samples each for alkali-high and alkali-moderately-high types under sub water type and all the samples indicate $MgHCO_3$ facies.
- In the USSL classification, all the samples fall under C3S1 category indicating high salinity with low sodium hazard.
- The chief mechanism controlling the chemistry of groundwater of this area is rock interaction according to the Gibbs' criteria.

The above observations suggest that the overall quality of the groundwater in Madaragalli village is good and is suitable for agricultural purposes.

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