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GIS Based Assessment of Groundwater Quality in Coimbatore District, India

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Abstract

Coimbatore city also known as Manchester of Tamil Nadu, is an industrial city. The study area is facing the problem of groundwater depletion and the quality is deteriorated to a greater extent. In this study, the quality of groundwater for its suitability for drinking and irrigational purposes was assessed by its hydro chemical parameters. Seventy eight groundwater samples were collected within the study area during post monsoon season of the year 2011.The samples were tested for the physical and chemical parameters. Geographic Information System (GIS) based analysis has been carried out to find out the quality of groundwater for drinking and irrigational purposes. Potassium concentration is found to exceed the maximum allowable limits in 62.82% of samples. Sulphate (SO_4) concentration of all the samples was found to be within allowable limits. Based on the study, it was found that most of the samples are suitable for irrigation purpose.

Keywords: Groundwater; Coimbatore district; Hydrochemical; Irrigation; SAR

Introduction

Groundwater is being used for various purposes like drinking, washing, irrigating etc. Knowing the quality of groundwater is important to determine the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities [1]. Suitability of groundwater for domestic and irrigation purposes is determined by its geochemical constituents. Subsurface rock formations control the composition of soil and hence that of water and vegetation. Groundwater geochemistry explains links between the chemical composition of groundwater and the health of plants, animals and people [2]. Decrease in soil fertility and the groundwater contamination is due to use of waste water for agricultural purposes without treatment [3]. Geographic Information System has been used to represent and understand the various geochemical elements in Panvel Basin, Maharashtra, India [4]. Correlation matrixes were prepared for the relationship between physical and chemical parameters of groundwater [5]. The suitability of water in Pudunagaram, Palakkad district for irrigation was determined by Sathish kumar et al. [6] and they concluded that the water is suitable for drinking and irrigation use. Haritash et al. [7] studied the water quality of Ganga in Rishikesh and concluded that regular monitoring of the quality is essential.

Logaswamy et al. [8] assessed the quality of groundwater in Kavundampalayam region in Coimbatore district and concluded that groundwater quality varied drastically. Sundar et al. [9] studied the groundwater quality along Noyyal River in Coimbatore district and concluded that the studied parameters were above the standards. An attempt has been made to determine the suitability of groundwater in Coimbatore district for different purposes. The groundwater quality of the Singanallur sub-basin have been analysed by Priya et al. [10] to check its suitability for drinking, irrigation as well as domestic usage. It was concluded that the Singanallur tank water was of bad quality because of the discharge of domestic sewage. The seasonal variations in the groundwater quality of Coimbatore city during the year 2011 are analysed during pre-monsoon and post-monsoon periods using Geographic Information System (GIS) by Jebastina et al. [11]. Based on the water quality index, the samples were categorized as excellent, good, poor, very poor and unsuitable. Multivariate statistical analysis, cluster analysis and Principal component analysis were performed by Jebastina et al. [12] on water quality data of twenty seven samples collected within Coimbatore district. The possible factors which cause contamination are identified. Water quality index has been calculated by Priya et al. [13] for the Singanallur sub-basin and the entire sub-basin was zoned to study the suitability of water for drinking purposes using the software ArcGIS and the results showed that the groundwater quality was unfit for drinking in some of the areas scoring a water quality index greater than 100.

The objectives of the present study is

i. To determine the hydrochemistry of the groundwater samples within the study area

ii. To determine the suitability of groundwater for drinking purpose using GIS

iii. To determine the suitability of groundwater for irrigational purpose using GIS

Materials and Methods

Study area

Coimbatore district lies between 10°10′N and 11°30′N latitude and 76°40′E and 77°30′E longitude. The type of groundwater in the district is CaCl, NaCl, Ca-HCO_3.The chemical constituents more than permissible limit in groundwater are Total Hardness as $CaCO_3$, NO_3, F and SO_4. The major issues related to groundwater resources in the district are (i) Declining groundwater level and drying of shallow wells (ii) Incidence of fluoride in groundwater (iii) Local pollution of surface

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and groundwater by industries [14]. The study area with sampling locations is shown in Figure 1.

Sample collection and analysis

Seventy eight bore well samples were collected from the study area during post monsoon period of the year 2011. The collected samples were analyzed for pH using pH meter, Electrical conductivity using conductivity meter and TDS by gravimetric method. The samples were analyzed for major ions by adopting standard methods [15]. The amounts of Sodium (Na^+) and Potassium (K^+) were found by flame photometry. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by titration with standard EDTA. Chlorides (Cl^-) were found by standard Silver Nitrate titration, Nitrate (NO_3^-) and fluoride (F^-) were determined by ion sensitive electrode. Sulphate (SO_4^{2-}) was found by spectrophotometer and bicarbonate (HCO_3^-) by titration. Statistical analysis was carried out using SPSS software and the spatial analysis was done using the software ArcGIS 10.1.

Results and Discussions

Hydrochemistry

Determination of groundwater quality is much important as it decides the suitability for drinking, industrial and agricultural purposes [1]. The statistical measures such as minimum, maximum, mean and standard deviation of the groundwater samples are presented in Table 1. Descriptive statistics results were compared with the standard guideline values recommended by the World Health Organization (Table 2). 63% of the samples within the study area had Potassium concentration above allowable limits, 29.5% of the samples had bicarbonates above allowable limits, 19% of the samples had concentration of sodium above allowable limits, 15% of samples had nitrate concentration above allowable limits and 10% of samples had fluoride concentration above allowable limits. Sulphate (SO_4) concentration of all the samples was found to be within allowable limits. pH value ranged between 7.7-8.7, which indicate alkaline nature of the groundwater within the study area.

Drinking water quality

Total dissolved solids: Total Dissolved Solids in the study area ranged 94-2258 mg/l with an average value of 797.22 mg/l. The classification of groundwater based on their TDS values Davis et al. [16] is shown in Table 3. According to WHO standards [17], the TDS values in 26.92% of the samples were found to exceed the permissible limits and in 73% of the samples, the TDS values were found to be within permissible limits. Higher value of TDS may be due to the nature of geological formations or due to higher residence time of groundwater with aquifer body. 26% of the samples had TDS within desirable limits and can be used for drinking purpose.

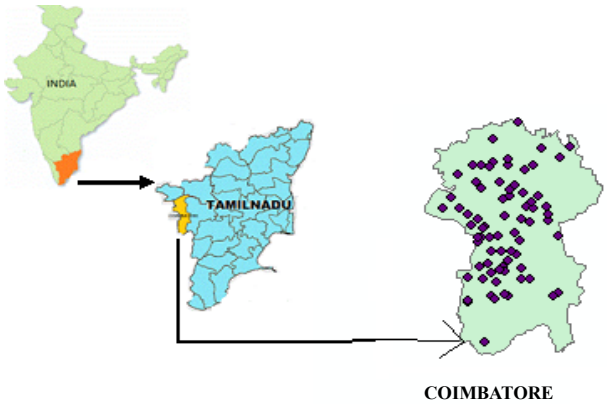

Figure 1: Study area with sampling locations.

Water Quality Parameters	Minimum	Maximum	Mean	Standard Deviation
pH	7.7	8.7	8.2	0.24
EC	170	3510	1325.51	756.59
TDS	94	2258	797.22	479.68
Ca	10	264	44.87	35.57
Mg	2.43	182.25	54.5	38.1
Na	14	506	150.5	97.44
K	1	211	20.04	28.35
Cl	11	922	214.24	203.57
SO_4	2	288	76.88	57.78
NO_3	0.1	112	23.13	24.16
F	0.05	2.07	0.76	0.53
TH	45	1240	336.47	222.01
HCO_3	36.6	573.4	251.56	109.44
CO_3	0	36	4.78	7.77
SAR	0.76	13.05	3.67	2.19

Table 1: Descriptive statistics of the groundwater samples (All values in mg/l except pH and EC in µs/cm)

Electrical conductivity: Electrical conductivity values within study area were found to range in between 170-3510 µs/cm with an average value of 1325.51 µs/cm. Table 4 shows the classification of groundwater based on Electrical conductivity.

It is found that 69.23% of samples are within permissible limits and 25.64% of samples exceed permissible limits. 5.13% of samples have EC>3000 µs/cm. The spatial distribution of electrical conductivity is shown in Figure 2.

Total hardness: Total Hardness was found to range between 45-1240 mg/l with an average value of 336.47 mg/l. The classification of groundwater based on hardness are shown in Table 5. Majority of the sample were found to fall under hard water category. Figure 3 shows spatial distribution of total hardness. The hardness values in South-Western part and Northern part of the district were found to be less than the desirable limit (300 mg/l). Samples from Central part of the district was found to have hardness beyond permissible limits (600 mg/l).Very hard water causes large soap consumption, corrodes pipes and cause stomach disorders.

Sulphate: Sulphate concentration was found to vary between 2-288 mg/l with an average of 76.88 mg/l. Sulphate concentration above 400 mg/l will affect human health. The sulphate concentration in the study area was found to be within the maximum allowable limits. The spatial distribution of sulphate concentration within the study area is shown in Figure 4.

Chloride: The concentration of Chloride varies between 11-922 mg/l with an average of 214.24 mg/l. Only 5.13% of the samples are having chloride concentration above maximum allowable limits. High chloride concentration causes heart and kidney problems. Chloride is higher due to industrial, domestic wastages and leaching from upper soil layers in dry climates [18]. The spatial distribution of chlorides is shown in Figure 5.

Nitrate: Nitrate concentration varies between 0.1-112 mg/l with an average of 23.13 mg/l. 15.38% of the samples are having nitrate concentration above 45 mg/l. Nitrate concentration above 45 mg/l in groundwater causes "Blue baby syndrome" which causes death in infants. Higher Nitrate indicating sources from plant nutrient leaching

Water Quality Parameters	Desirable Limits by WHO	Maximum Allowable Limits by WHO	Number of Samples Exceeding Allowable Limits	% of samples Exceeding Allowable Limits
pH	6.5	8.5	7	8.97
EC	780	3125	4	5.13
TDS	500	1500	7	8.97
Ca	75	200	1	1.28
Na	_	200	15	19.23
K	_	10	49	62.82
Mg	30	150	3	3.85
HCO_3	_	300	23	29.49
Cl	200	600	4	5.13
SO_4	200	400	0	0.00
NO_3	45	_	12	15.38
F	_	1.5	8	10.26

Table 2: Samples exceeding the permissible limits prescribed by WHO (2004) for domestic purposes (All values in mg/l except pH and EC in µs/cm).

Total Dissolved Solids (mg/l)	Classification	Sample Numbers	Number of Samples	Percentage of samples
<500	Desirable for drinking	1,6,7,15,19,20,21,28,31,34,36,37, 38,39,43,53,55, 57,69,76	20	25.64
500-1000	Permissible for Drinking	2,3,4,5,8,10,11,12,13,14,23,24,27, 33,35,40,41,42,45,46,47,48,50, 54,56,58,60,63,64,65,70, 71,72,73,74,75,77	37	47.44
1000-3000	Useful for Irrigation	9,16,17,18,22,25,26,29,30,32,44, 49,51,52,59,61,62,66,67,68,78	21	26.92
>3000	Unfit for Drinking and Irrigation	_	0	0
			78	100.00

Table 3: Groundwater classification based on TDS value.

ELECTRICAL CONDUCTIVITY (MG/L)	CLASSIFICATION	SAMPLE NUMBERS	NUMBER OF SAMPLES	PERCENTAGE OF SAMPLE
<1500	PERMISSIBLE	1,2,3,4,5,6,7,8,10,12,13,14,15, 19,20,21,23,24,27,28,31,33,34, 35,36,37,38,39,41,42,43,45,46, 47,50,53,54,55,56,57,58,60,63, 64,65,69,70,71,72,73,74,75,76,77	54	69.23
1500-3000	NOT PERMISSIBLE	9,11,16,17,18,22,26,30,40,44, 48,49,51,59,61,62,66,67,68,78	20	25.64
>3000	HAZARDOUS	25,29,32,52	4	5.13
		TOTAL	78	100

Table 4: Classification of groundwater based on Electrical Conductivity.

and application of nitrate fertilizers [19]. The spatial distribution of nitrate is shown in Figure 6.

Calcium: Calcium concentration varies between 10-264 mg/l with an average of 44.87 mg/l. Within the study area, only one sample is having calcium concentration above maximum permissible limit. The spatial distribution of calcium is shown in Figure 7.

Magnesium: The magnesium concentration varies between 2.43-182.25 mg/l with an average of 54.5 mg/l. Within the study area, 3.85% of the samples have magnesium concentration above maximum permissible level of 150 mg/l. Magnesium is higher, indicating sources from dissolution of magnesium calcite, gypsum and/or dolomite from source rock [20]. The spatial distribution of magnesium is shown in Figure 8.

Fluoride: Fluoride concentration ranges between 0.05-2.07 mg/l with an average of 0.76 mg/l. Northeast portion of the district (10.26% of the samples) is having fluoride concentration above maximum permissible limits. Fluoride in groundwater above permissible limits causes "fluorosis". The distribution of fluoride concentration is shown in Figure 9.

Irrigation water quality

About 23% of the geographical area of the district is used for irrigation purpose [14]. Therefore, it is necessary to know the quality of groundwater used for irrigation. Irrigation water having excess sodium, bicarbonate and carbonate ions will affect plants and soil texture. The agricultural productivity will also be reduced. Suitability of groundwater for irrigation is determined by Sodium Absorption Ratio, Percent sodium and Residual Sodium carbonate.

Sodium absorption ratio: It is an important parameter for determining the suitability of irrigation water. It is a measure of alkali/sodium hazard for crops.SAR can be estimated by the formula:

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

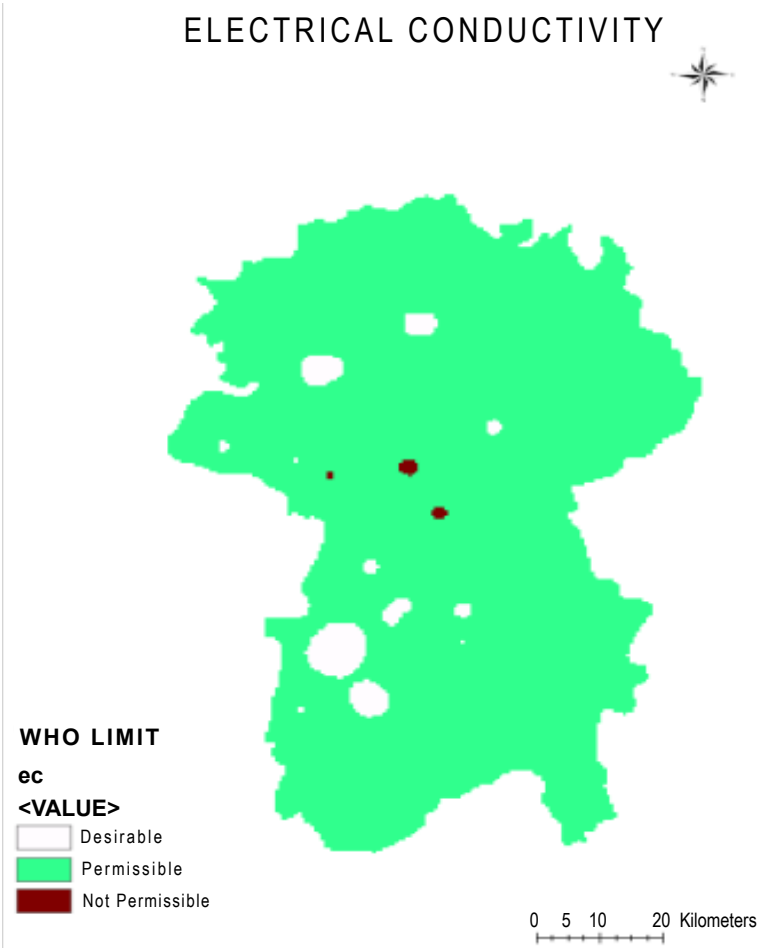

Figure 2: Spatial Distribution of Electrical Conductivity.

Total Hardness (mg/l)	Classification	Sample Numbers	Number of Samples	Percentage of samples
<75	Soft	31,43,69	3	3.85
75-150	Moderately high	15,55,64,76	4	5.13
150-300	Hard	1,2,3,4,5,6,7,12,13,16,19,20, 21,22, 23, 24,26,27,28,33,35,36,37,38,39, 41,42,45,46,47,50,53,54,56,5 8,59, 60,63,65,70,71,72,73,74,75,77	46	58.97
>300	Very hard	8,9,10,11,14,17,18,25,29,30, 32,34, 40,44,48,49,51,52,57,61,62,6 6,67, 68,78	25	32.05
		Total	78	100

Table 5: Classification of groundwater based on Total Hardness.

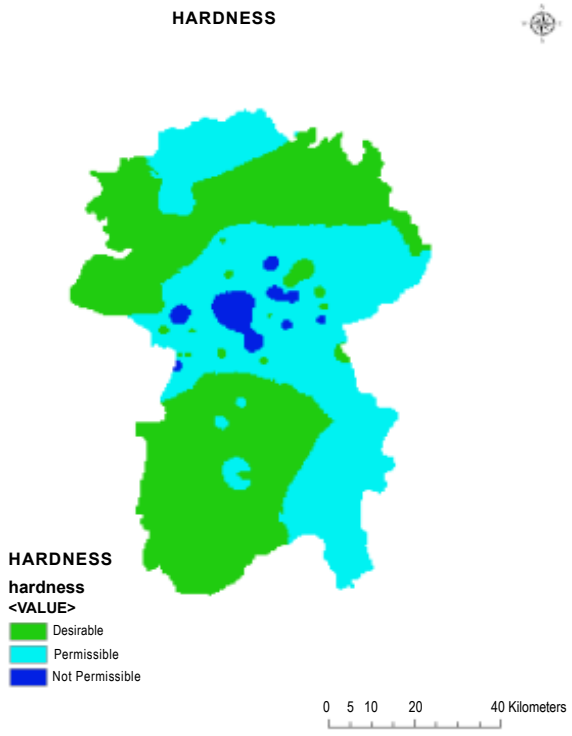

Figure 3: Spatial Distribution of Total Hardness.

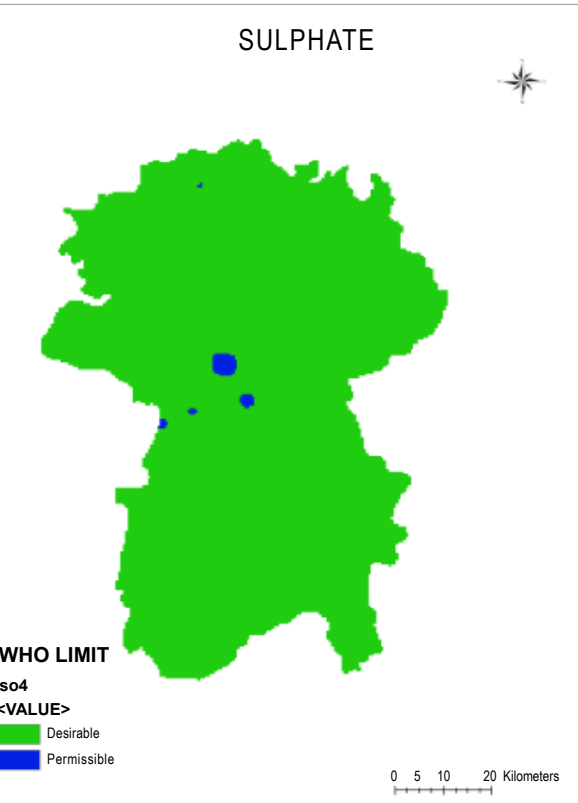

Figure 4: Spatial Distribution of Sulphate.

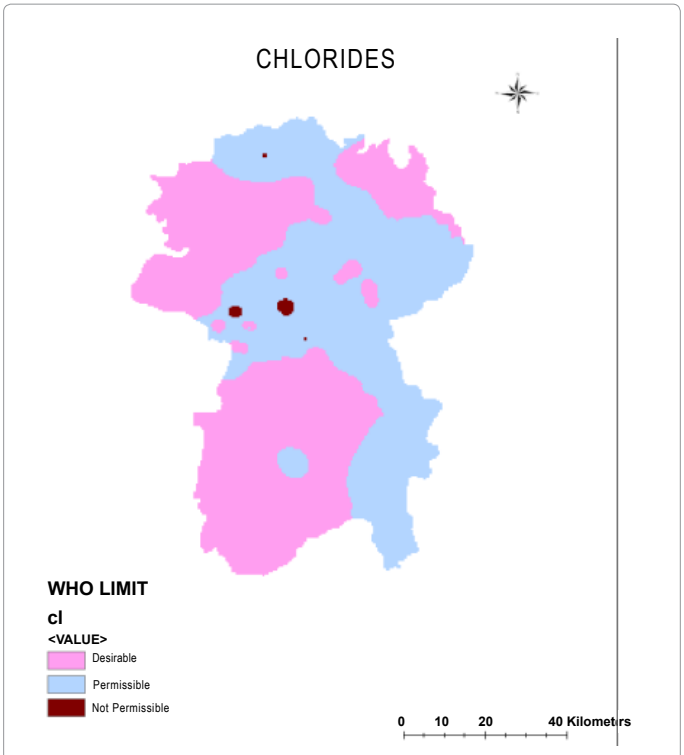

Figure 5: Spatial Distribution of Chlorides.

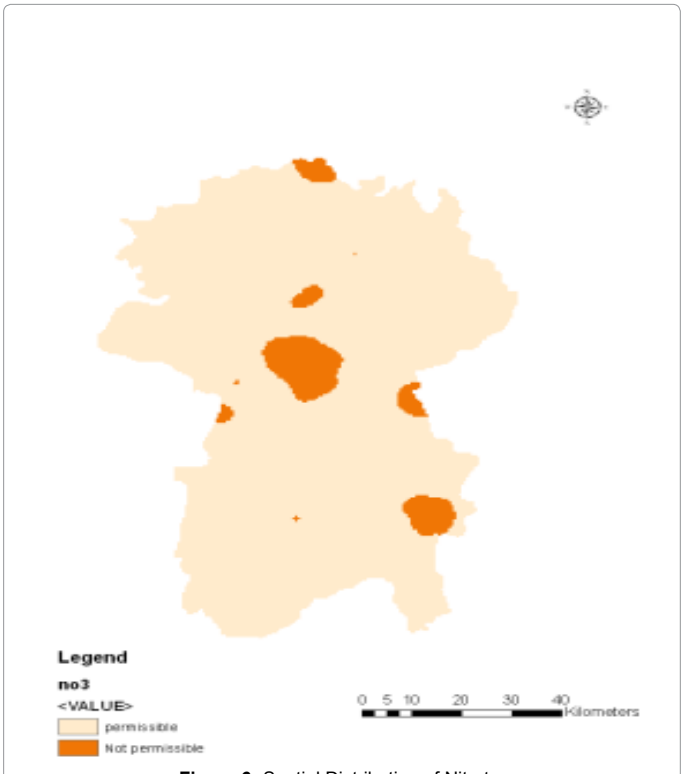

Figure 6: Spatial Distribution of Nitrate.

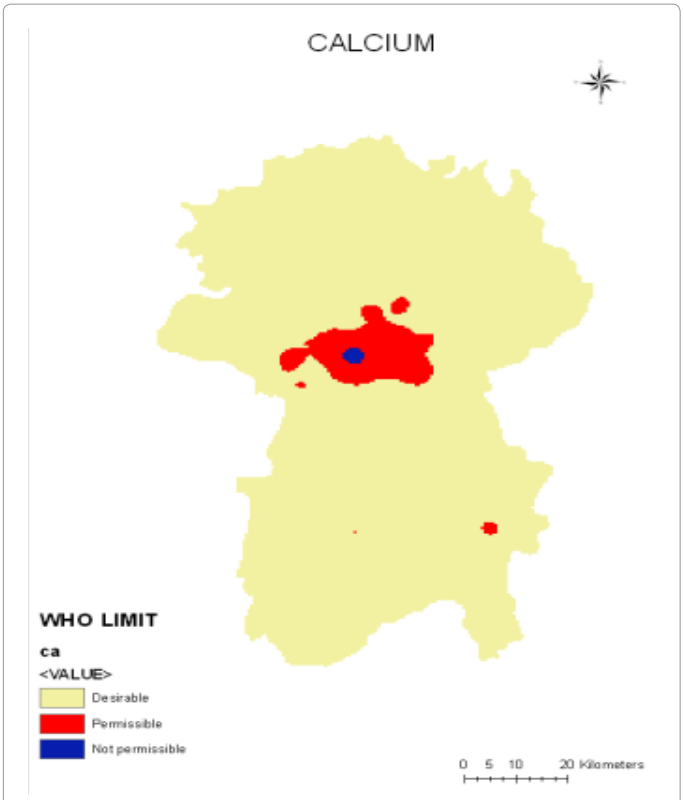

Figure 7: Spatial Distribution of calcium.

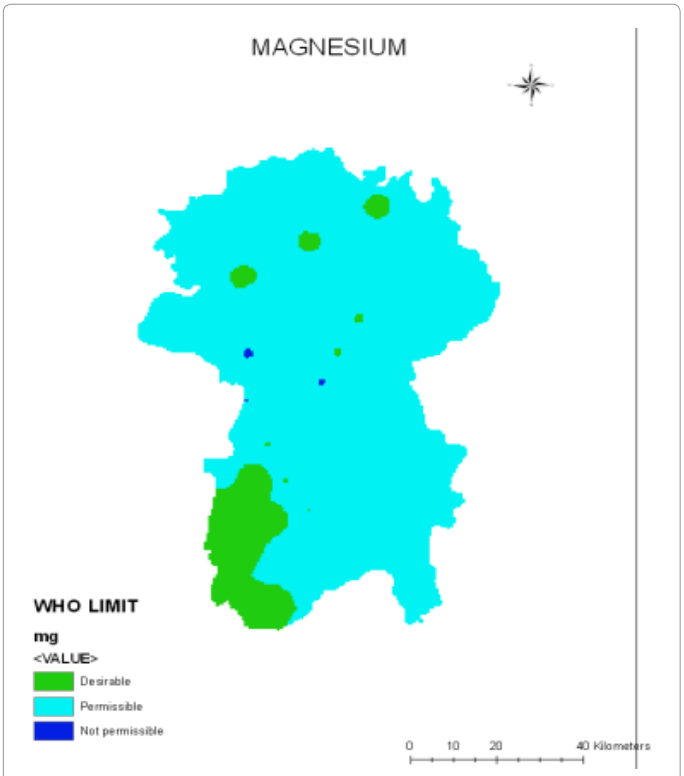

Figure 8: Spatial Distribution of magnesium.

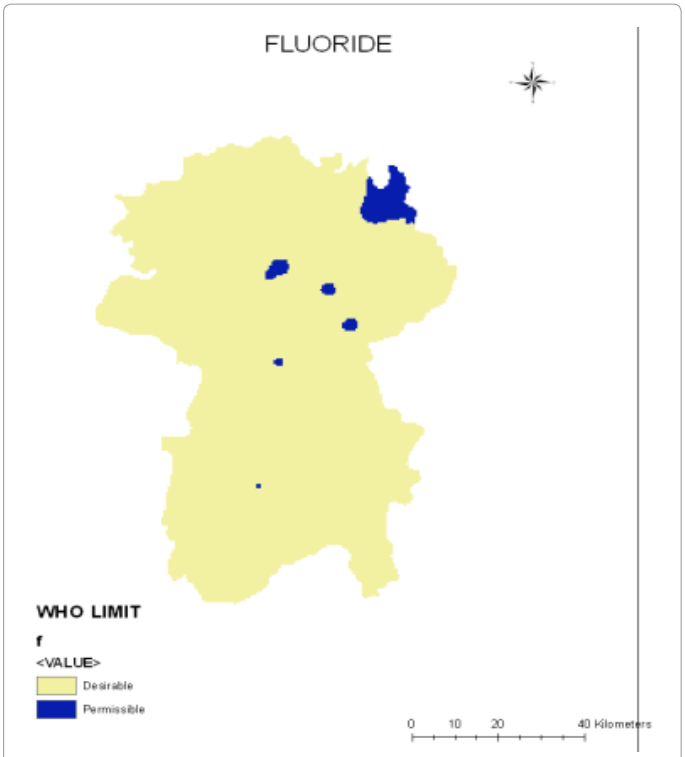

Figure 9: Spatial Distribution of fluoride.

SAR values in the study area were found to range between 0.76-13.05 with a mean value of 3.67. The classification of groundwater based on Sodium Absorption Ratio is shown in Table 6. The groundwater in the study area can be used for irrigation purpose based on sodium absorption ratio. The spatial distribution of sodium absorption ratio is shown in Figure 10.

Percent sodium: Sodium concentration can reduce the soil permeability and affect soil structure. Therefore, it is necessary to know the sodium percent in classifying water for irrigation purposes. Todd [21]. Sodium percentage is calculated by the formula:

$$Na^{+}\% = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \text{ X } 100$$

The classification of groundwater based on percent sodium is shown in Table 7. The spatial distribution of percent sodium within the study area is shown in Figure 11. 56.4% of the samples are having medium percent sodium and 14.1% of the samples are having bad percent sodium.

Residual sodium carbonate (RSC): The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability for irrigation. This is denoted as Residual Sodium Carbonate which is calculated as:

$$RSC=(HCO_3^{-}+CO_3^{2-})-(Ca^{2+}+Mg^{2+})$$

The classification of groundwater based on RSC value is summarized in Table 8. 85.9% of the samples are having excellent residual sodium carbonate and 3.85% of the samples cannot be used for irrigation purpose. The distribution of residual sodium carbonate is shown in Figure 12.

SAR	Water Class	Sample Number	Number of Samples	Percentage of samples
<10	Excellent	1-21,23-25,27-58,60-78	75	96.15
10-18	Good	22,26,59	3	3.84
		Total	78	100

Table 6: Classification of groundwater based on Sodium Absorption Ratio.

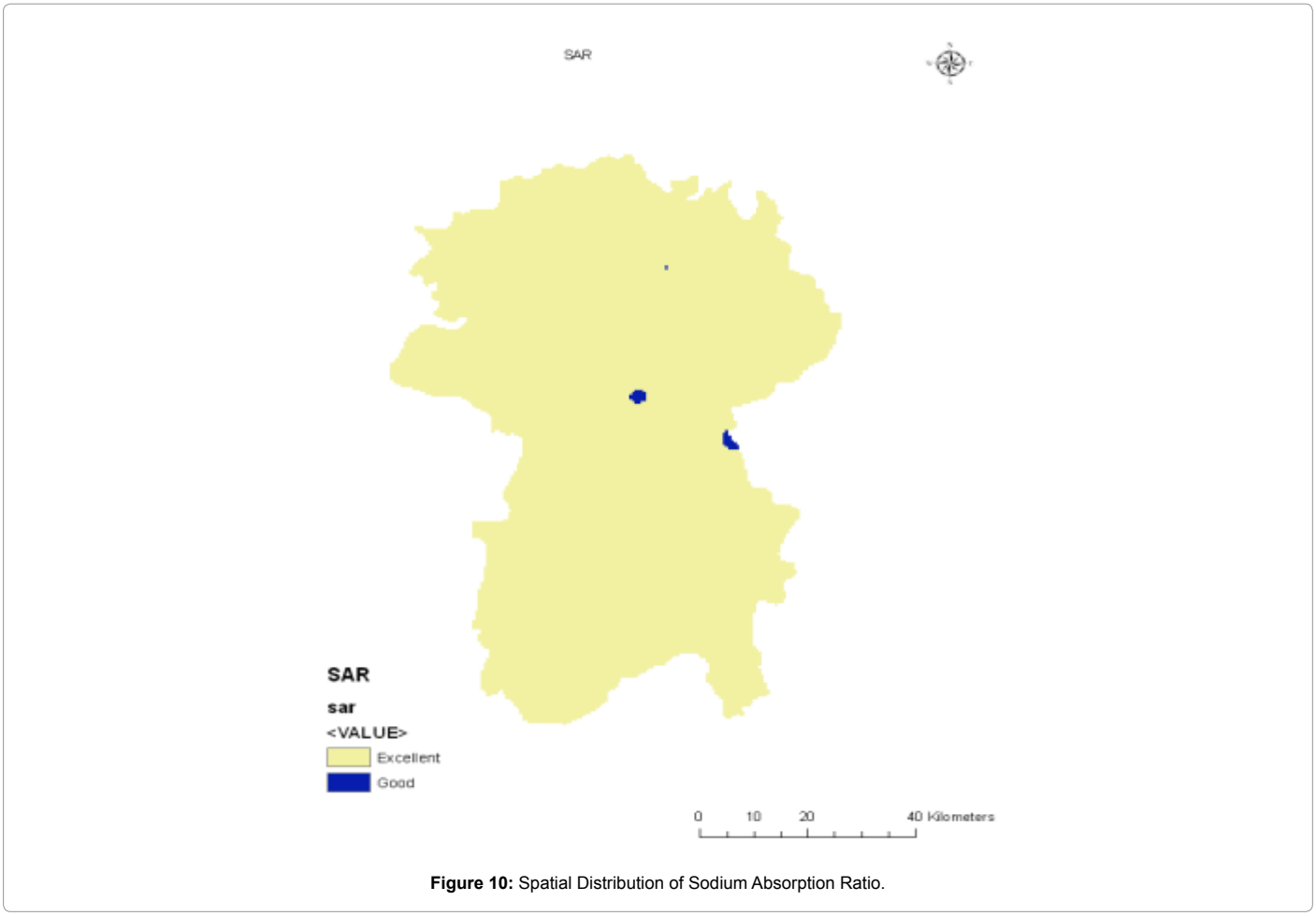

Figure 10: Spatial Distribution of Sodium Absorption Ratio.

Sodium %	Water class	Sample Number	Number of Samples	Percentage of Samples
<20	Excellent	53	1	1.28
20-40	Good	8,10,14,15,17,18,19,20,25,30,31, 32,34,36,37,39,40,50,57,66,67,68	22	28.21
40-60	Medium	1,2,3,4,5,6,9,11,12,13,16,21,23,24, 27,28,29,33,35,38,41,42,43,44,45, 46,49,51,52,55,56,58,60,61,62,63, 65,69,70,72,73,78	44	56.41
60-80	Bad	22,26,48,54,59,64,74,75,76,77	11	14.1
		Total	78	100

Table 7: Classification of groundwater based on percent sodium.

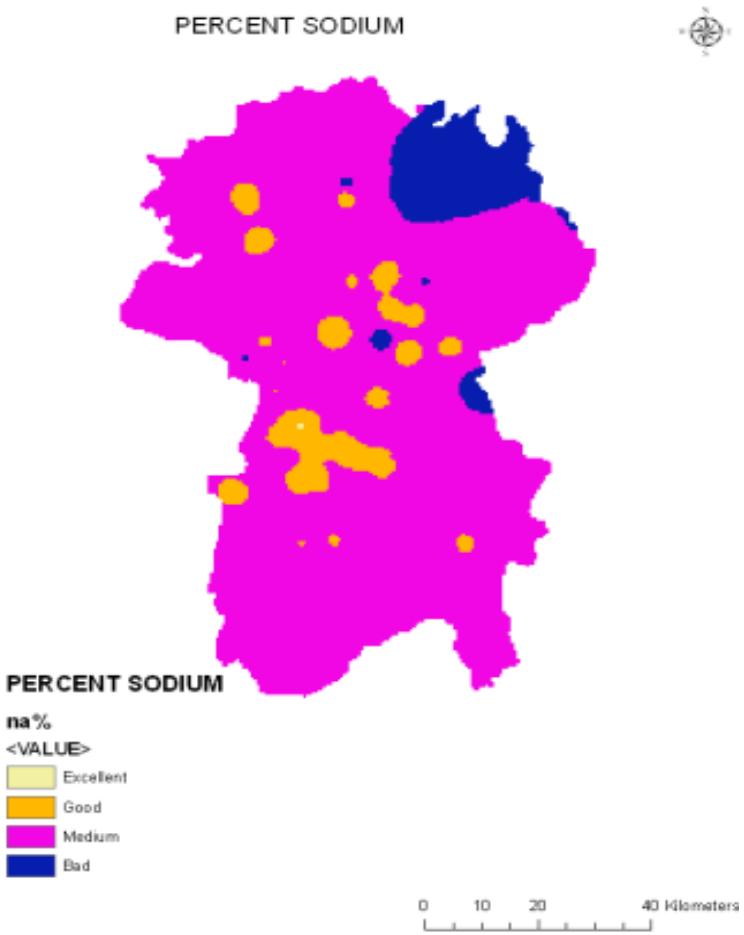

Figure 11: Spatial Distribution of percent sodium.

RSC	Water Class	Sample Number	Number of samples	Percentage of samples
<1.25	Excellent	1,2,4,5,6,7,8,9,10,11,12,14,15,16, 17,18,19,20,21,22,23,24,25,27,28, 29,30,31,32,33,34,35,36,37,38,39, 40,41,42,43,44,46,48,49,50,51,52, 53,54,55,56,57,58,60,61,62,63,64, 65,66,67,68,69,70,71,77,78	67	85.90
1.25-2	Good	3,13,45,47,72,73,76	7	8.97
2-2.5	Medium	-	0	0
2.5-3	Bad	75	1	1.28
>3	Very bad	26,59,74	3	3.85
		Total	78	100

Table 8: Classification based on RSC values.

Conclusions

The present study has been carried out to evaluate hydro chemical characteristics of groundwater of Coimbatore district, Tamil Nadu, India. To visualize the spatial distribution of groundwater quality in the study area, GIS has been applied. Seventy eight samples were collected and analyzed for various physicochemical parameters. The groundwater in the study area is alkaline in nature. Forty nine samples within study area exceed maximum allowable Potassium concentration. Twenty three samples are having HCO_3^- above maximum allowable limit and twelve samples exceed maximum allowable nitrate concentration. Groundwater in the study area is having sulphate concentration within permissible limit. Based on Total Dissolved Solids, 73% of samples are within permissible limit for drinking and all the groundwater samples in the study area is suitable for irrigation. Four samples are classified as hazardous based on their Electrical Conductivity value. Most of the groundwater in the study area is hard water or very hard water and 10% of the samples are having high fluoride concentration. Based on Sodium Absorption Ratio value, Percent sodium value and Residual Sodium Carbonate value, the groundwater in the study area is suitable for irrigation purpose.

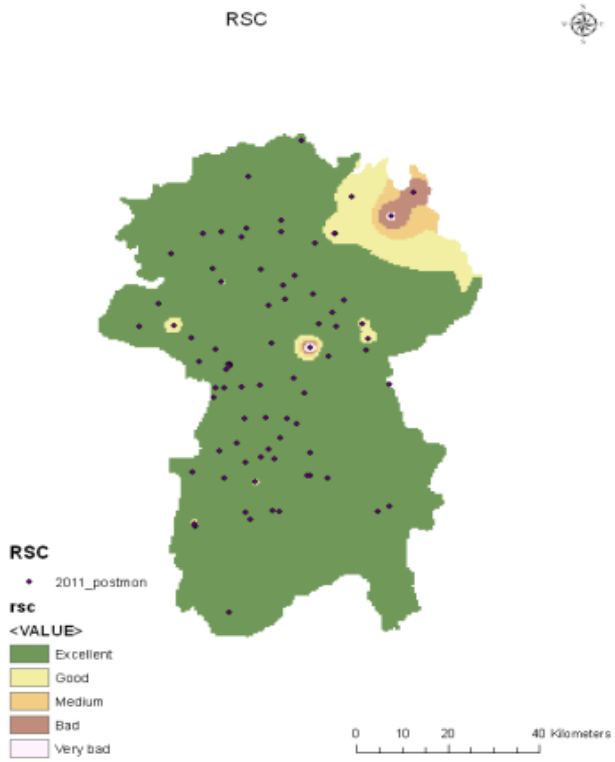

Figure 12: Spatial Distribution of Residual Sodium Carbonate.

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