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Groundwater Quality Assessment Using Chemical Idices, PIG and GIS Mapping in SitaNadi Watershed, Karnataka, India

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ABSTRACT

Groundwater is one of the most important natural resource of freshwater for agriculture, drinking and domestic uses. The problem of water quality become more important than quantity. Many natural factors like soil, geology, effluents, sewage disposal, influences on the groundwater quality of an area. Water quality is also affected due to human activitieslike improper agricultural practice, industrialwastes, and municipal solid wastes. As a result quality of groundwater in some parts of the country, particularly shallow groundwater is deteriorating. In context to the above issues an attempt has been made to study the geochemistry of groundwater available in SitaNadi watershed. The water samples have been analysed for cation and anions. The anomalies are highlighted by the Isoconcentration maps and the same has been interpreted. In general the overall quality of the groundwater in the study area is suitable for both domestic and agricultural activity as of now.

KEYWORDS: SitaNadi, Groundwater Quality, PIG

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INTRODUCTION

Groundwater is the major source for drinking water. Besides, it is an important source of water for the agricultural and industrial sectors. The water quality is of vital concern for mankind as it is directly linked with human welfare.The quality of ground water characterized by physico-chemical characteristics. The change in these parameters depends on the various types of pollution, precipitation, quality of recharged water, sub surface geochemical processes. Hence continuous monitor of ground water quality is required to minimize pollution and to identify point of pollution source.

Water pollution not only affects water qualitybut also threats human health, economic development, and social prosperity[1]. Various geostatistical concepts are used for the interpretation of complex data sets, which allows a better understanding of the water quality parameters [2, 3, 4].

Water quality data are utilized in the present study to analyse the groundwater chemistry. Pollution index of ground water (PIG) techniques of rating adopted to understand the individual parameters influence on the overall quality of water. PIG values were computed by calculating Relative weight, computation of weight parameters (WP), status of concentration (SC) and overall water quality (OW).

STUDY AREA

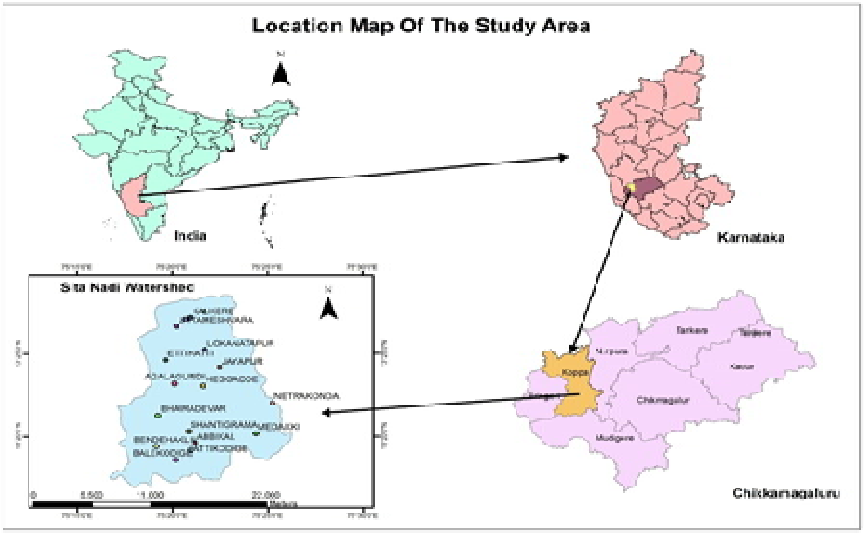


Fig 1 - Study area

The study area SitaNadi watershedFig-1 is a part of Tungabhadra catchment located in Koppataluk, which is approximately 57 km from west of Chikkamagaluru town. The aerial extent of the study area is situated between N 130 15 and N 130 30 Latitude and E 75 01 51 to 750301 E Longitude at an elevation of 672 m above the MSL, with a geographical area of 224.81 km^2. The majority of the climate in the study area is humid to sub humid, with average annual temperature of 23.10°C and rainfall is 2874.43 mm respectively.

METHODOLOGY

In the study area 20 groundwater samples have been collected from various locations Fig-2. The sampling points were located in areas where there was no treated water supply. The samples so collected were analysed for various physico-chemical parameters by adopting standard analytical procedures. The samples were analysed for pH, electrical conductivity (EC), major cations and anions. The pH was measured with pH meter and EC with Conductivity meter. Calcium, magnesium, bicarbonate and chlorides were estimated by titrimetric method. Sodium and Potassium were determined by flame photometer. Fluoride concentration was measured with Spectrophotometric technique. Geographical information system has been used to generate iso-concentration maps to depict the anomalies in the study area.

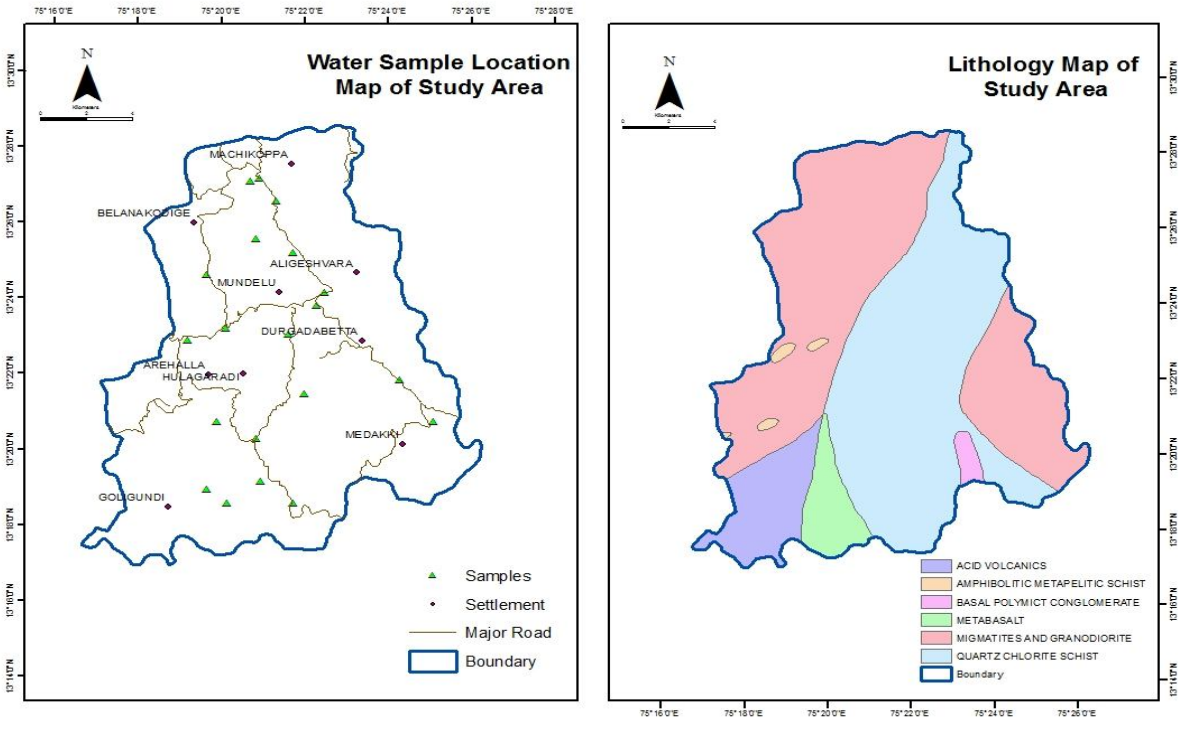


Fig 2: Water Sample locations and lithology

RESULT AND DISCUSSION

The groundwater samples are analysed and statistical parameters of the chemical variables are tabulated in Table-1. Examination of the correlation matrix is given in the Table-2. Distribution pattern of the ionic concentration over the study area is shown by generating Iso-contour maps.

Calcium (Ca^{2+})

The Calcium value in the study area ranges from 25.1 mg/l to 156 mg/l with an average of 59.26 mg/lFig-3. The permissible range of Calcium for drinking water is specified as 75 to 200 mg/l[5].Isoconcentration maps have been prepared to depict the chemical variations for both the seasons and the maps reveals that all the groundwater samples of the study area are well within the permissible range. Weathering of gneissic and granitic rock contributes calcium to the groundwater.

Magnesium (Mg^{2+})

The Magnesium value in the study area ranges from 1 mg/l to 22.45 mg/l Fig-3 with an average of 7.98 mg/l.The desirable limit specified for Magnesium concentration for drinking water is 30 mg/l.The Variation of the Magnesium over the study area is as shown in the isoconcentration map. Contribution of Magnesium in the study area is mainly due to the lithounits of the area. Weathering of schist and gneisses enrich the Magnesium content in groundwater.

Sodium (Na^{+})

The average Sodium content for the study area is 6.05 mg/l.Fig-3.There is no permissible limit for Sodium, thus it is not used in classifying drinking water but crucial from agricultural point of view. Application of animal waste and increased use of chemical fertilizers and weathering of clay minerals, pyroxenes and amphiboles contributes significant amount of Sodium to groundwater.

Potassium (K^{+})

Potassium concentration varies from traces to 0.17 mg/l, with an average of 25.8 mg/l with an average of 14.44 mg/l. The main source of Potassium is due to weathering of lithology rich in minerals such as orthoclase, microcline, biotite. Apart from this excess usage of organic fertilizers and plant and animal waste used as manure also contributes to the enrichment of Potassium in groundwater. The variation of Potassium is shown in the isoconcentraiton map Fig-3.

Chloride (Cl^-)

The concentration of Chloride is high in groundwater as it is highly soluble. Its presence in drinking water doesn't harm but excess of its concentration affects the taste. Chloride concentration in the study area range from 64.13 mg/l to 287.42 mg/l Fig-4 with an average of 148.23 mg/l. The permissible limit of Chloride in drinking water is 200 mg/l[5].Samples from Lokanathpur, Makkikoppa and Herur village shows high in Chloride concentration. Remaining water samples in the study area are well within the permissible range. Improper agricultural practice and ion exchange in underlying quartz chlorite schist adds most of the Chloride to groundwater.

Sulphate (SO_4^-)

Sulphur is readily soluble and chemically stable compound. The recommended upper limit of Sulphur in drinking water is 250 mg/l[5]. Sulphate concentration in the study area varies from 7.2 mg/l to 136 mg/l with an average of 28.13 mg/l. The sulphate concentration in groundwater samples of the study area is within the permissible limit. The distribution of Sulphate over the study area is as shown in the Fig-4.

Nitrate (No_3^-)

The main source of Nitrate comes due to human activity. Excessive usage of chemical fertilizers in agricultural activities and the cultivation of nitrogen fixing nodule plants like peas, beans, soybeans, and groundnut. Nitrate concentration in the study area varies from 0.1 mg/l to 24.98 mg/l with an average of 10.30 mg/l and prescribed limit in the drinking water is 45 mg/l[5].All thegroundwater samples of the study area are well within the permissible limit Fig-4.

pH

The pH of water indicates its quality and provides information on geochemical equilibrium or solubility calculation[6].pH values of the study area varies from 6to 7.14 with an average pH of 6.64. The desirable limit of pH for drinking water is 7 to 8.5. pH of the groundwater samples in the study area are within the permissible limitFig-4.

Electrical conductivity (Ec)

The conductivity indicates the ionic concentration and depends on temperature, concentration and type of ions present [6]. EC of the groundwater varies from 0.005 to 0.364micro Siemenswith an average of 0.06 micro Siemens.

Total dissolved solids (Tds)

TDS describes the inorganic salts and small amounts of organic matter present in water [5]. High TDS concentration is due to the presence of bicarbonates, carbonates, sulphates and chlorides of calcium. High value of TDS influences the taste, hardness and corrosive property of the water. The calculated values of TDS in the study area varies from 52 mg/l to 258 mg/l with an average of 90.55 mg/lFig-5. The permissible limit of TDS is 2000 mg/l[7]. Groundwater classification based on TDS shows that all the samples are permissible for drinking and all the groundwater samples are desirable for irrigation.

Total hardness (Th)

Hardness of water refers to the soap neutralizing power of water, while soap is precipitated primarily by calcium and magnesium ions, hardness is defined as the sum of concentration of these ions expressed as mg/l. of $CaCO_3$. The calculated values of TH in the study area vary from 88.5 mg/l to 380 mg/l with an average of 202.5 mg/l. The permissible limit of TH is 600 mg/l [7].Groundwater classification based on TH shows that allthe samples are of soft type.

Iron (Fe)

Iron is one of the major constituents in the rock next in abundance to oxygen, silica and aluminium. Iron is mainly derived from iron bearing minerals like pyroxenes, amphiboles and micas. Desirable limit of 'Fe' content in groundwater is 0.3 mg/l[7]. The 'Fe' value ranges from 0.012to 0.92 mg/l,with a mean of 0.14 mg/l in the study area. The variation of 'Fe' is as shown in Fig-5.

Fluoride (F)

The limit of Fluoride concentration in drinking water is specified as 1 mg/l. Fluoride concentration in the study area varies from 0.02 mg/l to 0.62 mg/l with an average of 0.18 mg/lFig-5. Fluoride concentration in the groundwater is mainly by the influence of lithology where gneisses and schist covers major portion of the area. Weathering of same has been contributed Fluoride to the groundwater and due to agricultural runoff containing chemical fertilizers add fluoride to the groundwater to some extent.

Table No 1: Statistical Parameters

Chemical Constituent	Min.	Max.	Mean	Stdv.
Ca	25.1	156	59.2	33.87
Mg	1	22.5	7.98	5.22
Na	0.1	14.5	6.05	3.51
K	0.17	25.8	14.4	7.47
Cl	64.13	287.42	148.23	62.06
SO_4	7.2	136	28.13	26.88
NO_3	0.1	24.98	10.30	7.13
pH	6	7.14	6.6	0.30
EC	0.005	0.364	0.063	0.08
TDS	52	258	90.55	48.68
TH	88.5	380	202.02	71.27
Fe	0.012	0.928	0.144	0.21
F	0.02	0.62	0.18	0.18

Table No 2: Correlation Matrix of Variables

	Ca	Mg	Na	K	Fe	Cl	SO4	NO3	F	EC	PH	TDS	TH
Ca	1.00												
Mg	0.16	1.00											
Na	0.18	0.36	1.00										
K	-0.19	-0.23	-0.44	1.00									
Fe	0.43	0.01	0.21	-0.53	1.00								
Cl	0.29	0.43	0.51	-0.36	0.18	1.00							
SO4	0.23	-0.09	-0.08	-0.44	0.86	0.12	1.00						
NO3	0.06	-0.25	0.35	0.39	-0.13	0.12	-0.13	1.00					
F	-0.21	-0.27	-0.04	0.28	-0.12	-0.23	-0.09	0.21	1.00				
EC	0.38	0.06	0.01	-0.47	0.82	0.32	0.84	-0.22	-0.18	1.00			
PH	-0.02	-0.06	-0.08	0.02	0.19	0.39	0.33	0.03	-0.35	0.43	1.00		
TDS	0.09	-0.04	-0.12	-0.19	0.53	-0.05	0.45	-0.25	-0.02	0.34	0.08	1.00	
TH	0.58	0.76	0.55	-0.42	0.22	0.60	0.01	-0.16	-0.24	0.15	-0.16	0.05	1.00

Pollution index of groundwater (PIG)

PIG is a technique of rating which provides the composite influence of individual water quality parameters on overall quality of water for human consumption[8].It is a mathematical tool to integrate the complex water quality data into a numerical score that describes the overall water quality status. The computation of PIG involves the following steps.

Relative weight (Rw)

Each Chemical parameter is assigned a weight by keeping its impact on human health into consideration. The range of numerical magnitude of relative weight ranges from 1 to 5 Table-3. For instance the parameters like F, Fe are assigned as Rw 5 and pH, Na, NO3, SO4, TDS are assigned the Rw4 and Cl , EC, TH as 3 and Ca, Mg as 2 and K as 1 respectively. The lower values of Rw indicates lesser impact of respective chemical parameters on health and higher values have more impact over human health.

Computation of weight parameter (Wp)

Weight parameter is the ratio of Rw of every water quality measure to the sum of all relative weights. Weight parameter enables to know about the relative share of each water quality measure on overall water quality. The Wp is given by the equation;

$$Wp = \frac{\mathrm{Rw}}{\sum \mathrm{Rw}}$$

Status of concentration (Sc)

Status of concentration is the ratio of concentration of each water quality measure of every water sample (C) to its respective drinking water quality standards (Ds). The Sc of each water quality measure is computed by the equation;

$$Sc = \frac{\mathrm{C}}{\mathrm{Ds}}$$

Overall water quality (Ow)

The overall water quality is computed by taking the product of each water quality measure with its corresponding status of concentration. Ow reflects overall water quality and also enables to understand the nature of weight parameter with respect to concentration of each water quality measure. Ow is calculated by;

$$Ow = Wp * Sc$$

Pollution index of groundwater (PIG)

PIG is calculated by the addition of all the values of Ow contributed by all the water quality measures of each water sample. PIG is given by;

$$PIG = \sum Ow$$

Pig classification

The classification of PIG is based on water quality standard for drinking purpose. PIG classification could also be used in the assessment of groundwater contamination. When both the values of quality of particular water sample and concentration of water quality measure are same then their impact on health could be insignificant. With an account of this, when the PIG value is less than 1.0, it could be considered as a non-pollution index and when PIG exceeds more than 1.0, then it may be the contribution from a contaminant into an aquifer thus polluting.

Table No 3:PIG Classification

Water Quality Measure	**Units**	**Relative Weight (*Rw*)**	**Weight Parameter (*Wp*)**	**Drinking Water Quality Standards (*Ds*)**
Ca	mg/l	2	0.046	75
Mg	mg/l	2	0.046	30
Na	mg/l	4	0.090	200
K	mg/l	1	0.022	10
Cl	mg/l	3	0.068	250
SO_4	mg/l	4	0.090	150
NO_3	mg/l	4	0.090	45
pH	-	4	0.090	7.5
EC	ms	3	0.068	1400
TDS	mg/l	4	0.090	500
TH	mg/l	3	0.068	600
Fe	mg/l	5	0.114	0.3
F	mg/l	5	0.114	1.5

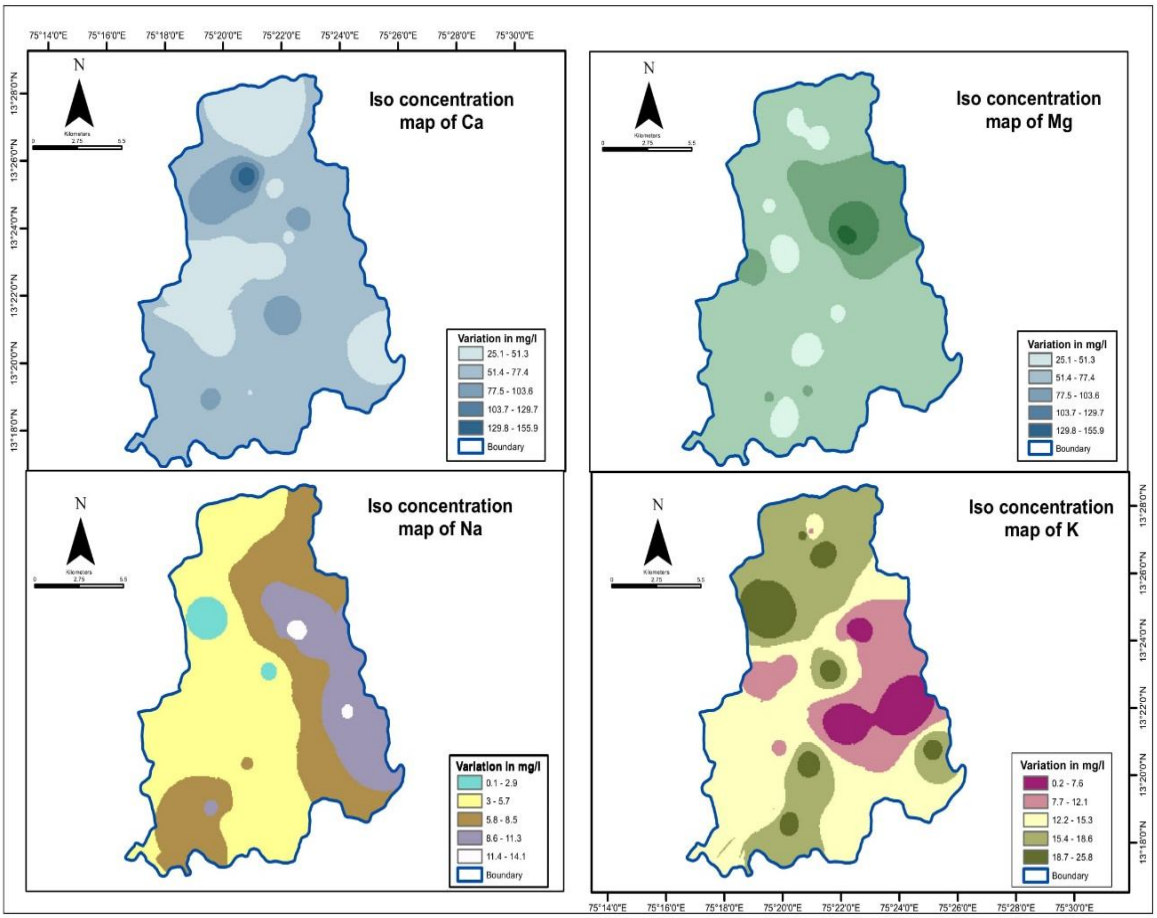


Fig 3: Iso-concentration maps of chemical parameters

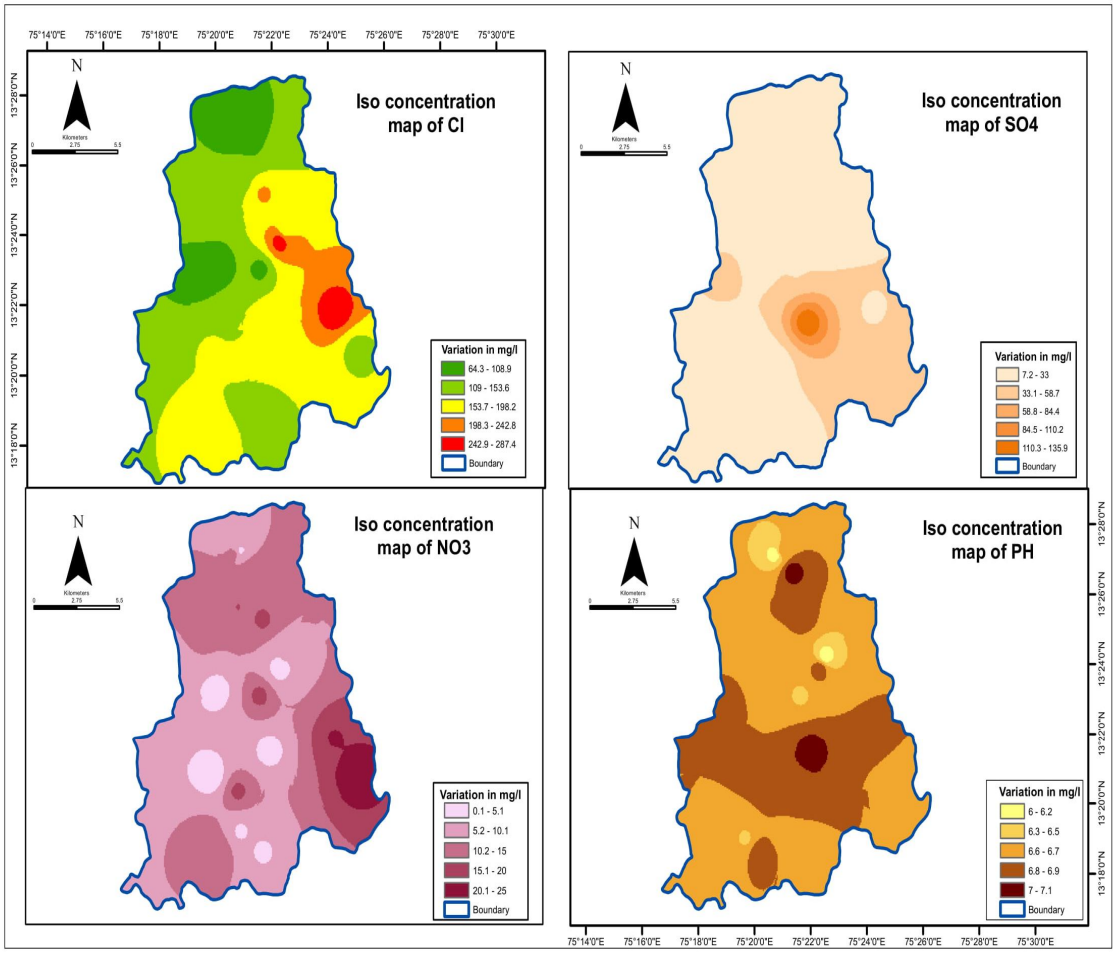


Fig 4: Iso-concentration maps of chemical parameters

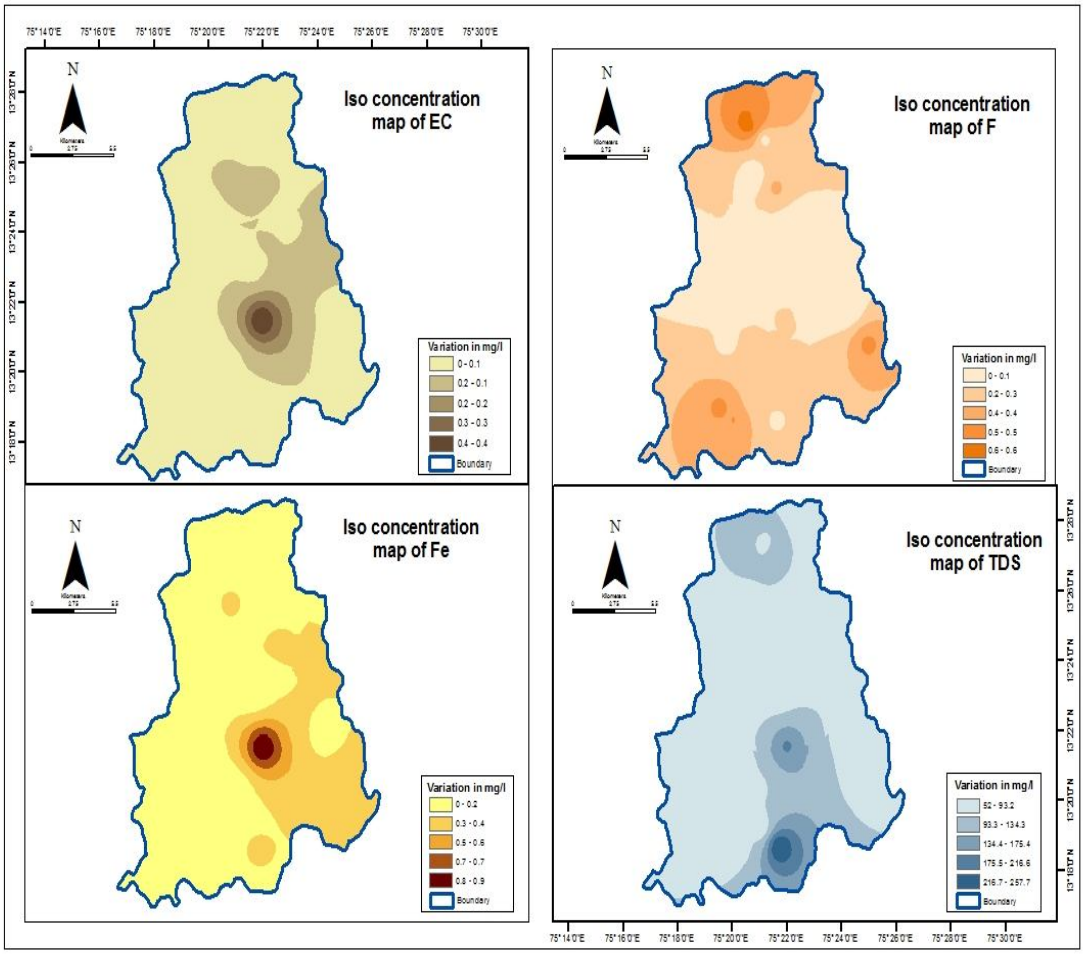
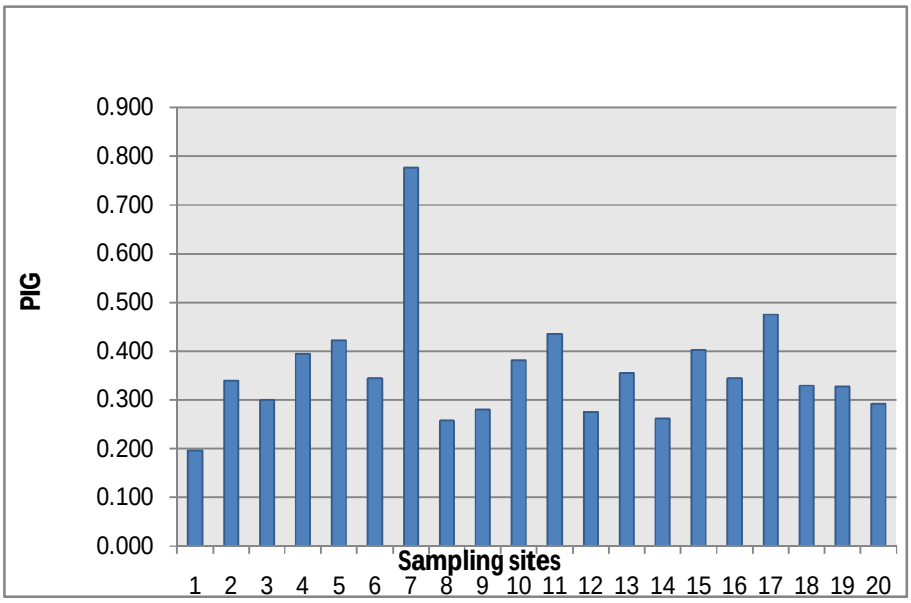


Fig 5: Iso-concentration maps of chemical parameters

CONCLUSION

The chemical parameters of SitaNadi ground water is studied by integrating the ground water indices, pollution index of ground water and geographical information system. The combined techniques provides a holistic approach to understand the groundwater and its chemical parameters through cartographic visualization. The PIG is a statistical tool to integrate the complex water quality data into a numerical score that describes the overall water quality status and the value varies from 0.196 to 0.777 (Graph 1). The Isoconcentration maps prepared by using IDW technique in GIS environment for 12parameters viz., Ca,Mg,Na,K,Cl,SO4,NO3,Ph,Ec,F,Fe,TDS) depict the variation in concentration of chemical parameters in different geographical locations of the study area. The maps reveal that all the groundwater samples inthe study area are well within the permissible range except chloride in areas like Lokanathpur, Makkikoppa, Herur Village. In these areas sustainable agriculture practice can be recommended in combination with water harvesting structure, which in turn balance the ion exchange between quartz chloride schist and ground water.



Graph 1: PIG concentration v/s Sampling Site

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