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RESEARCH ARTICLE

GROUNDWATER QUALITY IN PAMBAR SUB-BASIN, TAMIL NADU, INDIA USING GIS

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ABSTRACT

Groundwater is the most important natural resource used for drinking by many people around the world, especially in rural areas. An attempt has been made in this research paper to understand the groundwater quality of Pambar Sub-Basin in parts of Vellore and Krishnagiri districts, Tamil Nadu (India). Groundwater is the major source for domestic and agricultural activity in this area. Groundwater samples were collected from 41 wells during pre-monsoon period in the year 2010. The water samples collected in the field were analyzed for electrical conductivity, pH, total dissolved solids (TDS), major cations like calcium, magnesium, sodium, potassium, and anions like bicarbonate, chloride, nitrate, and sulfate, in the laboratory using the standard methods given by the American Public Health Association. The groundwater locations were selected to cover the entire study area and attention was given to the area where contamination is expected. Parameters exceeding permissible limit have been identified in most of the locations indicating higher ionic concentration. EC, TDS, Ca, Mg, Na, Cl and NO_3 exceed the maximum permissible limit in the seasons. SO_4 are within the permissible limit of WHO (2008) and BIS (1991) standard. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization. To know the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the spatial interpolation maps for various elements were also generated, discussed, and presented. Present work aims to interpolate major ions concentration in groundwater by using ARC/GIS software.

INTRODUCTION

Water is the most vital component of our planet and probably responsible for the existence of life on earth. Among all sources, the rivers are the most important source of fresh water both for human consumption and agricultural/ industrial usage. Groundwater is the main source of water that meets the agricultural, industrial and household requirements. Population growth, socioeconomic development, technological and climate changes has increased the demand for potable water manifolds in the past few years (Alcamo *et al.*,2007).One of the internationally accepted human rights is the access to safe drinking water which is the basic need for human health and development (WHO 2001). The general health and life expectancy of the people is reported to be adversely affected due to lack of the availability of clean drinking water in many developing countries of the world (Nash and McCall 1995). Geographic information system (GIS) is an efficient and effective tool in solving problems where spatial data are important. Therefore, it is widely used for assessment of water quality and developing solutions for water resources related problems (Chaudhary *et al.,* 1996). GIS based spatial distribution mapping and suitability of groundwater quality evaluation for domestic and agricultural purpose (Goyal *et al.* 2010). Anbazhagan and Nair (2004) used GIS to represent and understand the spatial variation of various geochemical elements in Panvel Basin, Maharashtra, India. Aravindan *et al.* (2010) and Shankar *et al.* (2010) have applied GIS to understand the behavior of various geochemical elements spatially in Upper Gadilam, River basin of Vizhupuram district and Paravanar basin of Cuddalore district Tamil Nadu. Therefore, groundwater quality plays a major role in planning water supply, water quality management, public health management, and environmental management. In the present study GIS was used to prepare spatial interpolation with the aim to evaluate the groundwater quality of Pambar Sub-Basin, by generating and amalgamating the groundwater quality data.

Study area

The study area taken is Pambar Sub-basin, covered in two districts such as krishnagiri district and Vellore district of Tamil Nadu It lies between the latitudes 12°10' - 12°45' and longitudes 78°15' - 78°50' of Toposheets No. 57 L/6, 57 L/7, 57 L/10, 57 L/11, 57 L/12, 57 L/ 14 and 57 L/15 of scale 1:50,000 published by survey of India in 1973. Pambar basin covers total area of about 1416 Sq.Km (Fig.1). Physiographically the area is flat with gentle slope. The study area is underlain by the Archaean

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crystalline rocks and the eastern side is covered by a chain of hills named Javadi and Mambakkam Reserved forest. The contribution of southwest monsoon ranges from 45 to 52 percent, whereas it ranges from 30 to 43 percent due to northeast monsoon. The basin experiences a moderately Tropical climate. Geological formations ranging in age from Archaean to Recent. The area in and around of basin forms a part of the Archaean Peninsular complex having intensive high grade regional metamorphism with folding, faulting and shearing structures. The major rock types of the area are hornblende biotite gneiss, charnockite and epidote hornblende gneiss, granitic gneiss, calc granulites, syenites and ultra basics (Fig.2).

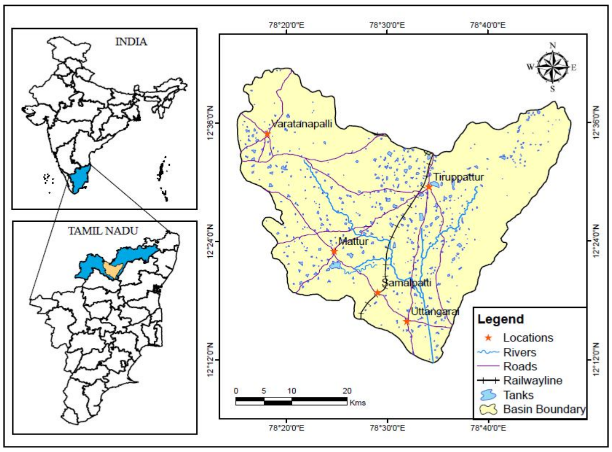

Fig.1 Location Map of the study area

MATERIALS AND METHODS

The sampling bottles soaked in 1:1 HCl for 24 h were rinsed with distilled water followed by deionized water. At the time of sampling, the sampling bottles were thoroughly rinsed two or three times, using the groundwater to be sampled. The chemical parameters viz. pH and electrical conductivity (EC) were measured, using digital instruments immediately after sampling. Forty one water samples were collected in 500-ml polyethylene bottles from bore wells during Pre-Monsoon (PRM) 2010 from the study area. The groundwater sampled bottles were labeled, tightly packed, transported immediately to the laboratory, and stored at 4°C for chemical analyses. The sampling preservation and analysis were carried out as per the standard methods prescribed by American Public Health Association (APHA 1995). The results of analysis are presented in Table.1

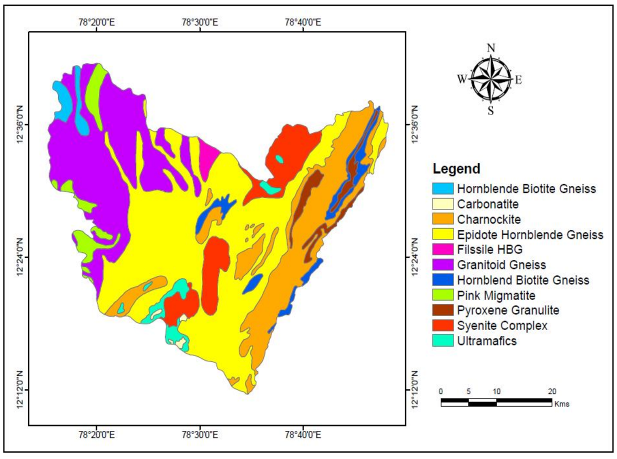

Fig.2 Geology of the study area

RESULT AND DISCUSSION

Physico-chemical parameters

General parameters

The pH value of pre monsoon ground water samples varies from 6.6 to 7.4 with an average around 6.9 indicating alkaline nature as per BIS (1991) standards (Fig.3). Almost all samples fall within the recommended limits (6.5 to 8.5) for human consumption. The pH indicates the strength of the water to react with the acidic or alkaline material present in the water. It controls by carbon dioxide, carbonate and bicarbonate equilibrium. The combination of CO_2 with water forms carbonic acid, which affects the pH of the water.

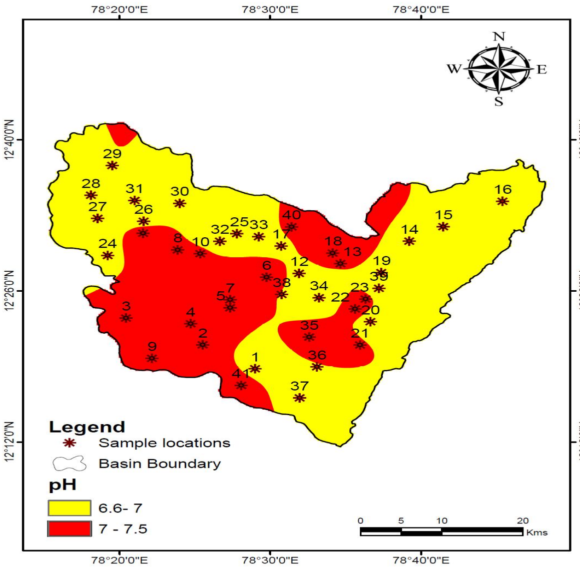

Fig.3 Spatial distributions of pH during PRM

The electrical conductivity values range from 591 to 6670 µS/cm at 25°C (Table 1 & Fig.4). A high salt content (high EC) in irrigation water leads to formation of saline soil. This affects the salt intake capacity of the plants through their roots. High salinity waters cannot be used on soil with restricted drainage. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Saleh *et al.*, 1999).

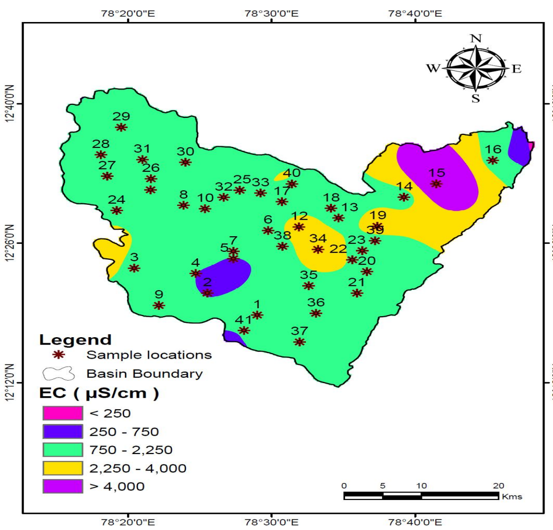

Fig.4 Spatial distributions of EC during PRM

The TDS, which indicates total dissolved ions in the water, is between 413 and 4,463 mg/L (Table.1 & Fig.5). Majority of the groundwater samples from the study area recorded, greater values than the permissible limit (1,000 mg/L) due to successive action of weathering and dilution processes. To ascertain the suitability of groundwater for any purpose, it is essential to classify based on the TDS values (Davis and DeWiest 1966) which are represented in Table.2 and displayed spatially in north eastern part (Figs. 5.) of the study area unfit for drinking and irrigation purposes.

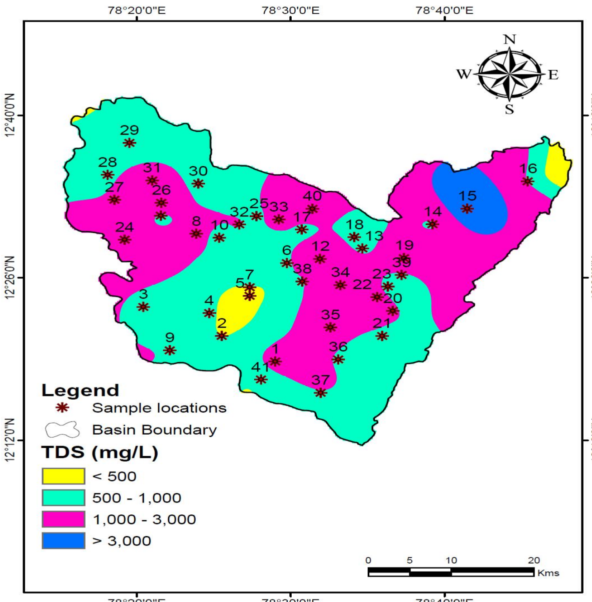

Fig.5 Spatial distributions of TDS during PRM

Chemical Characteristics of Ground water

Calcium (Ca) and Magnesium (Mg)

The concentration of Ca is between 48 and 421 mg/ L, while that of the concentration of Mg is varied from 19 to 187 mg/L (Table.1 & Fig. 6, 7). Calcium also participates in cation-exchange equilibria at aluminosilicate and other mineral surfaces. Solubility equilibrium models have been used widely in studying the chemical behavior of calcium. Calcium is an essential constituent of many igneous rock minerals, especially of the chain silicates pyroxene and amphibole and the feldspars. In igneous rock, magnesium is typically a major constituent of the dark colored ferromagnesian minerals. Specifically, these include olivine, the pyroxenes, the amphiboles, and the dark-colored micas, along with various less common species (Hem, 1985).

Sodium (Na)

Sodium concentration varies from 10 to 623 mg/L, with an average of 136.5 mg/L. The possible source of sodium might be located at deeper aquifer which may be percolation from waters of top soil layers and due to atmospheric precipitation that has been subjected to concentration effects of Magnesium (Herman Bower, 1978). Most of the samples records higher Na, indicating contribution from weathering process of Na plagioclase feldspar along with dissolution of Kankar (Srinivasamoorthy *et al.* 2008). Human activities can have a significant influence on the concentrations of sodium in ground water (Hem, 1985). The uses of salt for deicing

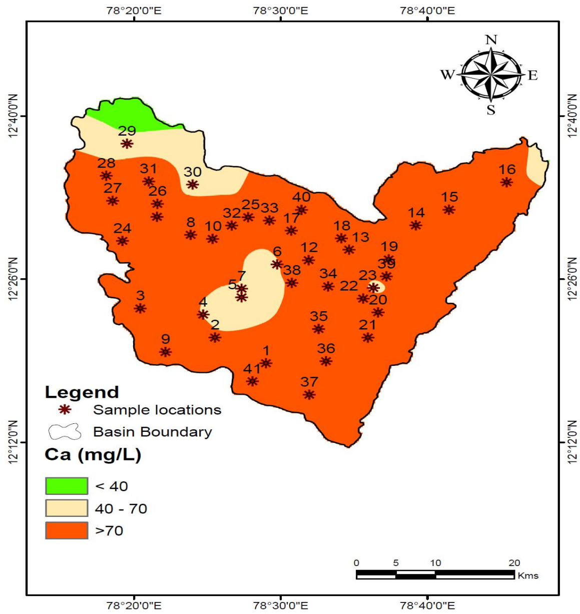

Fig.6 Spatial distributions of Ca during PRM

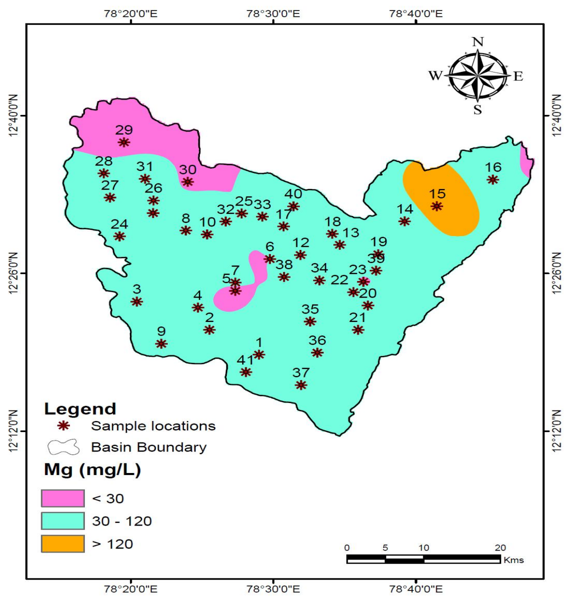

Fig.6 Spatial distributions of Mg during PRM

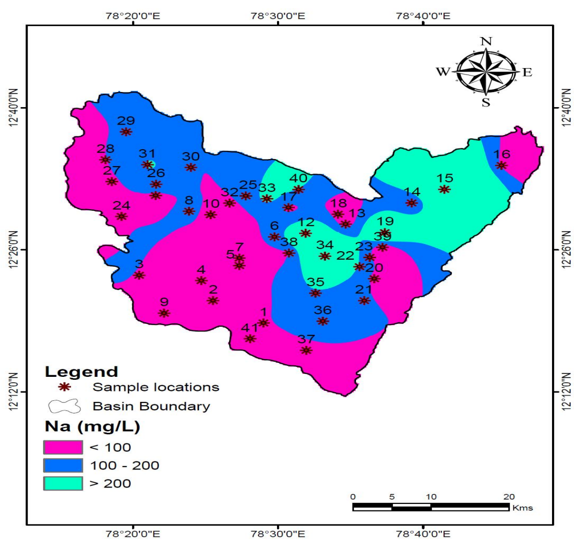

Fig.7 Spatial distributions of Na during PRM

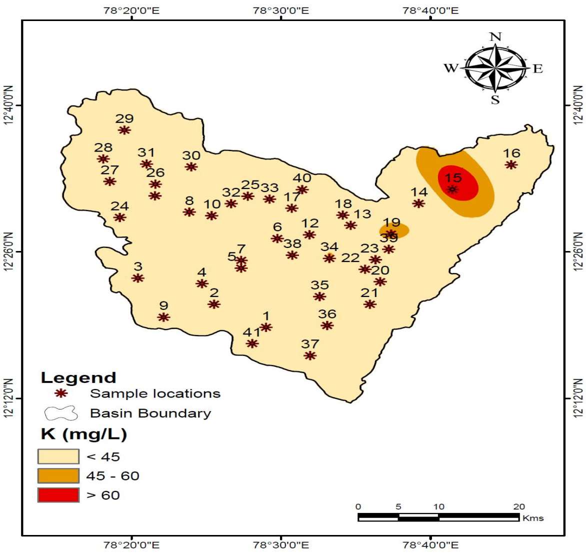

Fig.8 Spatial distributions of K during PRM

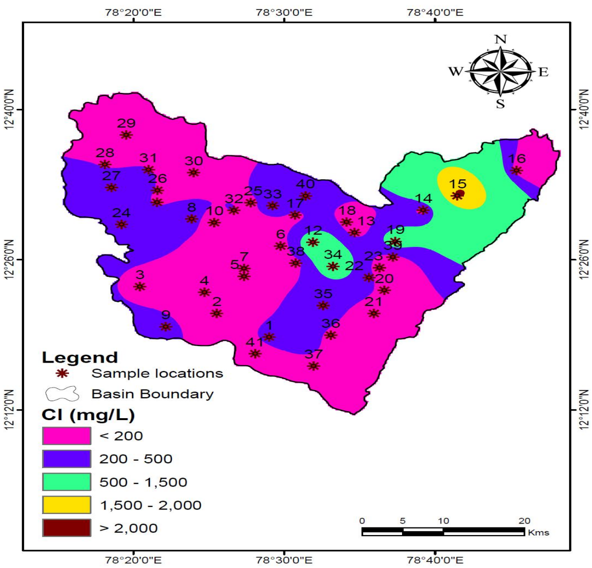

Fig.9 Spatial distributions of Cl during PRM

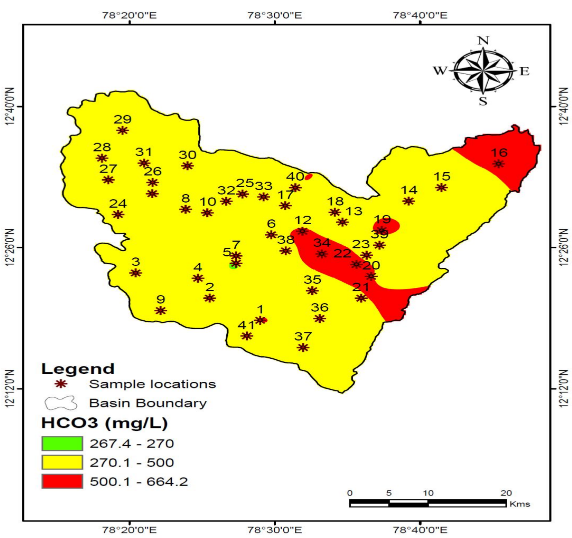

Fig.10 Spatial distributions of HCO_3 during PRM

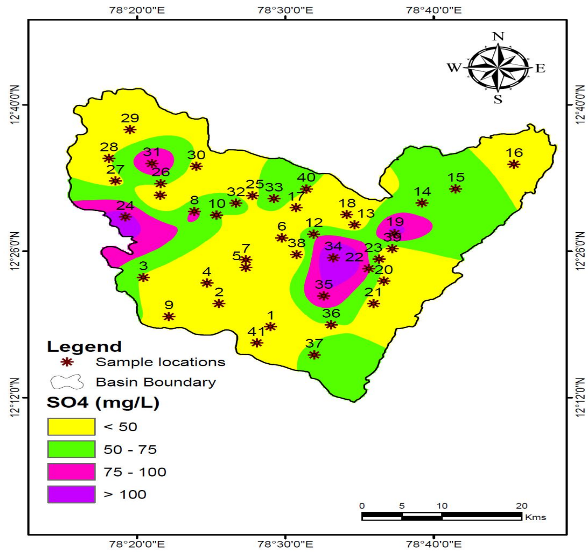

Fig.11 Spatial distributions of SO_4 during PRM

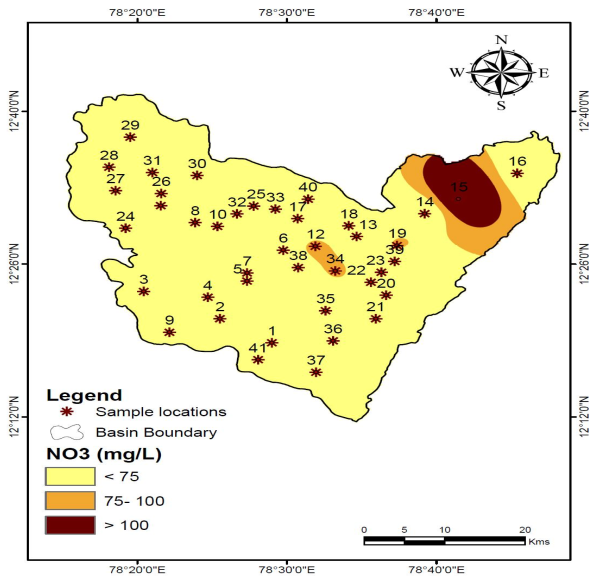

Fig.12 Spatial distributions of NO_3 during PRM

highways in winter flowing from wells have had direct, noticeable regional effects. Somewhat less directly, the reuse of water for irrigation commonly leaves a residual that is much higher in sodium concentration than was the original water. The spatial variation of nitrate in groundwater of the study area is illustrated in Fig.7

Table.2 Groundwater quality classification according to Davis and DeWiest (1966)

TDS (mg/l)	Classification
< 500	Desirable for drinking
500- 1000	Permissible for drinking
1000 - 3000	Useful for irrigation
> 3000	Unfit for drinking and irrigation

Potassium (K)

1In general, the natural water contains sodium, less than one-tenth because of the high degree of stability of potassium-bearing aluminosilicate minerals (Davis & DeWiest, 1966). Potassium in groundwater samples of the study area ranges

Table1 Statistics and Comparison of groundwater chemistry with WHO and BIS standards

Ions	PRM July-2010				WHO 2008	BIS 1991
	Min	Max	Average	SD		
pH	7.43	6.68	6.99	0.21	6.5-8.5	6.5-8.5
EC	6670	591	1667.12	1082.33	1500	-
TDS	4663	413	1151.05	764.45	500	500
Ca	421	48	113.17	63.23	75	75
Mg	187	19	52.15	28.15	50	30
Na	623	10	136.51	124.48	200	-
K	77	3	18.22	15.35	-	-
HCO_3	664	268	405.17	94.54	-	-
Cl	2070	24	251.56	341.97	200	200
SO_4	140	4	49.59	30.67	200	200
NO_3	160	5	36.24	28.40	50	45

Note: Max - Maximum; Min – Minimum; SD - Standard Deviation; (All Values in mgl^{-1} except EC in µS/cm and pH)

from 3 to 77 mg/L with an average of 18.2 mg/L. This may be the result of soil leaching by runoff. The spatial variation of nitrate in groundwater of the study area is illustrated in Fig.8.

Chloride (Cl)

Chloride concentration is classified based on BIS standard, less than 250 ppm as good water suitable for drinking. Chloride is often an important dissolved constituent in ground water, may originate from various sources including: dissolution of halite and related minerals. The concentration of Cl is between 24 and 2070 mg/L (Table.1) indicating the leaching of Cl from topsoil/weathered zone and Base Exchange reactions (Bower, 1978). Anthropogenic processes can locally affect chloride concentrations in ground water. Some anthropogenic factors commonly influencing chloride levels in water include road salting during the winter, improper disposal of oil-field brines, contamination from sewage and contamination from various types of industrial wastes (Hem, 1993). The spatial variation of nitrate in groundwater of the study area is illustrated in Fig.9.

Bicarbonate (HCO_3)

HCO_3^- concentration is classified based on WHO's (2008) standard < 100 ppm is categorized as poor quality water which is suitable only for industrial activity. Good quality water is found to occur in the study area by considering the concentration greater than 250 ppm (Fig.10). Higher concentration was noted in PRM indicates the contribution of CO_2 upon the basic material of soil and granitic rock (Vasanthavigar *et al.,* 2009).

Sulphate (SO_4)

Sulphate is naturally occurring anion in all kinds of natural waters. Sulphate produces an objectionable taste at 300 – 400 mg/l. As per BIS standard desirable limit for drinking is 200 mg/l. Sulphate concentration is classified based on the above standards as softwater and good water suitable for drinking is fixed as less than 200 ppm. Areas having concentration of sulphate between 200 - 400 ppm were classified as moderate ground water suitable zones. Concentration above 400 ppm was categorized as poor ground water zones. Sulphate above 400 ppm along with Mg individually at 30 ppm may likely to cause gastro-intestinal irritation. In hard rock region gypsum and anhydrite are the primary source of SO_4. In the study area sulphates are found to be within prescribed limit for drinking within the study area. The spatial distribution map of sulphate ion concentration in groundwater is presented in Fig.11.

Nitrate (NO_3)

Nitrogen plays a dominant role in life cycle process of plants and animals. Most investigators have attributed Nitrogen in groundwater, derived from organic industrial effluents, fertilizer or nitrogen fixing bacteria, leaching of animal dung, sewage and septic tanks through soil and water matrix to groundwater (Madison & Brunett, 1984). The nitrate ion concentration varies from 5 to 160 mg/l with an average value of 36.24 mg/l. The concentration of nitrogen in groundwater is derived from the biosphere (Saleh *et al.,* 1999). Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinaemia in children and gastric carcinomas (Comly 1945; Gilly *et al.,* 1984). Nine samples exceed the desirable limit of 45 mg/l as per WHO standard. Show spatial distribution of nitrate in the investigated area and depict that then 78% samples have nitrate less than 45 mg/l, while as remaining 22% of samples have nitrate more than 45 mg/l (Fig.12).

CONCLUSION

Parameters exceeding permissible limit have been identified in most of the locations indicating higher ionic concentration. EC, TDS, Ca, Mg, Na, Cl and NO_3 exceed the maximum permissible limit in the seasons. SO_4 are within the permissible limit of WHO (2008) and BIS (1991) standard. The pH indicates the strength of the water to react with the acidic to alkaline material present in the water. The occurrence of high EC values in the study area reflects the addition of some salts through the prevailing agricultural activities. To ascertain the suitability of groundwater for any purpose, it is essential to classify based on the TDS concentration (Davis and DeWiest 1966) spatially in north eastern part of the study area unfit for drinking and irrigation purposes. Mapping spatial extent of various quality parameters in GIS was found to be effective and efficient. Thematic maps generated in the study will be helpful to planners and policy makers especially of public health and irrigation departments, for sustainable water management in a holistic way.

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