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Research paper

Groundwater Quality Assessment of Ambuliyar Watershed using GIS

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Abstract

Groundwater is significant in satisfying domestic and agricultural needs.Besides scarcity, the groundwater resource is degrading drastically around the world. The Ambuliyar watershed falling in parts of Tamil Nadu also faces similar problems. To decipher the quality degradation, pre-monsoon and post-monsoon data on various physical and chemical parameters was collected for 29 wells for the year 2014 from Public Works Department. Spatial maps were generated on the above geochemical parameters and categorized into five classes using GIS software. Weights were assigned for each parameter based on their relative importance in with each other parameters. Finally, quality index map was generated by integrating them, and subsequently their aerial extent in monsoons was worked out. During the post-monsoon period, 18% of the study area represents "excellent", 46% "good", 25% shows "moderate" and 11% shows "poor" quality. While during pre-monsoon period, 34% of the area exhibits "excellent", 43% " moderate", and the remaining 23% of "poor".

***Keywords:** Groundwater quality, Ambuliyar watershed, GIS, Pre-Monsoon, Post Monsoon.*

1. Introduction

In India, both rural and urban population depends primarily on groundwater for their basic needs (Reddy et al., 1996). Owing to over-exploitation and population explosion the available resource is becoming scarce in many parts of India. Further, pollution from point and non-point sources like domestic, industrial, and agricultural wastewater too degrade the available limited resource. In addition, the adverse impact of global climate change is also imposing major threat. Hence effective utilization and management of the resource for both present and future generations is essential. Pollution added to quality deterioration, threatens the ecological and socio-economic aspects (Milovanovic, 2007). Therefore, it is essential to periodically assess and monitor the quality (Simeonov et al., 2003). Models are developed to better understand the water quality parameters (Kumar and Ahmed, 2003; Suk and Lee, 1999). Amongst, remote sensing and GIS has proven an effective tool in spatially analyzing the water quality. Especially, GIS is used for mapping, estimating and modeling groundwater pollution. Ahn and Chon (1999) spatially correlated groundwater contamination with parameters like topography, geology, landuse, and so on in Seoul.Yammani, (2007) based on the quality prepared suitability map for irrigation and domestic. Rangzan et al., (2008) identified possible locales of well construction based on water quality and availability. Accordingly in the present study, using GIS spatial distribution pattern of on various quality parameters were analysed.

2. Data and Methodology

The Ambuliyar sub-basin covers an area of 930 sq. km with its parts falling in Pudukottai and Thanjavur districts, Tamil Nadu.The riverruns from Thiruvarangulam, AlangudiTaluk, Pudukkottai District and confluences with the Bay of Bengal.Base map was perpared using Survey of India (OSM) Topographic sheets 58J15, 58J16, 58N3, 58N4, 58N7 & 58N8 on 1:50,000 scale.A thorough survey of Ambuliyar watershed was done and a base map was prepared(Figure.1). Subsequently, hydro geochemical parameters namely pH, total dissolved solids, NO3, Ca, Mg. Na, K, Cl, SO4, CO3, HCO3, F and pH collected from the State Surface and Groundwater Data Centre, Public Works Department, Chennai. The data includes pre-monsoon (July-2014) and post-monsoon (January-2014) for 29 wells. Unit of measure for the concentrations of these various chemical parameters is milligram/litre except pHand turbidity. The location of the wells was geo-tagged. Using inverse distance weighted (IDW) method, contours are generated for each parameter and later based on Indian Standard Specification for Drinking Water (IS: 10500), classified maps were generated. Later to assess the combined impact of different parameters on drinking criteria, a methodology had been devised to prepare water quality index of the study area. Thus the present study is aimed to analyse the pre and postmonsoon spatial distribution pattern of individual parameters and to prepareground water quality index map.

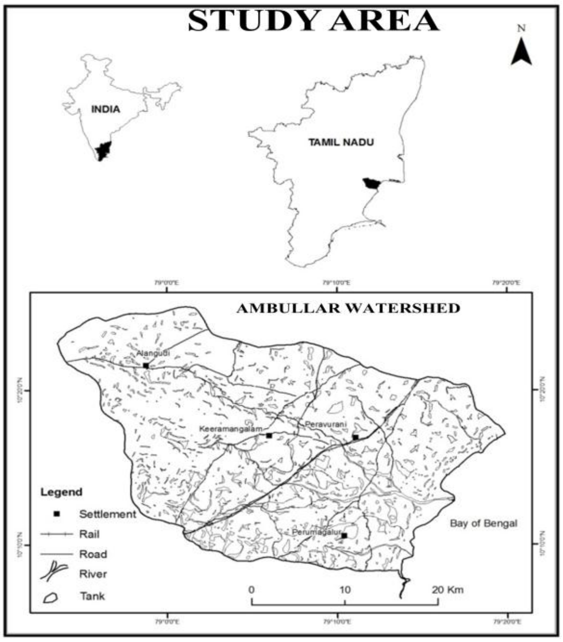


Fig. 1: Map showing study area

3. Analysis of Groundwater Quality Parameters

3.1 Total Dissolved Solids Concentration

The maximum TDS during the pre-monsoon and post monsoon was 6397 mg/l and 4301 mg/l respectively. Desirable value as per BIS standard is 500 mg/l and the permissible limitis 2000 mg/l. Perusal of the map shows that in both the seasons the TDS is increasing from south western part to the north eastern part with the maximum values concentrated in the south western part. In general, higher concentrations are attributed to the seepage of contaminated water from open drains. Further the host rocks is granitic gneiss which might imposed oxidation and reduction processes leading to enrichment of total dissolved solids(Figure.2).

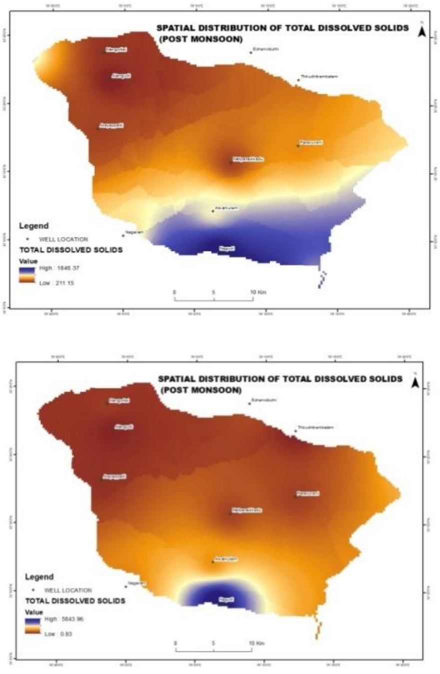


Fig. 2: Thematic map showing concentration of TDS

3.2 Nitrite Concentration

Average value of Nitrite (NO2_NO3) concentration in the groundwater exhibits a variation with 5 mg/l and 6 mg/l during pre and postmonsoon period. Desirable limit of NO3 is 10 mg/l and the permissible limit is 50 mg/l (BIS, 1991). From the table-1, the maximum Nitrate concentration is observed to be less than the permissible limit in both the seasons. Thus it can be surmised as the study area is free from Nitrate contamination. However amongst the measured data, higher concentration is noticed in the north eastern and the south western parts. Nitrate contamination is strongly related to land use pattern. During post monsoon period, the agricultural activities will be intensified and the same is attributed to higher concentration especially in the downstream of the watershed (Figure.3).

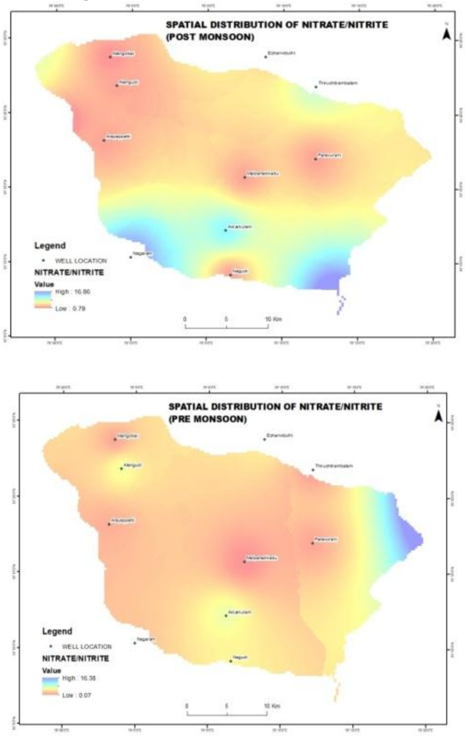
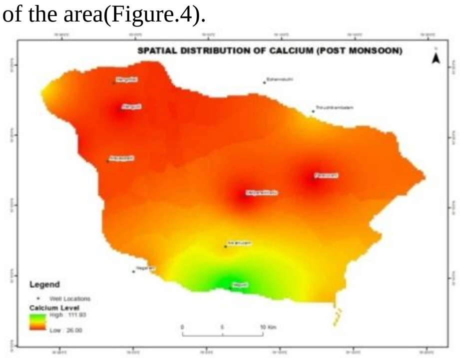


Fig. 3: Thematic map showing concentration of Nitrate/Nitrite

3.3 Calcium Concentration

The average Calcium concentration in the groundwater varies from 34 mg/l to 47 mg/l in pre and post monsoon. Both from figure.4 and table-1, the concentration of Caseems to be within BIS standard limits (70 mg/L and 200 mg/L). However amongst derived values a higher concentration is observed in the southern part. In general calcium is derived from the weathering of feldspar rich rocks. Thus presence of Ca is once again attributed to the lithology of the area(Figure.4).



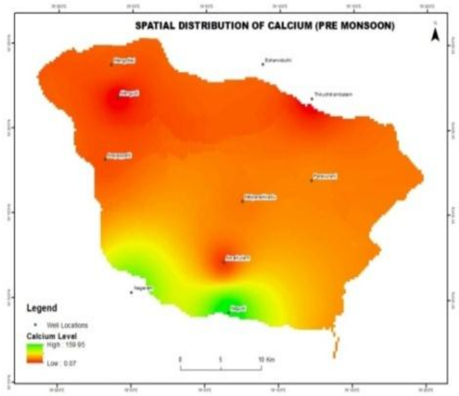


Fig. 4: Thematic map showing concentration of Calcium

3.4 Magnesium Concentration

The average value of magnesium was 383.88 mg/l and 72 mg/l during the monsoons. As per BIS (1991) the limits are 30 mg/l and100 mg/l. The magnesium content seems to be very high in both the monsoons in the south (Figure.5).Once again the leaching of host is attributed for anomalous concentration magnesium.

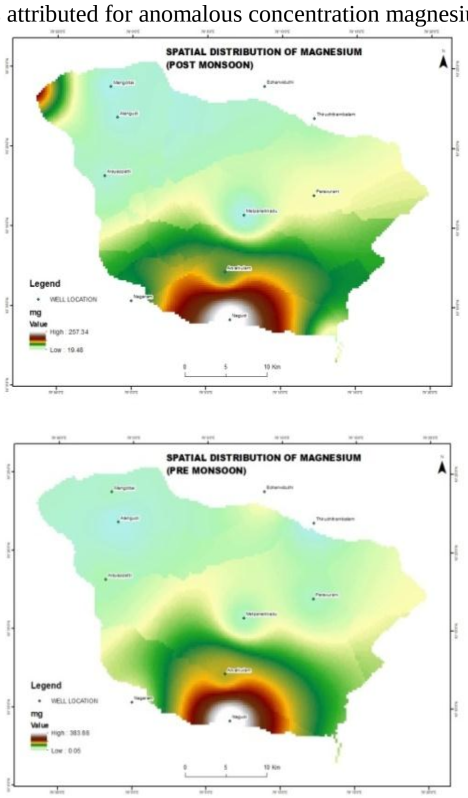


Fig. 5: Thematic map showing concentration of Magnesium

3.5 Sodium Concentration

The average value of sodium during pre-monsoon was 270 mg/l, whereas during post monsoon it was 216 mg/l. The desirable value for Na is 200 mg/l (BIS, 1991). Spatial distribution shows that the sodium concentration is high in the south eastern part during pre and almost within prescribed limit during post monsoon period. Excess concentration during the pre-monsoonis attributed to chemical weathering of granitic gneiss and the absence during post monsoon to the dilution of concentration due to rainfall (Figure.6).

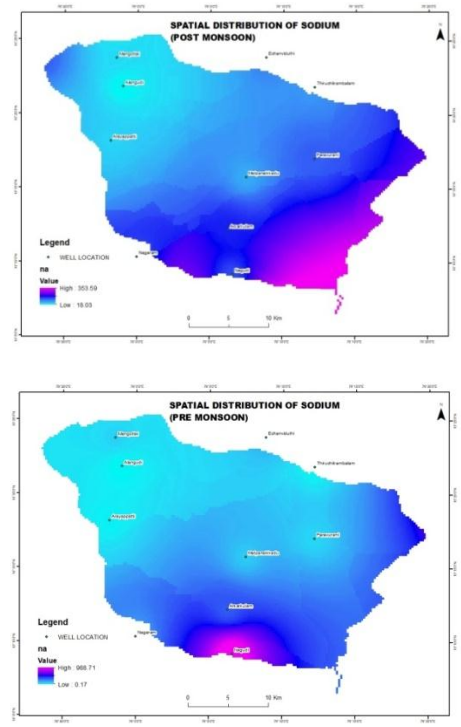


Fig. 6: Thematic map showing concentration of Sodium

3.6 Potassium Concentration

The average value of potassium during pre-monsoon was 10 mg/l whereas during post-monsoon the value was 13 mg/l. However a maximum potassium concentration of 43 mg/l and 70 mg/l is noticed (table-1). The BIS limits 25mg/l and 30 mg/l as permissible and desirable values. The excess concentration is observed in the south eastern during the pre monsoon and in the middle and southern portion during post monsoon period. Chemical weathering is attributed to the concentration in pre-monsoon time while agricultural activities for post monsoon concentration(Figure.7).

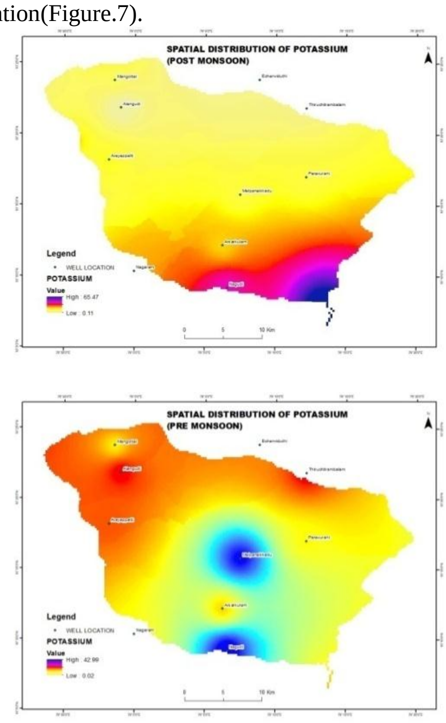


Fig. 7: Thematic map showing concentration of Potassium

3.7 Chloride Concentration

In groundwater, Chloride occurs in varying concentrations. In natural water, the concentration will be less than 100 mg/l while in brackish or saline water the concentration increases. Chloride originates both from natural and manmade activities like sewage and industrial effluents, urban runoff, and so on (WHO, 2004). Though the average value of Chloride during was 620 mg/l and390 mg/l during pre and post-monsoons, maximum value shows a very high concentrations. The Desirable value: 250 mg/L and Permissible value: 1000 mg/L for chlorine content. However, perusal of the GIS map shows higher concentration in the southern part during both the seasons (Figure.8).

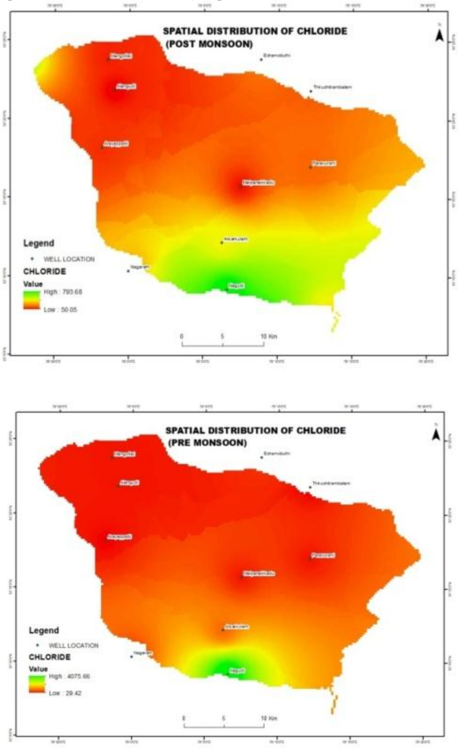
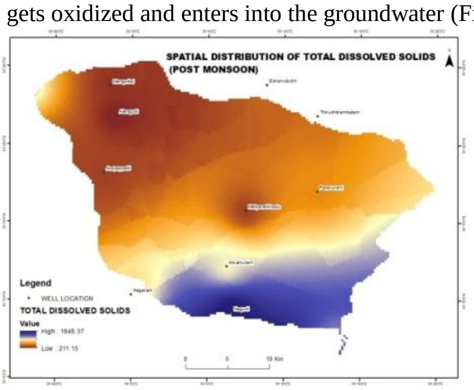


Fig. 8: Thematic map showing concentration of Chloride

3.8 Sulphate Concentration

Though the desirable and permissible values are 200 mg/l and 400 mg/l (BIS, 1991), a higher concentration is noticed in both the seasons. In general the leaching of metamorphic rock is considered as the reason for increased Sulphate concentration. However, the release of Sulphur gas due to anthropogenic activities gets oxidized and enters into the groundwater (Figure.9).



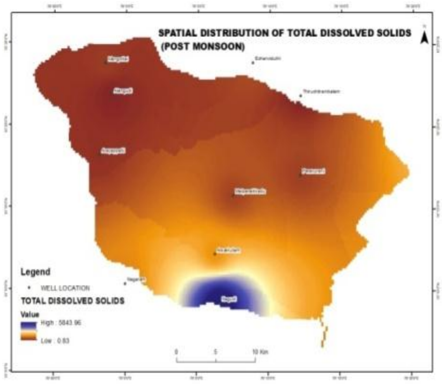


Fig. 9: Thematic Maps of Sulphate (Post monsoon and Pre Monsoon)

3.9 Hydrogen Carbonate Concentration

The average value of HCO3 was 159 mg/l and 280 mg/l, which is well within the BIS prescribed desirable value(500 mg/l). But a maximum concentration values of around 650 is noticed along the coastal tracts I both the seasons (Table-1 &Figure.10).

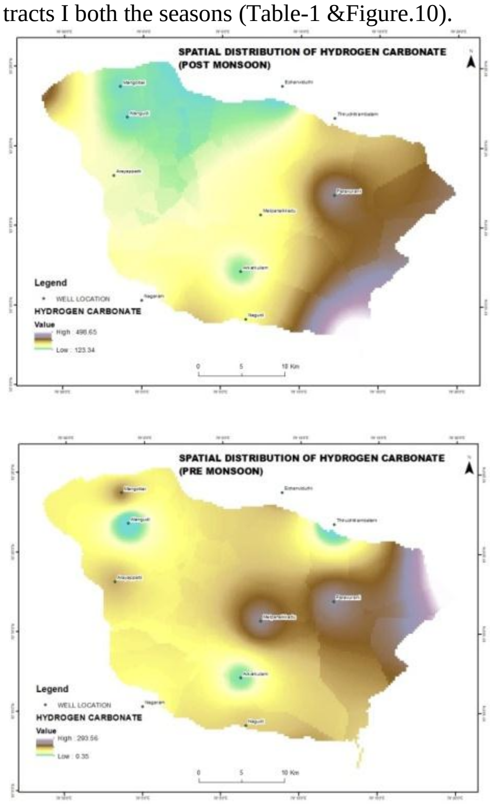


Fig. 10: Thematic map showing concentration of Hydrogen Carbonate

3.10 pH Concentration

The study area exhibits a maximum pH value of 8 during both the seasons which is well within the BIS prescribed limit of6.5 and 8.5. The release of sodium and calcium ions due to weathering of plagioclase feldspar along with dissolved atmospheric carbon dioxide increases pH and alkalinity in water. The study area exhibits pH value well within the recommended WHO standards(Figure.11).

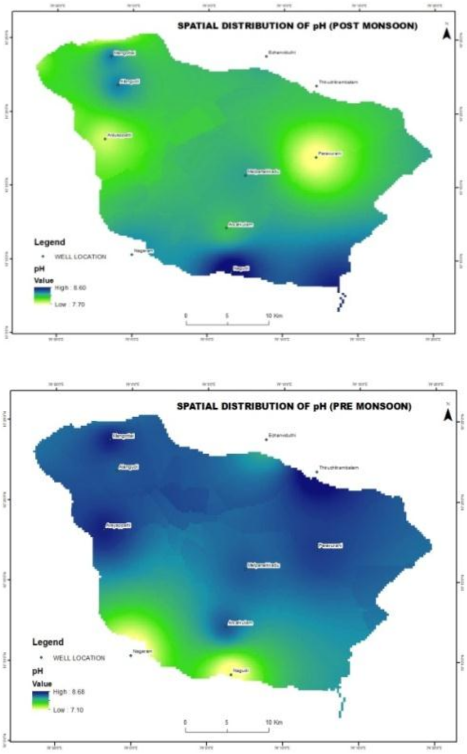


Fig. 11: Thematic map showing concentration of pH

3.11 Fluoride Concentration

The Desirable and permissible values of Fluoride is 1.0 mg/L and1.5 mg/L (BIS, 1991). From table-1, a mean value of 0.45 mg/l and 0.5 mg/l was inferred. However, maximum permissible value of 1.5 mg/l is noticed in the middle during post monsoon period and the same seems to be diluted after the monsoon. Thus the increase might be attributed to the underlying lithology (Figure.12).

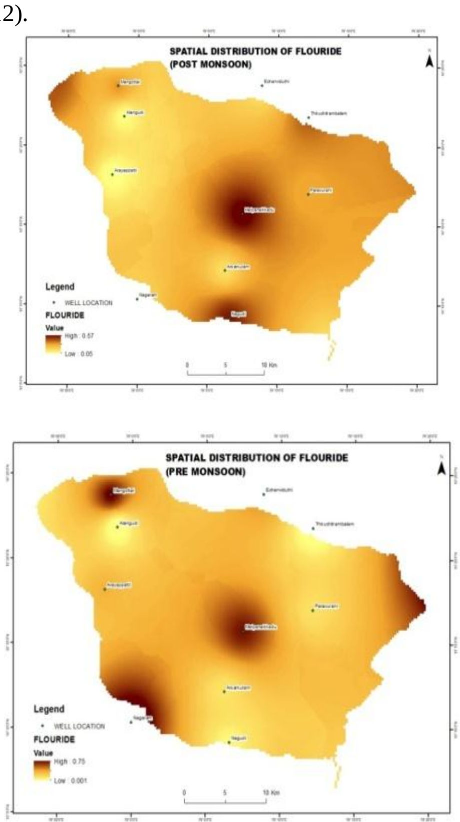


Fig. 12: Thematic map showing concentration of Fluoride

3.12 Electrical Conductivity Concentration

Electrical conductivity indirectly depicts the hardness of the water. The permissible limit is 300 micro Siemens. In the study area event the mean EC value exceeds the permissible limit on both the seasons (Table-1). Figure shows high concentration electrical conductivity in southern partsof the study (Figure.13).

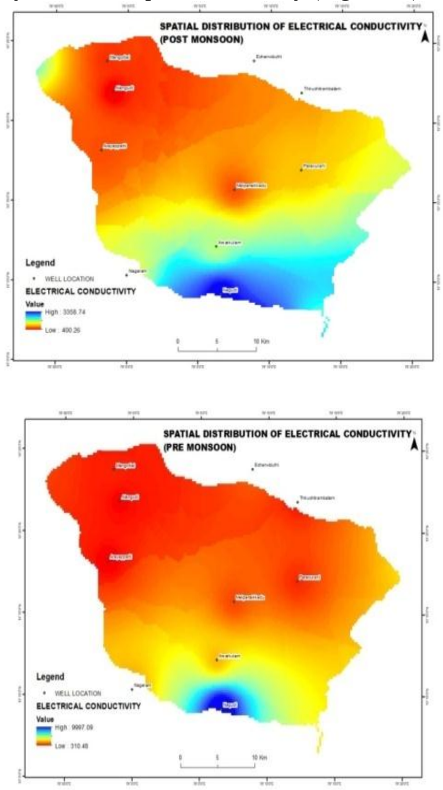


Fig.13: Thematic map showing concentration of Electrical Conductivity

4. Result and Discussion

Groundwater quality exhibitsspatio-temporal variation in their values. Water quality index is a method of rating groundwater for human consumption. The results provide a compositeinfluence of individual parameter in conjunction with the other parameters (Mitra and ASABE Member, 1998). Based on BIS standards(10500), index was computed. As suggested by earlier workers (Horton, 1965; Pradhan et al., 2001; Asadi et al., 2007; Vasanthavigar et al., 2010; Saeedi et al., 2010 and Yidana and Yidana, 2010) the quality index was computed.Firstly, individual weights (wi) were assigned for the above 13 parameters in conjunction with their relative importance in overall quality of water.Based on their importance, the parameters namely nitrate, TDS, chloride, fluoride and sulphatewere assigned with a maximum weight of 5 (Srinivasamoorthy et al., 2008). Since Potassium plays an insignificant role, a weight of 2 is given. While calcium, magnesium, sodium, and potassium were assigned with weight between 1 and 5 on the basis of their relative importance.

Then their relative weights (Wi) were computed using as:

$$Wi = wi \;/\; \sum_{i=1}^{n} wi$$

Where,

Wi = Relative weight
Wi = Weight of each parameter
n = Number of parameters.

Subsequently, a quality rating scale (qi) is derived for each parameter as follows:

qi = (Ci/Si)*100

Where

qi is the quality rating
Ci is the concentration in milligrams per liter.
Finally, water quality index is determined as:
$SI_i = W_i * q_i$
$WQI = \sum SI_i$
Where
SI_i is the sub-index of i^{th} parameter
q_i is the rating based on concentration of i^{th} parameter.
For easy understanding, the derivedwater quality index values were classified into four categories as excellent, high, moderate and poor qualities and accordingly GIS maps were generated for both the seasons separately(Figure.14).

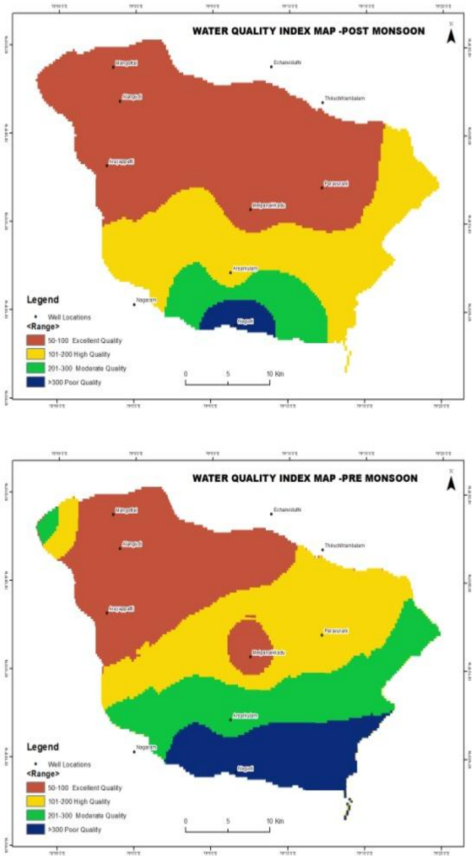


Fig. 14: Water Quality Index Map

From the above, areal extent of the all four categories during both the periods was computed. During postmonsoon period, 18% falls under "excellent", 46% under "high", 25% shows "moderate", and 11% of the area shows "poor" qualities. During pre-monsoon period, 34% shows "excellent", 43% shows "high", and remaining 23% shows "poor" qualities.Thus more than fifty percentage of the aerial extent falls under 'poor' quality category during pre-monsoon when matched with its counterpart. The spatial correlation of the groundwaterquality index map with other contaminating parameters shows that host rock namely the granitic gneiss and its associated leaching of ions as reason for the existence of 'very poor' quality in the southern part. However, the direct discharge of industrial effluents, domestic waste and sewage, and the impact of agricultural activities are inferred as the major causes of groundwater quality deterioration.

5. Conclusion

The study proposes a method for evaluating groundwater quality of an area with emphasis on drinking water standards. GIS has proven effective in analyzing the spatial distribution pattern of various groundwater quality parameters. The water quality index not only enables to spatially asses overall quality of groundwater but also to identify the deteriorating parameters. From the visualization of saptio-temporal pattern changes, the role of natural and anthropogenic impacts on groundwater quality is envisaged. Administrators and decision makers can utilize the water quality index method for assessing and monitoring the groundwater quality of an area.

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Table 1: Statistics of Groundwater Chemical Parameters for Pre & Post Monsoon

Parameters	Pre monsoon values				Post monsoon values			
	Min	**Max**	**Avg**	**Std**	**Min**	**Max**	**Avg**	**Std**
TDS	0	6397	1047	1670	185	4301	1031	993
NO2_NO3	0.07	42.28	5	8	1	21	6	6
Ca	0	160	34	40	6	160	47	35
Mg	0	384	53	92	16	258	77	72
Na	0	1863	270	445	17	1041	216	263
K	0	43	10	12	0	70	13	15
Cl	21	4077	620	1010	50	2099	390	468
SO4	0	444	74	125	5	538	105	144
CO3	0	132	15	30	0	54	7	13
HCO3	0	658.8	159	186	83	665	280	175
F	0	1.5	0.4	0	0	1	0.5	0
pH	7	9	8	0	7	9	8	0
EC	310	10620	2248	2778	340	7420	1841	1734
Where: TDS – Total Dissolved Solids, NO3 - Nitrate, Ca - Calcium, Mg Magnesium, Na - Sodium, K - Potassium, Cl - Chloride, SO4 - Sulphate, CO3 - HCO3 – Bicarbonate, Fe – Iron, pH, EC- Electrical Conductivity,Hardness Min – Minimum, Max – Maximum, Avg – Average & Std – Standard Deviation								