Assessment of Groundwater Quality Index for Upper Pincha Basin, Chittoor District, Andhra Pradesh, India using GIS

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ABSTRACT:

Present work is aimed at assessing Water Quality Index (WQI) for groundwater of Upper Pincha Basin, Chittoor District, Andhra Pradesh. This has been carried out by collecting groundwater samples and subjecting them to comprehensive physico-chemical analysis. Results obtained were compared with standard values recommended by WHO for drinking and public health. For computing WQI, eleven parameters viz., pH, TH, Cl, TDS, Ca, Mg, So_4, No_3, F, HCO_3 and Na have been considered. WQI values for the groundwater samples from the study area ranges from 71.99 to 273.82. High value of WQI has been found to be mainly from excess presence of TH, Cl, TDS, Mg and HCO3. Using GIS contouring methods with Arc/View GIS 9.3, spatial distribution maps of pH, TH, Cl, TDS , Ca , Mg , So_4 , No_3 , F , HCO_3 , Na and WQI have been created. WQI is used to assess the suitability of groundwater from the study area for human consumption. From the WQI assessment over 90% of the water samples are found to fall under poor water category. Analysis reveals that groundwater of the area needs field specific treatment before put to use.

INDEX TERMS: Physico-chemical analysis, Water Quality Index (WQI), Spatial analysis, GIS, Groundwater, Upper Pincha Basin, Inverse Distance Weightage (IDW).

1. INTRODUCTION

Groundwater occurs almost everywhere beneath the earth surface. Knowledge of occurrence, replenishment and recovery of groundwater has special significance in arid and semiarid regions due to spatial and timely variations in monsoon rainfall, insufficient surface waters and over drafting of groundwater resources. Groundwater quality depends on the quality of recharged water, atmospheric precipitation and inland surface water. Temporal changes in the origin and constitution of the recharged water, hydrological and human factors, may cause periodic changes in groundwater quality. Ascertaining the quality is crucial before its use for various purposes such as drinking, agricultural, recreational and industrial use [1,2,3].

Water Quality Index (WQI) is an important parameter for ascertaining groundwater quality and its suitability for drinking purpose. It is one of the most effective tools to communicate information on the quality of water. It is simple and easy to understand water quality issues by integrating complex data and generating a score that describes water quality status. It is also defined as a rating that provides the composite influence of water quality parameters on the overall quality of water for human consumption. Standards for drinking purposes as recommended by WHO [4,5] have been considered for the calculation of WQI.

Main objective of the present experimental study is to assess groundwater quality of Upper Pincha Basin by an integrated approach of traditional water quality analysis and Geographical Information System and to generate water quality index map.

1.1 STUDY AREA

Upper Pincha Basin lies between North Latitude $13^0 42'$ to $13^0 28'$ and East Longitude $78^0 54'$ to $78^0 45'$ with a total drainage 146.26 km² (Figure 1), and is spread over three mandals; Somala, Sodumu and Chowdapalle. This region is influenced by semi arid climate with temperature varying between 30 ^{0}C and 42 ^{0}C. Normal annual rainfall over the study area is about 860 mm. Major Industries

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located in the study area is sugar, chemicals, food and food processing.

Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of the rock formation. Major part of study area covers weathered and fractured rocks of biotite-hornblend gneiss, biotite granite(Hbgn) (Figure 2). Ground water conditions in these types of rocks are mainly controlled by fractured and intergranular porosities. Red loamy soils and black clay soils are found in the study area.

2 MATERIALS AND METHODS

2.1 Chemical Analysis: Water samples, in clean polyethylene bottles, were collected during July 2011 from 50 boreholes capturing the deep aquifer depth ranging from 300 feet to 600 feet (Figure 3). Before collecting the samples, bottles were thoroughly rinsed with groundwater to be sampled. In case of bore wells and hand pumps, water samples were collected after pumping for 10 min. Eleven characteristics, such as pH, TH, Cl , TDS , Ca , Mg , So_4, No_3, F , HCO_3 and Na, of the groundwater samples were determined using standard procedures recommended by APHA [6]. Parameters including statistical measures, such as minimum, maximum, mean and standard deviation, are presented.

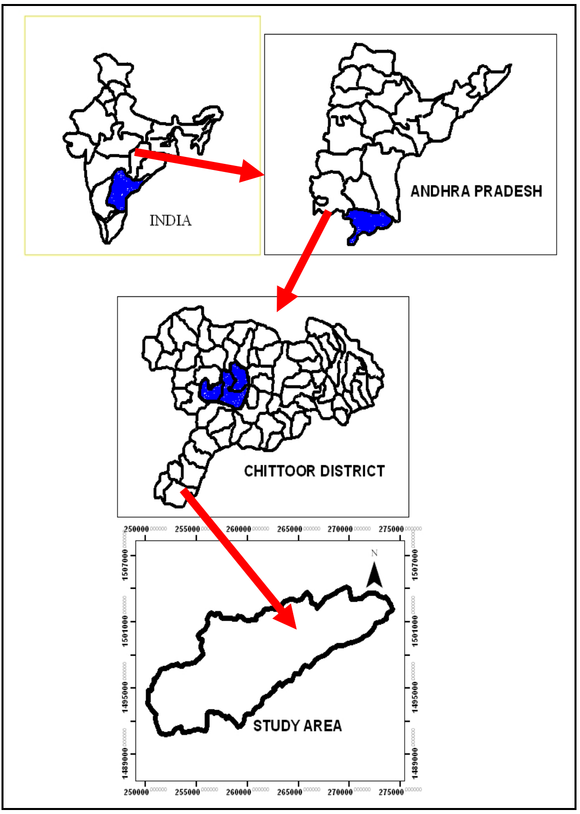

Figure 1: Location map of the study area

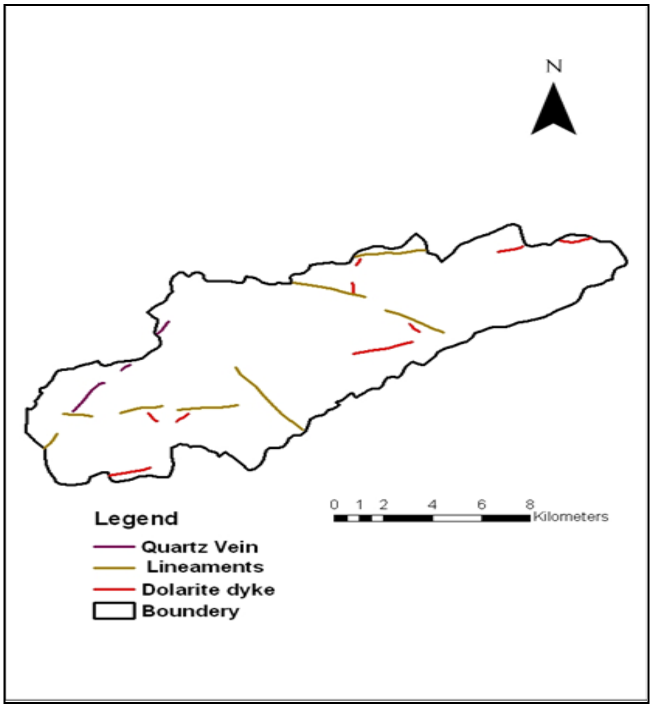

Figure 2: Geological map of study area

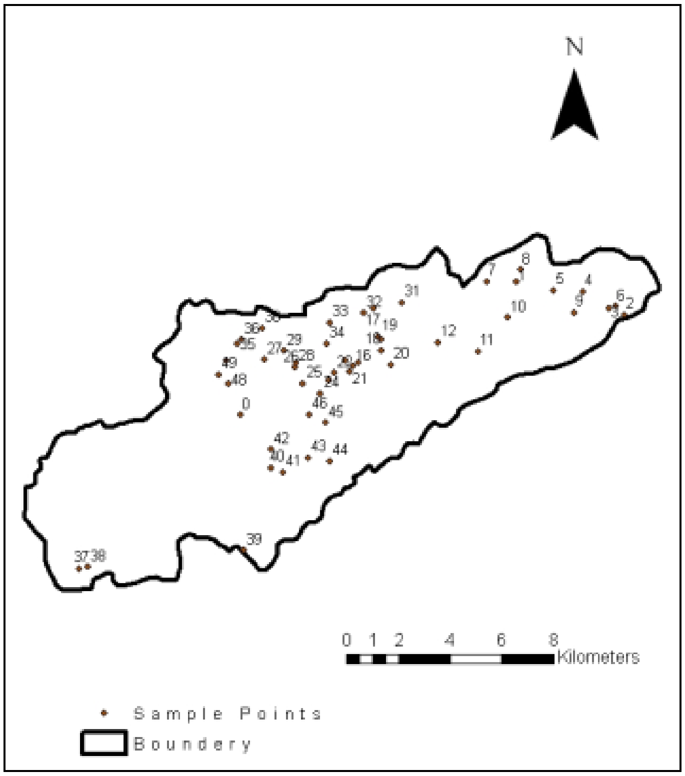

Figure 3: Groundwater sampling locations

2.2 Estimation of Water Quality Index: For computing WQI, three steps were followed [7]. In the first step, each of the 11 parameters (pH, TDS,TH, Cl, SO_4 , HCO_3 , NO_3, Ca, Mg, Na and F) has been assigned a weight (wi) based on their effect on primary health (Table 1).

Table 1: Relative weight of chemical parameters

Chemical Parameters	WHO Standards	Weight(wi)	Relative Weight $Wi = wi/\sum wi$
pH	7.0-8.5 (8.5)	4	0.108
Total Hardness (mg/l)	100 (mg/l)	2	0.054
Chlorides (mg/l)	200 (mg/l)	3	0.081
Total Dissolved solids (mg/l)	500 (mg/l)	5	0.135
Calcium (mg/l)	100 (mg/l)	2	0.054
Magnesium (mg/l)	30 (mg/l)	2	0.054
Sulphate (mg/l)	250 (mg/l)	4	0.108
Nitrate (mg/l)	50 (mg/l)	5	0.135
Flouride (mg/l)	1 (mg/l)	5	0.135
Bicarbonate (mg/l)	100 (mg/l)	2	0.054
sodium (mg/l)	200 (mg/l)	3	0.081
		$\sum wi$=37	0.999

Maximum weight of 5 has been assigned to parameters like total dissolved solids, fluorides and nitrate due to their major importance in water quality assessment. Bicarbonate is given the minimum weight of 2 as it plays an insignificant role in the water quality assessment [8]. Other parameters like calcium, magnesium, sodium and sulphate were assigned a weight between 2 and 5 depending on their importance in the overall quality of water for drinking purposes. In the second step, the relative weight (Wi) of each parameter is computed using Eq. (1):

$$Wi = wi/\sum_{i=1}^{n} wi \qquad (1)$$

where, wi is the weight of each parameter, n is the number of parameters. Weight (wi), calculated relative weight (Wi) values and the WHO standards for each parameter are given in Table 1. In the third step, quality rating scale (qi) was calculated for each parameter using Eq. (2):

$$qi = \frac{Ci}{Si} x\ 100 \qquad (2)$$

qi is the quality rating, ci is the concentration of each chemical parameter in each water sample in mg/l and si is the WHO standard for each chemical parameter in mg/l

Table 2: Status of Water Quality based on WQI

WQI Range	Status
< 50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unfit For Drinking

In WQI, the SI is first determined for each chemical parameter using Eq. (3)-which is then used to determine the WQI as per the Eq. (4):

$$SI = Wi\ x\ qi \qquad (3)$$

$$WQI = \sum_{i=1}^{n} SIi \qquad (4)$$

where, SIi is the sub-index of ith parameter. WQI Values are usually classified into five categories (Table 2): Excellent, good, poor, very poor and unfit for drinking [9,10].

2.2 WQI Contour Maps through GIS: GIS is a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale [11]. Visiting every location in a study area to measure the height, magnitude, or concentration of a phenomenon is usually difficult or expensive. Instead, measure the phenomenon at strategically dispersed sample locations, and predicted values can be assigned to all other locations. Input points can be either randomly or regularly spaced or based on a sampling scheme. The interpolation tools are generally divided into deterministic and geostatistical methods. IDW, Spline, and Trend are deterministic, while Kriging is a geostatistical method. The Inverse Distance Weighted (IDW) referred to as deterministic interpolation methods because they assign values to locations based on the surrounding measured values and on specified mathematical formulas that determine the smoothness of the resulting surface. Determines the cell values using a linearly weighted combination of a set of sample points and controls the significance of known points upon the interpolated values.

Groundwater quality classification maps for pH, TH, TDS, Cl, SO $_4$, HCO_3 , NO_3 , Ca, Mg, Na and F from thematic layers, based on the WHO Standards for drinking water, have been created for Upper Pincha Basin.

Table 3: Water Quality Parameters Values for Collected Groundwater Samples at Various Locations

			TH	**SO_4^{2-}**	Fluoride	**CL^-**	TDS	**Ca^{2+}**	**Mg^{2+}**	**Na^{2+}**	**NO_3^-**	**HCO3**
Sample	**T(°C)**	pH	-- mg/l --									
1	33.5	6.57	352	130	0.5	140	800	200	152	32	0.1	210
2	30	8.23	264	130	0.6	180	700	133.33	130.7	34	0.1	180
3	33	7.43	172	60	0.4	80	600	66.6	105.4	35	Nil	320
4	33	7.46	468	150	0.4	250	1200	283.3	184.7	43	Nil	360
5	31	7.13	296	95	0.4	130	900	170	126	39	0.2	350
6	30	6.91	520	235	0.2	260	1500	349.9	170.1	52	0.1	450
7	32	7.5	184	45	0.4	64	500	99.9	84.1	34	Nil	280
8	30	6.7	440	145	0.5	200	1000	366.6	73.4	38	0.2	310
9	31	7.5	416	120	0.4	200	1000	133.32	282.68	44	0.1	400
10	31	7.47	192	45	0.3	40	500	83.325	108.67	30	0.2	290
11	31	7.14	380	105	0.6	184	900	206.646	173.35	34	Nil	296
12	34	7.27	400	95	0.4	140	900	183.315	216.68	37	Nil	400
13	30	7.78	320	155	0.2	120	900	99.99	220.01	49	0.1	430
14	30	7.13	460	265	0.2	360	1200	383.2	76.8	48	0.2	380
15	32	7.37	320	135	0.2	150	1000	209.97	110.1	49	0.1	420
16	29	8.25	200	120	0.1	110	700	89.991	110.009	46	0.2	316
17	31	7.45	352	120	0.2	160	1100	105	247	45	Nil	472
18	33	6.43	368	135	0.2	140	800	120	248	48	Nil	184
19	31	7.71	300	145	0.2	184	700	60	240	50	Nil	424
20	31	6.86	248	65	0.2	86	700	30	198	36	Nil	294
21	32	7.26	540	220	0.3	330	1400	240	300	51	Nil	296
22	32	7.2	472	160	0.2	130	1100	201	270	41	Nil	326
23	31	7.18	300	160	0.2	160	1100	80	220	43	Nil	464
24	32	7.7	380	120	0.2	110	1000	85	305	36	Nil	382
25	31	6.66	480	180	0.2	170	1300	102	380	36	Nil	370
26	31	6.6	300	80	0.1	120	700	60	240	26	Nil	200
27	32	6.85	890	130	0.4	216	1700	200	684	40	Nil	428
28	30	6.85	300	50	0.1	60	1000	50	250	26	Nil	256
29	30	6.9	380	140	0.2	148	1200	70	310	48	Nil	516
30	30	7.5	520	150	0.2	150	1200	205	315	34	Nil	380
31	32	6.84	600	200	0.2	220	1300	240	360	47	Nil	482
32	30	7.59	240	20	0.2	24	500	40	200	34	Nil	308
33	32	6.83	640	230	0.1	144	1600	210	430	39	Nil	512
34	31	7.11	560	220	0.1	260	1500	160	400	47	Nil	454
35	31	7.33	320	60	0.2	104	800	60	26	35	Nil	324
36	31	6.32	800	70	0.2	380	1600	70	550	39	Nil	320
37	32	6.67	280	80	0.1	42	700	80	248	29	Nil	280
38	30	6.65	400	190	0.1	44	900	190	240	27	Nil	272
39	30	6.42	270	70	0.1	136	700	70	340	27	Nil	202
40	30	6.69	300	85	0.1	40	600	85	220	22	Nil	184
41	30	6.8	260	80	0.1	44	500	80	222	22	Nil	174
42	30	6.51	390	180	0.1	40	900	180	215	27	Nil	264
43	32	7.06	260	105	0.2	120	800	105	304	31	Nil	292
44	31	7.2	400	155	0.2	40	800	155	216	29	Nil	270
45	31	7.15	440	250	0.2	90	1100	250	325	32	Nil	300
46	31	7.06	360	102	0.2	180	900	102	345	36	Nil	266
47	31	7.42	640	120	0.1	96	1200	120	308	36	Nil	380
48	30	6.97	300	200	0.1	284	1100	200	400	41	Nil	274
49	30	7.52	320	97	0.1	104	800	97	350	36	Nil	310
50	30	7.02	560	190	0.1	252	1400	190	380	41	Nil	350
MIN	29	6.32	172	20	0.1	40	500	30	26	22	0.0	174
MAX	33.5	8.25	890	265	0.6	380	1700	383.2	684	52	0.2	516
Mean	31.05	7.123	391.08	131.78	0.23	148.32	980	147.027	252.24	37.62	0.145	332.04
SD	1.089	0.435	149.74	58.149	0.135	84.717	309.706	84.640	123.09	7.917	0.052	89.65

3 RESULTS AND DISCUSSION

3.1.1 pH

pH is one of the most important operational water quality parameters with the optimum pH required often being in the range of 7.0-8.5. The maximum permissible limit for pH in drinking water as given by the WHO is 8.5. The values of pH in the groundwater samples collected varied from 6.32 to 8.25 with an average value of 7.12 (Table 3). This shows that the quality of groundwater of the study area is within the desirable limit. Spatial distributions of pH concentrations are shown in Figure.4a.

3.1.2 Electrical Conductivity (EC)

Electrical Conductivity (EC) of water at 30°C is due to the presence of various dissolved salts. The EC varies widely and ranges between 1135 and 1999 µS/cm at 30°C with a mean of 1567 µS/cm. Knowing that the maximum limit of EC in drinking water is prescribed as 1,500 µS/cm at 30°C the interpreted water quality with respect to EC indicates that more than 98% of the study area lies in maximum permissible limit for drinking water purposes. The spatial distribution of EC concentrations are shown in Figure.4b.

3.1.3 Total Dissolved Solids (TDS)

Concentration of dissolved solids in groundwater decides its applicability for drinking, irrigation or industrial purposes. The concentration of dissolved matter in water is given by the weight of the material on evaporation of water to dryness up to a temperature of 180^0C. The values are expressed in mg/l. The major constituents of TDS include Bicarbonates (HCO_3) Sulphates (SO_4^{2+}) and Chlorides (Cl^-) of Calcium, Magnesium, Sodium and Silica. Groundwater containing more than 1000 mg/l of total dissolved solids is generally referred as brackish water. In the study area, the TDS amount ranges from 500 mg/l to 1700 mg/l with an average of 1000 mg/l (Table 3). About 48% of the water samples fall under higher solids content often has a laxative and sometimes reverse effect upon people whose bodies are not adjusted to them. The spatial distribution of TDS concentrations are shown in Figure.4c.

3.1.4 Total Hardness (TH)

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, sulphates, chlorides and nitrates. Total hardness is a measure of calcium (Ca_2^+) and magnesium (Mg_2^+) content in water and is expressed as equivalent of $CaCo_3$. Water with a hardness of less than 75 mg/l is considered as soft. Hardness of 75-150 mg/l is not objectionable for most purposes. Minimum total hardness of 172 mg/l (Table 3) and maximum value of 890 mg/l . In general, hard waters are originates in areas where top soil is thick and limestone formation is present. Hard waters cause excessive consumption of soap used for cleaning purpose. Lathering does not take place until all hardness ions precipitate out. This precipitate adheres to surfaced of tubes, sinks, dish washer and may stain clothing. The spatial distributions of TH concentrations are shown in Figure.4d.

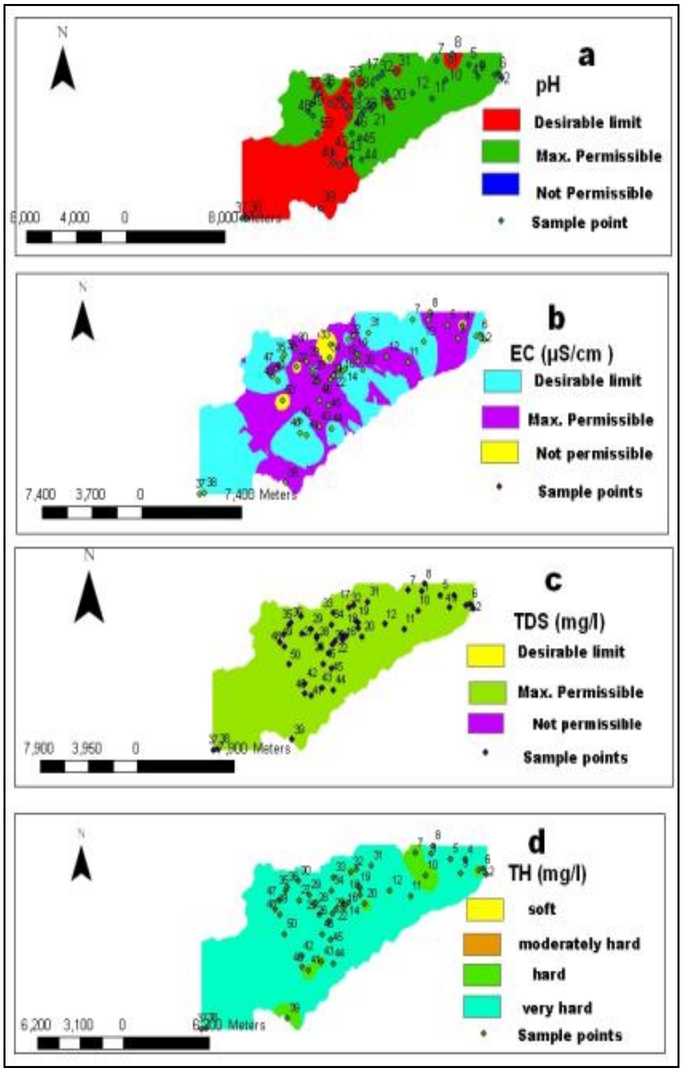

Figure 4: Spatial distribution of **a**. pH**, b**. EC, **c**. TDS, **d.** TH

3.1.5 Sulphate (So_4)

Sulphates occur in natural waters at concentration up 50 mg/l. concentration of 1000 mg/l can found in water having contact with certain geological formations such as concentrations of sulphate may be due to the presence of sulphide ore bodies like pyrite, lignite and coal. Rain water has quite high concentration of sulphates particularly in areas with high atmospheric pollution. Higher concentration of sodium sulphate in water can cause malfunctioning of the alimentary canal. The recommended upper limit is 200 mg/l in water intended to human consumption. Sulphate concentration ranges from 20 mg/l to 265.4 mg/l. The spatial distribution of chloride concentrations are shown in Figure.5a

3.1.6 Chloride (Cl)

Chloride is present in all natural waters at greatly varying concentration depending on the geochemical conditions. Major sources of chloride in groundwater are the constituents of igneous and metamorphic rocks like gneisse and granite etc. Because of sewerage disposal and leaching of saline residues in the soil, abnormal chloride concentrations may occur. Chlorides can only be removed by reverse osmosis process and electrolysis. Water quality analysis of the samples collected indicates that the chloride concentration ranges from 40 mg/l to 380 mg/l. The spatial distribution of chloride concentrations are shown in Figure.5b

3.1.7 Bicarbonates (HCO3)

Alkalinity is caused due to the presence of carbonates, bicarbonates and hydroxides of calcium, magnesium, potassium and sodium. Calcium carbonate is the most usual constituent that causes alkalinity. Bicarbonate is expressed in mg/l as $caco_3$ and the limit for drinking water is 100 mg/l as $caco_3$. Total Bicarbonate in the groundwater in the basin ranges between 174 mg/l to 516 mg/l (Table 3). Excess bicarbonate in water is harmful for irrigation which leads to soil damage and reduce crop yield. Water having bicarbonate less than 100 mg/l as $caco_3$ is desirable for domestic consumption. High alkalinity in natural waters will favour of producers (algae and phytoplankton groups) The spatial distribution of bicarbonate concentrations are shown in Figure.5c.

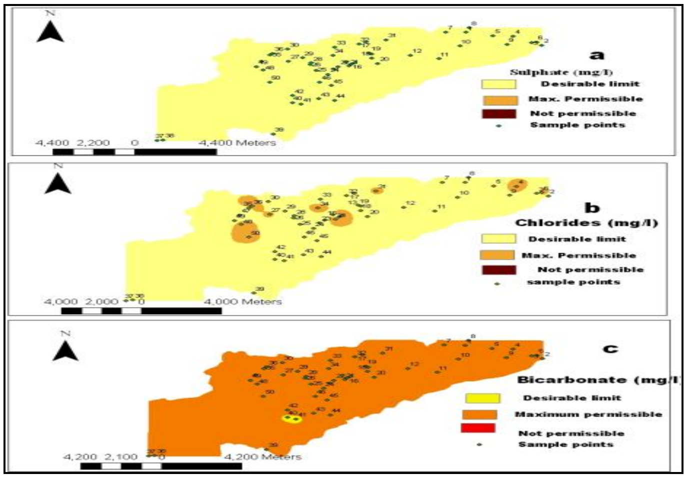

Figure 5: Spatial distribution of **a.** sulphate, **b.** chlorides, **c.** bicarbonate

3.1.8 Sodium (Na^+)

Major source of sodium content in the ground water is due to presence of salts. Desirable limit of sodium content in the ground water is 200 mg/l . Sodium in the ground water basin ranges between 22 mg/l to 52 mg/l. Spatial distribution of Sodium concentrations are shown in Figure 6a.

3.1.9 Calcium (Ca^{2+})

Calcium occurs in water mainly due to the presence of limestone, gypsum, dolomite and gypsiferrous minerals. Permissible limit of calcium is 75 mg/l. Calcium concentration ranges from 30 mg/l to 383.2 mg/l. The spatial distribution of calcium concentrations are shown in Figure.6b.

3.1.10 Magnesium (Mg^{2+})

Magnesium occurs in water mainly due to the presence of olivine, biotite, augite and talc minerals. Permissible limit of magnesium is 30 mg/l. Water quality analysis of the samples collected indicates that the magnesium concentration ranges from 26 mg/l to 684 mg/l. The spatial distribution of magnesium concentrations are shown in Figure.6c.

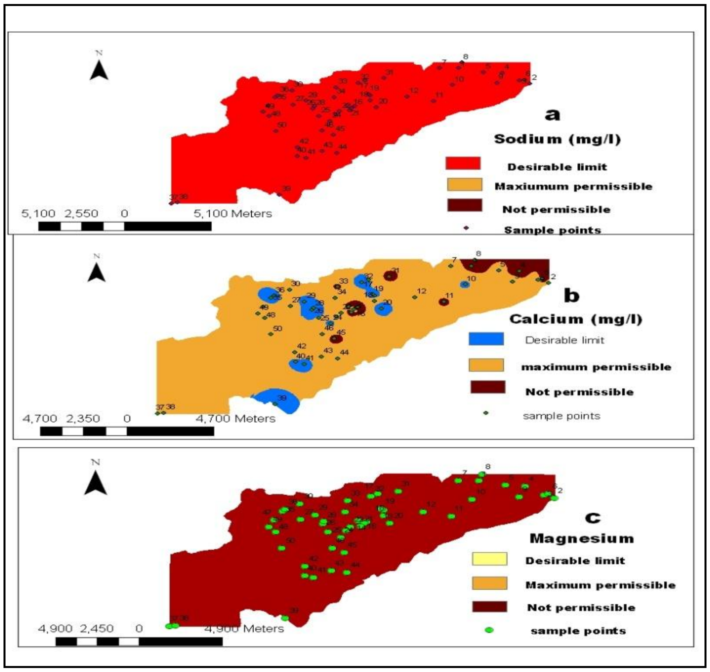

Figure 6: Spatial distribution of **a.** sodium, **b.** calcium, **c.** magnesium

4 .0 Conclusions

In the present investigation, an attempt was made to evaluate and to map the groundwater quality of Upper Pincha Basin. GIS makes the groundwater quality maps in an easily understood format. It is shown that the majority of the samples presented a pH value within the maximum permissible limit; water quality with respect to EC indicates that reflected a pH value is within the limit. The TDS value of Upper Pincha Basin is very high which results it is brackish water. In our study, spatial distribution map of TH shows that a majority of the groundwater samples falls in the very hard category causes excessive consumption of soap used for cleaning purpose. Lathering does not take place until all the ions causing hardness are precipitated. This precipitate adheres to surfaced of tubes, sinks, dish washer and may stain clothing. The predominant cation trend in Upper Pincha Basin is Ca $^{2+}$ >Mg $^{2+}$ >Na $^{+}$. Almost all groundwater samples exceed the maximum permissible limit of magnesium; Sodium(Na) concentrations are within the maximum permissible limit. The abundance of the major anions in Upper Pincha Basin is in the following order: HCO$_3^-$ >Cl$^-$>SO$_4$ $^-$. HCO$_3$ concentration is above the maximum permissible limit. Excess bicarbonate in water is harmful for irrigation which leads to soil damage and reduce crop yield.

The Water Quality Index is a very useful and an efficient tool to summarize and to report on the monitoring data to the decision makers in order to be able to understand the status of the groundwater quality; and to have the opportunity for better use in future as well. The overall view of the WQI (Table 4) of the present study zone shows a higher WQI. But, only eleven locations had a satisfactory result with a WQI below 100. This study demonstrates that the use of GIS and WQI methods could provide useful information for water quality assessment.

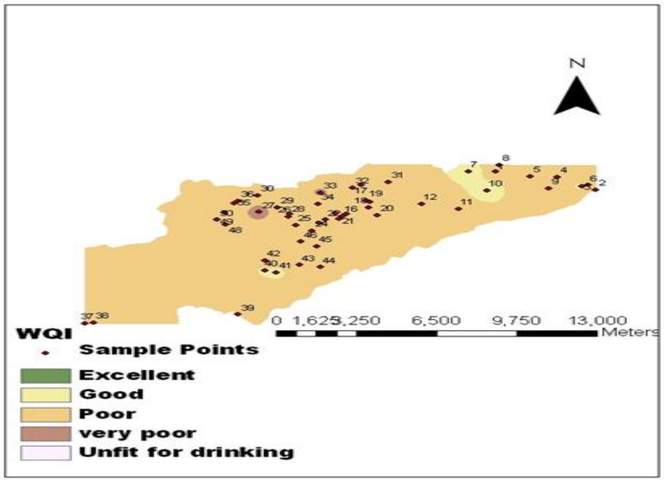

Figure 7: Spatial distribution of Water Quality Index

Table 4. Water Quality Index Values for different samples

Sample	WQI	Status
1	111	Poor
2	97.755	Good
3	79.559	Good
4	150.982	Poor
5	108.956	Poor
6	168.021	Poor
7	71.99	Good
8	124.634	Poor
9	151.227	Poor
10	74.053	Good
11	126.143	Poor
12	134.613	Poor
13	127.716	Poor
14	144.513	Poor
15	116.296	Poor
16	86.078	Good
17	142.09	Poor
18	120.036	Poor
19	124.51	Poor
20	97.33	Good
21	180.426	Poor
22	150.308	Poor
23	132.07	Poor
24	143.066	Poor
25	175.137	Poor
26	104.457	Good
27	273.827	Very poor
28	113.168	Poor
29	158.517	Poor

30	166.99	Poor
31	194.89	Poor
32	88.772	Good
33	214.292	Very poor
34	200.689	Very poor
35	76.77	Good
36	230.492	Very poor
37	107.194	Poor
38	127.89	Poor
39	121.703	Poor
40	95.476	Good
41	90.135	Good
42	121.254	Poor
43	126.645	Poor
44	118.745	Poor
45	161.615	Poor
46	149.217	Poor
47	162.851	Poor
48	168.125	Poor
49	136.661	Poor
50	188.511	Poor

REFERENCES

[1] Vasanthavigar, M., K. Srinivasamoorthy, K. Vijayaragavan, R. Ganthi, S. Chidambaram, P.Anandhan, R. Manivannan and S. Vasudevan, 2010.Application of water quality index For groundwater quality assessment: Thirumanimuttar sub-Basin, Tamilnadu, India. Environ Monitoring Assess. DOI 10.1007/s10661-009-1302-1.

[2] Sargaonkar , A. and V. Deshpande, 2003. Development of an overall index of pollution For surface water based on general classification scheme in Indian context,Environmental Monitoring and assessment, (89):43-67.

[3] Ravikumar, P., R.K. Somashekar and M. Angami, 2010. Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purpose in the Markandeya River Basin, Belgaum District, Karnataka State, India. Environmental Monitoring Assessment ,doi:10.1007/s10661-010-1399-2.

[4] WHO, 1996b. Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes.E and FN Spon, London,UK.

[5] WHO,2004. Guide lines for drinking water quality training pack,WHO, Geneva, Switzerland.

[6] APHA (1995). Standard methods for the examination of water and waste water (APHA).

[7] Kumar, M., K. Kumari, A.L. Ramanathan and R. Sexena, 2007. A Comparative Evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, Indian Environmental Geology [5]:553-574.

[8] Mouna Ketata-Rokbani, Moncef Guddari and Rachida Bouhlila,2011. Use of Geographical Information System and Water Quality Index and Assess Ground water quality in EI Khairat Deep Aquifer (Enfidha,Tunisian Sahel), Iranica journal of Energy and Environment , 2(2):133-144.

[9] Srinivasamoorthy, K,. M. Chidambaram, M.V. Prasanna, M. Vasanthavigar, A. John Peter and P. Anuradhan, 2008. Identification of major sources controlling Groundwater Chemistry from a hard rock terrain- A case study from mettur taluk, salem district, Tamil Nadu, India, J. Earthsystem science., 117(1):49-58.

[10] Subramani, T., L. Elango and S.R. Damodarasamy,2005. Groundwater quality and its suitability for drinking and agricultural use chithar River Basin, Tamil Nadu, Indian Environmental Geology 47:1099-1110.

[11] Asadi, S.S., P. Vuppala and M. Anji Reddy, 2007. Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Muncipal Corporation of Hyderabad (Zone-5), Indian International Journal of Environmental Research and Public Health,4(1):45-52..