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Geospatial Distribution of Groundwater quality using GIS techniques, in Chickballapur District, Karnataka, India

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Abstract: The rate of depletion and degradation of ground water poses a threat to the future generation's support system. The increase in population is resulting in over exploitation of water resources. Many sporadic degrading activities are being lead to the gradual deterioration in quality of surface and ground water. The loss of quality in the water resources is causing a major health hazards and even leads to death of human, livestock. The Geo Spatial variations of subsurface water quality in Chickballapur District, Karnataka, India, have been studied by utilising the new technology. Geographical Information System (GIS), a tool which is used for storing, analyzing and displaying spatial data is also used for analysing ground water quality information. For this study, the water samples representing the entire study area were collected from 65 bore wells and corresponding Latitude and Longitude of the sampling points using GPS Instrument. The water samples were analyzed for thirteen physico-chemical parameters such as Alkalinity, Hardness, Calcium, Chloride, Magnesium, Sulphate, Iron, Sodium, Potassim, pH, Electrical Conductivity, TDS and Nitrate using standard procedure in the laboratory and the results were compared with standards. The geospatial distributions of ground water quality map of the study area have been prepared using spatial analyst tools in GIS. The spatial database established in GIS and results obtained in this study will be helpful for monitoring and managing ground water pollution in the study area.

Keywords: Ground water, GIS, Quality, Distribution

1. INTRODUCTION

Groundwater in the study area is used for several purposes, including drinking water and agricultural, municipal, and industrial supplies. It has become one major water supply resource [1]. However, the pressure of groundwater, in terms of both quality and quantity, has increased to an extent whereby not only public health safety but also sensitive ecosystems are threatened by contamination of human exploitation [2]. So works of groundwater quality monitoring and evaluation in the study area become a key factor in groundwater studies and are imperative for devising preventive measures against health hazards. Analyses of several physical and chemical parameters are essential before suggesting water for various needs. In the present study the results of the water quality parameters tested were used to generate the spatial water quality variation maps in GIS platform. The results were compared with the permissible limits specified by Bureau of Indian Standards IS 10500 and their suitability for drinking was suggested.

2. STUDY AREA

Chickballapur district is the eastern gateway to Karnataka. It formed by bifurcating old Kolar district in to Chickballapur and Kolar districts. Chickballapur district lies between North latitude 13° 13' 04" to 13° 58'29" and East Longitude 77° 21' 52" to 78° 12' 31". It is bounded by Bangalore and Tumkur districts on the west, Ananthpur district of Andhra Pradesh on the north, Chittoor district on the east and by Kolar district on the south. It is land locked district and hard rock terrain of Karnataka in the maiden (plain) region and covers an area of 4208 sq.km. The district lies almost in the central part of peninsular India, which has immense bearing on its geo-climatic conditions. This district experiences tropical climate throughout the year. Chickballapur district owes its prosperity and development to the existence of ancient tanks. There are as many as 1243 tanks located in the district. The main occupation of people is agriculture. In the absence of surface water irrigation system, ground water is the main source of irrigation.

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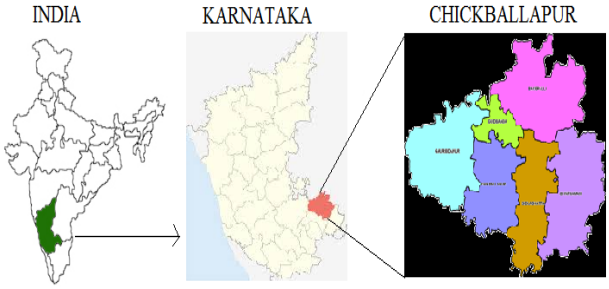

Fig. 1 Location of Study Area

3. METHODOLOGY

Ground Water samples were collected in 65 bore wells distributed all over the area and each point location is obtained by using a hand held GPS instrument GARMIN GPS-60 receiver. The latitude, longitude values were import to ArcGIS using UTM projections and converted to point feature. District boundary map was generated through online digitisation in Bhuvan website. Water samples were tested in the laboratory for thirteen parameters. Ionic inequality were found and Statistical analysis were done to find the deviations of water quality results in parameter wise and sample wise. Using Kriging interpolation method in ArcGIS, the spatial variation maps for each parameter were generated. Further all the spatial variation maps were reclassified using spatial analysis tool to have a common range of values. Weighted overlay analysis in ArcGIS is used to arrive at a final map which shows the extent of portable water existence and the places where the water quality is affected.

4. RESULTS AND DISCUSSIONS

In order to assess the ground water quality 65 sampling points were identified throughout the Chickballapur District and water samples have been collected. The major water quality parameters such as Alkalinity, Hardness, Chloride, Calcium, Magnesium, Sulphate, iron, Sodium, Potassium, pH, EC (Electrical Conductivity) TDS (Total Dissolved Solids) and nitrate have been estimated and tabulated as shown in the Table 1 . The Bureau of Indian Standard (BIS) Specification for Drinking Water is adopted to classify the water quality data.

4.1 Water Quality Parameters

4.1.1 Alkalinity

Alkalinity is the measure of capability of water to absorb the H+ ions without significant change of pH in water. Alkalinity is also defined as a measure of the acid buffering capacity of the water. The standard desirable limit of alkalinity in potable water is 200 mg/l. The maximum permissible level is 600 mg/l [3]. Total Alkalinity in the groundwater of the study area, varied from 80 to 544 mg/l. 24% of water samples shows low concentration of alkalinity (< 200 mg/l) and remaining 76% of water sample had the Alkalinity of the range 200 – 600 mg/l.

4.1.2Hardness

The factors that establish the quality of a drinking water is its degree of hardness. Hardness is defined as the calcium and magnesium ion content. Hardness in water is caused mainly due to the presence of the carbonates and the bicarbonates of calcium and magnesium, as well as due to sulphates, chlorides and nitrates [4]. The Total hardness in water is classified in to three ranges (< 300 mg/l, 300-600 mg/l and >600 mg/l). It was observed that 43% of the water sample has the low range of total hardness < 300mg/l (acceptable limit) and medium range 300 - 600 mg/l(permissible limit) was observed in major part of district. The high range of total hardness (>600 mg/l) was observed in Doddaganjuru, S-Gopalapalli, Bagapalli Town and Potenahalli.

4.1.3 Calcium

Calcium is fifth most abundant naturally available element. Calcium enters the ground water aquifers system through weathering of limestone, and from soil through leaching runoff and seepage. The main sources of this element in natural water are various industrial wastes, types of rocks and sewage. The concentration depends on the residence time of water in calcium rich geomorphologic formations [5]. Its value was found in Chickballapur district in the range of 24 mg/l to 184 mg/ l. According to BIS, the value should range from 75 – 200 mg/l. As per the analysis results 23% of the water sampling points shows the less content of calcium in chickballapur district.

4.1.4 Chloride

Chloride is one of the most important parameter in assessing ground water quality. Higher the concentration of chloride higher the degree of organic pollution in water [6]. According to BIS (Bureau of Indian Standards) the acceptable limit of chloride in drinking water is 250 mg/l. Chloride in the study area was found to be fluctuating between 5 and 395 mg/l. 16% of the study area has high concentration of chloride >250 mg/l. This concentration is due to the natural

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passage of water through salt formations in the earth. It also indicates pollution from industrial or domestic use is entering ground water aquifers without proper treatment. High chloride content in drinking water may lead to health issues [6].

4.1.5 Magnesium

The standard limit of magnesium is 30 mg/l. The maximum permissible level is 100 mg/l as per the BIS [3]. Magnesium in the groundwater of the study area, varied from 8 – 109 mg/l. Low concentration of magnesium (< 30 mg/l) was observed in 14% of the water samples. Water samples from Ablud, Gauribidanuru and Chikka Kudugodur village has magnesium content more than the permissible limit.

4.1.6 Sulphate

Sulphates are present in numerous minerals naturally. The acceptable limit for sulphate in ground water is 200 mg/L and the permissible limit is 400 mg/l as per BIS standards [3]. 21% of the water samples are higher than the acceptable limit. High concentration of sulphate increases corrosiveness of water towards concrete [6].

4.1.7 Iron

Quantitative determination of iron in samples of water is based on absorbance measurements of solutions obtained by adding thiocyanate ions [6]. The acceptable limit of Iron in water is 0.3 mg/l [3]. Except Kadalaveni and Potenahalli all the other areas indicates a presence of iron in high level. Iron is a common element in the earth's crust. Corrosion of Iron pipes leach iron into a water supply system. Iron gives water an unpleasant colour, odour and taste but not harmful to human health [6].

4.1.8 Sodium

Sodium occurs naturally in groundwater. However, sources such as more usage of fertilizers, industrial wastes, sewage and proximity to saltwater are the cause of high concentration of sodium in drinking water [7]. The acceptable limit of Sodium in ground water is 200 mg/l [3]. It has been found that sodium content is within the acceptable limit throughout the chickballapur district.

4.1.9 Potassium

The presence of potassium is usually due to minerals in igneous and metamorphic rocks and deposits of gypsum and sulphate and the other main reason for potassium into groundwater aquifers is due to agricultural activities. Potassium concentrations in ground water increase mainly due to the soluble miner rocks.[7]. The value was found in the range of 0.4 mg/l to 84 mg/l in the study area.

4.1.10 pH

pH is a measure of the activity of hydrogen ion (H+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. In general, water with a pH < 7 is considered acidic and with a pH > 7 is considered basic [8]. The normal range for pH in groundwater systems is 6 to 8.5 [3]. The analysis of water samples shows the pH value is within the limits in Chickballapur District.

4.1.11 Electrical Conductivity

Electrical conductivity is the measure of conduction of electric current. It depends on presence of ions, temperature and mobility of measurement. More concentration of dissolved ions leads to higher value of conductivity [8]. As per the IS 10500 conductivity can range from 750 – 2250 micro siemens per cm^{1} (µs/cm) [3]. Conductivity of water sample in the study area was found in the range of 202-1600 µs/cm. Analysis results shows that 34% of the water samples has EC less than the acceptable limit. The least value was recorded at Varadanayakkanahalli. Electrical Conductivity determines the suitability of water for irrigation. The maximum value of electrical conductivity was found at Bagepalli town.

4.1.12 Total Dissolved Solids

The mineral constituents dissolved in water constitute dissolved solids. Total concentration of the dissolve solids in water is a general indication of overall suitability of water for many purposes. The TDS usually classified in to two ranges (0-500 mg/l and 501-1000 mg/l). It is found that 58% of the water samples has TDS within the acceptable limit (<500mg/l).

4.1.13 Nitrate

Nitrate (NO_3) is a naturally occurring form of nitrogen found in soil. Nitrogen is essential to all life. More crops plants require large quantities to sustain high yields. Nitrate is colour less, odour less, tasteless compound that is present in some ground water. Nitrates and nitrites are nitrogen-oxygen chemical units which combine with various organic and inorganic compounds. Nitrate level is found to be varying between 5.52 and 43.61. Ablud, Mittemari, Kumbalapalli, Bagapalli Town are found to have high concentration of nitrate.

4.2 Ion balance

For each ground-water sample, Ion balances were calculated and examined as a check of the chemical analyses of major ions. The ion balance was calculated as the total dissolved cation concentration minus the total dissolved anion concentration divided by the total concentration of ions dissolved in solution in milli equivalent per litter (meq/L). The total cation concentration was calculated as the sum of major cations including calcium, magnesium, sodium, and potassium; the total anion concentration was calculated as the sum of acid neutralizing capacity of chloride, nitrate and sulphate. The percentage difference of Σcations and Σanions were within ±5, indicating that both the cation and anion

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analyses were of good quality. Difference of ±5 is because of unmeasured contents such as nutrients, organic anions and trace metals.

4.3 Statistical Analyses

Statistical analysis is used to calculate the mean, the standard deviation, the skewness and kurtosis. Mean explains average value; standard deviation refers to the measure of ‘‘spread’’ or ‘‘variability’’ of the sample; skewness describes the symmetry of the data; kurtosis describes the degree of flatness or peakedness in the region [9]. Statistical evaluation of groundwater quality parameters were showed in Table 2. Skewness value less than 0.5 shows a normally distributed sample values. The values greater than 0.5 (Sodium and potassium) were right skewed. Kurtosis shows all the parameters are normally peaked except potassium (Kurtosis > 4) is highly peaked.

Table 1

The values of physico-chemical parameters of Chickballapur district

S. No	Name	Alkalinity (mg/l)	$CaCo_3$ (mg/l)	Ca^{2+} (mg/l)	Cl^- (mg/l)	Mg^{2+} (mg/l)	So_4^{2-} (mg/l)	Fe (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	pH	EC (µS/cm)	TDS (mg/l)	No_3^- (mg/l)
1	H-CROSS	338	256	101.00	370.88	67.06	170	3.7	182.7	9.8	6.83	1414	737	25.45
2	Santekallahalli	220	228	65.73	46.98	15.55	75	3.1	29.9	8.2	7.33	548	285	14.7
3	Vaijakur	232	386	116.23	167.94	23.32	110	2.65	56.5	10.2	7.13	923	479	13.23
4	Talagvara	220	266	123.32	52.98	26.24	135	3.8	10	1.5	7.57	444	230	9.12
5	Kaivar	336	436	100.12	241.00	45.24	165	2.8	148.1	84.1	7	1215	649	5.52
6	Kendanahalli	168	202	102.10	71.97	17.49	150	3.5	48.1	2.8	7.36	488	253	16.11
7	Chintamani Town	250	504	84.168	317.90	71.44	65	2.95	72.3	8.4	7.09	1283	666	18.34
8	Doddaganjuru	326	646	144.28	362.48	69.49	90	2.9	95.8	15.6	7.04	1245	647	13.17
9	Siddimata	238	510	141.88	395.87	37.90	170	2.4	154.7	47.8	7.26	1308	656	22.09
10	Chimanahalli	264	218	156.11	110.96	18.94	105	5.6	45.8	3.7	7.35	660	343	32.43
11	Battalahalli	220	414	140.62	208.93	39.59	170	4.1	58.7	15.3	7.15	912	474	19.52
12	Bachuwarahalli	278	550	116.23	230.92	63.18	107	5.3	79.8	8.1	7.32	1031	536	24.17
13	S-Gopalapalli	282	700	184.36	330.89	58.32	230	5.4	92.8	3.9	7.27	1303	677	18.04
14	Murugamalla	360	590	172.34	385.88	38.88	227	3.3	186.9	10	6.95	1483	771	30.12
15	Kagati	264	368	168.00	290.94	48.6	265	3.9	144.1	1.6	7.2	981	509	36.93
16	Kachehalli	160	208	92.52	58.98	12.63	92	3.1	20	4.7	7.37	507	263	12.26
17	Melur	160	594	158.71	329.89	48.11	75	1.1	18.5	10.1	7.16	1345	698	8.98
18	Kshavapura	80	182	47.29	55.98	15.55	90	5.8	25	5.6	7.48	497	258	26.01
19	Handiganalla	160	210	52.10	45.98	19.44	160	2.8	66.1	4.6	7.38	511	266	24.25
20	Sidalaghattab Town	112	282	80.16	140.95	19.92	190	3.1	88.6	2.7	6.95	850	443	14.14
21	Varadanayakkanahalli	100	292	24.04	5.99	56.37	210	3.5	10	5.6	7.65	202	105	31.54
22	Ablud	164	184	60.12	15.99	8.262	55	3.9	25	1.9	7.5	406	210	40.06
23	Chage	124	190	56.91	50.98	11.66	62.	3.5	21	3.4	7.55	490	254	19.57
24	Ajjakadarenahalli	96	202	49.69	90.97	18.95	75	4.1	24	6.1	7.45	514	267	8.68
25	Kudupakunte	236	398	64.12	136.95	57.83	90	3.3	53.4	3.2	7.22	799	416	16.65
26	Dibburahalli	306	400	78.55	148.95	49.57	160	5.1	51	51.5	7.26	920	478	25.61
27	Mittemari	256	360	144.16	146.95	56.45	237	4.1	32.4	2.7	7.17	864	449	43.61

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28	Kumbalapalli	340	288	114.69	250.92	60.48	285	5.1	147.2	1.6	7.06	1392	723	40.83
29	Bagapalli Town	544	648	125.05	330.89	81.64	270	3.3	199.1	3.1	6.88	1600	832	36.38
30	Bagepalli Fire Ssation	230	520	184.36	94.97	14.58	240	5.3	51.3	2.4	7.15	1224	637	31.04
31	Paragudu	324	380	97.71	231.92	60.34	152	2.6	86.1	4.7	7.05	1165	605	23.23
32	Ramaganahalli	288	280	103.70	121.96	32.56	125	2.6	51.93	2.37	7.13	788	409	17.97
33	Peresandra	208	360	88.17	159.95	34.02	222	3.9	107.6	0.4	7.24	967	502	23.65
34	Dodda Payalagurki	188	334	98.59	82.974	51.38	242	2.4	34.4	3.9	7.32	790	410	15.44
35	Hunegal	140	142	98.47	39.98	11.17	120	3.1	15.1	2.9	7.33	545	283	18.09
36	Irechalli	126	120	38.85	150	51.66	75	4.6	50	1.6	7.21	565	297	11.63
37	Nandi Grama	120	210	47.29	64.98	22.35	95	6.5	37.9	1.2	7.29	580	300	10.54
38	Muddenahalli	262	414	97.79	136.95	86.19	230	5	37.3	43.6	7.02	1100	572	14.98
39	Chikkaballapur City	232	202	73.70	54.98	16.52	60	4.2	29.6	2.8	7.26	526	274	8.5
40	Tippenahalli	236	376	92.98	142.95	54.99	90	2.3	9.8	9.1	7.2	794	411	28
41	Chikkaballapur City	230	508	140.28	367.72	38.39	142	2.3	176.8	25.9	6.96	1221	635	9
42	Lingashettipura	150	286	79.35	81.975	31.38	210	3.2	54.9	11.3	7.4	703	365	8.7
43	Kalkunte	142	158	53.70	43.986	45.83	140	2.4	2.8	1	7.3	509	264	6.5
44	Adegaranahalli	228	246	85.77	93.588	57.77	162	4.6	10.1	3.2	7.22	682	353	16.2
45	Madinayakanahalli	230	200	52.90	38.988	76.52	170	4.9	14.1	3.7	7.35	511	266	7.8
46	Renumakalahalli	296	406	101.83	151.95	94.78	180	3.1	30.6	4.2	7.08	923	481	18
47	Gudibanda City	232	384	212.00	175.94	41.79	255	3.2	47.5	2.1	7.13	1032	536	24
48	Krishnarajpura	320	470	128.25	195.93	86.45	152	5	47.8	2.7	7.07	1026	532	23
49	Bandarahalli	320	244	52.90	40.987	77.21	125	3.3	13	5.6	7.26	549	285	27
50	Kallinayakanhalli	324	496	102.60	156.95	58.31	10	3.7	0.1	2.5	7.08	1005	522	26
51	Tonde bavvi Gate	310	284	84.12	41.987	30.13	110	2.3	42.1	3	7.35	522	270	11
52	Katanagenahalli	320	244	61.72	40.987	51.87	32	1.1	13.6	1.9	7.35	494	255	23.5
53	Machenahalli	442	560	124.24	285.91	90.75	142	2.4	64.8	8.9	6.78	1252	650	14.5
54	Pura	332	412	144.16	213.93	94.08	285	1.4	15.8	8.6	7.15	1144	594	25.8
55	Bisalahalli	368	276	58.00	25.992	71.58	72	3.3	11.2	1.2	7.15	609	315	25.7
56	Gauribidanuru	304	460	96.15	182.94	103.6	250	3.5	28.3	24	7.2	940	488	26
57	Chikka Kudugodur	340	644	91.76	285.91	106.9	195	1.8	72.9	23.5	6.97	1409	733	20
58	Vidurashwatta	380	438	94.93	156.95	67.06	122	5.3	58.4	7.7	7.3	981	510	12.5
59	Chandanaduru	330	240	38.47	35.989	54.99	37.	6	23.8	9.5	7.26	503	262	7.5
60	Jalahalli	280	496	125.35	333.89	74.84	40	1.9	24.6	4.4	6.93	1285	668	30
61	Ramapura	330	514	81.76	104.96	75.33	132	7.3	31.9	21.9	7.13	964	501	23.4
62	Kadalaveni	330	414	108.59	152.95	60.82	192	0.1	32.9	18	7.08	916	475	9.3
63	Alkapura	270	292	124.12	80.975	31.59	158	7.2	32.4	9.9	7.2	799	415	15.8

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64	Potenahalli	404	604	104.20	225.93	109.5	202	0.2	39.2	8.1	7.2	1193	620	28.2
65	Kamalapura	220	300	88.00	123.96	45.58	120	1.3	15.8	3.5	7.13	774	401	19.41

Table 2
Statistical evaluation of ground water Quality parameters

	MIN	MAX	MEAN	SD	SKEWNESS	KURTOSIS
Alkalinity	80.00	544.00	256.00	90.17	0.27	0.49
Hardness	50.00	700.00	354.00	157.03	0.25	-0.59
Calcium	24.00	184.37	100.33	39.86	0.51	0.04
Chloride	5.98	395.87	158.76	109.39	0.65	-0.68
Magnesium	8.26	109.00	50.32	26.35	0.31	-0.64
Sulphate	10.00	285.00	147.38	68.75	0.19	-0.79
Iron	0.15	6.50	3.54	1.48	0.26	0.34
Sodium	0.10	199.10	55.44	49.07	1.51	1.56
Potassium	0.40	84.10	9.67	10.28	2.83	8.51
pH	6.78	7.57	17.85	0.18	0.04	0.11
EC	183.00	1483.00	851.19	349.59	0.07	-0.81
TDS	95.00	771.00	442.06	181.74	0.07	-0.81
Nitrate	5.52	43.61	20.14	9.11	0.51	-0.25

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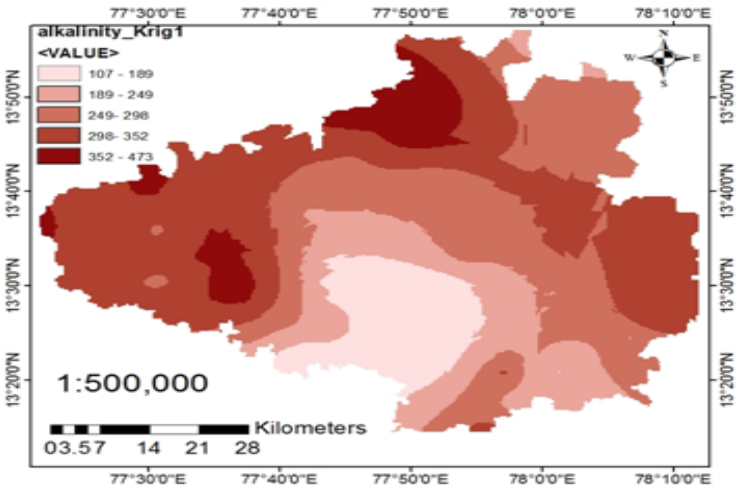
4.4 Generation of Spatial Analysis map for each water quality parameter

Chickballapur district boundary map was digitised online using Bhuvan website. Latitude and Longitude of the sampling points were projected and exported as a point shape file. Kriging Interpolation method is followed to generate spatial variation map of water quality for each parameter individually.



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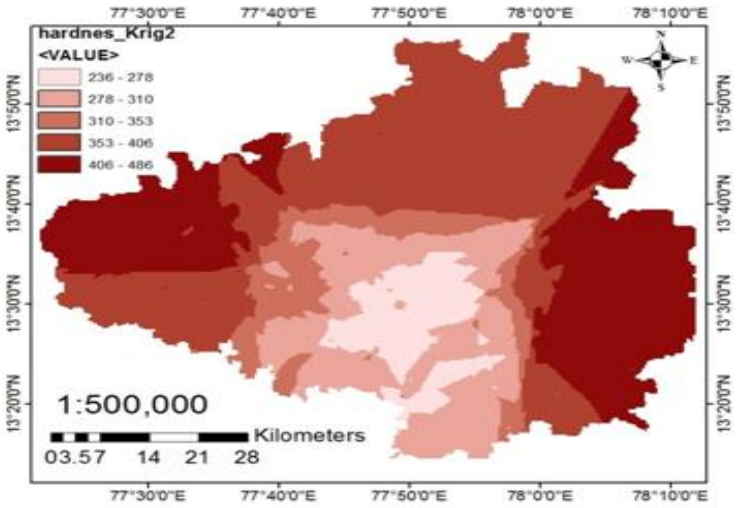

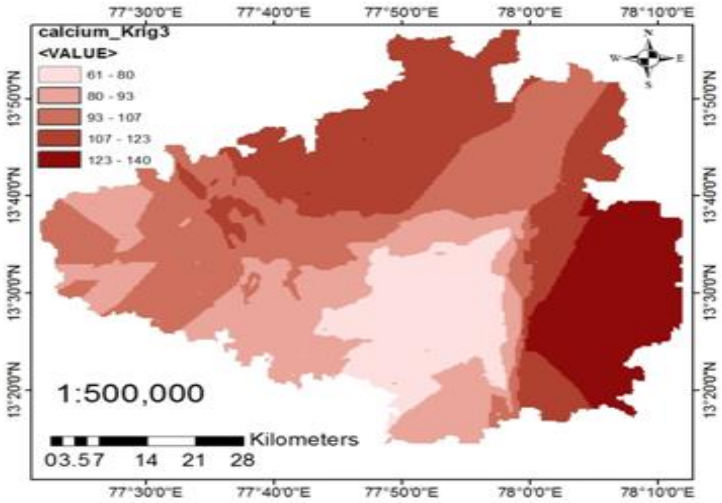

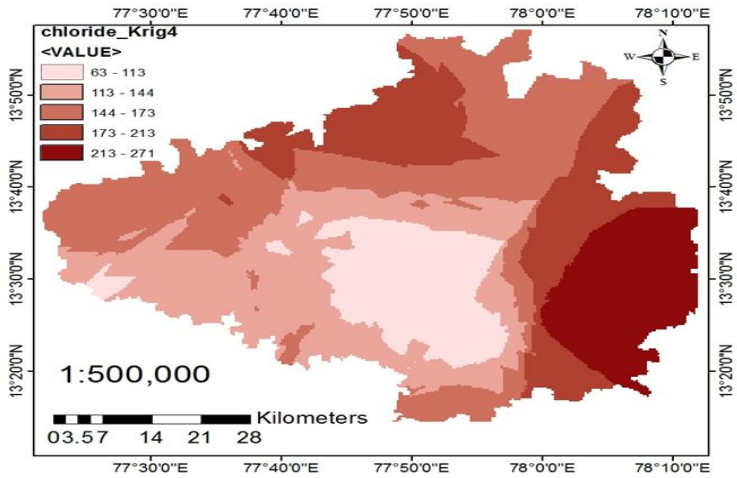

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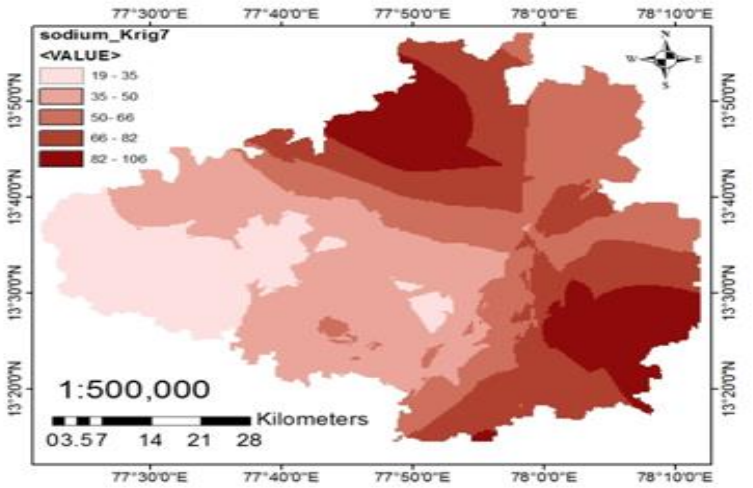

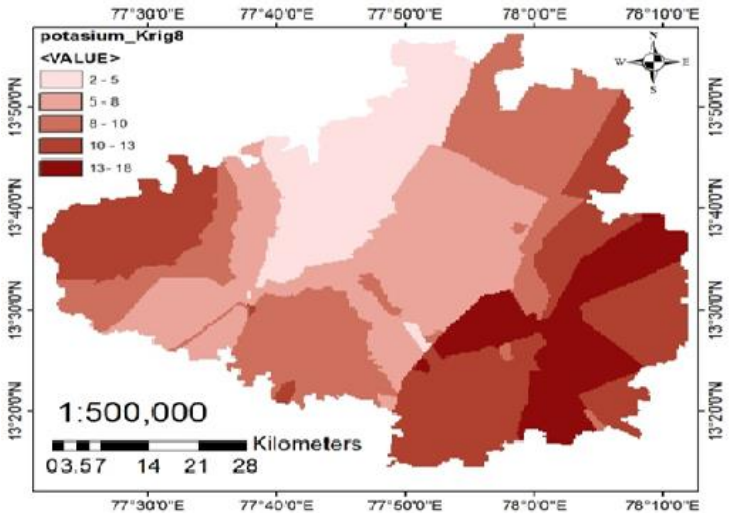

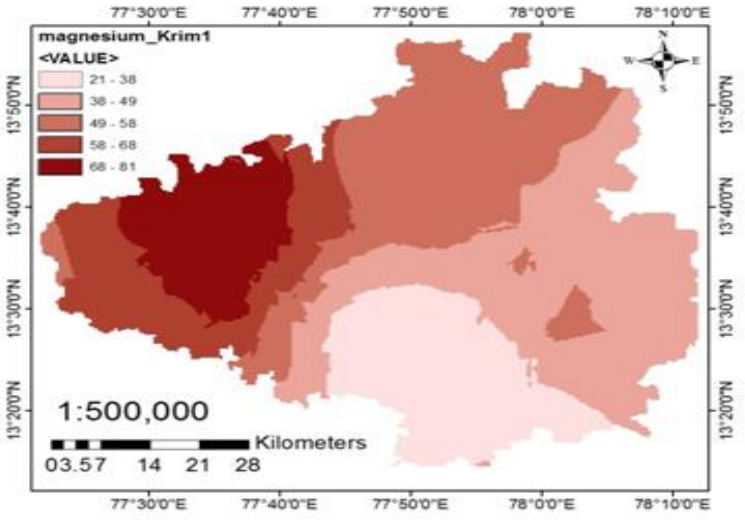

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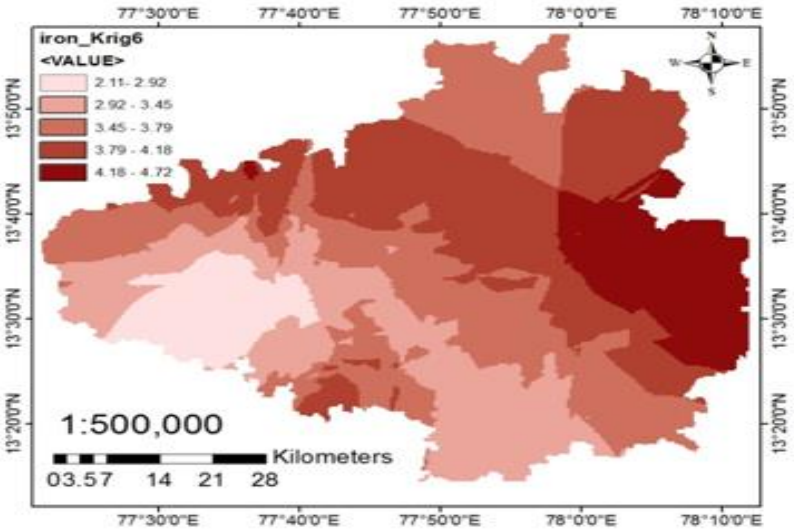

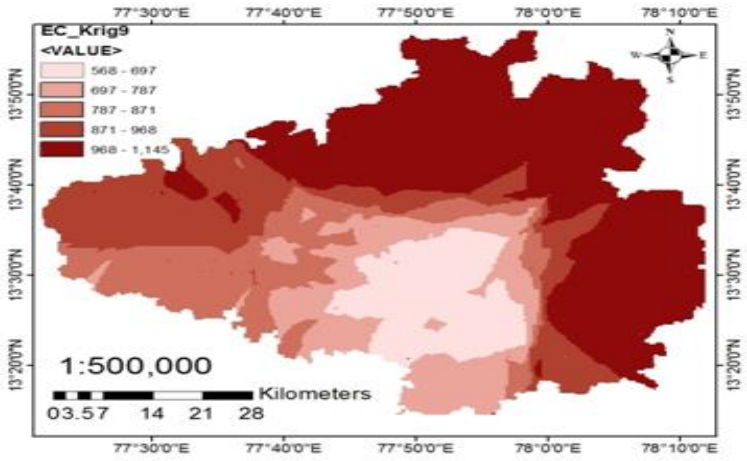

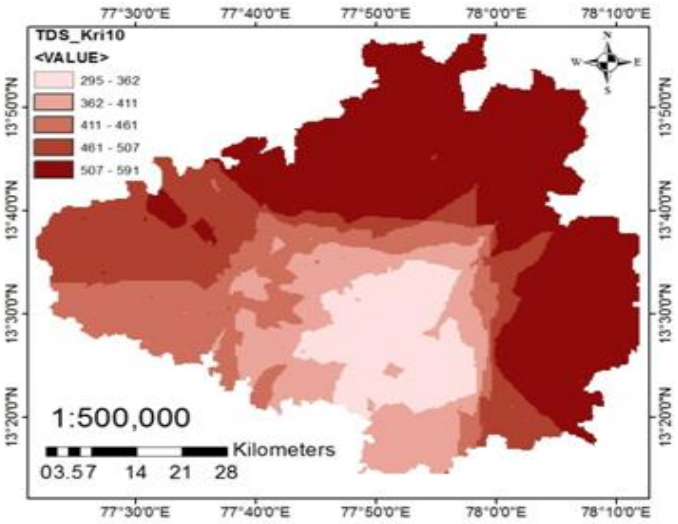

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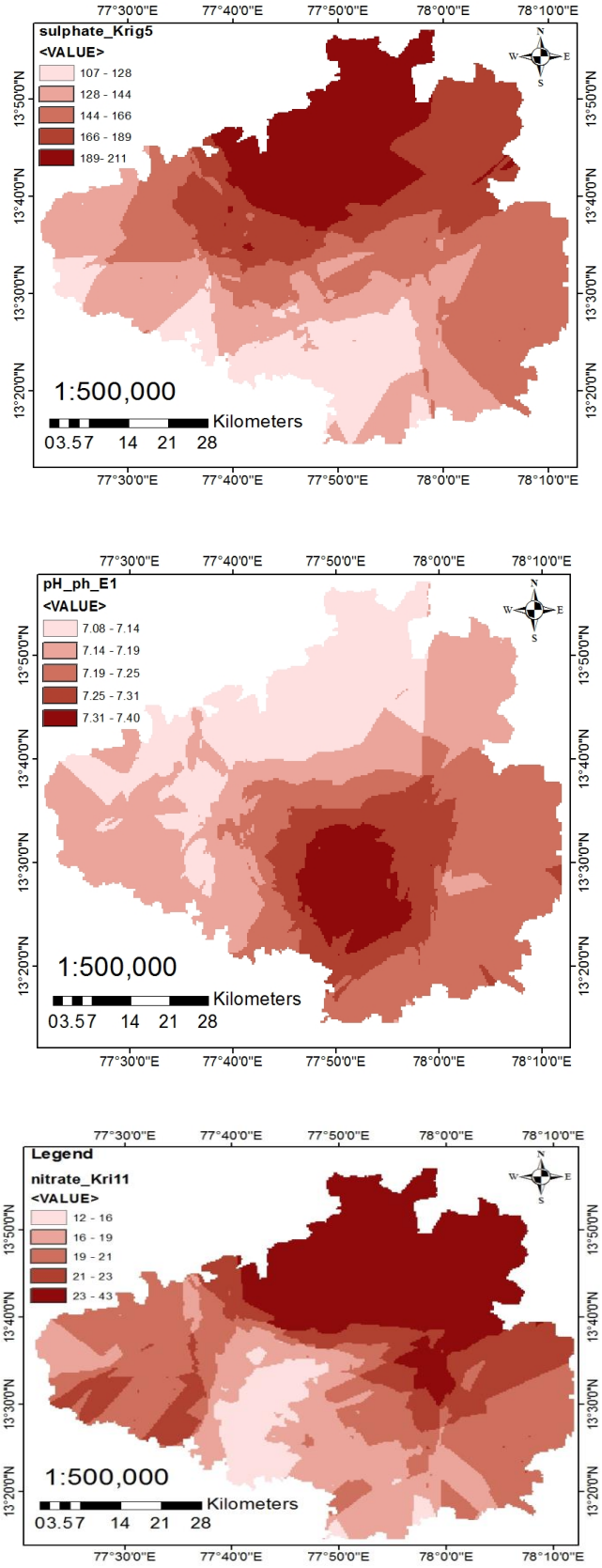

Fig.2 Spatial variation map of Water quality parameters (a) Alkalinity (b) Hardness (c) Calcium (d) Chloride (e) Sodium (f) Potassium (g) Magnesium (h) Iron (i) EC (j) TDS (k) Sulphate (m) pH (l) Nitrate

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4.5 Spatial Distribution of Ground water Quality map

Each water quality parameter map was reclassified to have a common classification. Reclassified maps were over-layed in ArcGIS-10 platform. Overlay tool helps to overlay several raster's using a common measurement scale and weights each according to its importance. Weighted overlay map was generated through giving equal weightage for all the water quality parameters. Final weighted overlay map classifies the entire Chickballapur area under four categories as effected, portable, accepted and good as shown in fig.3.

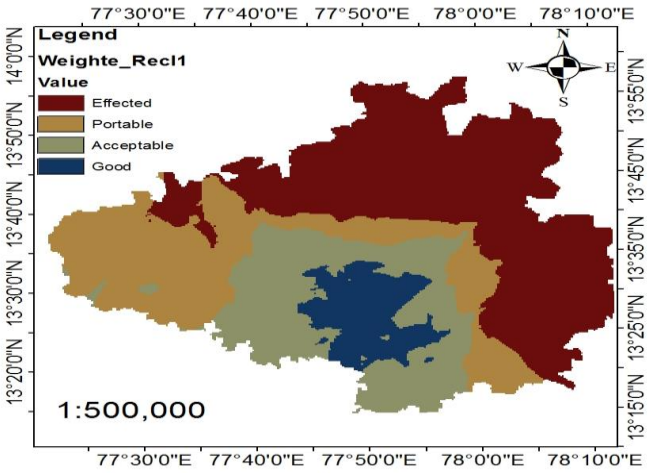

Fig.3 Ground water quality map

5. CONCLUSION

Ground water qualities of 13 parameters were determined for 65 sampling points. Statistical analysis and ion inequality were found as a quality check. As a further analysis, maps for spatial variation of the groundwater quality were prepared using Geographical Information Systems (GIS) techniques through kriging analysis. Through Ion balance equation the percentage difference of major cations and anions were within ±5%. Statistical analysis was carried out through mean, standard deviation, skewness and kurtosis. Skewness indicates that the sample values were normally distributed except sodium and potassium and Kurtosis indicates that all the parameters are normally peaked except potassium. Spatial variation map for each parameters were generated and weighted overlay analysis is carried out in ArcGIS platform. The final output map shows that water quality in Bagepalli taluk and Chickballapur taluks were affected.