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DELINEATION OF SALT WATER CONTAMINATION ZONES THROUGH CHEMICAL PARAMETERS IN NAGULERU SUB-BASIN, GUNTUR DISTRICT, ANDHRA PRADESH, INDIA

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ABSTRACT

Delineation of saltwater contamination zones in the groundwater, hydrogeochemical parameters such as Ca/Mg, Cl_2/CO_3+HCO_3,TA/TH, Base Exchange Index and Mg/Ca verses Cl_2 have been used. The area chosen for study lies between north latitudes of $16^0$14'29" and $16^0$43'05" and the east longitudes of $79^0$35'24" and $79^0$50'43". Fifty groundwater samples were collected to analyse chemical constituents of the area under study. The maximum and minimum values of Ca/Mg and Cl_2/CO_3+HCO_3 ratio are 6.078, 0.159 and 3.585, 0.316 respectively. Ca/Mg ratio values less than 0.20 indicate saline zones between 0.20 and 1.00 suggest slightly saline water zones and exceeding 1.00 have been considered as fresh water zones. The maximum and minimum values of TA/TH ratio are 3.266 and 0.38.7. The results reveal that salinity in groundwater is due to local environmental conditions such as drainage, application of industries in crop fields, water logging and domestic sewage.

INTRODUCATION

As population growth continues and modern industrial and agricultural processes introduced an increasingly complex suite of chemical constituents into the environment, scientists have begun to take a serious look at their effect on surface and ground water quality. The study area Naguleru sub-basin of Krishna River, is situated in the Palnad basin, on the western part of the Guntur District of Andhra Pradesh state of India as shown in Figure 1. It is located in between the north latitudes of $16^0$14'29" and $16^0$43'05" and the east longitudes of $79^0$35'24" and $79^0$50'43" and it falls in SOI Toposheet Nos.56 P/10, P/11, P/12, P/14 and P/15 on 1:50,000 scale. The areal extent of the study area is 572 sq.km., of which 201.09 sq km area is covered by forests and hills, the study area receives an annual rainfall of 853 mm. Groundwater occurs under water table conditions. In the preset study area, we report the origin of the salinity in groundwater on the basis of their hydrogeochemistry. Several people (Sambasiva Rao and Janardhan Raju, 1995 and Ravi Prakash and Chandu, 1993) have applied geochemical parameters for delineation of saltwater zones.

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Geology

The area generally comes under Cuddapah Super Group (Table 1) particularly Kurnool group. The northern portion of the study area from centre mainly consists of Nargi lime stones except at northern part where a patch of Banaganapalli conglomerates and quartzites is vividly observed. The southern portion is mostly occupied by Cumbhum shales/ phyllites. The other minor formations include Cumbhum dolomite/limestone, Cumbhum quartzites, Koilakuntla limestones, Banaganapalli conglomerate/quartzite. The Koilakuntla limestone is triangle in shape is underlined as basement is Cumbhum quartzite as the basement.

MATERIALS AND METHODS

Fifty ground sample were collected covering the area and analysed for various chemical constituents using the methods by Rainwater and Thatcher (1960) and Brown *et al*. (1970) and the sample locations are presented in Figure 2.

Chemical Constituents

Constituent ions and TDS play an important role in the salinity of groundwater. ChemicalConstituents such Ca, Mg, Na, K, CO_3, HCO_3, Cl_2 and SO_4 are present in the aqueous system of

Table 1. Geological Succession of the study area

Age	Group	Sub-Group	Rock Type
Upper Jurassic	Upper Gondwana	Vemavaram Budawada	Shales, Sandstones
	----------Unconformity----------		
Pre-Cambrian	Kurnool (Palnadu Series)	Nandyal Koilkuntla Panyam Owk	Shales Lime Stones Quartzites Shales
	Narjee Banaganapalli	--- ---	Lime Stones Shales Quartzites Shales, Sand Stones
	----------Unconformity----------		
Pre-Cambrian	Nallamalai Upper Cuddapah (Super Group)	Srisailam Cumbum	Quartzites Shales, Phyllites Slates with intercalated Quartzites Lime Stones.
	----------Unconformity----------		
Archean	Basement Complex	---	Granite Gneisses Charnockites Basic Dykes Amphibolites Khondalites, Schist

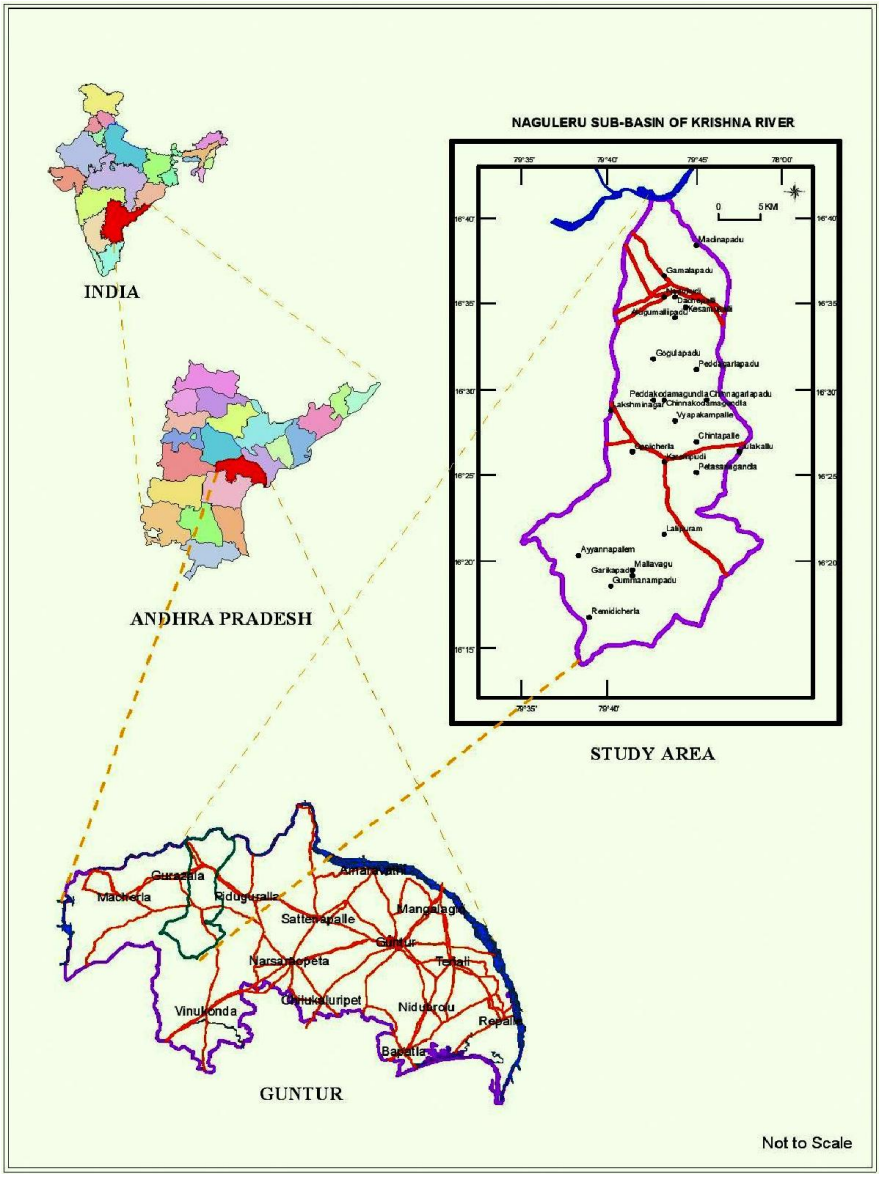

Fig. 1. Location Map of the Study Area

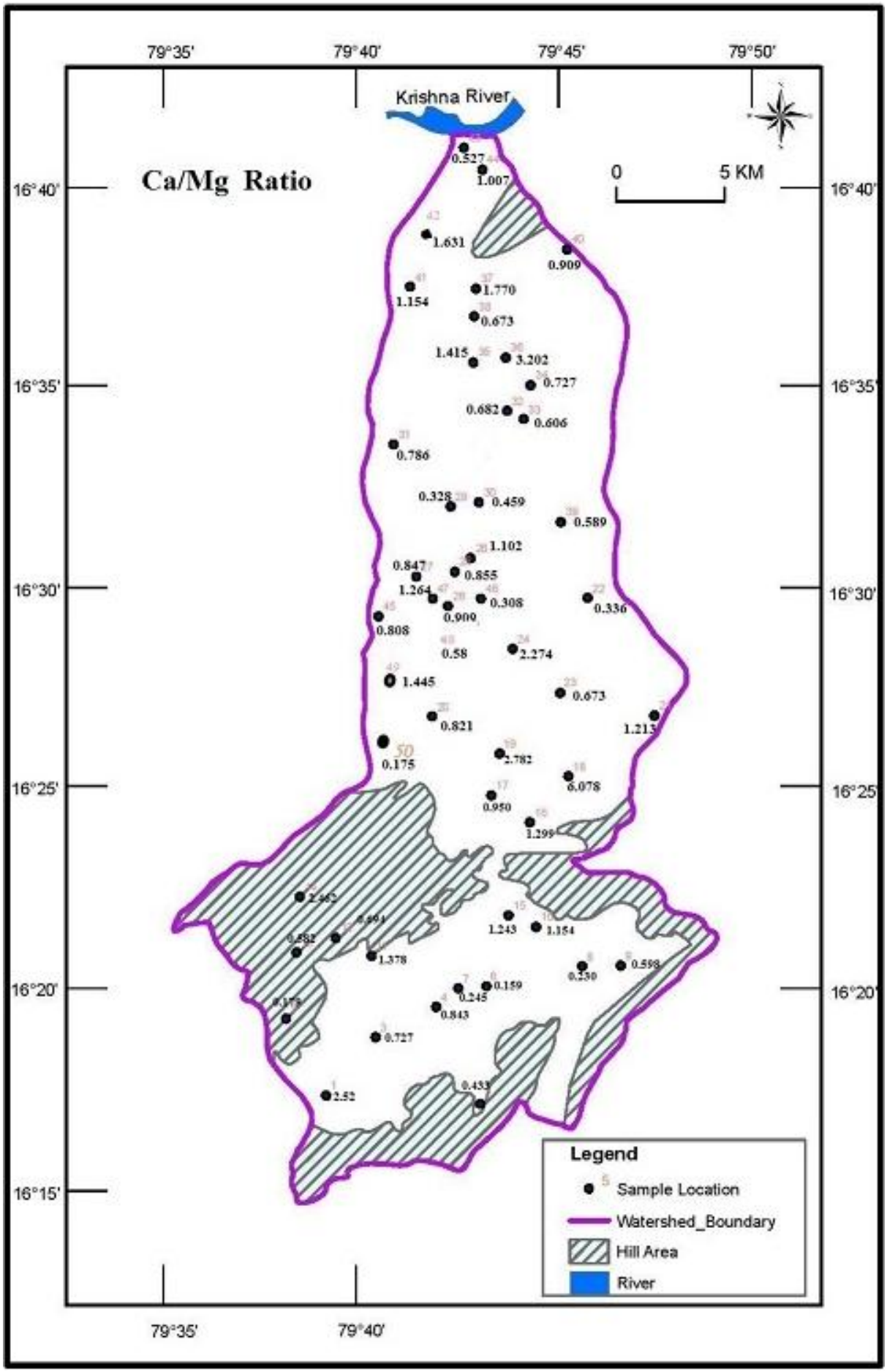

Fig. 2. Saltwater contamination zones on the basis of Ca/Mg ratio

groundwater. Ion exchange effects and modifies the composition of water. Saline water zones have been delineated in the study area using the hydrogeochemical parameters such as Ca/Mg, Cl_2/ CO_3+ HCO_3, TA/TH ratios and base exchange index and Mg/Ca verses Cl_2 are computed and presented in the Table 2.

Table 2. Chemical constituent ratios computed from the chemical data

S.No.	Ca/Mg	Cl_2/CO_3+HCO_3	TA/TH	Base Exchange Index	Mg/Ca	Cl_2
1	2.524	0.427	0.595	0.093	0.396	2.821
2	0.433	1.785	0.58	0.251	2.308	10.296
3	0.727	0.647	0.942	-1.135	1.375	3.949
4	0.843	0.474	0.971	-0.186	1.185	3.103
5	0.179	0.265	1.151	-1.77	5.584	1.833
6	0.159	0.317	0.954	-3.558	6.269	2.727
7	0.245	0.877	0.891	-0.122	4.068	7.475
8	0.230	0.735	0.651	-0.028	4.330	4.372
9	0.598	0.536	0.604	0.053	1.669	3.526
10	1.154	0.376	3.266	-2.176	0.865	3.667
11	1.378	1.129	1.346	-0.283	0.725	4.654
12	0.694	0.887	1.62	-0.556	1.439	7.334
13	0.582	0.832	1.684	-0.078	1.717	5.077
14	2.426	0.562	1.647	-0.861	0.412	2.962
15	1.243	0.926	0.965	-0.279	0.803	4.880
16	1.299	0.316	1.312	-1.257	0.769	1.410
17	0.950	2.317	0.55	0.029	1.052	14.105
18	6.078	0.637	1.42	-0.862	0.164	3.385
19	2.782	0.427	1.866	-1.444	0.359	2.397
20	0.821	1.317	0.758	-0.020	1.217	5.642
21	1.213	0.550	1.055	-0.578	0.824	2.821
22	0.336	3.249	0.480	0.209	2.969	15.515
23	0.673	0.740	1.08	-0.529	1.483	3.780
24	2.274	1.041	0.730	-0.017	0.439	3.949
25	0.855	1.002	1.041	-0.786	1.169	4.795
26	0.909	0.717	1.157	-0.589	1.099	3.075
27	0.847	2.215	0.421	-0.608-	1.179	11.00
28	1.102	1.305	1.043	-0.315	0.906	6.460
29	0.328	1.870	0.490	0.067	3.045	9.873
30	0.459	1.717	0.604	0.042	2.176	8.745
31	0.786	3.559	0.437	-0.007	1.272	14.66
32	0.682	3.585	0.387	-0.086	1.464	16.531
33	0.606	1.493	0.60	0.207	1.648	7.391
34	0.727	0.854	0.842	-0.191	1.374	4.231
35	1.415	2.472	0.875	-0.630	0.706	10.183
36	3.202	1.131	0.96	-0.191	1.374	4.231
37	1.770	0.987	1.188	-0.261	0.564	2.115
38	0.673	1.599	0.625	-0.261	0.564	2.115
39	0.589	2.575	0.605	-0.040	1.696	10.578
40	0.909	0.927	1.052	-0.374	1.099	3.667
41	1.154	1.535	0.733	-0.095	0.865	3.808
42	1.631	1.396	0.846	0.005	0.618	2.990
43	0.527	1.911	0.828	-0.245	1.896	10.38
44	1.007	0.781	1.055	-0.279	1.045	2.962
45	0.808	2.752	0.518	0.092	1.236	8.180
46	0.308	2.240	0.489	0.211	3.238	10.719
47	1.264	1.214	1.666	-0.497	0.791	7.616
48	0.588	2.542	0.602	-0.039	1.688	9.002
49	0.602	1.445	0.61	0.206	1.634	7.233
50	0.175	0.264	1.149	-1.76	5.582	1.798

RESULTS AND DISCUSSION

Ca/Mg Ratio

Seawater contamination is indicated by Ca/Mg ratio (Mandel and Shiftan 1981). Magnesium is present in sea water in much greater concentration than calcium (Hem 1975). Majority of saline water show significantly lower Ca/Mg ratio than non-saline waters (Muthuraman *et al*., 1992). The maximum and minimum values of Ca/Mg ratio are 6.078 (Sl No.18) and 0.159 (Sl No.6) respectively. Ca/Mg ratio values less than 0.20 indicate saline zones (Fig.2.) between 0.20 and 1.00 suggest slightly saline water zones and exceeding 1.00 have been considered as fresh water zones. Ca/Mg values lower than 0.20 (Sl. No.8) have been recorded in the southern portions, whereas those between 0.10 and 2.52 have been distributed throughout the area. Values exceeding 1.00 have been found in northern, eastern, central portions of the study area. Since Ca/Mg ratio for sea water is 0.18, such low values are suggestive of saltwater contamination.

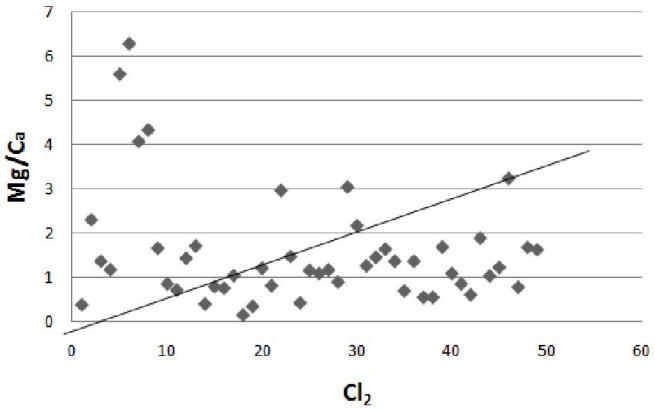

Fig. 3. Mg/Ca *Vs* Cl_2 in Groundwater

Cl_2/CO_3+HCO_3 Ratio

The degree of saltwater contamination can also be calculated on the basis of Cl_2/Co_3+HCO_3 ratio (Revelle 1941). Chloride is most abundant anion in sea water while bicarbonate is fresh groundwater. The maximum and minimum values of Cl_2/CO_3+HCO_3 ratio are 3.585 (Sl No.32) and 0.316 (Sl No.16) respectively On the basis of Cl_2/Co_3+HCO_3 ratio, Simpson (1946) classified (Table 3) the groundwaters as follows. Gambell and Fisher (1975) suggested that substantial contribution of chloride is made by erosion of crystalline rocks. Saline tract is characterized by the addition of sodium and chloride ions in the waters during the process of acquisition of the dissolved phase (Hem 1975). Carbonate has an important role in attacking primary silicates and in contributing dissolved solids to waters. The anion produced during the attack is bicarbonate. Moderately contaminated ground water is observed in northeast and south central part of study area (Fig.4), whereas injuriously contaminated groundwater is observed in the almost central portion of the study area as an isolated patch.

Table 3. Simpson Classification

Range of Cl_2/Co_3+HCO_3 ratio	Description
<0 - 05	Normally fresh groundwater
0.05-1.30	Slightly contaminated groundwater
1.30-2.80	Moderately contaminated groundwater
2.80-6.60	Injuriously contaminated groundwater
6.60-15.50	Highly contaminated groundwater
>200.00	Seawater

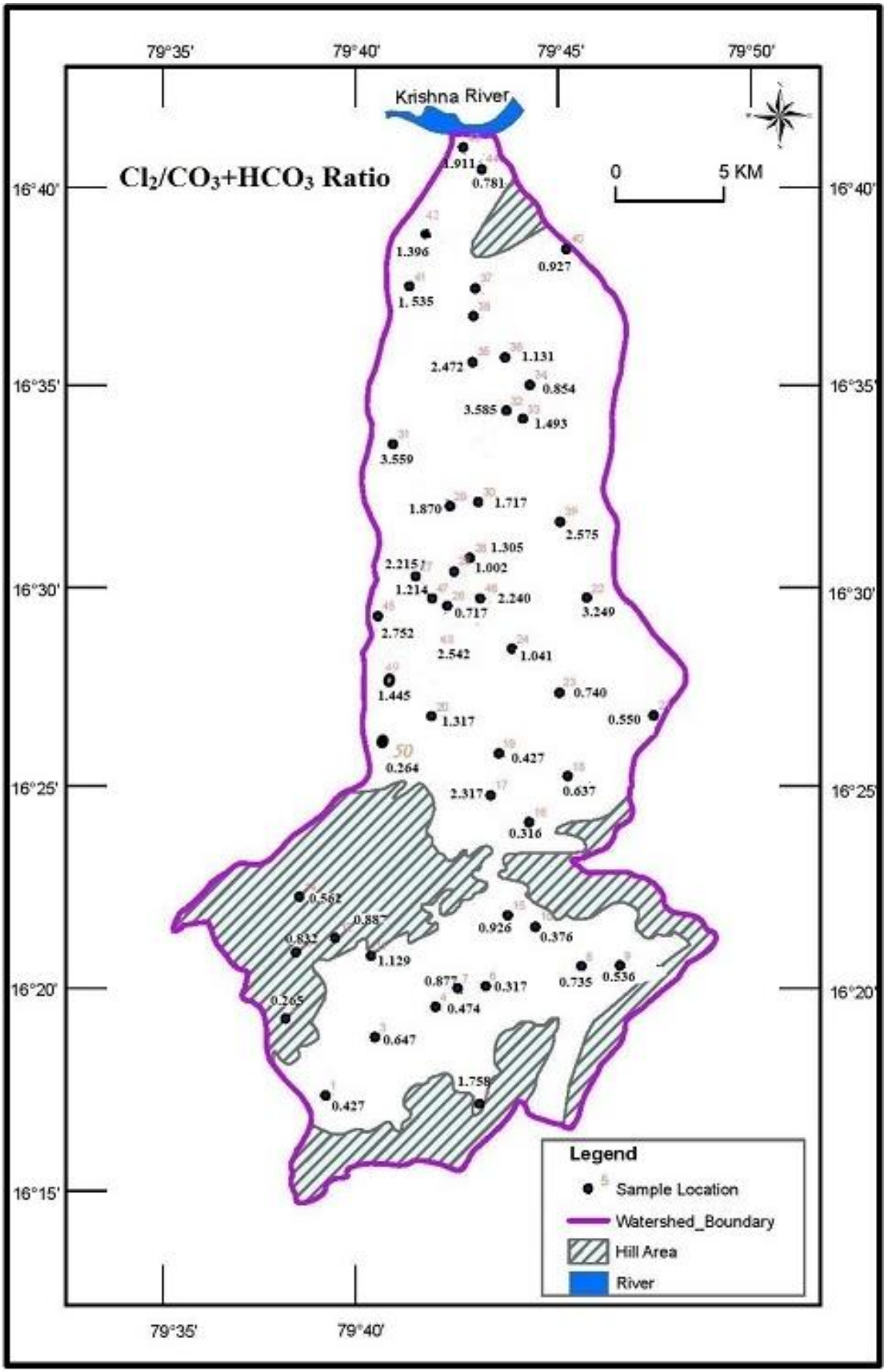

Fig. 4. Saltwater contamination zones on the basis of $Cl/(CO_3+HCO_3)$

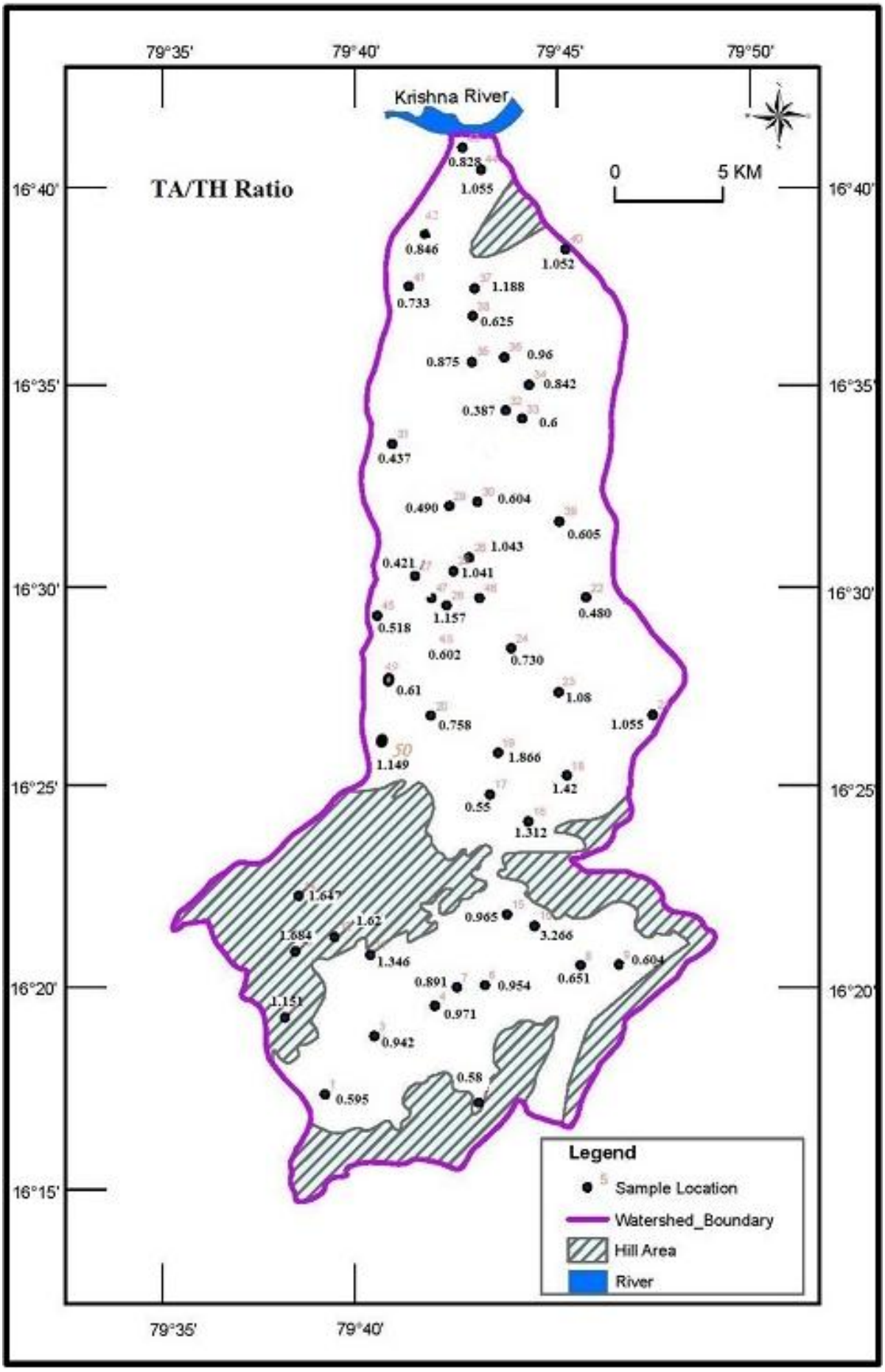

Fig. 5. Saltwater contamination zones on the basis of TA/TH ratio

TA/TH Ratio: Total alkalinity/Total hardness ratio is another parameter employed to ascertain the degree of salt water contamination (Hem 1975). Sodium bicarbonate is present if excess of total alkalinity and total hardness is observed. Most of the study area reveals an excess of total alkalinity over the total hardness indicating non-contaminated salt water zones (Fig.5). The maximum and minimum values of TA/TH ratio are 3.266 (Sl No.10) and 0.387 (Sl No.32) respectively On the basis of TA/TH ratio. Only in few zones at north, north-east, eastern, south-eastern, southern, south-western and western portions of the study area have the TA/TH values less than one. Some of the portions showing less value (<1) TA/TH also show less values of Ca/Mg (0.20) indicating salt water contamination in these zones.

Base Exchange Index: Base Exchange index is derived by Cl_2-Na+K/Cl_2 (Schoeller 1967). Negative values indicate no contamination but positive values indicate salt water contamination of groundwater. Majority of the samples (38) in the study area show negative base index values and only a few samples (12) show positive base index values (Table 1). It shows major portion of this water is meteoric in origin and cannot owe its source to sea water. Schoellor concept of water types is related to the evolution of groundwater with respect to chemistry.

Mg/Ca versus Cl_2: The distribution of saltwater contamination is often marked by Mg/Ca ratio plotted against Cl_2 (Nair *et al*., 1981) as shown in Fig.3. A straight line shows simple combination of saltwater and groundwater. The plotted points for the area under study are lower in the upper part and higher in the lower part, saltwater values suggesting that an increase in the quality of magnesium in groundwater or depletion of calcium precipitation seems to be an important factor influencing the trend of the data plots.

Conclusion: Saltwater zones have been delineated in Naguleru Sub-Basin based on certain geochemical parameters viz., Ca/Mg, Cl_2/CO_3+HCO_3 and TA/TH are indicating saltwater contamination. In some cases where all the parameters are not coinciding in delineating saltwater contamination zones, which necessitates further study.

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