



# Geological, Geomorphological and Ground Water Quality in the area of Amaravathi, Guntur District, Andhra Pradesh, India.

M. Venkataiah, G. Veeraswamy, P. Bharath kumar

**Abstract:** The area of Amaravathi, a new capital of the State of Andhra Pradesh, is located in the Guntur district, where the groundwater has been a potential resource to meet several needs due to frequent failures of monsoon, and its quality has been deteriorated under the different environmental conditions. The Amaravathi covers an area of about 217 km<sup>2</sup> and is distributed in 28 villages in three mandals viz., Mangalagiri, Thullur and Tadepalle. Agriculture is the main occupation of the people. The climate of the area is dry-humid, with average annual temperatures of 18° to 48°C. The average annual rainfall is about 1,357 mm. Field investigations were conducted in the month of December 2015. The data on rainfall, topographic conditions, soil cover, geomorphological features, geological, structural and hydrogeological conditions, drainage and land use practices was collected. Groundwater samples collected from the field were analyzed for major ion chemistry, viz. pH, total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO<sub>3</sub>), chloride (Cl), sulphate (SO<sub>4</sub>), nitrate (NO<sub>3</sub>) and fluoride (F). Keeping the increase of water consumption with respect to the rapid growth population in the near future of the capital area, it is essential to assess the contaminates caused by poor quality of groundwater with respect to drinking purpose and industrial developments. In order to provide this base-line information for the purpose of the decision-making by policy-makers and water-managers.

**Keywords :** Geomorphology, Geology, Ground water quality, Hydrogeology

## I. GEOMORPHOLOGY, GEOLOGY AND HYDROGEOLOGY:

### A. GEOMORPHOLOGY:

Geomorphologically, the district is assessed into 3 units supported relief, slope issue and soil. The three groups

are (i) hilly region (ii) pediplain region and (iii) fluvial land forms

#### Hilly Region:

The structural hills and denudational hills form the main relief areas. The structural hills are confined to the western part of the district comprising the rocks of Cuddapah and Kurnool systems. The denudational hills area unit related to residual hills, inselbergs etc. in the basement complex areas. These hills area unit mostly type the run-off areas with moderate to skinny forest cowl. Ground water occurrence is restricted to the joints and fracture planes and storage capacity is low due to lack of weathered zone and meager infiltration.

#### Pediplain Region:

The pediment shallow buried/ buried pediment constitutes the pediplain unit. The pediment area accelerates surface run-off with moderate to low infiltration along the joints and weathered zones. Buried gable areas usually possess thick zones of weathering and fracturing and sustain for long hours of pumping.

#### Fluvial land forms:

The valley fills, pediment zones, intermountain valleys fills and alluvial plains constitute the main fluvial land forms. The pediment zones form along the slopes of high relief areas and ground water development is poor. The valley fill material from the fluvial deposits and occupies topographic lows along Krishna.

## B. GEOLOGY:

The area is underlain by numerous earth science formations of various age teams starting from archaean to Recent. The Archaean basement complex comprising the granite-gneisses, Schists, Khondalites, Charnockites and basic dykes of dolerites form the predominant rock types in the central part. The fringe of the Archaeans within the central half is depicted by Cuddapah basin, namely Nallamalai group of Upper Cuddapahs. In a sequential order, the younger Kurnools occurring in the cuddapah and those in the western parts of the district are thrust over by the Cuddapahs and these in turn by the Archaean granite-gneisses. The higher Gondwana cluster of sandstones and shales outcrop area unit seen at places between Guntur. The youngest rock varieties of the district seem to be of Mio- Pliocene epoch age followed by the deposit deposits of Recent to Sub-Recent age.

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\* Correspondence Author

**Mallikanti Venkataiah**, Department Of Geology, Osmania University, Hyderabad, Telangana, INDIA. Email: venkatgeorocker.m@gmail.com  
**Veeraswamy Gollamudi**, Department Of Civil Engineering, Mrit College, Hyderabad, Telangana, INDIA. Email: gvsgeology@gmail.com  
**Punna Bharath Kumar**, Department Of Geology, Osmania University, Hyderabad, Telangana, INDIA. Email: bharath.india555@gmail.com

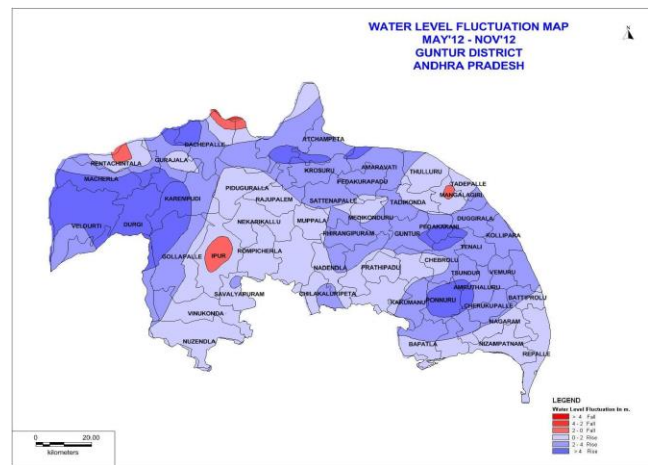
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**C. HYDROGEOLOGY:**

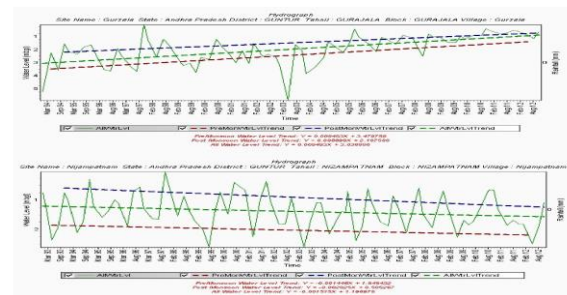
Precambrian iformations: Precambrian eon formations square measure the predominant water bearing formations with lack of primary body. Secondary body was developed through fracturing and consequent weathering over ages and become water bearing at hydrogeologically favourable locations. The depth of worn mantle ranges from regarding eight to 15m bgl and below this zone broken rocks square measure famous to occur right down to forty.0m bgl. The depth to water level ranges from but a meter to twelve m bgl. The worn zone has been broached extensively by the mamma wells and sustain four to 6 hours of pumping with yield ten to eighty or up to two hundred m<sup>3</sup>/day, and capable of irrigating regarding zero.8 to 3.0 hectares. The hydrogeological conditions within the district square measure bestowed in (Fig. 1). Central spring water Board has meted out spring water exploration at the locations from depth travel forty five to two hundred m bgl in arduous rock areas and twenty five to 430 m bgl in soft rock areas. The potential fractures were encountered between forty and a hundred and twenty m bgl. Existence of deep fractures up to 173 m bgl was additionally encountered. The additive yield of fracture zones varies from zero.12 to fifteen lps. Yield of bore wells generally varies between one to five lps. A perennial spring, with a discharge of regarding two hundred lpm is found on a fault, close to Bugga Melleswara temple of Papayapalem within the Bellamkonda Mandal, and it'saccording that this spring is being employed to irrigate ten hectares.

Alluvium formation: The thickness of alluvial sediment varies from a couple of meters to over 100m. The deltaic alluvial sediment found in palaeo/buried channels upto 30m depth with thick graveliferous sand. spring water is being developed within the flood plain areas on watercourse course largely through filter-points and shallow tube wells with yields starting from three to over fifteen lps as discovered around Rayapudi and Borepalem areas of Amaravati and Thullur mandals. The depth to water level within the alluvial sediment ranges from ground level to 5-12m bgl with poor to moderate discharges. In deltaic alluvial sediment spring water is salt in nature. Quality of water in palaeo-channels, buried channels is potable and salt to saline at shallow depths within the areas bordering the coast .it'ssensible in beach ridges.

Aquifer parameters: The Central Ground Water Board has drilled 64 Exploratory Wells, which include 41 bore wells in hard rock area and 23 tube wells in soft rock area were conducted on these wells. The results aquifer performance tests indicate that transmissivity of the fractured aquifer varied from 21 to 253 sq.m/day and storativity values varied from 0.75 x10<sup>-5</sup> to 3.9.5x10<sup>-3</sup>. The transmissivity of those soft rock aquifers varied from one to 616 sq.m/day and storativity values varied from 1.2 x10<sup>-4</sup> to 1.2 x10<sup>-2</sup>.



(A)



(B)

**FIG. 1 (A) WATER LEVEL FLUCTUATION MAP AND (B) HYDROGRAPHS SHOWING RISING AND FALLING TRENDS (1993-2012)**

**II. GROUND WATER QUALITY:**

In the gift study space, the cation-anion balance is computed for accuracy of complete qualitative analysis of groundwater sample. The computed value of the cation-anion balance is observed to be within the limit of ±5%, thus confirming the accepted range of hydrogeochemical values.

PH:The pH indicates the strength of the water to react with the acidic or alcalescent material gift within the water. It controls by carbon dioxide, carbonate and bicarbonate equilibrium. The combination of CO<sub>2</sub> with water forms carbonic acid, which affects the pH of the water. The pH in the ground water is varied from 7.40 (sample 18) to 8.56 (sample 1), with an average of 7.93.

**A. ELECTRICAL CONDUCTIVITY:**

The value of EC is between 1244 (sample 1) and 4883 (sample 20) μS/cm. The EC is a measure of a material's ability to conduct an electric current so that the higher EC indicates the enrichment of salts in the groundwater. Thus, the EC can be classified as Type I,

if the enrichments of salts are low ( $EC < 1,500 \mu S/cm$ ); Type -II, if the enrichment of slats are medium ( $EC: 1500$  and  $3000 \mu S/cm$ ) and Type III, if the enrichments of salts are high ( $EC > 3000 \mu S/cm$ ).

According to the classification of EC, 63% of the total ground water samples (1, 11, 12, 14 and 22) come under Type-I (low enrichment of salts) , 54% (4, 5, 8 to 10, 13, 15, 16, 18, 19, 21, 23 to 25 and 27) under type -II (medium enrichment of salts) and 28% (2, 3, 6, 7, 17, 20, 26 and 28) under type -III (high enrichment of salts). The groundwater samples represented by the low enrichment of salts are observed from the topographic- highs, the groundwater associated with the high enrichments of salts from the topographic-lows and the groundwater characterized by the medium enrichments of salts from the area located between the above topography due to differences in the enrichments of salts from the sources, following the water flow-path conditions.

**B. TOTAL DISSOLVED SOLIDS & RESULTS**

The TDS which indicates a total dissolved ions in the water is between 809 (sample 14) and 3074 (sample 2) mg/L. Low TDS (890 to 1170 mg/L) is observed from the areas of topographic-highs (samples 4, 9 to 12, 15, 16, 21 and 22) and river course (samples 2, 3, 8, 17, 19, 23 to 28) indicating the influence of rock water interaction in relation to recharge water compared to the high TDS ( 1,270 to 3520 mg/L) observed from the rest of the area. Among the high TDS, the TDS varying 1290 to 1880 mg/L may be influence of anthropogenic sources, Such as domestic sewage, septic tanks and agricultural activities. Degree of groundwater quality can be classified as fresh, if the TDS is  $< 1000$  mg/L; brackish if the TDS is between 1000 to 10000 mg/L ; saline if the TDS is varied from 10000 to 1,00000 mg/L; and brine if the TDS is more than 1 lakh mg/L. Accordingly, the quality of ground water in the present study area is classified as fresh in 75% (samples 1,3, 4, 5, 7 to16, 18, 19, 21, 22, 23 and 24) and 25% brackish (samples 2, 6, 17, 20, 25, 26, 27 and 28) of the total water samples respectively.

The TDS is classified into four types – (a) less than 1000 mg/L, (b) 1000 to 2000 mg/L, (c) 000 to 3000 mg/L and (d) more than 3000 mg/L. Fig. 2 shows the spatial distribution of TDS. The low TDS (less than 1000 mg/L) is observed from the northeastern part. Most of the study area shows the medium TDS (1000 to 2000 mg/L). High (2000 to 3000 mg/L) and very high TDS (more than 3000 mg/L) TDS are observed as isolated patches in the area.

**C. TOTAL ALKALINITY AND TOTAL HARDNESS:**

The value of TA is observed from 356 to 484 mg/L. The TA is a measure of  $HCO_3^-$  and  $CO_3^{2-}$  ions. In the present study area, the TA is caused by  $HCO_3^-$  ion only, as the pH is 7.40 between and 8.56 calcium and  $Mg^{2+}$  are the principle ions responsible for total hardness. The observed value of TH in the groundwater is between 326 and 673 mg/L.

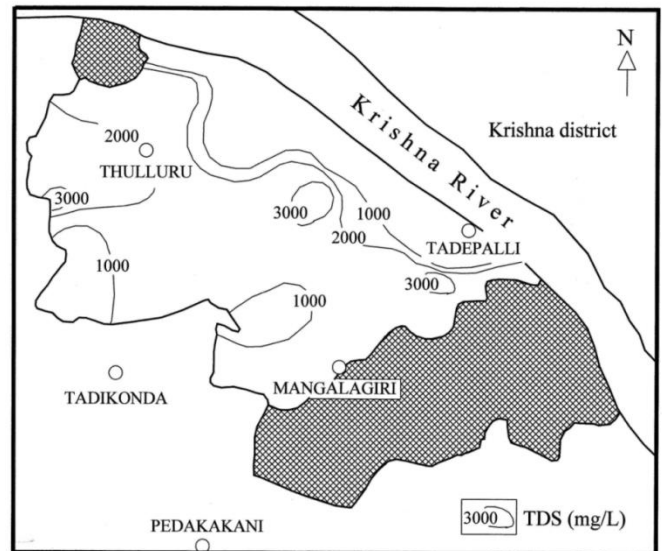


Fig. 2. Spatial distribution of TDS (mg/L)

The TH can be classified as soft, if the TH is less than 75 mg/l; moderately hard, if the TH is varied from 75 to 150 mg/L; hard, if the TH is between 150 and 300 mg/L; and very hard, if the TH is more than 300 mg/L. According to the classification of TH, maximum groundwater samples fall in the very hard category. Lower value of TH ( $< 250$  mg/L) is observed from the area of topographic-highs and higher value of TH ( $> 500$  mg/L) is from the area associated with the topographic-lows.

Based on the TA and TH, the groundwater quality can be classified as carbonate hardness (CH), non-carbonate hardness (NCH) AND excess alkalinity (EA), following the Indian Standard Institute (ISI 1963) and Chow (1964). The criterion followed is (a) the values, which are lowest (among TA and TH), are placed under CH, (b) when the value of TA is greater than TH, the difference (TA-TH) value is consider as EA and (c) when TH is greater than TA, the difference value (TH-TA) is consider as NCH. The CH is varied from 326 (sample 4) to 673 (sample 17) in all the groundwater samples. The NCH (17 to 311 mg/L) is observed from the groundwater samples (22 and 17). It is also noted that the EA is varied from 25 (sample 24) to 119 (sample 14) mg/L, which is due to the salts of  $NaHCO_3$ , where the TA is more than the groundwater. But, the EA is observed from the 4 groundwater sample, where the TH is more than TA.

**D. CALCIUM AND MAGNESIUM:**

The concentration of  $Ca^{2+}$  is between 58 (sample 7) to 128 (sample 8) mg/L while that the concentration of  $Mg^{2+}$  is varied from 29 (sample 14) to 86 (sample 17) mg/L. The higher contribution of  $Mg^{2+}$  than that of the contribution of  $Ca^{2+}$  is caused by the influence of ferromagnesium minerals, ion exchange between  $Na^+$  and  $Ca^+$  and precipitation of  $CaCO_3$ .

#### E. SODIUM AND POTASSIUM:

The concentration of  $\text{Na}^+$  is varied from 78 (sample 1) to 903 (sample 26) in a general case, which is the dominant ion among the cations, contributing approximately 73% to the total cations. This is because of the silicate weathering and/or dissolution of soil salts stored by the influences of evaporation and anthropogenic activities (Stallard and Edmond 1983; Meyback 1997; Subba Rao 2002), in addition to the agricultural activities and poor drainage conditions. Moreover, the solubility of  $\text{Na}^+$ - salts is generally high. The higher contribution of  $\text{Ca}^{2+}$  to the total cations is expected due to the influence of ion exchange. Comparatively, very higher concentration of  $\text{Na}^+$  from 588 to 648 mg/lit is observed from the groundwater samples 20 and 21, which contributes approximately 73% to the total cations, resulting from the impact of geogenic and anthropogenic activities. Relatively, low concentration of  $\text{Na}^+$  (<200 mg/L) is observed from the area associated with the topographic-highs and high concentration of  $\text{Na}^+$  (> 500 mg/L) from the area of topographic-lows, which is almost similar to the distribution of TDS. In contrast to the concentrations of  $\text{Ca}^+$ ,  $\text{Mg}^+$  and  $\text{Na}^+$  ions among the cations, the lower concentration of  $\text{K}^+$  is observed between 1 and 168 mg/L from the groundwater, because the potash feldspars are more resistant to chemical weathering and is fixed on clay products. The contribution of  $\text{K}^+$  to the total cations is approximately 1 to 5%.

**F. BICARBONATE:** The value of  $\text{HCO}_3^-$  is observed from 434 (sample 9) to 590 (sample 20) mg/L which is the dominant ion, except in the groundwater, occurring near the coast. The lower concentration of  $\text{HCO}_3^-$  (370 and 380 mg/L) is observed from the groundwater samples 1 and 18, which contributes approximately 16 to 17% to the total anions, while the higher concentration of  $\text{HCO}_3^-$  (450 to 890 mg/L) is observed from the remaining groundwater samples (19 to 28) approximately 93%, which contributes approximately 53 to 55% to the total anions. Relatively, low concentration of  $\text{HCO}_3^-$  (<400 mg/L) is observed from the low-lying area, where the clay occurs.

#### G. CHLORIDE:

The concentration of  $\text{Cl}^-$  is between 108 (sample 14) and 1285 (sample 6)mg/L. This is the second largest ion, after  $\text{HCO}_3^-$  ion. Relatively, the higher concentration of  $\text{Cl}^-$  (108 and 1106) mg/L is observed from the groundwater samples 14 and 20. In fact, the  $\text{Cl}^-$  is derived mainly from the non-lithological source and its solubility is generally high. The low (<200mg/L) and high (>500 mg/L) concentrations of  $\text{Cl}^-$  are observed from the areas of topographic-highs and lows respectively, as explained in the case of the distribution of TDS.

#### H. SULPHATE:

The content of  $\text{SO}_4^{2-}$  is observed from 28 (sample 1) to 278 (sample 17)mg/L. the application of gypsum

( $\text{CaSO}_4\text{H}_2\text{O}$ ), as amendment to alter the physical and/or chemical properties of the soils, is expected to be caused for the concentration of  $\text{SO}_4^{2-}$  in the study area, in a general case, since no lithological units occur.

#### I. NITRATE:

The value of  $\text{NO}_3^-$  in the groundwater is observed less than 75 (sample 2) mg/L. The  $\text{NO}_3^-$  is a non-lithological source. In natural conditions, the concentration of  $\text{NO}_3^-$  does not exceed 10 mg/L in the water (crushing et al. 1973)so that the higher concentration of  $\text{NO}_3^-$ , beyond the (10 mg/L), is an indication of anthropogenic pollution. It is mainly due to the influences of poor sanitary conditions and indiscriminate use of higher fertilizers for higher crop-yields in the study area.

#### J. FLUORIDE:

In the groundwater, the concentration of  $\text{F}^-$  is varied from 0.06 to 1.35 mg/L. Relatively, higher concentration of  $\text{F}^-$  is observed from the area of topographic-lows, except where the marine clay occurs. Low concentration of  $\text{F}^-$  is observed, especially from the northwestern side. The sources of geogenic (apatite, biotite and clays) and anthropogenic (chemical fertilizers), with a combination of higher rate of evaporation and longer interaction of water with the aquifer materials under alkaline environment, are the key factors for the concentration of  $\text{F}^-$  in the study area (Subba Rao 2009a).

Table- I : Chemical composition of groundwater quality

S.No	Gram Panchayat	pH	EC	TDS	TA	TH	CH	NCH	EA	Ca	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>3</sub>	NO <sub>3</sub>	F
1	Nekkallu	8.56	1244	828	450	408	408	-	42	78	52	78	35	550	119	28	-	0.1
2	Ananthavaram	8.06	3777	3074	390	587	390	197	-	99	82	798	33	476	1185	256	75	0.6
3	Vaddaman	7.69	2465	1594	450	522	450	72	-	99	66	307	24	550	439	124	42	0.6
4	Dondapadu	8.34	1489	971	436	326	326	-	110	60	43	182	22	532	142	100	5	0.4
5	Borupalem	8.24	1977	1244	428	540	428	112	-	80	83	186	1	522	307	118	4	0.2
6	Abbarju palem	7.89	4799	3070	462	428	428	-	34	59	68	888	1	564	1285	118	4	0.6
7	Tulluru	7.78	1934	1264	374	437	374	63	-	58	70	231	31	456	313	106	49	0.3
8	Rayapudi	8.38	2189	1413	432	578	432	146	-	128	63	230	1	527	408	80	4	0.5
9	Linga yapalem	7.98	1567	1018	356	396	356	40	-	80	48	174	6	434	235	62	39	0.5
10	Udandarayunipalem	8.24	1716	1113	428	508	428	80	-	100	63	156	5	522	240	65	30	0.4
11	Modugulankapalem	8.19	1512	1000	414	476	414	72	-	100	55	136	3	505	184	54	33	0.2
12	Velagapudi	8.1	1614	1068	400	438	400	38	-	80	58	182	1	488	245	58	1	0.3
13	Malkapuram	8.1	1712	1255	400	476	400	76	-	99	60	229	1	488	315	82	32	0.4
14	Tallayapalem	8.14	1262	809	418	299	299	-	119	72	29	141	5	510	108	50	10	0.4
15	Venkayapalem	7.9	1571	1026	368	392	368	24	-	80	47	156	47	449	241	60	19	0.5
16	Krishnaya palem	8.15	1635	1086	414	527	414	113	-	100	67	149	1	505	226	65	22	0.5
17	Mandadam	7.79	4355	3097	362	673	362	311	-	127	86	788	1	441	1220	278	7	0.3
18	Penumaka	7.4	1924	1269	430	544	430	114	-	100	71	186	33	524	312	79	12	0.5
19	Yerrabalem	8.13	2148	1395	410	573	410	163	-	100	79	227	3	500	329	171	27	0.8
20	Nulakapeta	7.79	4883	3034	484	609	484	125	-	121	74	834	3	590	1177	277	12	1.2
21	Dolas nagar	7.79	1713	1133	384	637	384	253	-	120	82	106	15	468	238	116	20	1
22	Undavalli	7.85	1708	1131	446	463	446	17	-	100	52	161	57	544	248	55	1	0.3
23	Navuluru	8.03	2449	1621	414	357	357	-	57	80	71	352	7	505	502	80	24	0.3
24	Bethapudi	7.62	2162	1411	376	351	351	-	25	80	38	296	69	459	441	79	1	0.5
25	Nidamaru	7.56	3440	2239	372	442	372	70	-	80	37	573	100	454	865	108	20	0.8
26	Kuragallu	7.42	4071	2654	362	421	362	59	-	72	59	903	126	442	1034	186	27	0.4
27	Nirukonda	7.51	4059	2663	412	442	412	30	-	80	59	650	165	503	993	184	32	1.4
28	Vaikuntapuram	7.42	4368	2830	482	509	482	27	-	100	63	664	168	588	1010	250	21	0.6

### III. FACTORS CONTROLLING GROUNDWATER CHEMISTRY

To understand the groundwater interaction, with precipitation (rainfall), rock and evaporation, as factors controlling the water chemistry (Gibbs, 1970), the ratios  $Na^+ + K^+ : Na^+ + K^+ + Ca^{2+}$  and  $Cl^- : Cl^- + HCO_3^-$  computed from the ionic concentration of groundwater of the area are plotted against TDS (Fig. 2). The ratios of cations ( $Na^+ + K^+ : Na^+ + K^+ + Ca^{2+}$ ; 0.31) as well as anions ( $Cl^- : Cl^- + HCO_3^-$ ; 0.62) are spread from the rock domain towards the zone of evaporation, indicating the initial existence of rock-water interaction, which is a major source of dissolved ions in the groundwater. This is due to the

influence of weathering caused by the alternative wet and dry conditions. The anthropogenic and marine activities are the additional casual factors for the dense clustering of points in the evaporation domain. For, example the  $Cl^-$  derives mainly from the non-lithological sources, where the content of  $Cl^-$  exceeds mg/L. Anthropogenic sources include intensive and long-term irrigation, irrigation-return-flows and agricultural fertilizers (Todd, 1980; Hem 1991; Subba Rao et al., 2002, 2007; Umar and Ahmed 2007). It is worth mentioning that no other sources are evident in the current study. A few groundwater samples in, which have  $Na^+$ :

Cl<sup>-</sup> ratio less than unity, are caused by the predominance of marine activity on the inland aquifer system. These groundwater sampling points show a clear cut deviation from other groundwater sampling points observed in the aquifer system. The anthropogenic activities lead to an increase in Na<sup>+</sup> and Cl<sup>-</sup> ions, and thus to higher TDS ( Zhang et al., 1995; Subba Rao et al., 2005; Subba Rao 2002, 2007). Therefore, the chemical data of the groundwater sampling points move towards the dominance of

evaporation zone from the zone of rock domain. The factors controlling the groundwater chemistry in the area shows that the quality of groundwater is originally regulated by geogenic process (silicate weathering, mineral dissolution, leaching, ion exchange and evaporation) and is latter influence by both anthropogenic (intensive and long-term irrigation, irrigation-return-flows and agricultural fertilizers) activities.

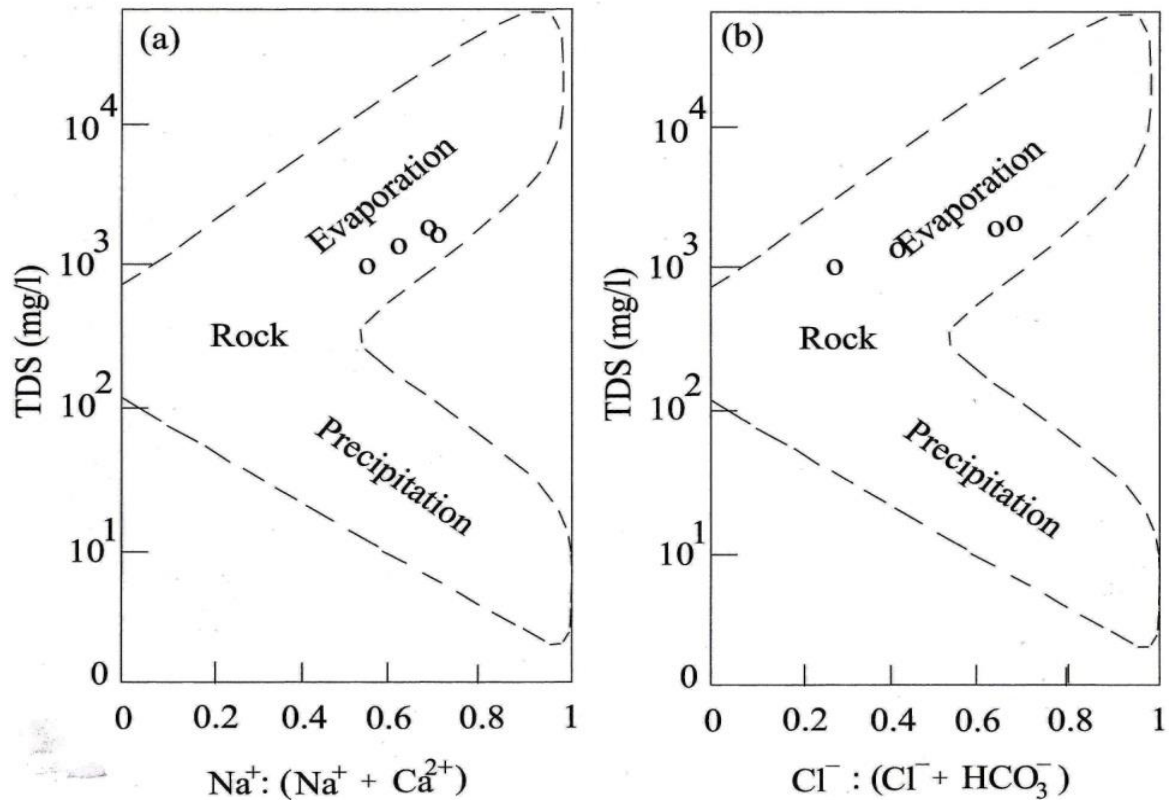


Fig. 3. Factors controlling the groundwater chemistry

Table-II: Percentage of chemical composition of groundwater with respect to TDS

TDS	Ca	Na	Mg	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	NO <sub>3</sub>	F
mg/L									
<1000	3.87	5.84	3.68	0.42	8.6	3.9	1.64	0.2	0.11
1000-2000	4.63	9.05	5.24	0.48	8.14	8.88	2.47	0.26	0.14
2000-3000	4.14	30.34	4.48	3.57	8.14	27.51	5.16	0.41	0.12
> 3000	5.08	35.97	6.36	0.25	8.49	34.31	6.52	0.44	0.08

**Table-III: Hydrogeochemical facies**

TDS (mg/L)	Hydrogeochemical facies	Sample	
		Numbers	Percentage
<1000	Na>Ca>Mg: HCO <sub>3</sub> >Cl>SO <sub>4</sub>	1, 4, 11 and 14	14
1000-2000	Na>Mg>Ca>K:Cl>HCO <sub>3</sub> >SO <sub>4</sub>	3, 5, 7 to 10, 12, 13, 15, 16, 18, 19 and 21 to 24	58
2000-3000	Na>Ca<Mg:Cl>HCO <sub>3</sub> >SO <sub>4</sub>	25 to 28	14
>3000	Na>Mg>Ca:Cl>HCO <sub>3</sub> >SO <sub>4</sub>	2, 6, 17 and 20	14

**Table-IV: Geochemical indices**

TDS (mg/L)	Chloro-alkaline indices		Gibb's indices	
	CA1: Cl-Na+K/Cl	CA2: Cl-Na+K/SO <sub>4</sub> +HCO <sub>3</sub> +NO <sub>3</sub>	Na+K/Na+K+Ca	Cl/Cl+HC O <sub>3</sub>
<1000	-0.39	-0.15	0.62	0.31
1000-2000	0.04	0.03	0.67	0.52
2000-3000	0.03	0.05	0.89	0.77
>3000	-0.04	-0.09	0.88	0.80

**IV. SUITABILITY OF GROUNDWATER QUALITY**

**A. DRINKING PURPOSE:**

In the field, it is observed that the groundwater is free from color, odor and turbidity, in general. The taste is good in 68% of the total groundwater samples (samples 1, 3, 4, 5, 7 to 16, 18, 19 and 21 to 24), while brackish in the remaining 32% of the groundwater samples (2, 6, 17, 20 and 25 to 28).

The pH decides the acidic or basic condition of water quality. If the pH is not within the prescribed limit of 7.4 to 8.56, it damages mucous membrane present eyes, nose, mouth, abdomen, anus etc. The pH (7.4 to 8.56) in all the groundwater samples (100%) observed from the study area is within the safe limit.

The observed TDS is between 809 and 3097 mg/L. Based on the TDS content allowed for drinking water, all the groundwater of the study area exceeds the desirable limit of 500 mg/L. The exceeding rate of TDS is 1.78 to 5.08 times higher in all the groundwater samples (100%) than that of its desirable limit. Generally, the upper TDS decreases palatableness, and causes gastrointestinal irritation in the consumers. It has also laxative effect, especially upon transits. But, the prolonged intake of water with the higher TDS can cause kidney stones, which are widely reported from different parts of country (Garg et al. 2009).

Hardness is a vital criterion for crucial the usability of water for drinking also as for alternative domestic provides, because it causes unpleasant style and reduces ability of soap to produce lather. In the present study area, the TH (299 to 587 mg/L) is 1.02 to 1.68 times higher than that of the 300mg/L allowed for drinking water in approximately 99% of the groundwater samples (1 to 13 and 15 to 28).

The Ca<sup>2+</sup> is an important element to develop proper bone growth. The concentration of Ca<sup>2+</sup> observed from the study area is varied from 58 (sample 7) to 128 (sample 8) mg/L. The concentration of Mg<sup>2+</sup>, ranging from 29 (sample 14) to 86 (sample 17) mg/L, is higher than that of the prescribed limit of 30 mg/L for potable water in approximately 98% of the groundwater samples (27 samples). Although, Mg<sup>2+</sup> is an essential ion for functioning of cells in enzyme activation, but at higher concentration, it is considered as laxative agent (Garg et al. 2009). The observed concentration of Na<sup>+</sup> between 78 (sample 1) to 903 (sample 26) mg/L from the groundwater is higher than that of the recommended limit of 30mg/L for safe water of the total groundwater samples. It makes the water unsuitable for drinking, because it causes severe health problems like hypertension (Holden 1971).

Groundwater in most of the study area comes under the non-safe zone for drinking, with reference to the concentration of Na<sup>+</sup>, which is more than 30 mg/L. Therefore, sodium restricted diet is suggested to the patients, who suffer from the heart diseases and also from the kidney problems. Generally, the concentration of K<sup>+</sup> is less than 10 mg/L in the drinking water. It maintains fluids in balance stage in the body.

Bicarbonate is a major element in human body, which is necessary for digestion. When ingested, for example, with mineral water, it helps buffer lactic acid generated during exercise and also reduces acidity of dietary components. It has a prevention effect on dental cavities.

The chemical data show that the concentration of  $\text{HCO}_3^-$  between 441 (sample 17) to 590 (sample 20) mg/L is higher than that of the desirable limit of 300 mg/L in all the groundwater samples (1 to 28). The  $\text{HCO}_3^-$  has no known adverse health effects on human health, if it exceeds 300 mg/L in the drinking water, in general. However, it should not exceed 300 mg/L in the potable water, as it may lead to kidney stones in the presence of higher concentration of  $\text{Ca}^{2+}$ , especially in dry climatic regions.

Generally, the  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  are considered as the important inorganic ions, which deteriorate the quality of drinking water at larger extent. For example, the  $\text{Cl}^-$  plays an important role in balancing level of electrolytes in blood plasma, but higher concentration can develop hypertension, risk of stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma (McCarthy 2004), while diarrhea, catharsis, dehydration and gastro intentional irritation may be associated with the ingestion of water, containing  $\text{SO}_4^{2-}$  (Garge et al. 2009) the safe limits of  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  for drinking water are, therefore, 250 and 150 mg/L, respectively. The groundwater in the present study area shows  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  in the range of 108 (sample 14) and 1220 (sample 17) mg/L and 28 (sample 1) to 278 (sample 17) mg/L respectively. The concentration of  $\text{Cl}^-$  is observed to be higher than that of the allowable limit of 250 mg/L from approximately 57% of the total groundwater samples (16 samples). The concentration of  $\text{SO}_4^{2-}$  is above the recommended limit of 15 mg/L in 100% of the groundwater samples.

The observed concentration of  $\text{NO}_3^-$  from the groundwater is 0 (sample 1) and 75 (sample 2) mg/L, while the prescribed limit of  $\text{NO}_3^-$  in the drinking water is 45 mg/L. The concentration of  $\text{NO}_3^-$  is higher than those of its desirable limit in approximately 7% of the total groundwater samples (2 and 7). It causes blue baby syndrome called methaemoglobinemia, which is an often fatal disease in infants of less than 4 months old (Bouwer, 1978). The spontaneous abortions are reported among women, who consume  $\text{NO}_3^-$  contaminated water (Grant et al. 1996).

The concentration of F<sup>-</sup> from 0.06 (sample 1) to 1.35 (sample 27) mg/L in the drinking water is physiologically beneficial, i.e., safe limit, as it promotes dental health (Subba Rao 2003). But, if F<sup>-</sup> is below 0.60 mg/L in water, it causes dental decay, while it is more than 1.20 mg/L in water, it result in dental fluorosis. In the present study area, the groundwater has F<sup>-</sup> from 1.35 to 0.06 mg/L, which is higher than those of the standard limit of 1.20 mg/L in approximately 3% of the total groundwater sample (27).

However, in the northeastern part, the groundwater quality is suitable for drinking, as the concentration of total dissolved solids (TDS) is less than the maximum permissible limit (MPL) of 2,000 milligrams per liter (mg/L) prescribed by BIS, where the river (Krishna) alluvium occurs. In this area, rainwater can infiltrate easily into the sub-surface due to the occurrence of sand and the movement of groundwater from one place to another is high. As a result, the groundwater shows the TDS in the lower concentration. In the rest of the area, the quality of

groundwater comes under a non-suitable category with TDS more than the MPL of 2,000 mg/L, because of the limited movement of groundwater due to the occurrence of black cotton soils on the surface and limited occurrence of fractures in the subsurface, where the charnockite rocks occur. It is significant to note that the concentration of  $\text{NO}_3^-$ , exceeding 10 mg/L in the water, indicates an anthropogenic pollution. The observed concentration of nitrate is more than 10 mg/L in 17 groundwater samples out of the total 28 samples studied from the study area. Thus, the unlimited usage of chemical fertilizers for higher crop yields may be the main source of  $\text{NO}_3^-$  (more than 10 mg/L).

## B. INDUSTRIAL PURPOSE:

The quality needs for industrial water provides vary wide and virtually each industrial unit has its own standards. Water used for industry can be classified into three principal categories. They are (a) cooling water, (b) boiler water and (c) process water. The cooling water is selected for temperature control, the boiler water for production of steam and the process water for manufactured products.

Industries frequently suffer from incrustation and corrosion activities, which are the chemical reactions caused by the poor quality of water. The incrustation involves deposition of undesired material of  $\text{CaCO}_3$  on surface of the metals, while the corrosion is a chemical action on metals that results in the metal being eaten away.

In the present study, the following water quality criteria have been adopted (Anon, 1983) for deciding the incrusting and corrosive properties of the water:

- (a) Water, having more than 400 mg/L of  $\text{HCO}_3^-$  or 100 mg/l of  $\text{SO}_4^{2-}$ , may cause incrustation, and
  - (b) Water, with pH less than 7 or TDS more than 1000 mg/l or  $\text{Cl}^-$  more than 500 mg/l may cause corrosion.
- Incrustation: As shown in Table, the content of  $\text{HCO}_3^-$  in approximately 100% sample (1 to 28) of the total pre-monsoon water sampling points exceeds the limit of 400 mg/l, which causes incrustation.

As the concentration of  $\text{SO}_4^{2-}$  in the ground water is more than 100 mg/l in approximately 46.42 % sample (2, 3, 5, 6, 7, 17, 19 to 21 and 25 to 28) of the total pre-monsoon sampling points it develops incrustation on the metal surfaces and hence water is not, generally, recommended for industrial applications.

Corrosion: The groundwater is free from corrosion property, as the water is alkaline, with pH more than 7.

Highly mineralized water, with TDS more than 1,000 mg/L, in approximately 85.71% of the total water sampling points of pre-monsoon unsuitable for industrial applications, as they enhance corrosion character.

In the study area, approximately 21.42 % pre-monsoon ground water sampling points exceed the limit of 500mg/l of  $\text{Cl}^-$  so that such water develops corrosion character



## V. CONCLUSION

Keeping the increase of water consumption with respect to the rapid growth population in the near future of the capital area, the present study emphasis the need for fixing a number of piezometers for understanding the seasonally rising and falling of water levels, and accordingly for constructing a number of rainwater harvesting structures not only to augment the groundwater resources, but also to improve the existing water quality.

It is further important to note that at least certain area nearer to the river course should be left without covering the concrete jungles for proper utilization for groundwater recharge and avoid resource crunch. Moreover, unscientific sand mining should be prevented in the adjacent the river course covered by the alluvium in order to protect the precious groundwater resources.

Public awareness program on the consequences of inferior water quality on human health and industrial sectors is mandatory. This is a key factor for success of water quality management measures for sustainable development. Policy-makers, planners and administrators must take the responsibility for implementing appropriate location-specific measures to improve the water quality.

The factors controlling the groundwater chemistry in the area shows that the quality of groundwater is originally regulated by geogenic process (rock weathering) and is latter influenced by anthropogenic (intensive and long-term irrigation, irrigation-return-flows and agricultural fertilizers) activity.

In the northeastern part, the groundwater quality is suitable for drinking, as the concentration of total dissolved solids (TDS) is less than the maximum permissible limit (MPL) of 2,000 milligrams per liter (mg/L) prescribed by BIS, where the river (Krishna) alluvium occurs. In this area, rainwater can infiltrate easily into the sub-surface due to the occurrence of sand and the movement of groundwater from one place to another is high. As a result, the groundwater shows the TDS in the lower concentration.

In the rest of the area, the quality of groundwater comes under a non-suitable category with TDS more than the MPL of 2,000 mg/L, because of the limited movement of groundwater due to the occurrence of black cotton soils on the surface and limited occurrence of fractures in the subsurface, where the charnockite rocks occur. It is significant to note that the concentration of NO<sub>3</sub>, exceeding 10 mg/L in the water, indicates an anthropogenic pollution. The observed concentration of nitrate is more than 10 mg/L in 17 groundwater samples out of the total 28 samples studied from the study area. Thus, the unlimited usage of chemical fertilizers for higher crop yields may be the main source of NO<sub>3</sub> (more than 10 mg/L).

Groundwater quality in most of the study area is not suitable either for industrial purposes due to the higher concentrations of TDS, TH, HCO<sub>3</sub>, Cl and SO<sub>4</sub>.

## REFERENCES:

1. APHA, (1992) Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, DC, 326 p.

2. Back, W. (1966) Hydrochemical Facies and Groundwater Flow Pattern in Northern Part of Atlantic Coastal Plain. US Geological Survey Professional Paper 498A, 42 p.
3. Bouwer, H. (1978) Groundwater Hydrology. McGraw-Hill Book Company, New York, 480 p
4. Ballukraya, P.N. and Ravi, R. (1995) Hydrogeology of Madras City Aquifer. Journal of the Geological Society of India, v. 45, pp. 87-96.
5. CGWB, (2001) Hydrogeological Framework and Development Prospects in Visakhapatnam District, Andhra Pradesh. Technical Report of Central Ground Water Board, Ministry of Water Resources, Government of India, Southern Region, Hyderabad, India, 65 p.
6. Chourasia, L.P. and Tellam, J.H. (1992) Determination of the effect of surface water irrigation on the groundwater chemistry of a hard rock terrain in Central India. Hydrological Sciences Journal, v. 27, pp. 313-328.
7. Cushing, E.M., Kantrowitz, I.H. and Taylor, K.R. (1973) Water Resources of the Delmarva Peninsular. US Geological Survey Professional Paper 822, Washington DC, 58 p.
8. Cucchi, F., Franceschini, G. and Zini, L. (2008) Hydrogeochemical investigations and groundwater provinces of the Friuli Venezia Giulia Plain aquifers, northeastern Italy. Environmental Geology, v. 55, pp. 985-999.
9. Drever, J.I. (1997) The Geochemistry of Natural Waters. Prentice-Hill, Inc, New York, 269 p.
10. Guo, H. and Wang, Y. (2004) Hydrogeochemical processes in shallow quaternary aquifers from the northern part of the Datong basin, China. Applied Geochemistry, v. 19, pp. 19-27.
11. Gupta, S., Dandele, P.S., Verma, M.B. and Maithani, P.B. (2009) Geochemical assessment of groundwater around Macherla-Karempudi area, Guntur District, Andhra Pradesh. Journal of the Geological Society of India, v. 73, pp. 202-212.
12. Gibbs, R.J. (1970) Mechanism controlling world's water chemistry. Science, v. 170, pp. 1088-1090.
13. John Devadas, D., Subba Rao, N., Thirupathi Rao, B., Srinivasa Rao, K.V. and Subrahmanyam, A. (2007) Hydrogeochemistry of the Sarada river basin, Visakhapatnam district, Andhra Pradesh, India. Environmental Geology, v. 52, pp. 1331-1342.
14. Jacks, G. (1973) Chemistry of groundwater in a district in Southern India. Journal of Hydrology, v. 18, pp. 185-200.
15. Kraft, G.S., Stites, W. and Mechenich, D.J. (1999) Impacts of irrigated vegetable agriculture on a humid north-central US Sand Plain aquifer. Ground Water, v. 37, pp. 572-580.
16. McCarthy, M.F. (2004) Should we restrict chloride rather than sodium?. Medical Hypothesis, v. 63, pp. 138-148.
17. Meyback, M. (1987) Global chemical weathering of surficial rocks estimated from river dissolved loads. American Journal of Science, v. 287, pp. 401-428.
18. Murthy, K.S.R. (2000) Groundwater potential in a semi-arid region of Andhra Pradesh - A geographical information system approach. International Journal of Remote Sensing, v. 21, pp. 1867-1884.
19. Naik, P. K., Awasthi, A.K., Anand, A. V. S. S. and Behera, P. N. (2009) Hydrogeochemistry of the Koyna River basin, India. Environmental Earth Sciences (DOI 10.1007/s12665-009-0059-8).
20. Nativ, R. and Smith, A. (1987) Hydrogeology and geochemistry of the Ogallala aquifer southern high plains. Journal of Hydrology, v. 91, pp. 217-253.
21. Pandian, K. and Sankar, K. (2007) Hydrogeochemistry and groundwater quality in the Vaippar River Basin, Tamil Nadu. Journal of the Geological Society of India, v. 69, pp. 970-982.

## AUTHORS PROFILE



**M.VENKATAIAH,**  
Research Scholar,  
Department of Geology,  
Osmania University, Hyderabad, Telangana,  
India.



**Dr. G. VEERASWAMY,**  
Associate professor  
Department of Civil Engineering  
MRIT College, Hyderabad, Telangana,  
India.



**P. BHARATH KUMAR,**  
Research Scholar,  
Department of Geology,  
Osmania University, Hyderabad, Telangana,  
India.