

2. Geology of the Study Area

The area is occupied by the rocks of Khondalite, Charnockite and Migmatites Groups of Eastern Ghats Supergroup in the north, overlain by Tirupathi Formation of East Coast / Gondwana of Gondwana Supergroup, Deccan Trap, Rajahmundry Sandstone towards southern part and Krishna-Godavari Formation towards southwest. The Khondalite Group is represented by khondalite, which occupies the northern part of the area. Khondalite is observed around Mellisala, Gopalpuram and Tirumalayyapalem. It is chiefly of garnet-sillimanite + graphite gneiss and contains a few thin impersistent bands of quartzite at places. Intermediate charnockite and hypersthene granite/acid charnockite comprising the charnockite Group occur as minor bodies. The Migmatite Group is made up of garnetiferous quartzofeldspathic gneiss and manganiferous quartzo-feldspathic rocks which are derived from the former due influx of quartzofeldspathic injections and observed near Rajavaram, korukonda and Srirangapatam. Tirupathi Formation of upper Gondwana Group overlies the Eastern Ghats Supergroup in the central and is overlain by flood plain deposits of Krishna-Godavari Formation in the west. It is composed of ferruginous boulder conglomerate at the base followed by sandstone with interbedded clays. The sandstone is ferruginous and the ferruginous content increases progressively from bottom to top. Basalts of Deccan trap are recorded on the eastern bank of Godavari River

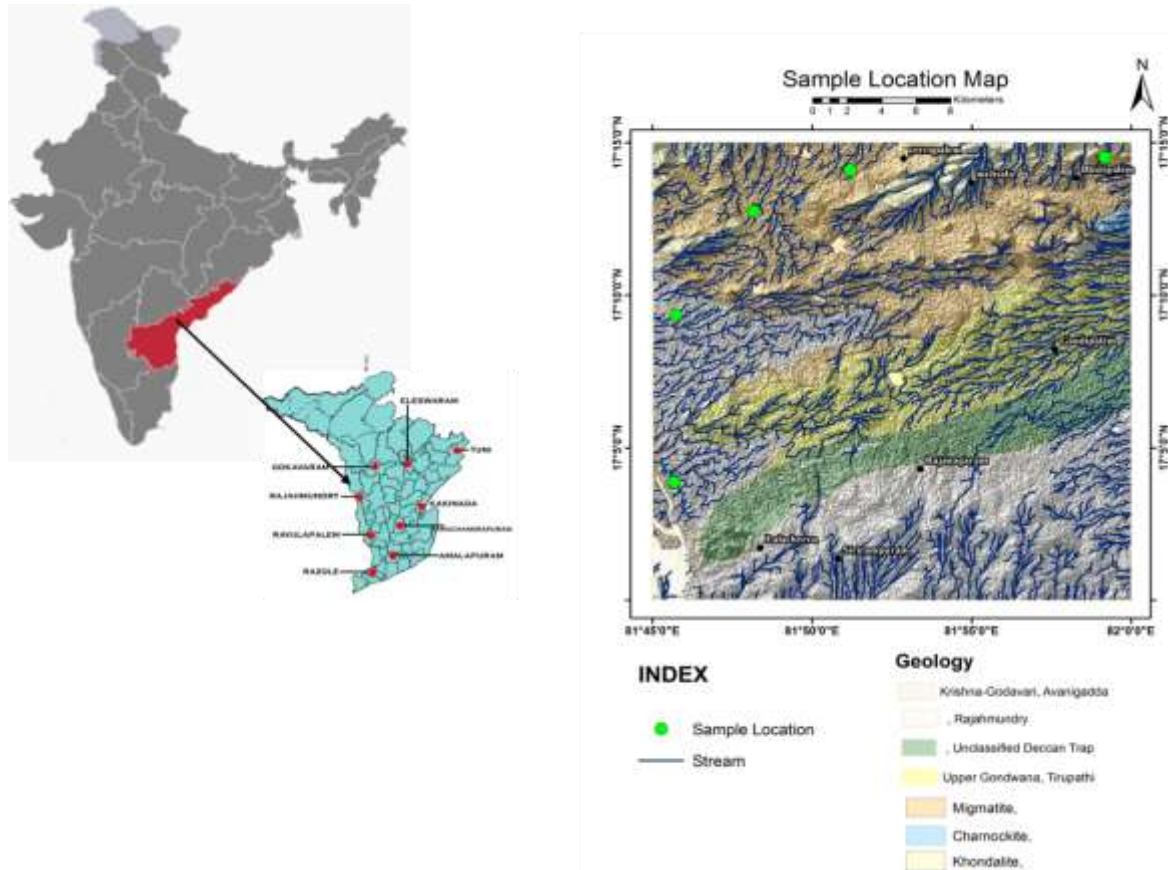


Figure 2: sample Location map showing water sample collection site in the geological map of the study Area

3. Methodology

5 samples were collected as a part geological survey of India's annual program. Sample collection, transportation, and analysis were carried out according to standard methods and procedures (APHA, 2006). To avoid the effect of floating debris, the samples were collected at depths greater than 20 cm below the water surface (Goldscheider and Drew, 2007). Prior to sample collection, the containers were washed with concentrated HNO₃ and completely rinsed with distilled water. The samples were collected and packed in these plastic water bottles for further analysis at GSI Geochemical Laboratory, SR, Hyderabad

4. Result & Discussion

4.1: pH

It is one of the most important chemical properties of natural water. The pH of a sample of water is a measure of the concentration of hydronium ions measured in moles per litre. In general, the pH of pure water is equal 7, water with pH lower than 7 is considered acidic, and with pH greater than 7 basic.

The pH of water determines the solubility and biological availability of chemical constituents such as nutrients (e.g., phosphorus, nitrogen, and carbon) and heavy metals (e.g., lead, cadmium, copper). The major controls of pH values are

- The organic process of photosynthesis, respiration and decay,
- Oxidation – reduction reaction involving iron, sulphur and carbon and
- The balance between dissolved CO₂ and CaCO₃ in natural waters.

The results of the water samples of the study area indicate that the water is slightly basic/ alkaline in nature, since the pH values range from 8.71 to 9 in the study area and the values are Above desirable limits

4.2: Electrical Conductivity (EC)

It is a measure of the ability of water to conduct an electric current. It shows significant positive correlation with pH value, alkalinity, total hardness and, salinity, hence higher electrical conductivity values in relatively higher pH area are expected. In the study area EC values ranges from 210µS/cm and 780µS/cm.

Table 1: Classification of water on the basis of Electrical conductivity

Quality of Water	Electrical Conductivity (µS/cm)	Water quality of the study area
Excellent	<250	C3 Quadrant
Good	250-750	A1, B1, C1 Quadrants
Doubtful	750-2250	C2 Quadrant
Unsuitable	>2250	---

4.3 Total Hardness

An increase of water hardness value suggests contaminations and also may be due to higher concentration of cations Mg²⁺ and Ca²⁺ indicating some basic to ultra-basic source. Hardness in water is expressed as calcium carbonate content. There are no general standards for hardness of water because it varies greatly due to variations in geology. The hardness of water can naturally range from zero to hundreds of milligrams per litre (or parts per million). Table 5.4 shows the classification water based on hardness.

Table 2: classification of water on the basis of hardness

Classification	Values in ppm
Soft	0-17.1
Slightly hard	17.1-60
Moderately hard	60-120
Hard	120-180
Very hard	180 and above

Total Hardness (as CaCO₃) in the area varies from 60 to 150 ppm. All the samples are falling in the field of temporary hardness. Samples falling in moderately hard category are A1, B1, C1 and C3. The samples of quadrant C2 has value 150 ppm and falls in hard category.

4.4 Water Quality interpretation by Piper Diagram

The Hydrochemical evolution of groundwater can be understood by plotting the major cations and anions in the Piper trilinear diagram (Piper, 1944). The diamond part of the piper diagram may be used to characterise different types of water. A Piper diagram is a graphical representation of the chemistry of a water sample or samples. The cations and anions are shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulphate, chloride and carbonate plus hydrogen carbonate anions. The two ternary plots are then projected onto a diamond.[2]The diamond is a matrix transformation of a graph of the anions (sulphate + chloride/ total anions) and cations (sodium + potassium/total cations).Piper divided the water into four basic types according to their placement near the four corners of the diamond. Water that plots at the top of the diamond is high in both Ca²⁺

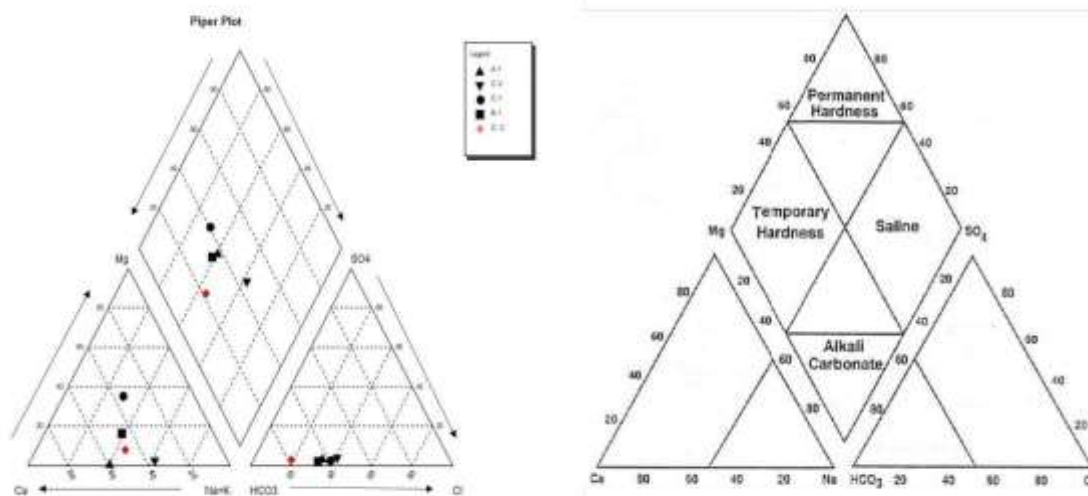


Figure 3. Piper diagram plot of the samples.

Mg²⁺ and the Cl⁻ + SO₄²⁻, which results in an area of permanent hardness. The water that plots near the left corner is rich in Ca²⁺ + Mg²⁺ and HCO₃⁻ and is the region of water of temporary hardness. Water plotted at the lower corner of the diamond is primarily composed of alkali carbonates (Na⁺ + K⁺ and HCO₃⁻ CO₃²⁻). Water lying near the right hand side of the diamond may be considered as saline (Na⁺ + K⁺ and Cl⁻ + SO₄²⁻). These division are shown in Fig. 6.3. Fig. 6.4 shows the plot of water samples of all 8 quadrant (A1,B1, C1, C2 and C3), from the plot it is inferred that all the water samples falls in the left corner which is rich in Ca²⁺ + Mg²⁺ and HCO₃⁻ and is the region of water of temporary hardness

4.5 Irrigation Quality of water

Sodium adsorption ratio (SAR): Sodium concentration is very important parameter for irrigation water quality because high level of sodium concentration in irrigation water produces an alkaline soil. Todd, 1980 describes that SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles (Venkateswaran, 2013). The SAR values in the study area can be calculated by the following equation given by (Hem, 1991) as:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})}}$$

where sodium, calcium, and magnesium are in milli equivalents per litre.

Table 3: Classification of water of the basis of Sodium Absorption Ratio

Quality of Water	SAR	Water quality of the study area
Excellent	<10	All the samples
Good	10-18	
Fair	18-26
Poor	>26

Sodium Percentage (SP): Wilcox (1955) classified irrigation water quality based on sodiumpercentage (Table 4.5) which is calculated as follows:

$$SP = \frac{K^+ + Na^+}{(Mg^{2+} + K^+ + Na^+ + Ca^{2+})} * 100$$

where all ionic concentrations are expressed in Milli equivalent per litre.

Table 4: classification of water on the basis of sodium percentage

Quality of Water	SP	Water quality of the study area
Excellent	<20
Good	20-40	C1
Permissible	40-60	A1,B1,C3
Doubtfull	60-80	C2
Unsuitable	>80

Table 5: classification of water on the basis of residual sodium concentration

	RSC	
Quality of Water		Water quality of the study area
Suitable	<1.25	All the samples except C2
Marginal	1.25-2.5	C2
Unsuitable	>2.5

Magnesium ratio (MR):

Calcium and magnesium in water are, generally, “in the state of equilibrium”. The large amount of magnesium in water adversely affects soil-quality. It converts the soil into alkaline in nature thus reducing its crop yield. It is expressed as

$$MR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}}$$

where all ionic concentrations values are in epm.

Magnesium ratio of more than 50% in a water body will make the water poisonous to plants.

The water in the present area is suitable for agricultural purposes

Table 6: classification of water on the basis of Magnesium ratio

Quality of water	MR	Remarks
Suitable	<50%	All the samples
Unsuitable	>50%	

Permeability index (PI):

The soil permeability is affected by consistent use of irrigation water which increases the presence of sodium, calcium, magnesium and bicarbonate in the soil (Chandu et al 1995). The permeability index (PI) is used to measure the suitability of water for irrigation purpose when compared with the total ions in meq/l. The PI is expressed as follows:

$$PI = \frac{Na^+ + (HCO_3^-)^{1/2} \times 100}{Ca^{2+} + Mg^{2+} + Na^+}$$

where all values are in epm.

The suitability of water for irrigation was based on PI water and can be classified as class I (good), Class II (good) and Class III (poor) orders (Doneen, 1964; Raghunath, 1987)

Table 7 : classification of water on the basis of Permeability Index

Quality of Water	PI	Water quality of the study area
Class I	>75%	B1,C2,C3
Class II	75-25%	A1 and C1
Class III	<25%

Kelly's ratio (KR):

Suitability of water for irrigation purposes is also assessed on the bases of Kelly's ratio (Kelly 1951). The formula used in the estimation of this ratio is expressed as,

$$KR = \frac{Na^+}{Mg^{2+} + Ca^{2+}}$$

where all values are in epm.

Kelly's ratio was more than 1 indicating an excess level of sodium in water; therefore, the water Kelly's ratio of less than 1 was suitable for irrigation. As per these criteria the water is suitable for irrigation purposes.

Table 8 : classification of water on the basis of Kelly ratio

Quality of Water	KR	Water quality of the study area
Excellent	<1	All samples except C2
Good	>1	C2

Irrigation Quality interpretation by Wilcox plot

Wilcox Diagram based on SAR v/s EC values, the two significant parameters of sodium and salinity hazards indicate usability for agricultural purposes. Assorted categories are demarcated in the diagram in proviso of salinity hazards and also in terms of sodium hazards, these are listed below: -

Table 9: Conductivity Classification

C1	Low salinity water – Good,
C2	Moderate salinity water – Good for soils of medium permeability for most plants
C3	Medium to high salinity water – Satisfactory for plants having moderate salt tolerance, on soils of moderate permeability with leaching.
C4	High salinity water-Satisfactory for salt tolerant crops on soils of good permeability with special leaching.
C5	Excessive salinity water – not fit for irrigation

Table 10: Sodium Classification

S ₁	Low sodium water - Good
S ₂	Medium sodium water - Good for coarse grained permeable soils. Unsatisfactory for highly clayey soils with low leaching.
S ₃	High sodium water - Suitable only with good drainage, high leaching and organic matter
addition. Some chemical additives in water may help if epm is low.	
S ₄	Very high sodium water - Unsatisfactory.

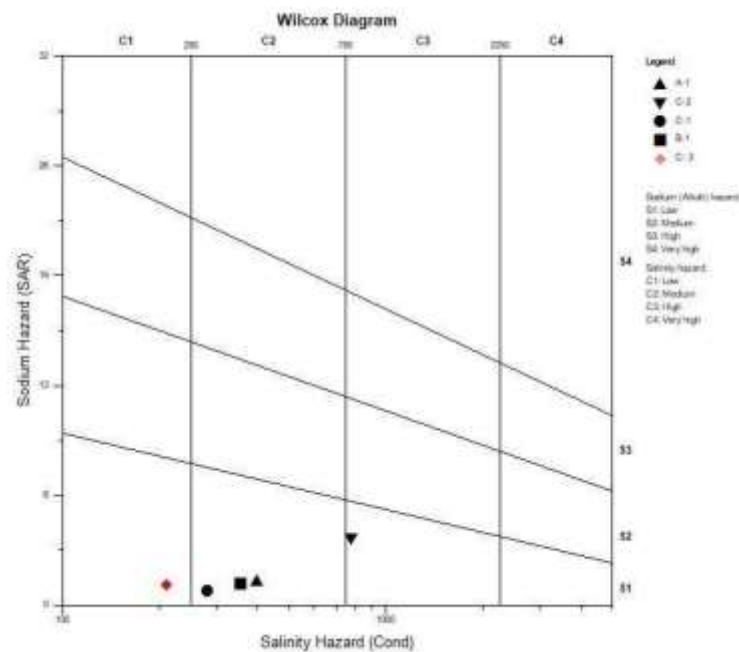


Figure 5: wilcox plot for salinity and conductivity hazard of the study area

The calculated SAR values and the analytical EC values are plotted on USSL Diagram (Fig 5). 3 sample falls in C₂S₁ area depicts moderate salinity and low salinity. C₃ samples fall in low salinity field and C₂ show extreme behaviour and falls in C₃S₁field , field of moderate salinity

Table 11: BIS prescribed limits for drinking water (trace element content in ppm)

Parameters	BIS Prescribed Limits (* WHO)		Values in the Study area
	Desirable	Permissible	
pH	6.5	8.5	8.71 to 9
TDS	500	2000	140 to 510
EC* (µS/cm)	400	2000	210 to 780
Total Hardnes	300	600	60 to 150
Al	0.03	0.2	-
As	0.05	-	<1

B	1.0	5.0	<0.1 to 0.2
Ba	2.0	-	42.42 to 150.73
Be	-	0.0002	<0.1
Ca	75	200	20 to 56
Cd	0.01	-	<0.01 to 0.03
Cl	0.20	-	14 to 106
Cr	0.05	-	2
Cu	0.05	1.50	0.25
F	1.0	1.5	0.34 to 0.48
Fe	0.30	1.0	<100 to 177
K*	10	12	2.5
Mg	30	100	<1 to 12
Mn	0.1	0.3	<0.05
Na*	20	200	20 to 109
Pb	0.05	-	<0.5 to 1.01
Sb	0.006	-	<0.02 to 0.43 ppb
Se	0.01	0.3	<100
Zn	5.0	15	4.93 to 19.36

From above table we can interpret that some water samples have high value of Cd, Cr, Ba, Pb and Zn which is above permissible limit. Increased amount of Cr in water is due to olivine basalt which is part of unclassified Rajahmundry Trap Basalt.

5. Geogenic Thorium and Uranium toxicity in the Stream water A reason of kidney Disorder in the Study Area .

From R&C data, Sediment Data and water data the unusual values of Thorium and uranium observed. This might be the result of Migmatization event which leads to the enrichment of Thorium and uranium in the form of Veins and pegmatites.

5.1 Uranium and thorium Geochemistry

Thorium is only found in nature as a tetravalent cation. This element usually occurs in geological materials as a trace constituent in solid solution with phosphate, oxide and silicate minerals, and adsorbed onto clays and other soil colloids (Hansen, 1970). It occurs as a major species only in a few rare minerals such as thorianite (ThO_2) and thorite (ThSiO_4). The former mineral is isomorphous with uraninite (UO_2), the latter with zircon (ZrSiO_4). For this reason, a large part of naturally occurring thorium is found incorporated in the zircon structure. The main source of thorium is monazite ($\text{Ce,La,Y,Th} \text{PO}_4$), which usually contains between 3 and 9% and even up to 20% ThO_2 . In addition, xenotime (YPO_4) represents another source of Th. Along with zircon, monazite and xenotime are concentrated with other resistant heavy minerals in stream and beach sands forming placers (Rankama and Sahama, 1950; Sakellariadou et al., 2022). These minerals are also source of rare earths and yttrium (REY), forming part of their mineral composition or as trace elements (Ni et al., 1995; Voncken, 2016). Igneous UO_2 can form a complete solid solution with ThO_2 (Rogers and Adams, 1969). Most thorium-hosting minerals are highly refractory to weathering, and thorium has long been considered an extremely insoluble and immobile element in natural waters (Langmuir and Herman, 1980). However, the exposition and weathering of black shales can generate acid rock drainage that helps to mobilize radioactive and hazardous elements (Th and U), and heavy metals. During the weathering process, the chemical behaviour of U and Th depends on several factors such as Eh (especially U), pH, the presence of organic and inorganic ligands, cation exchange sites on clays, mineralogical distribution of U and Th in the parent material and especially, the nature of the host rock accessory mineral association (Nesbitt, 1979). Three main processes are involved in weathering: 1) the breakdown of the parent minerals, 2) the removal in solution of some of the released constituents, and 3) the formation of secondary phases with components from the atmosphere, from the parent rock and shallower levels, and from components transported by the percolating solutions (Nesbitt et al., 1980). In contrast to U, Th is solubilized under specific conditions ($\text{pH} < 3$ and in the presence of complexing agents) (Langmuir and Herman, 1980). Thorium can be present in solution as Th^{4+} only in very acidic waters (Rai and Serne, 1978). This cation has a marked tendency to form ionic complexes with anions present in solution, such as Cl^- , F^- , NO_3^- , and OH^- (Langmuir and Herman, 1980; Mernagh and Miezitis, 2008).

Table 12: Table for elemental data of U (uranium) and Th (thorium) of collected water samples

Samples	U(ppb)	Th(ppb)
65G16/A1/W/2018	0.97	0.12
65G16/B1/W/2018	0.63	0.12
65G16/C1/W/2018	0.75	0.03
65G16/C2/W/2018	2.03	0.10
65G16/C3/W/2018	0.78	<0.01

Table13: Thorium and Uranium correlation between Soil, water and sediment Data

Elements	U	Th
U	1	
Th	0.987132	1

Table 14: Descriptive Statistics for Uranium and Thorium Sediment sample Data

Descriptive Statistics of U		Descriptive Statistics of Th	
Mean	4.36	Mean	86.88
Standard Error	0.12	Standard Error	3.50
Median	4.04	Median	79.98
Mode	2.81	Standard Deviation	48.77
Standard Deviation	1.74	Sample Variance	2378.87
Sample Variance	3.02	Kurtosis	1.06
Kurtosis	2.47	Skewness	0.91
Skewness	1.22	Range	258.55
Range	10.97	Minimum	12.64
Minimum	1.62	Maximum	271.19
Maximum	12.59		

Table 15: Descriptive Statistics for Uranium and Thorium R&C samples Data

Descriptive Statistics	Th	U
Mean	72.50	3.77
Standard Error	12.54	0.52
Median	51.43	2.94
Standard Deviation	53.20	2.22
Kurtosis	1.43	1.60
Skewness	1.49	1.58
Range	189.32	8.03
Minimum	22.00	1.55
Maximum	211.32	9.59

Conclusion

From the physicochemical properties and Statistical parameter for irrigation quality of collected water .it is obvious that water is safe for irrigation purpose .from thorium and uranium data of sediment, stream water and regolith and C -horizon it shows anomalous enrichment of Thorium and uranium which might be the main cause of kidney-related disease in the study area

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