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RESEARCH ARTICLE

Geochemical Analysis of Groundwater for Drinking, Irrigation, and Human Health Impacts in Uddanam Area of Srikakulam District of Andhra Pradesh, India

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ABSTRACT

The current study's goal is to discover the geochemical analysis of groundwater in the uddanam area of the Srikakulam district of Andhra Pradesh, India. In the current study area, 50 groundwater samples were collected and analyzed for physicochemical properties such as cations, anions, total hardness, conductivity, and alkalinity. This was assessed for its suitability for drinking and irrigation purposes by calculating pH, EC, TDS, hardness, and alkalinity in addition to major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (HCO_3^-, Cl^-, SO_4^{2-}, NO_3^{2-}, F^-). Chemical indices such as SAR, percent Na, permeability index, RSC, Kelly's Ratio, Magnesium Ratio, and Non-carbonate hardness (NCH) have been calculated based on the analytical results. Water with high alkalinity may be aesthetically unfit for drinking, whereas water with high TDS and TH may not be recommended for consumption by people suffering from kidney and related diseases. Geogenic, anthropogenic influence, agricultural activity, and mineral dissolution, Presence of high TDS and TH levels were the primary causes for chronic kidney disease (CKD), not suitable for drinking and irrigation purposes.

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Introduction

Water is a primary resource for the survival of the biotic and abiotic factors (Mahmoud Abdelshafy, 2019; Veeraswamy et al, 2020). The term "Water Quality" is normally used to prompt the physical, chemical, and biological characteristics of water, which in turn is utilized for deciding its suitability for the intended use (drinking, irrigation, industrial), particularly for drinking purposes which may affect human health (Balaji et al, 2019; Etikala et al, 2021). The qualities of water are mostly determined by the amount of dissolved or suspended inorganic or organic material (Hongming He, et al., 2014).

Under the natural condition, the composition of surface and groundwater depends on the composition of rainwater, soil strata, and aquifer material through which it passes (Willis Gwenzi, et al, 2015; Khan, R., 2018). The major ion data of groundwater samples were used to understand the hydro-geochemical processes dominant in the study area (Elango L, 2003). The Electrical conductivity and Sodium Adsorption Ratio (SAR) using the US Salinity diagram and the parameter Residual Sodium Carbonate (RSC) were used to quantify groundwater quality for irrigation purposes (Nagarju et al, 2017; Etikala et al. 2020). Overall, the water quality data was utilized to determine the presence of toxic elements, particularly those originating from geogenic sources that may be responsible for developing CKD in the area's human population.

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Study Area

Uddanam is a lush green region in the Srikakulam District of Andhra Pradesh state, India. (Fig.-1) located on the northeast coast of Andhra Pradesh with the rich coconut and cashew plantations. Geographically Uddanam is located at 18° 31' 2" to 19°7'54"N and 84°19'15" to 84°46"02'E. It has an average elevation of 41 meters above sea level. The study area was covered by parts of Survey of India (SOI) toposheet Nos.74 B/05, 74 B/06, 74 B/09 & 74 A/12. The study area is about 100 km northeast of the district headquarters at Srikakulam. The National Highway (NH-5) passes from the study area which connects Howrah in the east and Chennai in the south. It is connected to the major cities of Andhra Pradesh, Telangana and Orissa, and other parts of the country through road and rail. Most of the villages whether near the coast or in the forest area are well interconnected by a network of metaled roads. The Mandal offices are easily accessible from different villages. Sompeta and Palasa are the nearest railway station from where the train can be boarded for the other parts of the country. The study area consists of Eastern ghat Super Group represented by Khondalite Group, Charnockite Group, and Migmatites belongs to the Archaean age of more than 2500Ma. These are the oldest hard rocks in the area which are unconformably overlain by fluvio-marine Quaternary sediment horizons of Holocene age.

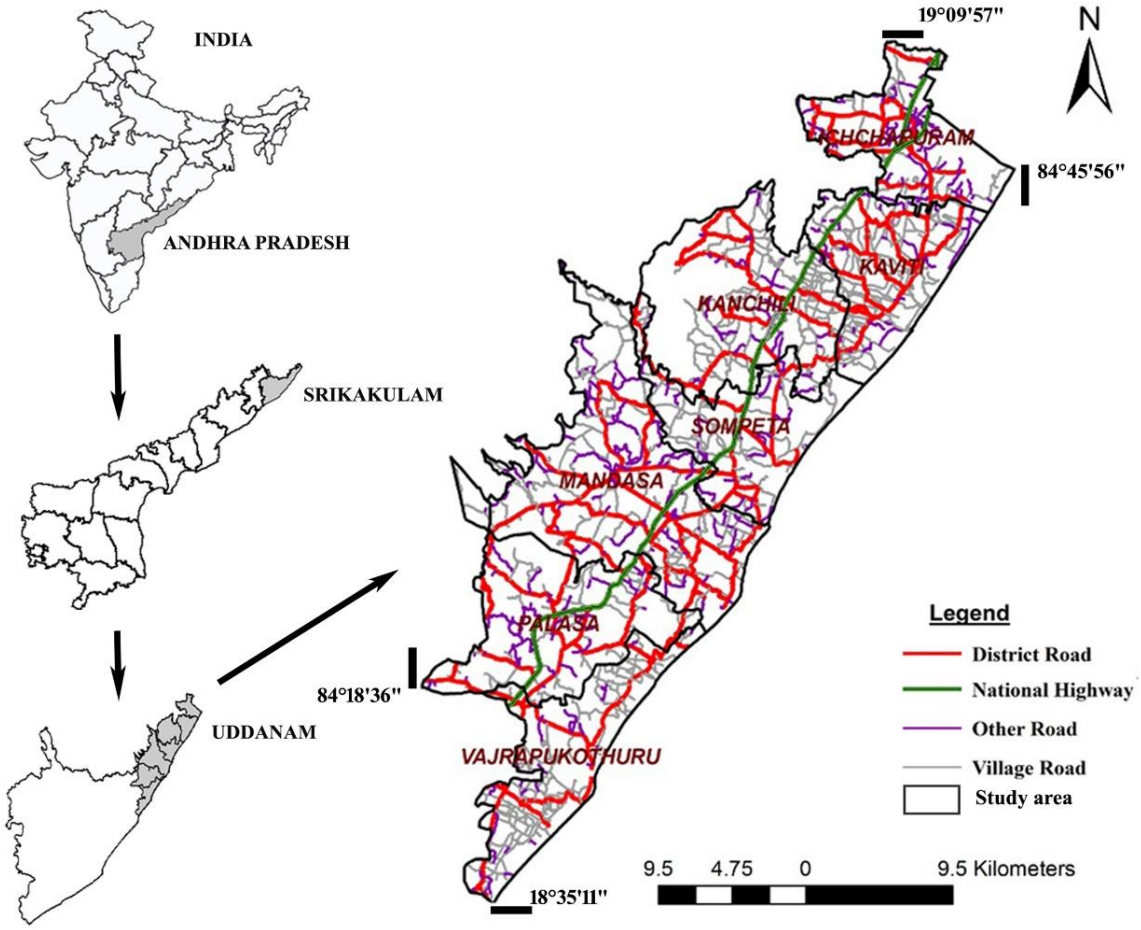

Figure 1.0. Location Map of the Study Area

Methodology

Groundwater samples were collected and analyzed within a short period to get more reliable analytical results. EC and Ph of water samples were measured in the field immediately after the collection of samples using ph and Electrical conductivity meters. Before each measurement, the PH meter was calibrated concerning buffer solution of P^H=4 and 7. Total dissolved solids (TDS) were determined by the evaporation method. Nitrate (NO_3^{2-}) and sulfate (SO_4^{2-}) analyses of the water samples were carried out using a UV-visible spectrophotometer. Carbonate (CO_3), Bicarbonate (HCO_3^-), Calcium (Ca^{2+}), and Magnesium (Mg^{2+}) were determined by volumetric methods. Sodium (Na^+) and potassium (K^+) were determined using a flame photometer. Fluoride (F^-) was determined using the SPADNS method. All concentrations are expressed in milligrams per liter (mg/l). Nitrate was analyzed using a UV-visible spectrophotometer. High purity analytical reagents were used throughout the study and chemical standards for (ICMR, 1995; APHA1995) (Table 1.0).

Table 1.0. Shows the Minimum, Maximum and Average Values of the Groundwater Chemistry

S.NO	Min	Max	Average	SD	Median
EC	330	2690	1150	729	1005
pH	6.00	7.20	32.80	128.74	6.85
TDS	160	4216	721	673	560
Ca	24	200	69	35	58
Mg	10	190	62	38	53
Na	14	1408	120	208	57
K	6	95	30	22	21
HCO3	60	612	288	143	278
F	0.03	1.01	0.42	0.24	0.34
CO3	0	0	0	0	0
Cl	27	650	186	169	144
SO4	10.00	131	47.02	31.04	46
Hardness as CaCO3	50	500	231	118	210
Alkalinity as CaCO3	110.00	740	277.30	143.07	260
Percent Sodium	13.35	80.95	33.50	15.25	30.46
Potential Salinity	1.08	19.27	5.74	5.01	4.53
RSC	-12.40	4.15	-3.83	3.43	-3.57
Non-carbonate Hardness	-207.58	620.04	191.27	171.57	178.45
CaI 1	-8.26	0.66	-0.27	1.33	0.03
CaI 2	-15.22	1.79	-0.20	2.21	0.01
GR I	0.10	0.88	0.47	0.18	0.48
GR II	0.24	0.91	0.53	0.18	0.52
Kell's Ratio	0.07	4.15	0.55	0.69	0.36
Mg Ratio	19.50	86.13	56.73	16.45	59.01
SAR	0.32	22.52	2.33	3.44	1.35
PI	20.79	87.51	49.15	15.06	47.47

Result and Discussion

pH

The results show that the pH of groundwater ranges from 6.00 to 7.20 in the area with a mean value of pH 6.0 indicating that the groundwater is slightly acidic to alkaline in nature. The range of pH is from 6.00 to 7.20. In the study area, the interaction of water with minerals presents in hard and soft rock formation influences.

EC and TDS

Groundwater EC and TDS in the region range from 330 to 2690 S/cm and 160 to 4216 mg/L, respectively. The EC and TDS values suggest that the groundwater in the region is somewhat mineralized and that the water has spent sufficient time interacting with the solid and gaseous media present in the targeted area. Groundwater EC and TDS are primarily caused by dissolved ions or dissolved solids.

Total Alkalinity (TA) and Bi Carbonate

The total alkalinity of groundwater in the region ranges from 110.00 to 740mg/L, with a mean value of 277 mg/L as $CaCO_3$, indicates that the groundwater has developed sufficient ability to neutralize the acids. The carbon dioxide dissolved in water and mineral calcite found in the rocks is the primary source of alkalinity in the area's groundwater. The concentration of CO_3^{2-} in groundwater was found in traces, whereas the concentration of HCO_3- ranges from 60 to 612 mg/L, with a mean value of 288mg/L. Anthropogenic activities contributing more bicarbonate to groundwater are likely possible in areas with moderate to high levels of total alkalinity.

Total Hardness (TH), Calcium, and Magnesium

The total hardness of groundwater in the area ranges from 50 to 500 mg/L as $CaCO_3$ with a mean value of 231 mg/L reflecting that the groundwater in the area is very hard in nature. The sources of hardness in groundwater are mainly the salts of calcium and magnesium present in groundwater. The concentrations of Ca^{2+} and Mg^{2+} in groundwater were found in the range of 24to 200mg/L and 10 to 190mg/L with an average concentration of 69 and 62 mg/L respectively.

Sodium and Potassium

The groundwater in the study area was found to have concentrations of Na^+ and K^+ in the range of 14 to1408 mg/L and 6 to 95 mg/L with a mean value of 120 and 30 mg/L respectively. The Na^+ is the most dominant cation in groundwater followed by Ca^{2+} and Mg^{2+} while K^+ is having the lowest concentration among all the cations in the groundwater. The concentration of Na^+ is significantly higher than the K^+ in groundwater. The Na^+ may also be contributed in groundwater from rainwater rich in sodium content from a coastal area (Balaji, E et al, 2018). The seawater ingression may also cause to increase in sodium content in groundwater. Anthropogenic sources such as domestic and industrial waste and wastewater are also rich in Na+ and if percolated to groundwater can significantly contribute to raising the concentration of Na+ in groundwater. Agricultural activities can contribute K^+ to groundwater if

potassium fertilizers are extensively used. The K^+ assimilated by plants can also become a source of K^+ in groundwater after organic decay and leaching from soil (Veera Swamy, G, 2019).

Chloride

The concentration of chloride in the groundwater of the study area ranges from 27 to 650 mg/L with an average concentration of 186 mg/L. The geogenic media present in the area do not significantly contribute chloride to groundwater.

Sulfate

The SO_4^{2-} in groundwater in the study area ranges from 10 to 131 mg/L with an average concentration of 47.02 mg/L. The SO_4^{2-} in groundwater may appear from the atmospheric precipitation, agriculture activity like usage of fertilizer and pesticide.

Fluoride

The Fluoride groundwater of the study area ranges from 0.03to 1.01 mg/L with an average of 0.42mg/L. The concentration of fluoride in groundwater in 98% monitoring wells is below 1.0 mg/L, an acceptable limit prescribed by the Bureau of Indian Standards in its drinking water specifications [IS 10500:2012].

Water Quality for Irrigation Purposes

The evaluation of water quality for irrigation purposes was carried out by using a diagram given by U.S. Salinity Laboratory (USSL). In this diagram, the electrical conductivity, as an index of dissolved-solids concentration is plotted on the x-axis and sodium adsorption ratio [SAR = Na / (√ Ca+Mg/2)] on the y-axis (Veera Swamy, G., et al, 2019). Numbers of samples falling under different salinity and sodium hazard zones are tabulated It is clear from the figures and table that the maximum number of samples falls in the category of medium and high Salinity hazard zone indicating that the groundwater in the study area cannot be used for irrigation on soils with restricted drainage and special management for salinity control is required. It further indicates that there is little danger of the development of harmful levels of exchangeable sodium if water is used for irrigation as most samples fall under the low sodium hazard zone. Overall, the groundwater quality for irrigation use is not suitable under normal conditions, and special management for salinity control is required.

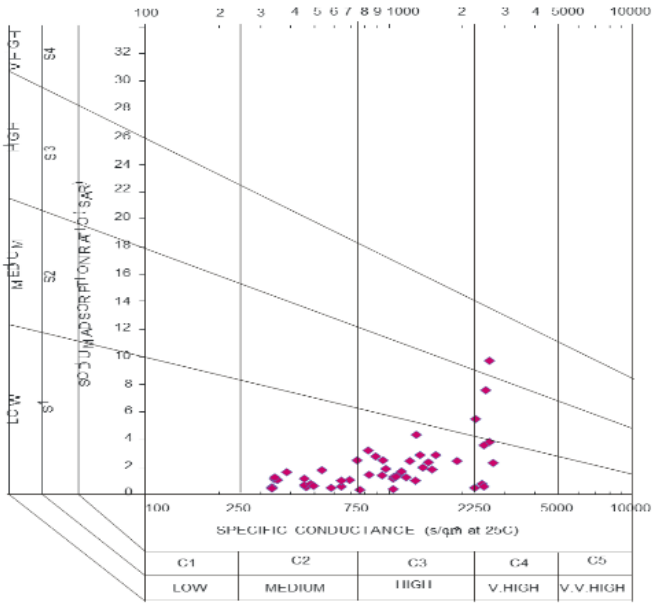

Figure 2.0. The Quality of Water Concerning Salinity and Sodium Hazard (after U.S. Salinity Laboratory 1854)

Percent Sodium

In the present study area 90% of samples fall in the good to permissible and remaining 10% are not suitable for irrigation, which is explained by Wilcox diagram as shown below fig 3.0.

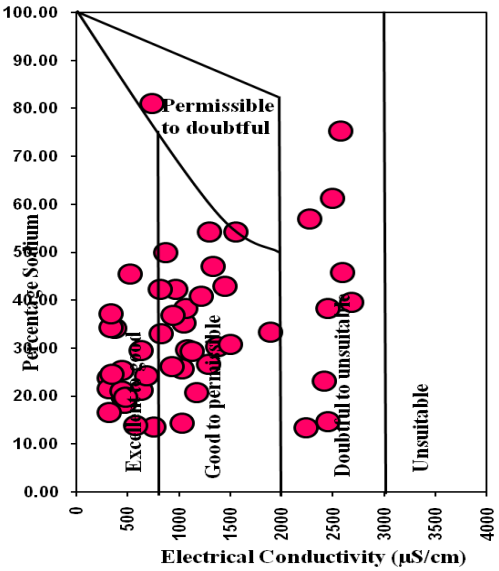

Figure 3.0. Wilcox Diagram

Human Health Impacts

World Health Organization (WHO) has identified the Uddanam study area as one of the three regions in the world, after Srilanka and Central America, where higher incidences of chronic kidney disease (CKD) of unknown etiology in the human population are reported. The water quality assessment study carried out in the area has shown that the portability of water is mainly affected due to the high concentrations of the parameters namely TDS, TA, TH

as well as Fe (G M N Sastry, 2019; Lal, Kanhaiya, et al, 2020). The high alkalinity can make the water aesthetically unfit for drinking while the water with high TDS and TH may not be advised for consumption to the people suffering from kidney and related diseases. A high concentration of magnesium in drinking water is known to have a laxative effect (Parvati Sai Arun, P.V., 2019).

Conclusions

The analysis reveals that in the study area groundwater contains a higher amount of sodium, calcium, and total hardness, higher amount of total dissolved solids, bicarbonates, and alkalinity. The main reasons are the dissolution of the Khondalite Group, Charnockite Group, and Migmatites rocks. Higher hardness indicates due to the presence of calcium and magnesium. The seawater ingression may also cause to increase in sodium content in groundwater, Anthropogenic sources such as domestic and industrial waste and wastewater are also rich in Na^+ and if percolated to groundwater can significantly contribute to raising the concentration of Na^+ in groundwater. The high alkalinity can make the water aesthetically unfit for drinking while the water with high TDS and TH may not be advised for consumption to the people suffering from kidney and related diseases. A high concentration of magnesium in drinking water is known to have a laxative effect. The disposal of domestic wastes and wastewater in unlined drainages is also playing a significant role in contributing major ions to water. At finally, before consumption of groundwater in the study area, proper treatment is necessary.

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