JOURNAL OF GEOINTERFACE, Vol. 3, No. 2, December 2024, pp. 1–10 e-ISSN: 2583-6900

Assessment of Stream Water Quality in parts of Sangareddy and Medak Districts, Telangana: Insights for Drinking, Agricultural, and Industrial Requirements

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ABSTRACT

The study assesses stream water quality in parts of Sangareddy and Medak Districts, Telangana, focusing on parameters crucial for drinking, agricultural, and industrial applications. Water samples were collected from higher order streams within $5' \times 5'$ grids of Survey of India Toposheet no. 56G/13. The analysis included pH, electrical conductivity (EC), total dissolved solids (TDS), and total hardness. The pH ranged from 7.5 to 7.9, indicating slightly alkaline water. EC variations were attributed to agricultural practices and geological factors. TDS levels (266-697 ppm) classified the water as fresh, while total hardness remained within Bureau of Indian Standards (BIS) guidelines. Suitability for drinking and irrigation was evaluated using Sodium Adsorption Ratio (SAR), Percentage Sodium (Na%), Residual Sodium Carbonate (RSC), and Corrosivity Ratio (CR). Hydro-chemical facies analysis via Piper diagrams revealed a dominant presence of magnesium and bicarbonate ions, likely due to agricultural runoff. CR values ranged from 0.95 to 8.22, indicating that water in the C3 quadrant is safe for metal pipes, whereas other quadrants (A1, A2, A3, B1, B2, B3, C1, and C2) showed higher CR values, making them unsuitable for metal piping. Non-corrosive pipes like PVC are recommended for water transport in these areas.

ARTICLE HISTORY

Received 14 June 2024
Revised 26 July 2024
Accepted 27 August 2024

https://doi.org/10.5281/zenodo.12789919

KEYWORDS

Water Quality
Hydrochemical Analysis
Drinking Suitability
Agricultural Impact
Corrosivity Ratio
Sodium Adsorption Ratio
Corrosivity Ratio

1. INTRODUCTION

Geochemical mapping is an indispensable tool for understanding and managing natural resources, addressing environmental concerns, and catering to societal needs (Xuejing et al., 1997; Garrett et al., 2008; SOP of NGCM, 2014, 2021; Sahoo et al., 2023). In the field season program for the year 2021-22, a detailed geochemical mapping was undertaken in the Sangareddy and Medak Districts of Telangana at a 1: 50,000 scale covering Survey of India Toposheet No. 56G/13, within latitudes 17°15′00″ to 17°30′00″ and longitudes 78°45′00″ to 79°00′00″, aimed to establish a geochemical baseline that would facilitate the sustainable management and development of natural resources (Sahoo et al., 2023).

Water quality is critical for its suitability in drinking, agricultural, and industrial sectors. The hydrochemical analysis of the study area revealed significant variations in water quality influenced by geological conditions, human activities, and mineral content. Key chemical constituents analyzed included Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, Na^+, K^+, and SO_4^{2-}. These parameters are essential for classifying and assessing water quality for different uses. The classification of water quality for specific purposes typically involves individual or paired ionic concentrations. However, a more holistic approach that considers the combined chemistry of all ions provides better insights into the water's suitability. Chemical classification offers a detailed understanding of predominant cations and

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anions and their interrelationships. The extensive dataset collected, including parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), and total hardness, is crucial for this analysis. For drinking water and public health assessment, hydrochemical parameters were compared against Bureau of Indian Standards BIS (2012) which is threshold values, indicating the water's suitability for domestic use. In agriculture, electrical conductivity is a vital parameter affecting soil structure and crop growth. Parameters like Sodium Adsorption Ratio (SAR), Percentage Sodium (Na%), Corrosivity Ratio (CR), and Residual Sodium Carbonate (RSC) were used to evaluate irrigation suitability. Piper trilinear and quadralinear plots were employed to classify water quality based on cations and anions. Results indicated that the water in the study area displayed characteristics of prolonged agricultural contamination, likely due to extensive use of fertilizers and pesticides. Predominantly, the water samples were of the magnesium-bicarbonate type.

This comprehensive analysis of surface water quality in Sangareddy and Medak Districts of Telangana highlights its potential applications across various sectors. It underscores the significant influence of geological and anthropogenic factors on water quality. The findings emphasize the need for sustainable water management practices to ensure the region's long-term water security.

2. GEOLOGICAL SETUP

2.1. Regional Geology

The major part of Telangana state lies on the Dharwar Craton, in the Peninsular India, spans ages from 3.4 to 2.5 Ga and has experienced significant magmatic events from the paleo-Archean to the neo-Archean periods, contributing to crust formation and reworking (Pahari et al., 2020). The Dharwar Craton is bounded by several geological features: the Pan-African Pandyan Mobile Belt to the south, the Deccan Traps to the north (Sarvothaman et al., 1983), the Archaean Karimnagar Granulite Belt and Proterozoic Pranahita-Godavari Basin to the northeast, the Neoproterozoic Eastern Ghats Mobile Belt to the east, and the Arabian Sea to the west (Fig. 1). The Dharwar Craton is divided into the Western Dharwad Craton (WDC) and the Eastern Dharwad Craton (EDC), separated by the Chitradurga Shear Zone Swami (Swami Nath et al., 1976; Rogers, 1986).

2.2. Local Geology

The study area falls on the Survey of India Toposheet no. 56G/13 (Fig. 2) comprising of gneissic terrain having gently undulating topography. The area (56G/13) comprises of Peninsular Gneissic Complex (PGC) and Deccan trap (Sahoo et al., 2023). PGC consists of grey hornblende granite gneiss, grey hornblende biotite granite, grey biotite granite, and alkali feldspar granite. The general trend of gneissosity of the PGC is NNW-SSE to NW-SE. Dolerite dyke and quartz vein are traversing the PGC. Deccan Trap consists of three flows of basalt that unconformably overlie the Archaean granite gneiss complex. These flows are characterized by vesicular and highly fragmented tops. Intertrappeans comprising chert, limestone, clay, and sandstone occur between basalt flow1 and flow2 and the infratrappean sediments occur at the contact of trap and alkali feldspar granite. The granitic terrain usually grades to pediplain with coarse sandy soil cover. Trap basalt yields brown/black clayey soil on weathering, which is exposed in the pediplain area. The maximum elevation is 588m above MSL and the minimum elevation is 513m above MSL. Manjira, a tributary of Godavari is the major river draining the area. The granitic terrain shows dendritic, sub-dendritic, and sub-parallel drainage patterns whereas the trap area shows a subparallel drainage pattern. The major reservoir of the area is Singur Reservoir.

3. MATERIALS AND METHODS

Stream water samples were collected from flowing streams of higher order in the post-monsoon period, using a $5' \times 5'$ grid system in the year 2021 to represent the elemental distribution within the drainage basin (Fig. 3). The water samples were collected from the nine locations of the toposheet at a $5' \times 5'$ grid pattern (Fig. 3) from the flowing higher-order streams. Four different volumes of samples were collected: (i) 500 ml for ion chromatography (IC) analysis, (ii) 100 ml for inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectrometry (ICP-AES) analysis, (iii) 60 ml for dissolved organic carbon (DOC) analysis, and (iv) 100 ml for mercury analysis. Each polythene decanter was rinsed twice with stream water before sample collection, with pH and conductivity measured directly in the decanter water. The 100 ml and 60 ml bottles were filled with filtered water, each rinsed

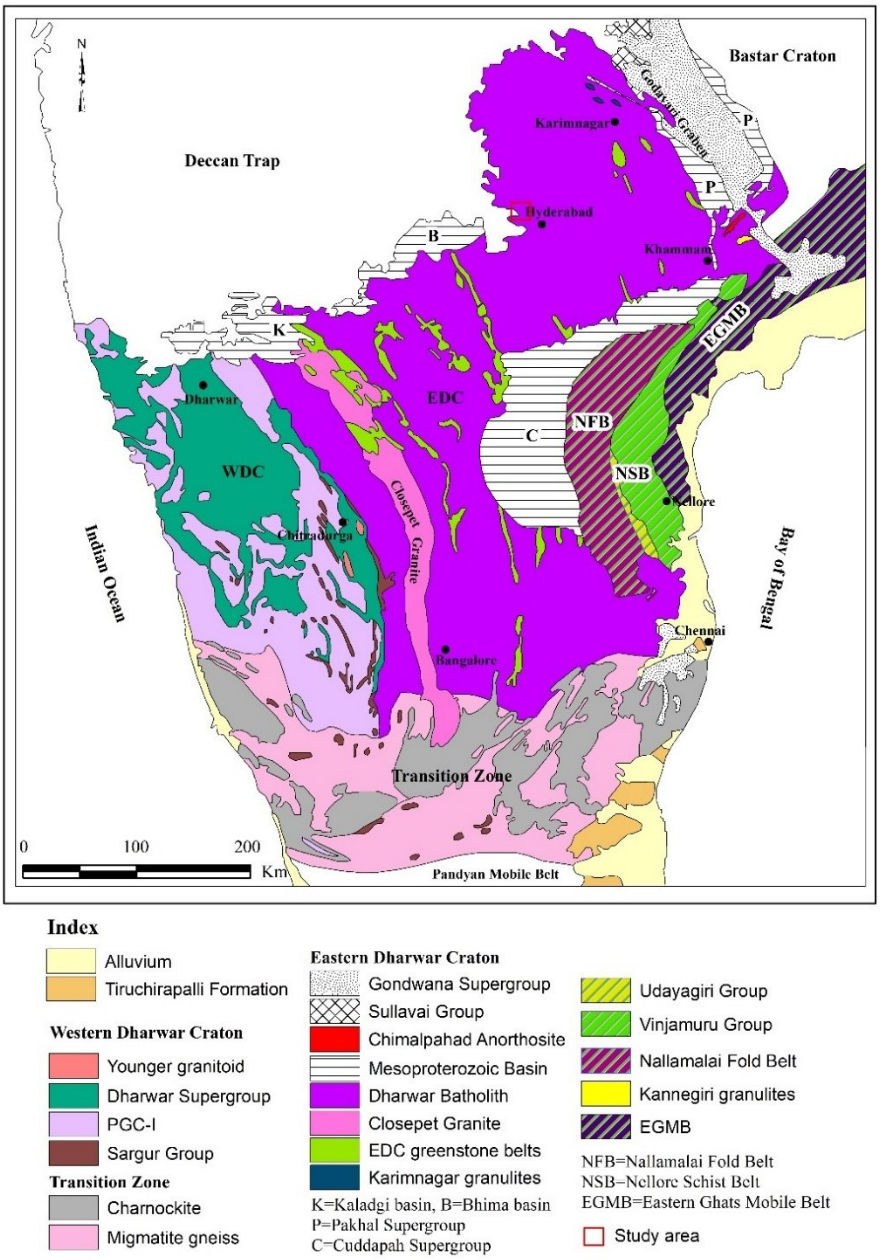

Fig. 1. Generalised geological map of EDC with the study area after GSI.

twice with the filtered sample beforehand. The 500 ml bottle was rinsed twice and filled by submerging it completely underwater to avoid air bubbles, then tightly sealed while still submerged. The bottle for mercury was similarly rinsed and filled to the neck before being tightly sealed. Within the same day, 1.0 ml of concentrated HNO_3 was added to the 100 ml sample for ICP-MS and ICP-AES analysis, with thorough mixing. No acid was added to the 60 ml DOC sample. For the mercury sample, 5 ml of HNO_3 and potassium dichromate ($K_2Cr_2O_7$) were added. Total alkalinity, representing ions such as CO_3^{2-}, HCO_3^-, OH^-, $HSiO_3^-$, $H_2BO_3^-$, HPO_4^{2-}, and $H_2PO_4^-$, was determined by titration, with HCO_3^- being the dominant ion between pH 4.5 and 8.3, often expressed as mg/L of $CaCO_3$. All other analyses were performed following the chemical laboratory's protocols (SOP of NGCM, 2014, 2021).

4. RESULTS AND DISCUSSION

Determining the quality of water is one of the most important aspects of surface water studies. The hydrochemical study reveals the quality of water that

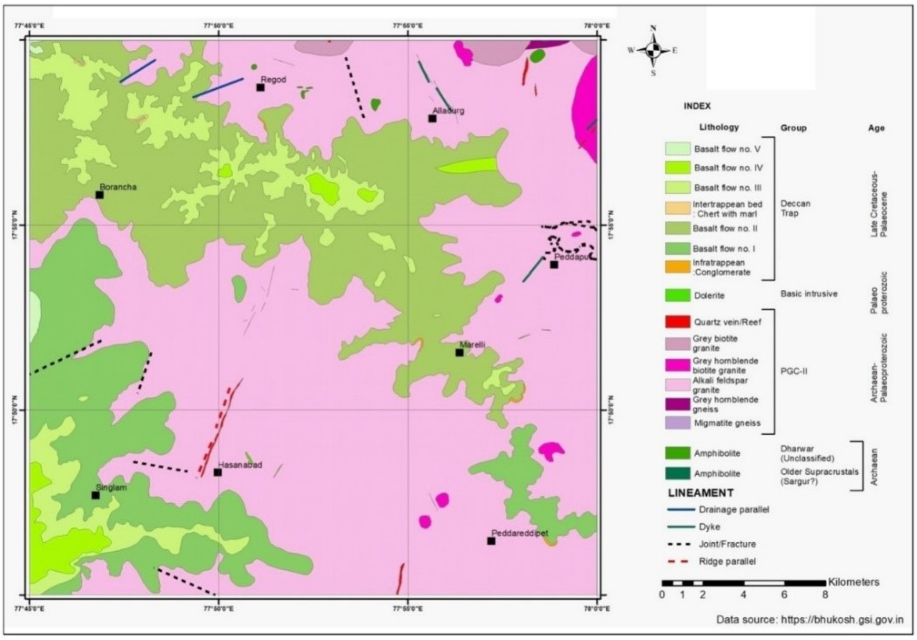

Fig. 2. Geological map of Toposheet 56G/13 in parts of Sangareddy and Medak districts of Telangana.

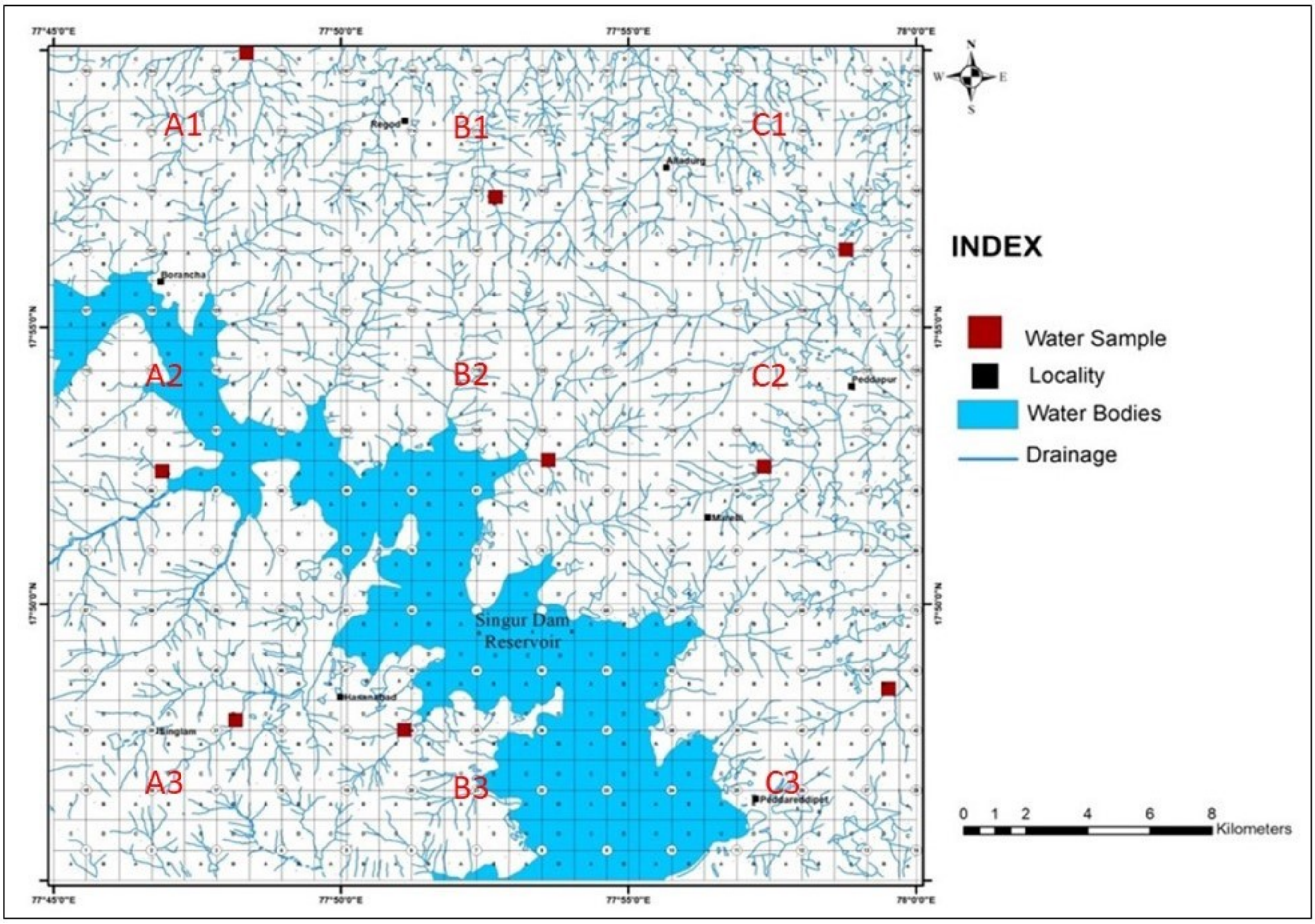

Fig. 3. Drainage map showing water sample locations in toposheet No. 56G/13 in parts of Sangareddy and Medak districts of Telangana.

Table 1. Analytical results of physicochemical parameters of water samples.

Quadrant No.	pH	EC µS/cm	TDS ppm	TH mg/L	Ca^{2+} ppm	Mg^{2+} ppm	Cl^{-} ppm	HCO_3^{-} ppm	Na^{+} ppm	K^{+} ppm	SO_4^{2-} ppm
A_1	7.80	687	446.55	320	68	36	57	256	2.5	13	22
A_2	7.90	1000	650.00	280	64	29	64	439	92	10	19
A_3	7.60	554	360.10	280	56	34	35	268	2.5	16	18
B_1	7.70	654	425.10	320	68	36	28	330	2.5	11	16
B_2	7.60	1073	697.45	430	68	63	78	452	42	8	27
B_3	7.80	1022	664.30	410	40	75	57	427	49	16	79
C_1	7.70	1046	679.90	500	68	80	106	378	2.5	14	65
C_2	7.50	872	566.80	420	68	61	43	378	2.5	17	44
C_3	7.60	409	265.85	190	40	22	28	183	2.5	14	11

is suitable for drinking, agriculture, and industrial purposes. Further, it is possible to understand the change in quality due to rock-water interaction or any type of anthropogenic influence. Surface water often consists of seven major chemical constituents- Ca^{+2}, Mg^{+2}, Cl^{-1}, HCO_3^{-1}, Na^{+1}, K^{+1}, and SO_4^{2}.

The chemical parameters of surface water play a significant role in classifying and assessing the water quality. Considering the individual and paired ionic concentration, certain indices are proposed to find out the alkali hazards. Residual sodium carbonate (RSC) can be used as a criterion for finding suitable water for irrigation. It was observed that the criteria used in the classification of water for a particular purpose considering the individual concentration may not find its suitability for other purposes and better results can be obtained only by considering the combined chemistry of all the ions rather than individual or paired ionic characters. Chemical classification also throws light on the concentration of various predominant cations, anions, and their interrelationships. The analytical results of water samples are given in Table 1.

pH: The normal range for pH in the surface water system is 6.5 to 8.5. pH of the water system depends on the presence of dissolved substances that come from bedrock, soils, and other materials in the watershed and their interaction. Chemical analysis of water indicates that water is slightly alkaline (pH values range from 7.5 to 7.9), since samples collected from these grids are mainly occupied by agricultural fields, the use of fertilizer in large amounts may be the reason for its alkalinity.

Electrical Conductivity (EC): Conductivity or specific conductance is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. The degrees to which salts dissociate into ions, the amount of electrical charge on each ion, ion mobility, and the temperature of the solution all influence conductivity. It is related to the concentration of total dissolved solids and major ions. Freshwater is usually between 0 and 1,500 µS/cm and typical seawater has a conductivity value of about 50,000 µS/cm. Low levels of salts are found naturally in waterways and are important for plants and animals to grow. When salts reach high levels in freshwater it can cause problems for aquatic ecosystems and complicated human uses.

In the study area, the conductivity of stream water samples varies from 554 to 1073 µS/cm (Table 1). The high conductivity in some of the samples is likely due to prolonged and intensive agricultural practices and geological conditions acquiring high concentrations of the dissolved minerals. It shows a mild positive correlation with pH value, alkalinity, total hardness, and salinity, hence higher electrical conductivity values in relatively higher pH areas are expected.

Total dissolved solid (TDS): TDS is the measure of the total amount of mobile charged ions, including minerals, salts, and metals dissolved in a given volume of water, expressed in mg per litre (mg/l). Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) and some small amounts of organic matter that are dissolved in water. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water. An important aspect of TDS with respect to drinking water quality is the effect on taste.

TDS of the water in the study area ranges from 266 ppm to 697 ppm (Table 2). Based on the USGS classification of water based on dissolved solids, the water in the area belongs to the fresh category.

Total Hardness: The degree of hardness of drinking water is classified in terms of the equivalent $CaCO_3$ concentration. The ions such as calcium and

Table 2. Water quality for drinking and agricultural purposes (after Davis and DeWiest, 1966).

TDS mg/I	Remarks on Quality	No. of samples
Up to 500	Desirable for drinking	A_1, A_3, $B_1$and C_3
500–1000	Permissible for drinking	A_2, B_2, B_3, C_1 and C_2
Up to 3000	Useful for Agriculture	
>3000	Unfit for drinking and irrigation	

magnesium in combination with bicarbonates, carbonates, sulphide, sulphates, and other anions make the water hard. Hard waters are believed to be more productive for agriculture than soft waters.

Total hardness in the area varies from 190 to 500 mg/L (Table 2). With reference to the BIS prescribed standard of hardness, water samples collected from all quadrants are within the desirable limit.

Domestic and drinking water quality standards. Water to be used in the home for drinking should be free from colour, turbidity, odour, and microorganisms. To assess the quality of surface water for drinking and public health purposes, the hydro chemical parameters of surface water in the study area are compared with the threshold values recommended by the BIS. Table 3 shows the compilation of prescribed limits and observed values from the study area.

Irrigational water quality. Water for irrigation should satisfy the needs of the soil and the crop as the liquid phase in soil water plant growth and crop production. Electrical conductivity is the most important parameter in determining the suitability of water for irrigation. Water used for irrigation can enhance salt concentration in the soils and problem occurs if the added salts accumulate to a concentration that is harmful to the crop. Therefore, the quality of irrigation water depends primarily on its silt and salt content. Water used for irrigation should contain measurable quantities of dissolved substances, which are collectively called salts. They include relatively small but important amounts of dissolved solids originating from the dissolution or weathering of the rocks and soils and the dissolving of lime, gypsum, and other salt sources as water passes over or percolates through them. The salt present in the water determines the electrical conductivity which in turn indirectly affects the plant's growth. The salts, besides affecting the growth of plants directly, also affect soil structure, permeability, and aeration, which indirectly affect plant growth. The dominant ions such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, and chloride in a water sample can be represented in several ways. The suitability of water for irrigation can be estimated by means of determinants, though, Sodium Adsorption Ratio (SAR), Percent Sodium (Na%), Permeability Index (PI), Corrosivity Ratio (CR), Residual Sodium Carbonate (RSC), Kelley's ratio (KR) and Magnesium Ratio (MR). For this purpose, the equivalents per million (epm) values are most commonly utilized. The values are shown in Table 4.

Sodium Adsorption Ratio (SAR): The sodium or alkali hazard of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio (SAR). SAR gives a very reliable assessment of water quality for irrigation with respect to sodium hazard since it is more closely related to exchangeable sodium percentages. The higher the sodium adsorption ratio, the less suitable the water is for irrigation, excessive sodium content relative to calcium and magnesium reduces soil permeability (Kelly, 1951). The classification of water samples from the study area with respect to SAR (Todd, 1959; Richards, 1954) is given in (Table 5). The SAR value in the study area ranges from 0.02 to 0.99 based on that, the water of the study area is found to be of excellent quality since none of the samples exceeds the SAR value of 10 (Table 5) (Richards, 1954).

$$\mathrm{SAR} = \frac{\mathrm{Na}^+}{\sqrt{\frac{1}{2}(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})}}$$

where all the concentrations are in epm value.

Percentage Sodium (Na %): The percentage of Na in the water samples ranges from 5.2% to 37.6%. (Table 4). A high sodium percentage causes deflocculation and impairment of the teeth and the permeability of soils (Karanth et al., 1989). A maximum of 60% sodium is recommended for irrigation water for better crop yields (BIS, 1991) since the suitability of the surface water for irrigation depends on the mineralization of water and its effect on plants and soil. If the concentration of Na^{1+} is high in irrigation water, Na^{1+} gets absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. This exchange process

Table 3. Water analysis with BIS drinking water specifications (IS 10500:1991).

Parameters	Prescribed Limits BIS, 10500 (2012)		Observed values (ppm) from the study area	Comments on the analytical values measured in the area
	Acceptable	Permissible		
pH	6.5-8.5	No relaxation	7.5 – 7.9	All values are within the acceptable limits.
TDS	500	2000	265-697.45	Only 4 (A_1, A_3, B_1 and C_3) samples are showing values within acceptable range.
TH (as $CaCO_3$)	200	600	190-500	All values are within the permissible limits.
Ca	75	200	40.08-68.14	All values are below the permissible limit.
Cl^-	250	1000	28.36-106.35	All values are below the acceptable limit.
F	1.0	1.5	0.65-1.36	All values are below the permissible limit.
Mg	30	100	22-80	All values are below the permissible limit.
SO_4^{2-}	200	400	11-79	All values are below the desirable limit.
NO_3^-	45	No relaxation	7 to 37	All values are below the acceptable limit.

Table 4. Calculated RSC, SAR, CR & % Na values for water samples.

Sl. No.	Sample No.	Grid	SAR	RSC	C.R	%Na
1	56G13/A1/W/S/21-22	A1	0.02	0.98	2.64	13.26
2	56G13/A2/W/S/21-22	A2	0.99	4.38	4.83	52.36
3	56G13/A3/W/S/21-22	A3	0.03	1.58	1.85	16.79
4	56G13/B1/W/S/21-22	B1	0.02	2.18	1.88	11.77
5	56G13/B2/W/S/21-22	B2	0.32	3.06	6.23	27.76
6	56G13/B3/W/S/21-22	B3	0.42	2.86	6.94	35.91
7	56G13/C1/W/S/21-22	C1	0.02	1.15	8.22	10.11
8	56G13/C2/W/S/21-22	C2	0.02	1.97	3.99	13.17
9	56G13/C3/W/S/21-22	C3	0.04	1.09	0.95	20.58

Table 5. SAR classification of water samples (BIS, IS: 11624-1986).

SAR (in meq/L)	CLASS	QUALITY	No. of Samples
0-10	Low sodium hazard	Excellent water	09
10-18	Medium sodium hazard	Good water	Nil
18-26	High sodium hazard	Fair water	Nil
>26	Very high sodium hazard	Poor water	Nil

of Na^{1+} in water for Mg^{2+} and Ca^{2+} in soil reduces the permeability of the soil and eventually results in poor internal drainage of the soil. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (Collins and Jenkins, 1996; Saleh et al., 1999). The percentage Na in the water samples ranges from 10.11% to 52.36%, thus water samples collected from all quadrants fall under permissible limit (Table 6).

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

where all the concentrations are in epm value.

Residual sodium carbonate: When the concentration of carbonates and bicarbonates exceeds

Table 6. Water Classes Based on Percent Sodium (After Wilcox, 1955).

% Sodium	Water Class	No. of samples
<20	Excellent	09
20- 40	Good	00
40- 60	Permissible	00
60- 80	Doubtful	00
>80	Unsuitable	00

that of calcium and magnesium, there may be the possibility of complete precipitation of calcium and magnesium. Bicarbonate and carbonates are considered detrimental to the physical properties of soils, as they cause the dissolution of organic matter in the soil, which in turn leaves a black stain on the soil surface on drying. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate, and this excess, denoted by RSC, is calculated as given below (Table 7)

$$RSC = (HCO_3^- + CO_3^-) - (Ca^{2+} + Mg^{2+})$$

Table 7. Water classes based on RSC (after Richards, 1954).

RSC Value (epm)	Sample Quality	No. Of samples
<1.25	Suitable	A_1, C_1& C_3
1.25–2.5	Marginal	A_3, B_1& C_2
>2.5	Not suitable	A_2, B_2& B_3

Industrial Water quality. Corrosivity Ratio (CR) The susceptibility of water to corrosion is denoted by the corrosivity ratio (CR), which is expressed as the ratio of alkaline earth metals to saline salts in water. Corrosivity ratio is calculated from the following formula,

$$CR = \frac{(Cl^-/35.5) + 2(SO_4^{2-}/96)}{2[(CO_3^{2-} + HCO_3^-)/100]}.$$

The water with a corrosivity ratio < 1 is considered to be safe for the transport of water in any type of pipe, whereas >1 indicates a corrosive nature and hence not to be transported through metal pipes. The calculated CR values of water samples from the study area range from 0.95 to 8.22 (Table 4). This result suggests that water samples collected from the C_3 quadrant show a corrosivity ratio < 1 and are found to be safe whereas water samples from the remaining quadrants show higher CR values (A_1, A_2, A_3, B_1, B_2, B_3, C_1& C_2 quadrants) and thus unsuitable for transport via metal pipes, so noncorrosive water pipes such as PVC pipes should be used for water supply instead of metal pipes.

Hydro-chemical facies and water quality. (Hill Piper trilinear and quadra-linear plot) Piper (1944) proposed this diagram for determining the quality of water for domestic purposes, especially for drinking. The Piper diagram has two triangles (cations and anions) & central diamond shape (combined). Cations are plotted as percent on the Ca-Mg-(Na+K) triangle and the anions are plotted as percent on the HCO_3-SO_4-Cl triangle. Points on the triangles are projected up to where they intersect on the diamond. Accordingly, the Piper diagram is classified into six fields. They are

I. Ca-HCO_3 type	III. Ca-Mg-Cl type,
II. Na-Cl type	IV. Ca-Na-HCO_3 type
V. Ca-Cl type	VI. $NaHCO_3$ type

After plotting the analytical values of water samples on a Piper trilinear plot (Fig. 4), It is observed that concentrations of cations in the surface water samples reveal that calcium content is higher in stream water. This composition is evident that the water here is derived from the source rock rich in calcium, this may be from the amphibole (hornblende) and/or pyroxene (augite, diopside, etc.) group of minerals. Anionic concentration from the water samples reveals that HCO_3^- is dominant. This ranges from 183.06 to 451.55 ppm. This high content of the bicarbonate from the study area may be due to groundwater mix with surface water and/or the decomposition of organic matter and root respiration in the soil zone. All nine samples fall in the magnesium-bicarbonate type. From the cation triangular plot, it is observed that B3, C1, and C2 are Magnesium types, and A1, A2, A3, B1, B2, and C3 are no dominant types. In the same way, in the Anion triangular plot, it is observed that all samples are Bicarbonate type. Thus, it has been stated that the water of the study area is showing clear imprints of agricultural contamination i.e., prolonged agricultural practices aided with prolific use of fertilizers, pesticides, etc.

5. CONCLUSIONS

The comprehensive analysis of water samples from all nine quadrants in the study area has provided valuable insights into the physicochemical parameters, water quality, and suitability for irrigation. The slightly alkaline nature of the water, with a pH range of 7.5 to 7.9, can be attributed to extensive agricultural activities and the use of fertilizers. Total hardness and TDS levels in the water samples fall within acceptable limits as per standards, indicating the suitability for both drinking and irrigation. Assessment of irrigation qualities based on SAR, and %Na values confirms the excellent quality of water in the study area. The water samples exhibit high corrosivity, suggesting the use of non-corrosive materials for water supply infrastructure. Fluoride levels also meet permissible limits, ensuring safe water consumption. Hydro-chemical facies and water quality analysis reveal a dominance of calcium and bicarbonate ions, indicative of the source rock composition rich in calcium. All samples fall into the Magnesium-bicarbonate type, underlining the influence of prolonged agricultural practices, including the extensive use of fertilizers and pesticides. This study

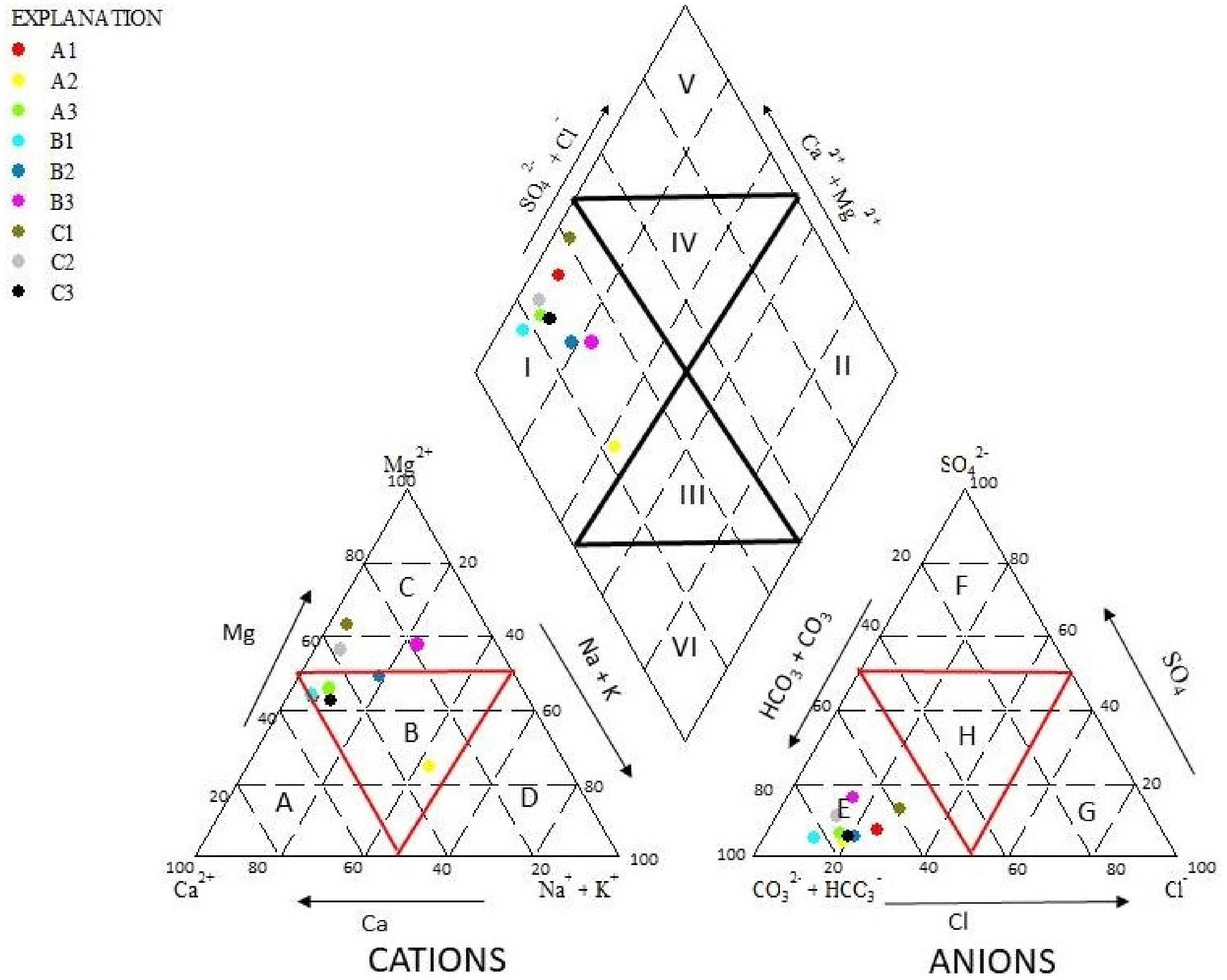

Fig. 4. Piper diagram for water samples collected from T.S No 56G/13.

underscores the need for sustainable water management practices in the region to mitigate the impact of agricultural contamination and ensure the continued availability of safe and suitable water resources for various purposes.

ACKNOWLEDGEMENTS

We would like to express our deep sense of gratitude to the Additional Director General (ADG) and Department Head (HOD) of the Geological Survey of India (GSI), Southern Region (SR), Hyderabad, the Deputy Director General (DDG) of Regional Mission Head, GSI, SR and the DDG, State Unit Telangana, GSI, SR, Hyderabad for generously providing the essential resources for the execution of this Field Season Programme. Their insightful suggestions and encouraging guidance during both fieldwork and office discussions have played a crucial role. The authors acknowledge each individual who is directly or indirectly associated with the work. The views expressed by the authors are not necessarily the views of the organization to which they belong.

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