Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Vol. 8	No. 1	pp. 111-118	2009

Original Research Paper

Hydrogeochemical Studies of Kabini River Basin, Karnataka, India

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Key Words:
Kabini river basin
Wilcox diagram
USSL diagram
Groundwater quality
Hydrochemical facies
Non-CO_3 hardness
Sodium adsorption ratio
RSC

ABSTRACT

The quality of ground water in the Kabini river basin, covering an area of 7040 sq km^2 in Karnataka, has been studied based on the composition of one hundred sixty one borewell water samples. An attempt has been made to classify the ground water by various methods. According to Bureau of Indian Standards, 97% of the water samples in the study basin are within the desirable to permissible limit. 93% of the samples fall in C_2-S_1 class of USSL diagram. According to Wilcox diagram, 91% of samples fall within the excellent to permissible classes. In the Hill-Piper diagram, majority of the groundwater samples fall in the Ca, Mg-CO_3, HCO_3, and Na, K-CO_3, HCO_3 hydrochemical facies. This has been attributed to highly weathered and fractured nature of the basement rocks. By plotting on modified Hill-Piper diagram, it is found that majority of the samples have non-carbonate hardness with a salinity ranging from 2.5 to 23 epm. It is inferred that groundwater of the area has low sodium hazard and low to medium salinity. The range of dissolved components, the values of SAR and residual sodium carbonate indicate that 97% of the water samples of the basin are suitable for domestic, irrigation and industrial purposes.

INTRODUCTION

The Kabini (Kapila or Kuppuhole), an important tributary of the river Cauvery, rises in the Western Ghats at an elevation of about 2140 m above MSL in the north Wyand in Kerala state. About 15 km below their confluence, the Kabini crosses the border between Kerala and Karnataka at Bavali from where it turns east to receive the Nugu and then Gundal at Nanjangud and joins the Cauvery from right side of the T. Narasipura. Kabini river basin comes under the semi-arid type with charnockites and gneisses occupying the total basin and has limited recharge facilities. The present study deals with the groundwater characteristics of this area and suitability of water for irrigation and other uses by employing various methods and classifications put forwarded by different workers.

STUDY AREA

The Kabini river basin lies between north latitude 11°45'-12°30' and east longitude 75°45'-77°00' with an area of 7040 sq. km^2 (Fig. 1). The basin covers the taluks of Wyand of Kerala, and Chamarajanagar, Gundlupet, Heggadadevana Kote, Hunsur, Nanjangud, Tirumakudalu, Narasipur, Mysore of Karnataka state. The basin represents an uneven landscape with intermingling hills and valleys. The eastern and western margins of the basin have hilly ranges trending NS. The central part is a plain with minor undulations. Overall slope of the basin is towards south. The trunk channel in the basin is of 7^{th} order and the drainage network shows dendritic pattern. Average annual rainfall is 1470 mm. The Kabini river basin covers the crystalline rocks, peninsular gneisses, migmaties, hornblend schist, older granites, younger granites, charnockites, interbedded sequence of pelitic schists, dolerite, amphibolites and lamprophyre dykes. Peninsular gneisses cover major part of the basin. The younger granites (close pet granite) are exposed in the western and eastern parts of the basin with almost N-S trend. Weathering is noticed up to a depth of about 35 m in the basin. A number of NNW-SSE and N-S trending dolerite dykes occur at the southeastern part of the basin. Red loamy soil and sandy loam represent major soil types of the area. The thickness of the soil cover generally varies from 1 to 3 m. Alluvium soils are found on gently sloping and flat valley bottom.

MATERIALS AND METHODS

One hundred sixty one bore well water samples of the basin were collected for chemical analysis from various locations (Fig. 2). The major chemical constituents determined were Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, $SO_4^{-2,}$ Cl^{-}, NO_3^{-}, CO_3^{-2}, HCO_3^{-}, TDS, EC and pH. Analyses were checked for completeness and accuracy on the basis of TDS content of the sample. Suitability of the groundwater for various uses

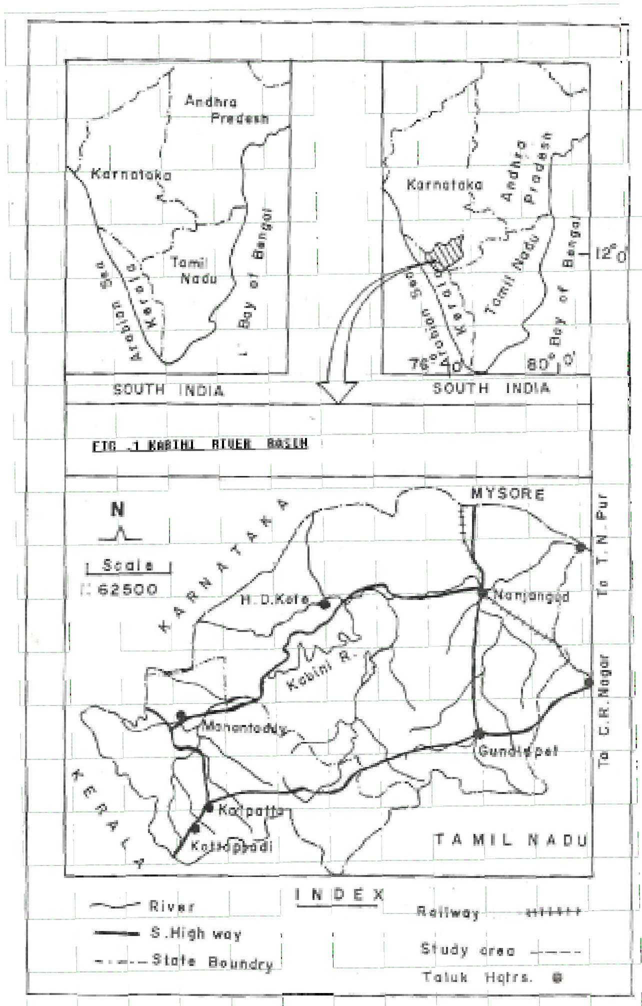

Fig. 1: Location of the geographical area and Kabini river basin.

was studied based on the major chemical constituents and the calculated parameter such as sodium adsorption ratio, residual sodium carbonate, and various classification schemes. The mechanism controlling the groundwater chemistry has also been studied using Gibbs diagrams**.** The Bureau of Indian Standards (BIS) has stipulated the concentration ranges of chemical parameters for desirable and unsuitable type of water for domestic use. The ionic concentration of the water samples from the sub-basin are compared with the BIS standards (Table 1).

RESULTS AND DISCUSSION

Electrical Conductivity (EC): The total concentration of soluble salts in irrigation water can be adequately expressed in terms of electrical conductivity for purposes of diagnosis and classification. It is highly dependent on the amount of dissolved solids (such as salts) in the water, and thus, is an index of degree of mineralization. It varies with the concentration and degree of ionization of the constituents and temperature. In general, water-having conductivity below 750 µmhos/cm is suitable for irrigation, although salt-sensitive crops may be adversely affected by irrigation water having an electrical conductivity in the range of 250 to 750 µmhos/cm. Water having a range of 750 to 2,250 µmhos/cm is widely used and satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water having a conductivity of more than 2,250 µmhos/cm is not common. The electrical conductivity in groundwaters from Kabini river basin varies from 150 to 2700 µmhos/cm with a mean of 937.36 µmhos/cm. 96% of the water samples in the area have EC values less than 2250 µmhos/cm.

Sodium Adsorption Ratio (SAR): In the past, the relative proportion of sodium to other cations in irrigation water usually has been expressed simply as the percentage of sodium among the principal cations (expressed in epm). According to the U.S. Department of Agriculture, the sodium adsorption ratio (SAR), used to express the equilibrium between exchangeable positive ions (cations) in the soil and cations in the irrigation water, is a better measure of suitability of water for irrigation with respect to the sodium (alkali) hazard. High SAR values may cause damage to soil. In the soils that are originally of non-saline and alkaline character, if excessive soluble salts or exchangeable sodium are allowed to accumulate as a result of improper irrigation and soil- management practices or inadequate drainage, they can turn into saline or alkaline. The sodium-adsorption ratio is determined by the following formula.

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

All the water samples from the area have SAR values below 10. Based on the classification of water for irrigation according to ranges of SAR (Todd 1959), groundwater from the study area is grouped as excellent class and suitable for irrigation purpose.

Residual Sodium Carbonate (RSC): Bicarbonate concentration of water affects its suitability for irrigation. Water having high concentration of bicarbonate (HCO_3) has a tendency of Ca and Mg to precipitate as the water in soil becomes more concentrated as a result of evaporation and plant transpiration and gets fixed in the soil by the process of base exchange, thereby decreasing the soil permeability. The Ca and Mg precipitate as carbonates, and residual CO_3 or HCO_3 is left in solution as sodium carbonate (Na_2CO_3). The potential amount of such residual sodium carbonate (RSC) may be computed by the formula.

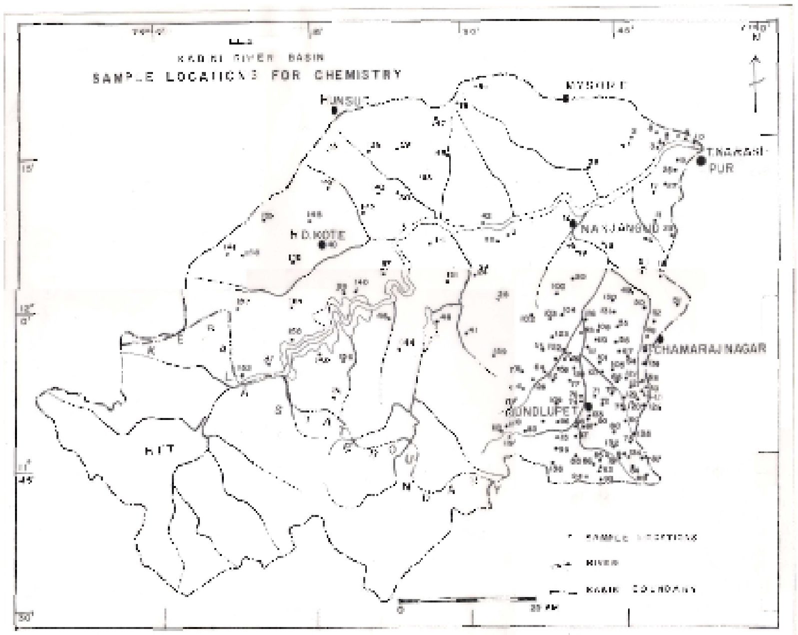

Fig. 2: Location of sampling stations.

Table 1: Standards of drinking water and the percentage of water samples.

Constituents	Category	Limits set by BIS (1991)	%of Samples
pH	I	>6.5 <8.5	96.84
	II	<6.5 >8.5	3.16
Electrical conductivity	I	<750	45.26
(EC) µmho/cm at 25°C	II	750-3000	54.74
	III	>3000	0.00
Calcium (Ca mg/L)	I	<75	64.21
	II	76-200	35.79
	III	>200	0.00
Magnesium (Mg mg/L)	I	<30	55.79
	II	31-100	42.11
	III	>100	2.11
Chloride (Cl mg/L)	I	<250	88.42
	II	251-1000	11.58
	III	>1000	0.00
Sulphates (SO_4 mg/L)	I	<200	97.89
	II	201-400	2.11
	III	>400	0.00
Nitrates (NO_3 mg/L)	I	<45	62.11
	II	46-100	26.32
	III	>100	11.58
Total hardness	I	<300	60.00
(as $CaCO_3$ mg/L)	II	301-600	31.58
	III	>600	8.42

Category I-Desirable; Category II-Permissible in absence of alternative source; Category III-Unsuitable.

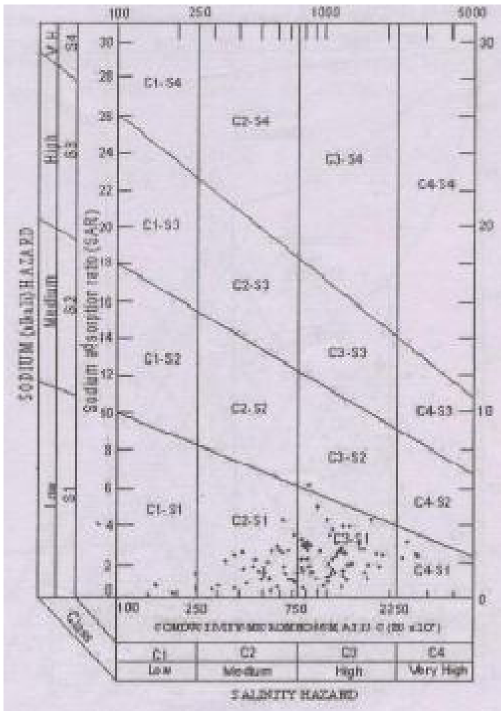

Fig. 3: USSL diagram for classification of irrigation water.

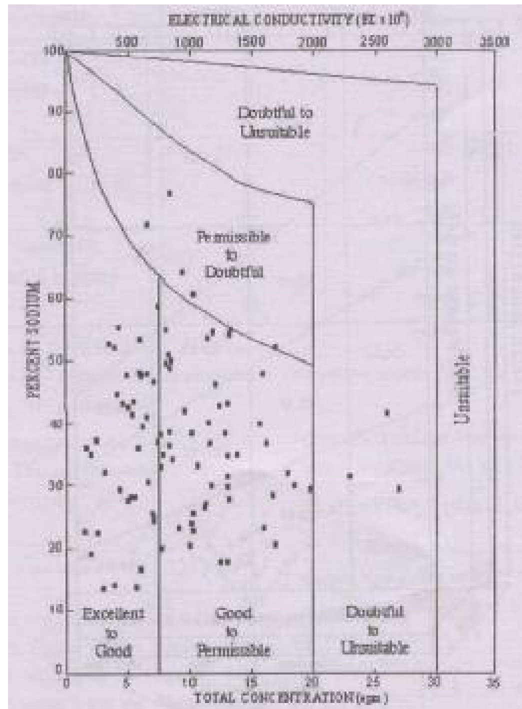

Fig. 4: Wilcox diagram for classification of irrigation water.

$(Na_2CO_3) = (CO_3 + HCO_3) - (Ca^{++} + Mg^{++})$

Based on the classification of groundwaters by the U.S. Department of Agriculture on the basis of the concept of residual sodium carbonate, 96% of the present samples fall in the safe and marginal category.

USGS Salinity Classification: Water used for irrigation can be rated based on salinity hazard and sodium or alkali hazard, according to a method formulated by the U.S. When the sodium adsorption ratio and the electrical conductivity of water are known, the classification of the water for irrigation can be determined by correlating them (Fig. 3). Low-sodium water (S_1) can be used for irrigation on almost all soils with little danger of developing harmful levels of exchangeable sodium (Kanas Geological Survey 1998). Medium-sodium water (S_2) will present an appreciable sodium hazard in certain fine-textured soils, especially poorly leached soils. Such water may be used safely on coarse-textured or organic soils having poor permeability. High-sodium water (S_3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage and leaching and addition of organic matter. Very high sodium water (S_4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil. Low-salinity water (C_1) can be used for irrigation of most crops on most soils with little likelihood soil salinity development. Medium-salinity water (C_2) can be used if a moderate amount of leaching occurs. Crops of moderate salt tolerance can be irrigated with C_2 water without special practices. High-salinity water (C_3) cannot be used on soils of restricted drainage. Very high salinity water (C_4) is not suitable for irrigation under ordinary circumstances. It can be used only on crops that are very

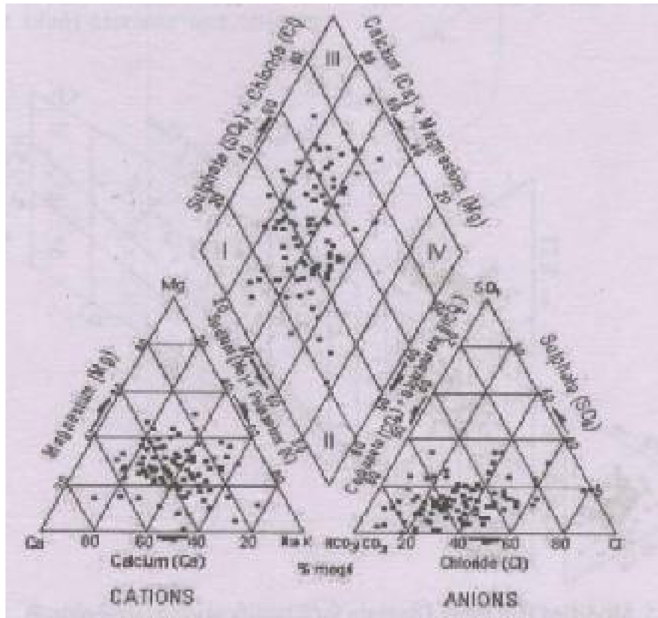

Fig. 5: Trilinear diagram showing chemical composition of water samples.

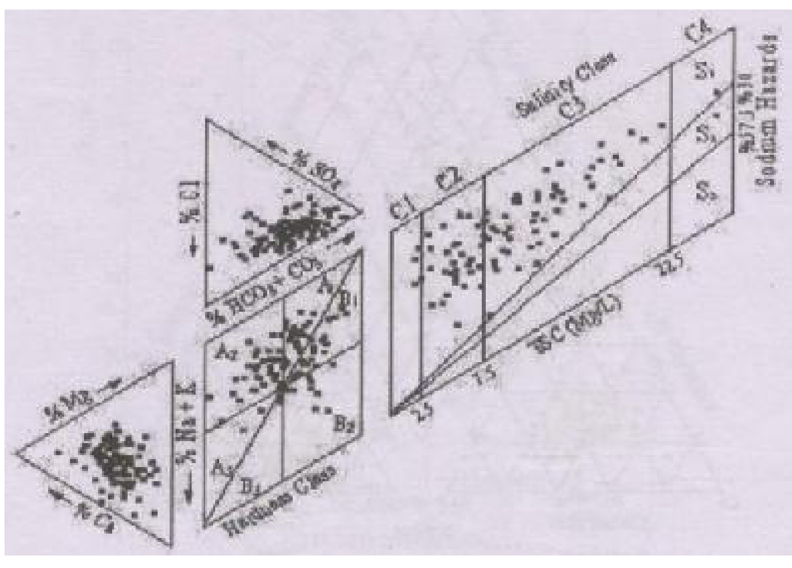

Fig. 6: Modified Hill Piper diagram for classification of irrigation water.

tolerant to salt and also only if special practices are followed including the provision for a high degree of leaching. Based on this, 95% of the samples of the study area fall in C_1-S_1, C_2-S_1 classes and are suitable for irrigation.

Wilcox Diagram: Quality of water used for irrigation can also be assessed based on salinity as determined by electrical conductivity and soluble sodium percentage according to the method pro-

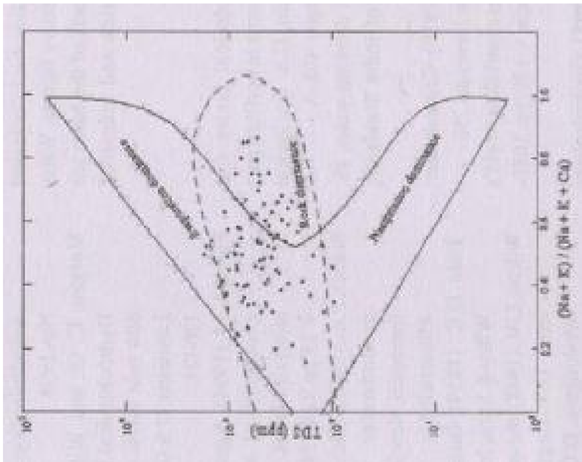

Fig. 7a: Plots of TDS against Na+K/Na+K+Ca (after Gibbs 1970).

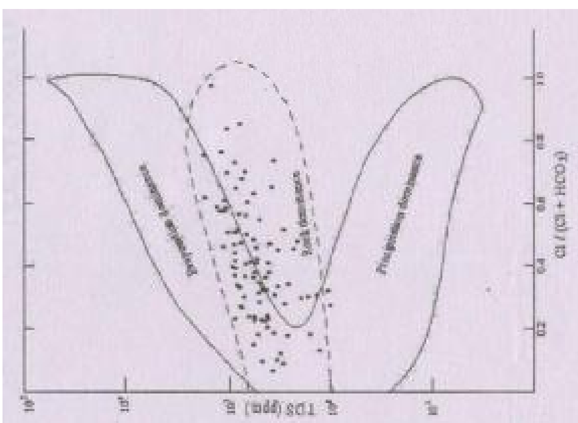

Fig. 7b: Plots of TDS against Cl/Cl+HCO_3 (after Gibbs 1970).

posed by Wilcox (1948). He proposed a classification in which percent sodium is correlated against electrical conductivity or total concentration of soluble salts to find the suitability of water for irrigation (Fig. 4). According to this classification more than 91% of the ground water samples of the study basin fall in the excellent to permissible class and are suitable for irrigation purposes.

Ground Water Facies: Back (1966), Morgan & Winner (1962) and Seaber (1962) introduced the concept of hydrochemical facies (Freeze & Cherry 1979). Hydrochemical facies depict the diagnostic chemical character of water in various parts of the system. The facies reflect the effects of chemical reactions occurring between minerals within the lithologic framework and groundwater. The mineralogy of an aquifer system largely determines the type of hydrochemical facies that will develop. Flow patterns modify the hydrochemical facies and control their distribution.

Hill Piper Diagram: The trilinear Piper diagram (Piper 1994) is one way of comparing quality of water. The first step is for determining the water facies for the purpose of studying the evolution of groundwaters. The lower left ternary or cation ternary, compresses the cation composition as on equivalent fraction (% epm) of calcium (total dissolved Ca), magnesium (total dissolved Mg) and the sum of sodium and potassium (Na + K). Similarly, the lower right ternary or anion ternary contrasts the anion composition in terms of fraction of equivalents of sulphate ion SO_4^{-2} + chloride ion (Cl^-) and the sum of bicarbonate and carbonate ions (HCO_3^- + CO_3^{-2}). The central diamond is a combination of the cation and anion fractions. The cation and anion plots (Fig. 5) indicate that most of the present samples fall in no dominant and carbonate types respectively. The central field reveals that single numbers 41, 7, 29 and 5 water samples of the study basin fall in I, II, III, IV hydrochemical facies. Majority of the samples belongs to Ca^{+2}, Mg^{+2}, CO_3^-, HCO_3^- and Ca^{+2}, Mg^{+2-} Cl^-, SO_4^{-2} facies.

Modified Hill Piper Diagram: A modification of Hill-Piper method was proposed in which the trilinear plot and U.S. Salinity Research Laboratory diagram are combined with few modifications. Instead of sodium adsorption ratio (SAR), the sodium concentration is plotted against salinity. The advantage of Handa's method of graphical representation is that the suitability of water for irrigation purposes can be distinctly brought out. Waters are classified as A_1, A_2, A_3 or B_1, B_2 and B_3 classes (based on hardness and other ionic characters), C_1, C_2, C_3, C_4 and C_5 classes (based on salinity) and S_1, S_2 and S_3 classes (based on sodium hazard) (Fig. 6). This classification shows that majority of the samples fall in A_1, A_2 classes of permanent hardness and B_1 class of temporary hardness. The parallelogram indicates that majority of the samples from the basin fall in C_2-S_1 and C_3-S_1 fields. From this diagram, groundwater of the area has been identified as of low sodium hazard, low to medium salinity and temporary hardness. The overall quality of the water is, thus, good for irrigation.

Mechanism of Rock Water Interaction: Mechanism controlling the chemical composition of water has been discussed by various workers. It is well established that there is a close relationship between water composition and aquifer lithology (Gibbs 1970). Gibbs plots distinguish the interaction of groundwater due to precipitation or rock or evaporation, which helps in understanding the factors that control the chemistry of groundwater. From ratios of (1) Na + K/Na + K + Ca and TDS (Fig.7a) and (2) Cl/C1 + HCO_3 and TDS (Fig. 7b), it is found that majority of the samples suggest an interaction between rock and the percolating water into the subsurface.

CONCLUSION

The area under study is a hard rock terrain and the groundwater occurs in unconfined condition and there is not much variation in the groundwater quality. The USSL and Wilcox diagrams indicate that samples 5 and 8 are not suitable for irrigation and the central part of the area falls under less recharge area due the clayey soil. The infiltrated water, circulated through weathered granitic and gneissic rocks that contain mafic enclaves, and rock water interaction due to increased resident time might be the causative factors. Water samples from the remaining parts of the basin are suitable for domestic, irrigation and industrial purposes.

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