

Hydrochemical Characteristics and Quality Assessment of Stream Water in Parts of Gadag, Koppal and Ballery Districts of Karnataka, India

Nadeem Ahmad Bhat*, Prasun Ghosh, Waseem Ahmed, Farha Naaz,
Alakananda Priyadashinee

Geological Survey of India, State Unit, Andhra Pradesh, SR, Hyderabad – 500 068, India

*E-mail: nadeem.bhat@gsi.gov.in

ABSTRACT

Seventeen water samples were collected from various streams in parts of Gadag, Koppal and Ballery districts of Karnataka and analyzed for major ions and heavy metals to determine the processes controlling surface water chemistry and suitability of water for drinking, livestock uses and irrigation purposes. The water samples are moderately alkaline to alkaline in nature and soft to moderately hard. The order of cations is $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$, of anions is $\text{HCO}_3 > \text{Cl} > \text{SO}_4 > \text{CO}_3 > \text{NO}_3$ and heavy metals $\text{Sr} > \text{Fe} > \text{V} > \text{Ba} > \text{Zn} > \text{Ni} > \text{Mn} > \text{As} > \text{Cu} > \text{Cr} > \text{Pb} > \text{Co}$. According to Gibbs diagram, the water samples fall in the dominant rock-water interaction area, suggesting chemical weathering of the rock forming minerals as the main process contributing ions to the surface water. Scatter plots of $\text{Ca} + \text{Mg}$ vs $\text{HCO}_3 + \text{SO}_4$ and Ca/Na vs HCO_3/Na clearly indicate the silicate weathering playing a dominant role on water chemistry. The evolution of surface water into Ca-Na-HCO_3 and Ca-HCO_3 water types is due to easy dissolution of silicate minerals and less time for water-rock interaction. Surface water samples are characterized by $\text{Na-Ca-HCO}_3\text{-Cl}$ the principal water type of schoeller's plot, which can be related to the weathering of the silicate rocks along with some anthropogenic input. The physical parameters, major ions and heavy metals are within the permissible limits of WHO and BIS standards except for two samples, suggesting the water as suitable for domestic and livestock uses. The stream water is suitable for irrigation as per the quality parameters and plots including EC, sodium percent, sodium adsorption ratio, Wilcox and USDA classification diagrams.

INTRODUCTION

Streams and rivers are integral parts of the hydrological cycle that carry water from higher to lower elevations downstream and provide an essential resource of water supply (Vörösmarty et al., 2000; Oki and Kanae, 2006). The chemistry of stream water is influenced by a number of factors such as geology of the catchment area, degree of chemical weathering of various rock types, inputs from sources other than water-rock interaction (Domenico, 1972; Parween et al., 2017) and anthropogenic urbanization and industrial activities (Potter, 1978; Patel et al., 2018). The combinations of all the factors make streams the most vulnerable water bodies to pollution (Arenas-Sánchez et al., 2016).

In India, scarcity of clean and potable drinking water has emerged as one of the serious issues in recent years particularly in West Bengal, Jharkhand, Orissa, Uttar Pradesh, Andhra Pradesh, Rajasthan, Karnataka and Punjab (Tiwari and Singh, 2014). Access to safe and potable drinking water remains an urgent necessity, as 90% of the rural and 30% of urban population depends on untreated surface or

groundwater resources (Kumar et al. 2005). The overdependence on groundwater has led to around 10 million at risk due to arsenic in six states and 66 million people in 22 states at risk due to high fluoride (Ghosh 2007).

In some parts of Karnataka limited availability of groundwater as also its salinity and fluoride problems restrict its usage for drinking and domestic purposes. The fluoride concentration in groundwater exceeds the desirable and permissible limits (CGWB, 2011, 2013). Recently, the Government of Karnataka has provided drinking water units at village level. In addition, ponds for rainwater harvesting and check dams across streams continue to be used for drinking, agriculture and domestic uses during the dry season. Taking above facts into consideration, stream water samples were collected from parts of Ballery, Gadag and Koppal districts of Karnataka during September-October, 2017 and analyzed for major ions and trace elements. The aim of the work is to understand the mechanism controlling the composition of surface water and its suitability for domestic and agricultural purposes. Water quality monitoring is a helpful tool not only to evaluate the impacts of pollution but also help in making more informed environmental decision to ensure an efficient management and protection of the valuable water resource of the area.

STUDY AREA

The study area covers parts of Gadag, Koppal and Bellary districts of Karnataka, bounded by latitudes $15^{\circ}00'00''$ and $15^{\circ}30'00''$ N with longitudes $75^{\circ}45'00''$ and $76^{\circ}00'00''$ E (Fig. 1), being a part of Tungabhadra drainage basin. The physiographic details are observed in the Survey of India toposheet. The area is a plain land with prominent N-S trending Kappatgudda ridge on the western side of the area. The general drainage pattern is sub-dendritic to dendritic with parallel pattern at places. The Tungabhadra river flows towards the south-western part of the area. The area is semi-arid, categorized as drought prone area with an annual rainfall of 600mm (CGWB, 2011, 2013). The annual temperature ranges from 25°C to 40°C , which may reach up to 45°C during the month of May and drops down up to 16°C during December and January (IMD, 2005).

GEOLOGY

The area is occupied by Precambrian meta-sedimentary and meta-volcanic rocks of Chitradurga Group of Dharwar Supergroup resting unconformably over the Peninsular Gneissic Complex (PGC) (Fig.2). The Chitradurga Group comprises para-amphibolite, greywacke, banded ferruginous chert/banded manganiferous chert, sericite-phyllite, argillite, metabasalt and polymictic conglomerate of Hiriyur Formation (Beckinsale et al., 1980; Chadwick et al., 2003). The PGC consists of granitic gneisses of PGC-I on the eastern margin of the

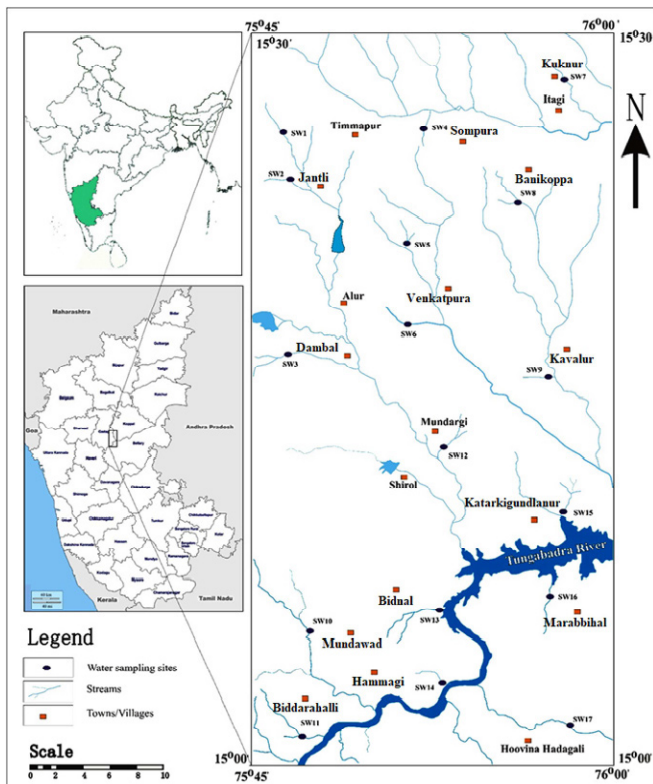


Fig.1. Location map of the study area showing stream water sampling sites.

schist belt and is a mixed assemblage of biotite and hornblende gneisses, granitic gneisses and migmatites in the southwestern corner of the area (Beeraiiah et al., 1996; Bhaskar, 1992).

METHODOLOGY

Seventeen water samples were collected from different streams in parts of Gadag, Koppal and Ballary districts of Karnataka during the post-monsoon period i.e., Oct-Nov, 2017 (Fig.1) as a part of National Geochemical Mapping (NGCM) programme of Geological Survey of

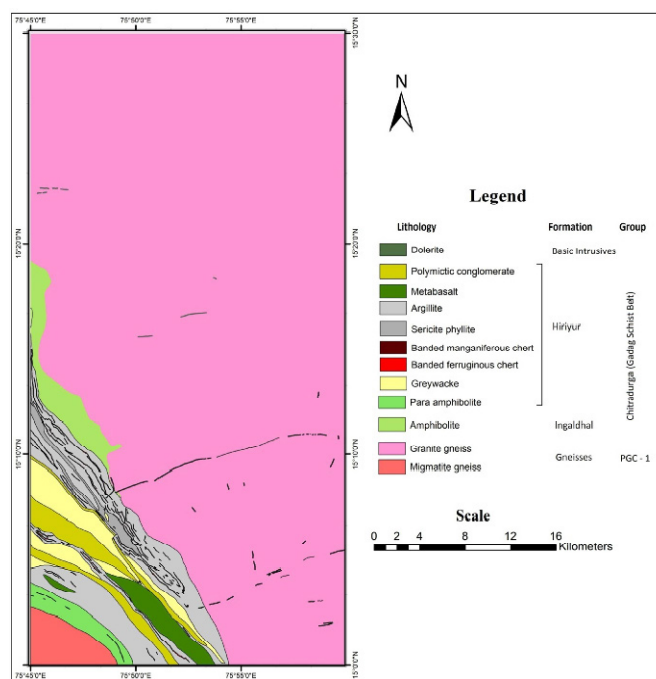


Fig.2. Geological map of the study area.

India. Sample collection, transportation and analysis were carried out according to the standard methods and procedures (APHA, 2006). To avoid the effect of floating debris, the samples were collected at depths greater than 30 cm below the water surface (Goldscheider and Drew, 2007). Prior to sample collection, the containers were washed with concentrated HNO_3 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.

RESULTS AND DISCUSSION

The analytical data of physical and chemical parameters including heavy metals in water samples and compliance of water quality to drinking standards of WHO (2006) and BIS (2012) are presented in Table 1 and discussed below.

Physical Parameters

The water samples are moderately alkaline to alkaline in nature with pH ranging from 6.9 to 9.4 with an average of 7.9. The weathering pattern in the catchments area are controlled by pH, which in turns determines the availability of major ions in the water (Gopal et al., 2018). Electrical conductivity ranges from 125 to 920 $\mu\text{S}/\text{cm}$ with an average of 387.9 $\mu\text{S}/\text{cm}$. The EC is the measure of ionic strength of a solution that depends on the concentration and rate of movement of ionic species (Fetter, 2000). Total dissolved solids (TDS) in the water samples vary from 80 to 1220 mg/l with an average of 251.8 mg/l. Total hardness (TH) from 25 to 485 mg/l with an average of 94.4 mg/l.

Major Ions

Major cation chemistry of the water samples is dominated by Na^+ followed by Ca^{2+} , Mg^{2+} and K^+ . The concentration of Na^+ ranges from 5.9 to 224 mg/l with an average of 45.4 mg/l. Weathering of the sodium-bearing minerals like plagioclase feldspar release the soluble sodium products in water. Ca^{2+} ranges from 8 to 130 mg/l with an average of 26.4 mg/l. Generally, calcium and magnesium ions are derived from the leaching of limestone, dolomites, gypsum and anhydrites (Garrels, 1976). The absence of carbonate lithology in the study area rules out the effect of carbonate weathering in water chemistry. Calcium may have been sourced from the minerals such as albite, hornblende and also from the plagioclase weathering. Further, the calcium ions can also be derived from cation exchange process. Mg^{2+} ranges from 1.2 to 38.9 mg/l with an average of 6.9 mg/l. The concentration of Mg^{2+} may be due to the ion exchange or weathering of amphiboles, pyroxenes and clay minerals. The concentration of K^+ ranges from 2.2 to 15.9 mg/l with an average of 3.3 mg/l. Weathering of the K-feldspar releases potassium into water.

Among the anions, HCO_3^- is the dominant ion followed by Cl^- , SO_4^{2-} , CO_3^- and NO_3^- . HCO_3^- ranges from 48.8 to 317.3 mg/l, at an average of 116.3 mg/l. Bicarbonate may be derived from carbon dioxide in the atmosphere and also from the surrounding soils, mainly due to weathering processes (Singh, 2000; Stumm, 1992). Cl^- concentration ranges from 3.5 to 425.4 mg/l with an average of 43.2 mg/l. Chloride is the major source of contamination due to its conservative characteristics and surficial origin. The concentration of SO_4^{2-} ranges from 2.5 to 111.1 mg/l at an average of 29.3 mg/l. The primary sources of sulphate ions include the evaporate minerals such as anhydrite, gypsum and also may be due to leaching of fertilizers used in agriculture. The CO_3^- ions are detected in only three samples, ranging from 6 to 12 mg/l with an average of 8 mg/l. NO_3^- concentration in water samples ranges from 2.5 to 18.9 mg/l with an average of 6.5 mg/l. Nitrate is the common form of nitrogen that occurs in surface waters and due to decomposition of soil organic matter, leaching of chemical fertilizers and animal excreta (Hill, 1982; Jeelani et al., 2011).

Table 1. Analytical results of stream water samples collected during September – October, 2017 and comparison with drinking water quality standards of WHO, 2006 and BIS, 2012.

Parameters	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	SW17	WHO	BIS
pH	7.9	8.0	8.0	8.8	8.1	9.4	7.9	8.0	8.4	7.7	7.2	7.9	7.9	6.9	7.9	7.5	7.5	7-8.5	6.5-8.5
EC $\mu\text{S/cm}$	210	180	125	295	240	235	145	220	170	990.0	505.0	1920	380.0	215.0	210.0	270.0	285.0		
TDS mg/l	135	115	80.0	190	155	155	95.0	140	110	645.0	330.0	1250	245.0	140.0	135.2	174.9	185.0	500	500
TH	30.0	55.0	35.0	25.0	40.0	35.0	35.0	25.0	35.0	190.0	150.0	485.0	120.0	60.0	65.0	120.0	100.0	100	200
Ca	10.0	18.0	12.0	8.0	10.0	10.0	10.0	8.0	10.0	48.1	36.1	130.3	34.1	16.0	18.0	38.1	32.1	75	75
Mg	1.2	2.4	1.2	1.2	3.6	2.4	2.4	1.2	2.4	17.0	14.6	38.9	8.5	4.9	4.9	6.1	4.9	30	30
Na	32.5	16.3	10.5	54.8	36.5	37.0	17.2	38.2	23.2	144.0	45.3	224.0	35.3	12.7	19.5	5.9	19.4	200	-
K	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	15.9	2.5	2.5	2.5	12	-
CO ₃	ND	ND	ND	6.0	ND	12.0	ND	ND	6.0	ND	ND	ND	ND	ND	ND	ND	ND	-	-
HCO ₃	97.6	85.4	48.8	79.3	85.4	85.4	48.8	85.4	61.0	292.9	128.1	317.3	134.2	85.4	91.5	122.0	128.1	-	200
Cl	3.5	3.5	3.5	3.5	7.1	7.1	3.5	3.5	3.5	102.8	60.3	425.4	39.0	10.6	17.7	17.7	21.3	200	250
SO ₄	11.3	9.1	9.4	60.6	29.0	19.2	16.8	27.7	19.9	111.1	48.7	99.3	18.2	7.2	5.9	<5	<5	200	200
NO ₃	7.7	<5	<5	7.1	6.0	<5	7.4	6.2	6.2	<5	11.1	5.8	9.6	18.9	<5	6.3	5.6	45	45
F	0.6	0.4	0.2	1.1	0.4	0.5	0.5	0.9	0.5	0.8	0.3	1.0	0.3	0.4	0.3	0.3	0.2	1.5	1.5
SiO ₂	14.4	19.4	18.8	16.4	18.4	17.1	22.0	32.0	23.0	11.2	6.7	29.1	16.0	19.1	10.1	5.6	9.0	-	-
As $\mu\text{g/l}$	7.5	4.1	<1	10.5	7.8	6.9	3.0	4.7	3.2	3.1	1.9	1.9	<1	<1	<1	1.0	1.3	50	10
Cr	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	50	50
Mn	5.2	5.9	7.5	3.8	4.5	4.7	4.0	9.1	3.3	2.9	3.0	3.3	2.0	10.3	3.9	<0.5	<0.5	100	100
Fe	50.0	50.0	109	50.0	50.0	50.0	50.0	148	50.0	50.0	50.0	137.8	50.0	50.0	50.0	403.2	107.4	300	300
Co	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.1	0.2	-	-
Ni	10.8	20.6	14.0	5.7	12.4	15.3	3.7	23.5	2.8	3.4	5.5	3.7	<1	2.5	2.7	<1	<1	-	20
Cu	8.0	5.0	6.1	3.0	4.8	2.4	1.8	2.7	1.6	2.1	2.3	2.2	<0.5	0.9	1.6	0.3	0.6	50	50
Zn	13.3	17.4	13.8	11.4	13.7	7.4	16.7	24.7	16.3	11.9	9.8	8.9	7.6	7.1	9.5	<2	<2	5000	5000
Sr	119	197	156	80.2	128	125.	94.0	109	109	474.5	353.2	1304	221.7	142.2	135.0	292.1	180.5	-	-
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	50	10
V	79.9	57.9	14.2	146	91.6	87.0	54.2	75.2	48.4	10.30	14.61	<5	<5	<5	5.51	5.01	<5	-	-
Ba	3.51	37.2	6.24	<1	13.8	22.4	6.09	21.7	19.0	101.1	68.39	213.2	10.14	81.83	38.22	64.09	22.82	-	-
Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	5	3

Apart from the major ions, SiO₂ and F⁻ were also analyzed. The concentrations of SiO₂ range from 5.6 to 32 mg/l with an average of 17 mg/l. The weathering of silicate minerals especially quartz releases silica in water. The F⁻ ion ranges from 0.2 to 1.1 mg/l with an average of 0.5 mg/l. The main source of the fluoride in water is fluorite and apatite, released due to the weathering of pegmatites. Leaching of chemical fertilizers also releases fluoride in water (Handa, 1988; Heller et al., 1997; Raju et al., 2012).

Heavy Metals

The dominance of heavy metals in the surface water are in the following order: Sr>Fe>V>Ba>Zn>Ni>Mn>As>Cu>Cr>Pb>Co. Heavy metals in water originate from either natural sources, derived from rock weathering and leaching from soils or anthropogenic sources such as from domestic and industrial wastes and use of chemical fertilizers in cultivated lands (Gopal et al., 2018).

Geochemical processes controlling surface water chemistry

Weathering of the crustal rocks dominantly controls water chemistry as different rock types yield diverse residual matters transported by water (Garrels and Mackenzie, 1971; Stumm, 1992). The relative proportion of each ion or compound depends on the composition of the host rock, solubility index of ionic species and anthropogenic factors (Zhang et al., 1995). Major ion chemistry thus acts as a powerful tool for determining the solute sources and for describing water evolution as a result of water–rock interaction leading to silicate weathering and ion exchange processes etc. (Hiscock, 1993; Jeelani and Shah, 2006). To understand the source of the solutes in a broader perspective, the hydrochemical data were plotted in the Gibb's diagram (Gibbs, 1970). The water samples fall in the rock–water interaction dominance area of the diagram which suggests that chemical weathering of the rock forming minerals is the main process contributing ions to the surface water (Fig. 3). The water samples were plotted in Ca²⁺+Mg²⁺/HCO₃⁻+SO₄²⁻ scatter diagram (Datta and Tyagi, 1996), where that majority of the samples fall below the equiline indicating that silicate weathering plays a dominant role for supplying the ions to the surface water (Fig. 4A). To further examine the effect

of lithological weathering, water samples were plotted between silicate and carbonate end members (Gaillardet et al., 1999). The plots fall towards the silicate end member, which clearly signifies the dominant role of silicate weathering in water chemistry (Fig. 4b). Further, the Na/Cl molar ratio ranges from 0.5 to 23.8 and the higher ratio is due to weathering of silicate minerals like plagioclase feldspar (Meybeck, 1987). Similarly, the low equivalent ratio of Na + K/HCO₃⁻ of 0.2 to 1.9 also implies the contribution from silicate rocks.

In order to assess the source of the solutes in a broader perspective, the hydrochemical data were plotted in the Piper trilinear diagram (Piper, 1994). The triangular fields are plotted separately with epm values of cations (Ca²⁺, Mg²⁺) alkali earth, (Na⁺+K⁺) alkali, (HCO₃⁻) weak acid and strong acid (SO₄²⁻ and Cl⁻). The water types identified include Ca-HCO₃ (n=7), Mixed Ca-Na-HCO₃ (n=7), Na-HCO₃ (n=1), Na-Cl (n=1) and Mixed Ca-Mg-Cl (n=1) (Fig. 5). The occurrence of dominant Ca-HCO₃ and Ca-Na-HCO₃ and Na-HCO₃ water types accounting for about 82% of samples is attributed to interaction of water with multiple lithologies, resulted from incongruent dissolution

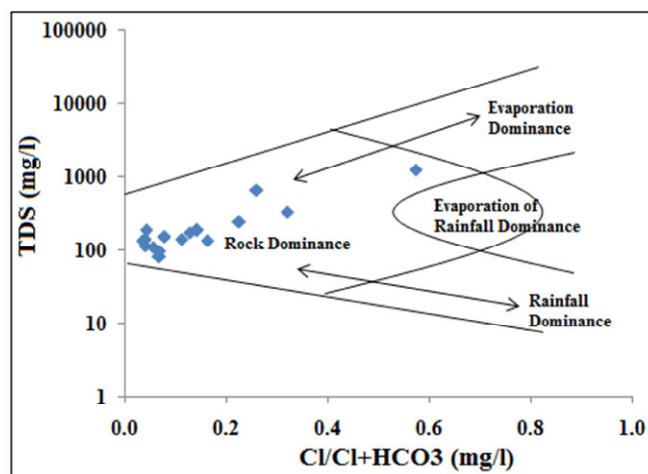


Fig 3. Gibbs plot showing geochemical processes controlling surface water chemistry of the study area (after Gibbs, 1970).

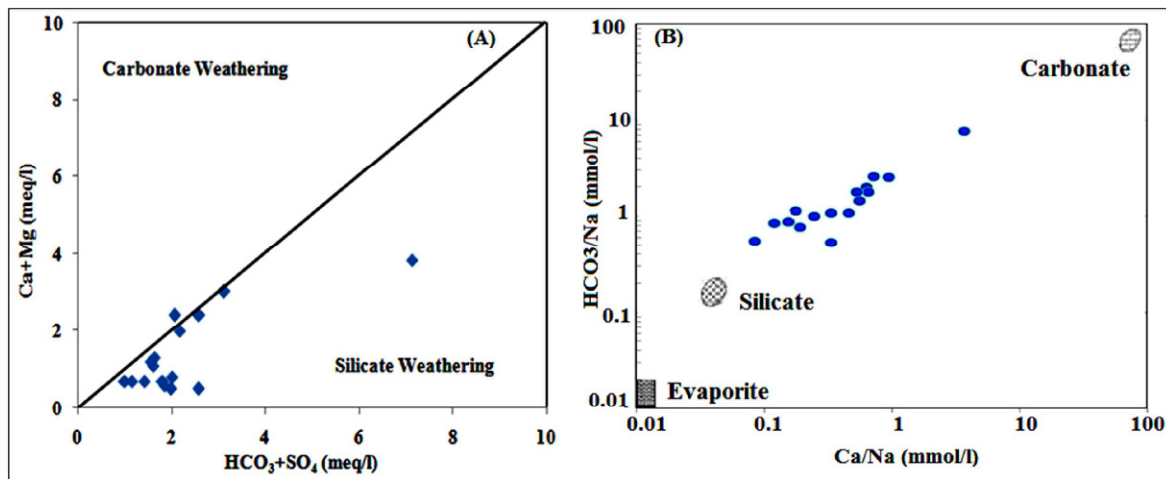


Fig 4. Scatter plots: (A) Ca + Mg vs. HCO₃ + SO₄ (Dutta and Tyagi, 1996) and (B) HCO₃/Na vs. Ca/Na Plot (Gaillardet et al., 1999).

of silicate rocks, as also to less time for water-rock interaction, dissolution of different gases and dust content in atmospheric precipitation and higher mixing processes in the waters of the area (Jeelani et al., 2011; Bhat et al., 2014). Na-Cl type may be due to the anthropogenic activity.

To study the comparative changes in the concentrations and ratios of water quality parameters for different samples, the different water quality parameters are plotted along with their concentrations (meq/l) in Scholler's diagram as shown in Fig. 6 (Scholler, 1965). It is evident from the figure that HCO₃, Cl, Ca and Na+K contents show an increasing trend whereas SO₄ and Mg contents are decreasing. The high concentrations of ions are observed in the sample no. 2, which may be due to anthropogenic activity. On an average Na-Ca-HCO₃-Cl is the principal water type which can be related to the weathering of the silicate rocks along with some anthropogenic input.

Water Quality Assessment

The suitability of water for drinking, domestic, livestock and agricultural purposes is based on the water quality standards of world health organization (WHO, 2006) and Bureau of Indian standards (BIS, 2012). Most of the parameters are within the permissible limits except for a few samples. Two samples including SW4 and SW6 exceed the

WHO and BIS permissible limits for making the water more alkaline and undesirable for drinking. Sample No. SW2 exceeds the WHO and BIS permissible limits for TDS, TH, Ca, Mg, Na, HCO₃ and Cl content, which may be due to anthropogenic influence. Sample no. SW10 exceeds permissible limit in TH, which may be due to increased Ca, Mg and HCO₃ content in water sample. Similarly, sample no. SW16 exceed permissible limit in Fe. This may be due to the leaching of the iron bearing rocks. Overall, the surface water of the study area can be regarded as potable and suitable for drinking purposes. For livestock, the quality specifications for drinking water are almost same as for humans, although the total permissible levels of total suspended solids and salinity may be higher (Ravindra and Garg, 2007). TDS is the main parameter to evaluate the suitability of water for livestock. Based on the Australian and UNESCO standards, TDS value between 0 and 2900 mg/l is suitable for all animals (Hamill and Bell, 1986). Hence the water samples with TDS ranging from 80 to 1200 mg/l with a mean value of 251.8 mg/l are good for livestock. As regards washing, hardness of the water causes more consumption of detergents and some evidences indicate its role in heart disease. As per the Sawyer and McCarthy hardness classification (Sawyer and McCarthy, 1967), 65% samples are soft (n=11), 24% are moderately hard (n=4), 6% are hard (n=1) while 6% fall in very hard category (n=1). The hardness of

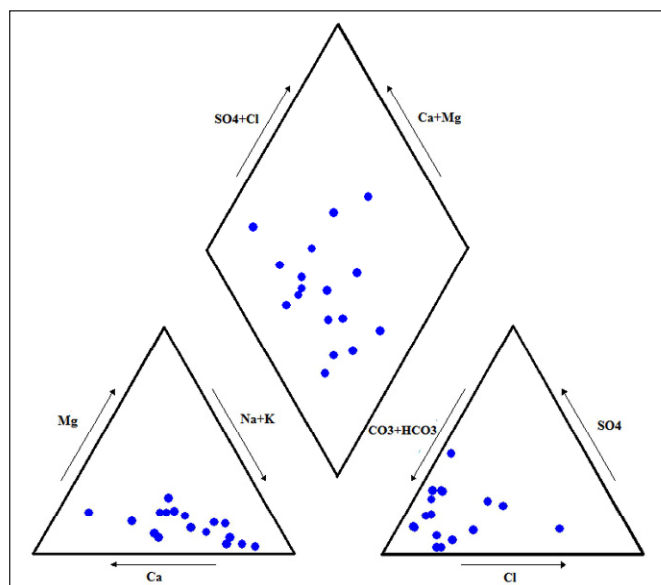


Fig 5. Piper Trilinear Diagram showing possible Hydrochemical facies in stream water samples (Piper, 1994).

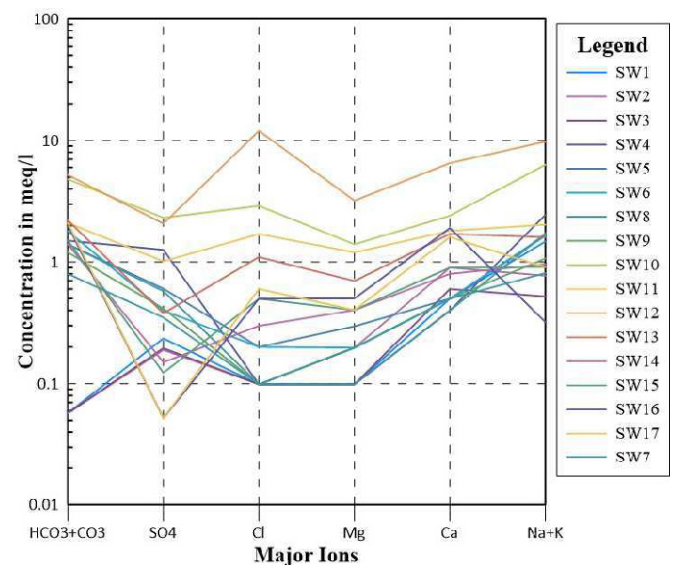


Fig 6. Scholler diagram showing comparative changes in the concentrations and ratios of water quality parameters for different samples (Scholler, 1965).

the water may be due to the increased Ca, Mg and HCO₃ ions in water (Aris et al., 2013). In fact, waters with more than 150 ppm hardness may cause carbonate precipitate problem (Salehi and Hosseinifard, 2012).

For irrigation purposes, a vital water quality parameter is salinity hazard as measured by total dissolved solids. The TDS of the water samples ranged from 80 to 1220 mg/l and hence are considered good for irrigation. Excessive sodium in irrigation water result in sodium hazards. Sodium replaces calcium and magnesium ions in soil causing reduced permeability and hardening of soil hardens. To assess irrigation water quality, the parameters such as percent sodium (Na %) and sodium adsorption ratio (SAR) were calculated.

$$\text{Na}\% = (\text{Na}/\text{Na}+\text{Mg}+\text{Ca}+\text{K}) \times 100\% \quad (\text{Wilcox, 1955})$$

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

Where all the ionic concentrations are expressed in milli-equivalents per liter (meq/L). The percent sodium values of the water samples less than sixty are thus safe for irrigation purposes. The water samples with TDS ranging from 0.2 to 4.8 mg/l with a mean value of 2.1 mg/l are classified as excellent for irrigation as all the samples fall in S1 category (sodium hazard class). Wilcox diagram with percentage Na plotted against specific conductance is used in evaluating the irrigation waters (Wilcox, 1955). An appraisal of the Wilcox diagram shows that 88% of the samples fall in excellent to good field and 12% fall under good to permissible fields of the diagram indicating that water samples from the study area are suitable for the irrigation purpose for majority of crops and most of the soils (Fig 7). A more detailed analysis for the suitability of water for irrigation can be made by plotting the sodium adsorption ratio (SAR) and electrical conductivity (Salinity Hazard) on the United States Department of Agricultural classification diagram (Richards, 1954). About 82% of the samples (n=14) fall in C1S1 category, 12% of samples in C2S1 category (n=2) and 6% of the samples in C3S1 category (n=1), indicating that the water is good for irrigation purposes (Fig. 8).

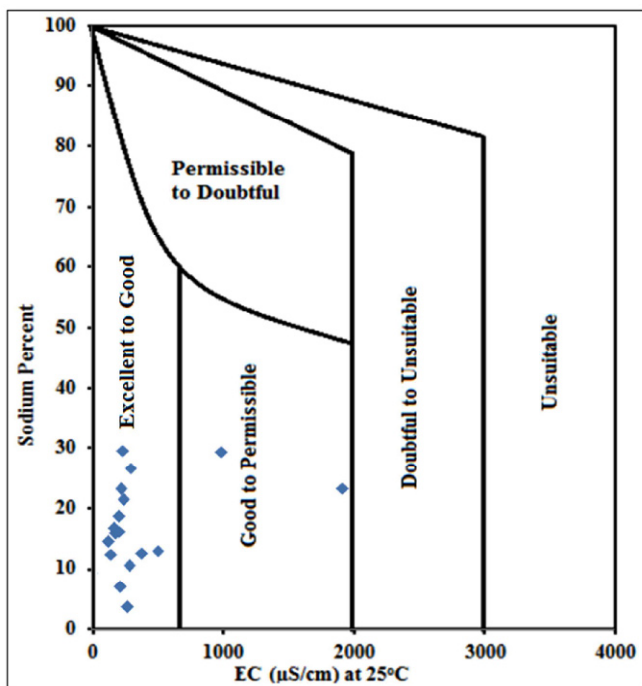


Fig. 7. Plot of percent sodium vs electrical conductivity for classification of water samples (after Wilcox, 1955).

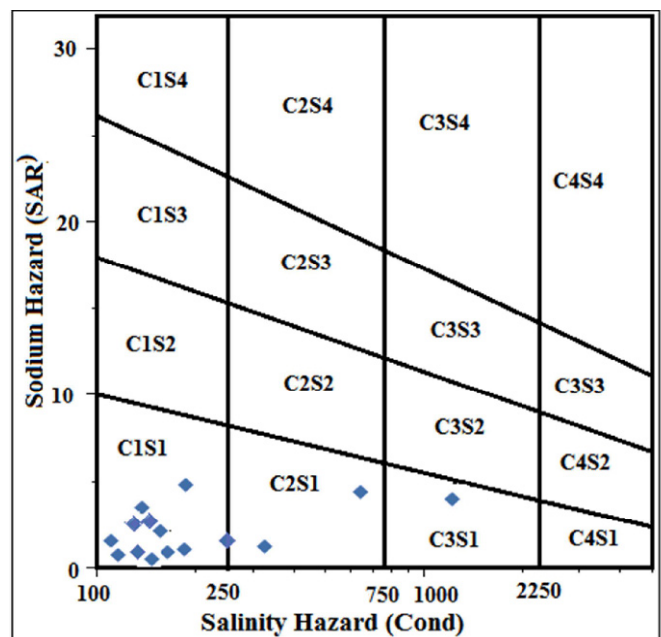


Fig.8. SAR vs Salinity Hazard diagram showing classification and suitability of water for irrigation (after Richards, 1954).

CONCLUSIONS

The chemical analysis of the surface water in parts of Gadag, Koppal and Ballary districts of Karnataka indicates that the water is moderately alkaline to alkaline, soft to moderately hard and fresh in terms of major cations and anions. Na is the dominant cation followed by Ca, Mg, K and among the anions, HCO₃ is the dominant ion followed by Cl, SO₄, CO₃ and NO₃. The surface water chemistry is dominantly controlled by the water rock interaction particularly weathering of silicate rocks. Broadly, two water types have been identified, viz. Ca-HCO₃ and Mixed Ca-Na-HCO₃. Scholler's plot has revealed Na-Ca-HCO₃-Cl as the principal water type which can be related to the weathering of the silicate rocks along with some anthropogenic impact. The water samples are suitable for drinking purposes as per WHO and BIS standards. The water is also found to be suitable for irrigation purposes based on parameters such as EC, %Na, SAR, Wilcox and USDA classifications. More frequent sampling is needed to better understand the processes controlling surface water chemistry and estimate the spatio-temporal variation in water quality for drinking, domestic, livestock and irrigation purposes.

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