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Original Research Paper

Assessment of Groundwater Quality for Drinking and Irrigation Purposes of Upper Bennihalla Basin, Karnataka

J. Davithuraj and S. Manjunatha*
Central Groundwater Board, SUO, Belgaum-590 019, Karnataka, India
*Department of Geology, Karnatak Science College, Dharwad-580 003, Karnataka, India

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ABSTRACT

A total of 89 representative water samples were collected from borewells and dugwells. The samples were analysed to determine physico-chemical parameters like pH, total dissolved solids, hardness, SO_4^{2-}, chloride, magnesium and calcium. Based on these analyses, the parameters like sodium adsorption ratio (SAR), sodium soluble percentage, residual sodium carbonate (RSC), permeability index and corrosive ratio have been also determined. The suitability of water from groundwater sources for drinking purposes was calculated by comparing the values of different water quality parameters with WHO and ISI guideline values for drinking water. The correlation of the analytical data has been attempted by plotting different graphical representations such as Wilcox and US Salinity Laboratory for the classification of water, and results show that most of the samples of Upper Bennihalla basin are fit for irrigation.

INTRODUCTION

Groundwater is a vital natural resource required for drinking and irrigation. Due to the effects of population growth and climate change, there is a severe stress to surface water supplies (Edmunds 2003, Shanmugam & Ambujam 2011). Groundwater is the major source of water both in urban and rural areas of many countries. In India, groundwater plays a pivotal role in fulfilling the demands of domestic, industrial and agricultural sectors. The quality of groundwater is largely controlled by discharge-recharge pattern, nature of host and associated rocks as well as activities causing contamination. Moreover, the nature and amount of dissolved materials in natural water are strongly influenced by mineralogy and solubility of rock forming minerals (Raymahasay 1996). The quality of groundwater is function of various parameters, which determine its suitability for drinking purposes (WHO 1971, ISI 1983, APHA 1985). In recent years, an increasing threat to groundwater quality due to human activities has become of great importance (Aher 2012, Reddy et al. 2012, Deshpande & Aher 2012). The geochemical study reveals that the quality of water is not suitable for drinking and irrigation uses, therefore, an attempt has been made to identify the hydrogeochemical characteristics and quality factors of the Upper Bennihalla basin, Karnataka.

STUDY AREA

The Upper Bennihalla basin lies between north latitudes 15°0'00' and 15°32'48' and east longitudes between 75°00' to 75°29'45', and the total geographical area is 1661 sq.km. The study area is surrounded by Gadag and Shirhatti taluks in the east, Dharwad and Kalghatgi taluks in the west, Shiggaon taluka in the southwest, and Navalgund taluk in the north. The study area falls in the semi-arid region. The physiography of the study area is characterized by gently undulating terrain with alternating ridges and slope elevation ranges form 660m above MSL. The climate of the study area is generally pleasant in the entire basin area. April and May are hottest months with average daily maximum temperature of about 38°C and average daily minimum temperature of about 20°C. The southwest monsoon sets in by June and ends by the middle of October. During this period the basin receives about 50% of the total annual rainfall, and the climate will be generally humid. Geologically, the study area is underlain by Dharwar schistose rocks and granitic gneiss. The northeastern part of the study area is occupied by granitic gneiss, which are mainly covered by thick black cotton soil, shales, phyllites, and altered greywackes of schistose rock cover rest of the area. The schistose formations strike in NNW-SSE direction and are dip varying from 35° to nearly vertical. Granitic gneiss strike in NNW-SSE direction and is highly weathered.

MATERIALS AND METHODS

Groundwater samples were collected from 89 locations during the April 1999, and locations of groundwater samples are shown in Fig. 1. The samples were collected from all available dug wells and bore wells, which are being used for

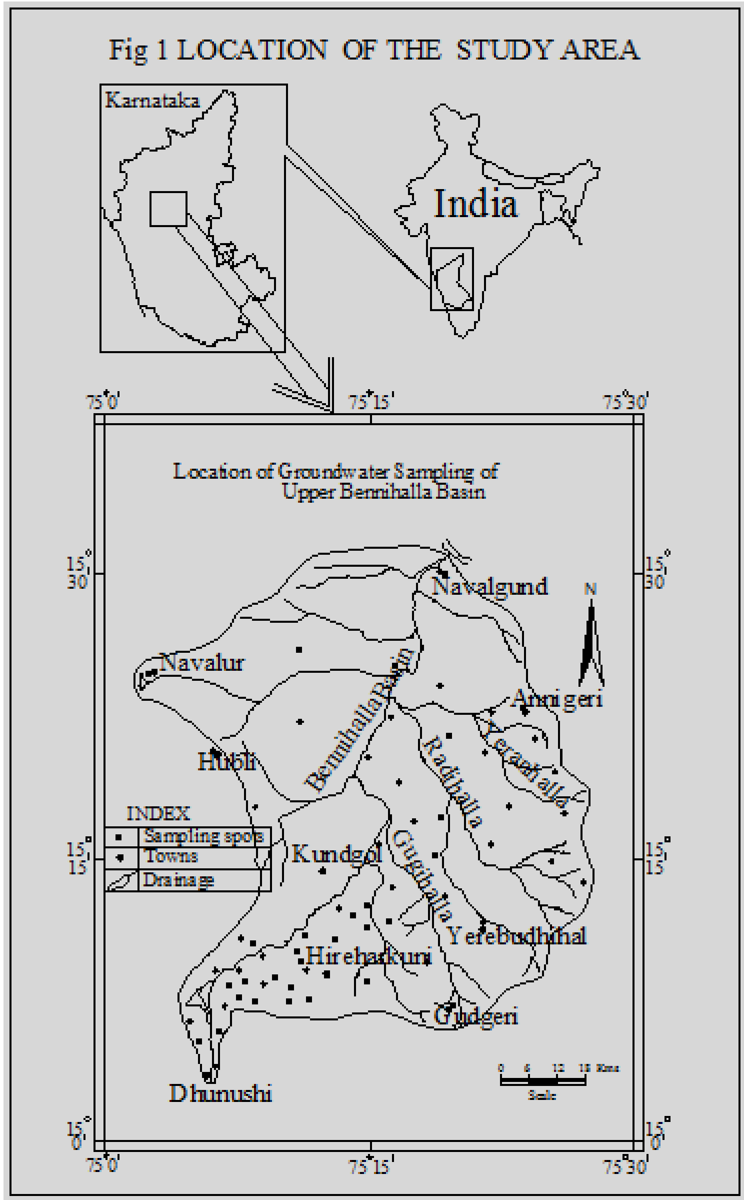

Fig. 1: Location of the study area and sampling stations.

drinking and irrigation purposes. The samples were collected in sterilized polythene bottles, and prior to sampling all the sampling containers were washed and rinsed with the groundwater. The analyses were done using standard procedures recommended by the APHA (1985) and Todd (1980). All the results are compared with standard limits recommended by the WHO (1971) and ISI (1983).

RESULTS AND DISCUSSION

Suitability of groundwater for drinking purposes: The suitability of groundwater for drinking purpose is determined keeping in view the effects of various chemical constituents in water on the biological system of human beings. Though, many ions are essential for the human, but when present in excess, they have an adverse effect on human body. Groundwater quality assessment was carried out to determine its suitability in terms of drinking purposes, the hydro chemical analysis of groundwater samples is presented in (Table 1). The physical and chemical parameters of the analytical results of groundwater were compared with the standard guideline values recommended by the ISI (1983) and WHO (1971) for drinking and public health purposes. The

Table 1: Groundwater quality for drinking purpose and ionic concentration range in Upper Bennihalla basin.

Sl. No	Substance/ Characteristic in ppm	Desirable limit in ppm	Undesirable effect out side limit	Permissible limit in ppm	Conc. range in study area in ppm		
					Max.	Min.	No of samples < Permissible limit
1	Calcium	75	Encrustation in water supply structure and adverse effects on domestic use.	200	600	14	70
2	Magnesium	30	-do-	100	844	3	65
3	Chloride	250	Taste, Corrosion palatability are affected	1000	3350	14	75
4	Sulphate	200	May cause gastro intestinal	400	1740	6	80
5	Hardness	300	Encrustation in water supply structure and adverse effects on domestic use.	600	3120	60	65
6	TDS	500	Palatability decrease and may cause gastro intestinal problems	2000	10080	47	69
7	pH	6.5-8.5	The water will affect the mucous membrane and water supply system.	No Relaxation	8.6	6.5	87

Table 2: Classification of groundwater based on SAR values (Todd 1980).

SAR Values	Classification	Percentage of Samples	Suitability for irrigation
<10	Excellent	89.8	Suitable for all soils and all crops except those which are highly sensitive to sodium.
10-18	Good	10.2	May be used on coarse textured or organic permeable soils. Addition of gypsum either to the water or soil is required for use on fine textured soils otherwise it is harmful and renders the soil less permeable.
18-26	Fair	Nil	May be used provided gypsum is added and good drainage and high leaching is provided
>26	Poor	Nil	Generally not suitable

pH value reveals that the groundwater in this area range from 6.7 to 8.8 and from 6.5 to 8.5 for dugwells and bore wells receptively. The average pH values for the groundwater of Upper Bennihalla basin is 7.3 indicating slightly alkaline in nature and suitable for drinking according to the WHO standards. It is observed from the classification based on TDS values that 45% of the groundwater in the study area falls in the slightly saline to moderately saline water. The total hardness of groundwater in the study area varies between 116 and 2780 ppm and 60 to 1288 ppm for dugwells and bore wells respectively. 92% of groundwater samples fall in "hard water" category and there is a need for softening of these waters if they are to be used for drinking and domestic purposes. The calcium in groundwater ranges from 14 to 600 ppm and 28 to 567 ppm, and magnesium from 10 to 438 ppm and 3 to 388 ppm in dugwells and bore wells respectively. The concentration of Na and K in groundwaters of area ranges from 4 to 2015 ppm and 4 to 127 ppm for dugwells and bore wells respectively. The carbonates range from 0 to 240 ppm and 0 to 120 ppm, and bicarbonates from 40 to 3026 ppm and 80 to 720 ppm in dugwells and bore wells respectively. The chloride content ranges from 16 ppm to 3350 ppm and from 14 ppm to 1575 ppm, and the sulphate content from 6 to 690 ppm and 98 to 157 ppm in dugwells and bore wells respectively. The concentration of fluoride in study area ranges from 0.4 to 1.2 ppm in dug wells. However, all the samples are within the permissible limit of WHO standards.

Suitability of groundwater for irrigation: The quality of water used for irrigation is an important factor in productivity and quality of the irrigated crops. The distribution of soluble salts depends on factors like chemical composition of water, nature and composition of the soils and sub-soils, topography, amount of water used and method of its application, kind of crop grown, the climate, rainfall, etc. Salinity is also one among the major factors controlling the osmotic process in plants. High percentage of dissolved salts contributes to stunted growth of plants. The impact of sum of dissolved salt is more important than the toxicity caused by a single constituent. Effects of salts on soils causing changes in soil structure, permeability and aeration, indirectly affect plant growth. Several classification schemes have been put

Table 3: Classification based on sodium percentage.

Soluble Na%	No.of Samples	Percentage	Class
Na% > 60	7	8	Safe
Na% <60	82	92	Unsafe

Table 4: Classification of groundwater based on Wilcox diagram.

Sl.No.	Water Class	No of samples	% of samples
01	Excellent to good	31	35
02	Good to permissible	27	30.0
03	Permissible to doubtful	-	-
04	Doubtful to unsuitable	12	3.3
05	Unsuitable	19	21

Table 5: Classification of groundwater based on RSC index (After Eation 1950).

S.No.	RSC (epm)	Irrigational suitability	% of samples in study area
01	<1.25	Suitable	93
02	1.25 - 2.5	Marginal	Nil
03	>2.5	Not Suitable	7.0

forth to classify irrigation waters (Wilcox 1948, Doneen 1962, Handa 1964, Richards 1954). The most important factors that influence the water quality for irrigation are sodium adsorption ratio (SAR), salinity hazard, residual sodium carbonate (RSC), sodium percentage, permeability index (PI) and corrosivity ratio.

Sodium Adsorption Ratio (SAR): The sodium adsorption ratio (SAR) is calculated from the ionic concentration of sodium, calcium and magnesium according to the following relationship.

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

SAR values can be used to predict the degree to which irrigation waters tend to enter into cation exchange section in soil. The higher values of SAR indicate soil structural damage. Groundwater has been classified into four groups based on SAR values and observed that 100% of groundwaters have SAR in the excellent to good class (Table 2).

USSL Classification: The classification of water suitability based on the relation between SAR and EC (Richards 1954) is shown in Fig. 2. The classification proposed by the United States Salinity Lab is in wide use as it takes into account both salinity and sodium hazards. The diagram gives the classification of water samples into C_1, C_2, C_3 etc., which represent water classes with increasing salinity hazards. Also S_1, S_2, S_3 etc., represent water classes with increasing hazards of exchangeable sodium accumulation in irrigated soils.

Salinity hazard: Low salinity water (C_1) can be used for irrigation of most crops on most of soils, and medium salinity water (C_2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. High salinity water (C_3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected. Very high salinity water (C_4) is not suitable for irrigation under varied circumstances. The soil must be permeable with adequate drainage to provide considerable leaching for irrigation water applied in excess, and only salt tolerant crops must be selected.

Sodium hazard: Low sodium water (S_1) can be used for irrigation on almost all soils. Medium sodium water (S_2) will present an appreciable sodium hazard in fine textured soils having high cation-exchange capacity. This water may be used on coarse textured or organic soils with good permeability. High sodium water (S_3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management (good drainage, high leaching and organic matter additions). Very high sodium water (S_4) is generally unsatisfactory for irrigation purposes, except a low and perhaps medium salinity. The classification of water suitability based on the relation between SAR and EC (Richards 1954) is shown in the Fig. 2. The classification proposed by the United States Salinity Lab is common as it takes into account both salinity and SAR. The analytical results of groundwater samples have been plotted separately on USSL diagram.

Soluble sodium (%Na): Sodium is very important from agricultural point of view because it reacts with soil to reduce its permeability. Soil containing a large proportion of sodium with carbonates as the predominant anion are termed alkali soils; and those with chloride or sulphate as the predominant anions are saline soils. Sodium content is usually expressed in terms of percent sodium and is estimated using the formula:

$$\%Na = \frac{Na + K}{Na + K + Ca + Mg} \times 100 \text{ (all values in epm)}$$

It is observed from the Table 3 that 92% of the groundwater samples of the study area have sodium percentage less than 60, whereas the remaining 8% of the samples are not within safe limit and are not suitable for irrigation.

Wilcox (1948) categorized five types of waters based on a plot of Na % Vs EC. The number of water samples falling

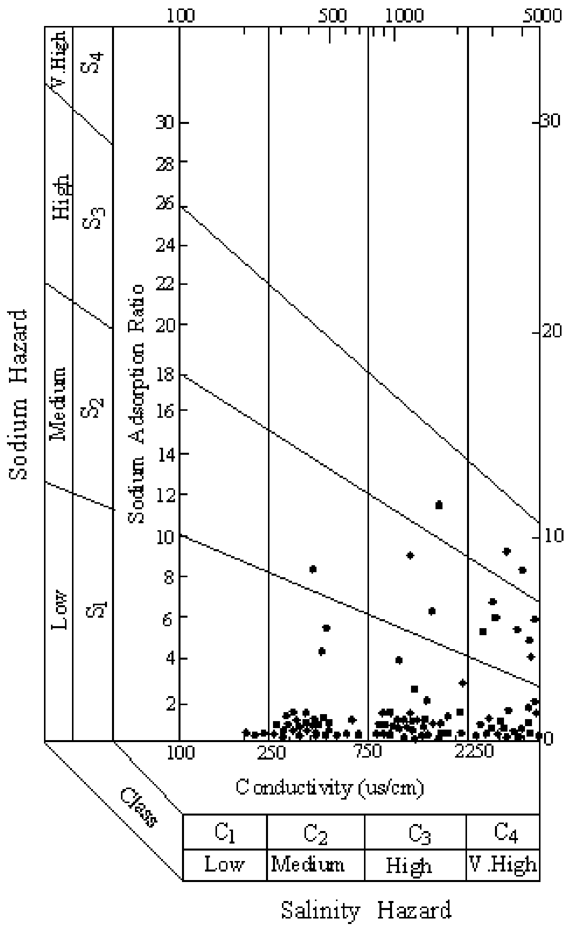

Fig. 2: Classification of water for irrigation (after Richard 1954).

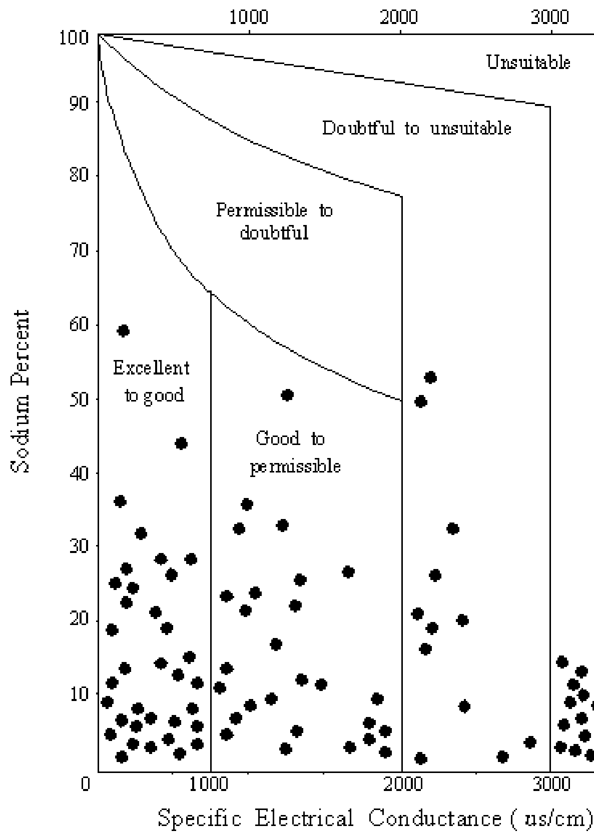

Fig. 3: Wilcox's diagram for irrigational sutabality of water.

in each category is shown in Fig. 3. The analysis indicates that 35% of the samples fall within the excellent to good, and 24% of the samples are not suitable for irrigation purposes (Table 4). The unsuitable groundwater can be used to grow salt tolerant crops like cotton, sunflower, wheat, chilly, coconut, etc.

Residual Sodium Carbonate (RSC): Bicarbonate concentration of water has been suggested as additional criteria for assessing the suitability for irrigation water. When the total of carbonates and bicarbonates exceeds the sum of calcium and magnesium present, the excess amount of such salts gets precipitated as residual sodium carbonate and is determined by using the formula (Richards 1954).

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

Where the concentrations are expressed in meq/L. Groundwater can also be evaluated for agricultural purposes based on RSC (Eaton 1950). It is used in classifying the quality of water for irrigation. If the RSC exceeds 2.5 epm, the water is generally unsuitable for irrigation. If the value is between 1.25 and 2.5 epm, the water is marginal in its quality, while the values less than 1.25 epm indicates that it is probably safe. The groundwater of the study area has been classified based on RSC and as presented in Table 5. Here, it is found that 7% of the samples have more than permissible range. In this area, soils have to be conditioned by adding gypsum or acids so as to neutralize the alkaline character. However, 93% of the samples are found within safe limit and are good for irrigation.

Permeability Index (PI): Soil permeability, as affected by long term use of irrigation water is influenced by (1) total soluble salts, (2) sodium content, (3) bicarbonate content, and (4) soil type. Incorporating the first three factors, an empirical relationship has been developed. This is the "Permeability Index" (PI).

$$PI = \frac{Na + HCO_3}{Ca + Mg + Na} \times 100$$

Where, the ionic concentrations are in meq/L. The permeability index in the study area ranges from 7.5 to 57.266.

Corrosivity ratio: In the study area, farmers use both metallic and plastic pipes to transport groundwater. The corrosivity ratio for a groundwater sample has been computed using Ryzner (1944) method.

$$PI = \frac{Cl/35.5 + SO_4/48}{(CO_3 + HCO_3)/50}$$

Where all ionic values are in ppm concentration. The groundwaters having corrosivity ratio less than one are considered as non-corrosive, while corrosive ratio greater than one is considered as corrosive.

In the present area, the corrosive ratios are in the range of 0.3580 to 10.9162. About 49% of the samples fall in the corrosive group. To control the corrosivity in the area of corrosive waters, non-corrosive plastic pipes are advisable for pumping and transporting water.

CONCLUSIONS

Hydrochemical parameters and quality assessment data of groundwater of Upper Bennihalla basin were compared with WHO and ISI standards, which shows that groundwater of the study area is suitable for drinking purposes and public health. The values of sodium adsorption ratio (SAR), sodium soluble percentage (SSP) and residual sodium carbonate (RSC) are within permissible limit indicating that groundwater is suitable for irrigation. The values of EC and SAR of groundwater samples have been plotted in U.S. salinity diagram indicating that all samples fall in C2-S1, C3-S1 and C4-S1 category showing moderate to very high salinity and low sodium hazard. However, 69% of samples fall within the excellent to good and 27% of samples are not suitable for irrigation as per Wilcox diagram. The permeability index ranges from 7.5 to 57.266 and corrosive ratios are in the range of 0.3580 to 10.92. Overall, the groundwater quality of the study area is suitable for the domestic and irrigation purpose except for few samples indicating signs of deterioration in the study area.

REFERENCES

APHA, AWWA, WPCF, 1985. Standard Methods for the Examination of Water and Wasterwater. 15th Ed., American Public Health Association, Washington D.C.

Aher, K.R. 2012. Groundwater Quality Studies of Chikalthana Area of Aurangabad, Ph.D Thesis, Dr.B.A. Marathwada University, Aurangabad, India.

Eaton, E.M. 1950. Significance of carbonates in irrigation waters. Soil Sci., 69: 123-133.

Edmunds, W. M. 2003. Renewable and non-renewable groundwater in semi-arid regions. Developments in Water Science, 50: 265-280.

Deshpande, S.M. and Aher, K.R. 2012. Evaluation of groundwater quality and its suitability for drinking and agriculture use in parts of Vaijapur, District Aurangabad, MS, India. Res. J. Chem. Sci., 2(1): 25-31.

Doneen, L.D. 1962. The influence of crop and soil on percolating water. Proc. 1961 Biennial Conference on Groundwater Recharge, pp. 156-163.

Handa, B.K.1964. Modified classification procedure for rating irrigation waters. Soil Sci., 98: 264-269.

ISI 1983. Indian Standard Specification for Drinking Water. IS: 10500, Indian Standard Institution, pp. 1-5.

Raymahashay, B.C. 1996. Geochemistry for Hydrologists, CBS Publishers, New Delhi, 190p.

Reddy, L., Chandra Sekhar, Deshpande, S.M., Reddy, K.V., Ramana and Aher, K.R. 2012. Hydrogeochemical processes in the groundwater environment of Vemula area, Kadapa District, South India. International Journal of Recent Trends in Science and Technology, 3(1): 18-24.

Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Deptt. of Agri. Handbook No. 60, U.S. Govt. Printing Press, Washington D.C.

Ryznar, J.W. 1944. A new index for determining amount of calcium carbonate scale formed by water. J. Amer. Water Works Assoc., 35: 2472-2486.

Shanmugam Packialakshmi and Ambujam, N. K. 2011. A hydrochemical and geological investigation on the Mambakkam mini watershed, Kancheepuram District, Tamil Nadu. Environ. Monit. Assess., DOI 10.1007/s10661-011-2189-1.

Todd, D.K. and Mays, L.W. 1980. Groundwater Hydrology. John Wiley and Sons, Hoboken.

WHO 1971. International Standards for Drinking Water. World Health Organization, Geneva.

Wilcox, L.V. 1948. The Quality of Water for Irrigation Use. U.S. Deptt. of Agri. Tech. Bull., Washington DC., pp. 40.