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GROUNDWATER QUALITY ASSESSMENT OF BANKI SUBDIVISION, CUTTACK DISTRICT, ORISSA

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Groundwater

Geochemistry

Water Quality

Banki

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ABSTRACT

A study on geochemical characterization of groundwater and its suitability for drinking and irrigation purposes was carried out in Banki Block of Orissa. Representative of 53 groundwater samples were collected from dug wells and bore wells. The samples were analysed for various water quality parameters such as pH, electrical conductivity, total dissolved solids, calcium, magnesium, sodium, potassium, bicarbonate, sulphate, chloride and phosphate. Calcium, magnesium and bi-carbonate are the dominant ions in the groundwater chemistry. The chemical composition of groundwater is controlled by rock-water interaction. The chemical quality was evaluated for drinking purpose following the guideline of WHO and Indian Standards (BIS-10500). Groundwater is generally potable except few locations. Moreover, as per USSL classification, water quality of the study area is assessed.

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INTRODUCTION

Groundwater is the most vital natural resource required for drinking, irrigation and industrial purposes. Rapid increase in population along with enhancing trend in industrialization and urbanization has contributed towards rising demand for groundwater in many areas. The quality of water invariably is contaminated in many ways by natural, agricultural and anthropogenic activities. Geochemical processes in groundwater involve the interaction of rocks with water, leading to higher concentration of certain chemical elements in water. The principles governing the chemical quality of groundwater are well documented in many parts of the world (Subba Rao, 1983; Saha *et al.*, 2008). The present paper deals with assessment of groundwater quality with respect to drinking and irrigation purposes.

Study area

The study area belongs to the Athgarh basin of Gondwana Formation. It consists of a thick pile of freshwater fluviatile and lacustrine sediments. The Athgarh basin is exposed to the north and northwest of Cuttack city. Banki subdivision (Fig. 1) covers an area about 512.80 sq.km and lies between 20^0 15' N and 20^0 29'N Latitudes and 85^0 20' and 85^0 45' 53"E Longitudes and belongs to survey of India toposheet Nos. 73H/7 and 73H/11.

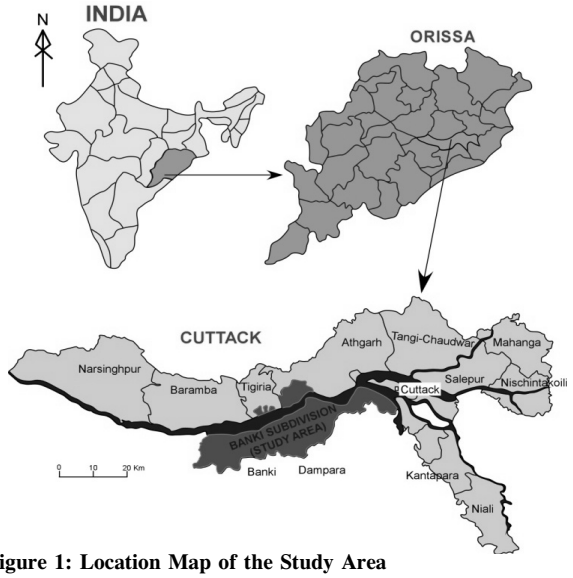

Figure 1: Location Map of the Study Area

Physiographically the study area can be divided into two units such as, the hilly terrain to gently sloping plain land. Mostly the cultivable lands are found to occur within 40 m to 60 m from M.S.L., which is considered as good reservoirs of ground water. The different geomorphic features marked in the area are hills, pediments, buried pediments, flood plains, intermontane valley along with structural features such as lineament, fault, joints etc. Flood plains, buried pediments and intermontane valleys are the favourable sites for ground water exploration.

Mahanadi River forms the main drainage artery of the Banki sub-division. It is flowing in the northern border of the sub-division from west to east direction. The regional slope and the geomorphic features control the drainage of the area. The sedimentary terrain is characterized by sub-parallel drainage, while the Precambrian crystalline terrain has a dendritic to sub-dendritic drainage pattern. The different litho units found in the area are mostly Khondalite, Granite gneiss, Quartz arenite and Laterite.

MATERIALS AND METHOD

53 water samples were collected during pre-monsoon and post-monsoon periods of 2007-2008. The samples

were collected in 1000 mL washed bottles with air tight lids. Out of 53 samples 25 samples were collected from tube wells and 28 samples from dug wells. The samples were analyzed for pH, E.C., TDS, major cations and anions by adopting standard analytical procedures (APHA, 2005; Trivedi and Goel, 1984; Vogel, 1964). To assess the quality of groundwater, different parameters of investigated water samples were compared with WHO (2004) and Indian Standards (BIS-10500).

RESULTS AND DISCUSSION

Hydrogeochemistry of groundwater

pH of water is an indicator of its quality and geochemical equilibrium for solubility calculation (Hem, 1985). The pH value in the pre-monsoon samples varies from 5.25 to 6.91 with an average 6.08 indicating acidic nature of the ground water. In the post-monsoon it varies from 6 to 8.21 with an average around 7.1.

The Electrical conductivity (EC) depends upon temperature, concentration and types of ions present in the water (Hem, 1985). The Electrical Conductivity varies from 103 to 1985 ms/cm in pre-monsoon and ranges from 133 ms/cm to 2250 ms/cm in post-monsoon. The difference between the values reflects the wide variations in the activities and chemical processes prevailing in the region.

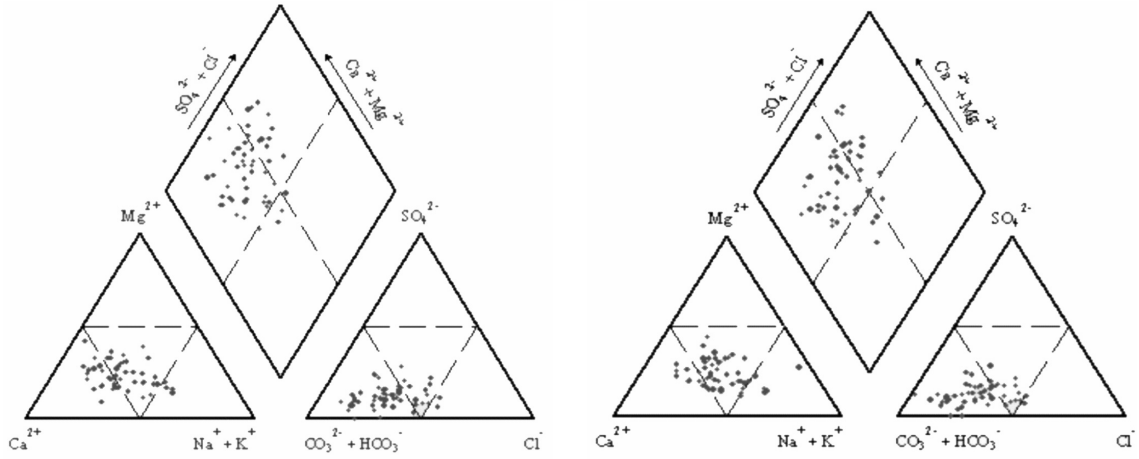

Figure 2: Piper's trilinear diagram

Table 1: Comparison of water quality of the study area with WHO and BIS 10500 standards

Para meter	Range Pre-monsoon	Post-monsoon	WHO(2004)	BIS 10500 Highest desirable	Maximum permissible
pH	5.25-6.91	6-8.21	6.5-8.5	6.5	8.5
EC	103-1985	133-2250	400-2000	---	---
TDS	77-1469	101-1687	500-1000	500	2000
Calcium	26-127	20-120	100-200	75	200
Magnesium	6.09-38.21	6.48-37.665	30-50	30	100
Sodium	1.7-88.3	11.3-97	20-1756	---	---
Potassium	0.68-83.3	1.0-77	10-12	---	---
Bicarbonate	94.7-437.5	98.5-451.4		200	600
Sulphate	0.27-127.5	0.062-125.75	25-250	200	400
Chloride	20.7-179.5	19.76-177.25	25-600	250	1000
Nitrate	0-40.76	0.01-43.97	---	45	100
Fluoride	0.04-1.73	0.97-1.76	---	1.0	1.5
Alkalinity		85-492	---	200	600
Total Hardness	97-466	87-425	---	300	600

The concentration of Total Dissolved Solids (TDS) ranges from 77 to 1469 mg/L and 101mg/L to 1687 mg/ in pre and post-monsoon periods respectively.

The Total Hardness value ranges between 97 to 466 mg/L and 87 to 425 mg/L in pre and post-monsoon respectively. Water samples of 39 locations are hard water, where as in 14 locations the water is very hard in nature. The results of chemical composition of groundwater are given in Table 1.
In the study area sodium concentration varies from 1.7 to 97.0mg/L, while calcium concentration varies from 20 to 127mg/L. The higher concentration of calcium is due to interaction of minerals like feldspar, amphiboles, pyroxene and weathering processes. Potassium concentration ranges from 0.68 to 83.3mg/l. Potassium in groundwater is generally less due to its higher solubility. Magnesium and bicarbonate concentrations range from 6.09 to 38.21mg/L and from 94.7 to 51.4mg/L respectively, while chloride and sulphate concentrations vary from 19.76 to 179.5mg/L and from 0.062 to 179.5mg/L respectively.

Assessment of drinking water quality

Piper's trilinear diagram

Piper's Trilinear diagram reveals that water of the study area belongs to the Ca–Mg - HCO_3 facies (Fig. 2). The plot of the ground water samples of pre-monsoon data and post-monsoon data falls in the fields 4 and 5, which suggest that alkaline earth exceeds strong acids. Calcium and magnesium are major cations in the study area (about 75-90% of the total cations). Bicarbonate is major anion in the study area (about 70-85% of the total anions). The plotting of the chemical quality data in the present study shows the dominance of calcium bicarbonate. The prolific presence of Ca, Mg and bicarbonate ions depicts that the total hydrogeochemistry is dominated by alkaline earths and weak acids. A comparison between the water quality of the study area with WHO and Indian Standards (BIS-10500) is given in the Table 1.

The Table 1 shows the surface and subsurface water of the study area is suitable for the drinking and domestic use with few exceptions, as most of the parameters are within the permissible limits.

Assessment of water quality for irrigation purpose

To reveal the suitability of ground water for irrigation purposes, the study on the effect of mineral constituent of the water on both plant and soil is essential. The parameters such as Sodium Absorption Ratio (SAR), Sodium Percentage (Na%) and Residual Sodium Carbonate (RSC) were estimated to assess the suitability of water for irrigation purpose.

Sodium Adsorption Ratio (SAR)

Sodium Absorption Ratio (SAR) is one of the criteria to study the suitability of water. The sodium concentration in water effects deterioration of the soil properties reducing permeability (Kelley, 1995; Tijani, 1994). The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Absorption Ratio (SAR), proposed by the U.S. Salinity Laboratory, U.S. Department of Agriculture (Richards, 1954). SAR is expressed as

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

where concentrations are expressed in equivalent per million (epm). In the U.S. Salinity diagram (Richards, 1954), where EC (Electrical Conductivity) plotted against SAR. According to the salinity hazard classification (Anbazhagan and Nair, 2004), there is a significant relationship between SAR values of irrigation water and the extent to which sodium is adsorbed by the soil. They proposed a diagram for classifying irrigation water on the basis of their specific conductance and SAR ratios.

The calculated value of SAR in the study area ranges from 0.339 to 14.79 in pre-monsoon and in post-monsoon SAR ranges from 2.417 to 20.56.

From Sodium Absorption Ratio (SAR) value, it is detected that in pre-monsoon 35 samples are of excellent water, 12 are good water and 06 samples show medium water quality for irrigation purpose. In post-monsoon

Table 2: Quality of water based on SAR value

Water classes for irrigation	SAR value	No. of samples (Total 53)	
		Pre-monsoon	Post-monsoon
Excellent	Up to 10	35	31
Good	10-18	12	14
Medium	18-26	06	07
Bad	>26	Nil	01

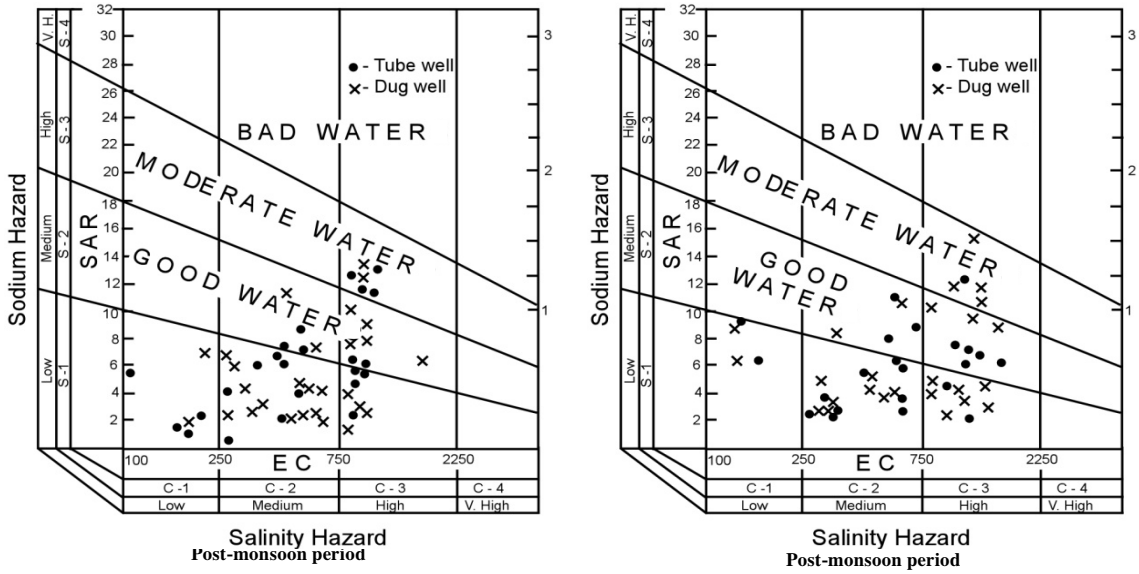

Figure 3: U. S. Salinity Laboratory diagram showing classification of water samples for irrigation purpose

31 samples show excellent, 14 are good, 07 samples are of medium quality and 01 sample falls in bad water category (Table 2).

In the U.S. Salinity Laboratory diagram (Fig. 3) based on Sodium Absorption Ratio (SAR) vis a vis specific conductance values, the two most significant parameters of sodium and salinity hazards determine the quality of water for agricultural purpose. Out of 53 water samples, 4 samples are plotted in C_1S_1, which indicates low salinity and lower alkali water. 16 samples plotted in C_2S_1 indicate medium salinity and lower sodium water. 11 samples present in C_3S_1 plot indicates moderate to high salinity. Such sample water locations have good water condition for irrigation purposes. 5 samples present in C_2S_2 plot are medium Alkali water, which have medium salinity also. Samples within C_3S_2 plot are of moderate to high saline and moderate alkaline in nature. 7 samples, those fall in C_3S_3 plot are highly alkaline in nature and have moderate to high salinity. Only 1 sample falls in C_3S_4 plot, which is highly alkaline and has salinity and considered as bad water.

Sodium Percentage (Na %)

Percentage of sodium content in natural water is an imperative parameter to assess its suitability for agricultural use. A maximum of 60% sodium in groundwater is allotted for agricultural purposes (Wilcox, 1948, 1955; USDA, 1955).

Sodium percentage can be defined in terms of epm of the common Cations (Wilcox, 1948).

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

The concentrations of cations are in meq/L. In pre-monsoon the sodium percentage (Na%) in the study area ranges from 10.29% to 58.16%. The highest percentage of sodium is found in the dug well water sample of

Table 3: Quality of water based on Na %

Water class for irrigation	Na %	No. of samples (Total 53)	
		Pre-monsoon	Post-monsoon
Excellent	Up to 20	31	24
Excellent to Good	20-40	22	25
Permissible	40-60	Nil	3
Permissible to Doubt full	60-80	Nil	1
Unsuitable	>80	Nil	Nil

Pakhalakhala. The minimum value of Na % is located in the tube well water sample of Talabasta. In post-monsoon, the value of sodium percentage (Na %) ranges from 11.06 % to 81.78%. Plot of analytical data of the Banki Sub-division on Wilcox diagram (Wilcox, 1948) relating electrical conductivity and sodium percentage shows different water classes for irrigation on the basis of Na% value and are presented in the Table 3. Excellent to good and good to permissible water can be used for irrigation purpose.

Residual Sodium Carbonate (RSC)

RSC = (CO_3+HCO_3) – (Ca+ Mg), where all concentrations are expressed in epm. Table 4 and Fig. 4 demonstrate that seventy eight percent samples are safe and suitable for agricultural purposes, eleven percent samples are marginally suitable and the rest eleven percent are unsuitable for irrigation use in pre-monsoon period and eight five percent samples are safe and suitable for agricultural purposes, nine percent samples are marginally suitable and the rest six percent are unsuitable for irrigation use in post-monsoon period.

Table 4: Residual sodium carbonate in groundwater

RSC (epm)	Water category	No. of samples (Total 53)			
		Post-monsoon		Pre-monsoon	
		No. of wells	% of sample	No. of wells	% of sample
<1.25	Safe	41	78%	45	85%
1.25-2.5	Marginally	6	11%	5	9%
>2.5	Unsuitable	6	11%	3	6%

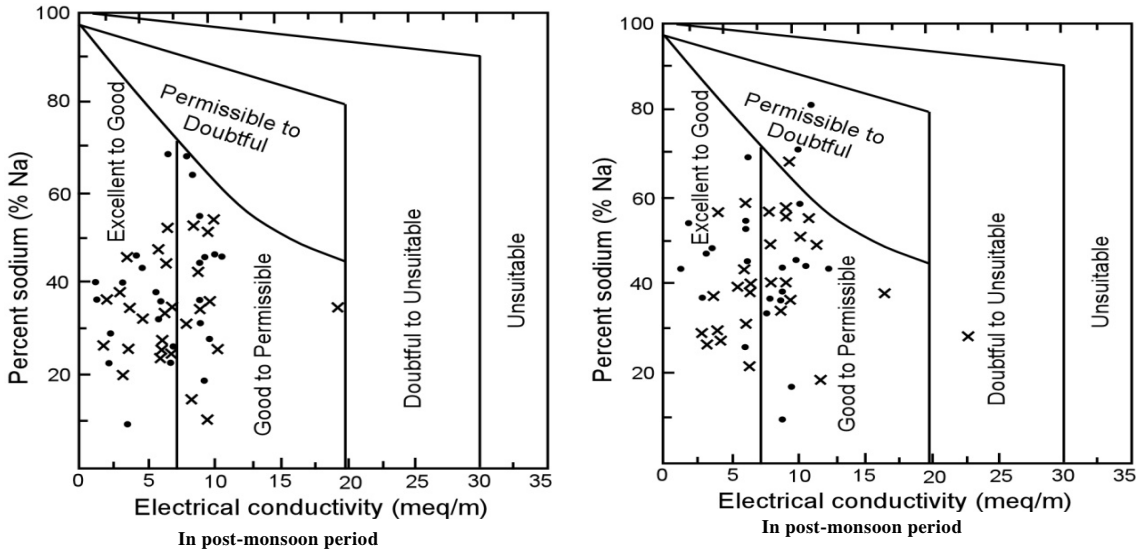

Figure 4: Wilcox diagram for classification of groundwater based on EC and Na%

CONCLUSION

The present chemical analysis explicitly demonstrates that the groundwater of Banki sub-division is alkaline and weakly acidic in nature. Calcium and magnesium are the major cations and bicarbonate is the major

anion in the study area. The higher concentration of the bicarbonate indicates chemical weathering of the rocks. The groundwater belongs to Ca-Mg-HCO_3 facies. The Ca, Mg, HCO_3 contents depict the temporary hardness, alkalinity of the investigated water. Total hydro-geochemistry of the study area is dominated by alkaline earth and weak acids. In general, groundwater is suitable for domestic and irrigation purposes with few exceptions.

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