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Assessment of Surface Water Chemistry of Jakkur Lake, Bangalore, Karnataka, India

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Abstract— The hydrochemical investigation in the present study is restricted to the major ions concentrations, distributions, their relative abundance and the pattern of the variability in water chemistry. On the basis of the water chemistry an evaluation of surface water for domestic and irrigation uses is established. Six water samples were collected from various locations of Jakkur Lake for a period of one year at 30 days intervals. The samples were analysed for various water quality parameters such as pH, Electric Conductivity, Total dissolved solids, Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Carbonate, Sulphate, Nitrate and Chloride. It is inferred from Piper trilinear diagram that the water is mixed type. Besides, suitability of water for irrigation is evaluated based on sodium adsorption ratio, Residual Sodium Carbonate, Stiff diagram, sodium percent, salinity hazard and USSL diagram. The study points out that water from the study area are within the excellent irrigation water class with permissible salinity hazard and are suitable for irrigation purposes.

Index Terms— Correlation, Hydrochemistry, Irrigation water quality, RSC, SAR, Surface water, USSL.

1 INTRODUCTION

WATER quality analysis is one of the most important aspects in surface water studies. The hydro chemical study reveals quality of water that is suitable for drinking, agriculture and Indus trial purposes. The chemistry of surface water is altered by the material through which they pass through. Residual sodium carbonate (RSC) can be used as a criterion for finding the suitability of irrigation waters (Sadashivaiah c. et. al, 2008)[1]. It was observed that the criteria used in the classification of waters for 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. A number of techniques and methods have been developed to interpret the chemical data.

The objective of the present work is to discuss the major ion chemistry and to classify the water in order to evaluate the water suitability for domestic and irrigation uses and its suitability for municipal, agricultural and industrial uses of Jakkur Lake water of Bangalore. In this case the methods proposed by Piper [2], Back and Hanshaw [3]. Wilcox [4] and USSL (US Salinity Laboratory) classification have been used to study critically the hydrochemical characteristics of Jakkur lake water.

2 STUDY AREA

For the present study, an urban surface water body of Jakkur Lake of Bangalore city was selected. Jakkur is located at latitude 13^{o}04′ N and 77^{o}36′ E and is in the North-East corner of Bangalore city and eastern side of NH-4, the same is seen in SOI topo sheet No. 57G/12. The average depth of annual rainfall for the study area is 811 mm.

3 METHODOLOGY

The water samples were collected from different locations of Jakkur lake. One liter of water samples were collected in polythene bottles for a period of one year at 30 days intervals.

Various physical parameters like pH, EC and TDS were determined at the site with the help of digital portable water analyzer kit (ELICO PE-138). Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride(Cl^-), Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-) by volumetric titration methods. Nitrate (NO_3^-) and Sulphate (SO_4^{2-}) were estimated by turbidity method. While Sodium (Na^+) and Pottassium (K^+) determined by Flamephotometry (Elico CL 378). To evaluate the data quality, the accuracy of the water analysis was checked with the anion-cation balance.

4 RESULTS AND DISCUSSION

The maximum minimum and average data showed in Table 1. All results are compared with standard limit recommended by Bureau of Indian Standards (BIS) [5], Indian Council of Medical Research (ICMR)[6] and WHO[7]. The principle of the anion-cation balance is that the sum of cations and sum of anions are equal because the solution must be electrically neutral. In electrically neutral solution, the sum of the cations should be equal to the sum of anions in meq/L. Based on the electroneutrality, analysis of water samples with a percent balance error <5% is regarded as acceptable (Fetter, 2001)[8]. The analysis result of all the samples is within the acceptable range of the reliability check of electroneutrality. The cations anions balance results are found to be reliable as the balance does not deviate from the 5% criterion.

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TABLE 1
Summary Statistics of the Physic-Chemical Parameters

Parame-ters	WELL ID	LW1	LW2	LW3	LW4	LW5	LW6
pH	Min.	7.0	7.2	6.9	7.2	7.0	6.6
	Max.	8.3	8.3	8.1	8.0	7.9	8.2
	Mean	7.7	7.7	7.5	7.5	7.5	7.3
EC (µS/cm)	Min	1003	925	1256	1496	1015	967
	Max.	1536	1548	1592	2189	1421	1308
	Mean	1254	1170	1470	1883	1167	1153
TDS (mg/L)	Min	409	411	448	743	404	49
	Max.	687	743	825	1204	625	614
	Mean	544	564	706	911	530	421
HCO3 (mg/L)	Min	160.0	160.0	220.0	312.0	164.0	156.0
	Max.	325.0	348.0	416.0	560.0	232.0	244.0
	Mean	211.3	202.0	314.8	442.0	186.7	187.5
Cl (mg/L)	Min	215.0	190.0	204.0	210.0	198.0	182.0
	Max.	375.0	310.0	340.0	430.0	360.0	345.0
	Mean	292.2	255.2	281.9	348.7	272.8	264.8
Na (mg/L)	Min	98.1	71.4	97.8	122.1	104.9	90.8
	Max.	193.6	163.4	160.9	221.3	190.3	181.2
	Mean	158.1	131.2	133.0	163.8	145.4	137.6
K (mg/L)	Min	24.0	26.3	23.2	12.5	22.6	24.8
	Max.	32.8	33.2	36.9	50.6	31.3	32.4
	Mean	28.8	29.6	31.0	38.9	28.8	29.4
Ca (mg/L)	Min	14.4	9.6	20.8	6.4	9.6	19.2
	Max.	46.4	76.8	66.4	160.0	48.8	36.8
	Mean	27.0	38.3	46.8	89.3	33.5	28.1
Mg (mg/L)	Min	30.3	28.3	43.6	25.8	28.3	29.4
	Max.	67.3	52.7	86.9	46.8	117.1	59.5
	Mean	39.2	36.0	64.0	32.7	65.4	37.5
SO4 (mg/L)	Min	4.6	6.3	20.9	5.7	6.5	6.6
	Max.	17.5	14.2	38.7	46.8	12.5	30.2
	Mean	12.6	10.1	27.8	19.5	9.5	12.7
NO3 (mg/L)	Min	12.2	10.8	7.1	3.6	10.2	4.6
	Max.	18.6	22.8	12.9	18.2	19.4	18.8
	Mean	16.1	14.4	10.0	11.4	13.3	11.1

TABLE 2
Ionic variation in Jakkur lake water

Parameter	Unit	Sampling Points					
		LW1	LW2	LW3	LW4	LW5	LW6
Ca	mg/L	27.0	38.3	46.8	89.3	33.5	28.1
	epm	1.4	1.9	2.3	4.5	1.7	1.4
	%	11.1	17.0	16.6	29.3	11.9	12.6
Mg	mg/L	39.2	36.0	64.0	32.7	65.4	37.5
	epm	3.2	3.0	5.3	2.7	5.4	3.1
	%	26.5	26.2	37.2	17.6	38.2	27.5
Na	mg/L	158.1	131.2	133.0	163.8	145.4	137.6
	epm	6.9	5.7	5.8	7.1	6.3	6.0
	%	56.6	50.5	40.9	46.8	44.9	53.5
K	mg/L	28.8	29.6	31.0	38.9	28.8	29.4
	epm	0.7	0.7	0.8	0.9	0.7	0.7
	%	5.8	6.4	5.3	6.2	5.0	6.4
HCO3	mg/L	211.3	202.0	314.8	442.0	186.7	187.5
	epm	4.8	4.2	4.6	5.7	4.5	4.3
	%	36.1	36.1	35.2	35.9	36.2	36.0
Cl	mg/L	292.2	255.2	281.9	348.7	272.8	264.8
	epm	8.2	7.2	7.9	9.8	7.7	7.5
	%	62.0	62.1	60.4	61.6	62.2	61.8
SO4	mg/L	12.6	10.1	27.8	19.5	9.5	12.7
	epm	0.3	0.2	0.6	0.4	0.2	0.3
	%	2.0	1.8	4.4	2.5	1.6	2.2
Na%		56.6	50.5	40.9	46.8	44.9	53.5
SAR		4.5	3.7	3.0	3.8	3.4	4.0
RSC	epm	0.2	-0.7	-3.0	-1.4	-2.6	-0.1
Water Type		Cl Na HCO3 Mg	Cl Na HCO 3 Mg	Cl Na Mg HCO3	Cl Na HCO3 Ca	Cl Na Mg HCO3	Cl Na HCO3 Mg

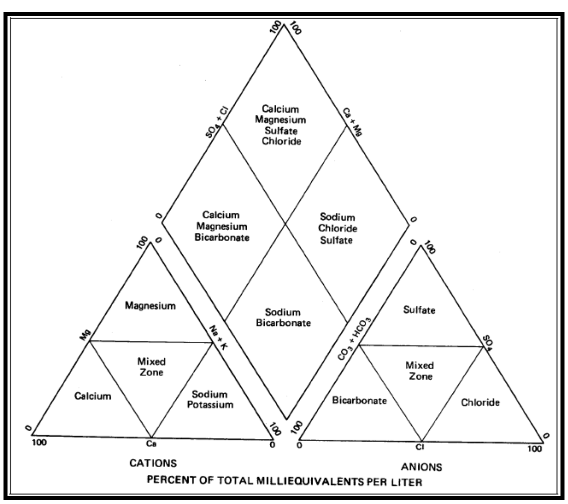

Figure 1. Trilinear diagram showing water type

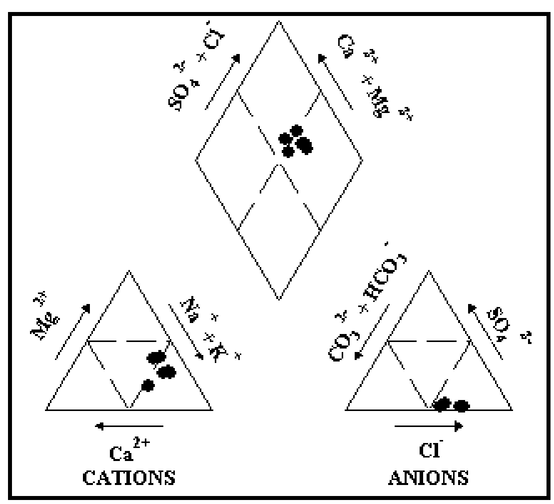

Figure 2.Piper diagram reflecting water type

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4.1 Hydrochemical Facies of lake water

4.1.1 IAH Classification of water

The concentration of cations and anions are incorporated in Table 2. Classification of water depends on the principle of the IAH (International Association of Hydrogeologist, 1979). Total equivalents of cations and anions were taken as 100% and ions more than 20% (meq/L) were evaluated for the classification.

4.1.2 Hill-Piper Diagram

One method of comparing the results of chemical analyses of ground water is with a trilinear diagram (Figure 2). This diagram consists of two lower triangles that show the percentage distribution, on the milliequivalent basis, of the major cations (Mg^{++}, Ca^{++} and Na^{+} plus K^{+}) and the major anions (Cl^{-}, SO_4^{2-} and $CO3^{2-}$ plus $HCO3^{-}$) and a diamond shaped part above that summarizes the dominant cation and anion to indicate the final water type. This classification system shows the anion and cation facies in terms of major-ion percentages. The water types are designated according to the area in which they occur on the diagram segments.

The cation distribution indicates that the samples range in composition form predominantly sodium/potassium to mixed cation. In the anion triangle (triangle on the right), all the samples plotted towards the Cl^{-} corner indicating chloride type water. The diamond diagram shows that most of the groundwater samples fall in the field of mixed Ca^{2+} - Mg^{2+} - Cl^{-} - Na type of water. It is also observed from the piper plot that groundwater in the region is alkaline earths (Ca^{++} & Mg^{++}) significantly exceeds the alkalis (Na^{+} & K^{+}) and the strong acids (SO_4^{--} & Cl^{-}) exceed the weak acids (HCO_3^{-}).

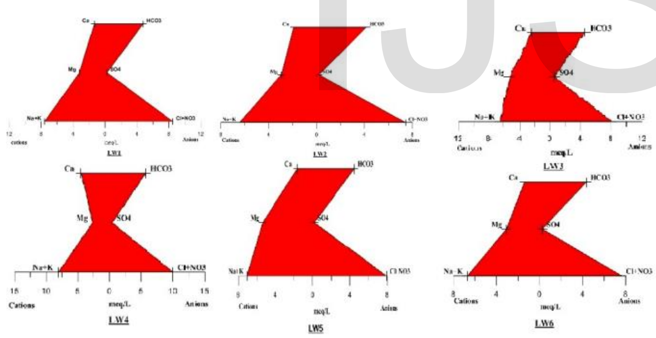

Figure. 3 Stiff diagrams of major ion analyses of water

4.1.3 Stiff Diagram

The major ion analyses of water from the study area were plotted in the form Stiff diagram[9]. Cations are plotted on the left of the axes and anions are plotted on the right in units of milliequivalents per liter (meq/L). The waters of the study area are classified into three water type namely Cl-Na-HCO3-Mg, Cl-Na-Mg-HCO3 and Cl-Na-HCO3-Ca. The stiff diagram agreed with the above mentioned water facies types. The high Cl-HCO3 concentration is due to the entry of sewage in to the lake or weathering of carbonate rocks exposed in the study area.

4.2 Groundwater Quality for Irrigation Purposes

The concentration and composition of dissolved constituents in a water determine its quality for irrigation use, several chemical constituents affect water suitability for irrigation from which the total concentration of the soluble salts and the relative proportion of sodium to calcium and magnesium. Moreover suitability of water for irrigation is depended on the effect of some mineral constituents in the water on both the soil and the plant. The following parameters were used to judge the suitability of the water for irrigating crops.

4.2.1 Total Dissolved Solids

Regarding to the TDS content the water is considered satisfactory when it contains lesser than 1000 mg/L, fair if it contains between 1000 to 2000 mg/L, and inferior when if salinity exceeds 2000mg/L. The TDS values below 2000 mg/L in all sampling stations hence lake water is considered suitable for irrigation uses.

4.2.2 Electrical Conductivity

The most significant water quality guideline on crop productivity is the salinity hazard as measured by electrical conductivity (EC). The primary effect of high EC water is the inability of the plant to compete with ions in the soil. The EC values of samples in the study area varying between 925 µS/cm and 2189 µS/cm and falling in high salinity zone.

4.2.3 Residue Sodium Carbonate (RSC)

The RSC is a valuable parameter that has a great influence on the suitability of irrigation water. The RSC significantly influence the pH, EC and SAR of the irrigation water. The samples of the study area have RSC between -3.0 meq/L to 0.2 meq/L, indicating good quality water for irrigation purpose. Continuous use of waters having RSC more than 2.5 meq/L leads to salt build up which may hinder the air and water movement by clogging the soil pores.

4.2.4 Sodium Percent (Na%)

It is the ratio of Na in epm in water to the total cation epm multiplied by 100. Irrigation water with Na% > 60% may result in Na accumulation and possibly a deterioration of soil structure, infiltration and aeration. Wilcox (1995)[4]classified water based on Na% as good (20 – 40 Na %), permissible (40-60 Na%) and doubtful (60-80 Na%) . The values of the all collected water samples ranged from 40.9 to 56.6 % and fall under the category of permissible.

4.2.5 Sodium Absorption Ratio (SAR)

SAR is an important parameter for determination of suitability of irrigation water. The SAR values <10 is classified as excellent for

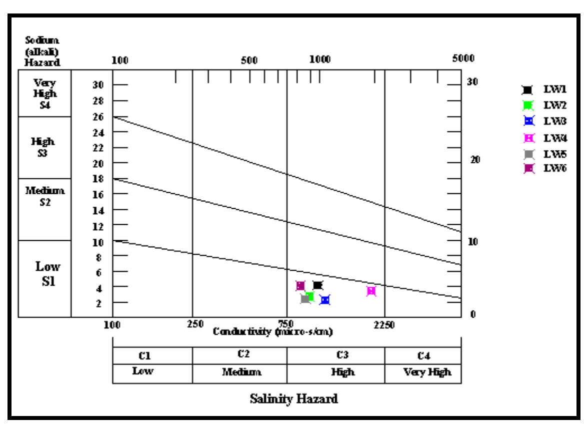

Figure. 4 USSL classification of groundwater

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TABLE 3
Correlation matrix of water samples

	pH	EC	TDS	HCO_3	Cl	Na	K	Ca	Mg	SO_4	NO_3
pH	1										
EC	-0.09	1									
TDS	0.11	0.96	1								
HCO_3	-0.09	1.00	0.97	1							
Cl	-0.08	0.93	0.86	0.89	1						
Na	0.04	0.58	0.49	0.50	0.84	1					
K	-0.15	0.96	0.91	0.95	0.90	0.57	1				
Ca	-0.08	0.96	0.95	0.96	0.86	0.50	0.99	1			
Mg	-0.12	-0.21	-0.10	-0.18	-0.29	-0.35	-0.37	-0.26	1		
SO_4	-0.17	0.64	0.63	0.69	0.41	-0.04	0.45	0.49	0.28	1	
NO_3	0.73	-0.44	-0.36	-0.49	-0.21	0.26	-0.42	-0.43	-0.26	-0.70	1

irrigation. Values 10-28 are moderate and >28 are hazardous. The highest value of SAR value of present study is 4.5 (Table 2), indicating that water is excellent for irrigation purposes.

When the SAR and specific conductance of water are known, the classification of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL)[11] diagram (Figure 4). All the samples in the study area grouped within the C3S1 class.

4.3 Correlation Anaysis

Correlation analysis is useful for interpreting groundwater quality data and relating them to specific hydro geological processes. These tools are quite useful in characterizing and obtaining first hand information of the groundwater system than actually going through complex methods and procedures. The degree of linear association between any two of the water quality parameters is measured by the simple correlation coefficient (r). Correlation matrix for different water quality parameters along the significance level (2 tailed) is shown in Table 3. It is observed that the significant correlation between EC and HCO_3, TDS, Cl, K and Ca. There is also good correlation between HCO_3 and Cl, K and Ca and between Cl and Na, K and Ca.

5 Conclusion

The study has thrown light on the hydrochemistry, quality and suitability for irrigation purposes. It is noticed that there is a good correlation between EC and HCO3, TDS, Cl, K and Ca. There is also good correlation between HCO3 and Cl, HCO3 and K, Ca and between Cl and Na, K and Ca. Characterisation of the water using Piper trilinear and Stiff diagrams has indicated three water facies types namely Cl-Na-HCO3-Mg, Cl-Na-Mg-HCO3 and Cl-Na-HCO3-Ca. In addition, all the water from the area are within the excellent irrigation water class with permissible salinity hazard and are suitable for most crops on most soils.

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