Status of salinity in aquifers of Ghataprabha Command Area, Karnataka, India

Slanostne razmere v vodonosnikih upravljalnega območja Ghataprabha v Karnataki (Indija)

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Received: July 27, 2009 **Accepted:** October 5, 2009

Abstract: The present study aims to understand the salinity status of Gokak, Mudhol, Biligi and Bagalkot taluks of Ghataprabha command area, Karnataka, India. The command area falls under semi-arid and drought hit areas. The samples were collected from 25 open wells and 41 bore wells during pre-monsoon and post-monsoon of the year 2007. From the chemical analysis, the open well shows more EC than deep bore wells. The EC is a useful parameter for indicating salinity hazard. In the present study area the EC values varies between 280 μS/cm and 6500 μS/cm during pre-monsoon and 290 μS/cm and 9020 μS/cm during post-monsoon. As per the classification of natural water based on EC concentration clearly shows that, water belongs to medium salinity to very high salinity. The factor analysis was carried out for both the seasons. The set of first five factors for pre-monsoon and first six factors for post-monsoon were identified for further analysis. The factor 1 of both pre-monsoon and post-monsoon seasons shows 38.70 % and 33.35 % variance with high positive loadings of EC, Na, Mg, Cl, Ca, and SO_4 as representing salinity that could be due to combination of various hydrogeochemical processes that contribute more mineralized water, rock weathering and agricultural activities.

Povzetek: Ta študija je namenjena razumevanju slanostnih razmer v talukih Gokak, Mudhol, Biligi in Bagalkot v upravljalnem območju Ghataprabha v Karnataki v Indiji. Omenjeno območje leži v semi-

Original scientific paper

aridnih in sušnih področjih. Vzorci so bili zbrani iz 25 odprtih vodnjakov in 41 vrtin v pred- in pomonsunskem obdobju v letu 2007. Iz geokemičnih analiz je razvidno, da imajo vode iz odprtih vodnjakov višjo elektroprevodnost (EC) kot iz globljih vrtin. EC je uporaben parameter za ugotavljanje povišane slanosti. V predstavljeni študiji se vrednosti EC gibljejo med 280 µS/cm in 6500 µS/cm v predmonsunski in med 290 µS/cm in 9020 µS/cm v pomonsunski dobi. Razvrstitev naravnih vod glede na koncentracijo EC kaže, da imajo vode slanost od srednje stopnje do zelo visoke. Za obe obdobji je bila napravljena faktorska analiza. Za nadaljnje analize je bil izbran nabor prvih pet faktorjev za predmonsunsko in prvih šest faktorjev za pomonsunsko obdobje. Faktor 1 za obe obdobji (pred- in pomonsunsko) kaže 38,70-odstotno in 33,35-odstotno varianco z visoko pozitivno obremenjenimi spremenljivkami EC, Na, Mg, Cl, Ca in SO_4, kar kaže na slanost, ki je lahko posledica kombinacije različnih hidrogeokemičnih procesov, ki zajemajo bolj mineralizirane vode, preperevanje kamnin in agrikulturne dejavnosti.

Key words: salinity, EC, factor analysis, weathering, agricultural activities
Ključne besede: slanost, EC, faktorska analiza, preperevanje, agrikulturne dejavnosti

Introduction

Groundwater is becoming an important source of water supply in many regions due to rapid growth of population, which is placing an increasing demand upon fresh water supplies. Water logging is a common feature associated with many of the irrigation commands leading to rise in the water table. The irrigation command areas are recharged not only by the rainfall infiltration, but also by seepage from reservoirs, canals, distributaries and field channels and return circulation of irrigation water. The rising salinity of groundwater used for water supply and irrigation is a major problem. The impact of various management activities on groundwater quality is closely related with the quality of water applied for irrigation. Fertilizers are normally applied to agricultural fields to increase the crop yields. However, a part of the chemical constituents present in the fertilizer may percolate down to reach the ground water table thereby polluting the fresh water aquifers.

Central Ground Water Board, (1997) carried out studies on Conjunctive use of surface and groundwater of Ghataprabha irrigation command and chemical analysis of the water samples of shallow wells which indicated pockets of salinity in certain parts of the command area. The study carried out by Water and Power Consultancy Services Limited (1997) on reclamation of affected areas in Ghataprabha irrigation projects, reported water logging and salinity problems in Kalloli, Yedahalli and Bisnal villages of the command. The remedial measures such as proper drainage plans, control of seepage in canals, cropping patterns and conjunctive use of surface and groundwater were also suggested. Purandara et al., (1996) carried out a study on optimal use of land and water resources in Ghataprabha command and suggested proper cropping pattern to control water logging. Purandara et al., (1997) carried out a study on water logging problems in canal commands of hard rock region of Ghataprabha command and highlighted the problems of water logging and salinity in the selected patches of the command area. Further studies were carried out to estimate the solute transport characteristics in different types of soils, particularly in salinity affected soils of Biligi and Bagalkot taluks of Ghataprabha command by using SWIM (Soil Water Infiltration and Movement) and VLEACH (Vadose Zone Leaching) models (Purandara et al, 2002).

Durbude et.al, (2002) analyzed groundwater characters of Ghataprabha command under GIS environment and reported the acute problem of ground water salinity. The NIH, Roorkee and Remote sensing directorate, Central Water Commission, New Delhi also carried out a study of Ghataprabha Command area using remote sensing and GIS (2003) and delineated the water logged and salt affected areas in the command. They estimated the total water logged area as 1 %. It is also reported that the salt affected area is distributed in the command area during premonsoon season is about 5.5 %. According to the study water logging is more in Bijapur than in Belgaum district. Hiremath (2005) carried out a study on water logging and salinity and impact of major irrigation projects on agriculture land and reclamation of affected areas in Bagalkot and Biligi taluks of Ghataprabha command area. Based on the study, it is suggested that the problem of rising of water table may be achieved by adopting conjunctive use of surface and groundwater by providing proper drainage and following appropriate cropping pattern.

The command area of Ghataprabha reservoir is located between 16°0’8” N–16°48’9” N latitudes and 74°26’43” E–75°56’33” E longitudes covering an area of 317,430 hectares covering parts of Belgaum and Bijapur districts of Karnataka. The index map of the study area is shown in Figure 1. The study area is bound by the Krishna River in the north, Maharashtra state to the west, the confluence of Krishna River and Malaprabha River in the east and the basin boundary between Ghataprabha and Malaprabha rivers in the south. The existing canal command area (net command area is 161,871 ha) is served by the Ghataprabha Left Bank Canal and six branch canals with a number of major and minor distributaries. The proposed right bank canal is expected to irrigate an area of about 155,000 ha.

The topography of the area is undulating with table lands and hillocks typical of Deccan trap. General topographic elevation varies between 500

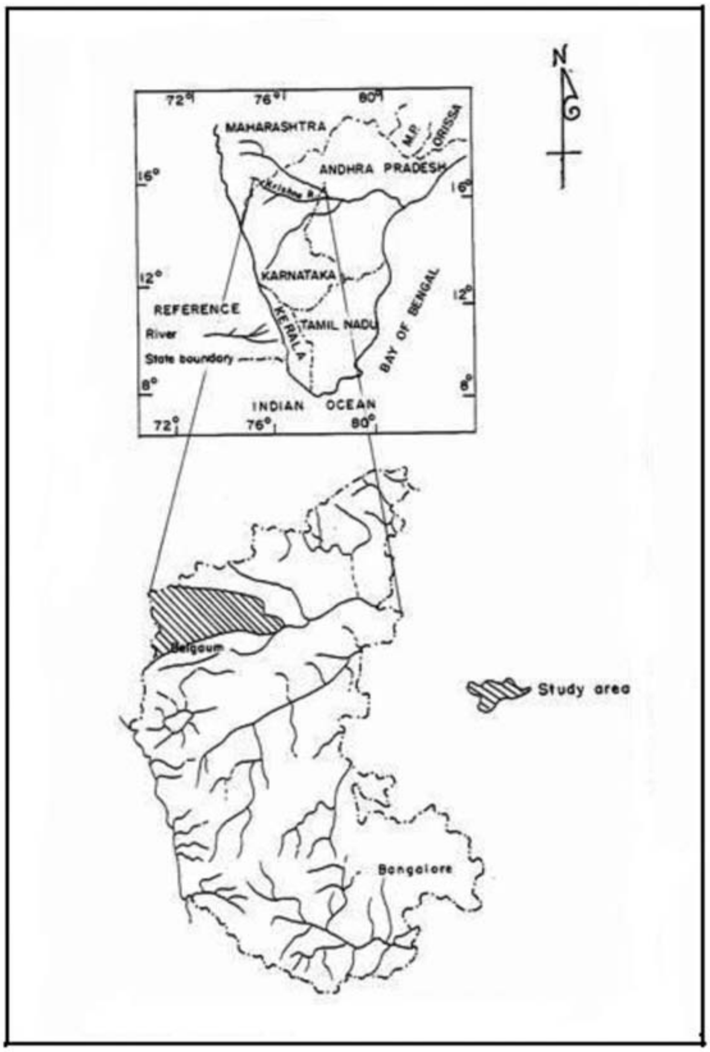

Figure 1. Index map of the Study Area

m to 900 m above msl with a gradual fall from West to East. The catchment boundary between rivers Krishna and Ghataprabha follows the Ghataprabha Left Bank Canal up to Biligi. The command area essentially lies within the Krishna river basin and is drained by the Ghataprabha River. Ghataprabha River is one of the right bank tributary of the river Krishna in its upper reaches. The river originates from the Western Ghats in Maharashtra at an altitude of 884 m and flows westwards for about 60 km through the Ratnagiri and Kolhapur districts of Maharashtra. In Karnataka, the river flows for about 216 km through Belgaum district.

The command area falls in the semi-arid zone and falls under drought hit areas. Average annual rainfall is about 700 mm with wide variation in time and space. The command area is underlain predominantly by sedimentary rocks of Deccan trap. Soils in the left bank canal command area are rich in clay and bases due to hydrolysis, oxidation and carbonation. However soils in the right bank canal command area is developed due to weathering of sedimentary rocks. Soils in the area can be classified based on the geological formations. Soil depth varies from 25 cm to 30 cm in the case of shallow soils with high permeability. Deep soils with dark grey colour are found between 45 cm to 90 cm depth. Black cotton soils with an average pH of 8–8.5 generally occupy the low-lying areas. These soils exhibit high water holding capacity but poor permeability.

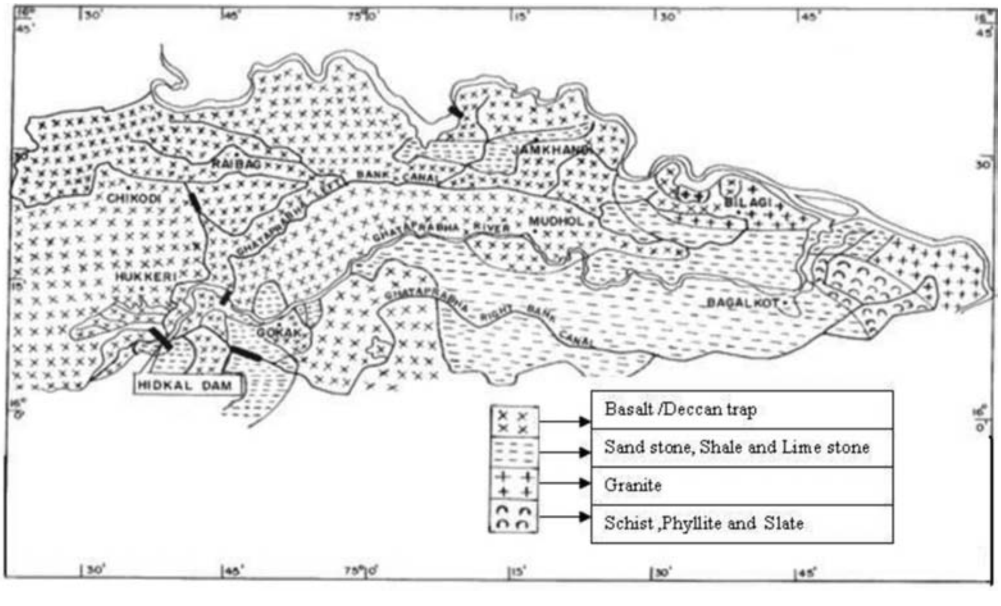

Figure 2. Hydrogeological map of Ghataprabha Command Area

The hydrogeology is complex, as Deccan traps occupy major portions of the study area (CGWB, 1997). The hydrogeological map of the Ghataprabha Command area is shown in Figure 2. River alluvium is found only along the course of rivers. Groundwater occurs in the weathered and fractured hard rocks as well as in the vesicular horizons in the traps. Unconfined to semi confined conditions are observed in weathered/ semi weathered rocks. Confined conditions can be encountered when the fractures are deep seated or in vesicular horizons underlain by massive traps.

Materials and methods

The area selected for the proposed study is left and right bank canal commands of Gokak, Mudhol, Biligi and Bagalkot taluks of Ghataprabha irrigation command. Major classification for sampling is based on reconnaissance survey and also based on interaction held with farmers. To achieve the objectives of the study samples were collected from both open shallow and deep bore wells including hand pumps, which are being extensively used for agricultural, drinking and other domestic purposes. The samples were collected from 25 open wells and 41 bore wells. Location of these wells is shown in Figure 3.

The depth of open wells from where samples being collected are from 6.00 m to 25.00 m and bore wells from 25.00 m to 122.00 m. The samples were collected

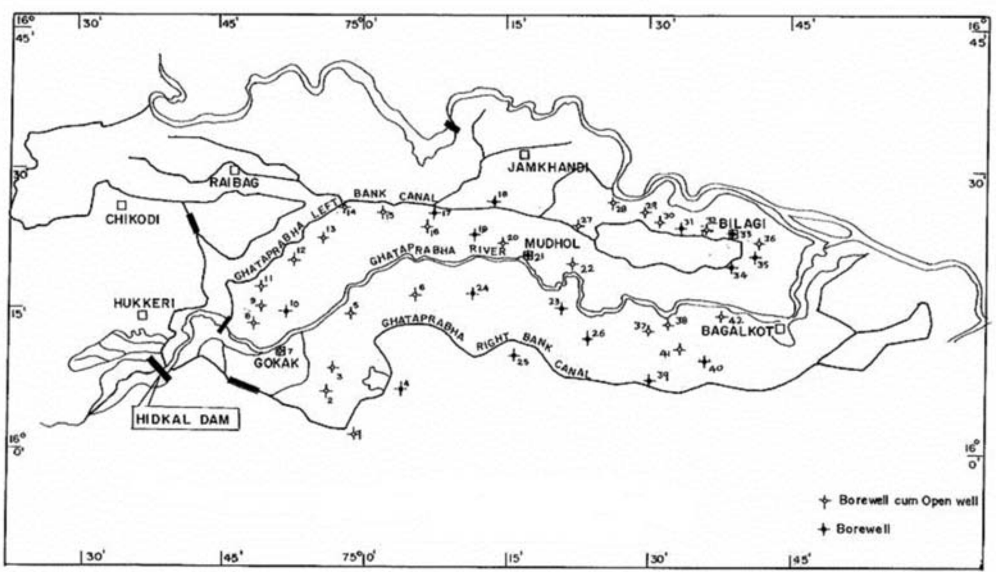

Figure 3. Location map of Groundwater sampling stations

by grab sampling method during pre-monsoon and post-monsoon of the year 2007. In this method a sample collected at a particular time and place can represent only composition of the source at that time and place. Depth integrated samples were collected by lowering the container in the open wells. Depth to water levels and total depth were measured for open wells and only total depth was measured for bore wells. The chemical parameters of the samples were analyzed in the laboratory by standard methods recommended in the manuals (APHA). In the present study the chemical parameters were analyzed are pH, Electrical Conductivity (EC), TDS, Temperature, carbonate, bicarbonate, alkalinity, chloride, sulphate, total hardness calcium, magnesium, sodium, potassium, phosphate, nitrate, fluoride and iron.

In the present study, the basic statistical analysis of the chemical parameters was done by using SYSTATW5 software package. The effect of salinity is one of the most important water quality considerations for agricultural purposes. Generally, salinity is measured in terms of Electrical Conductivity concentration. The EC is a useful parameter of water quality for indicating salinity hazards. The total salinity is a measure of the concentration of salts in water and as such is related to the usability of water for irrigation of crops. Water used for irrigation always contains some amounts of dissolved substances; in general they are called salts. The salts present in the water, besides affecting the growth of the plants, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. Based on EC and TDS in natural water, the classification of salinity of water (Jain et al. 1997) shown in Table 1.

Factor analysis is a technique of quantitative multivariate analysis with the goal of representing the inter-relationship among a set of variables or objects. Factor analysis gives a simple interpretation of a given body of data and affords fundamental description of particular set of variables related to hydro chemical processes beyond strict litho logical controls (Lawrence & Upchurch, 1982). Factors are con-

Table 1. Classification of Salinity of Natural Water (Richards, 1954)

Zone	Electrical Conductivity (µS/cm)	Total Dissolved Salts (mg/L)
Low Salinity Zone	< 250	< 200
Medium Salinity Zone	250–750	200–500
High Salinity Zone	750–2250	500–1500
Very High Salinity Zone	2250–5000	1500–3000

structed in such a way that they reduce the overall complexity of the data by taking advantage of inherent interdependencies. To reduce the data to an easily interpretable form, factor analysis was undertaken using the routine Factor of DAVIS (1973). Prior to the analysis, the data were standardized according to criteria presented by DAVIS (1973). This is necessary since the first step in factor analysis is computation of a correlation coefficient matrix, which requires normal distribution of all variables (LAWRENCE & UPCHURCH, 1982). The correlation matrix gives the inter-correlation among the set of variables. The Eigen value has been computed for all the principal axes. The Eigen values are helpful in deciding the number of components required to explain the variation in data.

The factor extraction has been done with a minimum acceptable eigen value as greater than 1 (KAISER, 1958; HARMAN, 1960). The factor loading matrix is rotated to an orthogonal simple structure, according to varimax rotation, which results in the maximization of the variance of the factor loading of the variables. The objective of varimax rotation is moving of each factor axis to positions so that projections from each variable on to the factor axes are either near the extremities or near the origin. Factor loading is the measure of the degree of closeness between the variables and the factor. The largest loading, either positive or negative, suggests the variance of the factor loading of the variables; positive loading indicates that the contribution of the variables increases with the increasing loading in a dimension; and negative loading indicates a decrease (LAWRENCE & UPCHURCH, 1982). The R – mode factor analysis provides several positive features that allow interpretation of the data set.

RESULTS AND DISCUSSION

The summary statistics of the chemical parameters for pre-monsoon and post-monsoon seasons of the year 2007 are presented in the Table 2 & 3. The EC is a useful parameter of water quality for indicating salinity hazards. In the present study area, the EC values varies between 280 μS/cm and 6500 μS/cm during pre-monsoon and 290 μS/cm and 9020 μS/cm during post-monsoon. The variation of EC values for both the seasons are shown in Figure 4 & 5. It is observed that waters of high EC values are predominant with sodium and chloride ions. In the present study, the sodium varies from 16.00 mg/L to 680 mg/L during pre-monsoon and from 32.00 mg/L to 550 mg/L during post-monsoon. Soils in the left bank canal command area are rich in clay and bases due to hydrolysis, oxidation and carbonation. Under suitable conditions clay minerals may release exchangeable sodium ions. This causes higher concentration of sodium in areas where clays are found. The chloride content of groundwater may be due to the presence of soluble chlorides from rocks. It is observed that concentration of chloride varies from 17.70 mg/L to 1348.90 mg/L during pre-monsoon and from 30 mg/L to 1960 mg/L during post-monsoon. Further, chloride is a common element distributed in some types of rocks in one or the other form. Its affinity towards sodium is high. Therefore, its concentration is high in groundwater's where the temperature is high and rainfall is less. Soil porosity and permeability also has a key role in building up the chloride concentration.

Table 2. Statistical summary of Chemical parameters May 2007 (Pre-monsoon)

Parameter	Units	Minimum		Maximum		Mean		Std. dev.		Range	
		BW	OW	BW	OW	BW	OW	BW	OW	BW	OW
pH	-	6.90	7.16	7.85	8.20	7.29	7.50	0.22	0.23	0.95	1.04
EC	μS/cm @25˚C	460	280	5740	6500	1809	2692	1160	2058	5280	6220
TDS	mg/L	300	170	3810	4270	1167	1749	763	1341	3510	4100
Hardness	mg/L	50	70	750	760	239	253	151	194	700	690
Carbonate	mg/L	0.00	0.00	22	40	2.36	3.80	5.28	10.50	22	40
Bicarbonate	mg/L	146	61.00	545	585	292	354	109	141	399	524
Alkalinity	mg/L	150	61.00	562	605	294	357	110	145	412	544
Chloride	mg/L	17.72	23.00	1349	892	220	327	252	335	1331	869
Sulphate	mg/L	6.00	8.00	110	100	56	54	26	30	104	92
Calcium	mg/L	12	20.80	115	111	47	47	26	28	103	90
Magnesium	mg/L	2	3.90	113	117	30	35	24	32	111	114
Sodium	mg/L	28	16.00	650	680	165	248	136	199	622	664
Potassium	mg/L	0.50	1.00	180	205	24	27	44	54	179	204
Nitrate	mg/L	1.00	1.00	19	20	5.80	5.40	3.67	4.70	18	19
Iron	mg/L	0.20	0.30	2.00	3.00	0.45	0.67	0.33	0.72	1.80	2.70
Phosphate	mg/L	0.00	0.00	0.35	1.25	0.025	0.17	0.07	0.37	0.35	1.25
Fluoride	mg/L	0.70	0.80	1.65	1.55	1.08	0.95	0.18	0.19	0.95	0.8

Table 3. Statistical summary of Chemical parameters Nov. 2007 (Post-monsoon)

Parameter	Units	Minimum		Maximum		Mean		Std. dev.		Range	
		BW	OW	BW	OW	BW	OW	BW	OW	BW	OW
pH	-	6.65	7.05	7.95	8.15	7.27	7.54	0.27	0.27	1.30	1.10
EC	µS/cm @25˚C	360	290	9020	6650	1669	2027	1528	1654	8660	6360
TDS	mg/L	230	180	6150	3900	1113	1318	1041	1034	5920	3720
Hardness	mg/L	78	108	2220	554	289	235	339	112	2142	446
Carbonate	mg/L	0.00	0.00	24	30	1.76	2.42	5.32	6.70	24	30
Bicarbonate	mg/L	165	110	512	542	290	313	89	115	347	432
Alkalinity	mg/L	165	110	512	542	291	315	90	117	347	432
Chloride	mg/L	30	30	1960	975	222	231	333	247	1930	945
Sulphate	mg/L	19	10	220	190	57	68	36	40	201	180
Calcium	mg/L	12.80	20	528	96	63	46	81	21	515	76
Magnesium	mg/L	6.70	10.60	215	80	32	29	34	17	208	69
Sodium	mg/L	41.00	32	398	550	158	191	102	141	357	518
Potassium	mg/L	1.00	2.00	205	110	17	20	36	26	204	108
Nitrate	mg/L	2.50	3.00	20.50	20.90	10.50	9.70	5.40	5.80	18	17.90
Iron	mg/L	0.30	0.4	2.00	3.00	0.83	0.84	0.44	0.56	1.70	2.60
Phosphate	mg/L	0.00	0.00	0.75	4.00	0.066	0.36	0.16	0.85	0.75	4.00
Fluoride	mg/L	0.80	0.60	1.45	1.10	1.08	0.92	0.14	0.11	0.65	0.50

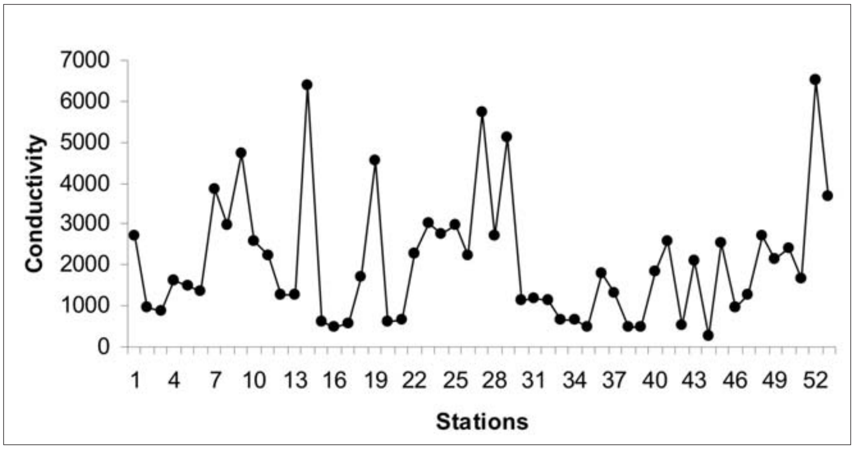

Figure 4. Distribution of EC for May 2007

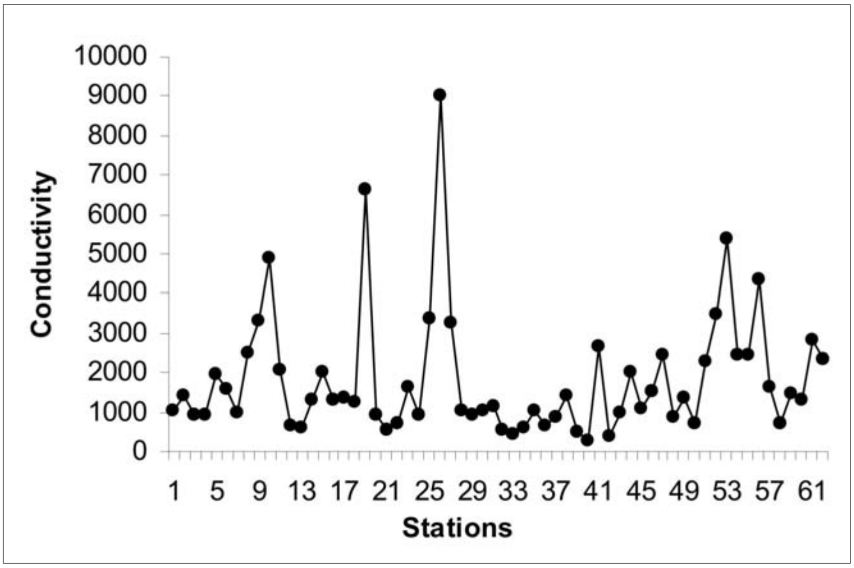

Figure 5. Distribution of EC for November 2007

Table 4. Percentage classification of salinity in wells

Zone	Pre-monsoon	Post-monsoon
Low Salinity Zone	-	-
Medium Salinity Zone	23 %	21 %
High Salinity Zone	35 %	52 %
Very High Salinity Zone	42 %	27 %

The TDS value varies between 170 mg/L and 4270 mg/L during pre-monsoon and 180 mg/L and 6150 mg/L during post-monsoon. The higher values are observed for post-monsoon samples. This indicates the effect of overland flow. From the chemical analysis, the open well shows more EC than deep bore wells and it indicates open wells are more saline than bore wells. Among the anions the dominating ions are bicarbonate and chloride and in the case cations sodium is dominating the other ions as Na > Ca > Mg > K. The classification of natural water based on EC concentration clearly shows that, water of medium to very high salinity zone. Based on the concentration of EC, the results of percentage classification of wells in the study area are shown in Table 4.

The groundwater quality data showed that there is a considerable quality variation in the study area. There is an increase in the Electrical Conductivity and chloride concentration particularly in open wells. This is attributed to the local conditions such as irrigation return flow and excessive agricultural activities. The non-systematic increase of high salinity zone during post-monsoon is basically due to two reasons. The Biligi taluk in the study area is covered by low permeable clayey soils and rainfall is less than 600 mm. Therefore due to rainfall infiltration the top saline soils are leached into open wells due to which an increase in salinity was noticed during post-monsoon.

Factor Analysis

For pre-monsoon season, the first five factors show eigen value more than 1, thus these five factors were chosen for further analysis. Factor 1 of the pre-monsoon season shows 38.70 % variance. This factor has high positive loadings and strongly associated with EC and ions such as Mg, Cl, Na, Ca, and SO_4. These ions contribute more salinity to the water. This factor may therefore be salinity factor and indicates saline water in the study area. Factor 2 of pre-monsoon season shows 14.60 % variance. This factor has high loading and strongly associated with ions CO_3, PO_4, and HCO_3. Factor 3 of pre-monsoon season shows 10.80 % variance. This factor has high loading and strongly associated with ions Potassium and Nitrate. Factor 4 of pre-monsoon season shows 9 % variance. This factor has high positive loading on fluoride indicating possible leaching of soil fluoride and weathering of fluoride bearing rocks. Factor 5 of pre-monsoon season shows 7.10 % variance and there is no significance contribution of any ions.

For post-monsoon season, first six factors show eigen value more than 1, thus these six factors were chosen for further analysis. Factor 1 of the post-monsoon season shows 33.35 % variance and strongly associated with EC, Cl, Ca, Mg, and Na. Factor 2 of the post-monsoon season shows 15.40 % variance. Factor 3 of the post-monsoon season shows 10.20 % variance and strongly associated with SO_4 and PO_4 ions. Factor 4 of the post-monsoon season shows 10.10 % variance and there is no significant contribution of any ions. Factor 5 of the post-monsoon season shows 7.75 % variance and strongly associated with PO_4 and NO_3 ions. Factor 6 of the post-monsoon season shows 6.60 % variance and there is no significant contribution of any ions.

Table 5 and 6 represents the factor loading which were used to measure the correlation between variable and factors. The components with larger variance are more desirable since they give more information about the data. The components with higher loading of hardness and magnesium are 0.936 and 0.920 respectively indicating the source of hardness is through magnesium. The concentration of chloride, Electrical Conductivity, TDS and Calcium also showed high positive loading (0.807–0.883). The sodium and sulphate showed a moderate positive loading (0.738–0.744). Based on the factor loading, it is clear that one of the major problems in the study area is the hardness of water which is indicated by highest loading of magnesium with hardness. This is further associated with the higher loading of EC and TDS accompanied by calcium ions. This could be due to the process of salinization taking place due to rock weathering and agricultural activities. Similar case is observed during the post-monsoon, however, with higher loading factors than the pre-monsoon. The grouping of factor 1 could be due to the combination of various hydrogeochemical processes that contribute more mineralized water (high value of EC and TDS).

Table 5. Rotated factor loading matrix (Pre-monsoon, May 2007)

Sl.No.	Parameter	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	pH	–0.366	0.509	0.225	0.250	–0.070
2	EC	0.877	0.125	0.349	0.188	–0.064
3	TDS	0.881	0.122	0.342	0.180	–0.069
4	Carbonate	–0.111	0.790	0.010	–0.039	0.159
5	Bicarbonate	0.474	0.616	–0.092	0.361	–0.360
6	Alkalinity	0.458	0.650	–0.090	0.352	–0.344
7	Chloride	0.883	0.063	0.261	0.181	0.004
8	Sulphate	0.744	–0.263	0.007	0.051	–0.048
9	Hardness	0.936	–0.197	–0.010	–0.045	0.147
10	Calcium	0.807	–0.117	–0.221	–0.025	0.278
11	Magnesium	0.920	–0.154	0.066	–0.094	0.069
12	Sodium	0.738	0.274	0.296	0.397	–0.169
13	Potassium	0.020	0.088	0.886	–0.066	0.102
14	Phosphate	–0.197	0.710	0.001	–0.308	0.115
15	Nitrate	0.361	–0.102	0.711	0.030	0.070
16	Iron	–0.165	–0.117	–0.150	–0.157	–0.854
17	Fluoride	0.065	–0.063	–0.042	0.907	0.163
Eigen Value		7.031	2.725	1.663	1.162	1.053
Fraction of variance, %		38.70	14.60	10.80	9.00	7.10
Cumulative fraction of variance, %		38.70	53.30	64.10	73.10	80.2

Table 6. Rotated factor loading matrix (Post-monsoon, Nov. 2007)

Sl.No.	Parameter	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	pH	–0.071	–0.030	0.247	–0.820	–0.057	0.252
2	EC	0.861	0.351	0.211	0.016	0.112	0.056
3	TDS	0.881	0.341	0.202	0.025	0.096	0.035
4	Carbonate	–0.014	0.128	–0.112	–0.798	–0.088	–0.113
5	Bicarbonate	0.103	0.970	0.006	–0.067	0.005	–0.105
6	Alkalinity	0.101	0.965	0.000	–0.112	–0.000	–0.110
7	Chloride	0.927	0.187	0.191	0.057	0.101	0.018
8	Sulphate	0.297	–0.057	0.788	–0.020	0.155	0.125
9	Hardness	0.966	–0.056	–0.079	0.132	0.033	–0.045
10	Calcium	0.944	–0.079	–0.088	0.163	–0.014	0.003
11	Magnesium	0.945	–0.013	–0.059	0.079	0.105	–0.109
12	Sodium	0.560	0.565	0.476	–0.041	0.165	0.058
13	Potassium	0.057	–0.115	0.147	0.053	0.855	–0.238
14	Phosphate	–0.107	0.079	0.769	0.019	–0.126	–0.105
15	Nitrate	0.241	0.274	–0.245	0.041	0.675	0.291
16	Iron	0.078	0.170	0.005	–0.075	0.058	–0.884
17	Fluoride	0.260	–0.073	0.084	0.574	–0.074	0.232
Eigen Value		6.385	2.595	1.635	1.357	1.175	1.053
Fraction of variance, %		33.35	15.40	10.20	10.10	7.75	6.60
Cumulative fraction of variance, %		33.35	48.75	58.95	69.05	76.80	83.40

The factor 2 shows a moderate loading of carbonate and bicarbonate (Alkalinity). Apart from carbonate ions, phosphate also showed higher positive loading (0.710). The enrichment of carbonate and bicarbonate is the result of underlying carbonaceous rocks such as limestone and dolomite. The phosphate is the result of excessive use of fertilizers in the canal command area. The higher loading of the above ions during post-monsoon season also shows the dissolution of carbonate rock during the monsoon season and get enriched in groundwater. Factor 3 shows the loading of potassium (0.886) and nitrate (0.711). This grouping clearly indicates that these processes are associated with anthropogenic disturbances. This is further indicated by the post-monsoon analysis which shows a negative loading of nitrate. Due to the rainfall recharge there could be flushing of nitrate ions out of the monitoring wells. The loadings of factor 5 and 6 during post-monsoon also an indication of different sources for potassium and nitrates.

Conclusions

Groundwater quality analysis of Ghataprabha command shows that water is highly saline both during pre-monsoon and post-monsoon. However, the salinity is confined to certain patches of the study area particularly in parts of Gokak and Biligi taluks. Excessive salinity zones are also reported from Mudhol and Jamkhandi taluks. In the present study area the EC values widely varies between 280 μS/cm and 6500 μS/cm during pre-monsoon and 290 μS/cm and 9020 μS/cm during post-monsoon. It is observed that waters of high EC values are predominant with sodium and chloride ions. From the chemical analysis, the open well shows more EC than deep bore wells and it indicates open wells are more saline than bore wells. As per the classification of natural water based on EC concentration clearly shows that, water belongs to medium salinity to very high salinity. It is also observed that the open wells are highly prone to salinity hazards due to the leaching of chemicals through the overlying soil layers.

The problem of salinity hazard is further substantiated through factor analysis. Based on the results obtained by the factor analysis, factor 1 of both pre-monsoon and post-monsoon seasons shows 38.70 % and 33.35 % variance with high positive loadings of EC, Na, Mg, Cl, Ca, and SO_4. This indicates that groundwater is affected by salinity factor that could be due to combination of various hydrogeochemical processes that contribute more mineralized water, rock weathering and agricultural activities. The enrichment of carbonate and bicarbonate is the result of underlying carbonaceous rocks such as limestone and dolomite. The higher loading of the above ions during post-monsoon season also shows the dissolution of carbonate rock during the monsoon season and get enriched in groundwater. The phosphate is the result of excessive use of fertilizers in the canal command area. The potassium and nitrate grouping clearly indicates that these processes are associated with anthropogenic disturbances.

Acknowledgements

The authors acknowledge the National Institute of Hydrology for carrying out this study as a part of doctoral programme and providing laboratory facilities at Regional Centre, NIH, Belgaum. The first author is thankful to the Director, National Institute of Hydrology, Roorkee, India for granting permission to undertake doctoral programme under Visvesvaraya Technological University, Belgaum, India.

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