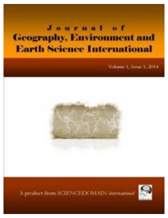

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Studies on Groundwater Quality and Its Suitability for Drinking Purpose in Baramati City, India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Groundwater is one of the natural resource with the potential for domestic, agricultural and industrial consumption. Groundwater quality of bore well water of Baramati city has undergone degradation due to anthropogenic and some natural factors. Groundwater samples were collected from thirty borewells and hand pumps of different areas of Baramati city, District Pune, Maharashtra (India) during the period January 2014 to December 2014 and analyzed for their physico-chemical characteristics. The various physico-chemical parameters such as pH, Electrical conductivity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, total dissolved solids (TDS), total hardness (TH), HCO_3^-, Cl^-, SO_4^{2-} and DO were determined using standard procedures of APHA. The results of analysis were compared with the drinking water quality standards of Indian Standard Institute (BIS) and World Health Organization (WHO). In study area electrical conductivity and TDS of 80% samples were found above the maximum permissible limit of WHO and BIS. The higher values during summer reflect concentration effect. 30 to 33% groundwater samples shows sodium values above 200 mg/l, which is guideline limit for drinking water by WHO. In the study area 30% water samples were hard water category. The groundwater quality of the study area for drinking purpose has been spoiled by anthropological and other activities. The 30 to 80% borewell and hand pump water samples were found to be unsuitable directly for drinking purposes. Such water can be purified by using suitable purification methods and can be used for drinking purpose.

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Keywords: Water quality standards; physico-chemical parameters; quality of groundwater; drinking water; World Health Organization.

1. INTRODUCTION

Water is a valuable resource on which all life is dependent. Water is a basic necessity of life, not only for people but for every type of plant and animal as well [1]. Water shortage have becomes an increasingly serious problem in India, especially in the arid and semi-arid regions of the country due to vagaries of monsoon and scarcity of surface water. The Baramati city area borewell and hand pump water is used for drinking and other household purposes by many peoples. The water quality of these borewells and hand pumps for drinking purpose had objectionable. To check the details about the water quality, study have been undertaken. The exhaustive literature survey indicates the extensive studies on water quality have been carried out by the various research workers.

The study area underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. Basaltic lava occupies more than 95% of the study area. These flows are normally horizontally disposed over a wide stretch and give rise to table land type of topography also known a plateau. These flows occur in layered sequences ranging in thickness from 7 to 45 meter and represented by 6 massive unit at the bottom and vesicular unit at the top of the flow [2].

The water bearing properties of these flows depend upon the intensity of weathering, fracturing and jointing which provides availability of open space within the rock for storage and movement of ground water. The thickness of weathering varies widely up to 20 m bgl. However, the weathered and fractured trap occurring in topographic lows forms the potential aquifer. The ground water in the study area occurs under phreatic, semi-confined and confined conditions. Generally the shallower zones down to the depth of 20 to 22 m bgl form the phreatic aquifer. The water bearing zones occurring between the depth 20 and 40 m bgl when weathered or having shear zones yield water under semi-confined condition. The deep confined aquifers generally occur below the depth of 40 m bgl [3].

Groundwater quality data gives important clues to the geologic history of rocks and indications of groundwater recharge, movement and storage [4]. Assessment of groundwater quality is necessary and immediate task for present and future groundwater quality management. Groundwater quality, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and input from sources other than water- rock interaction [5]. Such factor and their interaction results in a complex groundwater quality [6]. Various publications have concentrated on groundwater quality monitoring and evaluation for domestic and industrial activities.

Mohan reported geochemical facies and demarcation of locations unfit for human consumption in Uttar Pradesh state of India [7]. Quality of groundwater for domestic and agriculture purpose was attempted by Belkhiri and suggested groundwater suitability for drinking and public health [8]. The objective of the scientific investigations is to determine the hydrochemistry of the ground water and to classify the water in order to evaluate the water suitability for drinking and domestic uses and its suitability for drinking purpose.

2. MATERIALS AND METHODS

2.1 Sampling Sites

Ground water samples from different hand pumps and Bore wells of thirty sampling sites of Baramati city are selected randomly and by considering the topography and anthropological activities of the study area (Fig. 1).

2.2 Sample Collection

Water samples from the selected sites were collected in a good quality polyethylene bottle of one-litre capacity during period January 2014 to December 2014 (pre-monsoon and post-monsoon season).

2.3 Physico-Chemical Analysis

Physico-chemical parameters like colour, pH, EC, TDS, Ca^{2+}, Mg^{2+}, Cl^{-}, $CO_3^{\ 2-}$, $HCO_3^{\ -}$, SO_4^{2-}, Na^{+}, K^{+} etc. were analyzed in the laboratory for summer 2014 and winter 2014 season by using standard methods recommended by APHA [9]. Various physical parameters like pH, EC, and TDS were determined within two hours with the help of digital portable pH meter and Conductivity meter in the laboratory. Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^{-}), Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^{-}) and Sulphate (SO_4^{2-}) were determined by volumetric titration methods; while Sodium (Na^{+}) and Potassium (K^{+}) by Flame photometry as recommended by APHA. The respective values for all these parameters are reported in Table 1 and 2. Results obtained from analysis were compared with standard parameters recommended by the BIS [10], and WHO [11] (Table 3).

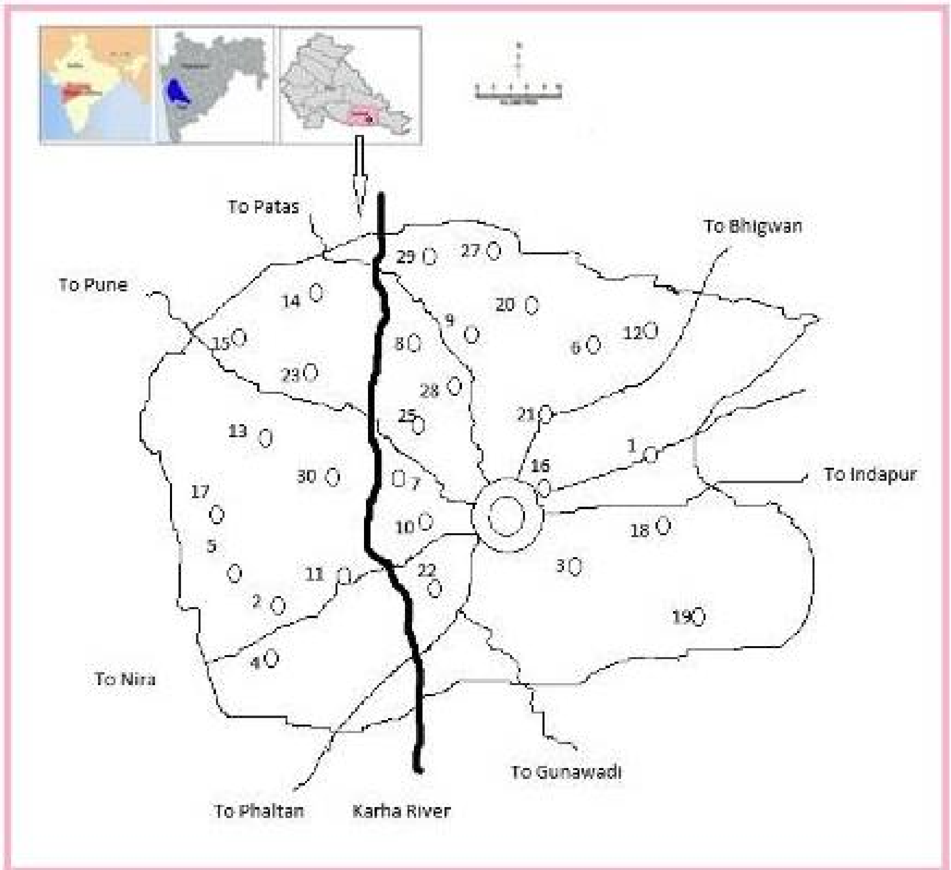

Fig. 1. Location map of the study area

Table 1. Physico-chemical data for the ground water of Baramati City, Pune, Maharashtra (Pre-monsoon, summer 2014)

Sr. no.	Sampling station	PH	EC μS/cm	TDS mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	TH mg/l	Na^{+} mg/l	K^{+} mg/l
1	Market Yard	6.91	1630	1043	112	54	502	105	0.70
2	Kasaba	8.10	1710	1094	32	14	138	324	9.50
3	Bobade Hospital	7.02	1130	723	65	46	352	106	0.80
4	Mukti Village	7.81	2020	1293	24	43	237	312	0.30
5	Kasaba	8.00	1430	915	28	24	169	290	0.70
6	Sangavi Estate	7.25	1000	640	34	18	159	143	0.80
7	Tahasil Office	7.41	880	563	72	29	299	457	24.00
8	Vivid Lahari	7.50	600	384	64	24	259	90	1.10
9	Durga Talkies	7.35	1200	768	58	58	384	98	0.60
10	Takar colony	7.65	960	614	55	48	335	114	1.00
11	River side	7.41	3124	1999	32	21	166	1500	160.00
12	Wadujkar Est.	7.68	1550	992	64	35	304	161	1.50
13	Mukti village	7.04	1230	787	20	18	124	610	2.40

Sr. no.	Sampling station	PH	EC	TDS	Ca^{2+}	Mg^{2+}	TH	Na^+	K^+
			µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
14	Patas road	6.96	640	410	48	31	247	125	1.20
15	Khandobanagar	6.80	780	499	64	24	259	129	0.90
16	Bus stand	6.83	810	518	60	31	277	155	0.70
17	Kasaba	7.09	1510	966	42	34	245	380	9.30
18	Market Yaard	6.84	1410	902	45	89	479	103	0.90
19	Wabale Hosp.	6.82	1140	730	35	53	306	110	0.90
20	Pragatinagar	7.20	580	371	80	50	406	60	0.90
21	Tahasil Office	6.84	730	467	56	43	317	168	5.40
22	Sidheshwar Galli	6.86	860	550	56	36	288	194	5.90
23	Koshti Galli	7.00	910	582	56	42	313	620	42.60
24	Dhor Galli	7.06	800	512	60	36	298	179	5.30
25	Koshti Galli	7.02	790	506	56	41	309	96	1.80
26	Khatik Galli	6.95	800	512	64	38	316	204	2.10
27	Pragatinagar	7.10	840	538	52	31	257	143	4.50
28	Ram Galli	6.86	890	570	80	38	356	231	0.80
29	Pragatinagar	7.04	760	486	85	45	397	78	0.60
30	Malegaon road	6.89	1610	1030	25	35	207	400	10.00
Average		7.18	1144	732	54	38	290	256	9.91
Maximum		8.10	3124	1999	112	89	502	1500	160.00
Minimum		6.80	580	371	20	14	124	60	0.30

Table 1 continued …..

Sr. no.	Sampling station	Salinity	Cl^-	SO_4^{2-}	NO_3^-	DO
		mg/l	mg/l	mg/l	mg/l	mg/l
1	Market Yard	145	260	178	36	5.50
2	Kasaba	110	290	189	38	8.50
3	Bobade Hosp	98	260	104	35	8.00
4	Mukti Village	213	210	255	55	6.00
5	Kasaba	185	214	234	36	5.00
6	Sangavi Estate	132	140	156	24	6.00
7	Tahasil Office	179	395	255	60	3.20
8	Vivid Lahari	135	164	181	28	3.70
9	Durga Talkies	175	170	157	37	4.30
10	Takar colony	124	213	162	47	3.00
11	River side	654	745	648	48	4.20
12	Wadujkar	143	214	150	25	6.00
13	Mukti village	324	423	347	52	7.50
14	Patas road	142	126	204	32	6.50
15	Khandobanagar	175	125	178	51	4.30
16	Bus stand	198	224	86	40	4.40
17	Kasaba	187	342	302	38	4.10
18	Market Yaard	201	210	307	38	5.90
19	Wabale Hosp.	205	160	278	51	3.10
20	Pragatinagar	204	140	185	26	5.00
21	Tahasil Office	205	245	107	74	3.80
22	Sidheshwar	206	278	142	30	4.10
23	Koshti Galli	524	405	421	32	3.20
24	Dhor Galli	275	236	158	37	3.80
25	Koshti Galli	136	147	203	48	4.20
26	Khatik Galli	285	304	156	40	4.30
27	Pragatinagar	208	146	247	32	4.70
28	Ram Galli	364	314	124	32	4.90
29	Pragatinagar	125	204	207	32	5.10
30	Malegaon road	367	324	198	35	8.40
Average		221	254	217	40	5.02
Maximum		654	745	648	74	8.50
Minimum		98	125	86	24	3.00

Table 2. Physico-chemical data for the ground water of Baramati City, Pune, Maharashtra (Post-monsoon, winter 2014)

Sr. no.	Sampling station	PH	EC	TDS	Ca^{2+}	Mg^{2+}	TH	Na^{+}	K^{+}
			µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	Market Yard	6.95	1432	916	98	65	512	123	0.65
2	Kasaba	8.24	1358	869	36	19	168	324	8.50
3	Bobade Hospital	7.30	955	611	62	37	307	121	1.10
4	Mukti Village	7.92	1654	1059	28	38	226	345	0.65
5	Kasaba	8.10	1245	797	30	22	165	321	0.74
6	Sangavi Estate	7.37	902	577	28	22	160	142	0.82
7	Tahasil Office	7.50	789	505	62	28	270	417	17.00
8	Vivid Lahari	7.46	721	461	58	22	235	102	1.10
9	Durga Talkies	7.24	1102	705	55	45	323	89	0.60
10	Takar colony	7.75	899	575	46	34	255	123	1.14
11	River side	7.24	2340	1498	28	19	148	1782	1.25
12	Wadujkar Est.	7.52	1155	739	60	31	277	158	1.20
13	Mukti village	7.15	1087	696	32	22	170	546	2.10
14	Patas road	6.90	704	451	32	42	253	570	1.32
15	Khandobanagar	7.20	809	518	60	21	236	155	1.32
16	Bus stand	6.90	712	456	47	27	228	123	0.70
17	Kasaba	7.16	1302	833	39	31	225	289	7.20
18	Market Yaard	6.90	1247	798	55	75	446	102	1.10
19	Wabale Hosp.	6.87	1024	655	38	47	288	142	1.20
20	Pragatinagar	7.10	706	452	65	42	335	104	1.10
21	Tahasil Office	7.23	755	483	52	39	290	132	3.70
22	Sidheshwar Galli	7.54	765	490	49	32	254	190	3.20
23	Koshti Galli	7.32	756	484	52	38	286	504	28.20
24	Dhor Galli	7.12	714	457	48	28	235	171	435.00
25	Koshti Galli	7.26	695	445	52	38	286	121	1.90
26	Khatik Galli	6.90	804	515	78	41	364	186	1.56
27	Pragatinagar	7.30	786	503	49	25	225	176	3.40
28	Ram Galli	6.85	805	515	86	40	379	180	1.00
29	Pragatinagar	7.20	675	432	78	36	343	98	0.92
30	Malegaon road	6.87	1432	916	22	32	187	317	5.80
Average		7.28	1011	647	51	35	269	272	17.85
Maximum		8.24	2340	1498	98	75	512	1782	435.00
Minimum		6.85	675	432	22	19	148	89	0.60

Table 2 continued ----

Sr. no.	Sampling station	Salinity	Cl^{-}	SO_4^{2-}	NO_3^{-}	DO
		mg/l	mg/l	mg/l	mg/l	mg/l
1	Market Yard	155	275	195	36	5.50
2	Kasaba	189	306	175	38	8.50
3	Bobade Hosp	132	214	165	35	8.00
4	Mukti village	234	325	265	55	6.00
5	Kasaba	215	319	216	36	5.00
6	Sangavi Estate	135	155	172	24	6.00
7	Tahasil Office	255	387	289	57	3.20
8	Vivid Lahari	125	160	175	32	3.70
9	Durga Talkies	177	201	155	35	4.30
10	Takar colony	115	208	156	47	3.00
11	River side	712	690	721	45	4.20
12	Wadujkar	145	227	168	34	6.00
13	Mukti village	321	435	388	48	7.50
14	Patas road	321	425	405	34	6.50
15	Khandobanagar	204	188	176	49	4.30
16	Bus stand	175	189	84	34	4.40
17	Kasaba	170	335	285	32	4.10
18	Market Yard	186	202	278	31	5.90
19	Wabale Hosp.	185	156	270	47	3.10

Sr. no.	Sampling station	Salinity	Cl^-	SO_4^{2-}	NO_3^-	DO
		mg/l	mg/l	mg/l	mg/l	mg/l
20	Pragatinagar	213	145	198	21	5.00
21	Tahasil Office	198	215	102	47	3.80
22	Sidheshwar	210	265	138	32	4.10
23	Koshti Galli	508	417	458	33	3.20
24	Dhor Galli	269	231	150	32	3.80
25	Koshti Galli	125	152	198	46	4.20
26	Khatik Galli	212	345	145	34	4.30
27	Pragatinagar	206	135	236	28	4.70
28	Ram Galli	355	302	124	32	4.90
29	Pragatinagar	120	215	227	28	5.10
30	Malegaon road	356	304	187	32	8.40
Average		231	271	230	37	5.02
Maximum		712	690	721	57	8.50
Minimum		115	135	84	21	3.00

Table 3. Ground water quality standards for drinking purposes

Sr. no.	Parameters	Unit	BIS: 2003	WHO: 2006
1	Colour	HU	5	5
2	Turbidity	JTU	5	5
3	pH		6.5 – 8.5	6.5 – 8.5
4	EC	(µS/cm)	No guideline	600
5	Ca^{2+}	mg/l	75	75
6	Mg^{2+}	mg/l	30	30
7	Na^+	mg/l	No guideline	200
8	K^+	mg/l	No guideline	No guideline
9	Fe^{2+}	mg/l	0.5	0.3
10	TDS	mg/l	500	500
11	TH	mg/l	300	200
12	HCO_3^-	mg/l	No guideline	No guideline
13	Cl^-	mg/l	250	200
14	SO_4^{2-}	mg/l	200	200
15	NO_3^-	mg/l	45	45
16	F^-	mg/l	1	1.5

3. RESULTS AND DISCUSSION

Physico-chemical parameters of ground water samples from different locations of Baramati City in pre-monsoon and post-monsoon season are given in Tables 1 and 2. pH values of water samples in summer 2014 season varies from 6.8 to 8.10 and in winter 2014 varies between 6.85 to 8.24. In the Pre-Monsoon (summer 2014) the maximum EC is 3124 µS/cm and minimum is 580 µS/cm having average 1144 µS/cm. In Post-Monsoon (winter 2014) the maximum EC is 2340 µS/cm and minimum is 675 µS/cm having average 1011 µS/cm.

WHO and BIS had given the guidelines for EC required for drinking water (750 mg/l). In Baramati city area 80% samples were found above the maximum permissible limit of WHO and BIS. The higher values during summer reflect concentration effect. This suggests the control of climatic factors on the hydro-chemical diversity in the area [12]. This value indicates the quality of groundwater in study area is disturbed (Fig. 2).

The electrical conductivity of water is the principal parameter used to measure a solution's salt content. EC was measured quickly and easily and readings are temperature dependent therefore, measurements typically are corrected to an equivalent value at 25°C [5]. The EC values of groundwater sample of study area are given in the Tables 1 and 2 for two seasons. Electrical conductivity measurement makes it possible to obtain information about the extent of mineralization in the groundwater.

In Baramati city area total dissolved solids in 73% samples (22 samples out of 30) were found above the maximum permissible limit of WHO and BIS (500 mg/l). These values clearly indicate the groundwater quality in 73% area was not suitable directly for drinking purpose on the basis of TDS.

Raja and Venkatesan [13] assessed the groundwater pollution and its impact in and around Punnam area of Karur District, Tamilnadu, India. They observed the range of TDS in the area was minimum 925 mg/l to maximum 3020 mg/l. similar results was observed in the Baramati city area (Fig. 3).

Amount of calcium in the groundwater dependent on solubility of $CaCO_3$, sulphates and very rarely chlorides. The solubility of $CaCO_3$ depends upon the partial pressure of CO_2 in the atmosphere [14]. Under such conditions, freshwater can contain 20 to 30 mg/l of calcium at saturated level. However, in the soil- air through which the water has to pass, the percentage of CO_2 in several times higher. Hence, the calcium content in groundwater can be as high as 70 to 100 mg/l [15].

The Calcium concentration of groundwater in winter 2014 ranges from 22 to 98 mg/l having average 50.83 mg/l. In summer 2014 Calcium value ranges from 20 to 112 mg/l having average 54.13 mg/l.

The magnesium concentration of groundwater in winter 2014 ranges from 19 to 75 mg/l having average 34.60 mg/l. In summer 2014 magnesium value ranges from 14 to 89 mg/l having average 37.63 mg/l.

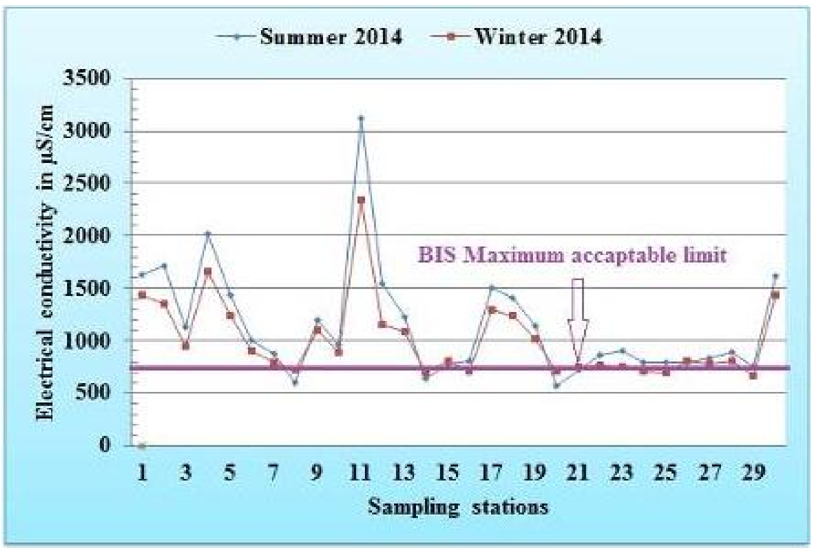

Fig. 2. Spatio-temporal variation in electrical conductivity

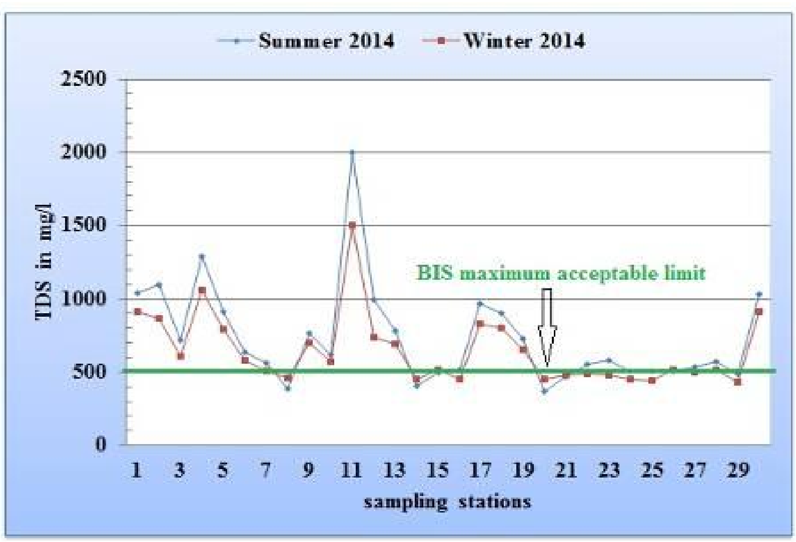

Fig. 3. Spatio-temporal variation in TDS

The concentration of Mg from present study is in agreement with the study conducted by Thitame [16]. He reported the Mg concentration of groundwater samples from Sangamner area, he observed less fluctuation in magnesium concentration ranging from 81.1 mg/l to 197.7 mg/l.

The concentration of sodium from Baramati city area were analyzed and data is given in table 1 and 2. The sodium concentration of groundwater in winter 2014 ranges from 89 mg/l to 1782 mg/l having average 271.8 mg/l. In summer 2014 sodium value ranges from 60 mg/l to 1500 mg/l having average 256.2 mg/l (Fig. 4).

Human activities can have a significant influence on the concentration of sodium in surface and groundwater. The reuse of water for irrigation commonly leaves a residue, which is much higher in sodium concentration than in the original water. This is possibly the important source of high concentrations of sodium in the area.

In the two seasons 30 to 33% groundwater samples shows sodium values above 200 mg/l, which is guideline limit for drinking water by WHO. From the health point of view, sodium is an important ion. High dietary intake of sodium plays a significant role in the development of hypertension and high blood pressure. However, concentrations in excess of 200 mg/l may give rise to unacceptable taste [11]. On the contrary, beneficial correlations for sodium have been reported. Areas where water is hard, highly mineralized, and also high in sodium tend to have lower cardiovascular death rates.

The hardness is an important criterion for determining the suitability of water for domestic, drinking and other industrial supplies. Traditionally, hardness is a measure of the capacity of water to react with soap. Water hardness is caused by dissolved polyvalent metallic ions. In fresh water, the hardness causing ions are calcium and magnesium, which exists in the form of bicarbonates, chlorides, sulphates and nitrates. In addition to these ions, manganese, strontium and barium also contribute to water hardness [17].

Pawar discussed that, hardness is caused by cations, it may be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. Carbonate hardness refers to the amount of carbonate and bicarbonates in solution that can’t be removed by boiling [12]. While non-carbonate hardness refers to the presence of sulphates, chlorides and nitrates. Water hardness is primarily due to the result of interaction between water and geological formation [19]. In the study area 30% water samples are exceeded the permissible limit of total hardness (Fig. 5).

Amongst the various dissolved constituents in groundwater, bicarbonate is most important and abundant anion. Pawar explained in his study, water charged with carbon dioxide dissolves carbonate minerals, as it passes through soil and rocks to give bicarbonates. The contribution of

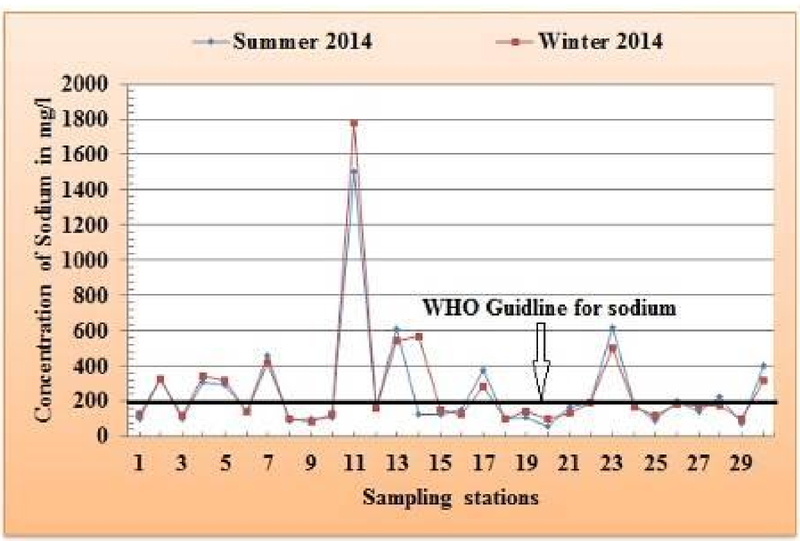

Fig. 4. Spatio-temporal variation in sodium

each source towards the total bicarbonate present in the water depends on the initial carbon dioxide content and the extent to which carbon dioxide gets converted into bicarbonate ions [19].

In winter 2014 alkalinity of groundwater of study area ranges from 115 to 712 mg/l having average 231 mg/l. In summer 2014 alkalinity value ranges from 98 to 654 mg/l having average 221 mg/l. It is established by Drever that, below pH 4.3, all the carbonate species exist in the form of H_2CO_3. As soon as the pH of water exceeds 4.3, they get converted into bicarbonate ions [20]. In the present study 50% samples alkalinity was more than the standard limit of BIS (200 mg/l) (Fig. 6).

Chlorides in the groundwater are originated from chloride bearing minerals such as sodalite, and chloroapatite. These minerals are very minor constituents of igneous and metamorphic rocks. The solutions of halite and other evaporate minerals sometimes give rise to high chloride content in ground water [21]. The concentration of chloride from study area were analyzed and data is given in Tables 1 and 2.

In winter 2014 chloride in groundwater of study area ranges from 135 to 690 mg/l having average 271mg/l. In summer 2014 chloride value ranges from 125 to 745 mg/l having average 254 mg/l (Fig. 7).

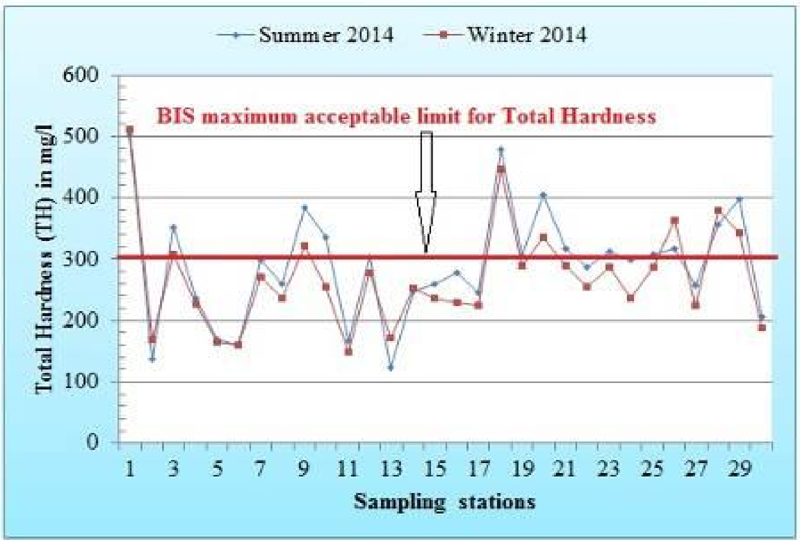

Fig. 5. Spatio-temporal variation in total hardness

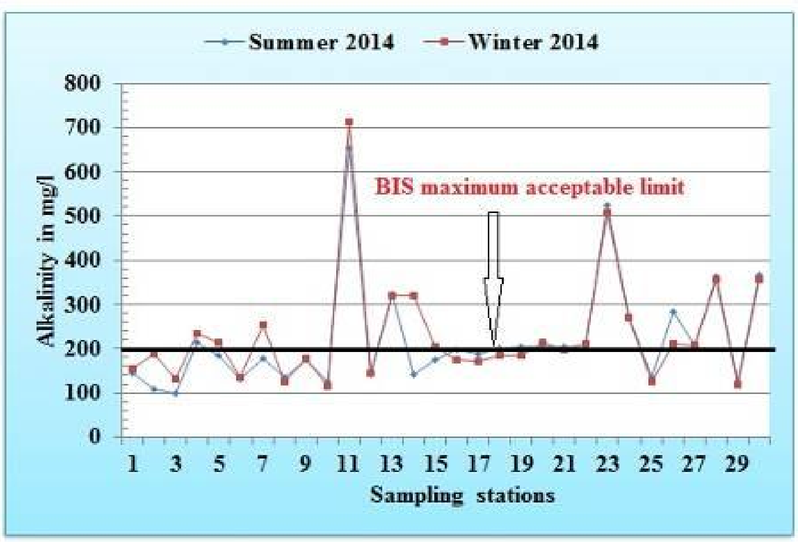

Fig. 6. Spatio-temporal variation in alkalinity

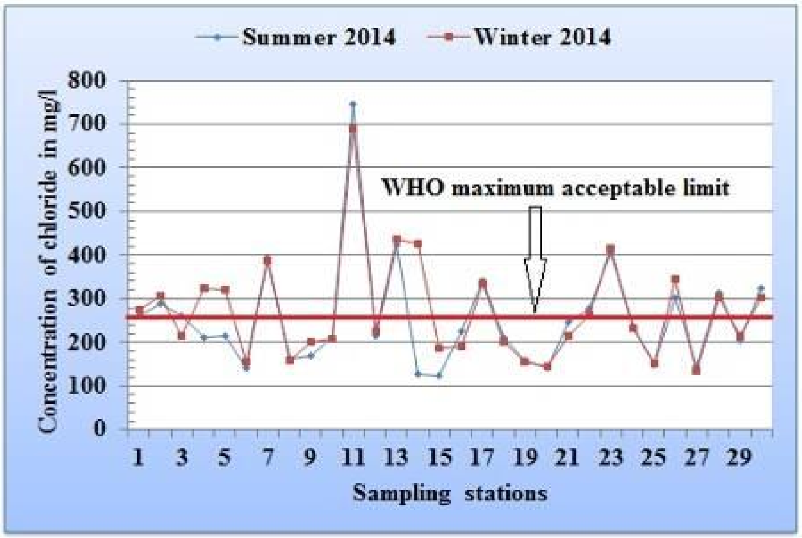

Fig. 7. Spatio-temporal variation in chloride concentration

In the present study, the maximum groundwater samples showed the pH greater than 7.0 indicating carbonate species exist in the form of bicarbonate ions. Karanath [21] found the bicarbonate concentration in the groundwater 100 to 200 mg/l in their study which matching with the groundwater samples of Baramati area.

Dissolved oxygen is one of the most important parameters in water quality assessment and reflects the physical and biological processes prevailing in the waters. Its presence is essential to maintain the higher forms of biological life in the water; and the effects of a waste discharge in a water body are largely determined by the oxygen balance of the system. Water with oxygen content above 5 mg/l will support desirable form of aquatic life while water with less than 2 mg/l oxygen will support mainly bacteria, fungi and other microorganisms [22].

In the Baramati city area DO concentration in the 37% samples were above 5 mg/l as recommended by BIS and WHO and such water is good for drinking purpose on the basis of dissolved oxygen concentration. While other samples DO is below 5 mg/l but it was well above 2 mg/l.

4. CONCLUSION

Groundwater quality in the Baramati city area had been analyzed for various physico-chemical parameters such as pH, EC, TDS, Ca^{2+}, Mg^{2+}, TH, Cl^-, $HCO_3{}^-$, $SO_4{}^{2-}$, Na^+, K^+, DO etc. It was observed that about 30 to 50% of ground water samples exceed the permissible limit prescribed by BIS and WHO. Overall groundwater quality of the study area is not suitable for drinking purpose directly. Borewell and hand pump water may be used after suitable purification treatments.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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