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Evaluation of Groundwater Quality and its Suitability for Drinking Purpose in Dharta Watershed of Udaipur District, Rajasthan, India

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ABSTRACT

Groundwater is a necessary and essential element of any existence support system. It is not only the basic need for human survival but also a compulsory input for all development activities. This study was carried out to analysis factors regulating quality of groundwater in an area with drinking as main use. Sixty groundwater samples-twenty form each year 2013, 2014 and 2015 respectively have been collected from four different villages of Dharta Watershed of Udaipur district. The analytical results shows higher concentration of TDS (53.33%), EC (45%), and MH (96.67%) which indicates signs of deterioration as per WHO and BIS standards. For drinking point of view water quality of the sample investigation reveal that the groundwater is not completely fit for utilization with respect to pH, EC, Na^{+}, Mg^{2+}, and Ca^{2+}. In some of the water samples of the area, the concentrations of these elements exceed the acceptable limits of BIS and WHO standards.

KEYWORDS: *Groundwater quality, Hydrochemical parameter, WHO & BIS Standards*

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1. INTRODUCTION

GROUNDWATER QUALITY

Groundwater is a significant natural resource of drinking water. The biological and chemical nature of ground water is suitable for most utilize but the quality of ground water is changed as a result of human's activities (Gajendra et al 2008, Hortan 1965). In order the natural quality of groundwater alters as groundwater flows from springs or rivers and recharge areas. Groundwater holds normally standard dissolved mineral substances such as calcium, sodium, magnesium, potassium, chloride, bicarbonate and sulfate (Ryznar John W 1986).The suitability of groundwater for different utility depends on various factors such as organic substances and dissolved minerals present in ground water in different concentrations (Karanth K R. 1997). In which, some components are safe, others are unsafe, and the minority may be highly toxic (ISI 1983, Parihar S. S. *et. al.* 2012). Inhabitant's expansion is one of the major factors responsible for increased solid waste. According to Backman B. et al 1998, where intensive practices take place, agriculture has wide impact on groundwater quality. Also urbanization and industrialization have significant impact on groundwater quality. In various parts of earth atmospheric conditions also alter the quality of the groundwater. Groundwater is not considered desirable for drinking if the quantity of dissolved minerals exceeds from permissible limit (Jain C.K. 2009, BIS 2012, Latha S. *et. al.* 1999). Groundwater in which dissolved natural resources are present then its character is saline. Dissolved minerals can be hazardous to animals and plants in large concentrate ions. Groundwater that contains a lot of calcium and magnesium is called hard water. The hardness of water is represented in terms of the amount of calcium carbonate (Verma S, *et. al.* 2015, Majumdar D and Gupta N. 2000). In current years, the expansion of industries, technology, and population has speed up the stress upon water resources. The quality of groundwater has been degraded (Kumar M. *et. al.* 2006).

Problem Definition:

In last decade requirement of water has lead to an increased due to the rapid development, which is increasingly being fulfilled by groundwater abstraction.

Complete information of the water feature can improve understanding of the hydrochemical structure, to get this; a hydrochemical analysis was performed in the study area. Groundwater feature and its appropriateness for agriculture and domestic point were observed by different physico-chemical constraints such as pH, EC (electrical conductivity), TDS (total dissolved solids), TH (total hardness), calcium, magnesium, sodium, potassium, bicarbonate, and sulfate. These constraints were used to evaluate the aptness of groundwater for household by comparing with the Indian standards and WHO.

2. STUDY AREA

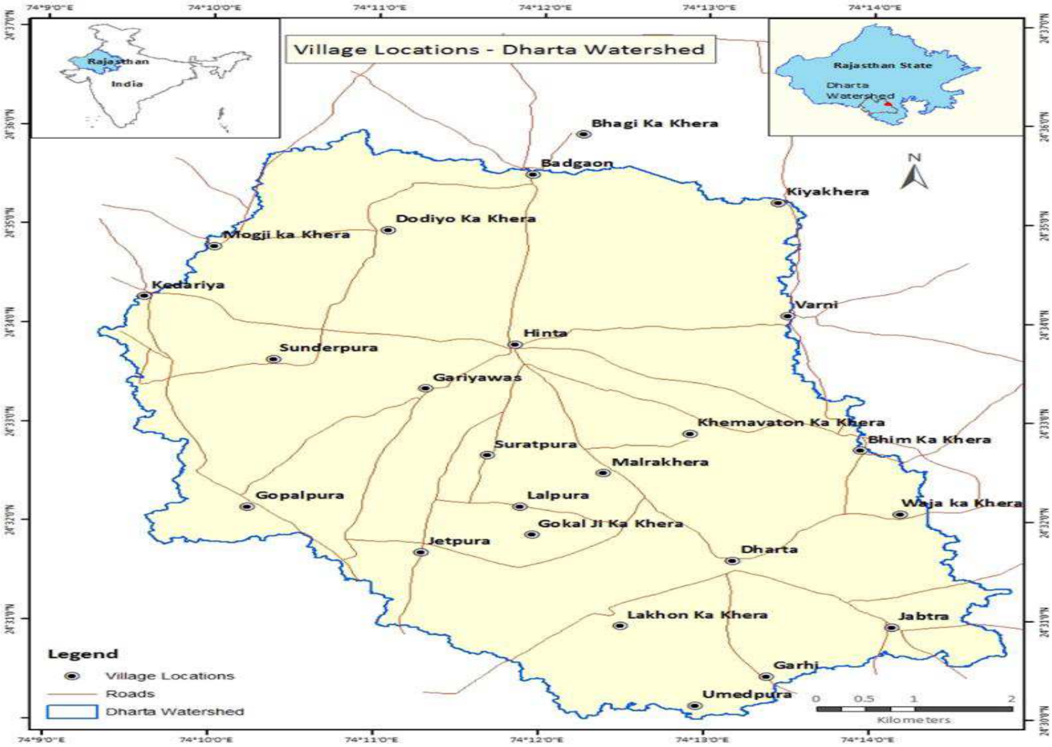

Figure 1: Village locations and road network of Dharta watershed.

Dharta watershed of the Bhinder block (an administrative district) of Vallabhnagar Tehsil has been selected as a study area due to existing engagement of project partners (Maheshwari *et al.*, 2014) and willingness of local community to participate and proximity to organizations to provide scientific and technical support. The watershed is situated at an altitude 470m above sea level at a latitude of 24º 37' to 24º 39' N, and longitude 74º 09' to 74º 15' E. It is about 5 km from its block head quarter and 65 km east of the city of Udaipur within the Udaipur District of Rajasthan (Figure 1).

3. METHODOLOGY

Analysis of water samples

The physicochemical parameters determine using standard methods. For preparation of solutions double distilled water were use and for analysis AR grade reagents were use. Table 1 showed the methods used for estimation of various physicochemical parameters. The water samples were analyzed in the laboratory of AICRP on groundwater utilization, CTAE, Udaipur (Rajasthan).

Table1. Methods use for estimation of physiochemical parameters.

S. No.	Parameters	Method	References
1	pH	Using Glass Electrode pH meter	Jackson (1973)
2	Electrical Conductivity	Using EC meter	Wilcox (1950)
3	Total Dissolved Solids	Using TDS meter	Singh and Kalra (1975)
4	Calcium and Magnesium	EDTA titration	Cheng & Bray (1951) and Diehl et. al. (1950)
5	Sodium	Flame Photometric method	Toth et. al. (1948)
7	Potassium	Flame Photometric method	Stanford and English (1949)
8	CO_3 and HCO_3	Titration with standard H_2SO_4	A.O.A.C. (1950)
9	Sulphate	Titrimetric method	Munger et. al. (1950)

4. RESULT AND DISCUSSION:

Water Quality Parameter of Dharta Watershed for Year of 2013, 2014 & 2015:

The quality standards for drinking water have been specified by BIS (2012). The behavior of major ions (Ca, Mg, Na, K, HCO_3, and SO_4) and important physico-chemical parameters such as pH, EC and TDS and suitability of ground water in the study area were discussed below:

Table2: Analysis of different parameters of Groundwater samples of Dharta watershed for year 2013, 2014 &2015

S.No.	YEAR	Well ID	pH	EC (dS/m)	SAR	RSC (meq/L)	TDS (ppm)	Ca	Mg
1	2013	H-1	7.5	3.40	2.07	-23.10	2276	17.2	550.4
2		H-3	7.8	1.34	1.89	-5.40	861	8.6	275.2
3		H-14	8.2	0.73	2.11	-0.20	426	4.6	147.2
4		H-15	8.2	0.73	2.36	-0.20	452	3.8	121.6
5		H-17	8.1	0.73	2.99	0.40	440	4.4	140.8
6		D-1	8.0	1.60	2.91	-4.7	1120	17.2	550.4
7		D-9	8.2	0.97	3.67	-0.2	609	9	288
8		D-31	8.1	1.41	3.49	-2.2	984	6.8	217.6
9		D-34	8.2	0.84	3.75	-0.6	513	7.4	236.8
10		D-37	8.0	1.79	4.54	-2.2	1270	8.6	275.2
11		B-40	7.8	1.30	2.53	-3.4	806	10.4	332.8
12		B-41	7.8	2.50	2.33	-12.6	1690	18.8	601.6
13		B-47	6.8	3.50	5.55	-10	2380	19.6	627.2
14		B-49	6.8	4.00	3.76	-17.6	2820	24.4	780.8
15		B-50	7.6	3.30	4.54	-11.6	2350	31.6	1011.2
16		SP-22	8.3	1.14	0.89	-5.8	743	5.4	172.8
17		SP-23	8.3	1.06	1.33	-3.2	702	4.8	153.6
18		SP-39	7.5	1.70	0.91	-3.6	1120	5.2	166.4
19		SP-40	8.3	1.64	0.98	-6.6	1090	5	160
20		SP-47	8.2	1.24	0.54	-6.4	776	4.8	153.6
1	2014	H-1	7.5	3.38	2.53	-22.5	2160	21.02	672.64
2		H-3	7.7	1.40	2.30	-8	900	9.4	300.8
3		H-14	8.1	0.80	2.62	-1.7	510	5.9	188.8
4		H-15	8.0	0.68	1.83	-1.2	430	4.3	137.6
5		H-17	8.1	0.70	1.87	-1.66	450	4.1	131.2
6		D-1	8.0	1.46	2.86	-4.87	930	15.7	502.4
7		D-9	8.0	1.00	4.05	0.89	630	11.5	368
8		D-31	8.1	1.30	3.96	-1.56	820	8.4	268.8
9		D-34	8.2	0.90	4.02	0.28	570	6.5	208
10		D-37	8.0	1.68	4.66	-1.34	1060	8.4	268.8
11		B-40	7.9	1.42	3.18	-3.49	900	10.52	336.64
12		B-41	7.8	2.44	2.56	-13.8	1520	17.1	547.2
13		B-47	7.0	3.22	5.28	-12.1	2010	22.2	710.4
14		B-49	7.0	3.84	3.91	-16.7	2380	23.5	752
15		B-50	7.6	3.22	4.39	-12.82	2050	28.4	908.8
16		SP-22	8.2	1.12	0.96	-7.25	710	8.2	262.4
17		SP-23	8.3	1.00	1.47	-3.72	632	5.6	179.2
18		SP-39	7.4	1.64	1.29	-6.27	1030	5	160
19		SP-40	8.2	1.68	1.64	-7.1	1040	7.3	233.6
20		SP-47	8.2	1.20	0.72	-8.4	750	4.2	134.4
1	2015	H-1	8.1	2.55	2.22	-26.25	2220	18.5	592
2		H-3	8.3	1.02	2.06	-9	717	10.2	326.4
3		H-14	8.7	0.56	2.31	-0.1	362	4.9	156.8
4		H-15	8.7	0.72	2.61	-1.62	466	4.8	153.6
5		H-17	8.7	0.60	3.23	0	385	5.8	185.6
6		D-1	8.6	1.59	3.48	-5.49	1240	19.8	633.6
7		D-9	8.8	0.99	4.46	1.24	684	10.3	329.6
8		D-31	7.9	1.74	4.05	-2.78	1440	12.7	406.4
9		D-34	8.6	0.97	4.20	0.79	674	9.1	291.2
10		D-37	7.8	1.50	4.46	-0.74	1130	11.4	364.8
11		B-40	8.7	1.26	2.13	-4	943	13.2	422.4
12		B-41	8.0	2.81	2.50	-14.4	2660	28.6	915.2
13		B-47	8.6	3.32	5.80	-9.52	3530	36.1	1155.2
14		B-49	8.2	3.40	3.72	-20.33	3470	33.4	1068.8
15		B-50	7.9	3.78	4.31	-17.2	4720	38.7	1238.4
16		SP-22	8.6	1.55	0.97	-4.61	1190	6.4	204.8
17		SP-23	8.7	1.29	1.38	-2.07	948	5.8	185.6
18		SP-39	8.3	1.41	1.10	0.02	932	5.6	179.2
19		SP-40	8.9	1.56	1.14	-5.1	1200	8.6	275.2
20		SP-47	7.9	1.13	0.97	-6.55	804	5.9	188.8

4.1. Measurement of pH of groundwater samples of Dharta watershed for Year 2013, 2014 & 2015:

The pH is major parameter, which validates the suitability of water for various purposes such as drinking, cooking, bathing, washing and farming etc. It gives essential information in many types of geochemical stability or solubility calculations (Hem 1985). The pH level of water having desirable limit is 6.5 to 8.5 as specified by the BIS, 2012; ISI 1993. Pure water is said to be neutral, with a pH of 7. Water with a pH below 7.0 is considered acidic while water with pH greater than 7.0 is considered as basic or alkaline.

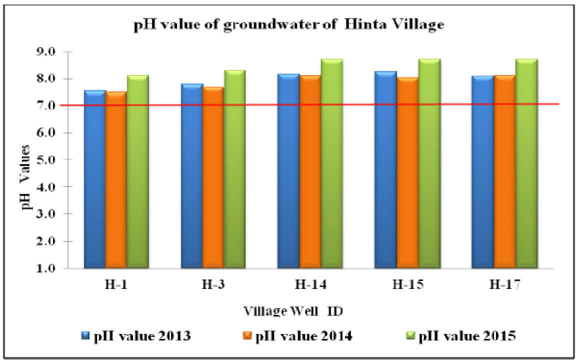

Figure 2: pHof Hinta Village

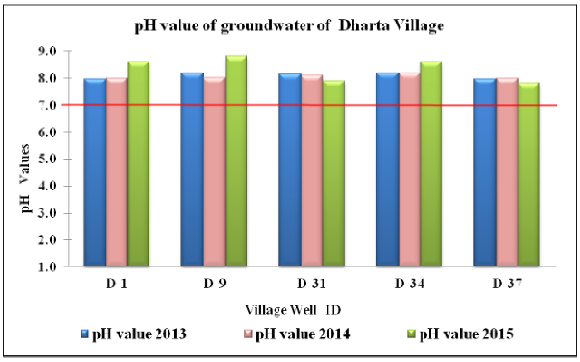

Figure 3: pHof Dharta Village

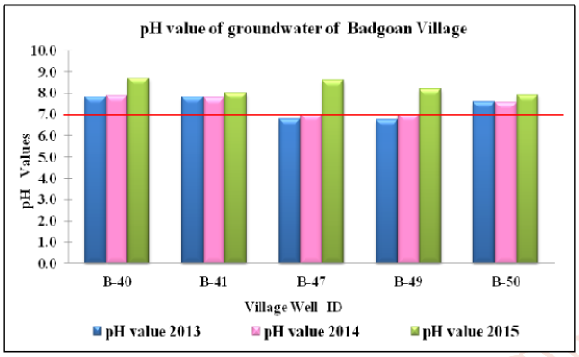

Figure 4: pHof Badgoan Village

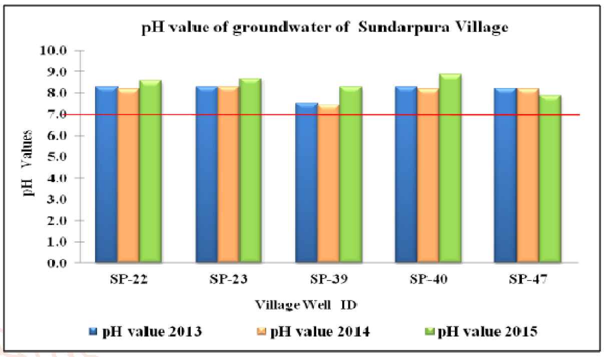

Figure 5: pHof Sundarpura Village

The pH value of the groundwater samples in Dharta watershed varies from 6.8 to 8.9 with an average value of 8.1 in open/dug wells (Table 2). In analyzed samples were found that 18.3 % samples were exceeds the permissible limit prescribed by BIS 2012, WHO 2008 (Appendix 1), whereas 81.7 % samples were within the permissible range and suitable for drinking purpose. PH of Hinta (Fig.2) and Dharta (Fig.3) village is slightly alkaline in nature meanwhile PH of sundarpura (Fig.5) village is slightly to strongly alkaline. The nature of groundwater samples of badgoan village is acidic to alkaline.

4.2. Measurement of Electric Conductivity of groundwater samples of Dharta watershed for Year 2013, 2014 & 2015: Electrical conductivity (EC) is a measure of how conductive the water is to electrical current. Greater the ion concentration, greater is the EC. Generally higher the EC, higher is the total dissolved solids. For finding the total dissolved solids in water body electrical conductivity is an indirect measure. To convert the electrical conductivity of a water sample (micro Siemens per cm, µS/cm) to the concentration of total dissolved solids (ppm), the conductivity must be multiplied by a factor between 0.46 and 0.9 (depending on the unique mixture of the dissolved materials). A widely accepted conversion factor is 0.67. TDS (ppm) = Conductivity {(µS/cm) x 0.67}.The instrument used for measuring conductivity is conductivity meter. Solutions of most inorganic acids, bases, and salts are relatively good conductors. In contrast, the conductivity of distilled water is less than 1 µmhos/cm.

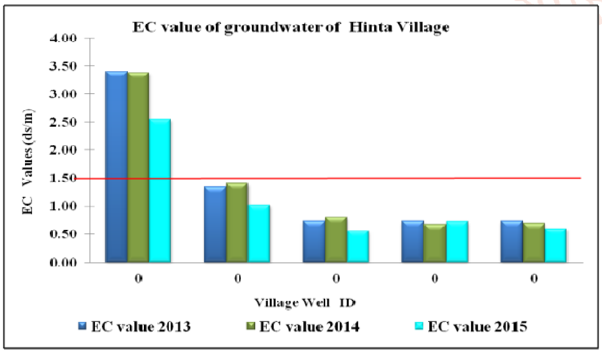

Figure 6: ECof Hinta Village

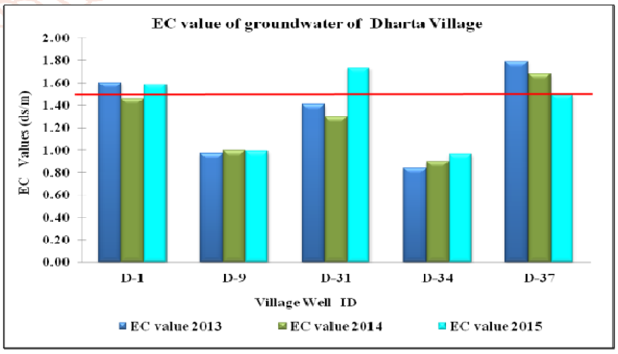

Figure 7: ECof Dharta Village

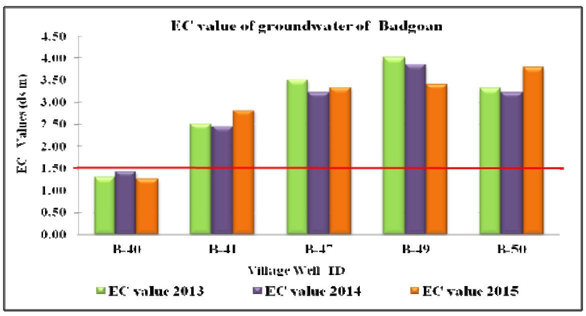

Figure 8: ECof Badgoan Village

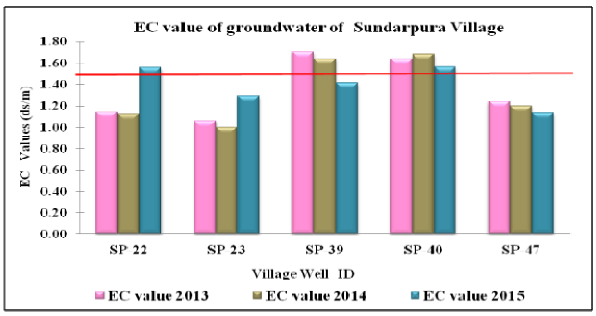

Figure 9: ECof Sundarpura Village

Electric conductivity in groundwater varies from 0.56 ds/m to 4.0 ds/m (Table 2) in Dharta watershed, whereas permissible limit is 1.5 to 3.0 ds/m (appendix1) for domestic use. The EC values in majority of samples are lesser than permissible limit. Conductivity values are divided into the three groups from general experience. The division based on conductivity values suggests that 56.67 % of the wells are within the range of safe limit of 1.5 ds/m, while 25% of the wells are in the range of 1.5 to 3ds/m and 18.33 % of the wells are above the range of permissible limit 3.0 ds/m in watershed area. The highest value of EC was found in well ID B-49 of Badgoan village in year 2013(Fig.8).

Table3: Classification of groundwater samples from electric Conductivity range:

Conductivity range (decisiemens per meter)	Classification	No. of Samples	% of samples
< 1.5	Permissible	34	56.67
1.5-3.0	Not permissible	15	25.00
>3.0	Hazardous	11	18.33

4.3. Measurement of Total Dissolved Solids (TDS) of ground water samples of Dharta watershed for Year 2013, 2014 & 2015:

TDS in groundwater can also be due to natural sources such as sewage, urban runoff and industrial waste (Joseph, 2001; Latha S., 2008). According to BIS and ICMR the desirable limit of TDS is 500 mg/L. If TDS value is more than 500 mg/L, it may cause gastro intestinal irritation. High TDS presence in the water decreases the quality and affects the taste of water (Guru Prasad, 2005).

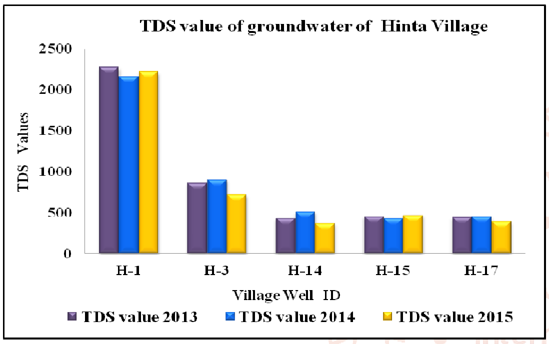

Figure 10: TDS of Hinta Village

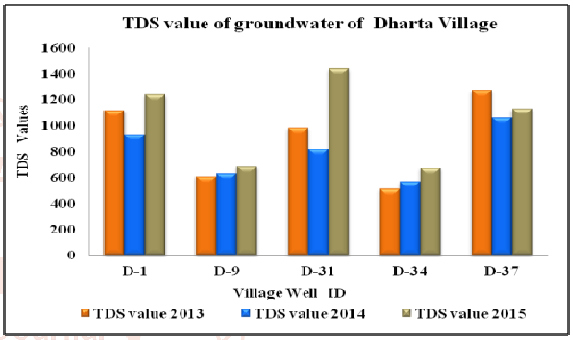

Figure 11: TDS of Dharta Village

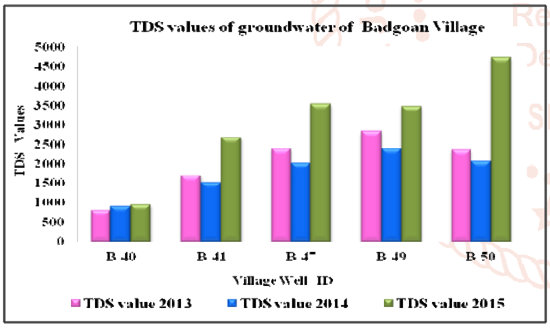

Figure 12: TDS of Badgoan Village

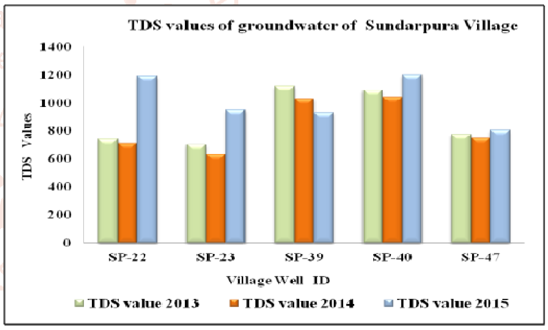

Figure 13: TDS of Sundarpura Village

According to WHO (2008) and ICMR (1975) specification TDS up to 500 mg/L or ppm is the highest desirable and up to 1,500 mg/L is maximum permissible. In Dharta watershed the TDS value varies between a minimum of 362 ppm and a maximum of 4720 ppm (Table 2), indicating that most of the groundwater samples lies within the maximum permissible limit. High concentration of TDS in the groundwater sample is due to leaching of salts from soil and also domestic sewage may percolate into the groundwater, which may lead to increase in TDS values.

In Dharta and Sundarpura village all samples were having permissible limit prescribed by the WHO and ICMR. 60 % groundwater samples were permissible for drinking (500–1,000 mg/L) and others 40 % samples are suitable for irrigation purposes. The Badgoan village have value of total dissolved solids varies from 806 to 4720 ppm (Fig. 12), indicating that only 20% samples are suitable for drinking purpose while 80% of the groundwater samples exceeding the maximum permissible limit and not suitable for drinking.

Table4: Taste of water with different TDS Concentration

Level of TDS (ppm)	Rating	No. of Samples	% of Samples
Less than 300	Excellent	0	0
300-600	Good	11	18.33
600-900	Fair	17	28.34
900-1200	Poor	14	23.33
>1200	Unacceptable	18	30.00

The sampling points found to have more TDS, may be influenced by domestic sewage as the sewage water was found to have high TDS values throughout the year. Further, high TDS in ground water may be attributed to nutrient rich surface waters that contaminate the ground water (Indirabai and George, 2002). Concentrations of TDS in water vary considerably in different geological regions owing to different in the solubility of minerals.

Table5: Classification of ground water samples on the basis of Total Dissolved Salts

Classification of ground water	Total dissolved salts in mg/L(ppm)	No. of Samples	% of Samples
Non saline	< 1000	33	55
Slightly Saline	1000-3000	24	40
Moderately Saline	3000-10000	3	5
Very saline	>10000	0	0

According to salinity classification (Table 5) suggested by Rabinove et al (1958), 40 % of ground water samples were slightly saline, while 5 % samples were moderately saline and non-saline at all other locations. TDS beyond 500 ppm decreases palatability and also favors gastro-intestinal diseases.

4.4. Measurement of Sodium Absorption Ratio (SAR) of ground water samples of Dharta watershed for Year 2013, 2014 & 2015:

The SAR value of water for irrigation purposes has a significant relationship with the extent to which sodium is absorbed by the soils. Irrigation using water with high SAR values may require soil amendments to prevent long-term damage to the soil, because the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This will also lead to a decrease in infiltration and permeability of the soil to water leading to problems with crop production.

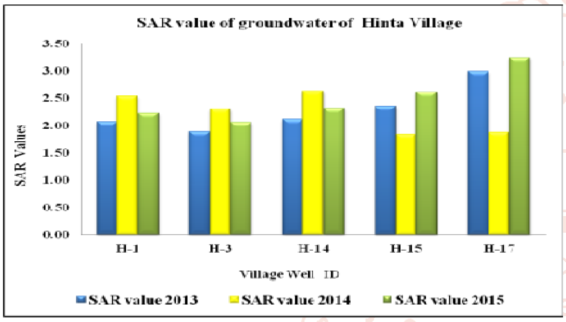

Figure 14: SAR of Hinta Village

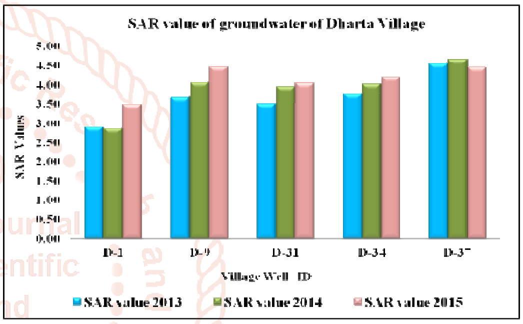

Figure 15: SAR of Dharta Village

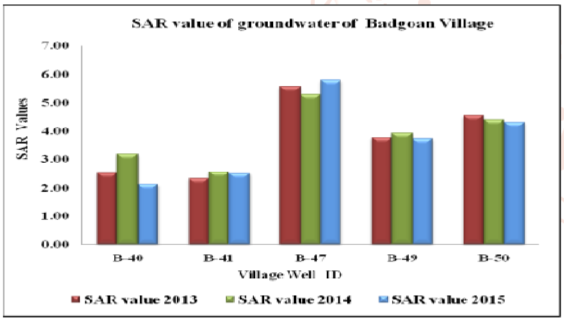

Figure 16: SAR of Badgoan Village

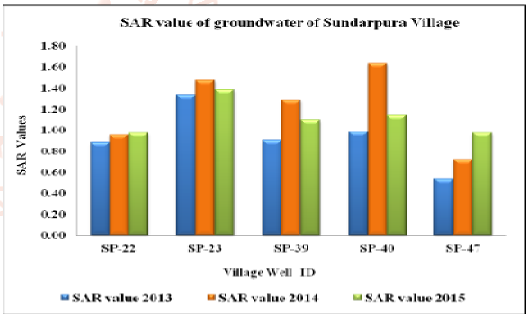

Figure 17: SAR of Sundarpura Village

The calculated values of SAR in the study area vary between 0.72 to 1.37 for hinta wells (Fig 14), 1.03 to 1.81 for dharta well (Fig 15), 0.79 to 2.07 for badgoan wells (Fig16), and 0.19 to 0.47 for sundarpura wells (Fig 17) of years 2013, 2014 and 2015 respectively. The classification of groundwater samples based on SAR values are shown in table 6. The SAR values of all the samples are found within the range of excellent category, which means to be suitable for irrigation purpose.

Table6: Classification of groundwater samples based on SAR

Water Class	SAR	No. of Samples
Excellent	<10	60
Good	10-18	-
Doubtful	18-26	-
Unsuitable	>26	-

4.5. Overall water type of Dharta Watershed (Year 2013-2015):

4.5 (a) Calcium Hardness

There is no definite trend in values of calcium hardness samples. Calcium is one of the most abundant elements found in natural water. It is important ion in imparting the hardness to the waters. The calcium hardness of groundwater samples ranged from 0.6 to 10.2 meq/L with overall average of 3.22 meq/L of successive three years analysis. At high pH much of its quantities may get precipitated as calcium carbonate.

4.5 (b) Magnesium Hardness
Magnesium is determined as the difference between the total hardness and calcium hardness. Magnesium also occurs in all kind of natural waters, but its concentration remains generally lower than the calcium hardness. There is no definite trend in values of magnesium hardness in groundwater samples. The magnesium hardness ranged from 2.2 to 18.40 meq/L with overall average of 8.33 meq/L of successive three years analysis.

4.5 (c) Sodium
Sodium values ranged from 1.2 to 17.21 meq/L and the average value of sodium was 6.45 meq/L in all of the studied samples of successive three- years. The maximum value of sodium examined in sample GWS/B-47/2015/post-monsoon and the minimum value of sodium measured in sample GWS/D-9/2015/post-monsoon.

4.5 (d) Potassium
Potassium values ranged from 0.02 to 3.66 meq/L and the average value of potassium was 0.69 meq/L in all of the studied samples of successive three-years. The maximum value of potassium examined in sample GWS/B-49/2013/post-monsoon. Maximum numbers of samples were having less than 2.0 meq/L potassium.

4.5 (e) Carbonate Alkalinity
The values varied between 0.02 to 7.4 meq/L. The minimum value was observed in (GWS/SP-23/2014/post-monsoon) and maximum in (GWS/SP-39/8-2015/ post-monsoon).

4.5 (f) Bicarbonates Alkalinity
Bicarbonates alkalinity ranged from 1.0 to 7.9 meq/L with an overall average of 3.90 meq/L in analyzed samples during successive three years. In sample (GWS/H-1/2013/post-monsoon) minimum value of bicarbonates alkalinity was observed and in sample (GWS/SP-40/2015/post-monsoon) maximum value of bicarbonates alkalinity was observed.

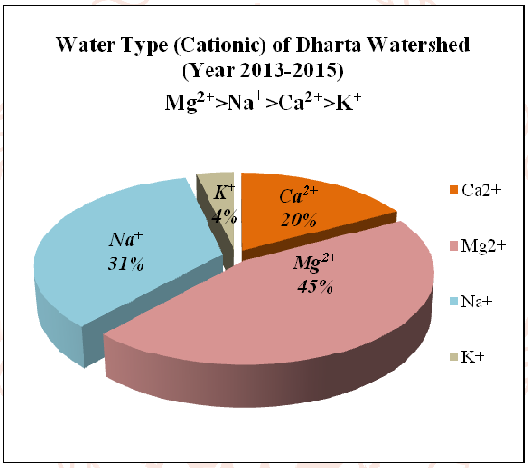

Figure 18: Water type of Dharta watershed

It was found that the nature of groundwater of Dharta watershed is $Mg^{+} > Na^{+} > Ca^{+} > K^{+}$ and HCO_3^{-} - CO_3^{2-} type (Fig. 18).

APPENDIX 1

Parameter		WHO(2008)	ICMR(1975)	BIS (10500-2012)
pH	Desirable Limit	7 – 8.5	7 – 8.5	6.5-8.5
	Max. per limit	6.5 – 9.2	6.5 – 9.2	No Relaxation
Fluoride	Desirable Limit	0.7	1	1
	Max. per limit	1.5	1.5	1.5
TDS	Desirable Limit	500	500	500
	Max. per limit	1500	1500	2000
EC	Desirable Limit	1.5	1.5	1.5
	Max. per limit	3.0	3.0	3.0
Chloride	Desirable Limit	200	200	250
	Max. per limit	600	1000	1000
Nitrate	Desirable Limit	45	20	45
	Max. per limit	-	50	No
Turbidity	Desirable Limit	5 NTU	5 NTU	1
	Max. per limit	25 NTU	25 NTU	5
Sulphate	Desirable Limit	200	200	200
	Max. per limit	400	400	400
Sodium	Desirable Limit	200	-	NG
	Max. per limit	250	-	NG

Calcium	Desirable Limit	75	75	75
	Max. per limit	200	200	200
Magnesium	Desirable Limit	30	50	30
	Max. per limit	150	150	100
Total Hardness	Desirable Limit	300	300	200
	Max. per limit	500	600	600
Potassium	Desirable Limit	10	-	NG
	Max. per limit	-	-	NG
Bicarbonate	Desirable Limit	500	500	500
	Max. per limit	-	-	NG
Arsenic	Desirable Limit	0.01	0.05	0.01
	Max. per limit	NR	NR	0.05
Iron	Desirable Limit	0.3	0.1	0.3
	Max. per limit	1.0	1.0	1

CONCLUSION

Analysis of water samples collected from various locations of Dharta Watershed revealed that all water samples do not comply with WHO standards and Indian Standards- 10500-91. Groundwater in Dharta region requires precautionary measures before drinking so as to prevent adverse health effects on human beings.

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