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Assessment of Water Quality Indices for Irrigation of Dharta Watershed, Udaipur, Rajasthan, India

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ABSTRACT

Validate the suitability of water for agriculture on the basis of the quality indices is the key objective of this study. The quality of water was evaluated by analyzing parameters such as calcium, magnesium, sodium, alkalinity and bicarbonates. The quality indices were evaluated and ranged as Sodium Absorption Ratio 0.54 to 5.80 ppm, Soluble Sodium percentage 10.47 to 59.17 ppm, Residual Sodium Carbonate -26.25 to 1.24 ppm, Permeability Index 25.16 to 79.78 and Kelly's Ratio 0.12 to 1.45 ppm. The outcomes were compared to the WHO and BIS standards. According to salinity hazard in which based on EC, 18.33% samples are unsuitable for irrigation, while 26.67% samples are utilize by suitable water treatment, On the basis of TDS 5% of water samples are belongs to moderately saline category which is reduce by some irrigation practices. On the other side based on Sodium hazard all the samples are found within the range of excellent category, which means water is suitable for irrigation purpose. The calculated indices were fit in agreement by means of WHO & BIS. The documentation contains information about the impact of the irrigation water quality on the agriculture.

KEYWORDS: *Water quality indices, SAR, SSP, RSC, KR, irrigation, Dharta watershed*

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1. INTRODUCTION

The irrigation of farming produce with water of poor quality reduces the yield. A method for reviewing the appropriateness of the accessible water for irrigation of the diverse crops, taking in concern the consequences of the substance investigation is required to avoid emerging troubles at use deficient class water (FAO). On the base of analysis the system issues recommendations how to use the water for agriculture, soil, on the basis of in order on cultivated crops and agro-climatic characteristics of the area. The purposes of the study are protection of crops, water resources; soil resource, and consumers, sustainable farming improvement etc. is a requirement for the agriculture production, which reduces the health hazards for the consumers.

Agriculture is the largest part of economic movement represents the foremost source of food and earning. The water is the key resource for irrigation in India. For irrigation water quality also depends on the environment, soil characteristics, the water table depth, sub-soil condition climate, topography, etc (Das *et al* 2018). The quality of water replicates contributions from the soil, atmosphere, water-rock conditions and contaminant sources. It required for irrigation depends up on the dissolved salts like Ca, Mg, Na, & HCO_3 in water (Patil & Patil, 2010). Studied said that the absorption of these salts and their ratio to one another are influence the quality of water for irrigation, (USEPA; 1974). However, such water influences crops yield.

With high salt substance can bring about displacement of cations like Ca and Mg from the clay minerals of the soil in irrigation water , followed by replacement of cation by sodium, (Pondhe; 1992). The key elements affecting the quality of irrigation water are Na, Mg, Ca, and alkalinity of water (USEPA; 1974). The increased concentration of these elements on irrigation water changes the soil quality and makes it unsuitable for cultivation of crop. But there is no literature for Dharta Watershed. Hence present assessment was undertaken to assess the suitability of water for irrigation.

2. Study Area

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 (Fig. 1).

Fig. 1 Study Area of Dharta Watershed

3. MATERIALS AND METHODS

Collection of Samples: Samples of water were collected from the selected twenty wells of Dharta Watershed. A plastic bottle [100 ml] rinsed with pechloric acid & distilled water were used for the sample collection and brought to laboratory. The water samples were collected for the period of three year during 2013 to 2015.

Examination of Water Samples: The Major elements [Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) & Cationic] were determined according to the standard methods (table 1), (APHA; 1998) in the laboratory. The results of yearly analysis were presented in table 2.

Water quality indices analysis: The evaluation of water quality fitness for irrigation was carried with the help of indices like Sodium Absorption Ratio, Soluble Sodium Percentage, Residual Sodium Carbonate,(USEPA; 1974), and Kelly's Index,(Kelly; 1940) showing in table 3.

Table:1 Different method used to determine various parameters:

Quality Parameters	Symbol	Formula adopted	Reference/source
Total dissolved solids	TDS	TDS = 640 × EC (for EC < 5 dS/m) TDS = 800 × EC (for EC > 5 dS/m)	Dinka (2010)[a]
Sodium adsorption ratio	SAR	$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$	USSL (1954)[a]
Residual sodium Carbonate	RSC	$RSC = (CO_3^- + HCO_3^-) - (Ca+Mg)$	Doneen (1964)[b]
Kelly's Ratio	KR	$KR = \frac{Na}{Ca+Mg}$	Kelly (1940)
Sodium Soluble percentage	SSP	$SSP = \frac{Na \times 100}{Ca+Mg+Na}$	Wilcox (1958)
Permeability index	PI	$PI = \left[\frac{(Na+\sqrt{HCO_3})}{Ca+Mg+Na}\right] \times 100$	Doneen (1964)[b]
Sodium percentage	%Na	$\%Na = \left[\frac{Na}{Ca + Mg + Na + K}\right] \times 100$	Khodapanah et al. (2009)
Magnesium ratio	MR	$MR = \frac{Mg \times 100}{Ca + Mg}$	Paliwal (1972)

Source: [a] Sarkar and Hassan (2006); [b] Reddy and Kumar (2010).

4. RESULTS AND DISCUSSION

The water from the study area is widely used for irrigation from all sites. Due to the importance of farming the evaluation of water quality indices are carried out that the water is suitable for irrigation or not. The condition of water for irrigation reflects on indices.

It is seen from table 2 that the collected water components are extremely erratic in respect to cationic & anionic components. The components such as Na, Mg, and Ca ranged from 1.24 to 17.21, 2.2 to 18.4 and 0.6 to 10.2 ppm respectively. The anionic component's like $CaCO_3$ ranged from 1.8 to 31.0. These components are used for the quality indices.

Table2: Showing physico-chemical parameters of Dharta Watershed

Year	Well ID	Cationic conc. (meq/L)				Anionic conc. (meq/L)	
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}
2013	H-1	8.10	16.20	7.20	2.30	0.20	1.00
	H-3	1.80	8.00	4.18	0.02	0.80	3.60
	H-14	2.00	2.60	3.20	0.20	1.00	3.40
	H-15	0.80	2.80	3.16	0.07	0.40	3.00
	H-17	1.00	2.20	3.78	0.04	0.40	3.20
	D-1	2.20	6.50	6.06	0.11	0.80	3.20
	D-9	1.00	3.60	5.56	0.06	1.20	3.20
	D-31	1.60	5.20	6.44	0.08	1.00	3.60
	D-34	0.60	3.60	5.44	0.04	0.60	3.00
	D-37	2.00	5.20	8.62	1.00	1.00	4.00
	B-40	2.40	6.40	5.30	0.16	0.60	4.80
	B-41	3.40	12.60	6.60	1.70	1.00	2.40
	B-47	3.80	12.60	15.88	0.16	1.20	5.20
	B-49	5.20	16.00	12.24	3.66	0.40	3.20
	B-50	4.60	10.80	12.60	0.44	0.60	3.20
	SP-22	1.40	7.60	1.88	0.20	0.60	2.60
	SP-23	1.80	5.40	2.52	0.32	0.00	4.00
	SP-39	2.80	9.20	2.22	0.22	6.00	2.40
	SP-40	4.60	8.80	2.54	0.62	1.60	5.20
	SP-47	2.40	8.20	1.24	0.02	0.60	3.60
2014	H-1	7.80	16.40	8.80	3.30	0.60	1.10
	H-3	3.40	8.90	5.70	0.80	1.10	3.20
	H-14	3.80	3.20	4.90	0.60	1.40	3.90
	H-15	2.10	2.90	2.90	0.09	0.90	2.90
	H-17	2.80	3.40	3.30	0.30	1.20	3.34
	D-1	2.80	7.10	6.36	0.17	1.23	3.80
	D-9	1.20	3.80	6.41	0.13	1.99	3.90
	D-31	2.00	5.30	7.56	0.20	1.64	4.10
	D-34	0.90	3.90	6.23	0.11	1.20	3.88
	D-37	2.40	4.90	8.90	1.30	1.40	4.56
	B-40	2.89	7.10	7.10	0.20	0.70	5.80
	B-41	4.10	14.50	7.80	2.40	1.40	3.40
	B-47	4.50	14.80	16.40	0.33	1.50	5.70
	B-49	5.80	15.50	12.77	2.50	0.80	3.80
	B-50	5.12	12.40	13.00	0.38	1.00	3.70
	SP-22	2.20	8.70	2.23	0.40	0.45	3.20
	SP-23	2.74	6.10	3.10	0.41	0.02	5.10
	SP-39	3.35	11.42	3.50	0.65	5.40	3.10
	SP-40	5.50	9.70	4.51	0.78	2.30	5.80
	SP-47	3.40	10.40	1.90	0.06	1.20	4.20
2015	H-1	10.20	18.40	8.40	3.40	0.55	1.80
	H-3	3.40	11.40	5.61	0.03	1.50	4.30
	H-14	4.10	2.50	4.20	0.40	1.60	4.90
	H-15	2.10	3.60	4.40	0.09	1.10	2.98
	H-17	2.90	3.10	5.60	0.03	0.90	5.10
	D-1	2.80	7.80	8.01	0.74	1.23	3.88
	D-9	1.20	4.30	7.40	0.08	2.00	4.74
	D-31	2.00	5.42	7.80	0.30	1.70	2.94
	D-34	0.88	3.33	6.10	0.03	0.90	4.10
	D-37	2.56	6.32	9.40	1.20	1.74	6.40
	B-40	2.10	8.10	4.80	0.20	0.80	5.40
	B-41	3.80	15.00	7.65	2.40	1.30	3.10
	B-47	4.12	13.50	17.21	0.35	2.60	5.50
	B-49	6.20	18.20	13.00	2.87	0.97	3.10
	B-50	7.80	13.40	14.02	0.65	1.20	2.80
	SP-22	1.30	8.12	2.11	0.60	0.78	4.03
	SP-23	2.20	6.40	2.87	0.45	0.03	6.50
	SP-39	2.70	8.80	2.63	0.32	7.40	4.12
	SP-40	5.40	9.40	3.10	0.70	1.90	7.80
	SP-47	3.10	9.05	2.40	0.04	1.10	4.50

Table3. Water quality indices for irrigation:

Year	Well ID	SSP	% Na	SAR	RSC	KR	PI
2013	H-1	22.86	21.30	2.07	-23.10	0.30	26.03
	H-3	29.90	29.86	1.89	-5.40	0.43	43.47
	H-14	41.03	40.00	2.11	-0.20	0.70	64.67
	H-15	46.75	46.27	2.36	-0.20	0.88	72.37
	H-17	54.15	53.85	2.99	0.40	1.18	79.78
	D-1	41.06	40.75	2.91	-4.70	0.70	53.18
	D-9	54.72	54.40	3.67	-0.20	1.21	72.33
	D-31	48.64	48.35	3.49	-2.20	0.95	62.97
	D-34	56.43	56.20	3.75	-0.60	1.30	74.40
	D-37	54.49	51.25	4.54	-2.20	1.20	67.13
	B-40	37.59	37.17	2.53	-3.40	0.60	53.13
	B-41	29.20	27.16	2.33	-12.60	0.41	36.06
	B-47	49.19	48.95	5.55	-10.00	0.97	56.26
	B-49	36.60	32.99	3.76	-17.60	0.58	41.95
	B-50	45.00	44.30	4.54	-11.60	0.82	51.39
	SP-22	17.28	16.97	0.89	-5.80	0.21	32.10
	SP-23	25.93	25.10	1.33	-3.20	0.35	46.50
	SP-39	15.61	15.37	0.91	-3.60	0.19	26.51
	SP-40	15.93	15.34	0.98	-6.60	0.19	30.24
	SP-47	10.47	10.46	0.54	-6.40	0.12	26.50
2014	H-1	26.67	24.24	2.53	-22.50	0.36	29.84
	H-3	31.67	30.32	2.30	-8.00	0.46	41.60
	H-14	41.18	39.20	2.62	-1.70	0.70	57.77
	H-15	36.71	36.30	1.83	-1.20	0.58	58.27
	H-17	34.74	33.67	1.87	-1.66	0.53	53.97
	D-1	39.11	38.71	2.86	-4.87	0.64	51.10
	D-9	56.18	55.55	4.05	0.89	1.28	73.49
	D-31	50.87	50.20	3.96	-1.56	1.04	64.50
	D-34	56.48	55.92	4.02	0.28	1.30	74.34
	D-37	54.94	50.86	4.66	-1.34	1.22	68.12
	B-40	41.54	41.06	3.18	-3.49	0.71	55.64
	B-41	29.55	27.08	2.56	-13.80	0.42	36.53
	B-47	45.94	45.52	5.28	-12.10	0.85	52.63
	B-49	37.48	34.92	3.91	-16.70	0.60	43.20
	B-50	42.60	42.07	4.39	-12.82	0.74	48.90
	SP-22	16.98	16.48	0.96	-7.25	0.20	30.61
	SP-23	25.96	25.10	1.47	-3.72	0.35	44.88
	SP-39	19.16	18.50	1.29	-6.27	0.24	28.79
	SP-40	22.88	22.01	1.64	-7.10	0.30	35.10
	SP-47	12.10	12.06	0.72	-8.40	0.14	25.16
2015	H-1	22.70	20.79	2.22	-26.25	0.29	26.33
	H-3	27.49	27.45	2.06	-9.00	0.38	37.65
	H-14	38.89	37.50	2.31	-0.10	0.64	59.39
	H-15	43.56	43.18	2.61	-1.62	0.77	60.66
	H-17	48.28	48.15	3.23	0.00	0.93	67.74
	D-1	43.04	41.40	3.48	-5.49	0.76	53.63
	D-9	57.36	57.01	4.46	1.24	1.35	74.24
	D-31	51.25	50.26	4.05	-2.78	1.05	62.51
	D-34	59.17	58.99	4.20	0.79	1.45	78.81
	D-37	51.42	48.25	4.46	-0.74	1.06	65.26
	B-40	32.00	31.58	2.13	-4.00	0.47	47.49
	B-41	28.92	26.52	2.50	-14.40	0.41	35.58
	B-47	49.41	48.92	5.80	-9.52	0.98	56.14
	B-49	34.76	32.28	3.72	-20.33	0.53	39.47
	B-50	39.81	39.09	4.31	-17.20	0.66	44.56
	SP-22	18.30	17.39	0.97	-4.61	0.22	35.71
	SP-23	25.02	24.08	1.38	-2.07	0.33	47.25
	SP-39	18.61	18.20	1.10	0.02	0.23	32.98
	SP-40	17.32	16.67	1.14	-5.10	0.21	32.92
	SP-47	16.49	16.45	0.97	-6.55	0.20	31.07

Sodium Adsorption Ratio (SAR): The SAR of water samples was varying from 0.54 to 5.55, 0.96 to 5.28, and 0.97 to 5.80 for year 2013, 2014 and 2015 respectively with an overall average value of 2.78 for all the samples analyzed in successive three years. The water having SAR<10 is good for irrigation (WHO & BIS, 2012). It was observed that all the sites studied were good for irrigation, (table 4). Sodium adsorption was stimulated while Na percentage increases as compared to Ca & Mg resulting in soil dispersion (Emerson et al 1973, FAO 1992).

Table: 4 Classification of groundwater samples based on SAR

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

The SAR was also expressed as Sodium Hazard, (WHO & BIS 2012). In SAR the Ca and Mg ions are important because they tend to resist the effects of sodium. Continual use of water having high SAR leads to go down in the physical structure of the soil particles. Sodium would absorb & becomes attached to the soil particles. The soil then turns into hard & compact when dry and gradually more impermeable to water dispersion. The degree to which irrigation water tends to enter in to cations exchange reaction in soil can be indicated by the sodium absorption ratio. Sodium replacing adsorbed calcium & magnesium is a hazard as it causes damage to the soil structure, (Nishanthiny *et al*; 2010). Classification of groundwater samples as per WHO & BIS agricultural norms reveals that all the samples of study area are found within the range of excellent category, which means to be suitable for irrigation purpose.

Percent Sodium (% Na): Calculated values of percentage sodium (%Na) were ranged from 10.46 to 56.20 with overall average of 35.80 for all the samples analyzed in year 2013. For year 2014 values of percent sodium ranged from 12.06 to 55.92 with an average value of 34.99 and 16.45 to 58.99 for year 2015. The minimum value was found in sample SP-47 during 2013 (Table 3). Use of water having excess sodium percentage is not suitable for irrigational purpose. Data reveals that all samples were range from excellent to permissible category.

Table 5: Classification of water class based on % Na

Water Class	Sodium (Na) %	No. of sample	% of Sample
Excellent	<20	10	16.67
Good	20-40	23	38.33
Medium	40-60	27	45
Bad	60-80	-	-
Very bad	>80	-	-

Kelly's Ratio: The concentration of Na, Ca & Mg in water is representing the alkali hazard. The values of KI < 1 indicate suitable for irrigation & > 1 indicate unsuitability, (Kelly; 1940). The values of KR in the study varied from 0.12 to 1.45. Therefore, according to KI, 80 percent of water samples were suitable for irrigation, while 20 percent sample were unsuitable for irrigation purpose (Table 3).

Residual Sodium Carbonate: When the excess carbonate [residual] concentration becomes too high, the carbonates combine with calcium & magnesium to form a solid material [scale] which settles out of the water,(USDA; 1954). The sodium with alkaline & the quantity of bicarbonate and carbonate in accessed of alkaline also affect the fitness of water for irrigation. This excess is denoted by residual sodium carbonate [RSC]. Accordingly Eaton, 1950 the water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black color of the soil. Further, continued usage of high RSC waters affects crop yields, (USDA; 1954).

Table 6: RSC Classification of water quality

RSC (me l-1)	Water quality
< 1.25	Water can be used safely
1.25 - 2.5	Water can be used with certain management
> 2.5	Unsuitable for irrigation purposes

In the study, the RSC value was in the range of minimum -26.25 meq/l to maximum 1.24 meq/l for successive three years. Values of RSC for the cropland in 2013, 2014 and 2015 indicate that 100 % of the water is suitable for irrigation. Additional the value of RSC is negative at all sampling sites, indicating that there is no complete precipitation of calcium and magnesium (Pondhe, 1992).

Soluble Sodium Percentage: The minimum SSP value was observed is 10.47 meq/l, while maximum value was recorded 56.48 meq/l. The maximum value was of well D-34(Table 3). The SSP value at site 12 only shows the doubtful quality of water for drinking purpose while all sites are within the permissible level for irrigation (USEPA, 1974).

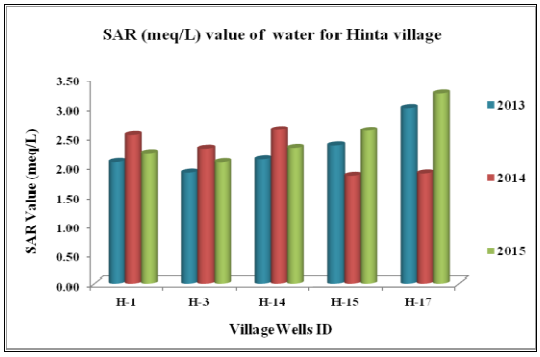
Permeability Index (PI): The permeability index proposed by Doneen (1964) indicates susceptibility of soil to permeability loss with respect to water quality, taking into account dissolved ions that can easily precipitate (expressed in percentage). Soil permeability is affected by a long-term use of irrigation water, depending on soil type and quality of the water used for irrigation. This index is calculated based on Na^+, Ca^{2+}, Mg^{2+} and bicarbonate content of water. Values of PI for the cropland and watershed area are injurious for 66.67% of the samples (Table 7), in other words, water should not be used without any irrigation practice management according to this index, while 33.33 % samples having a value of PI is good for irrigation purpose.

Table 7: Permeability Index range for water sample:

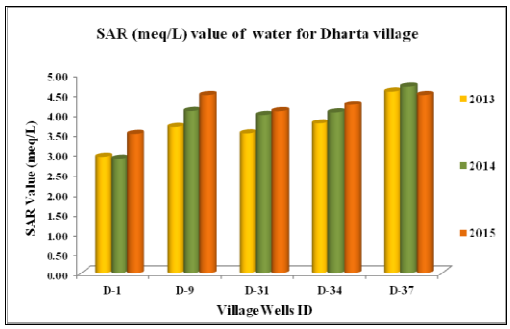
Parameter	Range	Class	No. of sample	% of Sample
Permeability Index (PI), %	<20	Excellent	0	0
	20-40	Good	20	33.33
	40-80	Injurious	40	66.67
	>80	Unsatisfactory	0	0

Conclusion:
The water quality indices studied showed that the water from Dharta Watershed is suitable for irrigation. Some of water samples are used by proper irrigation practices. The indices like KI, RSC, SSP, SAR and PI are within the permissible limits for irrigation, (BIS 2012, WHO & USEPA; 1974). For making water policy the time to time monitoring of water quality is necessary to help out farmers & irrigation department. Also water pollution should be monitoring frequently which help proper management & sustainable development.

Graph 1a to 1d: Graphical representation of value of SAR in meq/L for Hinta, Dharta, Badgoan and Sundarpura Village for year 2013, 2014 & 2015 respectively.



(1a)



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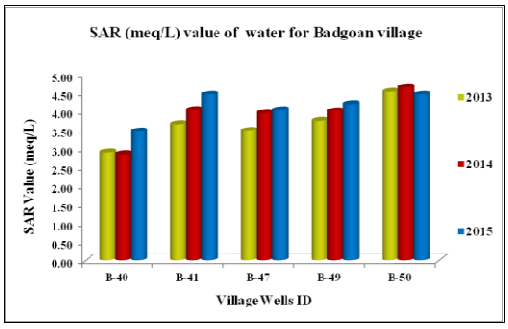

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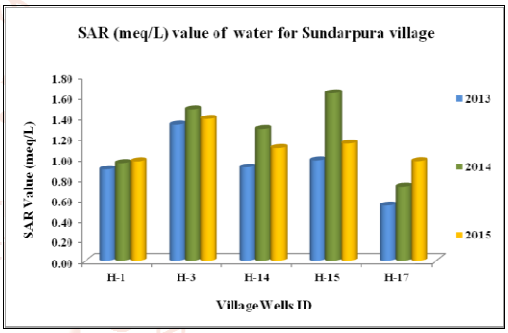
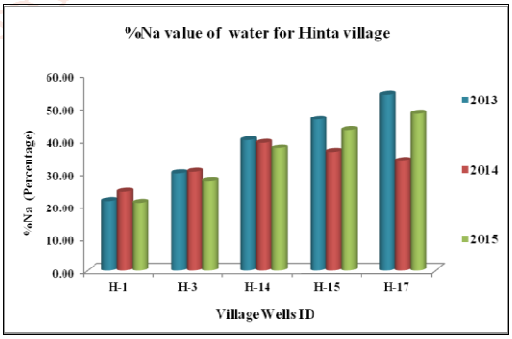
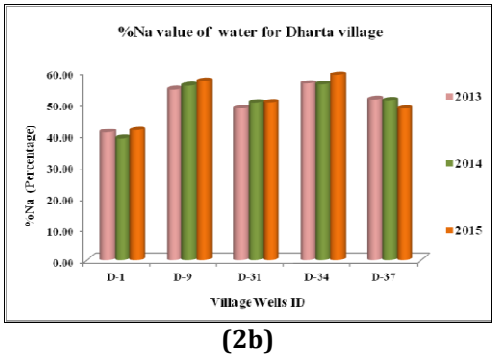


(1d)

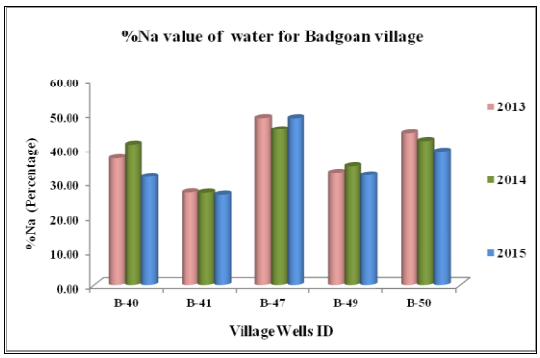
Graph 2a to 2d: Graphical representation of value of %Na for Hinta, Dharta, Badgoan and Sundarpura Village for year 2013, 2014 & 2015 respectively.



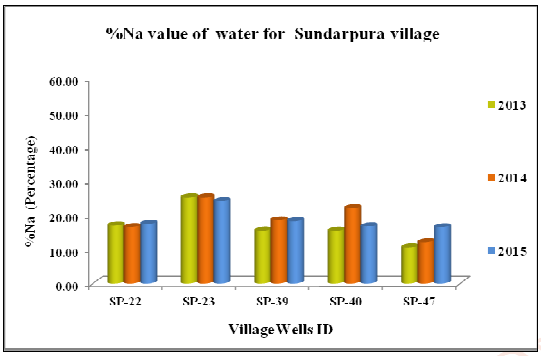
(2a)



(2b)



(2c)



(2d)

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