Statistical Analysis of Ground Water From Dharampur Taluka, Valsad District, (S. Guj.), India.

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Abstract:

Water plays an essential role in human life. A report of statistical analysis of groundwater samples taken from Dharampur Taluka, Valsad District, (S. Guj.), India is presented here. Groundwater samples were collected from three sampling stations duringAugust 2008 to July 2009 and were analyzed by using standard methods. In the present investigation, parameters viz. pH, Colour, Electrical Conductance (EC), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Sodium (Na), Copper (Cu), Manganese (Mn), Fluoride (F), Chloride (Cl), Silica, Sulphate (SO_4), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS)were determined. The results were compared with the Indian standard. Groundwater of the study area was classified according to Sodium Absorption Ratio (SAR). Observations indicated pH, Magnesium, Total alkalinity, TDS, Chloride, Sulphate and Fluoride values to be within permissible limit. Systematic calculations of correlation coefficient 'r' between water parameters and regression analysis provide useful mean for rapid monitoring of water quality. The results were used to calculate the water quality index (WQI) to draw conclusion about the suitability of the water for drinking and other domestic applications.

Keywords: Groundwater, Dharampur Taluka, Correlation coefficient, Regression equation, WQI.

1.0 Introduction

Groundwater is used for domestic and industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. The sources of water irrigation to agricultural land for irrigating are rainwater, surface and groundwater. The quality of ground water varies from place to place, with the depth of water table and from season to season. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, sub-surface and surface disposal of sewage and industrial wastes.Various classifications based on Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) etc. have been proposed to classify water for irrigation purpose.Water quality index (WQI) is one of the most effective tools [1-4] to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating reflecting the composite influence of different water quality parameters. The index is basically mathematical means of calculating a single value from multiple test results. The WQI suggestion is based on comparison of water quality parameter with respective to regulatory standards [5]. The idea of WQI was developed and proposed first by Horton [6]. The Statistical Regression Analysis has been found to be highly useful tool for correlating different parameters. Regression analysis helps in estimating or predicting the unknown value of one variable from known values of another variables [7-9]. The present investigation carried out for statistical analysis of groundwater from the Dharmpur Taluka, Valsad District, South Gujarat.

2.0 Materials and Methods

2.1 Study area

The study area, Dharampur Taluka of Valsad district. Valsad district is located in southern part of Gujarat State. It has total geographical area of 3055 sq km, extended by the North latitude of 20°07′ to 20°45′ and East longitude of 72°43′ to73°29′.The district is famous for its mango, chickoo trees. The other major crops are Rice [Oryzasativa], Sugarcane [Saccharum], Pigeon pea [Cajanus cajan] and vegetables.

2.2 Climate

Climate has significant effect on the adoption of crops in a locality. Depending on the combination of various meteorological elements, the climate of the place is determined. In general, best plant growth is obtained between 15.5 °C and 26.5 °C temperature for almost all crops, but the lower and upper critical temperature limits vary from crop to crop. The climate of the Valsad district is neither much hot nor much cool, it is temperate. It has three distinct seasons viz., Winter – from middle of October to February, Summer - from March to middle of June and Monsoon - from middle of June to middle of October.

2.3 Rainfall

Dharampur Taluka receives 1997 mm in 2007, 2743 mm in 2008 and 1772 mm in 2009 annual rainfall. Monsoon begins in the middle of June to middle of October.Usually, higher rainfall occurs in July and August months. (source : Gujarat Pani Purvatha and Gutter Vyavastha Board, Valsad)

2.4 Sampling and method of analysis

Polythene cans of 2 L capacity were made use for collection of water samples.These polythene cans were first washed with tap water, soaked in chromic acid solution for about 10-15 minutes to remove any impurities, again washed with tap water. Finally, they were rinsed with deionised distilled water. Then the polythene cans were taken for sample collection.Water samples were collected monthly from three sampling stations such as Dharampur (S13), Barumal (S14) and Kakadkuva (S15) from different sources viz. Hand pumps (300 ft. depth) and Bore well (250 ft. depth during August-2007 to July-2009.The samples were kept in a refrigerator till analyzed. pH measured on the sites during sampling.Eighteen physico-chemical parameters were taken for study such as: pH, Colour, Electrical Conductivity (EC), Total alkalinity, Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Sodium (Na), Copper (Cu), Lead (Pb), Manganese (Mn), Fluoride (F), Chloride (Cl), Silica, Sulphate (SO_4), Chemical Oxygen Demand (COD) and Sodium Adsorption Ratio (SAR) and were analysed by using standard techniques [10,11].

3.0 Results and Discussion

Physico-Chemical Parameters of sampled groundwater of two years Dharampurtaluka were presented and compared with IS Standards for Drinking Water [12] shown in Table 3.1.

Table 3.1 .Statistical value of physico-chemical parameters of groundwater of Dharampur taluka.

Parameters	**Results of two years (August, 2007 to July, 2009)**			**As per Standards for Drinking Water IS-105000-(1991)**[12]	
	Min.	**Max.**	**Mean± S.D.**	**Desirable limit**	**Permissible limit**
pH	6.5	8.1	7.3± 0.19	6.5-8.5	No relaxation
Colour	BDL	28	5.0 ± 2.04	5	25
EC	0.207	0.768	0.395± 0.06	-	-
Total Hardness	120	395	225 ± 26.91	300	600
Calcium	28.06	220	58± 5.54	75	200
Magnesium	7.29	46.09	19.33 ±4.39	30	90
Total Alkalinity	120	335	205 ± 21.34	200	600
TDS	186	707	355 ± 47.78	500	2000
Silica	5	40	23 ± 7.64	-	-
Chloride	9.23	215.13	36.6± 15.83	250	1000

Sulphate	4.9	54.5	12.6 ± 4.88	200	400
Fluoride	0.15	0.32	0.23 ± 0.14	1.0	1.5
COD	ND	15.84	1.9 ± 3.42	-	-
Copper	BDL	BDL	BDL	0.05	0.15
Lead	BDL	BDL	BDL	0.05	No relaxation
Manganese	BDL	0.06	0.005 ±0.04	0.1	0.3
Sodium	25.2	123	24.4 ±15.67	-	-
SAR	0.41	3.04	0.80 ± 0.45	-	-

(Results are expressed in mg/l except for pH, SAR, Colour in Hazen and EC in mmho/cm :

ND: Not Detected; BDL: Below Detectable Limit)

3.1 Correlation coefficient'r'[13-18]

The correlation between the various parameters is studied using Pearson's Correlation coefficient Matrix [19]. Generally, correlation coefficient is used to establish the relationship between two variables. The correlation is said to be positive when increase in one parameter causes the increase in other parameter and it is negative when increase in one parameter causes decrease in other parameters. The correlation coefficient 'r' has a value between +1 and -1. The correlation between the parameters is characterized as strong, when it is in the range of ± 0.8 to ± 1.0, moderate in the range of ± 0.5 to ± 0.8, weak when in the range of ± 0.0 to ± 0.5 [20]. Karl Pearson's measure, known as Pearson's correlation coefficient between two variable series X and Y, usually denoted by r and is defined as the ratio of the covariance between X and Y, written as Cov (X,Y), to the product of the standard deviations of X and Y, symbolically,

$r = \text{Cov}(X, Y) / \sigma_x\sigma_y$ ...(1)

If$(x_1,y_1),(x_2,y_2), \ldots (x_n, y_n)$ are n pairs of the variables X and Y in a bivariate distribution, then,

$\text{Cov}(x,y) = \sum (dx)(dy) / n$ ...(2)

$\sigma_x = \{\sum (dx)^2 / n\}^{1/2}$ and $\sigma_y = \{\sum (dy)^2 / n\}^{1/2}$ ...(3)

Substituting values from equation (3) in (2) we get,

$r = \text{Cov}(X, Y) / \sigma_x\sigma_y$

$= [\sum (dx)(dy) / n] / [\{\sum (dx)^2 / n\}^{1/2} \{\sum (dy)^2 / n\}^{1/2}]$

$= \sum (dx \times dy) / [\sum (dx)^2 \times \sum (dy)^2]^{1/2}$

Where, r is the correlation coefficient, x and y are the two variables,

dx is the deviation from x-mean of the x variable, dy is the deviation from y-mean of the y variable,

$\sum(dx \times dy)$ is the sum of the products of the deviations,

$\sum(dx)^2$ is the sum of the squares of the deviation of the x variable,

$\sum(dy)^2$ is the sum of the squares of the deviation of the y variable.

Table 3.2 shows the correlation coefficients between the major ions at three stations

Table 3.2. Correlation coefficient matrix water with various physico-chemical parameters of ground water samples from Dharampur taluka (from August 2007 to July 2009).

	pH	**Colour**	**EC**	**TH**	**Ca**	**Mg**	**TA**	**TDS**	**Silica**	**Cl^-**	**SO_4**	**COD**	**Mn**	**SAR**	**F^-**	**Na^+**
pH	1.00															
Colour	0.93	1.00														
EC	-0.42	-0.72	1.00													
TH	-0.49	-0.76	0.99	1.00												
Ca	-0.52	-0.78	0.99	0.99	1.00											
Mg	-0.49	-0.76	0.99	0.99	0.99	1.00										
TA	-0.30	-0.61	0.99	0.98	0.97	0.98	1.00									
TDS	-0.43	-0.72	0.99	0.99	0.99	0.99	0.99	1.00								
Silica	0.96	0.83	-0.22	-0.29	-0.31	-0.28	-0.08	-0.23	1.00							
Cl^-	-0.48	-0.76	0.99	0.99	0.99	0.99	0.98	0.99	-0.28	1.00						
SO_4	-0.74	-0.47	-0.28	-0.21	-0.18	-0.21	-0.41	-0.27	-0.88	-0.21	1.00					
COD	-0.84	-0.98	0.84	0.88	0.89	0.88	0.76	0.85	-0.69	0.88	0.27	1.00				
Mn	-0.64	-0.32	-0.42	-0.36	-0.33	-0.04	-0.54	-0.42	-0.78	-0.36	0.98	0.13	1.00			

SAR	-0.08	-0.43	0.93	0.91	0.89	0.90	0.97	0.93	0.13	0.91	-0.59	0.60	-0.72	1.00		
F^-	0.00	-0.36	0.90	0.87	0.85	0.87	0.95	0.89	0.20	0.87	-0.65	0.54	-0.77	0.99	1.00	
Na^+	-0.38	-0.68	0.99	0.99	0.99	0.99	0.99	0.99	-0.17	0.99	-0.32	0.82	-0.46	0.95	0.92	1.00

3.2 Regression analysis[21]

Regression equations are very useful for establishing some good correlations between physico chemical water parameters and these equations on the other hand are useful for determining contamination in water bodies. The regression equation is y = ax + b, where x and y are the independent and the dependent variables respectively and 'a' and 'b' are constants called regression coefficients. The following formulas are used to determine a and b [22]:

$$a = n\sum xy - \sum x\sum y \;/\; n\sum x^2 - (\sum x)^2 \qquad --(4)$$

$$b = \bar{y} - a\,\bar{x} \qquad (5)$$

Where,

$\bar{x}$ = mean of all values of x,

$\bar{y}$ = mean of all values of y. Correlation coefficient (r) values and regression equations for various parameters of groundwater samples from the period August 2007 to July 2009 were shown in Table 3.3.

Table 3.3 .Correlation coefficient (r) values and regression equations significantly correlated with parameters of groundwater samplesfrom the period August 2007 to July 2009.

Dharampur Taluka									
No.	**Correlation between**			**'r' value**	**Equation**				
1	pH	x	colour	0.933	Y=	7.0888	+	0.0422	colour
2		x	Silica	0.964	Y=	4.9395	+	0.1026	Silica
3		x	COD	-0.844	Y=	7.5398	+	(-0.1262)	COD
4	Coluor	x	Silica	0.835	Y=	-39.7895	+	1.9474	Silica
5		x	COD	-0.977	Y=	11.1613	+	(-3.2428)	COD
6	EC	x	TH	0.998	Y=	0.0317	+	0.0016	TH
7		x	Ca	0.995	Y=	0.0040	+	0.0067	Ca
8		x	Mg	0.997	Y=	0.0924	+	0.0159	Mg
9		x	TA	0.990	Y=	-0.0700	+	0.0023	TA
10		x	TDS	0.999	Y=	-0.0011	+	0.0011	TDS
11		x	Chloride	0.998	Y=	0.1892	+	0.0056	Chloride
12		x	COD	0.847	Y=	0.2331	+	0.0852	COD
13		x	SAR	0.934	Y=	-0.7920	+	1.4131	SAR

14		x	Fluoride	0.900	Y=	-0.0893	+	2.1057	Fluoride
15		x	Na	0.999	Y=	-0.0823	+	0.0166	Na
16	TH	x	Ca	0.999	Y=	-17.6842	+	4.1842	Ca
17		x	Mg	0.999	Y=	37.5724	+	9.8646	Mg
18		x	TA	0.978	Y=	-58.8292	+	1.3845	TA
19		x	TDS	0.998	Y=	-19.2568	+	0.6880	TDS
20		x	Chloride	0.999	Y=	97.5911	+	3.4435	Chloride
21		x	COD	0.881	Y=	120.9249	+	54.7764	COD
22		x	SAR	0.907	Y=	-487.6083	+	848.3432	SAR
23		x	Fluoride	0.871	Y=	-63.8143	+	1255.7143	Fluoride
24		x	Na	0.993	Y=	-68.2076	+	10.1808	Na
25	Ca	x	Mg	0.999	Y=	13.2507	+	2.3552	Mg
26		x	TA	0.971	Y=	-9.2881	+	0.3282	TA
27		x	TDS	0.995	Y=	-0.1952	+	0.1639	TDS
28		x	Chloride	0.999	Y=	27.5877	+	0.8220	Chloride
29		x	COD	0.896	Y=	32.7173	+	13.3067	COD
30		x	SAR	0.892	Y=	-109.5681	+	199.4858	SAR
31		x	Fluoride	0.853	Y=	-9.6857	+	294.2857	Fluoride
32		x	Na	0.989	Y=	-11.7297	+	2.4212	Na
33	Mg	x	TA	0.977	Y=	-9.7593	+	0.1403	TA
34		x	TDS	0.997	Y=	-5.7576	+	0.0697	TDS
35		x	Chloride	0.999	Y=	6.0844	+	0.3491	Chloride
36		x	COD	0.881	Y=	8.4377	+	5.5591	COD
37		x	SAR	0.904	Y=	-53.1681	+	85.9144	SAR
38		x	Fluoride	0.867	Y=	-10.2429	+	127.1429	Fluoride
39		x	Na	0.992	Y=	-10.7156	+	1.0318	Na
40	TA	x	TDS	0.989	Y=	34.0397	+	0.4816	TDS
41		x	Chloride	0.979	Y=	116.8938	+	2.3812	Chloride
42		x	SAR	0.974	Y=	-335.6300	+	643.6072	SAR
43		x	Fluoride	0.953	Y=	-18.4286	+	971.4286	Fluoride
44		x	Na	0.996	Y=	-2.6465	+	7.2099	Na
45	TDS	x	Chloride	0.998	Y=	170.4775	+	4.9871	Chloride
46		x	COD	0.850	Y=	209.3435	+	76.6613	COD
47		x	SAR	0.931	Y=	-706.2072	+	1263.3419	SAR

48		x	Fluoride	0.899	Y=	-77.7286	+	1881.4286	Fluoride
49		x	Na	0.998	Y=	-72.6221	+	14.8480	Na
50	Silica	x	Sulphate	-0.876	Y=	30.5581	+	(-0.5814)	Sulphate
51	Chloride	x	COD	0.878	Y=	6.8610	+	15.8626	COD
52		x	SAR	0.910	Y=	-170.4316	+	246.9424	SAR
53		x	Fluoride	0.874	Y=	-47.1143	+	365.7143	Fluoride
54		x	Na	0.994	Y=	-48.1984	+	2.9583	Na
55	Sulphate	x	Mn	0.983	Y=	10.7226	+	38.7979	Mn
56	COD	x	Na	0.819	Y=	-1.9913	+	0.1351	Na
57	SAR	x	Fluoride	0.997	Y=	0.5043	+	1.4594	Fluoride
58		x	Na	0.950	Y=	0.5537	+	0.0099	Na
59	Fluoride	x	Na	0.922	Y=	0.0407	+	0.0066	Na

3.3 Water Quality Index (WQI)

WQI is defined as a rating reflecting the composite influence of different water quality parameters. In the present study, WQI created by Canadian Council of Minister of the Environment (CCME) was used, and hence may referred to as CWQI. The CCME Water Quality Index takes the form [23]:

$WQI = 100 - \{[F_1^2 + F_2^2 + F_3^2]^{1/2} / 1.732\}$ ...(6)

Where, Scope (F_1) is number of variables not meeting water quality objectives. Frequency (F_2) is the number of times the objectives are not met. Amplitude (F_3) is the extent to which objectives exceeded.CWQI rating for Water quality is shown in Table3.4.

Table 3.4.CWQI rating for Water quality[23]

WQI	**Rating**
95-100	Excellent
80-94	Good
65-79	Fair
45-64	Marginal
0-44	Poor

The WQI of Dharmpur taluka for the study period was 86.35 from August 2007 to July 2008, 89.76 for August 2008 to July 2009 and 86.36 (composite of two year) which is in good category according to CCME (WQI).

3.4.1 Cation concentration in groundwater samples

The concentration of Ca^{+2}, Mg^{+2}, Na^{+} varied from 28.06 to 106.21, 7.29 to 46.17 and 10.5 to 123 mg/l with an average value of 58.33, 19.33 and 28.8 mg/l respectively in groundwater of Dharampur taluka.

3.4.2 Anion concentration in ground water samples

In Dharampur taluka, the concentration of Cl^- and F^- varied from 9.23 to 75.26, 0.15 to 0.32 mg/l with the mean values of 36.67 and 0.23 mg/l respectively.

3.5 Cation and anion ratio of ground water samples

Cation anion ratio of parameters of the Dharampur taluka was shown in Table 3.5.The relative proportion of different cations i.e., Na^+/Ca^{+2} + Mg^{+2}, anions i.e., Cl^{-1}/F^{-1} and cation anion ratio i.e., Na^+/Cl^{-1} and Ca^{+2} + Mg^{+2}/Cl^{-1} is derived.

3.5.1 Cation ratio of ground water samples

The Na^{+}/Ca^{+2} + Mg^{+2} ratiovaried from 0.14 to 0.86 with the mean value of 0.29; The Na^+/Cl^- ratiovaried from 0.76 to 4.65 with the mean value of 1.64; the Ca^{+2} + Mg^{+2}/Cl^-ratiovaried from 1.02 to 10.51 with the mean value of 6.01 in the groundwater samples of Dharmpur taluka.

3.5.2 Anion ratio of ground water samples

The Cl^-/F^- ratio varied from 24.73 to 360.32 with the mean value of 80.24.

Table 3.5 .Cation – Anion ratio of parameters of ground water samples.

Station	Ratio	Aug 2007- July 2009		
		Min.	Max.	Mean
S13	Na^+/Ca^{++} + Mg^{++}	0.16	0.86	0.26
	Na^+/Cl^-	0.76	0.91	0.87
	Ca^{++} + Mg^{++}/Cl^-	1.02	5.06	3.79
	Cl^-/F^-	87.16	360.32	127.69
S14	Na^+/Ca^{++} + Mg^{++}	0.19	0.57	0.33
	Na^+/Cl^-	1.23	4.65	2.58
	Ca^{++} + Mg^{++}/Cl^-	4.62	10.37	7.71
	Cl^-/F^-	24.73	46.70	34.51
S15	Na^+/Ca^{++} + Mg^{++}	0.14	0.80	0.27
	Na^+/Cl^-	1.07	1.74	1.48
	Ca^{++} + Mg^{++}/Cl^-	1.88	10.51	6.52
	Cl^-/F^-	33.30	235.93	78.51

CONCLUSION

In general, groundwater quality for Dharampurtaluka is found satisfactory for drinking purpose. Concentration of fluoride in the groundwater of Dharampurtaluka is found below desirable limit. Few water samples show TDS value greater than desirable limits for drinking water. None of groundwater samples had SAR value greater than 26.0, which suggests that groundwater of the Dharampurtaluka found free from alkali hazards and suitable for agriculture purpose. However, though the suitability of water for irrigation is determined based on SAR and salinity hazard, it is only empirical conclusion. In addition to water quality, other factors like soil type, crop type, crop-pattern, frequency and recharge (rainfall), climate etc., have an important role to play in determining the suitability of water. The WQI of Dharmpur taluka for the study period was 86.36 which is in goodcategory of CCME (WQI).

Conflicts of Interest

All authors declare no competing interest regarding this work.

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