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Evaluation of Ground Water Quality Index of Piedmont Plain of Jalgaon District Using Geo-Informatics Technology

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Abstract - Water quality indicates suitability of water for a specific purpose. The quality of water is based on physical, chemical and biological characteristics of water. In the present study, evaluation of groundwater quality of the piedmont plain of Jalgaon district, Maharashtra has carried out for its applicability with respect to domestic purpose. The present investigation revealed that, Water Quality Index of groundwater in the study area ranges from 35.64 to 93.12. The minimum value has been recorded 35.64 at Puri village while maximum 93.12 has been recorded at Nimgavhan village. The analysis results of WQI indicated that, 78% of ground water samples falls in good quality whereas 22% showed excellent quality the result indicates that, groundwater of the piedmont plain of Jalgaon district is fit for drinking purpose after treatment for excess dissolved salts. The physico-chemical analysis shows that 69% samples are very hard water due to presence of Ca, Mg, Na, and other metallic ions. As per the spatial distribution study, the WQI increasing trends were observed from central part towards eastern as well as western part of piedmont plain area of the Jalgaon district. The higher values of WQI were observed due to presence of higher amount of Fluorides, Alkalinity, TDS, Hardness, Bicarbonates, Calcium, EC and Sulphate in the ground water of the study region.

Keywords: Groundwater, WQI, Geo-informatics, Piedmont plain and Jalgaon district.

1. INTRODUCTION

The applicability of water for various uses is based on the water quality. The quality of ground water is reliant on natural impacts by geological, topographical, meteorological, hydrological and biological factors in the drainage basin and varies with seasonal variances in surface runoff volumes, weather conditions and water levels. Human interference also has considerable effect on water quality. There indices hydrological variations, such as the construction of dams, draining of wetlands and diversion of flow. Most noticeable are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the waterways and the application of inorganic fertilizer and pesticides on agricultural land in the drainage basin (UNEP/WHO, 1996). Numerous studies were carried out to measure the geochemical properties of groundwater (Sujatha and Reddy, 2003; Laluraj et al., 2005; Subramani et al., 2005; Ravikumar and Somashekar, 2012). The water quality can be evaluated using physico-chemical parameters, the harmful limits of those for human health being established at both international and national level (Subramani T., 2005, WHO, 2011). Water Quality Index (WQI) is the appropriate simple statistical method to estimate the quality of water for its potability. Using the water quality data is useful for preparation or alteration of existing policies for WQI (Yang and Wang, 2010; Mohemmad et al., 2011; Tyagi et al., 2013; Tiri et al., 2014). Water quality plays a vital role in encouraging agricultural production and human health. In the 21st century, due to modernization, industrialization and growth of population, there has been a tremendous pressure on the natural water resources (Tiwari et al., 2017).

The concept of indices to represent gradations in water quality was first proposed by (Horton, 1965) then the WQI was modified by Brown and its companion (Brown et al.,1970). The Water Quality Index (WQI) is one of the most significant and effective methods for determination of water quality. The WQI identifies the gap between WQI parameters and the uncertainty in the quality criteria (Khan et al., 2003; Soroush et al., 2011; Tirkey et al., 2016).

Remote Sensing data gives a qualitative and quantitive information of huge geographical region of the Earth surface and due to its exceptional property with better precision within short time and cost. RS and GIS have a capability for capture, storage, manipulation, analysis and retrieval of multiple layer resource information occurring both in spatial and non-spatial data (Mishra et al., 2001). The GIS technology provides suitable substitutes for proficient supervision of large and complex database Anju et al., (2015). GIS is the computerised data generation, management, analysis and modelling techniques and it is useful in the Earth sciences. The final GIS output provided drinking water quality mapping. Anbazhagan et al, (2016). In the present study, we have evaluated ground Water Quality Index based on 36 groundwater samples from Piedmont Plain of Jalgaon district of the Maharashtra. Then, displayed geo-spatial distribution of WQI using geo-informatics techniques.

2. STUDY AREA

The piedmont plain of Jalgaon district was selected for the present investigation which has been originating in eastern part of Khandesh region in between Satpuda mountain and Aner - Tapi river in Jalgaon district of Maharashtra. Geographically, it is located under 21° 00’ 40’’ to 21° 23’ 44’’ north latitudes and 75° 02’ 51’’ to 76° 02’ 39’’ east longitudes (Fig. – 1). According to Census of India (2011), the total geographical area of the piedmont plain has recorded 2,118 sq. km (18.00 %) out of total geographical region of the district (11,765 sq. km.) which constitute 0.69% of the total area of the Maharashtra state. The surrounded natural boundaries have been demarked by Tapi River at eastern and southern side, western boundary has marked by Aner River and Satpuda Mountain has covered northern part of the piedmont plain region District Gazetteers, (1965). The climate of the study area is classified as hot summer and dry throughout the year. According to meteorological view, this region has situated in tropical region, where mean annual temperature varies from 35°C to 45°C. In the past decade, the average rainfall has been fallen 75 to 80 cm per year in the region **TERI, (2014).** The piedmont area consists of alluvial plain of Tapti valley. Geologically, most of the part of study region is covered by Deccan traps excluding alluvium land on northern sides of Tapi River. These trap rocks are the result of outpouring of enormous magma flows which had extend over hundreds of kilometer of western, central and southern India to appearance a major part of the Deccan plateau at the end of Mesozoic era (Patil et al, 2015).

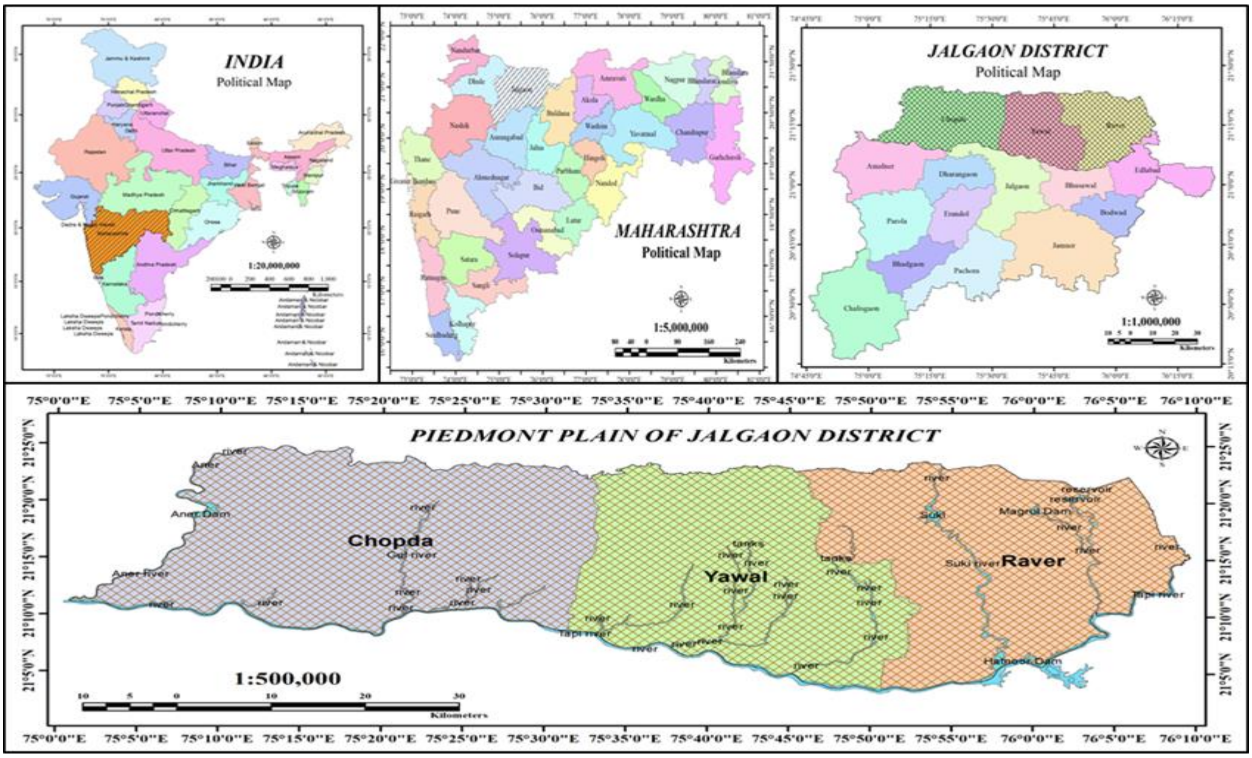

Figure: 1 - Location of Piedmont Plain of Jalgaon District.

3. MATERIALS AND METHODS

In the present study, the grab groundwater samples were collected from the 36 locations by using systematic sampling techniques from piedmont plain of Jalgaon district. The samples were collected in one litre polyethylene cans which were pre-rinsed and washed in the laboratory using proportionate distilled water and hydrochloric acid, and before filling the sample it is washed thoroughly with representative sample. Global Positioning Systems (Garmin Ertex 20) was used for recording and mentioned geographical coordinates of sampling location in (Table – 5). The standards methods were adopted for water sampling, handling, transporting, storing and laboratory analysis (APHA, 1998, Maiti, 2011). The collected samples were analysed for various water quality parameters like pH, EC, Sodium (Na) Potassium (K) Total hardness (TH) as $CaCO_3$, Calcium (Ca^{2+}), Bicarbonate (HCO_3), Fluoride (Fl), Chloride (Cl), Magnesium (Mg), Calcium (Ca), Sulphate (SO_4), Nitrate (NO_3), Phosphate (PO_4). The Inverse Distance Weighted (IDW) approach has used for presenting spatial distribution of groundwater quality index. Groundwater quality parameters were analysed by *Spearman`s* coefficient of correlation techniques for standardization of data in SPSS (17.0). Geo-spatial distribution of WQI trends and representation were done by applying IDW techniques for interpolation of Geo-statistical analyst tools from ArcGIS 10.2.2 software.

3.1 Calculation of Water Quality Index (WQI)

The WQI was calculated using weighed arithmetic index method (Ramakrishnaiah *et al*, 1972, Sahu et al, 2008, Ishaku et al, 2011). In the first step, each of the 14 water quality parameters has been assigned a weight (wi) according to its relative significance in the overall quality of water for drinking purposes (Table-1).

Table: 1 – Weight and Relative weight of water quality parameters

Chemical Parameters	Indian Standards	Weight (wi)	Relative weight (Wi)
pH	7	4	0.10
Electrical Conductivity	500	3	0.07
Total hardness (TH)	200	2	0.05
Total dissolved solids	500	4	0.10
Magnesium	50	1	0.02
Calcium	75	2	0.05
Sodium	200	2	0.05
Potassium	200	2	0.05
Chloride	250	3	0.07
Nitrate	45	5	0.12
Sulphate	200	4	0.10
Fluoride	1	4	0.10
Alkalinity	200	2	0.05
Bicarbonate	500	3	0.07
		$\sum$wi = 41	

Source: (Sahu et al, 2008, Ramakrishnaiah *et al*, 2009, and Ishaku et al, 2011.

The maximum weight of 5 has been given to the parameter nitrate due to its significant role in WQI. Magnesium which are given the minimum weight of 1 because it may not be harmful to human health. In the second step, the relative weight (Wi) is computed by using following formula.

$$\boldsymbol{Wi = wi\frac{wi}{\sum_{i=1}^{n} wi}} \qquad \text{Eq. - (1)}$$

Where; Wi is the relative weight of parameter as per their importance in the water quality, whereas wi is the weight of each variables and n is the number of variables. Computed relative weight (Wi) values of each parameter are also given in (Table-1). In the third step of WQI calculation, a quality rating scale (qi) for each quality parameter is calculated by dividing its estimated concentration in each water sample by its corresponding standard according to the guidelines of the BIS and the result multiplied by 100.

$$Qi = (Ci / Si) \times 100 \qquad \text{Eq. – (2)}$$

Where; qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, and Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS 10500, 2012.

For computing the WQI, the SI is first determined for each chemical parameter by multiplying quality rating with relative weight, finally the addition of sub-index is used to calculate WQI as per the following formula

$$SIi = Wi \times qi \qquad \text{Eq. – (3)}$$

$$WQI = \sum SIi \qquad \text{Eq. – (4)}$$

Where; SIi is the sub index of i^{th} variable; qi is the rating depends on concentration of i^{th} variable and n is the number of variables. The computed Water Quality Index values are classified into five types, Excellent, Good, Poor, Very Poor and Unsuitable water for drinking.

4. RESULTS AND DISCUSSIONS

In the present investigation, pH was observed in the range of 8.12 to 9.15, it was recorded highest at Korpawali village and minimum at Hingona village and 53% of samples were found beyond limits prescribed by BIS (IS 10500:2012). Higher level of pH in groundwater is closely correlated with the transformation of carbonate ions HCO_3^- CO_3^- . similar observation was presented by the analytical chemist and hydrochemists in the various studies on water quality (Garrels et al, 1965; Drever, 1982; Krainov et al, 1992; Laptev, 1955). As per BIS pH in drinking water should be in the range of 6.5 to 8.5. Total alkalinity was found in the range 3.32 to 24.44 mg/l. It was observed minimum at Savada village and maximum at Nimgavhan village. All locations were having alkalinity within limit prescribed by BIS. Minimum electrical conductivity 276.1 µS/cm (36^{0}C) was recorded at Puri village whereas maximum 1355 µS/cm (36^{0}C) at Nimgavhan village. As per Maiti, (2011) 44 % of samples falls in good and 56 % falls in permissible whereas none of the sample recorded as under excellent and doubtful categories (Table-2).

Table: 2 – Classification of Electrical Conductivity (EC)

Range	Types	No. of Samples	%
Below 250	Excellent	0	0
250 – 750	Good	16	44
750 – 2000	Permissible	20	56
2000 – 3000	Doubtful	0	0
		36	**100**

Maximum hardness 616 mg/l was noted at Nirul village while minimum 140 mg/l was recorded at Puri village. As per guidelines for classification of water based on total hardness, 6 % sites exabits moderate soft water while 25 % was showed hard water whereas significantly 69 % samples showed as very hard water and none of the sample exabit soft water (Table-3) Sawyer et al, (1967). As per WHO, 2011, Hardness is not caused by a single substance but various dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, and other cations.

Table: 3 – Classification of Hardness (TH)

Range	Types	No. of Samples	%
Below 75	Soft	0	0
75 – 150	Moderate	2	6
150 – 300	Hard	9	25
above 300	Very Hard	25	69
		36	**100**

Sulphate was observed in the range of 50.68 to 89.70 mg/l, it was found highest at Hingona village and lowest at Wadgaon Sim village. In the study area, fluoride was significantly detected in 81 % samples which indicates fluorides contamination in the piedmont plain area of the Jalgaon district. It was detected highest 1.22 mg/l at Nimgavhan village which below permissible limit is as per BIS and minimum of 0.02 mg/l at Nimgaon village. Chlorides are salts resulting from the combination of the gas chlorine with a metal. Chlorides concentration varies from 11.91 to 281.9 mg/l. It was found maximum at Savada and minimum at Vadgaon village. In the present investigation nitrate was also significantly observed at all locations. It was varied in between 0.02 to 4.91 mg/l. Highest level of nitrate detected at Nimgaon whereas lowest level found at Nirul village. As per BIS drinking water standards all the samples showed nitrate level below the prescribed limits. Potassium was found in the range of 1 to 4.4 mg/l. Calcium and magnesium was found in the range of 20.19 to 95.88 mg/l and 14.58 to 111.78 mg/l respectively. Total Dissolved Solids (TDS) were estimated maximum 939 mg/l at Nimgavhan village whereas minimum 214 mg/l at Puri village. According to WHO, (2011); specifications TDS up to 500 mg/l is the highest desirable and up to 1500 mg/l is maximum permissible. Sodium (Na) were found maximum 197.7 mg/l at Nimgavhan village while minimum 33.6 mg/l at Kumbharkhede village. Bicarbonate was found in the range of 3.54 to 27.57 mg/l.

5. COEFFICIENT OF CORRELATION MATRIX

Coefficient of correlation is generally calculated to verify relationship between two variables. Correlation is measured as coefficient of correlation (r). Its arithmetical value ranges from +1.0 to -1.0. It gives an indication of the strength of relationship between two parameters. In over all, $r > 0$ shows positive relationship, $r < 0$ shows negative relationship while $r = 0$ shows no relationship. If $r = +1.0$ it shows a perfect positive correlation whereas $r = -1.0$ shows a perfect negative correlation. Nearer the coefficients (r) to +1.0 and -1.0; greater is the strength of the association between the parameters. In the present investigation, the degree of linear relation between any two of water quality parameters, were measured by Spearman's correlation coefficient (r) is represented in (Table-6). TDS and EC are highly correlated ($r = 0.992$) among themselves whereas Alkalinity and Bicarbonate were found highly correlated ($r = 0.964$). Similarly, Hardness to Mg and EC were showed highly positive correlation ($r = 0.944$ and 0.730 respectively). Hardness of water due to carbonates of calcium and magnesium whereas permanent hardness due to sulphates and nitrates. Total dissolved solids are high due to alkalinity and sulphates (Sunita et al., 2014). Simple statistical results were obtained for water quality parameters shown in (Table-7).

6. WATER QUALITY INDEX (WQI)

In the present investigation, the calculated WQI ranges from 35.64 to 93.12 (Table - 5). The minimum value has been recorded 35.64 at Puri while maximum has been recorded 93.12 at Nimgavhan. The calculated WQI values are classified into five types as shown in (Table - 4).

Table: 4 - Classification of WQI for potable u**se**

Range	Types	No. of Samples	%
< 50	Excellent	8	22
51 – 100	Good	28	78
101 – 200	Poor	0	0
201 – 300	Very Poor	0	0
> 300	Unsuitable	0	0
		36	**100**

It was estimated that 78% of ground water sample falls in good quality. Whereas 22% showed excellent quality from the region, which revealed that, groundwater is fit for drinking purpose. As per spatial distribution study, the WQI showed increasing trends from central part towards eastern as well as western part of piedmont plain area of the Jalgaon district (Fig. – 2). The higher values of WQI were observed due to higher amount of Fluorides, Alkalinity, TDS, Hardness, Bicarbonates, Calcium, EC and Sulphate were detected at higher range in the ground water of the study region.

Table: 5 – Calculated water quality index of selected sites.

Sample No.	Village Name	Latitude	Longitude	Altitude	WQI
1	Mohrale	21.23	75.68	275	44.41
2	Ghodgaon	21.25	75.11	186	55.38
3	Rozoda	21.20	75.89	247	66.36
4	Duskheda	21.08	75.84	217	39.73
5	Nimgaon	21.12	75.73	208	63.28
6	Rukhankhede	21.20	75.47	189	63.07
7	Sakali	21.18	75.63	222	51.53
8	Manwel	21.16	75.62	211	55.64
9	Mangrul	21.21	75.39	193	66.53
10	Nhavi	21.19	75.84	237	61.42
11	Nimbol	21.19	76.03	242	69.95
12	Puri	21.11	75.98	231	35.64
13	Pimpri	21.31	76.07	289	60.13
14	Nirul	21.28	76.12	259	80.60
15	Yaval	21.17	75.72	224	60.70
16	Korpawali	21.21	75.67	244	48.20
17	Chahardi	21.21	75.22	181	55.90
18	Ganpur	21.29	75.15	202	76.71
19	Wadgaon Sim	21.17	75.34	182	44.37
20	Morgaon	21.24	76.09	243	64.42
21	Sawada	21.14	75.89	225	64.45
22	Adawad	21.22	75.46	204	66.15
23	Vadgaon	21.20	75.95	237	40.83
24	Kumbharkhede	21.22	75.93	243	41.67
25	Dasnoor	21.15	75.94	239	66.03
26	Wadode	21.20	75.07	165	75.96
27	Dhamodi	21.13	76.01	231	37.24
28	Warad	21.32	75.29	256	65.21
29	Nimgavhan	21.16	75.23	176	93.12
30	Hingona	21.19	75.78	239	86.26
31	Virwade	21.30	75.35	245	64.01
32	Chaugaon	21.31	75.22	242	63.35
33	Padalse	21.12	75.80	217	57.43
34	Kolnhavi	21.15	75.55	201	56.39
35	Pal	21.36	75.90	398	49.50

36	Dongaon	21.18	75.56	199	54.94

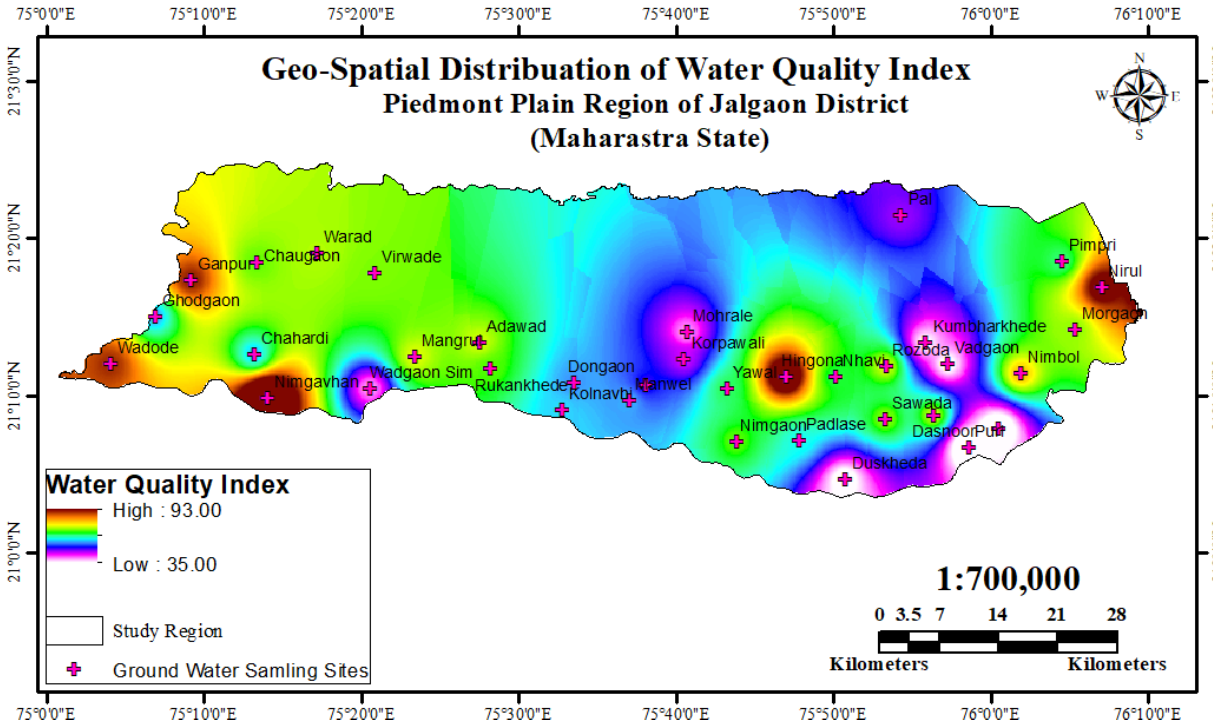

Figure: 2 - Geo-spatial distribution of Water Quality Index

7. CONCLUSION

The groundwater quality of the piedmont plain of Jalgaon district, Maharashtra has been evaluated for its applicability with respect to domestic purpose. The present investigation revealed that, 69% samples showed very hard water which was due to the presence of Ca, Mg, Na, and other metallic ions causes the higher concentration of hardness. The water quality index ranges have found from 35.64 to 93.12 in the study region. The minimum value 35.64 has been recorded at Puri village; while maximum 93.12 has been recorded at Nimgavhan village. The analysis results of WQI indicated that, 78% of ground water sample falls in good quality whereas 22% showed excellent quality which revealed that, groundwater of the piedmont plain of Jalgaon district is fit for drinking purpose after treating it for excess dissolved salts. Results obtained by Spearman's correlation coefficient (r) cleared showed that, TDS and EC are highly correlated (r = 0.992) among themselves whereas Alkalinity and Bicarbonate were found highly correlated (r = 0.964). Similarly, Hardness to Mg and EC were also showed highly positive correlation (r = 0.944 and 0.730 respectively). In these spatial distribution study, the WQI showed increasing trends from central part towards eastern as well as western part of piedmont plain region. The higher values of WQI were observed due to presence of higher amount of Fluorides, Alkalinity, TDS, Hardness, Bicarbonates, Calcium, EC and Sulphate in the ground water of the study region.

Table: 6 - Spearman's Correlation Coefficient

N = 36		pH	EC	TH	TDS	Mg	Ca	Na	K	Cl	No3	So4	Fl	Alkalinity	Hco3
pH		1.000	-.136	-.270	-.136	-.253	-.254	.137	.290	-.136	-.163	-.194	.049	.299	.228
	Sig. (2-tailed)	.	.430	.111	.430	.137	.135	.426	.086	.427	.343	.257	.775	.076	.180
EC		-.136	1.000	.730**	.992**	.708**	.396*	.728**	.057	.903**	.063	.363*	-.202	.441**	.426**
	Sig. (2-tailed)	.430	.	.000	.000	.000	.017	.000	.743	.000	.716	.030	.238	.007	.010
TH		-.270	.730**	1.000	.694**	.944**	.484**	.279	-.395*	.566**	.197	.159	-.236	.370*	.397*
	Sig. (2-tailed)	.111	.000	.	.000	.000	.003	.099	.017	.000	.250	.353	.167	.026	.016
TDS		-.136	.992**	.694**	1.000	.680**	.388*	.740**	.093	.911**	.006	.396*	-.194	.426**	.410*
	Sig. (2-tailed)	.430	.000	.000	.	.000	.019	.000	.590	.000	.974	.017	.257	.009	.013
Mg		-.253	.708**	.944**	.680**	1.000	.217	.285	-.348*	.575**	.192	.160	-.261	.315	.346*
	Sig. (2-tailed)	.137	.000	.000	.000	.	.203	.093	.037	.000	.262	.351	.124	.062	.038
Ca		-.254	.396*	.484**	.388*	.217	1.000	.081	-.194	.288	-.050	.224	-.023	.145	.184
	Sig. (2-tailed)	.135	.017	.003	.019	.203	.	.641	.257	.089	.771	.190	.895	.398	.282
Na		.137	.728**	.279	.740**	.285	.081	1.000	.415*	.679**	-.028	.271	-.035	.593**	.568**
	Sig. (2-tailed)	.426	.000	.099	.000	.093	.641	.	.012	.000	.869	.109	.842	.000	.000
K		.290	.057	-.395*	.093	-.348*	-.194	.415*	1.000	.160	-.259	.163	.154	.104	.058
	Sig. (2-tailed)	.086	.743	.017	.590	.037	.257	.012	.	.351	.126	.343	.369	.545	.736
Cl		-.136	.903**	.566**	.911**	.575**	.288	.679**	.160	1.000	.055	.487**	-.209	.193	.166
	Sig. (2-tailed)	.427	.000	.000	.000	.000	.089	.000	.351	.	.750	.003	.221	.261	.333
No3		-.163	.063	.197	.006	.192	-.050	-.028	-.259	.055	1.000	-.235	.037	.004	.037
	Sig. (2-tailed)	.343	.716	.250	.974	.262	.771	.869	.126	.750	.	.167	.828	.982	.832
So4		-.194	.363*	.159	.396*	.160	.224	.271	.163	.487**	-.235	1.000	.045	-.110	-.149
	Sig. (2-tailed)	.257	.030	.353	.017	.351	.190	.109	.343	.003	.167	.	.794	.524	.387
Fl		.049	-.202	-.236	-.194	-.261	-.023	-.035	.154	-.209	.037	.045	1.000	-.078	-.107
	Sig. (2-tailed)	.775	.238	.167	.257	.124	.895	.842	.369	.221	.828	.794	.	.653	.535
Alkalinity		.299	.441**	.370*	.426**	.315	.145	.593**	.104	.193	.004	-.110	-.078	1.000	.964**
	Sig. (2-tailed)	.076	.007	.026	.009	.062	.398	.000	.545	.261	.982	.524	.653	.	.000
Hco3		.228	.426**	.397*	.410*	.346*	.184	.568**	.058	.166	.037	-.149	-.107	.964**	1.000
	Sig. (2-tailed)	.180	.010	.016	.013	.038	.282	.000	.736	.333	.832	.387	.535	.000	.

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

Table: 7 – Statistical Investigation of water quality parameters.

Statistical Analysis	pH	EC	TH	TDS	Mg	Ca	Na	K	Cl	No3	So4	Fl	Alkalinity	Hco3	WQI
Minimum	8.12	276.10	140.00	214.00	14.58	20.19	33.60	1.00	11.91	0.02	50.68	0.02	3.32	3.54	35.64
Maximum	9.15	1355.00	616.00	939.00	111.78	95.88	197.70	4.40	281.90	4.91	89.70	1.22	24.44	27.57	93.12
Arithmetic Mean	8.50	713.28	359.84	501.96	60.94	45.86	79.10	2.38	93.69	0.98	68.55	0.49	13.57	15.31	59.63
Median	8.51	767.15	376.00	520.50	66.10	43.34	69.55	2.31	86.27	0.57	68.11	0.41	13.24	15.13	61.06
Mode	#N/A	#N/A	452.00	622.00	75.82	33.64	#N/A	2.70	103.23	0.02	61.85	0.07	13.24	13.42	#N/A
First Quartile	8.38	477.05	286.00	366.25	43.25	33.64	54.33	1.70	50.13	0.22	62.02	0.31	11.38	13.42	51.02
Third Quartile	8.59	867.73	445.00	599.50	78.49	52.57	100.40	2.80	116.13	1.10	74.74	0.66	15.64	17.93	66.06
Quartile Deviation	0.11	195.34	79.50	116.63	17.62	9.46	23.04	0.55	33.00	0.44	6.36	0.17	2.13	2.26	7.52
Standard Deviation	0.22	262.80	114.07	173.31	25.29	17.43	35.32	0.92	65.13	1.18	9.54	0.37	4.31	5.04	13.36

Note: - Measurement units of all parameters are mg/l, except pH, where, EC is measured in µS/cm, # - Not Applicable.

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