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Water quality assessment of the chporian village, Uttarakhand: India using multivariate statistical approach

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Abstract
In this study water samples were collected and analyzed for physico-chemical parameters like pH, Electrical Conductivity (EC), Turbidity (Turb), Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^{-}), Total Alkalinity (TA) and Dissolved Oxygen (DO) etc, using a statistical method. There is a relationship between variables that shows that one variable causes changes in another variable. In this paper, a statistical regression analysis method for different sources at four field's sites was calculated. This technique was studied and calculated the correlation coefficients between different physicochemical parameters of water samples. The results were also compared with the WHO water quality standards and it was concluded that most water samples do not seem to be drinking. The results have been shown to be a useful means of rapid observation of water quality through systematic calculations of parametric statistics between water parameters and multivariate analysis.

Keywords: Regression equation, water quality parameters, correlation coefficient method

Introduction
Water is one amongst the most vital and most precious natural resources. It is essential within the lifetime of all living organisms from the simplest plant and microorganisms to the foremost complex living system known as the humans. Easy fresh water availability is a big problem because 80% of the rivers become polluted (Singh *et al.* 2002) [8]. Combination with the chemical formula H_2o of hydrogen and oxygen atoms known to constitute 70% of the most abundant compound on earth surface. It has unique chemical and physical properties (Onifade & Ilori 2008) [6]. Unchecked disposal of solid waste and wastewater and excessive use of fertilizers are deteriorating the water quality (Thangavelu 2013) [10] The failure in solving this crisis leads to poor water quality in natural water resources (Abdalkarim *et al.* 2016) [1] The primary causes of groundwater contamination are the uncontrolled disposal of industrial and urban waste and the use of chemicals in agriculture (fertilizers, herbicides, and pesticides). Over the past decades, groundwater has been drastically polluted by increased human activity. As a result, there have been several cases of waterborne disease which are a sources of health risks (APHA 1998) [2]: Periodic water quality monitoring is crucial to understand the degradation in quality and also the planning of remedial actions to control further damage.

Materials and methods
Ground water samples were collected from four different fields namely: (a) Field I (Sabli) (b) Field II (Sabli Talli) (c) Field III (Sabli Malli) and (d) Field IV (Choparyali) as in Table 2 Collection, Preparation of Water Samples and Analysis One litre water samples were taken in transparent plastic container as possible to avoid unpredictable changes in physico-chemical characteristics from each sampling sites. Laboratory samples were stored in ice at 4°C until transport for analysis. Sample testing was carried out in accordance with the APHA (1998) [2], S.K. procedure. Trivedy and Goel (1986) [11] and Mati (2004) [4]. At sampling sites, pH, electric conductivity and turbidity were estimated. Each sample of water quality was characterized for four permanent stations and laboratory samples were stored in ice at 4°C until analysis was carried out and determined by method according to table 1.

Water Quality Analysis
The Water Samples were collected from four completely different places within the Morning Hours. The Water samples were immediately brought in to Laboratory for the Estimation of various Physico-chemical Parameters like Calcium & Magnesium, Chloride.

pH was recorded by using Thermometer and Digital pH Meter. (Systronics). Specific conductivities were measured by using a digital conductivity meter. The TDS values were measured by using TDS meter and were estimated in the Laboratory by using Standard laboratory methods. The above-mentioned instruments are employed in the limits of precise accuracy and chemicals used were of analytical grade. Statistical analysis of water samples from completely different sources as shown in Table 3.

Table 1: Details of the analytical method and equipment used in the study

Water quality test	Description	Instrument/method
pH	The major of acidity (hydronium ion, H+) in the water.	pH meter
Turbidity (NTU)	Turbidity in water is the reduction of transparency.	Turbidity meter
TDS	The measure of the amount of particulate solids that are in the water.	TDS meter
Dissolved oxygen	The amount of oxygen available in the water.	Titrimetric method (iodometric)
Dissolved carbon dioxide	The amount of carbon dioxide in the water.	Titrimetric method
Alkalinity	Alkalinity of water is its quantitative capacity to react with a strong acid to a designated pH.	Titrimetric method
Chloride	Measurment of Chloride amount in water	Titrimetric method
Calcium	Measurment of Calcium amount in water	Titrimetric method
Magnesium	Measurment of Magnesium amount in water	Titrimetric method

Table 2: Physicochemical parameters water samples at studied source location for chopriyal village (Note: all parameters are in mg/l except pH, EC in µ mhos/cm and Turb in NTU)

Sample no	Field	Ph	Ec	Turb	Ta	Tds	Ca^{2+}	Mg^{2+}	Cl	Do	Bod	No_3^-	So4
S1	I	8.4	386	2	130	200	30.8	14.4	17	3.2	2.06	2.4	21.4
S2		7.3	868	4	272	512	90.2	26.2	46	4	3	1.2	57.1
S3		7.7	906	1	380	534	23.9	63.4	48	3.5	3.5	1.5	55.9
S4		8.32	368	1	120	314	30.8	26.3	72	5.46	2.06	1.6	59
S1	II	7.4	824	4	296	498	90.2	25.8	48	4	3	1.4	56
S2		8.39	372	1	120	102	86.3	90	20	5.46	2	0.4	20
S3		7.32	492	1	142	156	23.8	26	30	5.36	2.8	1	25
S4		7.4	482	1	132	360	32	21.8	26	5.36	8.6	1.36	20
S1	III	7.7	592	2	380	544	40.9	63.4	58	3.5	3.5	1.5	25.9
S2		7.52	478	1	142	170	21.8	24	30	5.36	2.8	1.6	36
S3		7.82	565	1	130	262	28	5.83	49	6.07	4.5	1.19	46
S4		8.42	362	1	78	200	25.6	8.74	26	5.82	4	0.462	30
S1	IV	7.6	979	4	360	578	68.1	54.5	47	3	1.3	2.2	43
S2		8.32	476	1	60	396	24	4.8	25	6.8	6	1.1	12.6
S3		7.1	412	1	380	534	40.9	63.4	48	5.5	3.5	1.5	55.9
S4		7.2	749	4	396	436	92.2	25.8	46	4.2	3	1.4	53.2

Table 3: Statistical analysis of water samples from different source

Parameters	Minimum	Maximum	Mean	Std. Deviation
Ph	7.1	8.4	7.7444	0.47420
EC	362.0	979.0	581.9375	212.44402
Turb	1.0	4.0	1.8750	1.31022
TA	54	387	219.8750	125.89195
TDS	105.0	566.0	362.2500	162.94600
Mg^{2+}	4.8	90.0	34.0231	25.01358
CL	17.0	72.0	39.7500	15.24686
DO	3.0	6.8	4.7869	1.14812
BOD	1.3	8.6	3.4763	1.76008
NO^{-3}	0.4	2.4	1.3633	0.51277
SO_4	13	57	38.5625	16.40678

Linear Regression Model

The relationship between water quality parameters in the water samples analyzed was determined using the mathematical formula as provided below based on a literature review by determining the correlation coefficients (r). Let x and y be two variables (parameters for water quality in this study) and n= number of observations. Then the coefficient (r), between x and y, is determined by the relationship

$$r = \frac{n\Sigma(x*y) - (\Sigma x)*(\Sigma y)}{[f(x)*f(y)]^{0.5}}$$

Where

F(x) = n Σ (x^2)-$(\Sigma\ x)^2$, f(x)=n Σ (y^2)-$(\Sigma\ y)^2$ and all the summations are to be taken from 1 to n.

If the numerical value of the coefficient of correlation is quite large between two variables x and y, then these are very correlated. In these cases, a linear relationship of the form can be formed

y = Ax +B ……..…… (1)

To correlate x and y, the constant A and B are to be determined by fitting the experimental data on the variables x and y to equation (1). According to the well-known method of least squares, the value of constants A and B are given by the relations and B=$\bar{y}$-a$\bar{x}$ ……..…… (2)

Where $\bar{x}=\frac{\Sigma x}{n}$ and $\bar{y}=\frac{\Sigma y}{n}$

$$A = \frac{\Sigma(x*y) - (\Sigma x)*(\Sigma y)}{n(\Sigma x - \bar{x})}$$

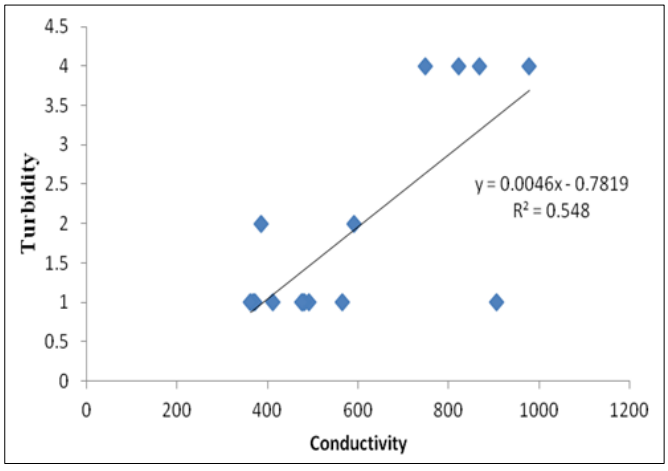
Table 4: By using these relations, with the help of spss finding the values of correlation coefficients (r) which has been given below in Table 4.

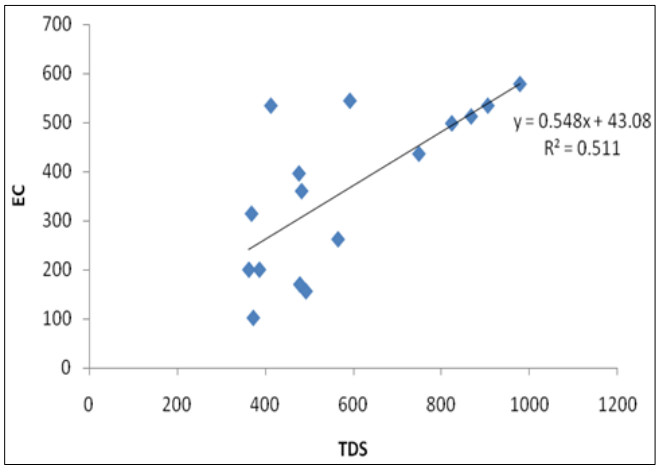
Correlations												
	Ph	**EC**	**Turb**	**TA**	**Tds**	**Ca^{2+}**	**Mg^{2+}**	**Cl**	**DO**	**BoD**	**No_3^-**	**So_4**
Ph	1	-.507*	-0.410	-.645**	-.500*	-0.300	-0.118	-0.292	0.247	-0.096	-0.181	-0.455
Ec		1	.740**	.693**	.715**	.499*	0.166	0.382	-.650**	-0.193	0.311	.517*
Turb			1	.567*	.545*	.800**	-0.003	0.265	-.652**	-0.353	0.339	0.420
Ta				1	.808**	0.446	.523*	.543*	-.677**	-0.282	0.370	.580*
Tds					1	0.316	0.253	.596*	-0.497	0.049	0.392	.513*
Ca^{2+}						1	0.320	0.144	-0.389	-0.346	-0.085	0.349
Mg^{2+}							1	0.167	-0.345	-0.365	-0.053	0.097
Cl								1	-0.239	-0.252	0.250	.756**
DO									1	0.471	-.630**	-0.288
BOD										1	-0.251	-0.363
No_3^-											1	0.217
So_4												1
*. Correlation is significant at the 0.05 level (2-tailed).												
**. Correlation is significant at the 0.01 level (2-tailed).												

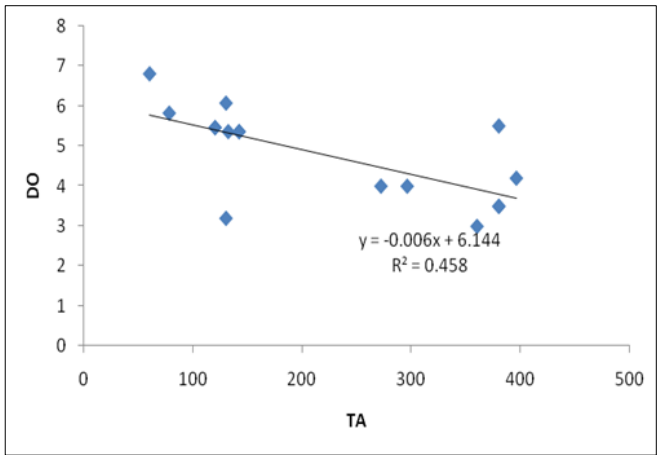
The correlation coefficient (r) measures the degree of association that exists between two variables, one taken as the dependent variable. The greater the value of the regression coefficient, the better is the fit and more useful the regression variables (Sami 2011) [9]. Correlation is the mutual relationship between the two variables. A direct correlation exists when an increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameters (Jothivenkatachalam 2010) [3].

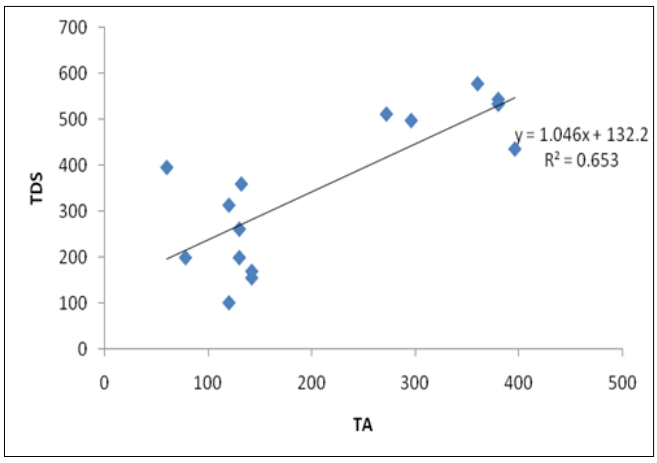
Result and discussions

In this present study water used for drinking should be odorless, and without slight turbidity and excess salt in the area under study. At some locations the taste of the water is somewhat brackish. The water temperature is between 25-30 degrees Celsius. The important physico-chemical characteristics of the water samples analysed, such as, minimum, maximum, Mean and Standard Deviation (SD), were presented in Table 2. This demonstrates that there is not too high a variation between these parameter values and a very small variation range at various locations. The regression equation has been used as a mathematical tool by substituting values for independent equation parameters in order to calculate different dependent water quality characteristics. Regression analyses for water quality parameters found that their correlation coefficient is better and more significant as demonstrated.









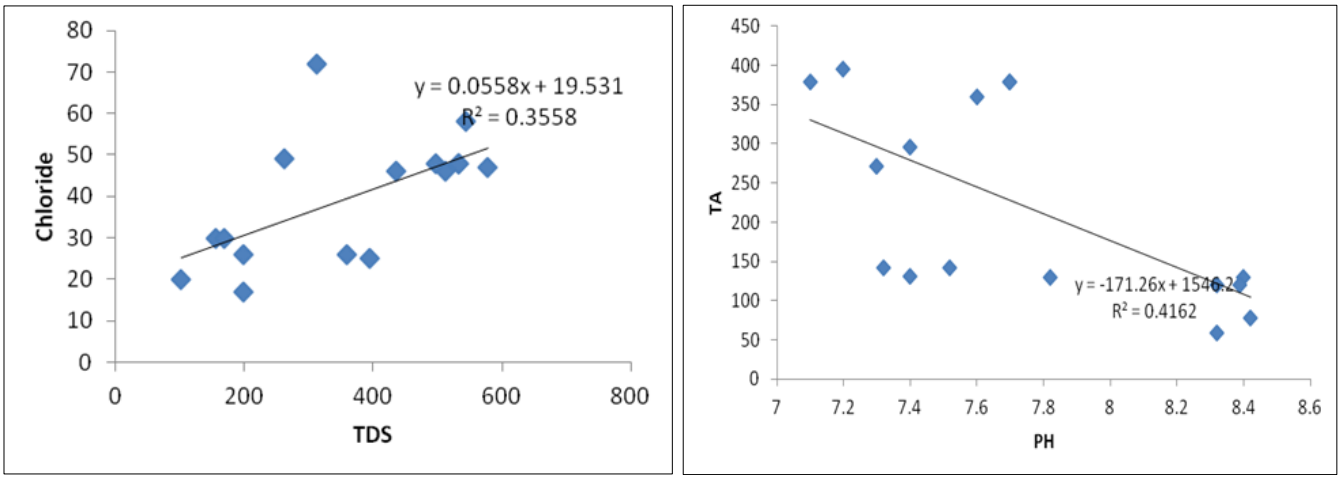
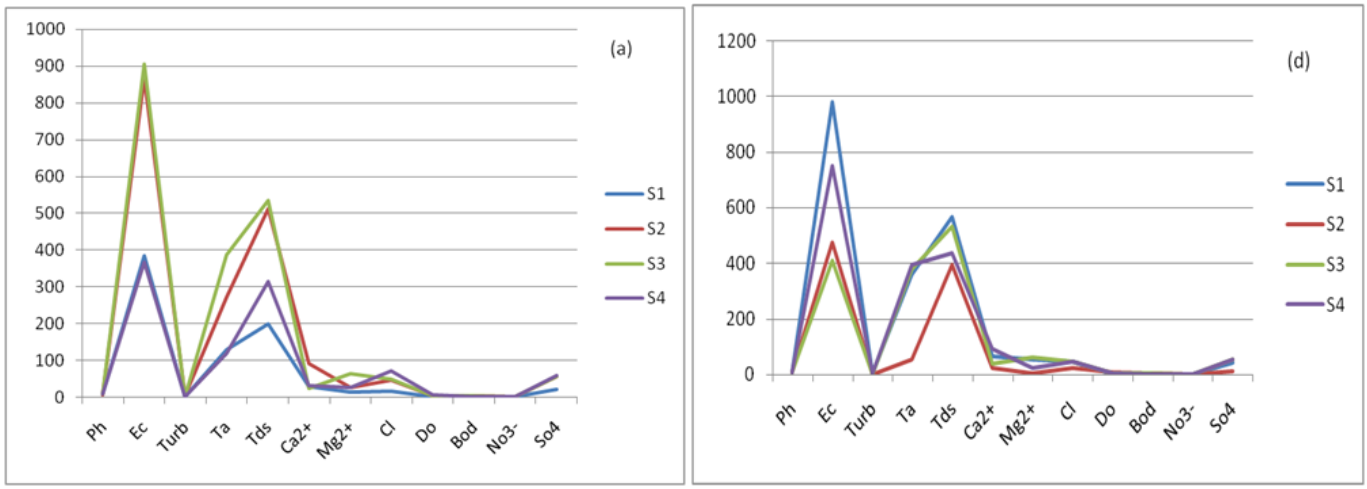


Fig 1: Scatter diagram showing positive and negative correlation between various physico-chemical parameters of water

Current study has shown significant correlation between pH dissolved oxygen DO, electrical conductivity EC, calcium Ca2+, magnesium Mg 2+, sulfate SO4, and chchloride Cl, whereas TDS explaining 65.4% of the variance in conductivity and graph shows a positive relationship between TDS and alkanity (R >0.65). Electric conductivity (EC) and Cl -were significantly correlated (R > 0.33). A considerably low correlation was observed between EC and Cl-(R=0.21) and Ca2+ and EC (R=0.33) Turb and DO (R=0.42), TA and DO (R=45.8%), The TA, DO and Turbidity are negatively correlated with most of the water parameters. Finally, we can conclude that the water quality parameter correlation studies are very important in the study of water resources.

Table 5: Linear correlation coefficient and regression equation for some pairs of parameters which have significant value of correlation

Pairs of parameters	Regression equation	R square	P-value
EC- DO	EC = 1157 - 120.3 DO	42.29%	0.005
Turb-DO	Turb = 5.61 - 0.776 DO	42.54%	0.005
Turb-EC	Turb =- 0.7819 +0.0046EC	54.90%	0.001
TA-DO	TA =575 -74.2345 DO	45.80%	0.001
TA-EC	TA = 19.24 + 0.4109 EC	45.60%	0.004
TA- Turb	TA = 119 + 56.9 Turb	32.10%	0.014
TDS-EC	TDS = 39.8 + 0.560 EC	51.10%	0.001
TDS-TA	TDS = 130 + 1.05 TA	65.40%	0
Ca^{2+} - EC	Ca^{2+} = 5.5 + 0.0728 EC	33.00%	0.02
Ca^{2+} Turb	Ca^{2+} = 17.00 + 14.95 Turb	63.90%	0
Cl- EC	Cl = 23.79 + 0.02742 EC	21.10%	0.022
Cl-TDS	Cl = 19.53 + 0.05581 TDS	35.50%	0.007



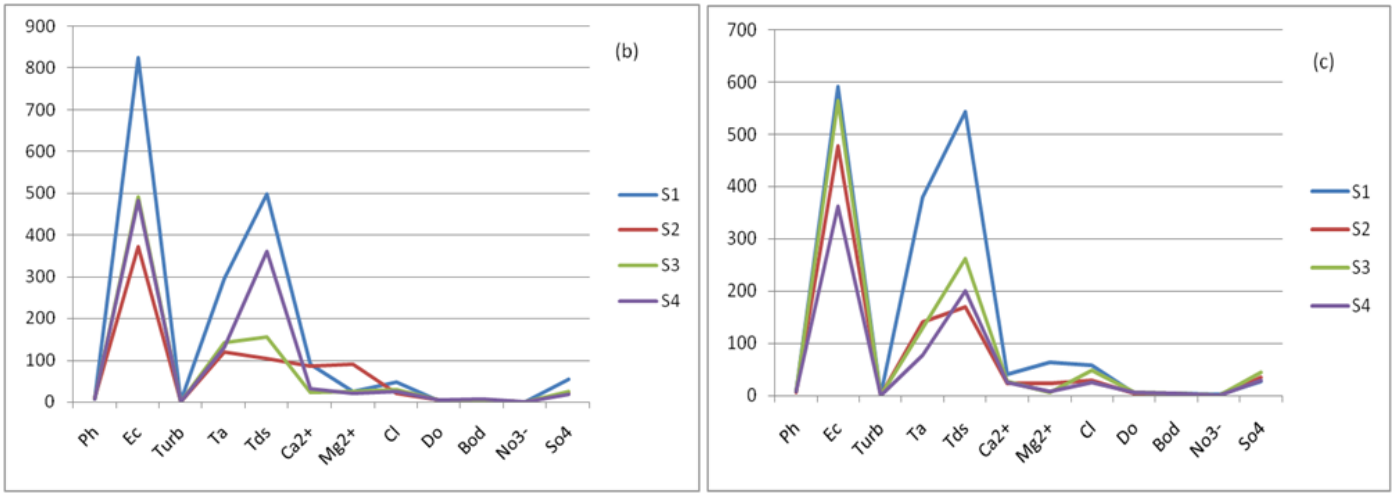


Fig 2: Line plots showing spatial variation of physico-chemical parameters of Water samples at four sites

Table 6: Comparison of ground water quality with drinking water standards

Parameter	pH	EC, µ mho/cm	TDS	Ca	Mg	Cl	Total Alkalinity	Sulphate
Bis standards (1991)	6.0-8.5	-	500	75	30	250	200	250
WHO	6.5-9.2	300	500	75	50	200	-	200
European standard	6.5-8.5	400	500	100	-	250	-	-
ICMR	6.5-8.5	-	500-1500	75	50	250	-	200
Present study	7.2-8.42	362-979	566-105	91.7-22.4	90-4.8	72-17	387-54	57-13

Conclusion

A statistical regression analysis very useful and liable method. A single step in the management of drinkable water quality can be considered as a linear connection between various physicochemical water parameters. There are two parameters used to describe realistic ground water situation as the mathematical models used to achieve water quality. The technology has been demonstrated to be a very useful tool for drinking water monitoring and is of good accuracy. There has been a significant relation between different pairs of physico-chemical parameters obtained by efficient correlation and regression. A significant approach to get a sense of ground water quality has been found by determining some parameters experimentally. The linear correlation method has been found. Dissolved oxygen and the electrical conductivity may be concluded to represent important physicochemical parameters of drinking water quality, as they are correlated with most parameters of water quality. The study can be enhanced in the near future by studying the movement of groundwater quality.

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