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Correlation and Regression Analysis to Determine the Percentage Existence of Physicochemical Parameters on Electrical Conductivity in the Industrial Area Drinking Water Around Cuddalore Old Town, Tamilnadu

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ABSTRACT

Introduction: Pure water is an acceptable one for persistent health. The superficial view on drinking water does not give much idea about the presence of minerals in it. Analyzing the physicochemical properties of groundwater samples helps in determining the constituents present in them as well as identifying quality standards. For this study, drinking water samples were collected from fifteen bore wells in and around the industrial area of Cuddalore old town. The Physico-chemical properties such as Potential of Hydrogen (pH), Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Total Alkalinity (TA), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Chloride (Cl-) and Sulphate (SO42-) are studied and then compared with the standard values of World Health Organization (WHO). Pure water does not have any conducting property. The drinking water may have a high value of Electrical Conductivity due to the presence of elements and salts which are not at the standard level.

Objectives: The acquisition of knowledge about the correlation matrix reveals that the interrelation between any two parameters. Using this, the relationship between electrical conductivity and all other parameters is analyzed in this present study. The regression equation is formed to calculate the impact of individual parameters on electrical conductivity.

Method: Statistical analysis helped to calculate the effect of each parameter on the high value of contamination in the groundwater due to electrical conductivity.

Result: It is found that the presence of cations is highest in the order Sodium, Calcium, Potassium, Magnesium and the abundance of anions is highest in the order Sulphate and Chloride.

Conclusion: The effect of each parameter on electrical conductivity has been studied. It showed that the percentage of TDS and Sodium was the maximum responsible for electrical conductivity. This study may be helpful to determine the quantity of each parameter that affects the quality of the groundwater and also used to evaluate the percentage of constituents present in it.

Key Words: Groundwater, Contamination, Correlation, Regression, Electrical conductivity and Sodium Chloride

INTRODUCTION

Water is one of the basic needs of living beings. The availability of freshwater is being reduced due to population growth and the development of industries. So maintaining the good quality of groundwater is most important to save living beings. The presence of minerals, organic, and inorganic matter in fresh water determines its quality. Many authors have noted that it may be polluted as a result of the landfill, sewage, domestic, industrial, and agricultural activities[11]. The high salinity of groundwater in the coastal region is caused by seawater intrusion, and the researchers also stated that the most of groundwater samples have Ca–Mg–Cl, Na–Cl, Ca–HCO3, and Na–HCO3 hydro – chemical[5,6,8,16-17,21]. The contaminated groundwater has a higher value of electrical conductivity, which indicates a large number of chemical compounds dissolved in it than that in pure water. The high value of TDS and EC due to the dumped solid wastes also affects the groundwater quality.[14,1] Consumption of this impure water will suffer human health. Men Baohui stated that in the

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future the concentration of hardness and conductivity will change in the fastest manner.[3] The presence of calcium and magnesium causes hardness, while high chloride levels produce a saline taste and increase the corrosive nature. Industrial wastes, sewage wastes, and landfills may add sodium concentration. The dominated concentration of Sodium and Chloride may be due to the presence of septic effluent and also the rock-water interaction.[15] The presence of Sulphate is due to the sedimentary rocks, and the existence of Potassium may be the availability of clay. The contamination of groundwater may be due to ion exchange, weathering, and saltwater intrusion as well. If the ratio of Calcium and Magnesium is more than two in the number indicates the dissolution of silicate minerals.[10]In the study area, Cuddalore district, already noted that the parameters total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), and Chloride (Cl^-) are in the higher value and also the salinity of the groundwater is heavy since the high value of TDS. The high salinity value may be caused by climate change or rising sea levels, and as a result, hypertension will rise in humans if it is used as drinking water. It represents that the dissolution of more inorganic compounds in groundwater will lead to elevated electrical conductivity value.[7,23] The current study focuses on the role of pH, TDS, TA, TH, positive ions, and negative ions in electrical conductivity.

Correlation matrix is used in this study to learn whether a positive or a negative relationship between the electrical conductivity and other variables.[9] A scatter plot shows a better illustration of this relationship. Linear regression foretells the value of each dependent variable using an independent variable. So the effect of individual physicochemical parameters on electrical conductivity has been calculated in this study using the regression equation.

MATERIALS AND METHODS

Study Area& Sample collection

The study area, Cuddalore, is situated along with the Eastern Coastal Region of Tamilnadu state. Its geographical area is 3678 square kilometers. During October, November, and December, the rainfall is heavy in the Cuddalore district. It receives 1168.08mm of rain per year on average.[19] Since 1971, the State Industries Promotion Corporation of Tamilnadu (SIPCOT) has been maintaining industrial complexes around Tamilnadu in order to achieve economic progress. In Cuddalore, SIPCOT Industrial Estate is functioning in Kudikadu. The district has highly polluting industries like dye, pesticides, drugs, pharmaceuticals, and chemical industries. Water samples were taken from fifteen sites near the SIPCOT industrial area of Cuddalore district in July month and named as S1 to S15. The sample sites are shown in Fig.1.

Before filling with samples, the sampling containers were rinsed and checked for contaminants. After collecting the samples, the containers were carefully labeled with sample codes S1 to S15, and analyses of the desired parameters began in the Chennai Testing Laboratory, Private Limited, Gundy, Chennai, Tamilnadu, within twenty-four hours. The samples were collected and analyzed in accordance with the established procedures.[2,18]

ANALYTICAL METHODS

Physicochemical properties

The various parameters such as Potential of Hydrogen (pH), Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Total Alkalinity (TA), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Chloride (Cl^-), and Sulphate (SO_4^{2-}) were determined using APHA standard procedures.[2] The pH is measured by a pH metre, electrical conductivity is tested using a conductivity metre, and titration methods were used to calculate the concentration of total hardness, total dissolved solids, calcium, magnesium, and chloride. The value of sodium is determined by a flame photometer. The concentration of sulphate is estimated using a spectrophotometer. Table 1 displays the results of all the received parameters. A bar diagram in Fig.2 depicts the concentrations of individual parameters in each of the fifteen sites.

Data Analysis

All the obtained data were analyzed statistically. Table 2 depicts the minimum, maximum and Standard Deviation (SD) of all the observed values. The standard deviation demonstrates the deviation of each parameter from its mean value. In addition, the Correlation matrix has been constructed to provide such a clear picture of the interrelationship of each parameter. To determine the effect of individual parameters on electrical conductivity, linear regression equations for each parameter is calculated. After determining the best fit line, the linear regression equation is written as $y = ax + c$, where 'y' is the dependent variable and 'x' is an independent variable, electrical conductivity.

Results

Fig.2. shows that, other than pH, TA, Mg, and K, all other parameters are high in sample S5 than the remaining samples. The obtained data were compared to the World Health Organization's(WHO) standard values. The minimum pH value observed among the fifteen locations is 5.4 in sample site S10 and the maximum is 7.9 in sample S11. The acceptable pH range, according to WHO standards, is 7.0 to 8.5. It has a permissible limit of 6.5 to 9.2[25]. Except for S8, S9, S10 and S13, all the other samples S1, S2, S3, S4, S5, S6,

S7, S11, S12, S14 and S15 are within the permissible limit of WHO. In comparison to all other parameters, pH has a very low standard deviation of 0.672 mg/l. It indicates that the pH values aren't too far off from the mean. The observed value of electrical conductivity is ranged from 294 µS/cm(S10) to3940 µS/cm (S5). The average value of electrical conductivity is 1148.4µS/cm. The samples S3, S4, S5, S11 and S14 are having the excess concentration than this mean value. High value of electrical conductivity shows that the high quantity of total dissolved solids, it means that more amounts of chemicals and minerals dissolved in it or may be the intrusion of salt water. Among the eleven parameters electrical conductivity has the highest amount of standard deviation which is determined as 978.152µS/cm. It concludes that it is significantly deviated from the mean value of 1148.40µS/cm.

The maximum total hardness was recorded in the sample name S5 which is noted as 700 mg/l. According to WHO, the permissible limit of total hardness is 500 mg/l and its acceptable limit is 100 mg/l. The lowest value 40 mg/l is observed in sample S6. The samples S3, S4, S5 and S14 have TH which is greater than the permissible limit. The standard deviation of total hardness is 227.17 mg/l. The presence of Calcium and Magnesium are in the form of their salts like bicarbonate, Sulphate, and Chloride. It determines the presence of hardness. High hardness causes stones in the urinary tract. In this study, sample S5 has the highest concentration of total hardness, Calcium, Chloride, and Sulphate.

As per World Health Organization standards, the acceptable and the permissible limit of total dissolved solids are 500mg/l and 1500 mg/l. The highest observed value of TDS is 2330 mg/lin S5, which is greater than the permissible limits. In this present study the TDS varies from 168 to 2330 mg/l. The concentrations in the samples with the names S3, S4, S5, S7, S11, S12, and S14 are higher than the acceptable limit. The standard deviation is 578.195 mg/l and the mean value is 680 mg/l.

The presence of carbonate, bicarbonate, and hydroxides indicates total alkalinity. Its concentration varies from 9 to 302mg/l among fifteen samples. The BIS (Bureau of Indian Standards) permissible limit of it is 600 mg/l. All the samples are within this permissible limit. As per the record of BIS, the acceptable limit of TA is 200 mg/l.[4] The samples S4, S5, S7, S11, and S12 are not within the acceptable limit. Calcium is essential for bone formation, but if it is present in excess, it can cause severe muscle problems. The samples S3, S4, S5, S7, and S14 have Calcium excess value that exceeds the WHO's acceptable limit 75mg/l. Sample S5 has the highest value of 196mg/l. The permissible limit of Calcium in WHO standards is 200 mg/l. In this current observation, all fifteen samples have Calcium levels that are within the permissible range.

Magnesium concentration levels in the fifteen samples vary from 3 to 56mg/l. According to the WHO, the acceptable and permissible limits of magnesium are 30mg/l and 150mg/l, respectively. The magnesium ion concentration in the samples S3, S4, S5, S7, S11, and S14 is above the acceptable limit. But all the samples are within the permissible levels. In this present work, Sodium levels ranged from 36.2 to 331mg/l. The taste of groundwater drastically changes when the concentration of sodium exceeds 200 mg/l. The sodium levels in samples S4, S5, and S11 are higher than 200 mg/l. The presence of mineral deposits, salt water intrusion, sewage effluents, as well as the occurrence of sodium fluoride and sodium bicarbonate may all contribute to the excess sodium.[15,24]In this work, the level of Potassium varies from 7.4 to 59 mg/l. Among fifteen samples, S5 has the lowest value of Potassium as 7.4 mg/l, but it has the highest value of Sodium as 331 mg/l and Chloride as 1280 mg/l. As a result, it is clear that the presence of Sodium and Chloride reduces the concentration of Potassium. Potassium in groundwater has a maximum allowable limit of 12 mg/l.[13] But the highest potassium concentration, 59 mg/l, was found in samples S2 and S12.

Chloride has an acceptable limit of 200mg/l and a permissible limit of 600 mg/l as per WHO. Sample S5 seemed to have the highest concentration of chloride (1280 mg/l). The samples S3, S4, S5, and S14 have more than the WHO's acceptable limit. S5 is the only location where Chloride levels exceed the WHO permissible limit. The average chloride concentration is 243.33 mg/l, with a standard deviation of 325.163 mg/l. S5 has the highest Sulphate concentration (214 mg/l), S10 and S12 have the smallest values. It has a permissible limit of 400 mg/l and an acceptable limit of 200 mg/l, according to the WHO standards. All of the samples in this study are within WHO's permissible limit. S5 is the only sample with Sulphate levels above the WHO's acceptable limit.

Correlation Analysis

The statistical Pearson correlation coefficient(r) identifies whether the two variables are in strong positive (if r = +1) relationship or strong negative relationship (if r = -1). A correlation matrix is developed using the various parameters pH, EC, TH, TDS, TA, Ca, Mg, Na, K, Cl^-, and SO_4^{2-} to determine the relationship of one variable with another, and it is tabulated in Table 3. The variables TH, TA, Mg, Na, and SO_4^{2-} have a moderately positive correlation with pH. Electrical conductivity is strongly positive relation with TDS, Na, and Cl^-, and it is also positively related to TH and Ca. Since EC has a perfect positive relationship with TH, TDS, Ca, Na, and Cl^-, it is confirmed that these parameters are more responsible for this study. It is clear that TA, Mg, and SO_4^{2-}have moderately positively correlated with electrical conductivity. TDS, Ca, Mg, Na, and Cl^- all have a strong positive relationship with

the parameter TH. The parameter TA and SO_4^{2-} moderately positively correlated with TH. The TDS has a strong positive correlation with Ca, Na, and Cl^-. It is linearly correlated with TA, Mg, and SO_4^{2-} Total alkalinity has moderate relation with Ca, Mg, Na, $Cl^-$and SO_4^{2-}. Calcium has a strong positive correlation with Chloride and has moderately correlated with Mg, Na, and SO_4^{2-}. Magnesium has a moderate correlation with Na, Cl^- and SO_4^{2-}. The sodium has a perfect positive correlation with Cl and moderately correlated with SO_4^{2-}.Cl^- has a moderately positive correlation with SO_4^{2-}. Potassium has a weakly negative relationship with EC, TH, TDS, Ca, Cl^-, and SO_4^{2-}. It is necessary to draw the scatter diagram for all of the parameters with electrical conductivity for better illustration.

Scatter diagrams are used to find the best fit, with electrical conductivity on the X-axis and each dependent variable on the Y-axis (Fig.3.(a), 3.(b), 3.(c),3.(d), 3.(e),3.(f),3.(g),3.(h),3.(i),3.(j)). In addition, the regression equation is formed in the form of a straight line equation, $y = ax + c$, using the line's Y-intercept (c) and slope (a). The "c" shows that the value of each dependent variable along the Y-axis when the independent variable (Electrical Conductivity) along the X-axis is equal to zero. The adjusted R^2indicates how long all of the data points fit perfectly. The scatter diagrams and regression calculations are done in Microsoft Excel only.[20, 22] Table 4 summarizes the calculated values. In this study, a high value of adjusted R^2, 0.9982, is obtained in the correlation of EC with TDS, denoting that the relationship is highly perfect one. The relation EC with Chloride has 0.9303, with Sodium has 0.8363, with TH has 0.7766, and EC with Calcium has 0.7696 as adjusted R^2. It is 0.6102 for Sulphate. Now it is necessary to determine the role of each parameter that contributes to the electrical conductivity. For safe drinking water, the electrical conductivity should be less than or equal to 400 µS/cm.[12]. Using this limit, while calculating the value of each dependent variable it confirms the perfect fit of TDS. The contribution of TDS to electrical conductivity is 38.28%. When compared to such contribution of other variables to electrical conductivity, it is considerably greater. The contributions of TH and TA seem to be 22.2 percent and 11.64 percent, respectively. Sodium contributes 8.6 percent, Sulphate 6.05, Calcium 5.36, Potassium 4.29, and Magnesium 2.11 percent only. The pH and Chloride make up only a very small percentage of the total, 1.06 and 0.42 %.

DISCUSSION

The sample taken from Vandippalayam(S5) has the highest concentration of EC, TH, TDS, Ca, Na, Cl^- and SO_4^{2-}. But potassium concentration is a less value. Low potassium will cause heart related diseases. The value of TA and Mg are also beyond the acceptable limit of BIS. So it has to monitor and do the proper treatment before consumption. The correlation analysis showed that the electrical conductivity is strongly positively correlated with Total Dissolved Solids (TDS). And also it is strongly positively correlated with Total Hardness (TH), Calcium (Ca), Chloride (Cl^-), and Sodium (Na). Similarly, TH is strongly positively correlated with Calcium (Ca) and TDS. There is a strong relationship between TDS with Calcium, Chloride, and Sodium. The above parameters are highly related to one another. The regression analysis proved that the total dissolved solids contribute 38.28 percent to electrical conductivity and followed by TH and TA as 22.2 and 11.64 respectively. The most important parameter related to electrical conductivity is total dissolved solids and, its percentage contribution showed that the groundwater samples contain more elements. Sodium, Calcium, Potassium, and Magnesium contribute 8.6, 5.36, 4.29, and 2.11 percent to electrical conductivity. Sulphate and Chloride contribute 6.05 and 0.42 percentage. This type of groundwater may be polluted due to intrusion of saltwater, sewage effluents, and sedimentary rock-water interaction. And also the samples were taken from Kodikalkuppam, Brookspet, and Periyakaraikadu have electrical conductivity beyond 1500mg/l. In this study region, the high value of sodium chloride reduces the potassium concentration.

CONCLUSION

The physicochemical properties were analyzed for water samples collected from fifteen bore wells in and around the industrial area of the Cuddalore old town. The mean and standard deviation of all the parameters have been determined and analyzed. The correlation and regression studies determine the percentage existence of each parameter on electrical conductivity. It shows that it is due to the high percentage of TDS and followed by sodium. So the presence of constituents in the groundwater should be continuously monitored and needs proper treatment to save the people who live in and around the industrial area of the Cuddalore district.

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Table 1: Physico-chemical parameters of samples from sites S1 to S15

Sample Code	pH (No unit)	EC (µS/cm)	TH (mg/l)	TDS (mg/l)	TA (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)
S1	6.6	533	112	330	54	36	5	74.9	38.3	75	47.6
S2	6.9	463	110	282	71	26	11	54.7	59	42	32.9
S3	7	1820	610	1132	119	152	56	193	56.2	486	62.8
S4	7.3	2271	530	1296	302	152	36	209	8.5	467	154
S5	7.1	3940	700	2330	281	196	51	331	7.4	1280	214
S6	7.4	606	40	346	108	10	3	85.9	8.8	69	51.9
S7	7.5	1075	420	654	259	84	51	63.3	10.7	74	173
S8	6	634	152	358	26	38	14	71.1	10.8	100	68.2
S9	6.1	461	120	280	19	35	8	56.7	10.9	89	52.5
S10	5.4	294	74	168	9	22	4	36.2	11.1	42	<1

Table 1: ***(Continued)***

Sample Code	pH (No unit)	EC (µS/cm)	TH (mg/l)	TDS (mg/l)	TA (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)
S11	7.9	1393	390	850	216	64	56	241	55	199	72.3
S12	6.5	960	224	546	285	61	18	55.4	59	144	<1
S13	6.1	552	174	326	54	51	12	55.3	11	84	60.1
S14	7.2	1753	610	1026	97	192	32	152	11	402	139
S15	6.9	471	128	276	35	33	11	58	14	97	22.6
Acceptable limit of WHO(1971)	**7.0 to 8.5**	-	**100**	**500**	-	**75**	**30**	-	-	**200**	**200**
Permissible limit WHO(1971)	**6.5 to 9.2**	-	**500**	**1500**	-	**200**	**150**	-	-	**600**	**400**

Table 2: Mean, Minimum, Maximum and SD of observed parameters

Parameters	Mean	Minimum	Maximum	SD
pH	6.793	5.4	7.9	0.672
EC µS/cm	1148.40	294	3940	978.152
TH mg/l	292.933	40	700	227.174
TDS mg/l	680.00	168	2330	578.195
TA mg/l	129.00	9	302	108.220
Ca mg/l	76.80	10	196	63.697
Mg mg/l	24.533	3	56	20.329
Na mg/l	115.833	36.2	331	88.429
K mg/l	24.780	7.4	59	21.576
Cl^- mg/l	243.333	42	1280	325.163
SO_4^{2-} mg/l	76.727	0	214	63.920

Table 3: Correlation Matrix among the drinking water parameters

	pH	EC	TH	TDS	TA	Ca	Mg	Na	K	Cl^-	SO4
pH	1										
EC	0.458	1									
TH	0.524	0.890	1								
TDS	0.465	0.999	0.897	1							
TA	0.613	0.683	0.632	0.676	1						
Ca	0.407	0.887	0.968	0.887	0.546	1					
Mg	0.647	0.730	0.877	0.747	0.678	0.728	1				
Na	0.564	0.921	0.825	0.926	0.593	0.774	0.767	1			
K	0.198	-0.106	-0.006	-0.086	0.147	-0.108	0.193	0.036	1		
Cl-	0.297	0.967	0.801	0.968	0.522	0.828	0.600	0.874	-0.145	1	
SO_4^{2-}	0.518	0.799	0.784	0.796	0.587	0.766	0.668	0.678	-0.426	0.710	1

Table 4: Percentage existence Calculation of dependent variable

Dependent variable	Adjusted R^2	Significance – F (P-Value)	Regression equation (y = ax + c)	Calculated ' y ' value	Percentage existence of dependent variable 'y' to EC
pH	0.1489	0.086	pH = 0.0003(EC) + 6.431	6.551	1.06
TH	0.7766	0.0000087	TH = 0.206(EC) + 55.48	137.88	22.2
TDS	0.9982	1.78E-19	TDS = 0.590(EC) + 1.730	237.73	38.28
TA	0.4249	0.005042	TA = 0.075(EC) + 42.26	72.26	11.64
Ca	0.7696	0.0000107	Ca = 0.057(EC) + 10.49	33.29	5.36
Mg	0.4976	0.001986	Mg = 0.015(EC) + 7.100	13.1	2.11
Na	0.8363	0.00000112	Na = 0.083(EC) + 20.23	53.43	8.6
K	-0.0649	0.707898	K = -0.002(EC) + 27.45	26.65	4.29
Cl	0.9303	4.17E-09	Cl = 0.321(EC) - 125.8	2.6	0.42
SO_4^{2-}	0.6102	0.000355	SO_4^{2-} = 0.052(EC) + 16.78	37.58	6.05

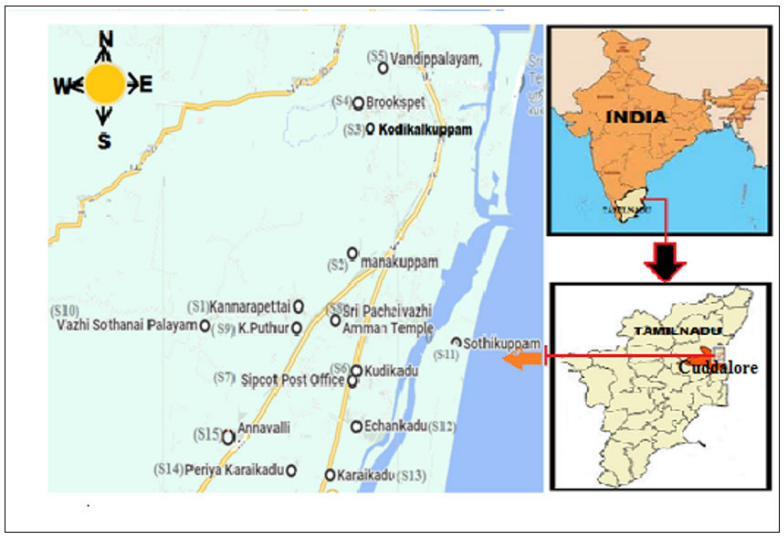

Figure 1: Location of the Study area (S1 to S15).

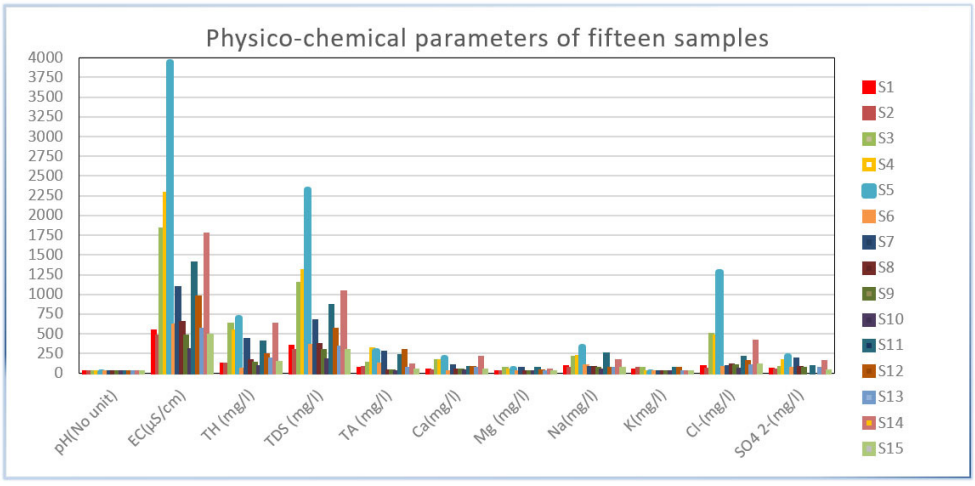

Figure 2: Status of each parameter in the every fifteen samples from S1 to S15.

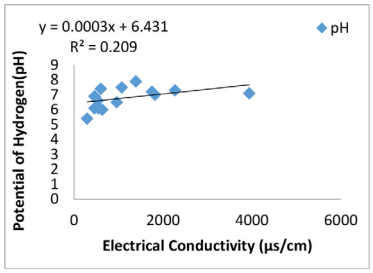

Figure 3.(a)

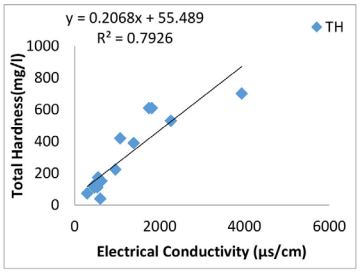

Figure 3.(b)

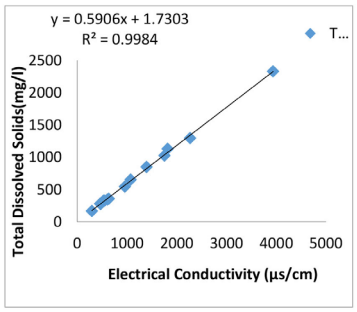

Figure 3.(c)

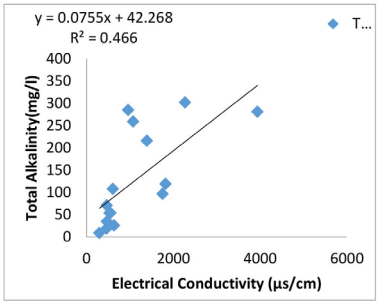

Figure 3.(d)

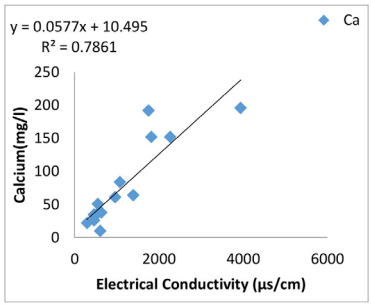

Figure 3.(e)

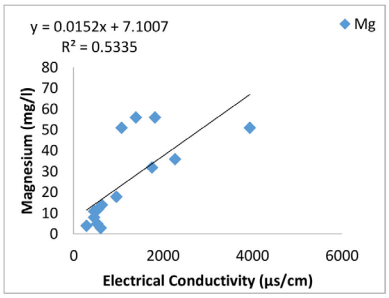

Figure 3.(f)

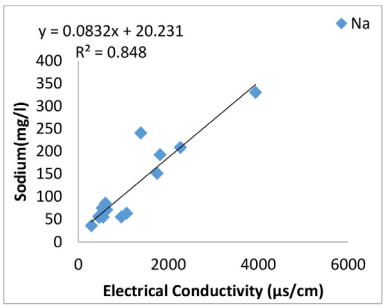

Figure 3.(g)

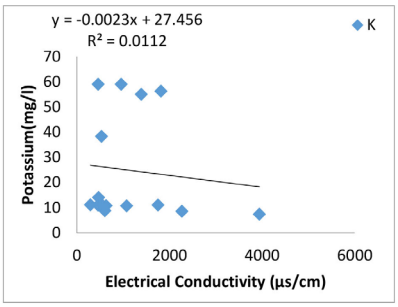

Figure 3.(h)

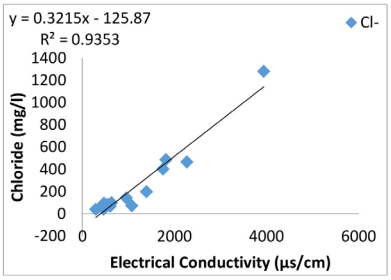

Figure3.(i)

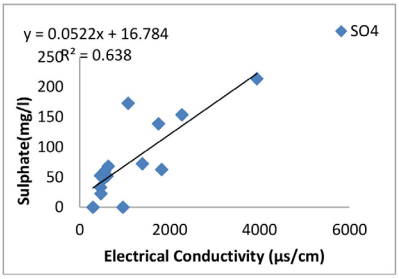

Figure 3.(j)

Figure 3: (a), 3.(b), 3.(c),3.(d), 3.(e),3.(f),3.(g),3.(h),3.(i),3.(j)- Variation of EC with pH, TH, TDS, TA, Ca, Mg, Na, K,Cl^- and SO_4^{2-}.