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Analysis of Groundwater Quality using Regression Model

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Abstract

Ground water is the main principal source for drinking water and other activities in Andhra Pradesh. It is the basic duty of every individual to conserve water resources. The present study attempts to bring an acute awareness among the people about the quality of ground water by taking water samples from 33 specific locations in Guntur city to characterize the physicochemical parameters of Ground water. To assess the quality of groundwater, each parameter was compared with the standard desirable limit of that parameter in drinking water as prescribed by different agencies. This paper is a new study on water quality parameters using the correlation coefficient and regression method in analyzing Guntur city drinking water. This technique was based to study and calculate the correlation coefficients between various physicochemical parameters of drinking water at Guntur city. The results revealed that the systematic calculations of correlation coefficient between water parameters and regression analysis provide useful mean for rapid monitoring of water quality.

Keywords- Water quality parameters, Regression Equation, Correlation Coefficient

I. INTRODUCTION

Fresh water has become a scarce commodity due to over exploitation and pollution of water. Increasing population and its necessities have lead to the deterioration of surface and sub surface water. However, uncontrolled extraction without commensurate recharge and leaching of pollutants from pesticides and fertilizers into the aquifers has resulted in pollution of groundwater supplies. In addition to leachates from agriculture, ground water is threatened with pollution from various sources viz., domestic wastes, industrial wastes, agricultural wastes, run off from urban areas and soluble effluents. All of these contaminants can find their way into local water bodies, and subsequently lead to the water quality problems. Contamination often goes undetected for many years. One of the most disturbing aspects of the problem is that groundwater and soil

pollution is essentially permanent. The major problem with the ground water is that once contaminated, it is difficult to restore its quality. Hence there is a need and concern for the protection and management of ground water quality. A systematic study of correlation and regression coefficients of the water quality parameters not only helps to assess the overall water quality but also to quantify relative concentration of various pollutants in water and provide necessary cue for implementation of rapid water quality management programmes. In this present study, an attempt has been made to evaluate and improve the quality of ground water in Guntur city area and thereby to analyze correlation and regression study of various Physico-Chemical parameters.

II. RESEARCH BACKGROUND

Water is a dynamic medium and its quality varies spatially and temporally. In order to characterise any water body, studies on the major components, hydrology, physico-chemical and biological characteristics, should be carried out.

A. Hydrological features

A detailed knowledge of the hydrological properties of the water body must be acquired before an effective water quality monitoring system is established. Each of the water-body is characterised by unique hydrological features such as

Rivers: characterised by uni-directional current with relatively high average velocity (0.1-1.0 m/S). In general, comprehensive and continuous vertical mixing is achieved in rivers due to the existing currents and turbulence.

Lakes: characterised by low, average current (0.001- 0.01 m/S) giving higher residential time for water. Currents within a lake are multi-directional with mixing regulated by the climatic conditions and lake depth.

Ground water: characterised by a steady flow pattern both in direction and speed that is largely governed by the porosity of the geological material as a result of which the mixing is poor.

B. Physical, Chemical and Biological Properties

The physical and chemical properties of a freshwater body are characteristic of the climatic, geochemical, geomorphological and pollution conditions (largely) prevailing in the drainage basin and the underlying aquifer where as biological quality is a combination of both qualitative and quantitative characterisation. The Physical, chemical and biological parameters analysed to assess the water quality are:

Physical parameters: Colour, Temperature, Transparency, Turbidity and Odour.

Chemical parameters: pH, Electrical Conductivity (E.C), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, Magnesium Hardness, Nitrates, Phosphates, Sulphates, Chlorides, Dissolved Oxygen (D.O), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fluorides, Free Carbon-di-oxide, Potassium and Sodium.

Heavy metals: Lead, Copper, Nickel, Iron, Chromium, Cadmium and Zinc.

Biological parameters: The biological parameters involved the qualitative analyses of

planktons (zooplankton and phytoplankton).
Field measurement: The field parameters measured include pH, conductivity, dissolved oxygen, temperature and transparency.

C. Physico- Chemical Parameters

It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physic-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity. Water does content different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Some physical test should be performed for testing of its physical appearance such as temperature, color, odour, pH, turbidity, TDS etc, while chemical tests should be perform for its BOD, COD, dissolved oxygen, alkalinity, hardness and other characters. For obtaining more and more quality and purity water, it should be tested for its trace metal, heavy metal contents and organic i.e. pesticide residue. It is obvious that drinking water should pass these entire tests and it should content required amount of mineral level. Only in the developed countries all these criteria's are strictly monitored. Due to very low concentration of heavy metal and organic pesticide impurities present in water it need highly sophisticated analytical instruments and well trained manpower. In this study we tested different physic chemical parameters monitoring quality of water.

PH

PH is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity.

EC (Electrical Conductivity)

Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, and chloride and iron concentration of water.

TOTAL DISSOLVED SOLIDS (TDS)

Dissolved solids are solids that are in dissolved state in solution. Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer.

TURBIDITY (TUR)

It is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer. Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter; plankton and other microscopic organisms cause turbidity in water.

ALKALINITY

It is composed primarily of carbonate (CO_3^{2-}) and bicarbonate (HCO^{3-}), alkalinity acts as a stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water.

TOTAL HARDNESS (TH)

Hardness is predominantly caused by divalent cations such as calcium, magnesium, alkaline earth metal such as iron, manganese, strontium, etc. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as CaCO3 in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness

Table:1 Hardness Chart (for drinking water)

Soft	0 – 60 mg/L
Medium	60 –120 mg/L
Hard	120 – 180mg/L
Very Hard	> 180 mg/L

CALCIUM (Cal)

It is measured by complexometric titration with standard solution of ETDA using Patton's and Reeder's indicator under the pH conditions of more than 12.0. These conditions are achieved by adding a fixed volume of 4N Sodium Hydroxide. The volume of titre (EDTA solution) against the known volume of sample gives the concentration of calcium in the sample.

MAGNESIUM (Mg)

It is also measured by complexometric titration with standard solution of EDTA using Eriochrome black T as indicator under the buffer conditions of pH 10.0. The buffer solution is made from Ammonium Chloride and Ammonium Hydroxide. The solution resists the pH variations during titration

CHLORIDES (Cl)

The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl-). Otherwise, high concentrations may indicate pollution by sewage, industrial wastes, intrusion of seawater or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. They are calculated by Argentometric method.

FLUORIDE (Fl)

Fluorides have dual significance in water supplies. High concentration causes dental fluorosis and lower concentration (<0.8 mg/L) causes dental caries. A fluoride concentration of approximately 1mg/L in drinking water is recommended. They are

frequently found in certain industrial processes resulting in fluoride rich wastewaters. Significant sources of fluoride are found in coke, glass and ceramic, electronics, pesticide and fertiliser manufacturing, steel and aluminium processing and electroplating industries. It is calculated by SPADNS method.

General of range of chemical constituents in ground water as given by Water Quality Standards of India (Source IS 2296:1992) are given in the TABLE 1

TABLE I. **WATER QUALITY STANDARDS IN INDIA (SOURCE IS 2296:1992)**

S.No	Chemical Constituent	Min.	Max.	General Range
1	**TDS**	305	729	
2	**Total Alkalinity**	108.5	198.6	
3	**TH**	150	1220	100-400 (600 mg/l)
4	**Calcium (mg/l)**	49.3	240	10-80 (200 mg/l)
5	**Magnesium (mg/l)**	12	185	15-100 (100 mg/l)
6	**Chlorides**	43	1358	25-500 (1000 mg/l)
7	**Fluoride**	0.26	2.25	< 0.5 (1.5mg/l)
8	**pH**	6.5	8.5	May be relaxed up to 9.2 in the absence
9	**EC (micromhos/cm)**	-	-	2250
10	**TUR**	5	10	

III. RELATED WORK

A. Sampling

The sample collected should be small in volume, enough to accurately represent the whole water body. The water sample tends to modify itself to the new environment. It is necessary to ensure that no significant changes occur in the sample and preserve its integrity till analysed (by retaining the same concentration of all the components as in the water body). The essential objectives of water quality assessment are to:

- Define the status and trends in water quality of a given water body.
- Analyse the causes for the observed conditions and trends.
- Identify the area specific problems of water quality and provide assessments in the form of management to evaluate alternatives that help in decision-making.

B. Types of Sampling

Generally three types of sampling are adopted for collecting water samples.

Grab or Catch sampling: the sample is collected at a particular time and place that represents the composition of the source at that particular point and time.

Composite sampling: a mixture of grab samples is collected at the same sampling point at different time intervals.
Integrated sampling: a mixture of grab samples collected at different points simultaneously

C. ***Study area***

The study area, Guntur City is one of the major regions in Guntur district, Andhra Pradesh situated in the south east and coastal of Andhra Pradesh, lies within the latitude ’North and the longitude- 800.17’East.In this we implemented integrated sampling method to collect 33 drinking ground water samples from four different fields for Guntur city namely: (a) Field I (8 wells), (b) Field II (8 wells), (c) Field III (9 wells), and (d) Field IV (8 wells) and analyzed during September, 2014 at local water authority in Guntur Medical College laboratories according to standard methods. A total of 4 water Samples per each station were collected in the selected regions in Guntur City viz., Nallapadu (S1), New Guntur (S2), Kothapet (S3), Koritipadu (S4), Srinagar Colony (S5), AT Agraharam (S6), Arundelpet (S7), Maruthi Nagar (S8) etc show in table 1 . The water samples were collected carefully in new 500ml polyethylene bottles.

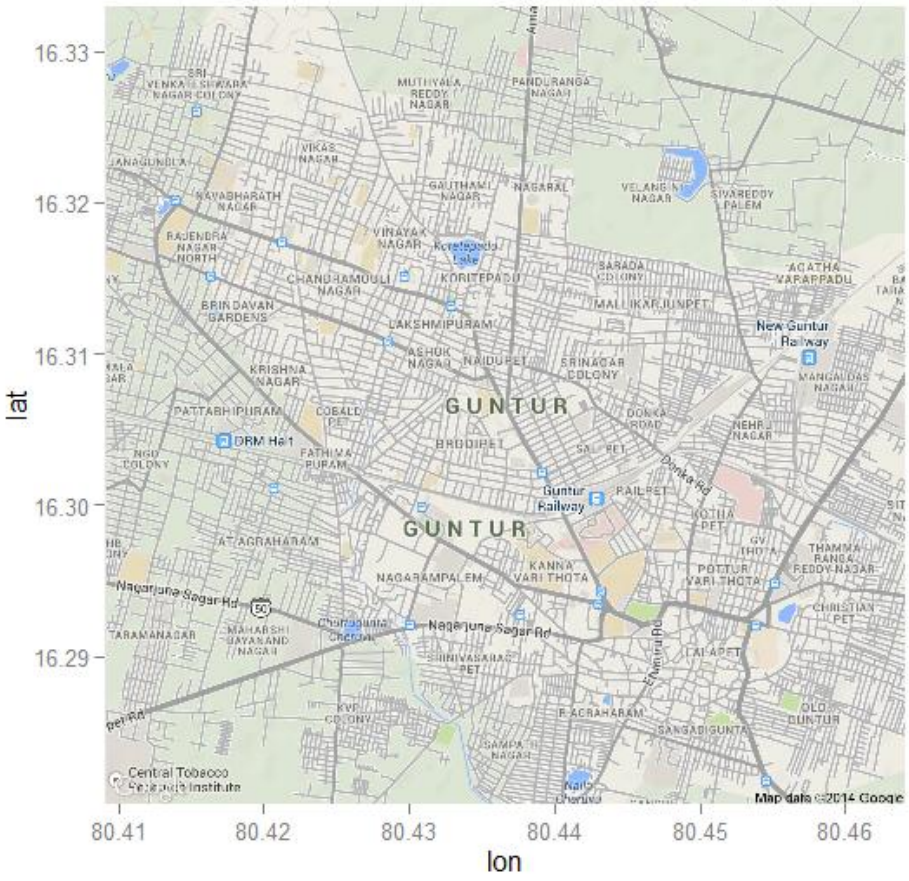

Figure 1. **Study area i.e Guntur City**

D. ***Water Quality Index (WQI)***

WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken into consideration for the calculation of water Quality index (WQI) .The indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and in water quality management. In formulation of water quality index the relative importance of various parameters depends on intended use of water. Mostly it is done from the point of view of its suitability for human consumption. The calculation of WQI was made using weighed Arithmetic index method. Let there be water quality parameters and quality rating (qn) corresponding to nth parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value. q_n values are given by the relationship. q_n =100 $(v_n\text{-}v_i) / (v_s\text{-}v_i)$ v_s = Standard value, v_n = observed value v_i = ideal value In most cases v_i = 0 except in certain parameters like pH, dissolved oxygen etc., Calculation of quality rating for pH & DO ($v_i \neq 0$) q_{pH} = 100 (v_{pH} – 7.0) / (8.5 – 1.0) and q_{DO} = 100 (v_{DO} – 14.6) / (5.0-14.6).

E. ***Calculation of unit weight***

The Unit weight (w_n) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$W_n = k/s_n$$

Where
w_n = unit weight for nth parameter
s_n = standard permissible value for n^{th} parameter
k = proportionality constant.
WQI is calculated by the following equation.

$$\text{WQI} = \sum_{n=1}^{n} q_n w_n \; / \sum_{n=1}^{n} w_n$$

The suitability of WQI values for human consumption is rated as follows. *0-25- Excellent*; *26-50- Good; 51-75- Bad; 76-100- Very Bad; 100 & above- Unfit.*

F. ***Calculation of unit weight***

Application of WQI is a useful method in assessing the suitability of water for various beneficial uses. The WQI values of the present investigation from different sampling stations are given below.

G. ***Linear Regression Model***

The mathematical models used quality parameters to estimate water quality require two parameters to describe realistic water situations. Correlation analysis measures the closeness of the relationship between chosen independent and dependent

variables. If the correlation coefficient is nearer to +1 or –1, it shows the probability of linear relationship between the variables x and y. The correlation between the parameters is characterized as strong, when it is in the range of +0.8 to 1.0 and -0.8 to -1.0, moderate when it is having value in the range of +0.5 to 0.8 and -0.5 to -0.8, weak when it is in the range of +0.0 to 0.5 and-0.0 to -0.5 [15]. This analysis attempts to establish the nature of the relationship between the variables and thereby provides a mechanism for prediction or forecasting. In this study, the relationship of water quality parameters on each other in data of water analyzed was determined by calculating Karl Pearson's correlation coefficient, R, by using the formula as given:

$$R = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}} \quad (1)$$

Where, X (X = values of x-variable, $\bar{X}$ = average values x) and Y (Y = values of y-variable, $\bar{Y}$ = average values y) represents two different water quality parameters. If the values of correlation coefficient 'R' between two variables X and Y are fairly large, it implies that these two variables are highly correlated. To determine the straight linear regression, following equation of straight line can be used:

$$Y = a + bX \quad (2)$$

Where, y and x are the dependent and independent variable respectively. a is the slope of line, b is intercept on y axis. The value of empirical parameters 'a' and 'b' are calculated with the help of the following equation:

$$b = \frac{\sum (XY - \bar{X}) \sum Y}{\sum X^2 - \bar{X} \sum Y} \quad (3)$$

$$a = \bar{Y} - b\bar{X} \quad (4)$$

In statistics, correlation is a broad class of statistical relationship between two or more variables. The correlation study is useful to find a predictable relationship which can be exploited in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. To study the correlation between various water quality parameters, the regression analysis was carriedout using R Language and the results are discussed below

IV. RESULTS AND DISCUSSION

The systematic calculation of correlation coefficient between water quality variables and regression analysis provide indirect means for rapid monitoring of water quality. The correlation coefficient measures the degree of association that exists between two variables, one taken as dependent variable. The greater the value of regression

coefficient, the better is the fit and more useful the regression variables Correlation are the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter. In this study, the numerical values of correlation coefficient, R for the10 water quality parameters are tabulated shown below. In this study we want to find the correlation of TDS with other parameters

TABLE II. **WATER QUALITY PARAMETERS**

	Max	Min	Range	Mean	SD	SE	CV%
pH	8.16	6.73	1.43	7.34	0.299	0.0514	4.07
EC	3220	812	2408	1777.75	508.749	88.562	28.618
TDS	5486	535	4951	1649.01	850.47	148.05	51.572
TUR	2.8	1.2	1.6	1.978	0.423	0.074	21.147
Total Alkalinity	1500	110	1390	315.75	235.399	40.978	74.553
TH	2000	120	1880	387.27	309.528	53.882	79.925
Calcium (mg/l)	1000	80	920	193.939	154.119	26.828	79.467
Magnesium (mg/l)	1000	40	960	192.727	155.196	27.016	80.526
Chlorides	2000	40	1960	223.79	338.986	59.0098	151.476
Fluoride	2.8	0.4	2.4	0.885	0.549	0.0956	62.034

TABLE III. **ANNOVA RESULT OF TDS**

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.933075295					
R Square	0.870629506					
Adjusted R Square	0.866456264					
Standard Error	86.02335484					
Observations	33					
	DF	**SS**	**MS**	**F**	**Significance F**	
Regression	1	1543805.516	1543805.516	208.6218715	2.59628E-15	
Residual	31	229400.5449	7400.017577			
Total	32	1773206.061				
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	-110.1427359	33.07137605	-3.33045519	0.002249231	-177.5922518	-42.69322
TDS	0.258263695	0.017880656	14.44374852	2.59628E-15	0.221795857	0.29473153

In this study we have taken confidence level as 95% then when significance F is very low then the regression is good else it is not good when the p value <5% then that coefficient values of x is fully depended on y else not depended.

TABLE IV. **PHYSICOCHEMICAL PARAMETERS OF DRINKING WATER AT STUDIED GUNTUR CITY**

	pH	EC	TDS	TUR	Total Alkalinity	TH	Calcium (mg/l)	Magnesium (mg/l)	Chlorides	Fluoride
S1 Nallapadu 1	7.44	3220	1317	2.3	320	200	100	100	160	2.8
S2 Nallapadu 2	7.44	2640	535	2.1	120	120	80	40	40	0.6
S3 Vidya Nagar	7.57	1722	5486	1.7	1500	2000	1000	1000	2000	2.6
S4 New Guntur	7.67	2240	1319	1.4	320	240	120	120	120	1.1
S5 Kothapet	7.49	1143	2138	1.9	240	320	160	160	320	0.4
S6 Koritipadu	7.49	2042	1416	2.5	280	260	130	130	360	0.8
S7 Srinagar Colony (1)	7.41	1238	1609	2.2	360	280	140	140	180	0.6
S8 Srinagar Colony (2)	7.40	2182	1810	1.7	270	260	130	130	90	0.7
S9 AT Agraharam	7.39	1084	1800	1.4	410	300	150	150	250	1.1
S10 Arundelpet	7.55	812	1550	2.4	250	240	120	120	170	0.5
S11 Maruthi Nagar	7.49	1999	1620	2.3	280	280	140	140	110	1.0
S12 Brodipet	7.56	1624	1410	2.3	310	280	140	140	120	0.6
S13 AT Agraharam 16th Lane	7.28	1910	1720	1.8	340	320	160	160	110	0.7
S14 SVN Colony	7.22	1735	2315	1.7	560	540	260	260	450	1.5
S15 Krishna Nagar	7.28	2170	1700	2.1	300	320	160	160	120	0.8
S16 Rajender Nagar	7.49	2480	1820	1.2	230	340	170	170	90	0.7
S17 GV Thota	7.47	1257	1512	2.1	310	410	205	205	105	0.6

S18 Sangati Gunta	7.42	1426	1620	1.8	290	360	180	180	110	0.8
S19 Kobalpet	7.37	2020	2100	1.4	410	560	280	280	120	0.8
S20 Mallikarjun pet	7.42	1939	1120	1.6	230	340	170	170	110	0.5
S21 Vasanth rai puram	6.73	1635	2400	1.7	450	620	310	310	520	1.4
S22 Nehru Nagar	6.98	1257	1400	1.9	230	320	160	160	120	0.5
S23 SitaNagar	7.79	1550	1640	1.6	240	340	170	170	90	0.6
S24 Lam	6.87	1550	2530	2.3	460	580	290	290	430	1.6
S25 Gujjana Gulla	7.01	2480	1840	2.4	210	340	170	170	110	0.8
S26 Gandhi Nagar	7.15	1823	820	2.6	140	320	160	160	120	0.6
S27 Ziyavuddin Nagar	7.27	2190	780	2.5	160	300	150	150	110	0.6
S28 Navabharath Nagar	7.28	1986	1213	2.3	260	410	205	205	140	0.8
S29 Narakoduru	6.92	1635	650	1.9	110	230	115	115	110	0.6
S30 Chebrolu(1)	6.83	1299	1150	1.7	210	320	160	160	120	0.8
S31 Chebrolu(2)	6.86	1402	1620	1.4	240	380	190	190	130	0.6
S32 Vengalai Palem	7.23	1587	560	2.8	120	230	115	115	110	0.5
S33 Palakaluru	8.16	1389	1900	2.6	260	420	210	210	140	0.6

TABLE V. **CORRELATION COEFFICIENTS AMONG VARIOUS WATER QUALITY PARAMETERS**

	pH	EC	TDS	TUR	Total Alkalinity	TH	Calcium (mg/l)	Magnesium (mg/l)	Chlorides	Fluoride
pH	1									
EC	0.051486	1								
TDS	0.110974	-0.13502	1							
TUR	0.085982	0.034908	-0.29555	1						
Total Alkalinity	0.11341	-0.07114	0.933075	-0.24654	1					
TH	0.031742	-0.10213	0.906723	-0.19599	0.9459	1				
Calcium (mg/l)	0.034107	-0.09552	0.903618	-0.19434	0.9444	0.999683169	1			
Magnesium (mg/l)	0.030936	-0.1085	0.907895	-0.19514	0.9445	0.999696373	0.999010748	1		
Chlorides	0.03452	-0.09562	0.884262	-0.11973	0.9478	0.95134082	0.951770738	0.949528693	1	
Fluoride	-0.03625	0.363507	0.599222	-0.08875	0.6962	0.582909956	0.580977552	0.581118555	0.647303	1

TABLE VI. **A LINEAR CORRELATION COEFFICIENT R AND REGRESSION EQUATION FOR SOME PAIRS OF PARAMETERS WHICH HAVE SIGNIFICANT VALUE OF CORRELATION**

PAIRS OF PARAMETERS	R VALUE	REGRESSION EQUATION
EC-TUR	0.034907703	EC= 1693.77(TUR)+42.2452
TDS-TUR	-0.295553986	TDS= 2837.695(TUR)-597.92
TDS-F	0.599221713	TDS = 828.46(F)+927.42
TDS-EC	-0.135020714	TDS=2050.352(EC)-0.2257
TA-EC	-0.071136124	TA=374.27(EC)-0.03291
TA-TDS	0.933075295	TA= -110.1427(TDS)+0.2582
TA-TUR	-0.24653624	TA= 590.185(TUR)-138.050
TA-F	0.696230518	TA = 51.845(F)+298.25
TH-EC	-0.102131446	TH=497.73(EC)-0.062
TH-TDS	0.9067234	TH=-156.931(TDS)+0.33
TH-TUR	-0.195993038	TH=674.14(TUR)-144.309
TH-F	0.582909956	TH=96.734(F)+328.347
CAL-EC	-0.095515441	CAL=245.3792(EC)-0.0289
CAL-TDS	0.903618368	CAL=-76.1009(TDS)+0.1637
CAL-TUR	-0.19434321	CAL=335.573(TUR)-71.249
CAL-F	0.580977552	CAL=49.7553(F)+162.947
MG-EC	-0.108502849	MG=251.57(EC)+0.033
MG-TDS	0.907894786	MG=-80.4881(TDS)+0.1656
MG-TUR	-0.195141907	MG=335.938(TUR)-72.042
MG-F	0.581118555	MG=47.4998(F)+164.1268
F-TUR	-0.088752131	F=1.1154(TUR)-0.1167

In this study, the numerical values of correlation coefficient, R for thirty three water quality parameters are tabulated in Table IV .The linear regression Analyses have been carried out experimentally for the water quality parameters which are found to have better and higher level of significance in their correlation coefficient (R>0.50). The regression equations obtained from the analysis are given in the Table VI. The different dependent characteristics of water quality were calculated using the regression equation and by substituting the values for the independent parameters in the equations. In current study, it is evident that distribution of TDS with TA, TH, CAL &MG were significantly correlated (R > 0.6). Based on above results TDS having high positive correlation with TA, TH, CAL, MG & F, so that the drinking people have an unfavorable physiological reactions, i.e Waters with high dissolved solids generally are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer

V. CONCLUSION

TDS having high positive correlation with TA, TH, CAL, MG & F, so that the drinking people have an unfavorable physiological reactions, i.e Waters with high dissolved solids generally are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer

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