e-ISSN No.: 2582-4228

Journal of Indian Association for Environmental Management

Journal homepage: www.http://op.niscair.res.in/index/php/JIAEM/index

Correlation and Regression Analysis of Physicochemical Parameters of Wainganga River Water in Central India

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Submitted:26 January 2023 Revised: 17 February 2023 Accepted: 27 February 2023

Abstract: **Wainganga River is the key source of water for few cities such as Balaghat, Seoni of Madhya Pradesh state and Bhandara, Gadchiroli of Maharashtra state. The river is main tributary of Godavari River and originates in the Mahadeo Hills in south-central Madhya Pradesh state of India near the villages Gopalganj in Seoni. The river flows in a winding course through two states Madhya Pradesh and Maharashtra with approximate length of around 579 km.**

Based on the chemical analysis of eighteen physico-chemical parameters of river water, water quality of the river was assessed with the help of statistical analysis. The analytical results were analyzed statistically to calculate correlation coefficients and to plot the regression equations of thirty different pairs of water quality parameters. The objective of the study was to establish the relation between the analyzed water quality parameters with help of Correlation Matrix and Regression Analysis. The various water quality parameters have a significant correlation. The results proved to be a useful mean for rapid monitoring of water quality with the help of systematic calculations of correlation coefficient between parameters and regression analysis. The statistical regression and Correlation analysis has been found to be a time saving and cost effective technique. Explore linear correlation between different physicochemical water parameters can be treated as an advanced step ahead towards the drinking water quality management. In current study regression equation established between different parameters can be employed to forecast the level of other parameters if its counterpart is known.

***Keywords*: Water Quality, Correlation Coefficient, Regression Equation, Wainganga River**

I. INTRODUCTION

India is growing and urbanizing, subsequently, river water is continuously polluted. It is projected that about 70% of surface water in India is not fit for human consumption. Every day, almost 40 million liters of wastewater are discharged into rivers and other surface water bodies with only a small portion effectively treated. A recent World Bank report recommends that the discharge of untreated water upstream of the river subsequently lowers the economic growth in downstream areas, reducing GDP growth in these regions(World Bank Report 2019). The fast-growing developing countries like India where controlling water pollution of water bodies is a major challenge, consequently increasing the loss of GDP of a country. Hence, there is a need for robust management of the water quality of all the rivers to detect changes in the Physicochemical parameters of water at different locations for remedial measures and create awareness among the common man.

The Wainganga is a river originating in the Mahadeo Hills in south-central Madhya Pradesh state near the Gopalganj village of Seoni district, Madhya Pradesh state, India. It is a major tributary of the Godavari River and it travels in a winding course through the states of Madhya Pradesh and Maharashtra for around 579 km south to the confluence of the Wardha River (another important of the Godavari), northeast of Kagaz Nagar of Maharashtra state. After confluences the Wardha River, the combined tributary, which is recognized as the Pranahita River, drains into the Godavari River at Kaleshwaram, Telangana state.The application of correlation and regression equations was used as a mathematical mechanism to determine the different dependent characteristics of water quality by substituting the values for the independent water quality parameters in the equations. The study was carried out by regression analysis for a better and higher level of importance in their correlation coefficient between various water quality parameters. The correlation study of water quality parameters is also applicable to finding a probable relationship which can be very useful in monitoring. This study contributes as an instrument to find the value of physicochemical parameters and the magnitude of pollution.

The most common practice statistical methods such as simulation and forecasting methods, correlation, linear regression, and Principal Component Analysis (Schreiber 2022). Out of these methods, Correlation, and regression may appear as more appealing methods to infer water quality as time-saving and cost-effective techniques. This analysis endeavors to find the nature of the relationship among the variables and thus provides a mechanism for forecasting.

II. Materials and Methods

Sampling: The river water samples were collected on the first working day of every month from the Wainganga River and analyzed at Wainganga Water Quality Laboratory, Central Water Commission, Nagpur. A total of ninety-six water samples were collected during June 2020–2021 from Wainganga River at eight locations from upstream to downstream such as Bakhari, Keolari, Magardharra, Kumhari at Madhya Pradesh, and Mahalgaon, Pauni, Sakhra, Ashti at Maharashtra. The details of water sampling locations are presented in Table-1 and Figure-1. Samples were collected as per the standard methods of sampling (WQMA 2017). The water samples were collected from the river from 08.00 AM to 10.00 AM at 30 cm depth from the surface, without disturbing the bottom sediments, from the point across the river at different section, maximum depth or flow along the cross-section of the river so that the collected samples are representative (HP 2003). The samples were collected in pre-cleaned one-liter bottles, filled to their full volume, and transported from the river site to the laboratory as per the standard procedure.

Chemical Analysis: The collected river water samples were preserved and transported from the water quality monitoring station to NABL Accredited Wainganga Water Quality Laboratory, Central Water Commission, Nagpur, India for Physico-chemical analysis as per the standard methods (APHA 2017). The instruments used were as per the accuracy and precision prescribed in the standard procedures. The Certified Reference Material (CRM), analytical grade Chemicals, calibrated instruments, and glassware were used during the analysis for accurate results. The parameters analyzed were pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Sodium (Na), Potassium (K), Nitrate (NO3), and Sulphate (SO4) by instrumental methods; Calcium (Ca), Chloride (Cl), bicarbonate (HCO3), Total Alkalinity, Total Hardness, and Ca-Hardness by titrimetric methods; and Magnesium (Mg), Mg-Hardness, Sodium percentage (% Na) and Sodium Absorption Ratio (SAR) by calculation method. Double distilled water was used during the entire water analysis. The analytical results were compared with the standard as prescribed by the Bureau of Indian Standards (BIS) 10500:2012 and 2296:1992. The number of instruments used for the analysis of water quality parameters such as pH meter, EC/TDS Meter, Turbidity Meter, Flame Photometer (Systronics), UV-Visible Spectrophotometer (ECIL), and Digital E-Burette (Microlit) as standard methods (Table-2).

Linear Regression Model: The relationship among all the eighteen water quality parameters with the help of ninety-six results of each water quality parameter obtained from the analysis of collected water samples of the river. Karl Pearson's correlation coefficient (r) was calculated by applying the mathematical formula describes below. The x and y be any two variables (water quality parameters in the current study) and n = number of observations. Then the correlation coefficient (r), among the variables x and y is given by the following relation:

$$r = \frac{n\sum(x_i y_i) - (\sum x_i).(\sum y_i)}{\sqrt{[n\sum x_i^2 - (\sum x_i)^2][n\sum y_i^2 - (\sum y)_i].^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, x (x =values of x-variable) and y (y =values of y-variable) represents two different water quality parameters. n = number of data points and all the summations are to be taken from 1 to n. To define the straight linear regression, following equation of straight line can be apply:

$$y = ax + b \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots (2)$$

Where, y and x are the dependent and independent variable correspondingly, a is the slope of line, b is intercept on y -axis. The slope, a, and y- intercept, b can be defined by applying the following formula:

$$a = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x^2) - (\sum x).^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$b = \frac{\sum y - a\sum x}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

To correlate x and y, the constant A and B are to be defined by using the experimental data on the variables x and y. According to the recognized method of least squares, the value of constants A and B are given by the relations.

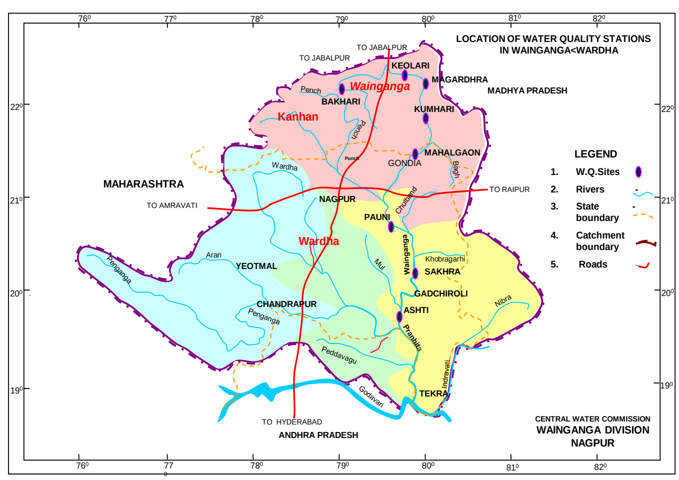

Figure 1: Water quality network of CWC at Main Stem of River Wainganga

TABLE 1

Details of water quality stations at Wainganga River

Sr.	Name of site	District	State	Frequency	Site type	Latitude	Longitude
1	Bakhari	Seoni	MP	Monthly	GDSQ	22°19'29"	79°28'05"
2	Keolari	Balaghat	MP	Monthly	GDQ	22°22'53"	79°53'59"
3	Magardharra	Bhandara	MP	Monthly	GDSQ	21°57'20"	80°06'33"
4	Kumhari	Balaghat	MP	Monthly	GDSQ	21°53'04"	80°10'31"
5	Mahalgaon	Gondia	MH	Monthly	GDSQ	21°33'02"	80°01'36"
6	Pauni	Bhandara	MH	Monthly	GDQ	20°47'35"	79°38'54"
7	Sakhra	Gadchiroli	MH	Monthly	GDSQ	20°18'40"	79°56'43"
8	Ashti	Gadchiroli	MH	Monthly	GDSQ	19°41'12"	$79^{0}47'02"$

TABLE 2

Statistical analysis of the water quality parameters of Wainganga River, Nagpur, Central India.

Sr. No.	Para-meters	Units	Data points	Min	Avg	Max	Sum	SD	Method	A. *BIS 10500:2012*		BIS 2296:1992
										B. *Desir-able*	C. *Permis-sible*	
1	*EC*	µs/cm	96	194.0	432.3	1431.0	41498	162.0	APHA 2510 B	NM	NM	E: 2250
2	pH	-	96	6.9	7.8	8.7	747	0.4	APHA 4500H	6.5-8.5	No relaxation	A & C: 6.5-8.5 E: 6.0-8.5
3	Turb	NTU	96	0.1	4.5	45.9	428	8.7	APHA 2130 B	1.0	5.0	NM
4	TDS	mg/L	96	112.0	230.8	761.0	22160	85.7	APHA 2540	500	2000	A: 500, C: 1500, E: 2100
5	TH	mg/L	96	69.0	151.7	577.0	14567	59.9	APHA4500 B	200	600	A: 300
6	Ca	mg/L	96	22.0	44.1	216.0	4236	21.0	APHA3500 B	75	200	NM
7	Mg	mg/L	96	2.4	9.9	19.0	954	4.3	APHA2340 C	30	100	A: 100
8	CaH	mg/L	96	56.0	109.1	400.0	10476	40.9	Calculation	NM	NM	A: 200
9	MgH	mg/L	96	10.0	42.6	177.0	4091	22.7	Calculation	NM	NM	NM
10	Na	mg/L	96	9.9	18.3	59.3	1755	7.6	APHA 3450-B	NM	NM	NM
11	K	mg/L	96	1.0	2.2	8.8	210	1.0	APHA 3450-D	NM	NM	NM
12	HCO_3	mg/L	96	92.0	175.8	294.0	16879	45.2	APHA2320 B	NM	NM	NM
13	SO4	mg/L	96	0.6	16.0	71.7	1532	9.2	APHA 4500 E	200	600	A & C: 400, E:1000
14	Cl	mg/L	96	4.0	14.6	92.2	1402.15	13.3	APHA 3500 B	250	1000	A: 250 C & E: 600
15	NO_3	mg/L	96	0.1	5.5	39.7	525.2	6.3	APHA 4500-D	45	No relaxation	A: 20 C: 50
16	TA	mg/L	96	76.0	145.9	391.0	14007	43.9	APHA2320 B	200	600	NM
17	%Na	-	96	11.0	21.0	37.0	2017	6.0	Calculation	NM	NM	D: 60
18	SAR	-	96	0.4	0.7	1.4	63.55	0.2	Calculation	NM	NM	D: 26

If the numerical value of the correlation coefficient among two variables x and y is fairly large, it suggests that these two variables are highly correlated. In such circumstances, it is viable to attempt a linear relation of the form by applying the above relations. Microsoft Excel was used to calculate the values of correlation coefficients (r) which have been given in Table-3.

The correlation coefficient (r) represents the degree of association that exists between two variables, one taken as a dependent variable. The higher the value of the regression coefficient, the better the fit and more convenient the regression variables (Daraigan Sami G, 2011 and Kumar and Sinha, 2010). Correlation is the reciprocated relationship between two variables. A direct correlation exists when an increase or decrease in the value of one water quality parameter is related to a corresponding increase or decrease in the water quality value of another parameter (K. Jothivenkatachalam, 2010 and Patil, 2011). The numerical values of the correlation coefficient (r) for all the eighteen water quality parameters are presented in Table-3.

The correlation study is suitable to investigate an expected relationship that can be exploited in practice. It is appropriate for the measurement of the strength and statistical significance of the relationships among two or more water quality variables and one taken as a dependent variable (Mehta, 2010).

TABLE 3
Correlation coefficients between different physico-chemical parameters of Wainganga River

Sr.	Parameter	EC	pH	Turb	TDS	TH	Ca	Mg	CaH	MgH	Na	K	HCO_3	SO_4	Cl	NO_3	TA	%Na	SAR
1	EC	1																	
2	pH	0.051	1.000																
3	Turb	-0.226	-0.457	1.000															
4	TDS	0.991	0.056	-0.229	1.000														
5	TH	0.706	0.299	-0.304	0.733	1.000													
6	Ca	0.723	0.156	-0.193	0.745	0.955	1.000												
7	Mg	0.258	0.453	-0.446	0.281	0.537	0.280	1.000											
8	CaH	0.692	0.249	-0.240	0.720	0.968	0.978	0.364	1.000										
9	MgH	0.617	0.340	-0.368	0.637	0.894	0.757	0.760	0.754	1.000									
10	Na	0.467	0.094	-0.240	0.472	0.533	0.521	0.254	0.469	0.561	1.000								
11	K	0.146	-0.015	-0.099	0.146	-0.026	-0.038	0.017	-0.029	-0.016	0.412	1.000							
12	HCO_3	0.499	0.448	-0.513	0.519	0.765	0.606	0.815	0.686	0.783	0.324	-0.063	1.000						
13	SO_4	0.448	0.086	-0.285	0.453	0.597	0.628	0.160	0.584	0.523	0.699	0.329	0.279	1.000					
14	Cl	0.544	0.133	-0.201	0.567	0.659	0.658	0.269	0.632	0.600	0.809	0.411	0.330	0.692	1.000				
15	NO_3	0.214	0.147	0.102	0.234	0.287	0.261	0.189	0.311	0.195	0.247	0.235	0.148	0.171	0.261	1.000			
16	TA	0.623	0.355	-0.393	0.645	0.889	0.792	0.665	0.808	0.890	0.483	-0.113	0.860	0.490	0.504	0.153	1.000		
17	%Na	-0.129	-0.234	0.060	-0.149	-0.348	-0.287	-0.318	-0.385	-0.225	0.571	0.403	-0.409	0.227	0.216	-0.096	-0.294	1.000	
18	SAR	0.201	-0.050	-0.131	0.196	0.124	0.155	-0.013	0.072	0.198	0.883	0.483	-0.014	0.543	0.584	0.099	0.131	0.864	1

Strong	(red)	**> 0.700**	**24**
Moderate	(blue)	**0.500 -0.700**	**30**
Weak	(green)	**0.500 <**	**63**
Negative	(yellow)		**36**

III. Results and Discussion

The water quality parameters were found to have a better and higher level of significance in their correlation coefficient by using Regression analysis. A correlation matrix of eighteen parameters, namely, pH, Turb, EC, TDS, Na, K, Ca, Mg, SO4, Cl, NO3, HCO3, TA, TH, CaH, MgH, % Na and SAR were prepared and presented in Table-3. The relationship between the dependent and independent variables always measures the correlation coefficient. The correlation coefficient is +1 or −1, which confirms the strong linear relationship among the variables. There was a strong positive and negative correlation between various physicochemical water quality parameters.

A graph of pairs of physicochemical parameters of the river water samples received from eight water quality of the Wainganga river basin from June 2020 to May 2021 was prepared to establish the relationship between the two variables. The plotted graphs reveal a direct linear and positive relationship between the two variables. The greater the value of the regression coefficient, the better the fit and the more suitable the regression variables. Linear regression was used to find out the regression coefficient (R2) and significance value (p) & regression relationship as shown given in Table-4.

The regression equation was used to calculate by different dependent characteristics of water quality and by substituting the values for the independent parameters in the equations.

The regression analysis has been carried out for thirty pairs of physicochemical parameters as given in Table-4. It is observed that the eight pairs such as EC-TDS (R2 = 0.982), MgH-Mg (R2 = 0.919), CaH-Ca (0.912), TH-CaH (R2 = 0.880), TH-HCO3 (R2 = 0.816), TH-Ca (R2 = 0.811), SAR-Na (R2 = 0.780, Na%-SAR (R2 = 0.747) are showing strong significant regression (> 0.70) relationship and the seven pair such as TH-MgH (R2 = 0.625), Mg-HCO3 (R2 = 0.664), Na-Cl (R2 = 0.654, TH-Mg (R2 = 0.598), Na-SO4 (R2 = 0.488), TDS-Ca (R2 = 0.454), EC-Ca (R2 = 0.412), are showing moderate significant (0.6 - 0.4) regression relationship. The remaining fifteen pair such as CaH-MgH (R2 = 0.350), Na%-Na (R2 = 0.326), TDS-TA (R2 = 0.323) TDS-CaH (R2 = 0.312), EC-TH (R2 = 0.283), Ca-HCO3 (R2 = 0.265), SAR-K (R2 = 0.233), Ca-SO4 (R2 = 0.174), K-Cl (R2 = 0.169), Na%-K (R2 = 0.162) Ca-Cl (R2 = 0.142), Na%-Ca (R2 = 0.131) K-SO4 (R2 = 0.107) Na-HCO3(R2 = 0.104) Na%-Mg (R2 = 0.100) are showing weak regression relationship. The significance (p-value) also supported the above relationship as given in Table-4. Similar types of results were obtained by Jothivenkatachalam et. al (2010).

TABLE 4
Correlation between water quality parameters of River Wainganga

Sr	WQ parameter Pairs	1. Regression 2. Equation	R Square	P-Value	Observation of regression analysis
1	EC-TDS	y = 0.524x + 4.192	0.982	2.896×10^{-83}	Strong Significance Regression (Refer Figure 2 and 3)
2	MgH-Mg	y = 4.105x + 0.791	0.919	2.176×10^{-52}	
3	CaH-Ca	y =0.438x + 3.891	0.912	7.124×10^{-51}	
4	TH-CaH	y = 0.642x + 11.51	0.880	1.600×10^{-58}	
5	TH-HCO_3	y = 0.857x + 2.103	0.816	2.931×10^{-36}	
6	TH-Ca	y = 0.283x + 0.957	0.811	7.260×10^{-51}	
7	SAR-Na	y = 28.96x - 0.895	0.780	1.106×10^{-32}	
8	Na%-SAR	y = 22.34x + 6.220	0.747	8.834×10^{-30}	
9	TH-MgH	y = 0.357x - 11.51	0.695	1.613×10^{-34}	Moderate Significance regression (Refer Figure 4 and 5)
10	Mg-HCO_3	y = 0.077x - 3.661	0.664	5.509×10^{-24}	
11	Na-Cl	y = 1.426x - 11.47	0.654	2.118×10^{-23}	
12	TH-Mg	y = 0.077x - 1.572	0.598	5.412×10^{-20}	
13	Na-SO^4	y = 0.852x + 0.374	0.488	2.478×10^{-15}	
14	TDS-Ca	y =4.279x + 46.46	0.454	7.822×10^{-14}	
15	EC-Ca	y = 0.053x + 19.95	0.412	2.702×10^{-12}	Weak regression (Refer Figure 6 and 7)
16	CaH-MgH	y = 0.370x + 1.923	0.350	7.560×10^{-19}	
17	Na%-Na	y = 0.450x + 12.78	0.326	1.220×10^{-9}	
18	TDS-TA	y =1.135x + 62.12	0.313	5.332×10^{-9}	
19	TDS-CaH	y =1.629x + 56.38	0.312	4.739×10^{-9}	
20	EC-TH	y = -0.141x + 87.65	0.283	4.739×10^{-9}	
21	Ca-HCO_3	y = 0.374x - 12.92	0.265	6.002×10^{-11}	
22	SAR-K	y = 2.180x + 0.742	0.233	6.276×10^{-7}	
23	Ca-SO_4	y = 0.117x + 9.763	0.174	7.535×10^{-12}	
24	K-Cl	y = 0.032x + 1.717	0.169	3.148×10^{-5}	
25	Ca-Cl	y = 0.152x + 6.516	0.142	3.196×10^{-13}	
26	K-SO_4	y = 0.037x + 1.549	0.107	0.0011	
27	Na-HCO_3	y = 1.937x + 140.4	0.104	0.0013	
28	Na%-K	y = 2.307x + 15.96	0.162	4.644×10^{-05}	
29	Na%-Ca	y = -0.065x + 24.48	0.131	0.0046	
30	Na%-Mg	y = 0.440x + 25.38	0.100	0.0016	

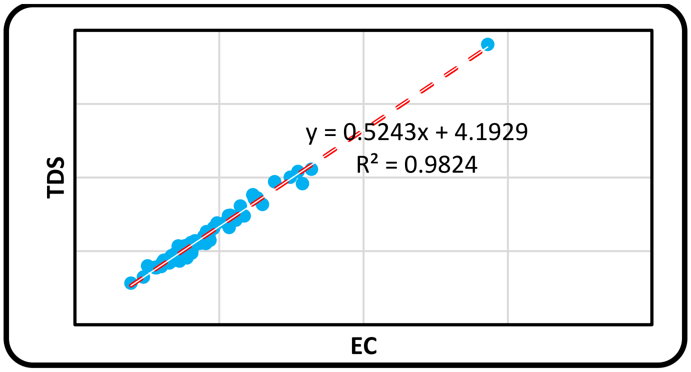

Figure 2 Correlation between Electrical Conductance and Total Dissolved Solid

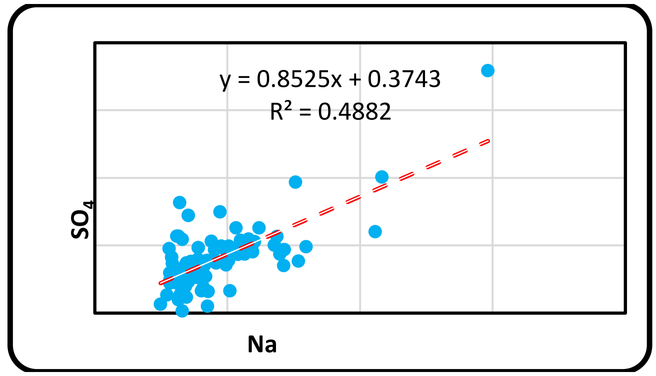

Figure 5 Correlation between Sodium and Sulphate

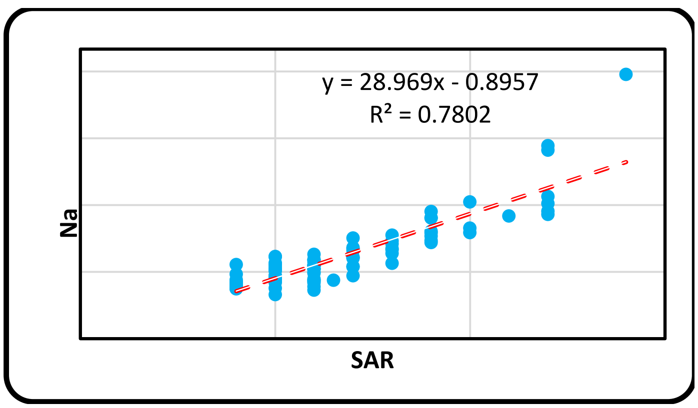

Figure 3 Correlation between Sodium Absorption Ratio and Sodium

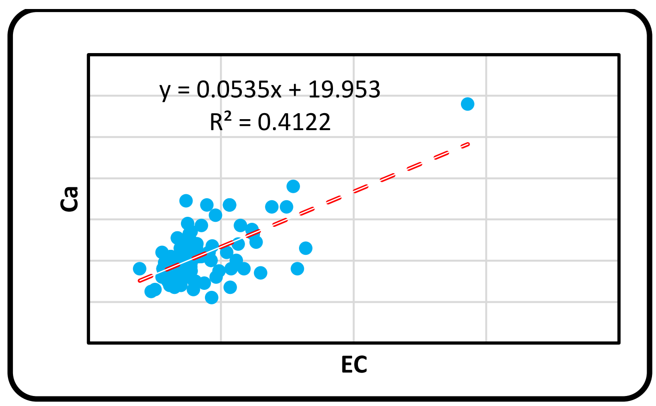

Figure 6 Correlation between EC and Calcium

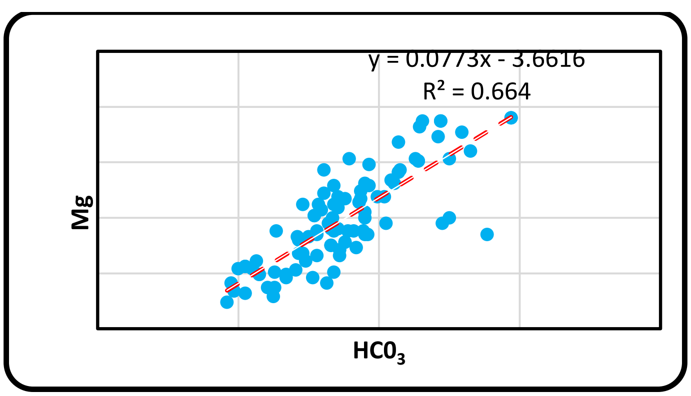

Figure 4 Correlation between Magnesium and Bicarbonate

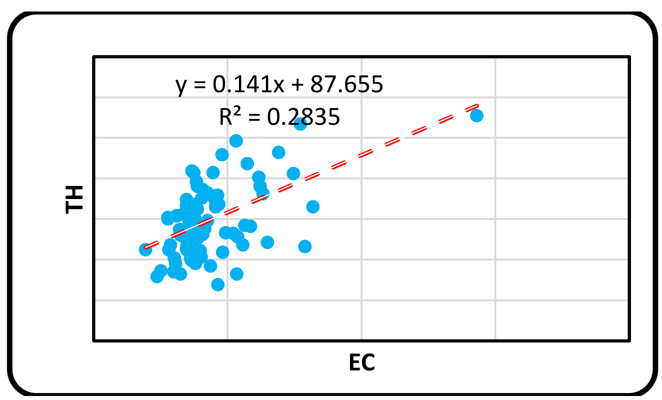

Figure 7 Correlation between Electrical Conductance and Total Hardness

IV. CONCLUSION

Regular monitoring of water quality is to be ensured to identify variations in the Physicochemical parameters of river water at different sites, its remedial measures and create awareness among the public. The statistical regression analysis tool has been established as an instrument for monitoring water monitoring and has good accuracy. The outcome of linear correlation between different physicochemical water parameters such as EC, TDS, Cl, F, PO4, TH, CaH, MgH TA, Ca, Mg, K, Na, DO pH, Turb, Mg, SO4, NO3, HCO3, % Na and SAR can be treated as an advanced step ahead towards the water quality monitoring. The eight pairs are showing a strong significant regression relationship, seven pairs are showing a moderate significant regression relationship and remain fifteen pairs are showing a weak regression relationship.

The use of mathematical models to assess water quality involves two parameters to pronounce accurate water quality conditions. A substantial relationship accomplished from a systematic correlation and regression in the current study has been established between different physicochemical parameters. The study shows that the fact that all the physiochemical parameters of the Wainganga river water are correlated in some or another way. The linear correlation method is a substantial method to get an indication of the quality of surface water by pair of physicochemical parameters.

Because other water quality parameters and their functions can be described by using these conditions, utilization of such an approach will thus to a great extent make possible the assignment of fast water quality monitoring of the exact status of water pollution. The furthermost important part of water pollution or water quality study to intended some actual and economic way for water quality monitoring. Based on the current study it may be recommended confidently that the surface water quality of the study area can be checked efficiently by controlling one parameter of water and this may also be used to water quality monitoring of new study areas.

The major tasks of environmentalists have to transfer their interpretation of complex environmental data into information that is easily understandable to people. The method of linear correlation is a vital approach to getting an idea of the quality of surface water by determining a few parameters experimentally. The further suitability of this correlation and regression equations model can be worked by multiplying water samples and analysing more water quality parameters for future research.

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