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Correlation and linear regression analysis of water quality parameters of Wainganga River at Desaiganj (Wadsa) in Gadchiroli district Maharashtra, India

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Abstract
The present investigation reveals, the monthly and seasonal variations in concentration of physico-chemical parameters in river Wainganga at Wadsa dist. Gadchiroli. Water samples under investigations were collected from the four different sites during rainy, winter and summer season for the period of one year from July 2014 to June 2015. Wainganga river water was chosen for analysis, because of people's reliance on the water for their domestic and agricultural use. The present study emphasizes on the magnitude of pollution by monitoring water quality parameters such as water temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH),calcium hardness (CaH), magnesium hardness (MgH), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), iron (Fe^{2+}), chloride (Cl^-), fluoride (F^-), nitrate (NO_3^-), sulphate ($SO_4^{- -}$), and phosphate (PO_4^{3-}). The samples of Wainganga river water is assess for physico-chemical parameters and their results are compared with WHO drinking water standards. A correlation matrix test was carried out to check the significant relationship among the physico-chemical parameters (significance level 0.05). Statistical analysis shows that many of the parameters bear a good positive correlation and some bear a negative correlation. Results have shown wide variations from high concentration during rainy season and low concentrations during winter season. Statistical analysis carried out through correlation method and correlation coefficients are calculated between different pairs of parameters to identify the highly correlated and interrelated water quality parameters. The present study indicates that site W_1 and W_2 were comparatively more polluted due to various athropogenic activities taking place at these sites whereas site W_3 and W_4 were comparatively less polluted. It is also been found that the upstream water remains unpolluted, but the downstream water was found to be more polluted.

Keywords: Water pollution study, Physico-chemical properties, Wainganga river water, Correlation coefficient, Regression analysis, Desaiganj (Wadsa), Gadchiroli district

1. Introduction
The fresh water is of vital concern of mankind, since it is directly linked to human welfare. The surface water bodies, which are the most important sources of water for human activities are unfortunately under severe environment stress and are being threatened as a consequence of development activities. Quality of water generally refers to the component of water, which is to be present at the optimum level for suitable growth of plants and animals. Aquatic organisms need a healthy environment to live and have adequate nutrients for their growth. The productivity depends on the physico-chemical characteristics of the water body. The maximum productivity is obtained when the physical and chemical parameters are at optimum level [1]. The quality of water is defined in terms of its physical, chemical and biological parameters, and ascertaining its quality is important before use for various intended purposes such as potable, agricultural, recreational and industrial water usages, etc., [2]. It is assessed with the help of various parameters to indicate their pollution level. It is quite likely that any sample of water will exhibit various levels of contamination with respect to the different parameters tested [3].

Water has played an important role not only in the history of countries, but in religion, mythology, and art. Water in many religions cleanses the soul through holy water. Rivers are the most important natural resource for human development but it is being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects its physico-chemical and microbiological quality [4]. In India almost 70% of the water has become polluted due to the discharge of domestic sewage and industrial effluents into natural water source, such as rivers, streams as well as lakes. The improper management of water systems may cause serious problems in availability and quality of water. Since water quality and human health are closely related, water analysis before usage is of prime importance [5].

The main objectives of study of Wainganga river water are

1. To study some Physico–chemical properties of water quality indicator in Wainganga river.
2. To access the quality of river and its comparison with WHO standards.
3. To determine correlation coefficient and linear regression analysis.

2. Materials and Methods

2.1 Study Area

Desaiganj (Wadsa) is a town and taluka place of Gadchiroli district, in the Nagpur division of the Central Provinces. Geographically Desaiganj is situated 20^0 64' North latitude and 79^0 99' East longitude. The population of this town is 83,600. (2011). the town is situated on the left bank of the Wainganga river. The Wainganga originates about 12 km from Mundara village of Seoni district in the southern slopes of the Satpura range of Madhya Pradesh and flows course of approximately 360 miles. After joining the Wardha, the united stream, known as the Pranahita, ultimately falls into the Godavari River at Kaleshwaram, Telangana [6].

2.2 Sampling and Collection of water samples

The present work was planned to assess the quality of water from four different sites of Wainganga river nearby Desaiganj (Wadsa) in Gadchiroli district for physico-chemical analysis and the results were compared with the standards given by WHO [7]. To determine the extent of pollution. Water samples were collected in the double stoppered polythene containers of two liters capacity on the first day of each month (once in a month), from the four selected sites at 9.00am to 11.00am of Wainganga river for a period of one year from July 2014to June 2015.

Table 1: Sampling sites of Wainganga River at Desaiganj (Wadsa)

Sampling sites	Place
W_1	Near bridge on Desaiganj-Bramhapuri highway
W_2	Virshi Ghat
W_3	Amgaon Ghat
W_4	Sawangi Ghat

MAP OF WAINGANGA RIVER – DESAIGANJ WADSA AREA (Showing Four Spots)

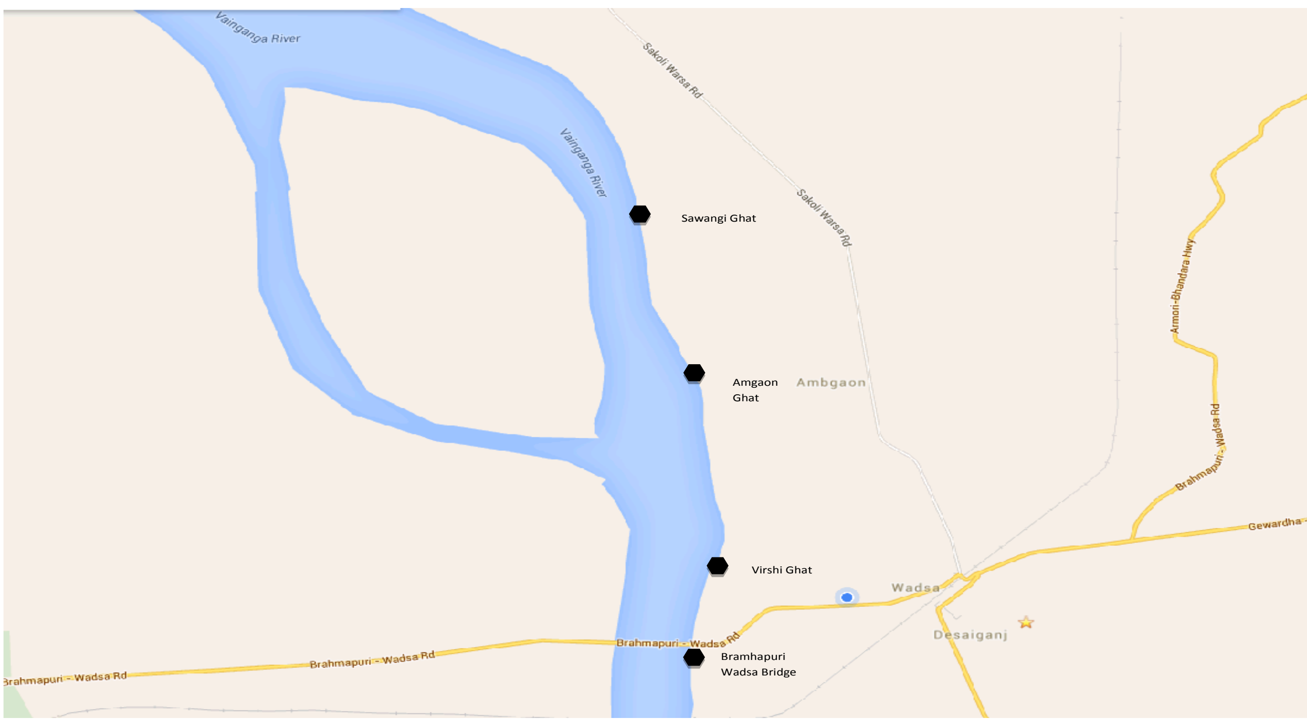

Fig 1: Map of Wainganga River, Desaiganj (Wadsa) showing four sampling sites denoted by dot.

2.3 Methodology

The water temperature, pH and conductivity of the water samples were determined on the spot using a digital thermometer, pH meter and conductometer respectively. The physico-chemical analysis of samples of drinking water were carried out according to standard methods of APHA [8].

Table 2: List of physico-chemical parameters and their test methods

S. No.	Parameters	Unit	Test methods
1	Water Temperature	^{0}C	Digital thermometer
2	pH	-	pH meter
3	Electrical Conductivity (EC)	µSiemens/cm.	Electrical conductivity meter
4	Total Dissolved Solids (TDS)	mg/L	Evaporation method
5	Total Alkalinity (TA)	mg/L	Titration method
6	Total Hardness (TH)	mg/L	EDTA titrimetric method
7	Calcium Hardness (CaH)	mg/L	EDTA titrimetric method
8	Magnesium Hardness (MgH)	mg/L	From the determined total hardness and calcium hardness.
9	Dissolved Oxygen (DO)	mg/L	Winkler method
10	Chemical Oxygen Demand (COD)	mg/L	Dichromate Reflux Method
11	Biochemical Oxygen Demand (BOD)	mg/L	5 days incubation at 20° C and titration of initial and final DO.

12	Iron (Fe^{2+})	mg/L	Phenanthroline method
13	Chloride (Cl^{-})	mg/L	Argentometric titration
14	Fluoride (F^{-})	mg/L	Spectrophotometrically
15	Nitrate (NO_3^{-})	mg/L	Spectrophotometrically
16	Sulphate (SO_4^{--})	mg/L	Turbiditimetric method
17	Phosphate (PO_4^{3-})	mg/L	Stannous chloride method

2.4 Statistical analysis

A correlation matrix test was carried out to check the significant relationship among all the physico-chemical parameters (significance level 0.05).

All the data obtained subjected to statistical analysis. In statistical analysis, a correlation developed between parameters by using Karl Pearsons Coefficient of correlation. The average mean values of all the four sites are summarized in table 3 and correlation coefficient among physicochemical parameters are shown in table 4.

2.5 Correlation coefficient

Correlation coefficients (Karl Pearson) (r) have been calculated between each pair of water quality parameter for the experimental data. Let x and y be the two variables, then the correlation 'r' between the two variables are given by Karl Pearson's coefficient r as follows

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2]\,[n(\sum y^2) - (\sum y)^2]}}$$

Where n = number of observations.

2.6 Regression analysis

If the value of the correlation coefficient 'r' between the two variables x and y are fairly large, it emplies that these two variables are highly correlated. In such cases, linear regression equation were developed [9, 10, 11].

To determine the straight linear regression, following equation of straight line can be used.

$$y = a\,x + b \qquad (1)$$

Where, y and x are the dependent and independent variable respectively. a is the slope for the line, b is intercept on y-axis.

The slope, a and y-intercept, b can be determined using the following.

$$a = \frac{n\,\Sigma x\,y - \Sigma x\,\Sigma y}{n\,\Sigma x\,2 - (\,\Sigma x\,)2} \qquad (2)$$

and

$$b = \frac{\Sigma y - a\,\Sigma x}{n} \qquad (3)$$

Significance column indicates the statistical significance of the regression model that is applied. It is denoted by p value, if it is under 0.05 then the variable is significant. Significance is determined using MS-Excel spreadsheet.

3. Result and Discussion

The samples of Wainganga River are tested for physico - chemical parameters and their results are compared with WHO drinking water standards. The results obtained from analysis of water samples of river Wainganga are shown in table 3 and table 4. The reported values refer to the mean value of water samples collected from four different sites during three seasons and these values are compared with WHO. The results indicate that the quality of water varies considerably from location to location.

In present study, during the year 2014-15, maximum parameters showed strong to moderate positive correlation with each other's, some of them were TA with pH, COD and BOD, TH with pH, TA, COD and BOD, TDS with pH, TA, TH, COD, BOD and chloride, COD with pH and BOD, BOD with pH, chloride with pH, TH, COD and BOD. Whereas iron with pH, TDS, TA, TH, COD, BOD and chloride. Similar positive correlations between above parameters were also observed by [12] Pandey *et al.*, (2014) in river Ganga.

It was clear from the results that the DO was negatively correlated with all the variables and was not positively correlated with any of the studied parameters. The DO exhibited strong negative correlation with BOD ($r = -0.860$) and COD ($r = -0.847$) indicating decrease in DO concentration is linked with oxidation of re-suspended organic matter [13] (Kriest and Oschlies, 2013) similar results were found by [14] Shriwastava *et al.*, (2015) in Patalganga river.

It is revealed that pH exhibited positive correlation with all parameters except DO, whereas DO showed negative correlation with all parameters, thus it can be served as a single useful pollution index of water quality, as with rise in the value of these parameters decreases the DO concentration [15] (Khaiwal *et al.*, 2003)

The highly positive correlation were observed between the parameters like TH with CaH ($r = 0.991$) and with MgH ($r = 0.983$), CaH with MgH ($r = 0.950$) proved that the total hardness is mainly due to the presence of calcium and magnesium salts in water. Similar results were observed by Saxena (2015).

The linear regression analysis was carried out for the water quality parameters having highly significant correlation coefficients ($0.9<r<1.0$) and found to have better and higher level of significance with their correlation coefficients. Adjusted R^2 values were closed to estimated R^2 values which indicates the utility of regression model.

4. Conclusion

The maintenance of a healthy aquatic ecosystem is dependent on the physico-chemical properties of water and the biological diversity. Now-a-days, the ecology of river water is under stressed condition due to the fast pace of development, deforestation, cultural practices and agriculture. On the basis of experimental findings it can be concluded that site W_1 has higher pollution index than other sites, it may be attributed due to increased intensity of EC, pH, TDS, TA, TH, chloride, sulphate and phosphates compare to other sites .Wainganga river water is used for drinking, fishing, irrigation and other domestic purposes. This study would help the water quality monitoring and management in order to improve the quality of water with maintaining better sustainable management.

The results from the present study clearly pointed out that river water is comparatively polluted at the downstream site. The study provides an informative data and helps to understand the contamination of water in the Wainganga river due to discharge of effluents from industries nearby site W_1.
The physico-chemical parameters show significant monthly variations. These temporal fluctuations are either by various physico-chemical parameters which are positively or negatively correlated to each other. In present investigation, water samples collected from Wainganga river are below permissible limit as per WHO standards except pH, DO, calcium and phosphate, this may be due to discharge of effluent from nearby paper mills and also due to the cremation activity and addition of cremation ashes to river water at site W_1. Seasonally rainy season shows higher values at downstream, maximum value recorded during rainy season might be due to the runoff bringing more salts from the domestic wastes from the nearby village as well as from agriculture fields and also due to the sediment load that is transported from the watershed during rainy season.
Both the correlated variables might have influenced by one or more other variables. This study proved beyond doubt that all the physicochemical parameters of drinking water in Wainganga River are more or less correlated with each other.
In above study, it is found that, the maximum parameters are within the permissible limit of WHO and therefore, water quality of Wainganga river at Desaiganj (Wadsa) dist. Gadchiroli is good for domestic and drinking purpose. The water is also suitable for culture of aquatic animals in river in the studied period.

Table 3: Monthly mean value of physico-chemical parameters of Wainganga river water at Desaiganj from July 2014 to June 2015

Months	Physico-chemical parameters																
	Temp	pH	EC	TDS	TA	TH	CaH	MgH	DO	COD	BOD	Fe^{++}	Cl^-	F^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
Jul-14	24.64	8.04	287.90	214.30	177.04	152.93	96.62	56.31	4.03	6.34	2.34	0.24	35.70	0.77	4.24	20.52	0.124
Aug-14	25.02	7.91	308.60	190.99	174.42	142.27	88.97	53.30	4.16	6.91	2.17	0.21	36.47	0.83	4.45	19.42	0.102
Sep-14	25.45	7.82	282.54	192.53	163.39	138.39	84.07	54.32	4.23	7.19	2.45	0.20	30.67	0.69	3.92	18.57	0.089
Oct-14	24.43	7.65	198.76	131.87	132.68	113.28	76.46	36.82	4.51	7.02	2.46	0.11	28.55	0.58	1.83	12.71	0.064
Nov-14	23.33	7.56	184.34	116.43	90.5	62.48	41.25	21.23	6.50	4.49	1.71	0.09	13.85	0.55	1.37	10.82	0.050
Dec-14	21.98	7.48	172.52	100.56	74.6	43.62	30.42	13.20	6.77	4.21	1.53	0.08	15.40	0.56	1.65	12.53	0.027
Jan-15	22.20	7.42	168.78	104.22	55.7	58.51	42.31	16.20	5.83	4.86	1.65	0.12	20.21	0.61	1.55	11.64	0.054
Feb-15	22.94	7.78	220.62	119.39	87.8	83.64	62.42	21.22	5.96	4.36	1.53	0.13	30.30	0.61	2.27	13.44	0.077
Mar-15	27.81	7.84	236.53	178.54	153.52	101.17	63.56	37.61	4.34	6.85	2.02	0.16	22.42	0.67	2.51	15.51	0.072
Apr-15	29.62	8.02	254.61	181.32	162.83	120.07	76.77	43.30	4.81	5.06	1.77	0.15	25.32	0.62	2.95	16.32	0.079
May-15	31.19	8.13	278.54	198.23	178.93	126.93	81.41	45.52	4.39	5.60	2.13	0.14	28.67	0.64	3.28	17.62	0.086
Jun-15	28.30	8.35	245.61	201.63	164.46	123.69	77.96	45.73	4.47	5.37	2.19	0.18	22.93	0.68	3.75	16.24	0.093
Min	21.98	7.42	168.78	100.56	55.73	43.62	30.42	13.20	4.03	4.21	1.53	0.08	13.85	0.55	1.37	10.82	0.03
Max	31.19	8.35	308.60	214.30	178.93	152.93	96.62	56.31	6.77	7.19	2.46	0.24	36.47	0.83	4.45	20.52	0.12
Mean	25.57	7.83	236.61	160.83	134.66	105.58	68.52	37.06	5.00	5.69	2.00	0.15	25.87	0.65	2.81	15.44	0.08
SD (±)	3.00	0.28	47.88	42.57	44.90	35.84	20.85	15.44	0.98	1.12	0.35	0.05	7.22	0.08	1.10	3.21	0.03
WHO	40	8.5	600	600	200	500	100	75	6	10	10	0.30	250	1.5	50	250	0.1

(All parameters are in mg/l except pH and EC. EC is in μSiemens/cm)

Table 4: Correlation coefficient (r) among the mean values of studied physico chemical parameters of Wainganga river

	Temp	pH	EC	TDS	TA	TH	CaH	MgH	DO	COD	BOD	Fe^{++}	Cl^-	F^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
Temp	1.000																
pH	0.789	1.000															
EC	0.570	0.746	1.000														
TDS	0.727	0.874	0.912	1.000													
TA	0.760	0.833	0.901	0.961	1.000												
TH	0.570	0.761	0.921	0.919	0.936	1.000											
CaH	0.544	0.755	0.897	0.878	0.900	0.991	1.000										
MgH	0.590	0.748	0.926	0.947	0.956	0.983	0.950	1.000									
DO	-0.620	-0.697	-0.821	-0.887	-0.906	-0.938	-0.922	-0.931	1.000								
COD	0.269	0.270	0.603	0.602	0.680	0.734	0.702	0.756	-0.847	1.000							

BOD	0.363	0.477	0.619	0.700	0.759	0.822	0.797	0.833	-0.860	0.883	1.000						
Fe^{++}	0.326	0.659	0.876	0.867	0.772	0.877	0.854	0.882	-0.819	0.631	0.649	1.000					
Cl^-	0.214	0.480	0.810	0.631	0.652	0.838	0.880	0.756	-0.748	0.625	0.610	0.783	1.000				
F^-	0.220	0.538	0.849	0.756	0.693	0.779	0.754	0.790	-0.737	0.621	0.553	0.923	0.772	1.000			
NO_3^-	0.463	0.770	0.952	0.909	0.851	0.900	0.870	0.913	-0.799	0.566	0.638	0.934	0.773	0.904	1.000		
SO_4^{2-}	0.498	0.716	0.962	0.919	0.875	0.904	0.873	0.920	-0.822	0.604	0.638	0.925	0.790	0.876	0.967	1.000	
PO_4^{3-}	0.428	0.762	0.885	0.870	0.805	0.920	0.929	0.880	-0.827	0.552	0.646	0.943	0.846	0.837	0.899	0.885	1.000

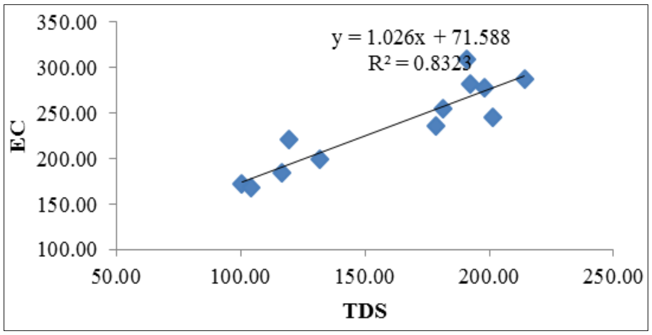

Fig 1: Positive correlation between TDS and EC for year 14-15.

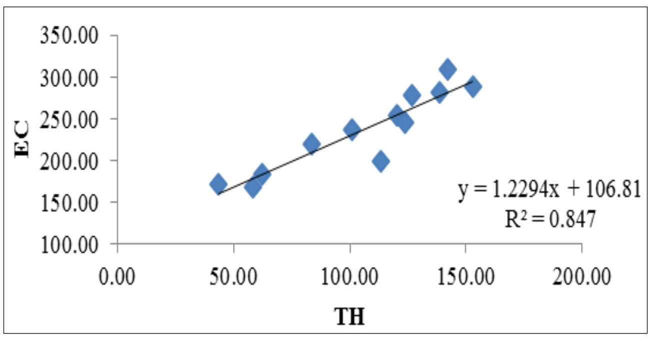

Fig 2: Positive correlation between TH and EC for year 14-15.

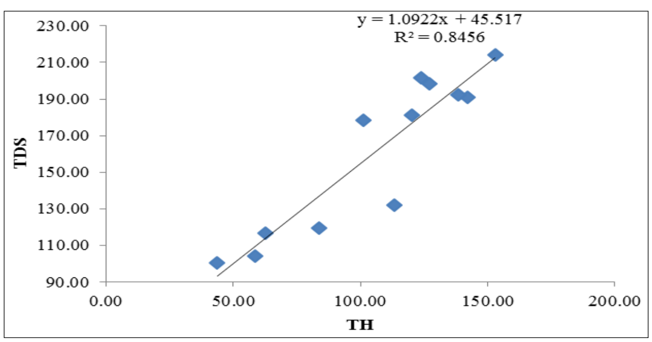

Fig 3: Positive correlation between TH and TDS for year 14-15.

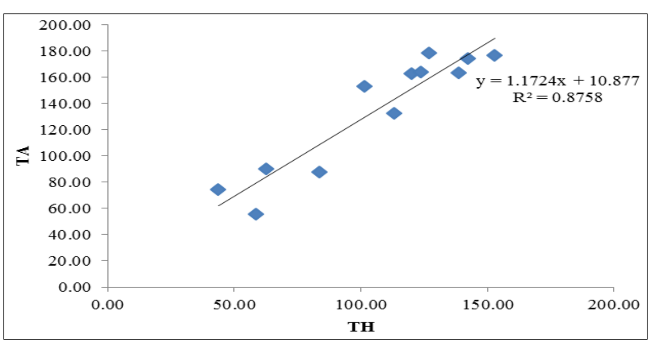

Fig 4: Positive correlation between TH and TA for year 14-15.

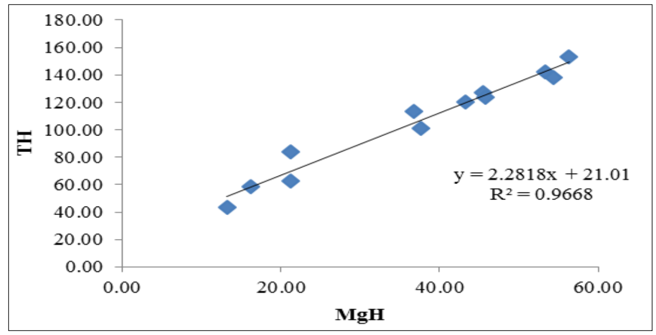

Fig 5: Positive correlation between MgH and TH for year 14-15.

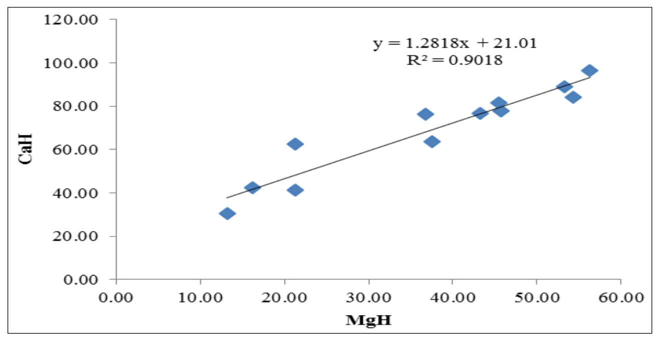

Fig 6: Positive correlation between MgH and CaH for year 14-15.

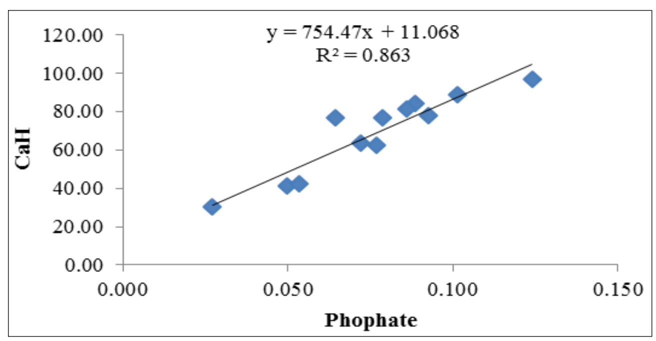

Fig 7: Positive correlation between phosphate and CaH for year 14-15.

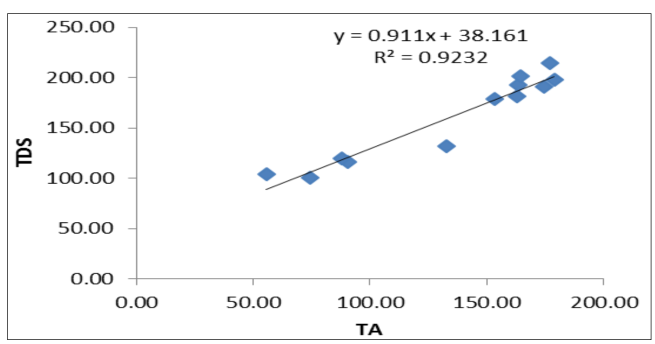

Fig 8: Positive correlation between TA and TDS for year 14-15.

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