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INTERDEPENDENCEY BETWEEN PHYSICOCHEMICAL WATER POLLUTION INDICATORS: A CASE STUDY OF RIVER BABUS, SAGAR, M.P., INDIA

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Abstract: Water samples were collected from river Bebas at 10 collection places where human and animal activities were negligible. A total of 180 samples were analyzed for 16 chemical parameters pH, Alkalinity, DO, BOD, COD, TH, Ca Hardness, Mg Hardness, TDS, Chloride, Residual chlorine, o-Phosphate, Fluoride, Nitrate, Ammonia and Iron during PreMonsoon, monsoon and post monsoon seasons. The total data points were used to establish interdependency between the chemical parameters and data were also subjected to multivariate statistical. The later was used as test data. Regression analysis was carried out using SPSS.11, MVSP to relate the parameters and interdependency in form of scatter grams were obtained between DO/pH DO/Alkalinity DO/BOD, DO/COD, DO/TH DO/Ca Hardness, DO/ Mg Hardness, DO/TDS, DO/Chloride, DO/Residual chlorine, DO/o-Phosphate, DO/fluoride, DO/Nitrate, DO/Ammonia and DO/Iron. The validity of the empirical equations obtained were tested with the test data and the relationships were found to be similar, indicating that the equations can be used to predict the levels of these pollution indicators when one variable is known especially for similar river waters.

Key words: regression analysis, scatter gram, variable.

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INTRODUCTION

The availability of water determines the location and activities of humans in an area and our growing population is placing great demands upon natural fresh water resources. Bebas state like quite is faced with increasing pressure on water resources and the widespread, long-lasting water shortages in many areas are as a result of rising demand, unequal distribution and increasing pollution of existing water supply (Raja et al., 2002). Correlation/regression analysis has been found to be a highly useful tool for correlating different parameters. This way analysis attempts to establish the nature of the relationship between the variables and thereby provides a mechanism for prediction or forecasting (Patil et al., 2001).

Following regression equations were obtained through statistical regression analysis of data presented in above given river water sources of Sagar city (M.P.). Taking DO as dependent variable for all the 10 water sampling points of water sources at critical and logical analysis of given regression equations reveal important facts regarding correlation studies among various physicochemical parameters (Sudhir et al., 1999).

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To study the correlation between various water quality parameters, the regression analysis was Carried out using computer software SPSS, version - 11. Regression coefficient measures the degree of association exists between two variables, DO taken as dependent variable. The greater the value of regression coefficient, the better is the fit and more useful the regression variables.

The following regression models have been obtained from the results of analysis of water samples. Considering a mean DO (dependent variables) and important chemical parameters taken as independent variables, regression equations can be obtained for the entire study area for all season (Shrinivasa et al., 2000). It is important to analyse water to determine its suitability for drinking, domestic use industrial use, agricultural use etc. It is also important in water quality studies to know the amount of organic matter present in the system and the quantity of oxygen required for stabilization of the water. The impact of organic pollutants on water quality in this work is expressed in terms of the Biochemical Oxygen Demand, BOD and Chemical Oxygen Demand, COD which all depend on the Dissolved Oxygen, DO and Total Dissolved Solids; TDS on the other hand are used to define the organic content of the water and the total ions in solution respectively (Adak et al., 2001).

Empirical relationships were also developed to assess the quality of waste waters using testing and calculation methods but not much was mentioned in literature on the interrelationship between the parameters as it affect river waters. The fact that every problem in environmental studies must be approached in a manner that defines the problem necessitates the use of analytical techniques in the field or laboratory to produce reliable results. Once the problem is identified, samples are collected and analysed (Trivedy and Goel, 1986).

The procedure for statistical analysis of results could be tedious, time consuming and fraught with pitfalls especially when results are needed urgently in cases like an outbreak of contagious water bound disease. However, models can be designed which will provide a simple, economic and precise means of interpreting results leading to satisfactory findings. The aim of this study therefore, is to determine the levels of some pollution indicators and to study the statistical relationships between them. Regression equations will also be established in a view to providing an idea on the levels of pollution by the parameters investigated and possibly proffering a preventive measure prior to detailed investigation of the Bebas River.

EXPERIMENTAL

Bebas State is situated in Madhya pradesh passing near Sagar district. Water samples were collected in precleaned plastic containers from 10 sampling locations spread across the River Bebas from areas where human, animal and agricultural activities were high. The duration of sampling were categorized into three Pre Monsoon, monsoon and post monsoon period for 2008 - 2010. Samples were collected regularly throughout the seasons. The samples were analysed for pH, Alkalinity, DO, BOD, COD, TH, Ca Hardness, Mg Hardness, TDS, Chloride, Residual chlorine, o-Phosphate, fluoride, Nitrate, Ammonia and Iron using standard analytical techniques (Manivaskam, 2005).

All the chemicals used were of AR grade. Analysis was carried out for most water quality influencing 21 parameters with concerning units and test methods discussed in table 1.

Table 1. List of physicochemical parameters and their test methods (APHA, 1992)

S.N.	Parameters	Unit	Test Methods
1	pH	-	pH meter
2	Dissolved Oxygen (DO)	mg/L	Winkler method
3	Biochemical Oxygen Demand (BOD)	mg/L	5 days incubation at 20° C and titration of initial and final DO.
4	Chemical Oxygen Demand	mg/L	Open Reflux Method
5	Alkalinity	mg/L	Titration
6	Total dissolved Solids	mg/L	Digital conductivity meter (LT-51)
7	Chloride	mg/L	Argentometric titration

8	Residual Chlorine	mg/L	Iodometric
9	Orthophosphate ($P0_4^{3-}$ - P)	mg/L	Ammonium molybdate ascorbic acid reduction method
10	Nitrate -Nitrogen (NO_3 - N)	mg/L	Spectrophotometric method
11	Ammonia-Nitrogen (NH_3 -N)	mg/L	Spectrophotometric (Phenate method)
12	Total Hardness as $CaCO_3$	mg/L	EDTA titration
13	Ca Hardness as $CaCO_3$	mg/L	EDTA titration
14	Mg Hardness as $CaCO_3$	mg/L	EDTA titration
13	Fluoride	mg/L	Colorimetric Method
19	Iron	mg/L	Colorimetric Method

Regression analysis, multiple regression analysis for the total data points were carried out using SPSS.11, MVSP and WINKS SDA. The nature of correlations between parameters were determined based on the correlation coefficient obtained. Data obtained from chemical analysis compared with WHO guidelines.

RESULTS AND DISCUSSION

Regression curve between the mean chemical Parameters (independent) and the mean DO (dependent) in Babus river waters Samples of in and around Sagar city (Monsoon 2007 to Pre Monsoon 2010) represented by following figures. The results of the analysis for all the parameters used as test data are presented in table 1 and relationships between the parameters in form of scatter gram are shown in figures.

Table 2. Multiple regression analysis at different locations of the River

Dependent variable is DO, 25 independent variables, 4 cases.			
Variable	Coefficient	Variable	Coefficient
Intercept	-769.4688	O-PHOSPHATE	-323.5806
BOD	134.14209	NITRATE	-1.249023
COD	-180.498	AM	-1596.57
TA	-10.6131	TH	1.0390015
TS	.6571045	Ca HARDNESS	9.5629272
TDS	-7.569855	Mg HARDNESS.	-25.84875
pH	628.58984	FLUORIDE	-7036.031
CHLOIDE	36.796387	IRON	784.38818
RESI.CHLORINE	9404.875		
R-Square = 0.0, Adjusted R-Square = 1.1364			
Cohen's f-square = 0.0, a small effect size.			

Table 3. Regression Analysis of chemical Parameters in Bebas water Samples of in and around Sagar city (Monsoon 2007 to Pre Monsoon 2010)

Dependent Variable	**Independent Variable**	**Regression equation**	**Slope**	**R^2**
DO_{mean}	BOD_{mean}	DO = - 23.17 + 4.320 * BOD	4.320	0.871
DO_{mean}	COD_{mean}	DO = 0.175 * COD + 8.356	0.327	0.013
DO_{mean}	BOD_{mean}, COD_{mean}	DO = 10.310156 + .253079 * BOD - .5406958 * COD		0.995
DO_{mean}	$Alkalinity_{mean}$	DO = 29.46 + 21.34 * alkalinity	21.34	0.993
DO_{mean}	pH_{mean}	DO = 0.174 * pH + 6.629	0.174	0.022
DO_{mean}	TDS_{mean}	DO = - 351.6 + 93.55 * TDS	93.55	0.828
DO_{mean}	$Chloride_{mean}$	DO= - 165.5 + 33.61 * Chloride	33.61	0.689
DO_{mean}	Residual $Chlorine_{mean}$	DO = - 0.519 + 0.1 * Residual Chlorine	0.1	0.343
DO_{mean}	$o\text{-}Phosphate_{mean}$	DO = - 0.659 + 0.311 * o-Phosphate	0.311	0.882

DO_{mean}	$Nitrate_{mean}$	DO= 2.327 - 0.153 * Nitrate	-.153	0.253
DO_{mean}	$Ammonia_{mean}$	DO = 0.649 - 0.070 * Ammonia	-.070	0.598
DO_{mean}	$Chloride_{mean}$, Residual $Chlorine_{mean}$	DO = 5.2898461 + .0014619 * Chloride + 7.3416583 * Residual Chlorine		0.995
DO_{mean}	$Chloride_{mean}$, Residual $Chlorine_{mean}$ o-$Phosphate_{mean}$	DO = 4.9030929 -.0002217 * Chloride + 7.3140616 * Residual Chlorine + .3584516 * o-Phosphate		0.0
DO_{mean}	$Chloride_{mean}$, Residual $Chlorine_{mean}$ o-$Phosphate_{mean}$ $Nitrate_{mean}$	DO = 11.367188 + .0188141 * Chloride - 2.865234 * Residual Chlorine - 1.897461* o-Phosphate + 1.9199219 * Nitrate		0.0
DO_{mean}	$Chloride_{mean}$, Residual $Chlorine_{mean}$ o-$Phosphate_{mean}$ $Nitrate_{mean}$ $Ammonia_{mean}$	DO = 3.9335938 - .0105438 * Chloride - 2.738281 * Residual Chlorine + 2.193573* o-Phosphate + 3.0136719 * Nitrate - 11.80859 * Ammonia		0.592
DO_{mean}	Temporary $Hardnessness_{mean}$	DO = 7.349073 - 0.005019988 * Temporary Hardnessness	- .005	0.009
DO_{mean}	Permanent $Hardnessness_{mean}$	DO = 7.6280614 - .0218256 * Permanent Hardnessness	- .022	0.180
DO_{mean}	Calcium $Hardnessness_{mean}$	DO = 428.2 - 41.19 * Calcium Hardnessness	- 41.19	0.949
DO_{mean}	Magnesium $Hardnessness_{mean}$	DO = 72.49 - 4.656 * Magnesium Hardnessness	- 4.656	0.177
DO_{mean}	Temporary $Hardnessness_{mean}$ Permanent $Hardnessness_{mean}$	DO = 10.037029 - .0161477 * Temporary Hardnessness - .0253295 * Permanent Hardnessness		0.187
DO_{mean}	Calcium $hardness_{mean}$ Magnesium $hardness_{mean}$	DO = 11.803454 - .01078 * Calcium hardness - .0887259 * Magnesium hardness		0.11
DO_{mean}	$Fluoride_{mean}$	DO = - 1.539 + 0.35 * Fluoride	0.35	0.217
DO_{mean}	$Iron_{mean}$	DO = 0.535 - 0.030 * Iron	-0.030	0.018
DO_{mean}	$Fluoride_{mean}$ $Iron_{mean}$	DO = 5.120312 + 2.2574179 * Fluoride - 1.356825 * Iron		0.564

The regression analysis carried out to relate DO with BOD, COD with DO, BOD with % and COD with % gave correlation coefficient r = 0.9, r = 1.0, r = 1.0 and r = 0.7 respectively (figures 1 - 4) indicating very good correlation between the parameters. Good correlation was also obtained for COD/TDS (figure 6, r = 0.5), however, the correlation between BOD and TDS (figure 5, r = 0.3), though within the acceptable range but the deviations of some points are large, indicating poor correlations between BOD and TDS.

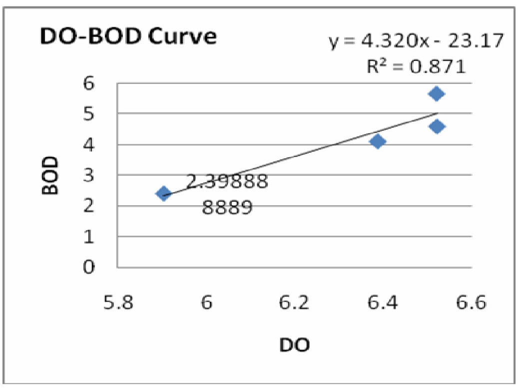

Figure 1. Regreession curve of BOD

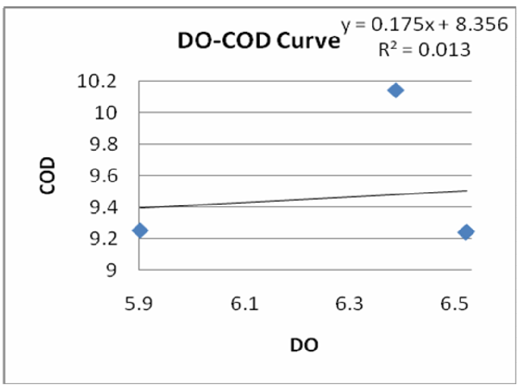

Figure 2. Regreession curve of COD

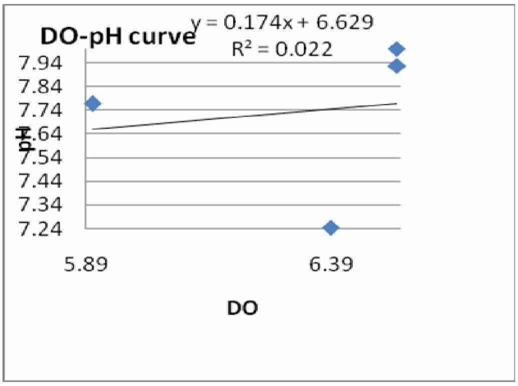

Figure 3. Regreession curve of pH

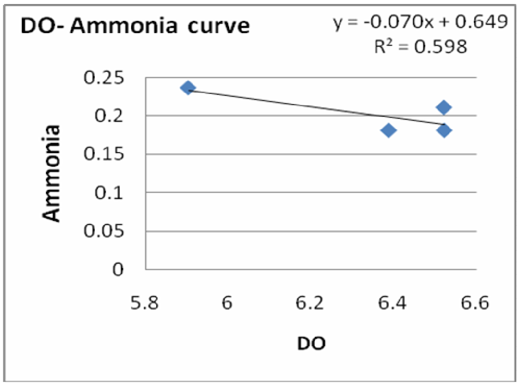

Figure 4. Regreession curve of Ammonia

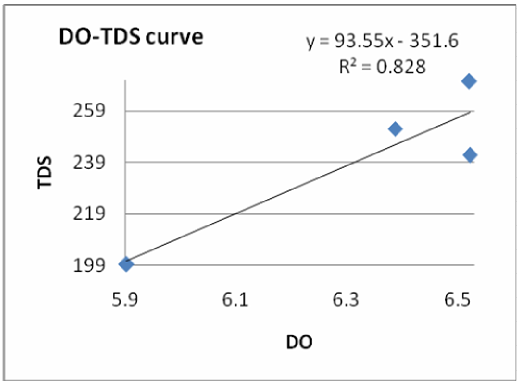

Figure 5. Regreession curve of TDS

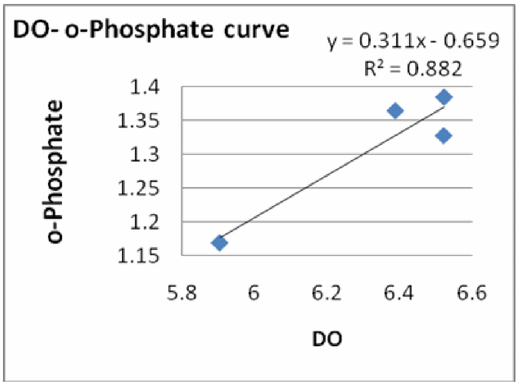

Figure 6. Regreession curve of o-Phosphate

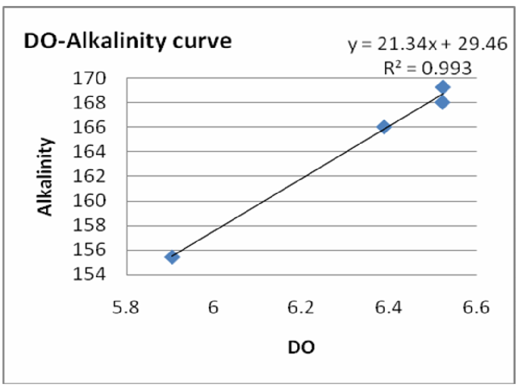

Figure 7. Regreession curve of Alkalinity

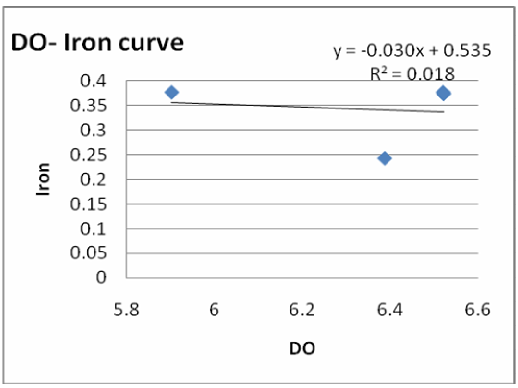

Figure 8. Regreession curve of Iron

BOD tests only measures biodegradable fraction of the total potential DO consumption of a water sample, while COD tests measures the oxygen demand created by toxic organic and inorganic compounds as well as by biodegradable substances. High BOD levels indicates decline in DO, because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of fish and other aquatic organisms to survive in the river. Since DO can be measured in-situ the regression equations $y = 4.320\,x - 23.17$ and $.175\,x + 8.356$ can be used to estimate the values of BOD and COD respectively.

This will also ease the calculations of BOD/COD ratios in order to predict the biodegradability of the water since high BOD/COD ratios indicates that water is polluted and is relatively biodegradable.

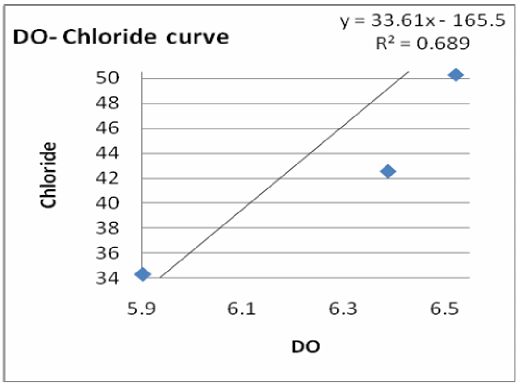

Figure 9. Regreession curve of Chloride

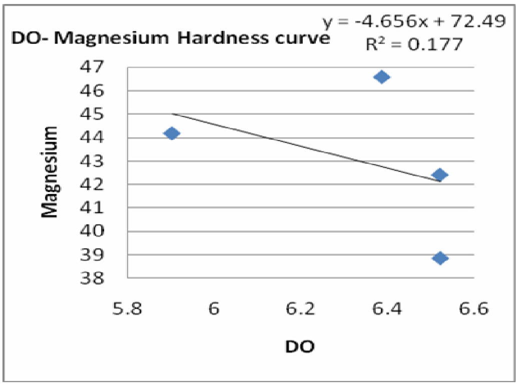

Figure 10. Regreession curve of Mg Hardness

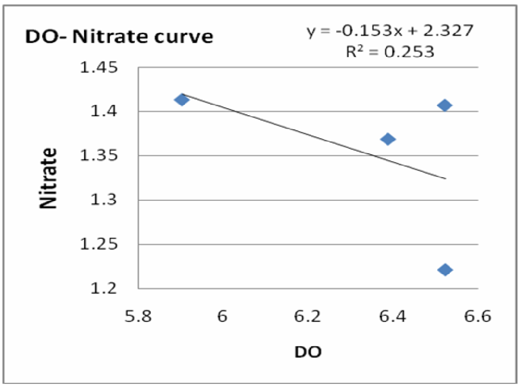

Figure 11. Regreession curve of Nitrate

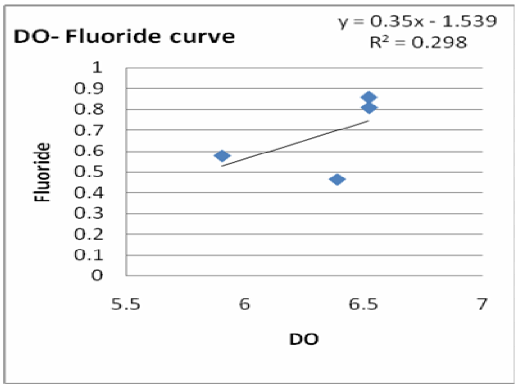

Figure 12. Regreession curve of Fluoride

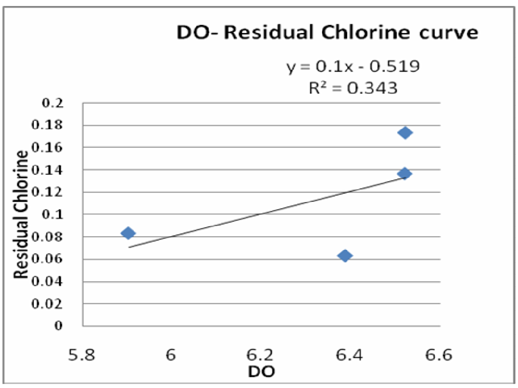

Figure 13. Regreession curve of Residual Chlorine

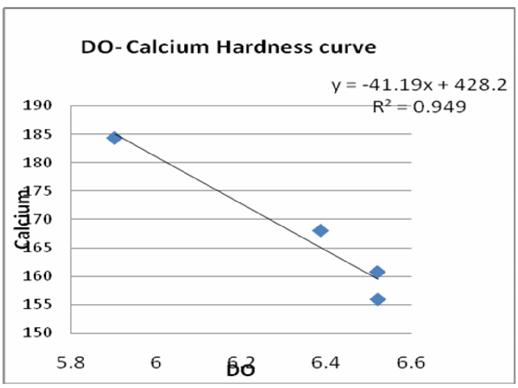

Figure 14. Regreession curve of Ca Hardness

Studies have shown that the River Bebas contains high concentrations of nitrates and phosphates which led to the quick growth as well as death of plants and algae. The result is accumulation and decomposition of organic wastes leading to high BOD values is used to define the organic content of an aquatic system. Since there is good correlation between DO and TDS as well as between DO and o-phosphates, the regression equations, $y = 93.55x - 351.6$ and $y = 0.311x - 0.659$ can be used to estimation.

From the regression analysis obtained in this work poor correlations were obtained in relation to DO with pH, Iron, Mg Hardness, Residual chlorine, Fluoride, Nitrate which suggests that other models must be used to correlate DO to the other parameters investigated. Strong relationship with alkalinity suggested that water is slightly alkaline in nature. Strong relationship with Ca Hardness suggested that calcium is predominant ions in water.

CONCLUSION

Interrelationships were established between some physicochemical water pollution indicators where reliable correlations were established using regression analysis. The validity of the equations were tested with the test data results analysed in this work and results obtained from Rivers indicated that relationships were found between variables. This indicates the reliability of the relationships which suggests that it can be used to predict the levels of pollution by the parameters investigated and possibly proffering a preventive measure prior to detailed investigation of the Bebas River or in pollution monitoring. However, it may be said that Bebas River is slightly contaminated compared to WHO standards.

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