Journal of Environmental Biology **September 2009,** 30(5) 773-775 (2009)

Short Communication

Numerical interdependence in pH, acidity and alkalinity of a polluted river water

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(Received: October 02, 2006; Revised received: March 24, 2007; Accepted: April 05, 2007)

Abstract: *Acidity and alkalinity are independent parameters and they directly or indirectly regulate the pH of a medium. These are the prime factors which control the nature of the reactions in a medium. The present study was designed to explore the numerical interdependence of the three parameters and also, to develop the regression models. For physico-chemical analysis of the selected parameters, water quality of a polluted tropical river was analysed fortnightly, for complete one year. Correlation coefficients between pH-acidity and acidity-alkalinity were negative while that between pH and alkalinity were positive. The value calculated by the developed multiple regression models, explain pH, acidity and alkalinity up to 57, 65 and 79% respectively, suggesting their utility and relevance.*

Key words: *Pollution, River, pH, Acidity, Alkalinity, Regression model*
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Introduction

Acidity and alkalinity are two independent variables which depend upon the quantity of positive and negatively charged ions present in the medium and interaction of both together determines the pH. According to Kirby and Cravotta III (2005) net acidity and net alkalinity are widely used, poorly defined and commonly misunderstood parameters. Though, these variables are very important, as they affect other physico-chemical properties of medium, which ultimately determine the biotic composition of the systems (Saygideger and Dogan, 2005; Dwivedi and Tripathi, 2007). The values are interdependent and affect each other (Rajmohan *et al*., 2003). A constant relation exists among the values, although the relation is also regulated by other factors, such as the level and nature of pollutants (Dwivedi *et al*., 2006). The above variables have been studied by some workers, but in isolation (Singh *et al*., 2005; Lalitha *et al*., 2004). Thus, paucity exists where extensive study of the three parameters and the statistical relationships among them is needed. In addition, regression models, for predicting the value of one parameter in the presence of other were also wanted. The regression models are very useful in field studies. Thus, the present work was conducted to fulfill these gaps.

These are the three parameters which directly affect each other and also they regulate most of the other activities and parameters in the system. This can be justified by an example; presence of any ion in a medium can be toxic or not depends upon the pH of the medium (Dutta *et al*., 2005).

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Materials and Methods

The study was designed to inter-relate three parameters of water, namely pH, acidity and alkalinity of a polluted lotic ecosystem during April 2001 to March 2004. For the study, river Varuna in Varanasi, India was selected. River Varuna is an important tributary of the holy river Ganga. Varanasi is situated in the eastern part of Uttar Pradesh, a province of India located in NE of the Indian subcontinent. On the globe, Varanasi finds its location at 25°18′ N, 83°1′ E and 76.19 m above msl. In its 15 km long flow through Varanasi, river Varuna receives sewage from twenty-two municipal drainage (nalas) located on both sides of the river in addition to agricultural run-off at some selected points.

Four study sites were selected along river Varuna for detailed investigation. A summary of the study sites is given in Table 1. For uniform sampling, five sub-sites were located on each study site. Sampling and analysis of the river water was conducted at all the four sites (at 5 subsites each) fortnightly for three years. To express the true representative value, arithmetic mean of the respective sub-sites of each site is represented as monthly value. Standard methods for the examination of water and waste water (APHA, 2005) was followed for the analysis of pH, acidity and total alkalinity.

Results and Discussion

Monthly arithmetic mean value of pH, acidity and alkalinity is expressed in Table 2. The lowest and highest values of the parameters among all the sites have been printed bold in the table.

Seasonally, pH was found to be highest during rainy season followed by winter and summer seasons at all the sites. Annual mean pH at sites 1, 2, 3 and 4 was recorded to be 8.406, 8.325, 8.087 and 7.842, respectively. Mean level of variance of pH was significant between sites (F = 67.98, $p<0.001$) and between months (F = 4.71, $p<0.001$) (Table 3).

Acidity of the river water was found to be highest during summer followed by rainy and winter season at most of the sites. Annual mean acidity at sites 1, 2, 3 and 4 was recorded to be 0.386, 2.429, 6.526 and 18.516 mg l^{-1} $CaCO_3$, respectively. Mean level of variance of acidity at the study sites showed significant difference among the sites (F = 42.34, $p<0.001$). For months, the level of variance was not significant (F = 0.82, N.S.). Parallel findings regarding seasonal variation in parameters of surface water have also been reported by Singh *et al*. (2005).

Annual mean alkalinity at sites 1, 2, 3 and 4 was recorded to be 345.233, 250.316, 218.066 and 193.331 mg l^{-1} $CaCO_3$, respectively. Alkalinity of the river water was found to be highest during rainy season followed by winter and summer season at all the sites. Mean level of variance of alkalinity at the study sites showed significant difference among the sites (F = 44.90, $p<0.001$) and months (F = 9.23, $p<0.001$).

The higher value of pH and alkalinity at site 1 as compared to the other sites was due to the addition of fertilizers and other organic components from the agricultural run-off. Most of the agrochemicals including fertilizers are basic in nature due to the presence of phosphatic and nitrogenous compounds. During rainy season the increase in pH of river water at all sites could be attributed towards the addition of street runoff, nitrogenous waste washing from open fields at the bank of the river *etc.* Comparatively, lower pH at sites 4, 3 and 2 throughout the study period may be due to the reaction of acidic components with pollutants at these sites which lowers the pH.

The Pearson correlation coefficient between pH, acidity and alkalinity shows significant interdependency (Table 3). The correlation coefficient between pH-acidity and acidity-alkalinity were – 0.744 ($p>0.001$) and – 0.515 ($p>0.001$) respectively, parallel to the findings of Kirby and Cravotta III (2005) in the case of mine drainage. The correlation coefficient between pH and alkalinity was 0.801 ($p> 0.001$), justifying that the variables were positively correlated or interdependent. The existence of some specific correlation among the ions in water of

Table - 1: Characteristics of the research sites of Varuna river

Characters	Site 1	Site 2	Site 3	Site 4
Location	Rameshwar	Razabazar	Chaukaghat	Kazzakpura
Important source of pollution	Agricultural runoff	Small scale battery industries	Small scale automobile servicing stations	Small scale saree dyeing industries
Number of marked and allied industrial units	Nil	586	117	164
Nala pouring in the river	Nil	Razabazar nala	Chaukaghat nala	Narokhar nala
Amount of effluent pouring in the river	N A	1.13 mld	2.55 mld	5.45 mld

NA = Not available, mld = Million liter day^{-1}

Table - 2: Arithmetic mean of the value of pH, acidity and alkalinity

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
pH												
Site 1	8.140	8.260	8.290	8.320	8.530	8.490	8.620	**8.660**	8.550	8.500	8.330	8.180
Site 2	8.110	8.230	8.230	8.190	8.500	8.420	8.440	8.510	8.470	8.420	8.210	8.170
Site 3	8.020	8.040	8.190	8.000	8.180	8.330	8.110	8.100	8.180	7.820	8.150	7.920
Site 4	**7.610**	7.910	8.080	7.790	7.820	7.970	7.890	7.790	8.000	7.720	7.800	7.720
Acidity (mg l^{-1})												
Site 1	**0.210**	0.260	0.700	0.230	0.230	0.600	0.230	0.260	0.730	0.517	0.400	0.260
Site 2	0.260	0.260	1.210	0.250	0.250	3.360	0.230	0.450	6.600	5.950	5.380	4.950
Site 3	6.020	5.060	7.000	4.200	10.980	7.950	4.300	4.560	7.160	8.350	6.180	6.550
Site 4	**34.460**	24.880	21.950	19.150	17.180	11.180	11.250	10.360	11.080	11.700	22.000	27.000
Alkalinity (mg l^{-1})												
Site 1	193.660	311.330	315.830	338.500	362.160	415.330	459.830	**461.660**	370.830	361.500	351.660	200.500
Site 2	142.330	251.000	261.660	243.830	268.660	347.330	273.160	253.330	288.500	260.830	272.830	140.330
Site 3	131.500	245.660	252.830	220.660	242.330	249.830	262.830	201.160	243.500	193.330	247.160	126.000
Site 4	**120.830**	225.330	215.830	193.660	205.500	235.500	214.500	135.660	213.830	191.000	243.830	124.500

Table - 3: Correlations among the water quality variables

	pH	Acidity	Alkalinity
pH	1.000		
Acidity	–0.744	1.000	
Alkalinity	0.801	–0.515	1.000

$p > 0.001$

Kancheepuram region has also been suspected by Rajmohan *et al.* (2003). There fore, multiple regression models for the three parameters were developed.

The multiple regression models for acidity, alkalinity and pH were derived as below:

$$\text{Acidity} = 234.836 + 0.02249\,\text{Alkalinity} - 28.603\,\text{pH}$$

$$\text{Alkalinity} = -2135.973 + 290.887\,\text{pH} + 1.820\,\text{Acidity}$$

$$\text{pH} = 7.805 - 0.01458\,\text{Acidity} + 0.01832\,\text{Alkalinity}$$

It is well known that these three parameters are largely interdependent although they are not isolated parameters. Values of acidity, alkalinity and pH calculated through the above three models explain the variable up to 57, 65 and 79% respectively. The regression models are of relevance because of their direct application in the field study. Modern development and rapid industrialization have directly affected the quality of the water bodies (Shashi and Dwivedi, 2008) as well as that of the surrounding air (Dwivedi *et al.*, 2008). Thus, in the present scenario, the regression models are relevant for management of the water bodies and prediction of the future prospects (Dwivedi *et al.*, 2007). In intensive research programmes, it may be unfeasible to conduct all the above three tests or some time only crude idea may be required in preliminary study for site selections in case of polluted rivers. The models can also be helpful in testing or predicting the accuracy of any given variable.

Acknowledgments

Authors are thankful to Prof. R.S. Ambasht, Emeritus Scientist, Centre of Advanced Study in Botany and Prof. B.D. Tripathi, Coordinator, Centre for Environment Science and Technology, Banaras Hindu University, Varanasi for their valuable suggestions in preparing the manuscript and Dr. R.P. Singh, Head, Department of Chemistry, Udai Pratap Autonomous P.G. College, Varanasi for extending the laboratory facilities.

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