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Full Length Research Paper

Reginol interpretation of river Indus water quality data using regression model

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Water samples were collected from river Indus over 591 km^2 from Kashmor to Keti Bandar/Shah Bandar in the province of Sindh, Pakistan, during 2008 and 2009 on seasonal bases. These samples were analyzed for 12 water quality variables including physical and chemical parameters. Then correlation study was carried out and correlation co-efficient "r" was determined using correlation matrix to identify the highly correlated and interrelated parameters. Regression model were developed to test the significant 'r' and P-value test was carried out to test the significance of the pair of parameters. F-test was also used to examine the joint-effects of several independent variables without taking into account the separate effects of each variable. The comparison of the observed and predicted values of different parameters using regression equation suggested that the regression model provide useful means of rapid and easier monitoring of water quality of a river in a region.

Key words: Regression model, correlation coefficient, river indus, monitoring, physico-chemical parameters.

INTRODUCTION

Water is undoubtedly the most precious natural resource that exists on our planet. Although we recognize this fact, we disregarded it by polluting our rivers, lakes and oceans. It is the basic duty of every individual to conserve water resources (Jothivenkatachalam et al., 2010; Vega et al., 1998). The riverine system is most important resources of water supply in different countries of the world. At the source of a river, the water is relatively pure as it flows towards downstream. In Pakistan riverine system are getting polluted day by day. A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic) are concentrated along the river belt and work together to reduce water quality which is a cause of alarm.

According to world wide fund for nature (WWF), five rivers in Asia serving 870 million people are among the most threatened in the world, as dams, water extraction and climate change all take their toll. The Indus River is among the top five most threatened river basins. Various studies were carried out to investigate the quality of Indus River water (Sadia et al., 2013; Ali et al., 2004; Tassaduqe et al., 2003; Khuhawar et al., 2000).

The environment, economic growth and development of Pakistan especially in province of Sindh are highly influence by water, it regional and seasonal availability, and quality of surface water and microbiological parameters. A few number of research articles are available regarding the analysis of water quality data using regression techniques (Mulla et al., 2007; Patil and Patil, 2010, 2011; Kumar and Sinha, 2010; Obiefuna and Orazulike, 2010; Mehta, 2010; Sami et al., 2011; Jain and Sharma, 2000; Joarder et al., 2008). These parameters are closely interlinked. All the research so far reported on river water quality of Pakistan based on physico-chemical analysis, no attempt has been made to predict the river water quality by using regression analysis.

In the present study, river water quality was determined by measuring the concentration of some physico-

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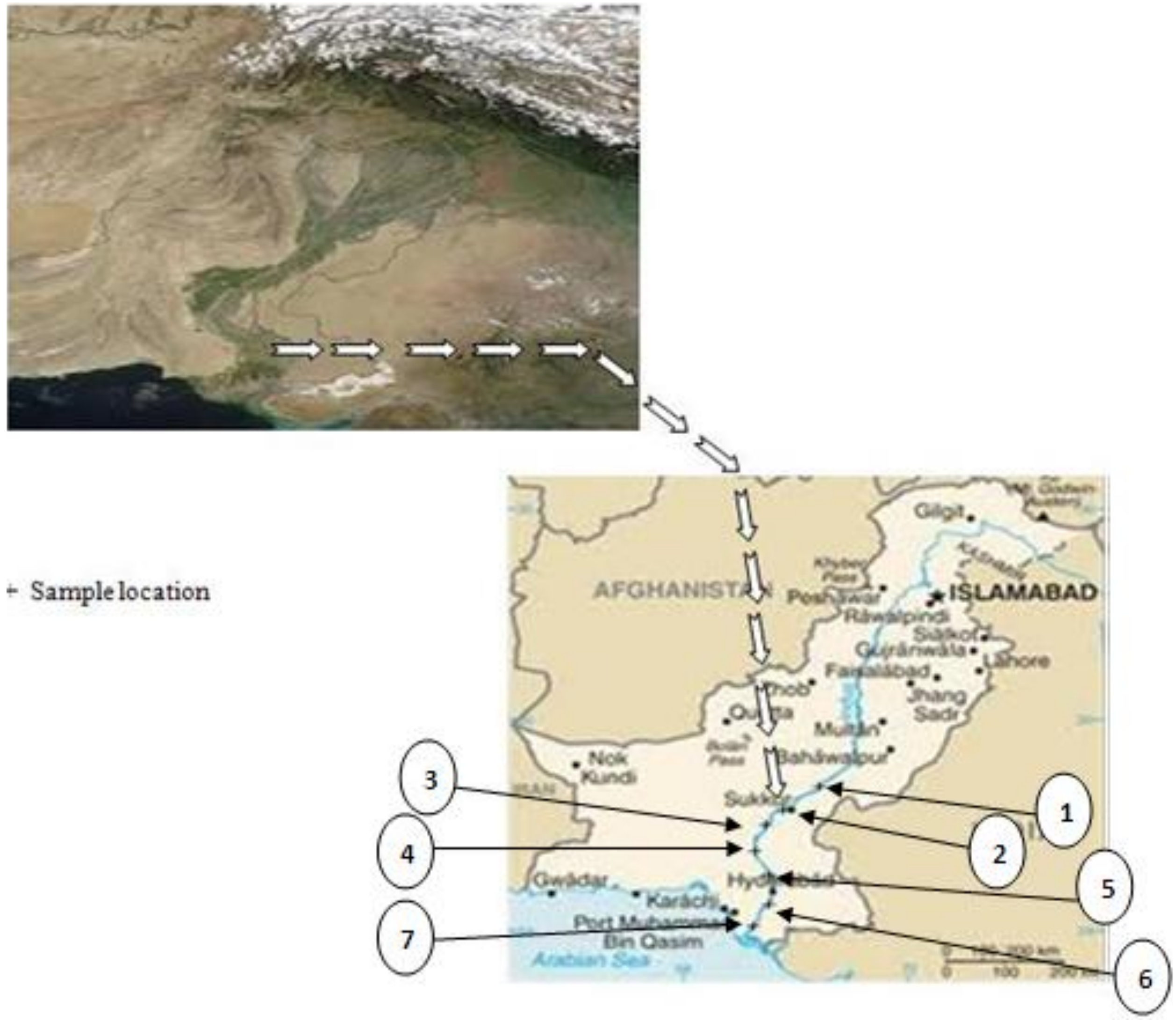

Figure 1. Location map. 1. Guddu Barrage; 2. Sukkur barrage; 3. Dadu-Moro Bridge; 4. Indus link 1 km downstream from Latifabad; 5. River Indus after Indus link outfall 6. Kotri Barrage at main bridge; 7. Sajawal bridge.

chemical parameters and comparing them with drinking water standards (WHO). Regression equations for the parameters having significant correlation were used to estimate the concentration of other constituents. Regression model were developed to test the significant correlation coefficient to overall water quality relative concentration of various pollutants in water to provide necessary clue for implementation of rapid water quality management.

MATERIALS AND METHODS

Water quality parameters of Indus River were monitored at seven different sampling points: Guddu Barrage; Sukkur barrage; Dadu-Moro Bridge; Indus link 1 km downstream from Latifabad; River Indus after Indus link outfall ; Kotri Barrage at main bridge and Sajawal bridge, considering sampling locations (receiving bulk quantity of effluent either by municipal/industrial/agriculture return flow) (Figure 1).

Chemical analysis

The samples were collected using boat from the middle of the flow within 3-9 inches from the surface of water. Two to four sub samples of equal volume were also collected from vertical section. The samples were mixed well and saved in a 2.5 L glass bottle. The samples were analyzed for physicochemical parameters such as alkalinity, bi-carbonate, calcium, pH, conductivity, total dissolved solid, and total suspended solid, chloride, chemical oxygen demand, biological oxygen demand, sulfate, sodium, potassium and magnesium using standard methods (APHA, 2005). Results obtained were subjected to regression statistical analysis using Statistical Package for social Scientist (SPSS) 14th version.

Table 1a. Estimated values of water quality parameters and WHO prescribed limits (pre-monsoon).

Parameter	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	St.Dev	WHO limit
Conductivity	0.381	0.323	0.323	0.417	0.380	0.396	0.494	0.059	0.3
pH	7.7	7.5	7.6	7.8	7.6	7.7	7.7	0.098	7 to 8.5
Alkalinity	71.5	61.1	77	89	91.2	45	76	16.021	100
BOD	28	24	22	33	57	21.3	39	12.711	06
COD	67	56	53.3	41.7	131	50	93	31.449	10
TSS	324	321	187	63.3	167	60.3	24	123.342	500
TDS	220.3	200.5	224.7	233.7	237.1	207.1	287	28.372	500
Cl^{-1}	40	38.7	38.4	39.3	39.3	37	50.3	4.454	200
HCO_3^{-1}	87.3	74.7	93.6	93.3	92.7	73.0	97.7	9.798	-
SO_4^{-2}	30.3	28	29.3	33.3	35	37.3	53	8.520	-
Ca^{+2}	35.3	29.3	35.6	37	37.7	37.5	40	3.358	100
Mg^{+2}	5.2	6	5.9	6.1	6	2.9	8.5	1.645	-
Na^{+1}	21.8	22	21.6	22.1	23	24.6	31.3	3.476	-
K^{+1}	1.9	1.8	1.8	2.2	2.2	3	6	1.513	-

Statistical screening

The regression analysis was used to estimate two water quality parameters to describe realistic ground water situations. In addition, this analysis attempts to establish the nature of the relationship between the variables and thereby provides a mechanism for prediction or forecasting (Kumar and Sinha, 2010; Agarwal and Sexena, 2011; Mulla et al., 2007). To find the relationship between two physicochemical parameters X and Y, the Karl Pearson's correlation coefficient, r is used and it is determined as follows:

$$r = \frac{n \Sigma xy - (\Sigma x . \Sigma y)}{\sqrt{[n \Sigma x^2 - (\Sigma x)^2][n \Sigma y^2 - (\Sigma y)^2]}} \quad (1)$$

where, n = number of data points; x = values of X-variable; y = values of Y-variable.

To evaluate the straight-line by linear regression, the following equation of straight line can be used:

$$Y = aX + b \quad (2)$$

where, Y = dependent variable ; X = independent variable ; a = slope of line; b = intercept on y-axis

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

and

$$b = \overline{y} - a \overline{x} \quad (4)$$

Where, x = arithmetic mean of all values of x; y = arithmetic mean of all values of y.

For good correlation, value of r should be between $-1 < r < 1$.

RESULTS AND DISCUSSION

The values of physicochemical parameters, standard deviation and WHO prescribed limits are presented in Table 1a and b during pre and post-monsoon, respectively. The relationship between alkalinity with HCO_3^{-1} is highly correlated and with BOD and Mg^{+2} are moderately correlated where as alkalinity is weakly correlated with COD and TDS during pre-monsoon (Table 2a).

The relationship between alkalinity with Na^{+1}, Ca^{+2} and TDS during post-monsoon which give correlation co-efficient are equal to 0.448, 0.546 and 0.531, respectively (Table 2b) showing less moderate to moderate as values of 'r' lies between -1 and +1.

The terms alkalinity and hardness are often used interchangeably when discussing water quality. These aggregate properties of water share some similarities but are distinctly different. Alkalinity is a measure of the acid-neutralizing capacity of water.

Alkalinity in most natural waters is due to the presence of carbonate (CO_3^{-2}), bicarbonate (HCO_3^{-1}), and hydroxyl (OH^{-1}) anions. However, borates, phosphates, silicates and other bases also contribute to alkalinity if present. This property is important when determining the suitability of water for irrigation and/or mixing some pesticides and when interpreting and controlling wastewater treatment processes.

In the present study, the alkalinity values were maximum during pre-monsoon. This may be attributed to increase in the rate of organic decomposition during which CO_2 is liberated, which reacts with water to form HCO_3^{-1}, thereby increasing total alkalinity in pre-monsoon. The increased alkalinity during pre-monsoon was due to the concentration of nutrients in water. The decrease was due to dilution caused by the rainwater during monsoon. Similar observation was reported by

Table 1b. Estimated values of water quality parameters and WHO prescribed limits (post-monsoon).

Parameter	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	St.Dev	WHO limit
Conductivity	0.377	0.408	0.342	0.378	0.415	0.330	0.119	0.102	0.3
pH	7.8	7.8	7.8	7.4	7.6	7.3	7.4	0.219	7 to 8.5
Alkalinity	63.5	67.5	70.8	62.4	49.3	53	75.4	9.336	100
BOD	14.3	25.2	18	35.6	36	15.9	9.7	10.447	06
COD	38	67.3	40.3	98.3	67.7	46	21	25.572	10
TSS	239.7	260.3	160.3	153.3	321.3	210.3	3.3	101.735	500
TDS	229.2	228.6	234.5	399.2	276.7	227.8	805.3	213.055	500
Cl^{-1}	42.3	40.7	42.3	35	81.4	35.7	35.7	16.484	200
HCO_3^{-1}	75.7	77	80.3	82.5	97.1	80	101.7	10.239	-
SO_4^{-2}	40	43	39	38.7	89.4	34	87.3	24.262	-
Ca^{+2}	38	37.1	38.7	36.8	37.5	42	80	15.838	100
Mg^{+2}	8.3	7.6	8.4	6.3	71.6	5.2	22.7	24.11	-
Na^{+1}	20.6	20.3	22	19.7	45.3	18.7	129.3	40.731	-
K^{+1}	4	2.7	3.7	18.3	15.1	3.3	6.3	6.365	-

Table 2a. Statistical regression analysis data (pre-monsoon).

R -Equation	I-Var.	D-Var.	n	r	F value	S.E
Alkalinity =30.650 x pH - 161.720	pH	Alkalinity	7	0.187	0.181	17.241
Alkalinity = 0.234x COD+56.499	COD	DO	7	0.460	1.342	15.583
Alkalinity = 0.880x BOD + 44.785	BOD	DO	7	0.698	4.748	12.569
Alkalinity= - 0.012 x TSS + 74.926	TSS	DO	7	-0.092	0.043	17.476
Alkalinity = 0.278 x TDS +8.905	TDS	DO	7	0.493	1.607	15.267
Alkalinity = 45.23 x Conductivity+55.44	Conductivity	DO	7	0.166	0.141	17.307
Alkalinity = 0.841x Cl^{-1} + 38.97	Cl^{-1}	DO	7	0.234	0.289	17.063
Alkalinity = 1.391 x HCO_3^{-1} - 48.66	HCO_3^{-1}	DO	7	0.850	13.070	9.232
Alkalinity = 0.069 x SO_4^{-2} + 70.55	SO_4^{-2}	DO	7	0.037	0.007	17.538
Alkalinity = 1.421 x Ca^{+2} + 21.74	Ca^{+2}	DO	7	0.298	0.487	16.754
Alkalinity = 5.952 x Mg^{+2} + 38.450	Mg^{+2}	DO	7	0.611	2.982	13.890
Alkalinity = -0.359 x Na^{+1} + 81.512	Na^{+1}	DO	7	-0.078	0.031	17.497
Alkalinity = -0.531x K^{+1} + 74.404	K^{+1}	DO	7	-0.050	0.013	17.528

Table 2b. Statistical regression analysis data (Post-monsoon).

R-Equation	I-Var.	D-Var.	n	r	F value	S.E
Alkalinity = 11.134 xpH-21.328	pH	Alkalinity	7	0.262	.367	9.871
Alkalinity = -0.153 x COD +71.379	COD	DO	7	-0.418	1.057	9.292
Alkalinity=-0.477 x BOD +73.664	BOD	DO	7	-0.533	1.989	8.650
Alkalinity = -0.067 x TSS + 76.119	TSS	DO	7	-0.735	5.868	6.937
Alkalinity = 0.023 x TDS +55.142	TDS	DO	7	0.531	1.966	8.664
Alkalinity = -54.03xConductivity+81.4	Conductivity	DO	7	-0.588	2.645	8.271
Alkalinity = -0.341 x Cl^{-1} + 78.395	Cl^{-1}	DO	7	-0.603	2.851	8.161
Alkalinity = 0.25 x HCO_3^{-1} + 61.024	HCO_3^{-1}	DO	7	0.027	0.004	10.224
Alkalinity = -0.010 x SO_4^{-2} + 63.662	SO_4^{-2}	DO	7	-0.026	0.003	10.224
Alkalinity = 0.322 x Ca^{+2} + 48.880	Ca^{+2}	DO	7	0.546	2.119	8.571
Alkalinity= -0.192 x Mg^{+2} + 66.689	Mg^{+2}	DO	7	-0.495	1.620	8.888
Alkalinity = 0.103 x Na^{+1} + 59.083	Na^{+1}	DO	7	0.448	1.254	9.145
Alkalinity = -0.562 x K^{+1} + 67.415	K^{+1}	DO	7	-0.383	0.860	9.447

(Brion, 1973; Wetzel, 1983).

Alkalinity is important because it buffers the pH of water within the system. Without this buffering capacity, small additions of acids or bases would result in significant changes of pH, which could be deleterious for aquatic life. Alkalinity also influences the distribution of some organisms within aquatic systems. The pH range was 7.5 to 7.8 during pre-monsoon and 7.3 to 7.8 during post-monsoon. The pH of most natural waters falls in the 6 to 9 range because of the bicarbonate buffering.

In the present study, the TDS and TSS values were maximum during post-monsoon and minimum during pre-monsoon. High values of TSS during post-monsson may be due to siltation, deterioration, heavy precipitation and mixing runoff rain water which carried mud, sand, etc. Similar observations were made by Jawale and Patil (2009) and Salve and Hiware (2006).

COD is the amount of chemical oxidant required for the oxidation of the organic matter present in the waste. River Indus receives high amount of organic matter which generally originate from domestic and industrial effluents on the bank of Indus River. In the present study, the COD value vary from 41.7 to 131 during pre-monsoon and 21 to 98.3 during post-monsoon. For biodegradation, this organic waste requires oxygen, causing significant depletion of dissolved oxygen in river Indus water. The oxygen depletion not only effect biotic community of the river but also affects the purification capacity. High value of COD indicates that river received high amount of organic matter during pre monsoon. Hence the low value of alkalinity indicates that the compound responsible for decrease alkalinity is working as chemical oxidant for COD and hence significant increase in the value of COD. As regression equation, $Y = 0.477 X + 73.664$ and $Y = -0.153 X + 71.379$ was used to estimate the values of BOD and COD, respectively. It also helps to find the value of BOD/COD ratio to analyze the extent of pollution and biodegradability of water. The high value of BOD suggest that oxygen present in water is consumed by aerobic bacteria which makes fish, blind dolphins and other aquatic species to find it difficult to survive during pre monsoon.

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