Assessment of Seasonal and Polluting Effects on the Quality of River Water by Using Regression Analysis: A Case Study of River Indus in Province of Sindh, Pakistan

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***Abstract*- In this study, statistical techniques such as regression analysis is applied to water quality data set monitored during Pre and Post monsoon 2008 and 2009 to investigate in the extent of pollution and seasonal variation in river Indus waters. The variables were pH, BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand, TSS (Total Suspended Solid), TDS (Total Dissolve Solid), alkalinity, Cl^-, HCO_3^-, SO_4^{-2}, Ca^{+2}, Mg^{+2}, Na^+ and K^+. Regression equations established between above parameters and dependent variable such as electrical conductivity, which caused to predict the value of one parameter, if value of other is known. The above study provides us a tool to find the value of physico-chemical parameters and extent of pollution theoretically and seasonal variation, which is time saving as well as cost effective.**

Keywords-* *Water Quality; Regression Analysis; Correlation; Indus River; Monsoon

I. INTRODUCTION

Water is vital to the existence of living organisms but this valued resource is increasingly being threatened as human population grown which increases the demand for more water of high quality for domestic purposes and economic activities [1].

Because river flow, rivers have been used by man throughout history, for the transport of materials, removal of wastes and supply of portable water. Their extended form also means they are shared by many people across national boundaries. They are, therefore, venerable to abuse. Polluting effects of domestic sewage, agricultural return flows and industrial effluent have, recently formed the focus of attention to the researchers [2, 3, 4].

Most of the rivers in urban areas especially in developing countries are the ultimate ends of effluent, discharge from the industries and sewage. Asian countries experiencing population growth, rapid industrial growth with improper management of effluent, pollution has become a devastating problem in these countries including Pakistan. This results in abnormal concentration of hazardous wastes in the natural environment [5].

Pakistan available water resources are already almost fully utilized and under stress. At the projected population growth and economic development rates, it is unlikely that the projected demand of water resources in Pakistan will be sustainable. Water will be increasingly becoming the limited resource in Pakistan, and supply will become a major restriction to the future socio-economic development of the country in terms of both the amount of water available and the quality of what is available [6].

The river Indus and its tributaries are the major source of water for drinking, agricultural and industrial desires in province of sindh, Pakistan. The river cover a drainage area of exceeding 1,165,000 km^2, flows through densely populated areas from the North in a Southerly direction along the entire length of the country and finally merge into Arabian Sea near port city of Karachi, Pakistan.

In the bank of Indus River in the province of Sindh, Pakistan big cities like Sukkur, Nawabsha, Dadu and Hyderabad are situated along the bank of the river with numerous small towns and villages. Additionaly, industrial estates like Sukkur Industrial Estate, Hyderabad and Kotri Industrial Estates are also situated on the side of the Indus River.

These industrial estates are releasing their effluents into River Indus without treatment. Therefore, the River water is getting contaminated by both domestic and industrial waste as well as agricultural return flow.

In addition, hydrology of Indus River altered significantly by the construction of channels, barrages, embankments, dykes and dams for hydroelectric power generation, irrigation and flood control. These have reduced the discharge significantly in the lower Indus region. The water quality in the region depends upon the water flow. There are concerns that extensive deforestation, industrial pollution, agriculture return flow and global warming are affecting the vegetation and wildlife of the Indus delta, while affecting agriculture products as well, in addition to quality of water.

Environmental targets for water quality are implicitly biological in broad sense. First, there is consideration of human health. Is water contact hazardous and how much treatment is necessary before it is safe to drink or use in various ways? Second, are fish and other desirable ‘living’ things abundant? Is conservation further thread? Chemistry is important in that it enables environmental targets to be met and because various standard chemical determents have proved useful in surveillance because they are easy to measure and monitor. Compared with other parts, relatively little hydrological research has been conducted in the area of the impact of seasonal limnological variation, nutrient load and urbanisation on the downstream of River Indus system, especially in the territories of the Sindh Province. This study addresses these gaps by assessing the water quality of River Indus.

Therefore, various Physico-chemical parameters were analysed by many workers to understand the quality of surface water. Whereas, some researchers suggested the empirical relationship to measure the quality of water. Recently, correlation method has been established between Physico-chemical parameters to study pollution of surface water, which is cost effective as well as reliable. In the present study, an attempt made to analyse quantitatively and Physico-chemical parameters and to establish a mathematical relation between these parameters [7, 8]. For that, correlation coefficient is calculated to understand the nature of correlation between Physico-chemical parameters to understand the extent of pollution through regression equations. With the help of these regression equations one can easily predict the future trends of pollution in the water body.

II. THE RIVER INDUS

A. Indus Plain

The Indus River basin stretches from Himalayan Mountains in the North to the dry alluvial Plains of Sindh in the South. The Area of Indus basin is 944,574 Km^2. The Vast alluvial plains of the Indus basin (The Indus plains) cover an area of 207,200 Km^2. The relatively flat plain in largely made up of deep alluvium deposited by Indus River and its tributaries. Soils in the whole of Indus basin plain consists of deep deposits of unconsolidated and highly permeable alluvium brought in by Indus River and its tributaries (mostly over 300 meters). The alluvium mass is mostly homogeneous and forms highly transmissive aquifer.

B. Climate

The climate in the Indus plain is arid to semi-arid. In lower Indus plain Dec. to Feb. in the cold season and mean monthly temperatures vary from 14-20^{o}C. Mean monthly temperature during March to June vary from 42-44 ^{o}C. In the upper Indus plain mean temperature ranges from 23-49 ^{o}C during summer and from 2-23 ^{o}C during winter.

The average annual rainfall in the Indus plain is about 23cm. In lower Indus, Larkana and Jacobabad areas receive on the average about 9cm of rain fall annually. In upper Indus plan Multan receives 15cm and Lahore about 51cm of rain. Because of hot climate, evaporation rate is very high and mean annual evaporation in lower Indus plain (Nowabsha) is 204 cm while in upper Indus plain (Sargodha) it is 165cm.[9]

C. Indus Water

Primary source of surface water is precipitation in the form of rainfall and snow and glacier melt. Glacier in the upper Indus basin are the largest outside the polar region and serve as natural storage reservoirs that provide perennial supplies to River Indus and some of its tributaries.

D. Geology of Indus Basin

The geology of the Indus Basin is closely tied to the concept of continental drift. As early as 1937, West applied Wegener's 1910 concept of continental drift to the Indian subcontinent. India was understood to have been part of a 200 million year old supercontinent which broke up with the parts drifting north. The Himalayas were seen as the wreckage of a head-on collision between what was then south Asia and the Indian subcontinent.

The past two decades have seen a fantastic amount of data collected which confirms in detail this seemingly preposterous hypothesis. Let us reconstruct in brief, a history of the geologic events producing the Indus Basin. Prior to the impingement of the Indian subcontinent, the southern coast of Asia lay approximately along the southern front of the present Himalayas. Afghanistan and what is now largely China, poured sediment into the sea in the arc now occupied by the Indo-Gangetic plain. As the Indian subcontinent moved north and began to interact with the Asian continent at depth, the Himalayas began to form. However, at the same time, it down warping produced the Himalayan fore-deep, a 25, 000 foot trench between Asia and India.

Even as the trench developed, it was being filled with sediment, sometimes marine, sometimes continental. Occasionally lakes were found in the continental deposits, and with the passage of time marine deposits were more and more restricted to the extremities of what is now the Indo-Gangetic plain, near Karachi and Calcutta.

Deposition was so continuous in some parts of the trough that one of the most nearly continuous of sediments from pre-Cambrian to the present exists in the Salt Range. However, as noted earlier, the type of sediment and depositional environment frequently changed in haphazard fashion. Deltaic deposits were replaced by channel alluvium or great saline lakes which were replaced in turn. The vast amounts of salt water and salt deposits now found in the rocks and alluvium of the Indus Basin are a legacy of this period in large part, and are derived from saline lake deposits, and connate, or sea water left in the interstices of marine deposits.

Deep freshwater zones in the Indus plain are largely in fluvial deposits of the early Indus River or its tributaries. Much of the fresh or brackish water nearer the surface of the present plain owes its existence to the flushing effect of groundwater moving from the Himalayas towards the Arabian Sea over low gradients. This flow may locally be interfered with the presence of a buried portion of the Indian subcontinent overlain by Indus Valley alluvium.

This buried basement rock, the Aravalli Range, lies between the Himalayan tough and the shallower sediments of the lower Indus plain. It is largely buried by at least 600 feet of sediments, and according to PSGS findings, cannot be considered a major barrier to useable groundwater flow.

Concurrent with sedimentation, tectonic adjustment continued to take place troughout this period. The Himalayas grow younger in the south- westerly direction, and faults grow progressing younger in the same direction. As early as [9] recognized recent or sub recent faults in the Punjab.

III. METHODOLOGY

Seven (07) different sampling locations are selected to study the physic-chemical parameters of Indus River; these are receiving bulk quantity of effluent either by municipal/ industrial/ agriculture return flow, resulting in reasonably high pollution.

E. Chemical Analysis

Most of the samples were collected from the middle of the flow using boat, two to four sub samples of equal volume were collected from vertical section. The water samples were collected within 3-9 inches from the surface of water. The samples were mixed well and a sample of 2.5 L was transferred to clean glass bottle.

The samples were analysed for pH, electrical conductivity, total dissolved solid, total suspended solid, alkalinity, chloride, hydrogen carbonate, chemical oxygen demand, biological oxygen demand, sulphate, sodium, potassium, calcium and magnesium using standard methods (APHA 2005). Results obtained were subjected to regression statistical analysis using Statistical Package for social Scientist (SPSS) 14th version.

F. *Statistical Analysis*

Main function of regression analysis is to explore the relationship between a dependent variable and one or more dependent variables. This statistical technique is most commonly used in program evaluation to estimate the effects. This technique, however, can also be applied in fore casting and extant evaluation.

Regression analysis is used to understand the statistical dependence of one variable on other variables. The technique can show what proportion of variance between variables is due to the dependent variable, and what proportion is due to the independent variable [10].

The relation between the two Physic-chemical parameters X and Y, can be illustrated the by more usually using Karl Pearson's correlation Coefficient, r, and it is determined as follows

$$r = \frac{n\,\Sigma\,xy - (\Sigma x.\Sigma\,y)}{\sqrt{[n\,\Sigma\,x2 - (\Sigma\,x)\,2\,]\,[\,n\,\Sigma\,y2 - (\Sigma\,y)\,2]}}$$

Here,

n = number of data points;

x = values of X–variable;

y = values of Y–variable

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

Y = a X+ b

Here,

Y = dependent variable;

X = independent variable;

a = slope of line;

b = intercept on y–axis

$$a = \frac{n\,\Sigma\,xy - (\Sigma x.\Sigma\,y)}{n\,\Sigma\,x2 - (\Sigma\,x)\,2}$$

and

$$b = \bar{y} - a\bar{x}$$

Here,

$\bar{x}$ = Arithmetic mean of all values of x

$\bar{y}$ =Arithmetic mean of all values of y

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

IV. PROBABLE ERROR AND INTERPRETATION

$$\text{All P.E} = \pm\,0.6745\,\left(\frac{1-r2}{\sqrt{n}}\right)$$

Now,

Coefficient of correlation (r) is less than the P.E; there is no correlation between two variables.

r is more than P.E., then correlation exists, however if r is less than 0.20, the correlation is not appreciable.

r is more than 6 times the size of P.E the correlation is greatly significant.

Limits of correlation are r ± P.E.

V. RESULTS AND DISCUSSION

A. *Electrical Conductivity*

Electrical conductivity values varied between 329 to 494 µS/cm and 320 to 419 µS/cm during pre & post monsoon season. Highest conductivity was recorded in the downstream at sujawal in both seasons. Generally, the conductivity of a river lowest at the source of catchments; and as its flows along the course of the river, it leaches ions from the soils and also pick up organic material from the biota and its detritus [12] The average value of typical, unpolluted rivers is approximately 350µS/cm [13]. Therefore, the parameters do not give cause of concern and it makes the water suitable for domestic use. The fluctuation in electric conductivity correlated positively with the total dissolved solids. Suspended solids (SS) and total dissolved solids (TDS) are common indicators of polluted waters.

In present study the TDS values vary from 220.3 to 287 during pre-monsoon, and 228.6 to 85.3 during post-monsoon season. These values were not high compared with WHO guidelines values of 1000mg/l. According to [14], the palatability of water with TDS level less than 600mg/l is generally considered to be good where as water with TDS greater than 1200mg/l increasingly unpalatable.

B. *Biological Oxygen Demand (BOD)*

Biological oxygen demand is the amount of oxygen required by the bacteria in stabilizing the decomposable organic matter. The aim of BOD test is to determine the amount of bio-chemically oxidisiable carbonaceous matter [15]. The BOD observation for the two seasons i.e, pre and post monsoon varies from 21 to 57 and 9.7 to 35.6 respectively. The entry of sewage water, industrial effluent and agricultural runoff might be responsible for the increased level of BOD. [16]., reported increased levels in BOD values due to decomposition of animal exereatory wastes. Higher concentration of BOD was recorded during pre-monsoon presumably due to low flow of water during this period.

C. *Chemical Oxygen Demand (COD)*

Chemical oxygen demand is the oxygen consumed during the chemical oxidation of organic matter. The COD is linked with heavy pollution from industries, domestic sewage and industrial effluents on the bank of river Indus. In present observation the value of COD vaies from 41.7 to 13mg/l during pre-monsoon and 21 to 97.7 during post-monsoon. The highest value of COD during pre-monsoon season was one of the caused by the low flow of water in lower Indus basin.

TABLE I SAMPLING DATA DETAIL

Site No	Name of Location	No. of Samples	Type of source	General Characteristic of water	Purpose of use
01	Guduu Barrage	4 seasons	Major Source of Water	Odourless	Drinking/ Agriculture/ Industrial.
02	Sukkur barrage	-do-	-do-	Odourless	-do-
03	Dadu-Moro Bridge	-do-	-do-	Odourless	-do-
04	Indus link one kilometer downstream from Latifabad	-do-	-do-	Odourless	-do-
05	River Indus after Indus link outfall	-do-	-do-	Odourless	-do-
06	Kotri Barrage at main bridge	-do-	-do-	Odourless	-do-
07	Sajawal bridge	-do-	-do-	Odourless	-do-

TABLE 2A VALUE OF WATER QUALITY PHYSICO-CHEMICAL PARAMETERS AND THEIR WHO PRESCRIBED LIMITS URING PRE MONSOON

Serial No.	Parameters	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	WHO STD.[11]
01	Electrical conductivity	0.381	0.323	0.323	0.417	0.380	0.396	0.494	0.3
02	pH	7.7	7.5	7.6	7.8	7.6	7.7	7.7	7 to 8.5
03	Alkalinity	71.5	61.1	77	89	91.2	45	76	100
04	BOD	28	24	22	33	57	21.3	39	06
05	COD	67	56	53.3	41.7	131	50	93	10
06	TSS	324	321	187	63.3	167	60.3	24	500
07	TDS	220.3	200.5	224.7	233.7	237.1	207.1	287	500
08	Cl^-	40	38.7	38.4	39.3	39.3	37	50.3	200
09	HCO_3^-	87.3	74.7	93.6	93.3	92.7	73.0	97.7	-
10	SO_4^{-2}	30.3	28	29.3	33.3	35	37.3	53	200
11	Ca^{+2}	35.3	29.3	35.6	37	37.7	37.5	40	100
12	Mg^{+2}	5.2	6	5.9	6.1	6	2.9	8.5	50
13	Na^+	21.8	22	21.6	22.1	23	24.6	31.3	50
14	K^+	1.9	1.8	1.8	2.2	2.2	3	6	-

TABLE 2B VALUE OF WATER QUALITY PHYSICO-CHEMICAL PARAMETERS AND THEIR WHO PRESCRIBED LIMITS DURING POST MONSOON

Serial No.	Parameters	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	WHO STD.[11]
01	Electrical conductivity	.377	.408	.342	.378	.415	.330	.119	0.3
02	pH	7.8	7.8	7.8	7.4	7.6	7.3	7.4	7 to 8.5
03	Alkalinity	63.5	67.5	70.8	62.4	49.3	53	75.4	100
04	BOD	14.3	25.2	18	35.6	36	15.9	9.7	06
05	COD	38	67.3	40.3	98.3	67.7	46	21	10
06	TSS	239.7	260.3	160.3	153.3	321.3	210.3	3.3	500
07	TDS	229.2	228.6	234.5	399.2	276.7	227.8	805.3	500
08	Cl^-	42.3	40.7	42.3	35	81.4	35.7	35.7	200
09	HCO_3^-	75.7	77	80.3	82.5	97.1	80	101.7	-
10	SO_4^{-2}	40	43	39	38.7	89.4	34	87.3	200
11	Ca^{+2}	38	37.1	38.7	36.8	37.5	42	80	100
12	Mg^{+2}	8.3	7.6	8.4	6.3	71.6	5.2	22.7	50
13	Na^+	20.6	20.3	22	19.7	45.3	18.7	129.3	50
14	K^+	4	2.7	3.7	18.3	15.1	3.3	6.3	-

TABLE 3A CALCULATED VALUE OF REGRESSION COEFFICIENT AND RELATED FACTORS DURING PRE MONSOON

Serial No.	R –EQUATION	I-VER	D-VER	N	r	F	S	P.E
01	Electrical conductivity= 0.405 x pH - 2.710	pH	Electrical conductivity	7	0.672	4.117	0.0476	±0.14
02	Electrical conductivity= 0.001x COD+0.352	COD	DO	7	0.269	0.391	0.0619	±0.24
03	Electrical conductivity= 0.002x BOD + 0.332	BOD	DO	7	0.376	0.822	0.0596	±0.22
04	*N.E.F	TSS	DO	7	-0.732	5.479	0.0444	±0.12
05	Electrical conductivity= 0.002 x TDS - 0.005	TDS	DO	7	.824	10.571	0.0364	±0.08
06	Electrical conductivity= 0..001 x Alkalinity+ 0.343	Alkalinity	DO	7	.166	0.141	0.0634	±0.25
07	Electrical conductivity= 0.010 x Cl^- -0.034	Cl^-	DO	7	.791	8.383	0.0393	±0.09
08	Electrical conductivity= 0.003 HCO_3^- + 0.156	HCO_3^-	DO	7	.443	1.218	0.0577	±0.20
09	Electrical conductivity= 0..006 x SO_4^{-2} + 0.167	SO_4^{-2}	DO	7	0.911	24.418	0.0265	±0.04
10	Electrical conductivity= 0.014x Ca^{+2} - 0.101	Ca^{+2}	DO	7	0.776	7.548	0.0406	±0.1
11	Electrical conductivity= 0..016 x Mg^{+2} + 0.297	Mg^{+2}	DO	7	0.439	1.197	0.0578	±0.20
12	Electrical conductivity= 0.014 x Na^+ + 0.049	Na^+	DO	7	.843	12.254	0.0346	±0.07
13	Electrical conductivity= 0.034x K^+ + 0.296	K^+	DO	7	0.871	15.646	0.0316	±0.06

TABLE 3B CALCULATED VALUE OF REGRESSION COEFFICIENT AND RELATED FACTORS DURING POST MONSOON

Serial No.	R –EQUATION	I-VER	D-VER	n	r	F	S	P.E
01	Electrical conductivity= 0.211 xpH-1.260	pH	Electrical conductivity	7	0.454	1.297	0.099	±0.20
02	Electrical conductivity= 0.003 x COD + 0.195	COD	DO	7	0.666	3.987	0.083	±0.14
03	Electrical conductivity= 0.007 x BOD + 0.194	BOD	DO	7	0.670	4.079	0.082	±0.14
04	Electrical conductivity= .001 x TSS + 0.164	TSS	DO	7	0.903	22.050	0.048	±0.05
05	*N.E.F	TDS	DO	7	-0.894	19.866	0.50	±0.46
06	Electrical conductivity= -0.006 x Alkalinity+0.742	Alkalinity	DO	7	-0.587	2.628	0.090	±0.34
07	Electrical conductivity= 0.003 x Cl^- + 0.226	Cl^-	DO	7	0.408	.996	0.102	±0.25
08	Electrical conductivity= -0.006 x HCO_3^- + .844	HCO_3^-	DO	7	-0.599	2.797	0.089	±0.16
09	Electrical conductivity= -0..002 x SO_4^{-2} + 0.435	SO_4^{-2}	DO	7	-0.435	1.168	0.100	±0.30
10	Electrical conductivity= -0.006 x Ca^{+2} + 0.615	Ca^{+2}	DO	7	-0.973	90.173	0.026	±0.50
11	*N.E.F	Mg^{+2}	DO	7	0.104	0.055	0.111	±0.25
12	Electrical conductivity= -0.002 x Na^+ + 0.425	Na^+	DO	7	-0.887	18.463	0.051	±0.46
13	Electrical conductivity= 0.003 x K^+ + 0.312	K^+	DO	7	0.212	0.234	0.109	±0.24

D. Alkalanity

Total Alkalinity showed similar fluctuation trends and ranged between 45 to 91.2mg/l during pre-monsoon and 49.3 to 70.8 during post-monsoon. Natural water containing 40mg/l or more of total alkalinity is considered as more productivity [17]. Minimum content was noted during monsoon presumably due to dilution, while maximum was noted during pre-monsoon presumably due to evaporation of the water from the system. Pollution by sewage and its decomposition seems to be a possible cause for the higher values of alkalinity in the water bodies near to big cities like Latifabad and river Indus after Indus link out fall, which is bringing saline water into river Indus.

E. Total Dissolve Solids

Kotri barrage is situated at about 200km from the Arabian Sea and is used to regulate the water flow for agricultural purposes. In addition, supply portable water for cities such as Hyderabad and Karachi. The water flow down the Kotri barrage and back flow of sea water along the river Indus affects the quality of water especially downstream below

Kotri barrage. The samples collected during both seasons indicated that conductivity and TDS remained nearly constant up to Kotri barrage. However, pronounced effect was observed on the quality water with increase in TDS, Conductivity and alkalinity contents at downstream at Sujawal bridge. However, TDS was within the safe limits of 500mg/l above Kotri Bridge.

F. Ionic Dominance Pattern

Estimated means of major elements (both cations and anions) for all sampling stations in both sampling seasons of lower Indus basin exhibited an over ionic dominance pattern as below.

Pre-monsoon

Ca >Na>Mg>K and Cl > SO_4>HCO_3

Post-monsoon

Ca > Na > Mg> K and HCO_3 > SO_4> Cl

The ionic dominance of the lower Indus basin as compare with fresh water and sea water is

Ca> Mg >Na >K and HCO_3>SO_4>Cl (For fresh water)

And Na>Mg>Ca>K and Cl>SO_4>HCO_3 (For Sea water) [18].

Thus, like most tropical fresh water there is dominance of Ca^{+2} and HCO_3^- in the cationic and anionic components respectively during post-monsoon period. It is apparent that the dominance of Cl^- over SO_4^{-2} could be due to the large amount of domestic and sewage water being discharged into river waters. Studies conducted by [19], on characteristics fresh water and coastal eco-systems in Ghana also confirmed this observation.

Chloride found to be high during pre-monsoon season, whereas it was low during the monsoon season. This may be assigned to the cations evaporation of water during pre-monsoon and relatively lower values after rainy season can be attributed to the increase in dilution of rain water.

G. pH

The river water was slightly alkaline, pH range 7.5 to 7.8 and 7.3to7.8 during pre and post monsoon and was unaffected by seasonal variation. The pH was within the range of 6.5 to 8.5 stipulated for drinking and domestic purposed (WHO-1993). The EU also sets protection limits of pH from 6.0 to 9.0 for fisheries and aquatic life [20]. The pH obtained in river waters was within these ranges. Based on these guidelines, the pH of the river water would not adversely affect its use for domestic and recreational; and aquatic ecosystem. The well buffered natures of the river waters are identified by the nature of the deposits over which they flow [21].

VI. REGRESSION ANALYSIS

Main function of regression analysis is to explore the relationship between a dependent variable and one or more dependent variables. This statistical technique is most commonly used in program evaluation to estimate the effects. This technique, however, can also be applied in fore casting and extant evaluation.

Significant and coherent analysis of regression equations calculated suggest the following facts regarding correlation studies among various Physico-chemical parameters when electrical conductivity is selected as a dependent variable.

The regression analysis carried out to relate conductivity with pH, TDS, Cl^-, $SO4^{-2}$, Ca^{+2}, Na^+ and K^+ gave correlation coefficient 0.672, 0.824, 0.79, 0.91, 0.776, 0.843 and 0.871 during pre-monsoon period indicating very good correlation between parameters, whereas, moderate correlation was obtained between electric conductivity with HCO_3^- and Mg^{+2} (r= 0.443 and 0.439 respectively). However, the correlation was also obtained for BOD & COD (r = 0.376 and 0.269 respectively), though within nearly acceptable range (indicating poor correlation).

The regression analysis was also carried out to relate conductivity with COD, BOD and TDS gave correlation 0.66, 0.67 and 0.903 respectively during post-monsoon indicating very well to good correlation between the parameters, whereas moderate correlation was obtained for conductivity and Cl^{-1}. Rest parameters indicate poor to very poor correlation.

VII. PIPER DIAGRAM

Pipe diagram can define the patterns of spatial change in the water chemistry among geological units, along the line of section or along the path line [22, 23]. In present study, the results of chemical analysis of the sampling points are plotted on piper diagram. Piper diagram demonstrates that river Indus water samples occupy an area ranging from mixing (Fresh & Saline zone) to intrusion waters during pre-monsoon and intrusion zone during post-monsoon period.

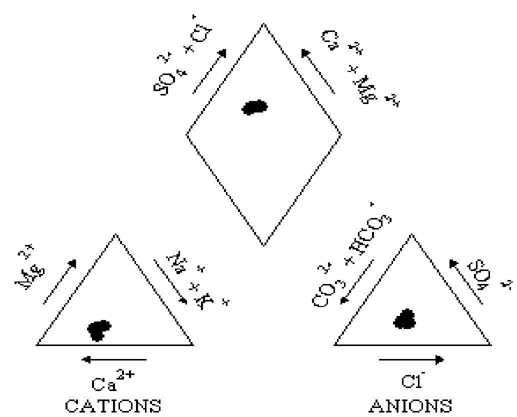

Fig. 1 Piper diagram of pre monsoon data

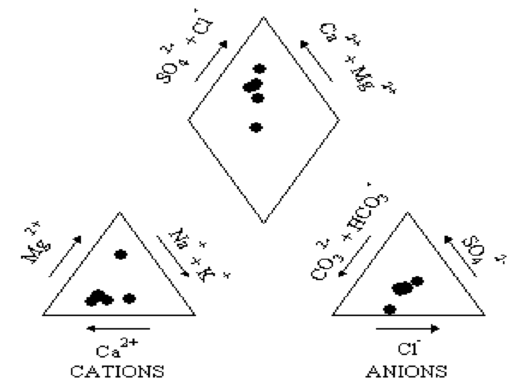

Fig. 2 Piper diagram of post monsoon data

River water is characterized by only one type of hydro chemical facie: $Ca^{+2} + Mg^{+2} + Cl^{-1} + SO_4^{-2}$, which have a tendency to dominate in the lower Indus basin. The rainfall and regional flow from North to West has a significant impact on the spatial distribution of the hydro chemical facie.

VIII. CONCLUSION

It is concluded on the basis of above observations the water quality during Pre-monsoon is reasonably better than Post-Monsoon period. It is due to rain/storm water, which carries away domestic, agriculture and industrial effluent in large quantity with it, resulting in more pollution in River Indus water.

Since water quality parameters and their functions can be explained by using these conditions, utilization of such methodology will thus greatly facilitate the task of rapid monitoring of the status of pollution of water economically and this is one of the important tasks of any pollution study to suggest some effective and economic way of water quality management. On the basis of this study it may be suggested that the Indus River water quality of study area can be monitored effectively by controlling electrical conductivity of water and this may be also applied to water quality management of other study area as well as water bodies.

It is further concluded that Indus River was highly productive and primary productivity was influenced by various factors like eutrofication, agriculture run off, industrial effluents, sewage water and other anthropogenic activities. Productivity was also found to be influenced for seasonal variation and was highest in summer season/ post-monsoon season.

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