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Seasonal variations in physicochemical parameters in relation to algal nutrient enrichment at Tarbela dam, Pakistan

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Abstract

Current industrial and agricultural activities are resulting in discharge of effluents into the water bodies that significantly contribute to water pollution and related problems. Indus River is the major river of Pakistan. Present study was conducted at selected sites (upstream and downstream) of Tarbela Dam to check the status of nutrients. Various physicochemical and biological parameters were analyzed both in summer and winter season to find out nutrient status and its seasonal variation. In summer season average values observed for various parameters were temperature 26.8˚C, pH 8, TDS 174.2mg/l, TSS 26.8mg/l, DO 3.5mg/l, NO_3 1.4mg/l, PO_4 0.18mg/l, BOD_5 31.1mg/l, EC 249.16μS/cm, TH 152.5mg/l and TA 134.31mg/l. In winter season the average values observed were temperature 19.9˚C, pH 7.56, TDS 61mg/l, TSS 17.28mg/l, DO 3.18mg/l, NO_3 0.47mg/l, PO_4 0.02mg/l, BOD_5 10mg/l, EC 118.16μS/cm, TH 102.6mg/l and TA 98mg/l. Large floating algal masses were seen as clear evidence of the river being enriched in nutrients. Study revealed presence of high concentration of nutrients in river, especially in summer season.

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Introduction

Indus River is the major river of Pakistan. It is vulnerable to pollution, due to high population pressure and mismanaged agricultural practices. Once the river was one of a major tourism site at Tarbela reservoir and downstream areas; but it is losing its aesthetic values due to more human exposure to river banks and open-dumping of loads of domestic, commercial and industrial effluents (WAPDA, 2011).

With increase in development, industrial and agricultural practices have also increased (Ashton *et al.,* 2008). But the dark side of the revolutionary era is also being unveiled. Various anthropogenic activities are resulting in the discharge of effluents into the water bodies, which significantly contribute to water pollution and related problems (Litke, 1999). Although the running water in rivers and streams is continuously renewed and is usually considered safe for consumption but natural purification system works till the time when rate of water discharge is less than or equal to the natural degradation process (Vegnetti *et al.,* 2003; Addy and Green, 1996).

Major problems occurring in fresh water reservoirs are low water level due to over usage, rapid siltation by soil erosion, acidification due to acid precipitation, contamination of water and the eutrophication or nutrient enrichment due to excess of nitrates and phosphates (Zeb *et al.,* 2011). A large number of chemicals which either exists naturally in the land dissolve in the water, or human excreta added due to human activity thereby, contaminating and leading to various diseases (Shafiqu *et al.*, 2011). Microbial contamination of drinking water poses a threat to human health due to break out of certain epidemics including gastro-intestinal diseases (Bianchi and Giulaino, 1996). During the year 1988 in Brazil about 2000 cases of algal poisoning along with deaths up to 88 persons were reported in an area with contaminated water (due to presence of *Anabaena* and *Microcystis*) supply from a dam. Even after using boiled water people still caught victim to the diseases (WHO, 2002).

Indus Basin is the most exploited river basin with a diverse ecosystem. Water resource development, in terms of population with improved and easy access to drinking water is also greater in the Indus Basin (87%) as compared to the River Ganges, Brahmaputra and Megna (83%) and Helmand (43%) Basins (Babel *et al*, 2008) .This population pressure poses a direct threat to water reservoirs resulting in water scarcity and loss of ecological balance. Objectives of the present study were to analyze the nutrient status and physicochemical parameters of Tarbela lake from selected sites. So far no study regarding nutrient enrichment has been conducted in the area. This research study will help to find out status of the water quality and recommendations for future use.

Materials and methods

Sample collection sites

Samples were collected from six different sites of the River Indus. Three sites U1, U2 and U3 are located upstream of Tarbela dam and other three D1, D2 and D3 are located in downstream area of the dam. All sampling sites are located in the district Haripur, KPK Province Pakistan; except site D3 which is located in district Sawabi, KPK Province, Pakistan.

Collection of samples

Samples were collected in both winter and summer seasons in 1.5 litre plastic bottles. Bottles were submerged and unscrewed under water facing the mouth in upstream direction and screwed again. Samples were fixed and taken to the lab in ice cooler and analyzed within 24hrs.

Temperature and pH

Temperature and pH of water samples were measured using calibrated pH meter PHEP new (S519705) pH meter in the field. The pH meter was washed with distilled water prior to measuring pH and temperature of each sample.

Electrical Conductivity (EC)

EC was measured with calibrated conductivity DIST 3 new (530205). Pre washed Conductivity meter was placed in water samples one by one. When reading stabilized, it was recorded as the EC of the water sample.

Total Alkalinity (TA)

Water sample of 50ml was taken in conical flask. 2-3 drops of Phenolphthalein were added to check its p-alkalinity. Bicarbonate alkalinity was determined using 2-3 drops of methyl orange and then titrated this against the standard Sulphuric acid till yellow color changed to orange. Used volume of H_2SO_4 was noted (APHA, 1992).

Total Hardness (TH)

First the 50ml well mixed sample was taken in a conical flask. Then 1-2ml of buffer solution and 1-2 drops of Eriochrome Black T were added after which the sample was titrated against standard (0.01 M) EDTA till the color changed from wine red to blue. The volume of EDTA used was recorded (APHA, 1992).

Total Dissolved Solids (TDS)

50ml well shaken water sample was first filtered through filter paper. The filtrate was evaporated to dryness on hot plate at 110°C.

Total Suspended Solids (TSS)

A filter paper was dried and weighed. 50ml well shaken water sample was filtered through this filter paper. After filtration the filter paper was dried on a hot plate (at 110°C) and weighed again for the residue remained on it after filtration.

BOD_5 analysis

For BOD_5 a pre washed DO meter was placed in water samples one by one and initial dissolved oxygen (DO_i) was noted for each sample. Elevation set on DO meter was 1500 ft above mean sea level. Then the samples were placed in air tight BOD bottles and kept in the incubator for 5 days at 20°C. After 5 days the samples were again tested for final dissolved oxygen (DO_f) using the calibrated DO meter. The difference of initial and final readings give the amount of oxygen consumed in 5 days i.e. BOD_5 of the samples.

Dissolved Oxygen (DO)

Dissolved oxygen was measured with calibrated BANTE Dissolved Oxygen Meter model 820. Pre washed DO meter was placed in water samples one by one.

Phosphates (PO_4) using Stannous Chloride Method

Phosphates were analyzed using spectrophotometer. A 50ml water sample was taken in 100ml conical flask and few drops of phenolphthalein indicator were added. If solution turns pink then few drops of H_2SO_4 can be added until the color disappears. Then 2ml of the Ammonium Molybdate solution and 5 drops of stannous chloride solution were added and well shaken. Blue color appeared in the solution. To stabilize the color waited for 10 minutes and then the color was measured using spectrophotometer at 690nm. Readings were compared with the calibration curve using distilled water as standard blank solution.

Nitrate (NO_3) using Phenol-disulphonic Acid (PDA) Method

Phosphates were analyzed using spectrophotometer. 50ml water sample was taken in a china dish and evaporated to dryness on a hot plate. Residue of china dish was washed with 2ml of Phenol-disulphonic acid and then 7ml of concentrated Ammonia solution was added to it. Yellow color appeared. This yellow solution was transferred to 50ml Nessler tube and diluted up to the mark. Color was measured using spectrophotometer set at 410nm and amount of nitrates in the sample was determined by plotting a standard curve using the same method.

Statistical Analysis

All values were measured as means of three and standard deviation was calculated.

Results and discussions

The study of the water showed significantly different results in both seasons. The results also vary from site to site. Overall the upstream site due to less human exposure as compared to downstream shows lower values of parameters. Following results were observed in both seasons:

Physical Parameters

Physical parameters including TSS, TDS, pH and temperature were analyzed in both summer and winter seasons at three upstream and three downstream sites of Tarbela Dam, River Indus (Table I).

Table 1. Average values for physical parameters from selected sites of Tarbela Lake.

Sample from site	TSS (mg/l)		Temp (°C)		TDS (mg/l)		pH	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
D1	20±0.29	20.2±0.288	25±0.05	15.7±0.11	150±1.15	50±1.15	7.4±0.11	7.2±0.173
D2	14±0.17	17±0.05	29.3±0.08	20.1±0.057	184±0.34	65±0.288	7.9±0.23	7.71±0.2
D3	18±0.519	15.2±0.23	30±0.15	22.6±0.69	245±0.17	72±0.173	8.3±0.11	7.8±0.17
U1	40±0.34	15±0	26.8±0.12	22.2±0.23	213±0.57	69±0.577	8.5±0.05	7.98±0.005
U2	31±0.288	19±0.057	24±0.11	18±0.057	115±0.288	52±0.577	7.85±0.03	7.2±0.011
U3	38±0.17	17.3±0.11	25.7±0.17	21±0.23	138±0.57	58±0.23	8.4±0.02	7.51±0.005
Average	26.8	17.28	26.8	19.9	174.2	61	8	7.56
Min site	D2	U1	U2	D1	U2	D1	D1	D1, U2
Max site	U1	D1	D3	D3	D3	D3	U1	U1

TSS showed values 14-40mg/l in summer season. Minimum values were observed during summer at downstream site D2 and maximum values at upstream site U1. U1 is a more populated site and water is exposed to most anthropogenic activities like bathing, washing, fishing, rowing and sewage dumping etc. In winter the values were 15-20mg/l. Minimum values were observed at site U1 and maximum at D3. During winter season the glacial melt decreases and this also significantly reduces the water flow in the river and gives sediments more settling time (Rood *et al.,* 2008). Also the anthropogenic activities are reduced.

TDS showed values between 115-245mg/l in summer and 50-72mg/l in winter season. During both summer and winter seasons the site D3 showed maximum values. This is because the anthropogenic activities are more at this site. Also the water is shallow and flow speed of the river significantly reduced. As the river flows from upstream to downstream the pollution also magnifies point after point as water is a universal solvent (Pohorille *et al.,* 2012). So the combined affect is higher at this site. Site U2 showed minimum values in summer and D1 in winter.

PH varies between 7.4-8.5 in summer and 7.2-7.98 in winter. Site U1 showed higher pH values and D1 lower values in both seasons. It is due to the combined effect of suspended and dissolved solids. Sediments flow is higher in summer and lower in winter (Rajasegar, 2003). PH changes due to change in temperature, salinity and biological activities (Trivedy and Goel, 1984). Temperature record was between 24-30°C in summer and 15.7-22.6°C in winter. During both seasons the shallow water site D3 showed higher values of temperature. Shallow waters usually have higher temperature due to the direct thermal absorption and little stratification (Paldor, 1979). On the other hand site U2 and D1 showed minimum values in summer and winter season respectively. These sites have relatively deeper water.

Chemical Parameters

Chemical parameters also showed variation in both seasons (Table II). EC showed values between 227-280mg/l in summer and 102-134mg/l in winter. During summer season the maximum values were recorded at site D3 and during winter at site U1. TA showed values between 97.52-171.72mg/l in summer and 72-116mg/l in winter. Maximum concentrations were shown by site U1 in summer and D3 in winter. While for TH the values were between 124-180mg/l in summer and 85-121mg/l in winter. The sites showing maximum concentration were U1 during summer and D3 during winter season. TH, TA and EC are due to the presence of ions in water. These ions result due to mixing of mineral substances from soil and atmosphere (Kuzhali *et al.,* 2012). Certain reactions may occur between anions and cations present in water which could result in formation of precipitates and foul smells in water bodies (Smil, 1996). Hardness results due to the presence of multivalent metallic cations in water which react with anions in water to form solid precipitates. The multivalent cations in water are mostly calcium and magnesium while others may include iron, manganese, strontium and aluminum (Leng, 2009). EC is the measure of both TA and TH. Results of the study are consistent to data recorded from the area that these sites are near the populated areas and anthropogenic activities are regularly carried out in these sites like deposition of liquid and solid waste and washing along the bank etc.

Table 2. Average values for chemical parameters from selected sites of Tarbela Lake.

Sample from Site	EC (µS/cm)		TA (mg/l)		TH (mg/l)		D.O (mg/l)		BOD_5 (mg/l)	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
D1	229±0.23	111±0.75	97.52±0.028	90±2.02	132±0.6	92±0.11	4.6±0.35	4.5±0.57	16.8±0.4	4.22±0.011
D2	246±0.17	119±0.288	122.96±0.61	104±0.2	152±1.15	102±0.6	3.5±0.34	3.8±0.2	41±0.98	9.49±0.011
D3	280±0.58	130±0.23	137±1.15	116±1.15	165±0.288	121±0.57	2.1±0.09	2.7±0.17	52±0.98	16.02±0.011
U1	278±0.35	134±1.15	171.72±0.09	112±1.5	180±0.43	118±0.6	2.6±0.057	2.5±0.23	38±0.57	12.69±0.67
U2	227±0.21	102±0.98	133.56±1.5	72±0.05	124±0.11	85±0.57	4.3±0.05	3±0.144	13±0.28	7.78±0.017
U3	235±0.11	113±0.57	143.1±0.05	94±0.288	162±0.8	98±0.46	4±0.57	2.6±0.15	26±0.57	10.33±0.11
Average	249.16	118.16	134.31	98	152.5	102.6	3.5	3.18	31.1	10
Min site	U2	U2	D1	U2	U2	U2	D3	U1	U2	D1
Max site	D3	U1	U1	D3	U1	D3	D1	D1	D3	D3

Dissolved Oxygen concentrations observed during summer were between 2.1-4.6mg/l and during winter 2.5-4.5mg/l. Maximum concentration were observed at site D1 during both seasons. Higher DO values depict little aerobic activity and good water quality (Atkinson *et al.,* 2007).

Lower DO values were observed at site D3 in summer and U1 in winters; which are most human exposed sites. Higher DO values during rainy summer season may be due to the cumulative effect of higher wind velocity joined with heavy rainfall and the resultant fresh water mixing (Ramalingam *et al.,* 2011).

BOD and DO are negatively correlated with each other. BOD values measured during summer were 13-52mg/l and in winter 4.22-16.02mg/l. Site D3 showed maximum values in both seasons. Higher BOD values depict a condition called hypoxia or low oxygen. Algal blooms may lead to hypoxia and in severe cases anoxia (no oxygen) in the water too (Heisler *et al.,* 2008). D3 is a shallow downstream site having relatively deeper light penetration and warmer water with most human activities. These conditions are ideal for algal growth and hence due to aerobic respiration of algae the levels of dissolved oxygen decrease in water.

Algal Nutrients

Nitrate and phosphate are the most important algal nutrients present the river water. The presence of both stimulates algal growth. Along with other parameters algal nutrients were also observed in both seasons (Table III).

Table 3. Concentration of algal nutrient at selected sites of Tarbela Lake.

Sample from Site	NO_3 (mg/l)		PO_4 (mg/l)	
	Summer	Winter	Summer	Winter
D1	0.53±0.17	0.09±0.028	0.056±0.01	0.011±0.005
D2	0.9±0.08	0.35±0.034	0.034±0.002	0.023±0.0011
D3	4±0.15	0.97±0.011	0.51±0.02	0.076±0.0034
U1	1.8±0.23	0.88±0.06	0.042±0.001	0.043±0.001
U2	0.5±0.05	0.21±0.017	0.028±0.002	0.01±0.002
U3	0.68±0.04	0.34±0.017	0.041±0.001	0.015±0.002
Average	1.4	0.47	0.18	0.02
Min site	U2	D1	U2	U2
Max site	D3	D3	D3	D3

Phosphates measured during summer season were 0.028-0.51mg/l and in winter it was 0.01-0.076mg/l. In both seasons site D3 showed maximum concentration. Phosphorus appears exclusively as phosphates in aquatic environment. Phosphates may be soluble or in the particulate form or may be constituents of plant tissues (Mohemed, 2014). It is used extensively in fertilizers to enhance the fertility of soil in agricultural lands. It is also an ingredient of animal waste (UNESCO, 1997). Condensed phosphates are used as builders in detergents and organic phosphate is also a component of body waste and food residue. Other sources are industrial waste water in which phosphate compounds are used for different purposes (UNEP, 1998). Phosphates are not toxic and do not represents direct impact on human and other organisms. But they do represent a serious indirect effect on water quality (Sharpley, 2016). It is a limiting nutrient but when available in excess cause rapid growth of aquatic plants and algal blooms. According to an estimate, 400 grams of phosphates could potentially bring on algal blooms to an extent of 350 tons (Sharma, 2009). Phosphate concentrations are higher at site D3 due to washing and bathing activities and more sewage mixing in water from domestic and industrial effluents.

Nitrate values measured during summer season were 0.5-4mg/l and during winter 0.09-0.97mg/l. Maximum concentrations were observed during both seasons at site D3 due to more human exposed site and also the domestic animals visiting regularly to this site. Nitrogen constitutes about 80 percent of the atmosphere and is a vital element for plant metabolism. Like phosphorus, nitrogen is also imperative in the primary production of an aquatic ecosystem. According to Hedin *et al.,* 1998 and Goolsby *et al.,* 2001, nitrate represents the dominant form of N in enriched ecosystems which is highly soluble and hence seeps easily in water from soil. On reaching water bodies it is also readily taken up by algae and bacteria, which can cause excessive growth of these microbes in aquatic systems (Ombaka *et al.,* 2012). Chief sources of nitrogen widely range from agricultural to domestic waste and from urban and commercial wastes to air and back to water through rainfall. When phosphorus is in plenty, nitrogen would be regarded as a limiting nutrient in biomass production (Vahtera *et al.,* 2007).

Conclusion

Keeping in view all above results; the Indus River shows early signs of water contamination due to nutrient enrichment. It is also evident that humans are the chief contributors in this case. As many people along the banks are relying on untreated river water for drinking and bathing, but the results of the study show that it is unhygienic to use this water untreated. Although the river is partially eutrophied at present; but the effects could be adverse in coming decade. There is also a possibility of reduced water quantity along with quality in further downstream areas because algal blooms use up significant amount of water.

Recommendation

In order to safeguard the river, anthropogenic activities must be reduced by ensuring the proper water supply lines in each house. Open dumping of untreated waste must also be reduced. National Environment Water Quality Standards also need to be implemented on the water of entire River Indus.

Abbreviations

BOD (Biological Oxygen Demand), DO (Dissolved Oxygen), NO_3 (Nitrates), PO_4 (Phosphates), TH (Total Hardness), TA (Total Alkalinity), EC (Electrical Conductivity), TSS (Total Suspended Solids), TDS (Total Dissolved Solids).

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