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Anthropogenic Activities and Water Quality: A Case of River Satluj, Pakistan

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Abstract. Pakistan has large freshwater reservoirs and Satluj river is one of them. Length of river Satluj in Pakistan comprises 329 miles. Through the Indus Water Treaty between Pakistan and India, three rivers management has been assigned to India, Satluj is one of them.Pakistan with the help of World Bank, has made water reservoirs and link canals to use the river bed of Satluj. The main objective of study was to find out Water Quality Parameters during the present study seasonally. Overall seven factors were selected for the current study; which were temperature, pH, dissolved oxygen, total dissolved solids, total alkalinity and total hardness. All the water quality parameters under investigation revealed their presence in permissible limits as prescribed by National and International quality guidelines (except dissolved oxygen) and fit for aquatic fauna. Dissolved oxygen remained 4 ppm in summer) and (4.5 ppm in winter) at SZ-1. It might be due the less water discharge and the presence of municipal and industrial wastes at Sulemanki Barrage (study zone-1) of the study area. Moreover, the river water of Satluj investigated throughout the research period indicated that water contamination was due to the various anthropogenic activities.

Keywords: river Satluj, water quality, anthropogenic activities, fresh water resources

Introduction

On this earth, no living creature can survive without water, the most important of all for life. Human beings and fresh water bodies are strongly bound to each other. Every human civilization began, grew and flourished only at the places blessed with fresh water resources. Water plays an exceptional role in nature. The discharge system of a river is crucial to be understood for various reasons. The most important one being the interpretation of water quality measurement, specifically of those that carry suspended sediment or planned to find out the flux of sediment or contaminant (Mallika *et al*., 2017; Sharma and Walia, 2017).

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Pakistan covers an area of 796,096 km^2 and stretches from 24° N on the Arabian sea coast to 37° N, where the northern mountainous regions border the Pamir Wakhan. Most of the country could be described as semi desert with a subtropical climate. In the major desert tracts, average annual precipitation is only 20-40 mm, with large areas often receiving no rain at all in some years. The highest rainfall zone lies along the Himalayan outer foothills of which Hazara district and the Murree Hill range experience an average of 6.5 m of winter snow (Grimmett *et al*., 2008).

Now a days, environmental impact on bio-diversity related to water reservoirs, results through water pollution of various anthropogenic activities. The main aim of the current study was to evaluate the physico-chemical properties of river water.

Materials and Methods

Study area. The Satluj ascends from the north slant of the greater Himalaya in Lake Rakshas Tal in south west Tibet, at a height over 15,000 ft (4.6 km). Streaming towards north west and after that west-south-west from the Himalaya canyons, it goes through and passes Himachal Pradesh, just prior starting its course during the Punjab (India) land. Proceeding with south westward in a wide channel, it is joined by the Beas waterway for 105 kilometres, at the Indian-Pakistani boundary ahead of in flowing to Pakistan and streaming a further 350 kilometre, to meet the River Chenab, west of Bahawalpur district and start of Muzaffargarh district Fig 1. (Sharma and Walia, 2017; Haider, 2011).

Collection of water samples. Samples were collected seasonally (June 2015 to May 2017) from different sites of river Satluj along the river stretch of approximately 372 km in Punjab province. The study area was divided into four zones, Sulemanki zone, Islam zone, Mailsi Syphone zone and Panjnad zone (Fig 1). Each zone was further divided into three sub sampling points, making total 12 sampling sites. The water was collected in glass bottles of 1 L capacity.

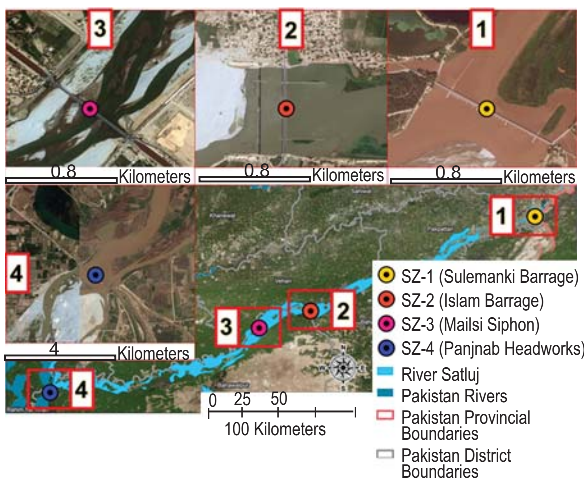

Fig. 1. Map of study area.

Physico-chemical parameters of water. The physical and chemical parameters of river water, including Dissolved Oxygen (DO), pH, conductivity, Temperature, Total Dissolved Solids (TDS), Electrical Conductivity (EC) and alkalinity were determined by using multi-parameter instrument (HANNA-9829), while total hardness (TH) by the portable instrument (HI-96735).

Results and Discussion

The temperature remained non-significant ($P > 0.05$) for all the study zones, during winter and summer (Table 1 and 2). Minimum temperature was observed during winter at SZ-4, with minimum 16 °C along mean 20.80±1.16 °C, while mean temperature during winter for SZ-1, SZ-2 and SZ-3, remained 20.30±0.76 °C, 18.77±0.88 °C and 21.20±0.76 °C, respectively (Table 1). Average minimum temperature was noted in summer at SZ-2, 26.3 °C together with mean 26.03±0.68 °C, while the mean temperature noted in other three zones during summer were 27.83±0.68 °C, 27.50±0.49 °C and 26.70±0.47 °C, respectively for SZ-1, SZ-3 and SZ-4 (Table 1 , Fig. 2).

pH is usually used for investigating the acid base balance affecting the aquatic ecosystem. Present values remained variable from neutral to alkaline. Maximum pH during winter was noted at SZ-3, with an average (7.48±0.17). The pH observed during the present study showed values significantly different ($P < 0.05$) at SZ-3 during winter season (Table 1). Mean pH of SZ-2 during summer in the study area (6.92±0.13) showed significant difference to the mean pH of SZ-3 (7.90±0.22) as mentioned in Table 1 & 2. Also mean pH (summer) of

Table 1. Mean±SE for different water quality parameters during winter season

WQP	Study zones			
	SZ-1	SZ-2	SZ-3	SZ-4
Temperature (°C)	20.30±0.76^{A}	18.77±0.88^{A}	21.20±0.76^{A}	20.80±1.16^{A}
pH	6.98±0.07^{B}	6.82±0.21^{B}	7.48±0.17^{A}	6.87±0.13^{B}
DO (ppm)	4.50±0.20^{C}	6.05±0.41^{AB}	5.40±0.4^{BC}	6.41±0.16^{A}
EC (µS/cm)	200.70±20.2^{B}	205.20±11.4^{B}	188.00±11.6^{C}	220.70±6.54^{A}
TDS (ppm)	124.00±8.73^{A}	144.90±8.13^{A}	144.90±8.13^{A}	133.10±12.0^{A}
TA (ppm)	132.00±8.39^{B}	116.00±4.88^{C}	107.90±3.45^{D}	143.40±8.53^{A}
TH (ppm)	155.30±11.7^{A}	132.80±11.9^{B}	126.30±8.49^{B}	115.90±4.34^{C}

Means sharing similar letter in a row are statistically non-significant (P>0.05).

Table 2. Mean±SE for different water quality parameters during summer season

WQP	Study zones			
	SZ-1	SZ-2	SZ-3	SZ-4
Temperature (°C)	27.83±0.68^{A}	26.03±0.68^{A}	27.50±0.49^{A}	26.70±0.47^{A}
pH	7.33±0.18^{BC}	6.92±0.13^{C}	7.90±0.22^{A}	7.51±0.16A^{B}
DO (ppm)	4.08±0.10^{C}	6.01±0.40^{A}	5.45±0.37^{AB}	4.65±0.45^{C}
EC (µS/cm)	276.60±5.53^{B}	284.60±7.16^{B}	294.20±11.9^{AB}	311.40±9.59^{A}
TDS (ppm)	191.70±0.42^{A}	229.40±22.9^{A}	172.70±26.8^{A}	215.20±27.2^{A}
TA (ppm)	84.52±1.29^{B}	92.80±2.46^{AB}	98.70±4.21^{A}	97.40±4.19^{A}
TH (ppm)	135.90±4.77^{A}	134.00±7.18^{A}	126.60±6.83^{A}	125.40±6.78^{A}

Means sharing similar letter in a row are statistically non-significant (P>0.05).

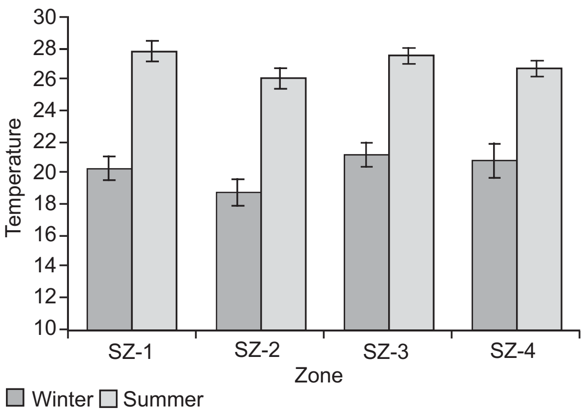

Fig. 2. Seasonal fluctuations of temperature effect on water quality.

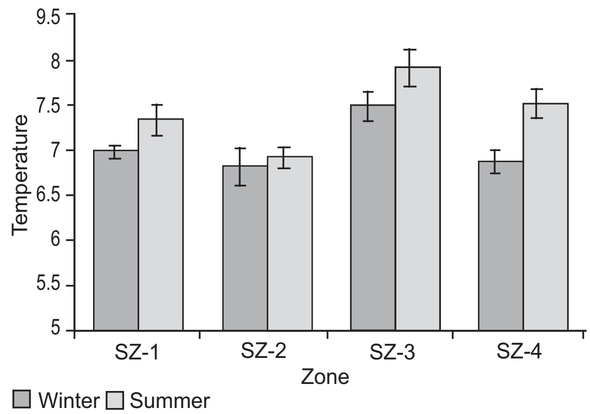

Fig. 3. Seasonal fluctuations of pH effect on water quality.

SZ-2 (6.92±0.13) and SZ-4 (7.51±0.16) reflected the same statistically significant pattern (Table 2), while the other zones of the study area was remained non significant during summer (P>0.05). It was noted that pH values observed during winter, were comparatively low (Fig 3). Sinlan finding were also oberverd by Azmet *et al*. (2016) and Rajan and Saranya (2017).

Oxygen is critical to the survival of aquatic organisms and a shortage of Dissolved Oxygen (DO) is not only a sign of pollution, it is harmful to fish. This DO can be obtained from the surrounding environment. The present study reflected significant difference (P<0.05) in mean values of dissolved oxygen of water in summer season among SZ-2 (5.45±0.37 ppm) and SZ-1 (4.08±0.10 ppm) and between SZ-4 (4.65±0.45 ppm) and SZ-2 (5.45±0.37 ppm) (Table 2, Fig. 7). During winter season, DO at SZ-1 (4.50±0.20 ppm) and SZ-4 (6.41±0.16 ppm) remained with difference significantly (P>0.05), while SZ-2 (6.05±0.41 ppm) and SZ-3 remained non significant (P>0.05) Table 1, Fig. 4. This might be possible due to increased decomposition rate of organic matter and limited flows of water, leading to consumption of oxygen from water.

Seasonal fluctuation in Electrical Conductivity (EC) was recorded high in the summer season (311.40±9.59) µS/cm for SZ-4 and low in winter season (188.00±11.6) µS/cm for SZ-3 (Table 1 & 2; Fig. 5). Total dissolved solids were found high in winter season as compared to summer season (Table 1 and 2; Fig. 6).

Total alkalinity (TA) of water is because of the presence of salts, amount of fragile acid and of the balanced cations across them. The presence of carbonate and bicarbonate ions is mainly causing factors. High levels of alkalinity have bad effects on the aquatic life. The mean values of alkalinity were found in winter season for SZ-1, SZ-2, SZ-3 and SZ-4 having (132.00±8.39) ppm, (116.00±4.88) ppm, (107.90±3.45) ppm and (143.40±8.53) ppm, respectively (Table 1). The mean values obtained during winter season showed a significant difference among all the study zones selected during this study (Table 1). The mean values of alkalinity

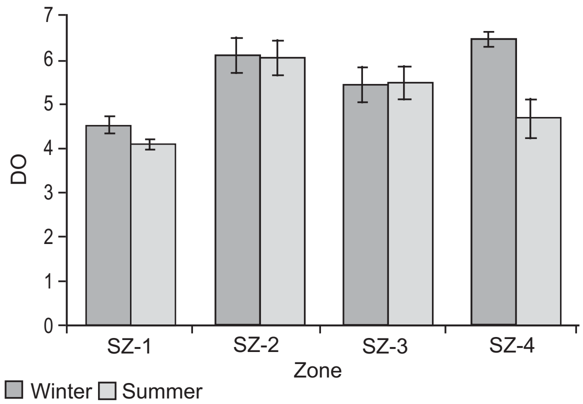

Fig. 4. Seasonal fluctuations of DO effect on water quality.

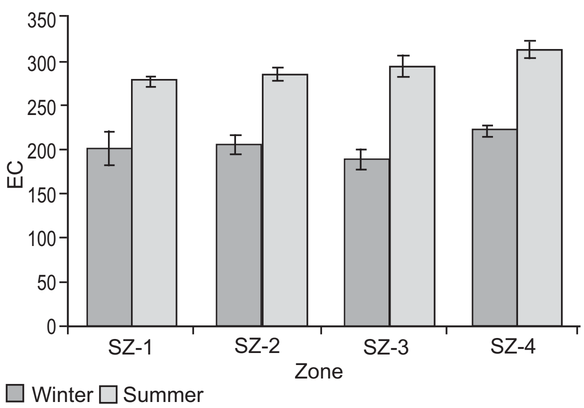

Fig. 5. Seasonal fluctuations of EC effect on water quality.

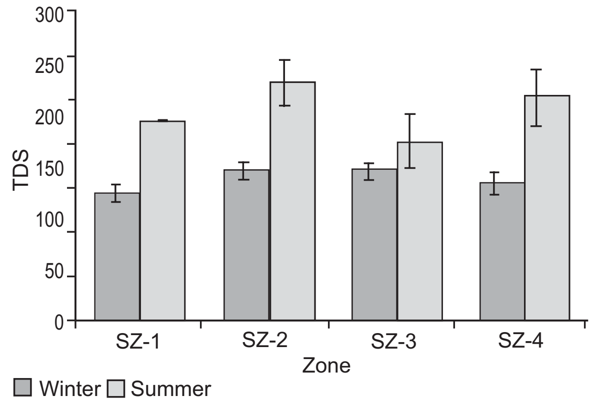

Fig. 6. Seasonal fluctuations of TDS effect on water quality.

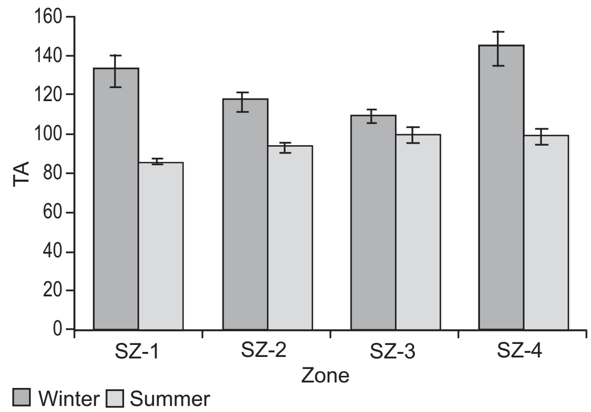

Fig. 7. Seasonal fluctuations of TA effect on water quality.

were found in summer season for SZ-1, SZ-2, SZ-3 and SZ-4 were (84.52±1.29 ppm), (92.80±2.46) ppm, (98.70±4.21) ppm and (97.40±4.19) ppm, respectively. The study zone 2 and study zone 4, showed significant differences in mean values during summer season (Table 2, Fig. 7).

Water hardness can be determined by the levels of multivalent cations. Hardness of water and fish tolerance has been found interrelated. The hardness of water is being considered an important factor which effect on the flora and fauna of fresh water. Total hardness was observed lowest during winter (115.90±4.34) ppm at SZ-4, while high at SZ-1 with 155.30±11.7 (ppm). In summer it was noted as 140 (ppml) at SZ-1 and 125 (ppm) at SZ-4 (Fig. 7).

Temperature and pH, result showed highly significant correlation during summer season at SZ-1 (Table 2). The result obtained from present study indicated that temperature correlation remained highly significant to dissolved oxygen, total dissolved solids, and significant to total hardness positively (Table 1 and 2).

Dissolved oxygen and pH also remained as highly significant correlation positively during summer season at SZ-1. Total hardness and total dissolved solids appeared as highly significant correlation positively during the summer season, while all the other factors remained in low correction to each other (Table 1 and 2).

Electrical conductivity and pH showed significant correction positively to each other for SZ-2, during winter season in the present study (Table 1). The other factors remained in low to moderate correlation either positively and negatively in winter season for study zone 2. During winter, in the same study zone (i.e., SZ-2), there were low to moderate correlation among all the studied water quality parameters describein (Table 1 and 2).

The data of water quality parameters in winter season studies during the current research at study zone 3 reflected that pH and total alkalinity appeared in significant correlation positively, while all the other showed no correlation. Similarly, in same study zone 3, during summer season, pH and dissolved oxygen appeared in significant correlation positively. The remaining factors showed no significant correction to each other in said study zone.

The study zone 4 (Panjnad Barrage) water quality parameters, findings during winter in current study revealed that dissolved oxygen and pH, total harness and electrical conductivity, had significant correlation positively to each other, while the remaining ones factors had no correlation. During summer, in SZ-4, electrical conductivity and pH showed highly significant correlation positively. Also the dissolved oxygen and EC showed the significant correlation positively to each other. The results obtained from this study, reflected there were no significant correlation to all other factors of water quality parameters during summer season for the study zone 4.

Water temperature is being regarded a vital factor influencing various physico- chemical besides biological activities (Rajan and Saryana, 2017). Water temperature is fluctuated due to various climatic conditions. It is considered that solar heat and rainfall are the chief climatic conditions, which mostly influence the physico-chemical parameters of water reservoirs (Gomez *et al*., 2012; Khan, 2011; Qadir, 2009). Several factors are responsible in controlling the water temperature, water flow, phytoplankton species diversity, surface area of water, velocity of wind and particles of solid matter suspended in water besides of solar radiations (Khan, 2011). However, temperature was observed during the winter at SZ-4 with minimum of (20.80±1.16 °C), while temperature, remained during the winter for SZ-1, SZ-2 and SZ-3, was 20.30±0.76 °C, 18.77±0.88 °C and 21.20±0.76 °C, respectively. Average minimum temperature was noted in summer at SZ-2(26.3 °C) together with mean 26.03±0.68 °C.The findings clearly indicates the absence of pronounced seasonal variations in surface water temperature of river Satluj.These studies are in consistent with the findings of (Rajan and Saranya, 2017; Khan, 2011).

These values are in line with the findings of others researchers who found DO in freshwater like (Azmat *et al*., 2016; Hussain *et al*., 2013; Mishra *et al*., 2013; Khan 2011; Qadir, 2009).

These high values of Electrical Conductivity might be due to high discharge of soluble salts along with waste from various sources and reduced water flow. River Satluj, receives effluents and other agricultural waste of soluble salts which in turn pose significant effects on freshwater ecosystem. The study conducted by Sharma and Walia, 2017) on river Satluj, Himachal Pradesh India, revealed that higher EC was due to excessive siltation. Electrical conductivity values of preset investigation are in line with other studies (Khan *et al*., 2014; Hussain *et al*., 2013) in which EC values were high in summer and low in winter.

As discussed for EC, maximum TDS recorded during hot period may be correlated to the elevated water temperatures which lead to increase in rate of evapouration as well as increase in dissolved salts in water. The current findings revealed high in summer at SZ-2 (229.40±22.9) and least at SZ-1(124±8.73 ppm). A linear relationship was observed between EC and TDS, which showed high mean values in summer (229 ppm) for SZ-2 and less in winter (124 ppm) for SZ-2. This type of relationship was studied by (Hussain *et al*., 2013; Singh *et al*., 2010) in which both of these factors fluctuated with temperature as high in summer and low in winter.

High levels of alkalinity have bad effects on aquatic life (Jindal and Sharma, 2012; Qadir, 2009).The current study of alkalinity were found in winter season for SZ-1, SZ-2, SZ-3 and SZ-4 having 132.00±8.39 ppm, 116.00±4.88 ppm, 107.90±3.45 ppm and 143.40±8.53 ppm, respectively.The findings obtained during winter season showed sinficant difference among all the selected study zones during this study. The high values in winter could be attributed with low water discharge.

Water hardness can be determined by the levels of multivalent cations. Hardness of water and fish tolerance has been found interrelated. The hardness of water is being considered an important factor which effect on the flora and fauna of fresh water (Khan *et al*., 2014; Khan, 2011). Total hardness was observed lowest during winter (115.90±4.34) ppm at SZ-4, while high at SZ-1 with (155.30±11.7 ppm). In summer it was noted as 140 (ppm) at SZ-1 and 125 (ppm) at SZ-4, described in Fig. 8

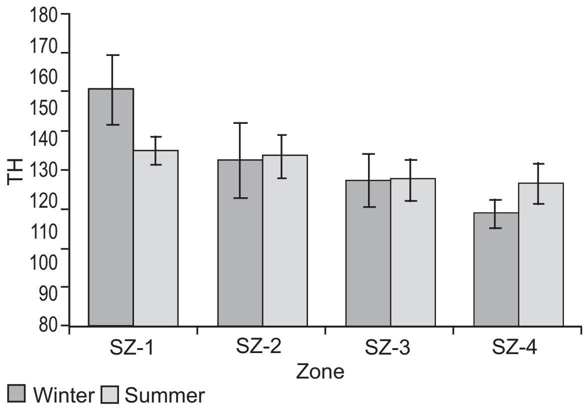

Fig. 8. Seasonal fluctuations of TH effect on water quality.

Conclusion

All the water quality parameters under investigation revealed their presence in permissible limits as prescribed by National and International quality guidelines (except dissolved oxygen) and fit for aquatic fauna. Dissolved oxygen remained (4 ppm in summer) and (4.5 ppm in winter) at SZ-1. It might be due the less water discharge and the presence of municipal and industrial wastes at Sulemanki Barrage (SZ-1) of the study area. Also, it might be possible due to increased decomposition rate of organic matter and limited flows of water, leading to consumption of oxygen from water.

Moreover, the river water of Satluj investigated throughout the research period indicated that water contamination was due to the various anthropogenic activities. Therefore, prompt and relevant actions are required for properly management of wastes in the cities and long term measure and control of human activities in order to ensure lessened effects of these parameters on the river Satluj. Ever increasing anthropogenic activities are severely affecting and degrading river habitats. This habitat degradation combined with changes in natural flows of rivers is changing the patterns of distribution of the fish fauna in these water bodies.

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Conflict of Interest. The authors declare they have no conflict of interest.

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