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Effects of Erosion on Indus River Bio-diversity in Pakistan

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Abstract: The present study was conducted to ascertain the impact of erosion and such other factors with particular reference to the river Indus starting from Layyah to Mithan kot. Certain physico-chemical parameters including light penetration (20-205 mm), suspended solids (0.6-3.4 g l^{-1}), alkalinity (90-193 mg l^{-1}), total dissolved solids (150-245 mg l^{-1}), electric conductivity (300-490 mhos), total volatile solids (0.01-0.052 g l^{-1}), dissolved oxygen (7.4-17.4 mg l^{-1}) and pH (7.6-8.52) were taken into account from Layyah, Taunsa Barrage and Mithan kot. Study results revealed that area is subjected to immense erosion pressure exerted by the local hill torrents coupled with influx of upland pollution and Himalayan watershed erosion. It further resulted in enhanced turbidity level that is detrimental to the very survival of endangered Indus Dolphin (*Platanista minor*), certain local fish fauna, aquatic plants and other biotic life forms of the river ecosystem.

Key words: Watershed management, Indus river, bio-diversity of Pakistan, water quality, pollution, drought, erosion, turbidity

Introduction

The Indus river forms one of the worlds' greatest, oldest and longest river systems. Arising at its source in North-western Tibet (at 5,100 m elevation), the Indus river runs the length of 3,180 km from north to its entrance into the Arabian sea (Searle and Owen, 1999) to make most important life sustaining river system of Pakistan (Ahmad, 1999).

Siltation of lakes and streams, due to soil erosion is one of the most serious, damaging and widespread pollution. Most of the soil erosion arises by hill degradation during the rainy season, due to deforestation, intensive agriculture, mining, extensive road building projects, extensive house building schemes, leaving large dumps of sand and debris. Natural silting is going for thousands of years as a slow process but manmade silting has become 5-fold during last 20 years of silt pollution. Siltation not only affects the organisms but also changes the character of water body completely (Ali, 1999).

Indus is one of the highly turbid and torrential river in its upper reaches. After emerging from its source, it gorges through hilly rough and rugged mountain ranges (Rafique, 2000). Rivers in hilly areas usually flow through confined sections and carry away the entire sediment load. All the important tributaries of Indus such as Siran, Harrow, Soan, Kabul and Kurrum flow through hilly tracts. Infact Kalabagh is the first site on the Indus where the river debouches out of the hills into the plains. The tributaries of Indus also bring with them the eroded soil. The Kurrum for instance, passes the highest order of eroded material nearly 3-1/4 times that of the Indus above Durband (Ahmad and Pervez, 1963).

Estimation of water quality is among frequently conducted research activities in Pakistan. Chowdhry *et al.* (1997) have analyzed the physico-chemical characteristics of river Indus like pH, conductivity, total dissolved solids, alkalinity, chloride contents, chemical oxygen demand and mineral elements (Na, K, Ca, Mg). However, no attempts have been noticed to depict erosion effects on freshwater ecosystems in Pakistan. Thereafter, this study represents an assessment of erosion impacts on water quality and bio-diversity of river Indus.

Materials and Methods

Samples were collected on monthly basis from Layyah (GPS: N 30 59 553, E 070 51 276), Taunsa Barrage(GPS: N 30 30 805, E 070 51 372) and Mithan kot(GPS: N 28 56 999, E 070 22 935) for a period of 10 months from May 2001 to February 2002 (Fig. 1). Climate of the region is arid and semi-arid with hot summers and mild winters (Khan, 2000).

The water samples were collected from the river streams at the depth of 0.5 m in acid washed polystyrene bottles and were brought to the laboratory. The samples were immediately refrigerated at 4°C and various physico-chemical parameters were analyzed within 24 h. Standard water quality analytical protocols were adopted following Boyd (1979) and Slingsby and Cook (1986). Mean, standard deviation and range values were computed. Results were compared with standard water quality indicators to evaluate probable pollution.

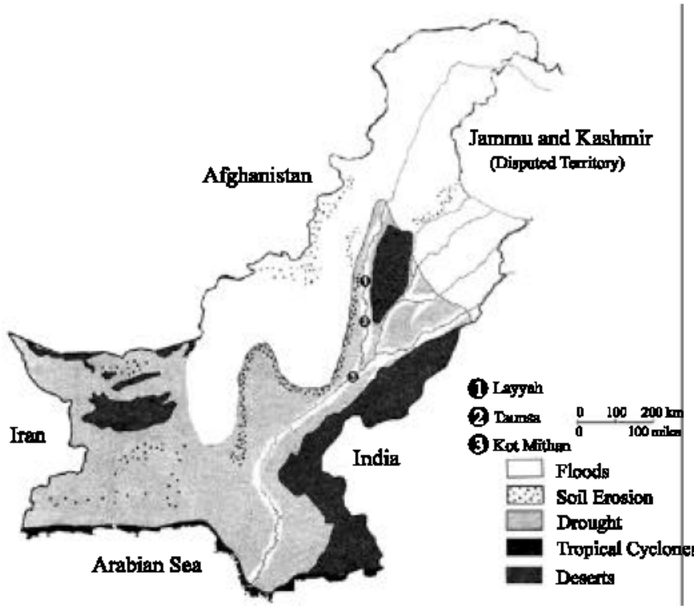

Fig. 1: Map of Pakistan showing areas of natural hazards including erosion and study area (Source: Khan, 2000)

Results

The overall range of light penetration was 20-205 mm. The highest value (205 mm) was observed at Mithan kot in December and lowest (20 mm) at Mithan kot in July (Fig. 2, Table 1).

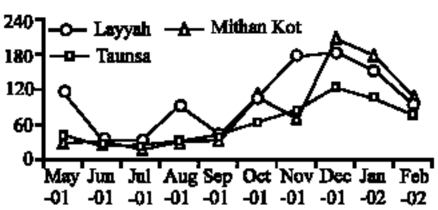

Fig. 2: Monthly variation in light penetration

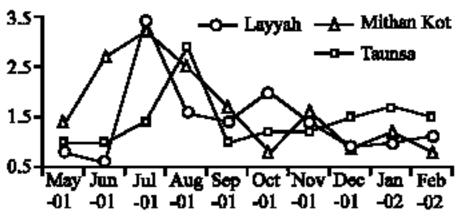

Fig. 3: Monthly variation in suspended solids

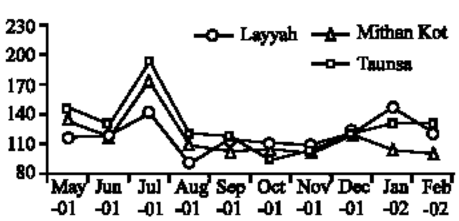

Fig. 4: Monthly variation in alkalinity

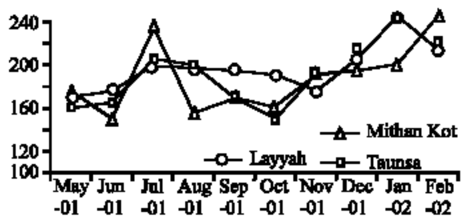

Fig. 5: Monthly variation in total dissolved solids

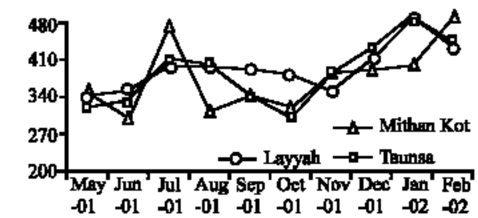

Fig. 6: Monthly variation in conductivity

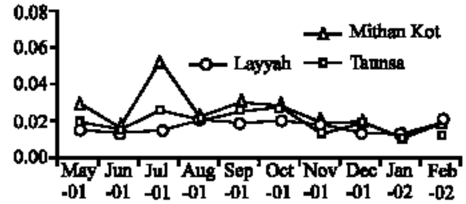

Fig. 7: Monthly variation in volatile solids

The overall range of suspended solids was 0.6-3.4 g l^{-1}. The highest value (3.4 g l^{-1}) was observed at Layyah in July and lowest value (0.6 g l^{-1}) at Layyah in June (Fig. 3, Table 1).

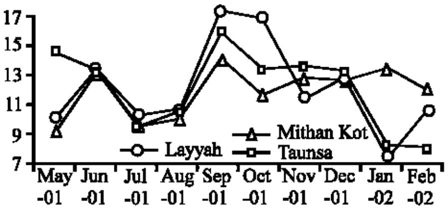

Fig. 8: Monthly variation in dissolved oxygen

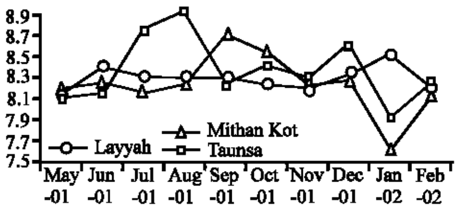

Fig. 9: Monthly variation in pH

The value of suspended solids showed high values from June to August indicating the introduction of sediments via runoff during monsoon rains. This was accompanied by consequent impacts on light penetration that showed a decreasing trend during the period. The values remained lower until November after which local rains again increased the suspended load of the river but smaller in comparison to that during monsoons. Light penetration followed the inverse trend, i.e., increasing in post-monsoon period and then decreasing during winter rains.

The overall range of alkalinity was 90-193 mg l^{-1}. The highest value (193 mg l^{-1}) was observed at Taunsa in July and lowest value (90 mg l^{-1}) at Layyah in August (Fig. 4, Table1).

The alkalinity values showed a sharp increase during July monsoons. It shows the high input of bases into the river via runoff. Since these substances are involved in the buffering system of water body, so they showed a decline onwards. Due to local rains the values increased during December and January and subsequently declined during February.

The overall range of total dissolved solids was 150-245 mg l^{-1}. The highest value (245 mg l^{-1}) was observed at Layyah in January, at Taunsa in January and at Mithan kot in February. The lowest value (150 mg l^{-1}) was observed at Layyah in August, at Taunsa in October and at Mithan kot in June (Fig. 5, Table1).

The overall range of conductivity was from 300-490 mhos. The highest value (490 mhos) was observed at Layyah in January, at Taunsa in January and at Mithan kot in February. The lowest value (300 mhos) was observed at Layyah in August, at Taunsa in October and at Mithan kot in June (Fig. 6, Table1).

Overall the total dissolved solids values were higher during summer and winter rainfalls, which shows input of dissolved solids via run off from catchment area. This demonstrates the effects of erosion on water quality. The values of electrical conductivity are proportional to the TDS concentration (Tebbutt, 1998). This relationship has been quite obvious from this result.

The overall range of total volatile solids was 0.01-0.052 g l^{-1}. The highest value (0.052 g l^{-1}) was observed at Mithan kot in July and lowest value (0.01g l^{-1}) was observed at Taunsa in January (Fig. 7, Table1).

On the whole total volatile solid values increased during monsoon period and were low in post-monsoon. The values again increased during winter rains.

Table1: Mean, Standard deviation and Range values of various parameters used to evaluate erosion at different locations along the River Indus

Parameters	Layyah	Taunsa	Mithan kot
Light penetration (mm)	99.8±56.04	60.2±35.31	80.6±66.08
	(30-180)	(23-123)	(20-205)
Suspended solids (g l^{-1})	1.42±0.8	1.44±0.46	1.68±0.84
	(0.6-3.4)	(1-2.9)	(0.8-3.2)
Alkalinity (mg l^{-1})	118.3±16.04	128.3±26.89	116.4±22.88
	(90-146)	(94-193)	(100-174)
Total dissolved solids (mg l^{-1})	196.7±22.24	192±30.48	187.5±32.43
	(150-245)	(150-245)	(150-245)
Conductivity (mhos)	393.5±44.48	384±60.96	375±64.85
	(300-490)	(300-490)	(300-490)
Total volatile solids (g l^{-1})	0.0191±0.0089	0.0211±0.0118	0.0234±0.0012
	(0.012-0.043)	(0.01-0.051)	(0.012-0.052)
Dissolved oxygen (mg l^{-1})	12.06±3.11	12.03±2.75	11.83±1.71
	(7.4-17.4)	(8.06-15.93)	(9.2-14.06)
pH	8.28±0.1	8.35±0.3	8.22±0.28
	(8.2-8.38)	(7.91-8.1)	(7.6-8.52)

The overall range of dissolved oxygen was 7.4-17.4 mg l^{-1}. The highest value (17.4 mg l^{-1}) observed at Layyah was in September whereas, the lowest value (7.4 mg l^{-1}) was observed in January at Layyah (Fig. 8, Table1).

The overall decrease in DO levels during July and August may be attributed to lower light penetration, elevated suspended load, increased dissolved and volatile solids and high temperature.

The overall range of pH was 7.6-8.52. The highest value (8.52) was observed at Mithan kot in October and lowest value (7.6) at Mithan kot in January (Fig. 9, Table 1).

In general the pH values showed a boost in the months of July, August and September and a reduction after December.

Discussion

Up to Layyah the sediment load (0.6-3.4 mg l^{-1}) in Indus river is the product of erosion in its own drainage area as well as its upper tributaries. At Taunsa the impact of local hill torrents (Suleman ranges) becomes pronounced (Fig. 1) and sharp increase in turbidity (1-2.9 mg l^{-1}) can be observed. Erosion has strong influences on various water quality parameters.

Increased turbidity may reduce light below levels needed to sustain photosynthesis (Jefferies and Mills, 1990).

Silngsby and Cook (1986) have classified waters with reference to the extent of light penetration in following manner:

Good waters:	Light penetration above 600 mm
Satisfactory:	Light penetration above 300 mm
Poor waters:	Light penetration above 100 mm

The observed range of light penetration is 20-205 mm, which clearly demonstrates the poor water quality conditions of Indus river. By restricting light penetration, excess turbidity leads to fewer photosynthetic organisms available to serve as food sources for many invertebrates whose numbers may decline as a result, which may then lead to a fish population decline (Tebbutt, 1998). According to Trivedi and Gurdeep (1992), waters with less than 2.5 mg l^{-1} turbidity show more light penetration, 12.8 times more planktons and 5.5 times more fish production. While the waters with turbidity exceeding 100 mg l^{-1} have low light penetration and low fish production. Throughout the study period, suspended solid contents have remained enormously high with a range of 0.6-3.4 g l^{-1}, which is quite alarming. Aquatic vegetation is destroyed by muddy water. It may be a source of food for fish and wildfowl, or it may be serving as protection for some of the lower forms of life. In either case, however, some food chain is almost certain to be broken and higher forms of life will suffer as a result (Masrur, 1970). Moreover, these particles gather on gill filaments, block them up and reduce the area of gas exchange (Ali, 1999). During monsoon rains in the month of July, a sudden rise in suspended load of water was observed. The amount of suspended solids increased from 0.6 g l^{-1} in June to 3.4 g l^{-1} in July at Layyah, at Taunsa from 1 to 1.4 g l^{-1} and at Mithan kot an increase from 2.7 to 3.2 g l^{-1} was observed.

The increase in turbidity during monsoon has quite detrimental impacts upon the aquatic bio-diversity, particularly fish because they spawn in this season. According to Ali (1999), the suspended solids may burry the eggs and kill them. In murky waters another problem that the fish face is accuracy in mate recognition during spawning. Seehausen *et al.* (1997) have indicated that increasing turbidity of littoral waters is constraining mate recognition systems and this has resulted in decreased color diversity and a greater probability of hybridization.

Alkalinity is a measure of such ions in water that will react to neutralize H^+ ions. In most natural waters alkalinity is entirely due to HCO_3^-, CO_3^{-2} and OH^- ions (Abbasi, 1998). In these results only HCO_3^- and CO_3^{-2}alkalinity was detectable and their were no indication of OH^- alkalinity. According to Rath (1993), waters with alkalinity in the range of 50-200 mg l^{-1} are thought as most productive. The observed alkalinity values (90-193 mg l^{-1}) are within optimal range for productivity.

The concentration of total dissolved solids and hence conductivity increases during rainfall. The concentration of dissolved solids increased from 175 mg l^{-1} in June to 200 mg l^{-1} in July at Layyah, at Taunsa from 165 to 205 mg l^{-1} and at Mithan kot an increase from 150 to 235 mg l^{-1} was observed.

The value of conductivity increased from 350 mhos in June to 400 mhos in July at Layyah, at Taunsa from 330 to 410 mhos and at Mithan kot an increase from 300 to 470 mhos was observed.

This increase in the concentration of dissolved solids and conductivity reflects high erosion pressure in the Indus river watershed. A maximum value of 400 mg l^{-1} of dissolved solids is permissible for diverse fish population (Frank and Cross, 1974). The observed range (150-245 mg l^{-1}) is below the maximum level. But if erosion persists, the total dissolved solid contents may elevate to a harmful extent. Since this increase interferes with the physical and biological characteristics of aquatic system, a further increase can lead to hazardous environmental impacts. The increase in the concentration of dissolved solids decreases the oxygen solubility in water (Taylor *et al.*, 1997) so in coming years a further rise in dissolved solids due to erosion can cause a decline in dissolved oxygen content of the water.

The total volatile solids concentration represents organic matter (Boyd, 1979). The value of volatile solids increased from 0.013 g l^{-1} in June to 0.014 g l^{-1} in July at Layyah, at

Taunsa from 0.015 to 0.025 g l^{-1} and at Mithan kot an increase from 0.016 to 0.052 g l^{-1} was observed. The volatile solids may contain fertilizers as well which are introduced into the water body via agricultural runoff. An increase in volatile solids during rainfall reflects soil erosion in the catchment area.

The concentration of Dissolved Oxygen (DO) acts as a strong limiting factor for aquatic organisms because its concentration fluctuates in water (Taylor *et al*., 1997). DO amount may decline due to excessive suspended particles (Ali, 1999), organic matter (Tebbutt, 1998) and dissolved solids (Taylor *et al*., 1997). The lowest acceptable values of DO for aquatic life are 5.5 mg l^{-1} for warm water fish (Rath, 1993). The observed DO values (7.4-17.4 mg l^{-1}) are in acceptable range for the physical and biological fitness of the system. However, the minimum value (7.4 mg l^{-1}) observed during the study period clearly indicates that if erosion is further enhanced it will have catastrophic impacts on aquatic bio-diversity due to consequent decline in dissolved oxygen content.

pH shows seasonal variation which may be due to increase or decrease in concentration of CO_2 (Matthews, 1998). According to Boyd (1979) the desirable range of pH for fish production is 6-9.5. The observed values (7.2-8.52) are within this favorable range.

The results obtained through water quality analysis reflect high erosion pressure in watershed of Indus river system. Soil erosion enhances during drought, which is supposed to be a product of global warming (Philander, 1998). During drought soil water dries up and the soil becomes a palyball of winds causing erosion. Moreover, a sudden rain causes enormous damage. The deterioration of water quality and water shortages have strong influences on Indus river bio-diversity.

In this scenario the bio-diversity will go under stress and species will have to adapt themselves in a changing environment while those not able to keep up pace with climate change will become endangered. The impacts will be severest for already endangered or threatened species. Their extinction rate will enhance and they will vanish in quite shorter times than that under slow pace of environmental change (Adam *et al*., 1993). An equivalent example of this process is the Blind Indus Dolphin (*Platanista minor*) listed in the Red Data book of IUCN. Increasing water pollution and persisting drought conditions will accelerate the extinction rate of this endemic species already under stress of habitat fragmentation due to barrages built for irrigation purposes. Aquatic animals are sensitive to and their limits of tolerance are narrower for certain environmental conditions (Odum, 1971). Therefore, impacts will be devastating for aquatic wildlife. According to Rafique (2000) one of the main reasons for poor fish diversity in the Indus river is the long torrential upper courses and high sediment load.

In short the erosion will have two major impacts, i.e.:

I) Loss of productive topsoil, thus making land poor. This poor land will make the people poor and harmfully affect wildlife resources
II) The sediments introduced into the water body will increase pollution level posing stresses on people living in plains and on aquatic bio-diversity.

Water quality of Indus river is found to be severely affected due to erosion. Drought and elevated air temperature have been supposed to intensify the problem of erosion through deforestation and windstorms. The erosion leads to high sediment load in rivers, enhancing the process of sedimentation. As a result the riverbed will reduce, increasing the possibilities of floods again escalating erosion. This sedimentation is particularly dangerous for water reservoirs. Sediments fill up these reservoirs causing decline in their water holding capacity. This situation is not only harmful for aquatic bio-diversity but for national welfare as well, since it can cause decline in hydroelectric power generation.

The best strategy to combat erosion is the improvement in watershed management. This can be done by preservation of existing forests and by afforestation.

This is necessary because soils with vegetation cover have higher water holding capacity as compared to bare soils thus minimizing erosion and floods. As our numbers have grown over 140 million we should now realize the importance to preserve our indigenous freshwater resources, as these are indispensable.

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