Influence of Water Discharge on Chemical Assessment of Water Quality of River Indus at Kotri Barrage, Pakistan

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Summary: The work monitors the quality of river Indus, its variation with seasonal changes and discharge of water at Kotri Barrage during April 1993-1995. A sample was collected after every 4 to 6 weeks and was analyzed for residues (Total, filterable, non filterable, volatile and fixed), pH, conductance, chloride, hardness, alkalinity, dissolved oxygen (DO), chemical oxygen demand (COD) nitrite, nitrate, phosphate, sulphate, nitrogen (Kjeldalh, organic and ammonia) and phenols. The results obtained were compared with permissible limits for river water (EEC). The total average residues transported was calculated to be 12.14×10^7 tonnes/year, which accounts for 8.8×10^6 tonnes/year used for irrigation and 11.26×10^7 tonnes/year drain down to Arabian Sea.

Introduction

The Indus river represents one of the major water distribution system of South East Asia. It is 2737 km long and originates in the Himalayas. After leaving the Himalayan mountains, it travels about 1000-1200 km in the plains before flowering in the Arabian Sea. During its travel in the plains it is joined by several tributaries [1].

The hydrology of the catchment basin is characterized by dry and wet seasons. The wet season starts around the middle of the May and continues through middle of October. Most of the rain fall occurs during this period. Much of the Indus plain is rain deficient (less than 240 mm/year) [2].

Kotri Barrage is 3000 feet long and is designed to pass a maximum flood of 24500 m^3/s. It is situated about 200 km from Arabian Sea. The barrage is used for regulating the flow of river Indus to irrigation channels. In the wet season after supplying water to the irrigation channels the surplus water is released to the sea [1].

The water in the Indus is originally snow melt, but as it passes through plains it gets run off water containing agricultural waste and top soil in the wet season [1]. The river and its tributaries receive effluent discharges as they pass near town and cities. The Indus water from Kotri barrage is used for agricultural purpose in lower Sindh (Districts Hyderabad, Badin, Sanghar and Mirpur Khas) and as a source of drinking water in the same region. This drinking water may be treated, partially treated or untreated depending upon the locality where it is used.

From 1981-1985 Arain *et al.* [3-5] examined at Kotri Barrage the transport of carbon and minerals by the river Indus to the Arabian Sea. Their observations indicated that more than 90% of water and sediments transported to the sea occurred between June and November, each year. Dissolved organic carbon (DOC) reached a peak value during the rising water stage and decreased within the peak and at receding water stage. The particulate organic carbon (POC) contents in the suspended matter were high during low sediments discharge period and low during high sediment discharge period [7].

The composition of non filterable residues (total suspended solids) transported by Indus, based on the samples collected in 1981 using energy dispersive x-ray analysis (EDXA) comprised mainly of SiO_2 (60%), $CaCO_3$ (22.5%), Al_2O_3 (7%), Fe_2O_3 (8.4%), K_2O (3.4%), MgO(2.4%) and P_2O_5 (1.8%) [3,8]. Tahir *et al.* [9] have reported iron, zinc, nickel copper and lead in Indus water using flame atomic absorption technique. Akil and Khattak [10] have

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examined sulphate, nitrate, nitrite, ammonia, chloride, filterable residue, hardness and iron of Indus water near Tarbela dam, during 1968-69.

The present work examines the transport of residues (total, filterable, non-filterable, volatile and fixed) by the river Indus to irrigation channels and to Arabian Sea, and examines the water quality in term of organic and inorganic components.

Results and Discussion

The average monthly discharge, up-stream and down-stream of Kotri barrage varied during 1993-94 within 89 to 5704 m^3/s and 0 to 4871 m^3/s respectively. Similarly during 1994-95 the values varied between 208-20484 m^3/s and 0-20321 m^3/s at upstream and down stream, respectively at Kotri barrage. The water discharges passing upstream and downstream from total annual discharge were 86.8% and 91.9% during May to October 1993 and 94.4% and 97.8% during same month in 1994.

Total residue varied between 360-1598 mg/L during 1993-94 and 300-1950 mg/L during 1994-95, with a maximum amount in the month of July and August and minimum during December to April. The volatile and fixed residue present in the total residue respectively varied within 40-100 mg/L and 320-1560 mg/L during 1993-94. Similarly these values varied between 44-240 mg/L and 220-1760 mg/L during 1994-95. Non filterable residue (total suspended solids) varied within 56-1390 mg/L and filterable residue (Total soluble salts) within 157-303 mg/L during 1993-94 (Fig. 1). High total residue, fixed residue and nonfilterable residue corresponds with high discharge in River Indus (Table-1). Because of high water discharge and high flow in Indus it carries a lot of silt and suspended solids which pushes high total residue, fixed residue and nonfilterable residue. The volatile residue corresponds roughly to the organic matter present in the total residue and its percentage in the total residue varies within 1 to 40% . Minimum was observed during high water discharge and maximum during low water discharge. A similar observation has been reported by Ittekot *et al.*, [7]. COD corresponds to acid dichromate oxidizable material present and represent total organic compounds available in water body thus COD also showed parallel co-relation to that of volatile residue. The percentage of non-filterable and filterable residues with respect to total residue varied within 26-90% and 12-84% respectively. The non-filterable residue reached maximum in August and minimum in December where as filterable residue reached maximum in December and minimum in August.

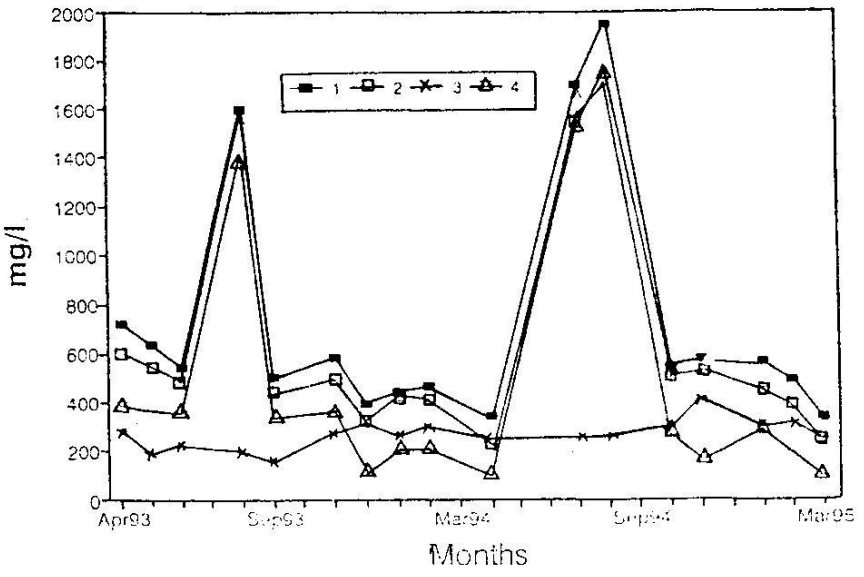

Fig. 1: Variation in (1) total residue, (2) filterable residue, (3) non filterable residue and (4) fixed residue in river Indus at Kotri barrage during 1993-1995.

Table-1: Average monthly discharge of water and total residues upstream and down stream at Kotri Barrage during April 1993-March 1995.

Month	Water discharge upstream m^3/s	Total residue tonnes/month	Water discharge down stream m^3/s	Total residue tonnes/month
Apr 1993	1296.1	$2.08x10^6$	956.15	$1.5x10^6$
May 1993	2019.58	$2.82x10^6$	1451.08	$2.03x10^6$
Jun 1993	1734.77	$2.42x10^6$	1213.0	$1.7x10^6$
Jul 1993	5317.76	$2.07x10^7$	4566.74	$1.8x10^7$
Aug 1993	5703.96	$2.36x10^7$	4871.10	$2.02x10^7$
Sep 1993	910.92	$1.2x10^6$	244.50	$0.32x10^6$
Oct. 1993	558.74	$6.1x10^5$	118.68	$1.3x10^5$
Nov. 1993	293.54	$4.4x10^5$	20.76	$0.31x10^5$
Dec. 1993	93.80	$8.75x10^4$	Nil	Nil
Jan. 1994	380.96	$4.34x10^5$	23.48	$0.28x10^5$
Feb. 1994	308.45	$3.67x10^5$	23.48	$2.8x10^4$
Mar 1994	88.98	$7x10^4$	1.008	$7.83x10^2$
Apr. 1994	208.43	$2.08x10^5$	Nil	Nil
May 1994	363.40	$3.86x10^5$	Nil	Nil
Jun. 1994	1186.77	$1.58x10^6$	289.76	$0.39x10^6$
Jul. 1994	6141.24	$10.6x10^6$	5614.37	$9.7x10^6$
Aug. 1994	20484.08	$10.35x10^7$	20321.64	$10.27x10^7$
Sep. 1994	13883.62	$6.65x10^7$	13792.82	$6.61x10^7$
Oct. 1994	1146.62	$1.6x10^6$	798.31	$1.11x10^6$
Nov. 1994	402.32	$6x10^5$	73.17	$1.08x10^5$
Dec. 1994	386.51	$5x10^5$	116.28	$1.5x10^5$
Jan. 1995	692.31	$1x10^6$	480.76	$0.7x10^6$
Feb. 1995	539.50	$8.2x10^5$	216.06	$3.27x10^5$
Mar. 1995	332.04	$4.82x10^5$	Nil	Nil

In order to calculate the monthly load of the residues carried by river Indus upstream and downstream at Kotri Barrage, total residue (mg/L) was multiplied by one to convert it to g/m^3. The average monthly water discharge was obtained from control room, department of irrigation Kotri Barrage. Total load in tonns/month was calculated using following relation.

= Total residue (g/m^3) x average water discharge (m^3/s) x (60x60x24x30x0.000001)

= Total residue (g/m^3) x average water discharge (m^3/s) x 2.592

Now the results (Table-1) indicates that the total load of solids carried by river Indus varied between $8.8x10^4$ to $2.7x10^7$ tonnes/month during 1993-94 and $5.0x10^5$ to $18.x10^8$ tonnes/month during 1994-95. After supplying water for irrigation purposes at Kotri Barrage, which carried total load within $6.8x10^4$ to $3.45x10^6$ tonnes/month during 1993-94 and $9.1x10^4$ to $1.2x10^6$ tonnes/month during 94-95 the, surplus water which drains down to the Arabian Sea carried between $0\text{-}2.0x10^7$ tonnes/month during 1993-94 and $0\text{-}1.0x10^8$ tonnes/month during 1994-95. A similar result has been reported by Milliman and Meade [11].

As far as the water quality of river Indus at Kotri is concentrated during the study period of two years pH varied between 7.9-8.35, conductivity 225-746 us/cm, dissolved oxygen 6.4-8.75 mg/L which corresponds to 70-96% oxygen saturation in temperature range 12.5-32°C. During this period chloride varied between 26-98 mg/L, alkalinity 89-200 mg/L as $CaCO_3$, hardness 100-212 mg/L as $CaCO_3$, sulphate 38-148 mg/L, nitrate 1.33-6.84 mg/L, nitrite 8-145 µg/L acid hydrolyzable orthophosphate 50-567 µg/L, nitrogen (Kjedalh) 0.98-2.8 mg/L (organic) 0.46-1.92 mg/L, ammonia 90-880 µg/L Phenol (total) 12-45 µg/L and COD 10.5-55 mg/L. (Fig. 2 and 3).

The mean values of all the samples analyzed (n=7 to 17) together with confidence intervals (C.I) at 95% are summarized in Table-2. The values are within the permissible limits for surface water [12] but conductivity, COD and phenols are on the higher side.

Experimental

A water sample about 100m upstream from the Kotri Barrage was collected every four to six weeks from the boat by mixing 2 to 4 sub samples of equal volume from vertical section. The water

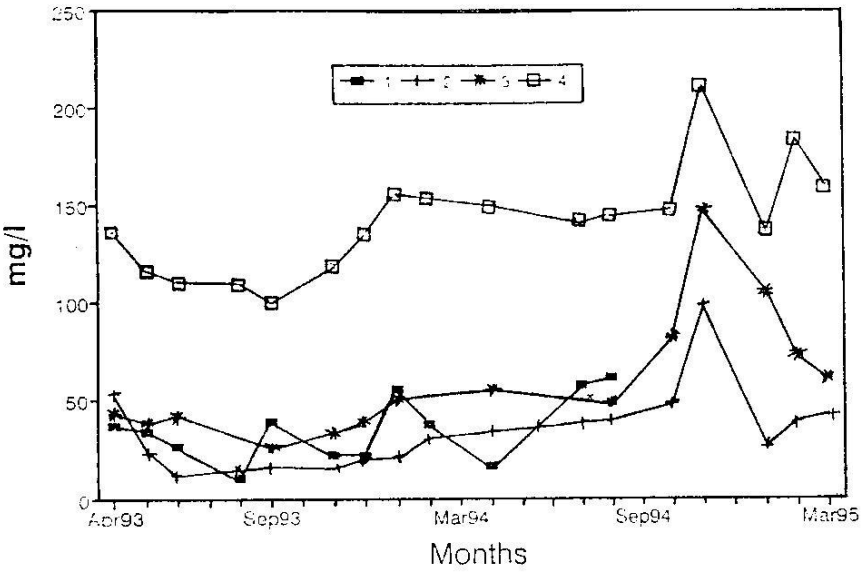

Fig. 2: Variation in (1) COD, (2) chloride, (3) sulphate and (4) hardness in river Indus at Kotri barrage.

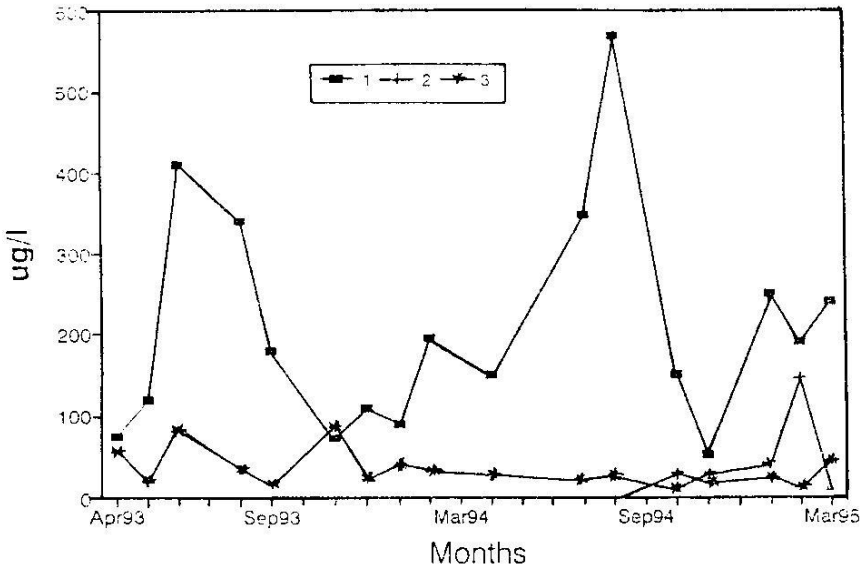

Fig. 3: Variation in (1) acid hydrolyzable phosphate, (2) total phenols, (3) and nitrites in river Indus at Kotri barrage.

samples were collected within 3-9 inches from the surface of water. The samples were mixed well and a sample of 2.5 liters was transferred to a clean glass bottle. The temperature of water and air 1m above the surface of water was noted on the spot. pH was measured with Orion 420 pH meter and conductivity by Jenway 4070 conductivity bridge. Total residue was determined by evaporating water (100 ml) on water bath and heating the residue at 105°C for 2 hours. Volatile residue was measured by recording the loss in weight when heated at 550°C for 2 hours. Nonfilterable residue (total suspended solids) was

Table-2: Quantitative data of water analysis

Parameter	Number of results(n)	Min. Max. level (observed results)	Average results confidence interval at 95%	EEC Standards for surface water
Temperature °C	17	12.5-32	23.76 ± (3.14)	12-25
pH	17	7.9-8.35	8.05 ± (0.15)	6.5-8.5
Conductivity ($\mu S\ cm^{-1}$)	17	225-746	417.88 ± (66.76)	400
Dissolved Oxygen (mg/L)	17	6.4-8.75	7.7 ± (0.484)	4.0
% Saturation	17	70-96	89.31 ± (4.25)	--
Alkalinity (mg/L)	17	80-200	142.4 ± (12.46)	--
Hardness (mg/L)	17	100-212	141.58 ± (28.11)	--
Chlorides (mg/L)	17	26-98	33.52 ± (10.76)	25-200
Sulfates (mg/L)	17	38-148	53.93 ± (14.51)	25-250
Nitrates (mg/L)	17	1.33-6.84	3.05 ± (0.90)	25-50
Nitrites (µg/L)	17	8-145	42 ± (18)	100
Kjeldalh Nitrogen (mg/L)	17	0.98-2.8	1.45 ± (0.68)	2.0
Organic Nitrogen (µg/L)	17	0.46-1.92	1.07 ± (0.47)	--
Ammonia Nirtrogen (µg/L)	17	90-880	340 ± (340)	50-500
Acid hydrolyzable orthophosphate (µg/L)	17	50-567	210 ± (70)	1000
Chemical Oxygen Demand (µg/L)	12	10.5-55	28.8 ± (10.33)	20-35
Total Phenols (µg/L)	7	12-45	20 ± (18)	10

separated by filteration of known volume of water from glass filter (0.45 µm) (Gelmen science, Australia) and noting the increase in weight after drying at 105°C [2]. Chemical oxygen demand (COD) was determined by acid dichromate oxidation method. Nitrate, nitrite and phosphate contents were determined by spectrophotometric methods. Nitrate was determined by the Brucine, method [13]. Nitrite by diazo coupling reaction with sulphanilic acid and N-(naphthyl) ehylenediamine dihydrochloride, orthophosphate was determined by reducing phosphomolybdic acid formed with ascorbic acid to molybdenum blue [14]. Total hydrolyzable phosphate was determined by persulphate digestion method [14] followed by spectrophotometric determination as orthophosphate. Sulphate was determined by turbidimetric method as barium sulphate [14]. Kjedalh nitrogen was evaluated using mercuric oxide red as catalyst [15]. Ammonia nitrogen was determined by phenate [16] method after distillation of ammonia from alkaline solution. The organic nitrogen was found by substraction of ammonia nitrogen from Kjeldalh nitrogen. Total phenols were determined using 4-aminoantipyrine as derivatizing reagent [13]. Chloride, alkalinity and hardness were determined by titration with standard silver nitrate, hydrochloric acid and E.D.T.A respectively. Dissolved oxygen was evaluated by Wrinkler method [14].

Samples preservation

The samples for nitrogen contents were preserved with sulphuric acid 0.8 ml/L, for phenols they were adjusted to pH within 3-4 with H_3PO_4 and 1g Cu $SO_4.5H_2O$/L was added. The samples for phosphorous determination were stored at 10°C. The samples for DO were added manganese(II) sulphate and alkali-sodium iodide solution in wrinkler bottle at the time of collection of sample and determination was completed in laboratory. The samples for pH, conductivity, chloride, alkalinity, hardness, sulphate, COD and residues were analysed within 24 hours from the collection of the samples.

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