Study of Polluted Water Mixing on Sediment of Lahore Canal

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***Abstract*-**People living in societies along the canals which pass through the urban areas, are adding domestic & industrial waste water and wastes into them like Lahore canal. This untreated industrial and municipal waste and contaminated water may become a risk to irrigation water quality and sediment moving in it in the form of suspended load. The results disclose that as suspended sediment concentration increases the pH value drops. Consequently it can be established from results that they are inversely related to each other but this behaviour is generally due to effect of rain water runoff. The suspended sediment content was at its highest during monsoon season. Similarly pH values varied considerably from limit of 6.5-8.4. Other water quality chemical parameters did not stray from their recommended limits. The dumping of waste water from pipes did not have any major effect on the water quality of the canal due to its less percentage to the total canal discharge.

***Keywords*-**Suspended Sediments, pH, Water Quality, Electrical Conductivity, TDS.

I. Introduction

Lahore Branch canal was originally off-taking from Upper Bari Doab Canal System, from Madhupur Headworks in District Gurdaspur India. The system was irrigating the area of district Gurdaspur, Amritsar and Lahore District before partition. After partition of the sub-continent, supplies from India were cutoff and BRBD Canal was constructed to feed the various truncated channels including Lahore Branch Canal. This canal is off-taking from BRBD canal near Jallo village Fig. 1. It carries discharge of 11.38 cumecs and is 30 km long. Its banks are brick lined through its length. The bed width and full supply depth varies through its length. The average bed width is 11.58 m and average full supply depth is 1.22 m. The culturable command area is about 17 km^2.

Presently, people are releasing/draining/adding domestic & industrial waste water and wastes into this canal. The drainage water contains trace metals in addition to biological contaminations. These untreated industrial and municipal wastes and polluted water have created multiple hazards and have become a threat to irrigation water quality and sediment moving in it. Also, this contaminated water adds pollution to our food chain when used to irrigate the crops in addition to groundwater contamination.

Therefore, this study has been designed mainly to investigate the effects of this polluted water mixing on the temporal and spatial variation of suspended load and Irrigation water quality in Lahore Canal.

II. Literature Review

Over the years, different researchers have experimented on the effects of sediments on the water quality, these are discussed below.

A. International research/studies

Sediment and its effect on water quality were discussed. It was defined that what the water uses are affected by sediments, how these uses are affected, and the influence of sediment on water quality in New Mexico and the factors which contribute to its presence [i].

The correlation between water quality and sediment transport was studied. Also discussed was that the effect of sediments on water quality, the influence of water quality on sediments, and the use of sediments as environmental indicators, are not widely understood; as yet, only limited use of sediment data has been made in most environmental and water quality studies [ii].

The cation exchange capacity of a soil is the sum of interchangeable cations that a soil or soil component can adsorb at a specific pH was concluded. Thus, the cation exchange capability is a measure of a soil's adsorption capacity and sediment can absorb nutrients at certain pHs [iii].

The suspended sediment load in a stream, which drains a rural watershed, is derived primarily from soil erosion arising on the watershed and due to agricultural undertakings. The suspended sediment load is a water quality component with two aspects. Its removal from the soil in surplus quantities might be damaging to the productivity of the soil. On the other hand, the suspended sediment in a stream is a contaminant, by itself and by being a carrier of adsorbed chemicals like metals and organics [iv].

Decrease of sediment loads enhanced water clarity, and thus allowed more handling of nutrients in shallow waters. The degraded water quality in Chesapeake Bay was attributed to algal blooms and reduced water clarity due to excess nutrient and sediment inputs [v].

Clay particles add to suspended sediment in surface waters when soil dispersion occurs. The dispersed soil or sediment vulnerable to being eroded retains nutrients and contaminants via adsorption to clay particles. Therefore, more information is needed regarding the effect of dispersive clays and suspended sediment on water quality [vi].

Soil mineralogy affects water quality in several ways. Soil mineralogy determines the dispersivity of the clay portion of the soil and dispersive clays are likely to end up as suspended sediment in surface waters, weathering reactions contribute elements to water as dissolved load, and clay minerals, with their absorption properties, contribute to soils' ability to filter and carry pollutants. Suspended sediment in surface waters is a concern for water quality because it results in decreased availability of oxygen for aquatic life, an increase in algal blooms with an increased rate of sedimentation. Suspended particles also carry contaminants and excessive nutrients [vii]

Water quality study was done in the Koga Irrigation Project, Ethiopia. Some important conclusions of this study were that the water used for irrigation showed good values for conductivity. The values of the parameters works fine for some crops grown in Koga, but not all. Calcium and alkalinity levels were overall too high, especially downstream. Ingesting crops without proper preparation is not recommended due to high bacteria counts. The spatial difference in water quality in the sampled canals of Koga was not that large. Most of the parameters displayed relatively uniform values. The physical parameters, turbidity and temperature, are the only parameters that progressively increases down the irrigation canals however, to draw conclusions more samples need to be taken [viii].

B. National research/studies

A study on the canal system of Punjab regarding its water quality was performed. In the observing period, five rivers at head works, 27-canals and 19 drains at their head, middle and tail were sampled. The analysis was carried out in the laboratories of Directorate of Land Reclamation. The analytical data reveals that water quality of rivers and canals towards irrigation parameters (pH, EC, SAR and RSC) are excellent. In case of trace metals (Cu, Ni, Pb and Zn) the detected values range within limit. The values of Cu slightly stray from FAO limit, occasionally. The drains waters are generally unfit for irrigation parameters and also have heavy load of trace metals but their influence is not so substantial on our irrigation system [ix].

The pollution status of Lahore branch canal was studied by physical, chemical and metal constituents analysis as this water is used for irrigation of lands nearby. They selected twelve different sites along the canal for sampling. The results of their samples were compared with FAO. All physical and chemical parameters were found to be within limits specified by FAO. While trace metals were found to vary considerably from limits, as cadmium, copper and chromium concentration were much higher than limits. Turbidity of water was also high [x].

A study was conducted to find pollution load of Lahore canal. Four different sites were selected on the canal. Sampling was done for surface water at the middle of the canal. Water samples were analyzed for physiochemical parameters such as temperature, pH, EC, DO, BOD_5, turbidity, nitrates, phosphates and biologically for bacteria, coliform and fungi. These parameters were analyzed from May to August. The results showed that the water was fit for irrigation purposes but with treatment for high microbial load [xi]

A study concluded that BRB and Lahore canal were being polluted by municipal and industrial wastes. The need for a comprehensive study was felt to observe the concentration of pollutants in the Lahore canal and their effects. Sampling was done from twelve locations between February and March 2008. pH, EC, TDS, BOD, COD, SAR, RSC, cations, anions and heavy metals like Pb, Zn, Fe were analyzed. The results showed that BRB canal water quality was better than Lahore canal water quality. Water from both canals can be used for irrigation but is unfit for general public use. pH and Electrical conductivity (EC) of canal water had a wide variation in results but remained in limits as specified by irrigation department. TDS was also within limits for canal water [xii].

In the light of the above reviewed literature, studies have been done on suspended sediment load's effect on water quality regarding the ability of suspended sediments to absorb contaminants. Similarly, research has been done on irrigation water quality parameters but these polluted water chemical parameters have not been linked to suspended sediments. Likewise, no specific study has been done on effect of contaminants/ polluted water mixing on the suspended load, whether the change in water quality chemical parameters due to polluted water /waste has an impact on the suspended sediment load concentration. For this purpose this study has been designed with the following objectives.

III. Study Objectives

The objectives fixed for of this study were:

a. To collect suspended sediment and water samples and assemble relevant water discharge data from Irrigation Department and observe sediment

deposits/ solid waste depth and gradation of bed deposits in the canal during closure.

b. To analyze the temporal and spatial variation of suspended sediment load due to addition of waste water from pipes and household waste.

c. Make a comparison of standard/normal irrigation water (quality) standards with the present water quality of the canal after mixing of polluted water/waste from pipes.

d. Develop relationship between suspended load concentration and each tested chemical parameter of water quality.

Fig. 1. Location map of Lahore canal and sampling sites for water quality parameters and suspended sediments

IV. METHODOLOGY

A. *Sampling for Deposited Sediment*

During closure of canal in January 2014, a field visit was made to the specified stations and the depth of deposited sediment was measured along the cross section. These depths were measured by calculating the depth with reference to the bank of the canal. The total depth of the canal was known from the data from irrigation department. The depth comprised of full supply depth and free board. Total vertical distance was measured from the bank to the top of the deposits for each selected site at center line of the canal and left and right sides at extreme width of the canal bed at that specified site/ station. The depths obtained were cross checked with the help of bhal safai workers after excavating the bed material. The samples from these deposits were collected in polythene bags. Basic purpose of this sampling was to find the gradations of deposited sediments and maximum depth of deposits along the canal. Sieve analysis was done by ISRIP WAPDA.

Gradation of deposited sediments was done using USGS sieve analysis. Wet and dry sieving method were used as per guidelines of USGS. Wet sieving method was used to separate coarse fraction (gravel and sand) from fine fraction (silt and clay). Samples were soaked for up to 2 hours for disaggregation. Then the samples were washed into the sieve using a squeeze bottle. When on the sieve the fine fraction was washed through it using hands/fingers into a bowl. This fine fraction was then sealed in a Mason Jar. It was afterward analyzed using a pipette. The coarse fraction was put into a pre-weighted beaker and oven dried. Oven dried sample was then dry sieved. For dry sieving a pan was placed below stacked sieves. The finest mesh/ sieve was placed at the bottom most above the pan.

Forty grams sample was placed on the top sieve and a cover was attached. It was then placed into a mechanical shaker. After 10-15 minutes the sieves were separated and then each sieves contents were measured. This gave the particle size distribution.

B. *Sampling for Suspended Sediment*

Sampling for suspended sediment was carried out using USGS instrument. US-DH-48 sampler shown in Fig.2 was used for this specific study, however; only one sample was taken from a cross section due to cost constraints. This sample was taken from mid of the section at the RD's specified in this research. This sampling was done at alternate weeks on Saturdays. Sampling was started in the 2nd week of February 2014 after the canal was opened after bhal safai and was continued up to start of September 2014 for 8 months. One alternate week was skipped in end of April because of canal closure. The samples were submitted to ISRIP (International Sediment Research Institute Pakistan) for gradation and PPM of sediment concentration.

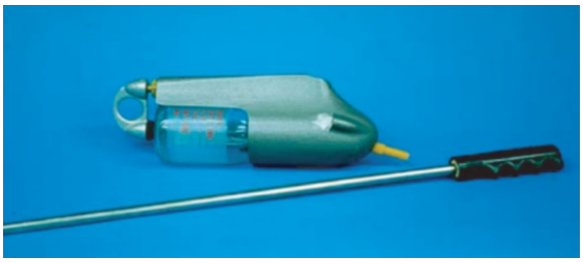

Fig. 2. US-DH 48 sampler used for suspended load data collection

At each selected station, this sampler (US- DH 48) was lowered with the help of a wading rod at a uniform rate into the deepest point of the section and then raised again at the same uniform rate to the surface of the canal. Special care should be taken that the sampling bottle is not over filled as it may not be a true representative of the vertical. After all the samples have been collected they are allowed to settle and then are analyzed further for suspended sediment concentration.

For suspended sediment load USGS methods were followed. These are:

a. USGS VA Tube method (Visual Assessment Method)
b. Pipette Method
c. Sieving USGS method

C. Sampling for Water quality

Water sampling for chemical parameters was done using Grab sampling technique. USGS has also specified samplers for water quality analysis, but due to cost constraints such sampler could not be arranged for water sampling.

Bottles of 1 liter attached to self-made wading rod were lowered into the canal at mid-section and raised at a uniform rate at each selected site. Mouth of the bottle was directed toward the direction of flow. Materials such as leaves, twigs and other floating material were avoided. Collected samples were labeled with the sample number, date, collection hours, location and information about surroundings. The samples were brought to the laboratory within two hours of collection and processed accordingly for the analysis of different water quality chemical parameters. Irrigation water quality analysis was done at Soil and Water testing laboratory, Thokar Niaz Baig, Lahore.

V. Data Collection

In order to begin research on a specific project, the first step is to collect relevant data about that project. In this study, the general information for Lahore branch canal was collected in October 2013, from Irrigation department offices located near Mughalpura on Canal Bank road. This data included the line diagram of Lahore branch canal specifying its RD's. On the basis of RD's specified on the line diagram the sampling sites were selected. The sampling sites were not equidistant and simply selected on the basis of waste water dumping locations. These locations were identified by the Irrigation Department people and on personal observation of the canal during closure period of January 2014 and ten locations were selected starting from upstream as shown in Table I.

TABLE I
Sampling Locations on Lahore Canal

Sr. No	Station	Location
1	10	Khaira Head Bridge
2	9	Rani Pindi Bridge
3	8	Harbanspura Underpass
4	7	Tajbagh Bridge
5	6	Tajpura Bridge
6	5	Mughalpura Underpass
7	4	Dharampura Underpass
8	3	FC College Underpass
9	2	New Campus Underpass
10	1	Jinnah Hospital Underpass

Sampling for canal water and suspended sediments was conducted over a period of 8 months from February 2014 to September 2014 on a specific day at alternate weeks. The dates for sampling of suspended sediments and canal water are shown in Table II.

No specific discharge data for waste water dumping into the canal at various stations could be obtained from irrigation department. This was because the dumping was illegal therefore no legal record could be found. However, on personal observation the locations where most discharge from embedded waste water pipes was entering the canal were recorded i.e. between Khaira Head Bridge (Station 10) and Tajbag bridge (Station 7). A visit was made to observe the pipe sizes at these locations, as given in Table II.

TABLE II
Timings for Sampling and Waste Pipe Location and Size

A. Timings for sampling		B. Waste pipe location & sizes	
Sampling Date	Set No.	Station	Pipe Size (m)
15-02-2014	1	9	0.3048
01-03-2014	2	1.046 km D/S of 9	0.3048
15-03-2014	3	1.33 km D/S of 9	0.1524
29-03-2014	4	1.39 km D/S of 9	0.3048
12-04-2014	5	R/S 1km U/S of 8	0.3048
10-05-2014	6	L/S 1km U/S of 8	0.1524
24-05-2014	7	0.733 km D/S of 8	0.3048
07-06-2014	8	0.219 km U/S of 7	0.1524
21-06-2014	9	7	0.3048
12-07-2014	10		
09-08-2014	11		
09-09-2014	12		

The samples were sent to International Sediment Research Institute Pakistan (ISRIP) WAPDA for gradation of sediment concentration in PPM [xiii].

The collected samples for chemical parameters and suspended sediments were analyzed by Soil and Water Testing Laboratory, Thokar Niaz Baig and International Sediment Research Institute Pakistan, respectively for a period of about 8 months.

Apart from suspended sediment and pH data for canal water shown in Table III, rest of the parameters namely bicarbonates, electrical Conductivity, sodium absorption ratio, residual sodium carbonate and chloride were within permissible limits. SAR and RSC values were almost zero for various samples and therefore they do not have significant impact.

RSC data is shown in Table III while SAR, bicarbonates, electrical conductivity and chloride values for this study and their standard values for irrigation water quality are tabulated in Table IV.

TABLE III
SUSPENDED SEDIMENT, pH AND RSC DATA FOR LAHORE CANAL

Station	Timings for sampling											
	Set 1 15 Feb	**Set 2** 1 Mar	**Set 3** 15 Mar	**Set 4** 29 Mar	**Set 5** 12 Apr	**Set 6** 10 May	**Set 7** 24 May	**Set 8** 7 Jun	**Set 9** 21 Jun	**Set 10** 12 Jul	**Set 11** 9 Aug	**Set 12** 9 Sep
Suspended sediment concentration in PPM												
10	213	32	27	128	861	316	168	377	361	893	692	11
9	173	24	29	107	1647	246	176	301	329	825	1486	14
8	146	28	20	115	2375	241	188	335	280	1048	952	25
7	71	31	21	100	448	241	290	327	351	1007	751	23
6	56	34	17	110	618	440	154	374	339	799	650	23
5	121	27	24	111	437	291	53	265	428	934	593	18
4	128	25	19	135	433	256	111	246	398	1031	641	22
3	76	32	25	121	346	247	183	232	314	960	614	45
2	63	28	36	127	531	285	129	193	312	909	445	41
1	191	33	26	143	510	210	162	131	343	832	507	28
pH (permissible range 6.5-8.4)												
10	7.9	7.8	7.6	7.8	6	9.1	9.5	6.8	5	5	5.8	6.9
9	7.8	7.7	7.6	7.8	7	7.8	8	7	5	5.5	5.3	5.7
8	7.7	7.7	7.6	7.6	6.1	6.4	7.2	6.4	4.6	5	5.6	6.8
7	7.5	7.6	7.6	7.7	6.9	6.6	7.2	6.7	5.7	5	6	6.1
6	7	7.6	7.6	7.3	5	7.1	6.2	6.8	6.9	6.4	5.9	5.2
5	7.8	7.7	7.6	7.2	5.7	8.3	8.8	6.9	6	6	5.9	6.9
4	7.9	7.8	7.6	7	6.1	9.3	7.5	7	6.8	6.3	6.3	6.1
3	7.9	7.7	7.5	7.5	5.7	9.2	6.9	6.7	7.4	6.3	6.5	6.9
2	7.9	7.5	7.4	7.4	6.4	8.8	5.8	6.4	7	6.1	6.3	6.4
1	7.9	7.5	7.4	7	6	7	6.8	6.2	4.8	6.1	5.9	6.7
RSC in meq/l (permissible range 0-2.5)												
10	1.0	0	0	0	0	5.2	0.6	0	0	0	0	0
9	1.2	0	0	0	0	0	0.1	0.1	0	0	0	0
8	1.0	0	0	0	0	0	0	0	0.1	0	0	0
7	1.0	0	0	0	0	0	0	0.1	0.1	0	0	0
6	1.2	0	0	0	0	0	0	0	0	0	0	0
5	1.0	0	0	0	0	0	0	0	0	0	0	0
4	1.0	0	0	0	0	0	0	0	0	0	0	0
3	1.0	0	0	0	0	0.2	0	0	0	0	0	0
2	0.9	0	0	0	0	0	0	0	0.1	0	0	0
1	1.1	0	0	0	0	0	0	0.2	0	0	0	0

TABLE IV
SAR, BICARBONATES, EC AND CHLORIDE DATA FOR LAHORE CANAL

Station	Timings for sampling											
	Set 1 15 Feb	**Set 2** 1 Mar	**Set 3** 15 Mar	**Set 4** 29 Mar	**Set 5** 12 Apr	**Set 6** 10 May	**Set 7** 24 May	**Set 8** 7 Jun	**Set 9** 21 Jun	**Set 10** 12 Jul	**Set 11** 9 Aug	**Set 12** 9 Sep
SAR in meq/l (permissible range 0-10)												
10	1.9	0	0	0	0	0.1	0	0.1	0.1	0.09	0	0
9	1.9	0	0	0	0	0.1	0	0.3	0.1	0.09	0	0.6
8	1.9	0	0	0	0	0.5	0	0.2	0.1	0.09	0	0.6
7	1.9	0	0	0	0	0.1	0	0.2	0.1	0.06	0	0.6
6	1.9	0	0	0	0	0.5	0	0.2	0.1	0.09	0.1	0.6
5	1.9	0	0	0	0	0.3	0	0.2	0.1	0.08	0.1	0.6
4	1.9	0	0	0	0	0.5	0	0.1	0.1	0.08	0.2	0.6
3	1.9	0	0	0	0	0.2	0	0.2	0.1	0.09	0.2	0.6
2	1.9	0	0	0	0	0.3	0	0.2	0.4	0.1	0.2	0.6
1	2.2	0	0	0	0	0.1	0.1	0.3	0.1	0.2	0.2	0.7
Bicarbonates in meq/l (permissible range 0-6)												
10	2.4	2.6	2	2	1.8	7.2	3	1.9	1.7	2.2	2	2
9	2.6	2.6	2	2	1.8	2	2.6	1.9	2	2	2	2
8	2.4	2.4	2	2.2	1.8	2	1.6	1.9	2	2	2	2
7	2.4	2.6	2	1	1.8	2	2	1.9	2	2	2	2
6	2.6	2.6	2	2.4	1.8	2	2	1.9	1.6	2	2	2
5	2.4	2.6	2	2.4	1.8	1	1.6	1.9	2	2	2	2
4	2.4	2.6	2	2.4	1.8	0.4	2.2	2	2	2	2	2
3	2.4	2.6	2	2.4	1.8	1.8	1.8	2	2	2	2	2
2	2.4	2.8	2	2.4	1.6	1.8	2.2	2	1.8	2.1	2	2
1	2.4	2.6	2	2.6	2.6	2	2.2	2.2	1.8	2	2	2
EC in microS/cm (permissible range 0-1250)												
10	310	316	300	274	271	225	200	200	190	249	206	285
9	313	324	309	274	270	285	212	211	210	256	200	289
8	312	322	300	256	283	310	220	213	200	261	200	290
7	317	324	305	200	274	250	210	208	205	257	204	296
6	314	317	306	292	280	317	210	210	189	250	210	289
5	314	319	310	296	275	282	215	210	213	268	210	297
4	310	318	292	291	280	255	221	212	215	267	223	288
3	310	321	295	235	278	218	220	219	210	256	220	285
2	310	321	290	235	260	290	235	218	209	254	220	292
1	311	325	291	346	275	295	255	235	218	256	220	293
Cl in meq/l (permissible range 0-4.5)												
10	0.5	0.36	0.6	0.4	0.4	0	0	0	0	0	0	0
9	0.5	0.44	0.6	0.3	0.4	0	0	0	0	0	0	0
8	0.6	0.72	0.7	0.7	0.4	0	0	0	0	0	0	0
7	0.5	0.44	0.9	0.6	0.4	0	0	0	0	0	0	0
6	0.6	0.47	0.7	0.6	0.5	0	0	0	0	0	0	0
5	0.5	0.39	0.7	0.7	0.4	0	0	0	0	0	0	0
4	0.5	0.38	0.8	0.6	0.5	0	0	0	0	0	0	0
3	0.5	0.45	0.5	0.6	0.5	0	0	0	0	0	0	0
2	0.6	0.31	0.7	0.6	0.5	0	0	0	0	0	0	0
1	0.5	0.45	0.7	0.8	1.4	0	0	0	0	0	0	0

Note: Sampling skipped on 26 APR due to canal closure

VI. Results and Discussion

It can be seen that the suspended sediment concentration was at its peak during the 5th week (5th set) on 12th April 2014 with value of 2375 PPM at Harbanspura Underpass Fig. 3. This high concentration was due to the rainfall in early April 2014 and storm water being dumped from pipes just upstream of Harbanspura. Water clarity was reduced due to excessive sediment input.

Another result on the same day also showed high concentration of 1647 PPM at Rani Pindi Bridge. Other high concentrations occurred on 12th July and 2nd August with concentrations of 1048 and 1486 PPM respectively for two of the results.

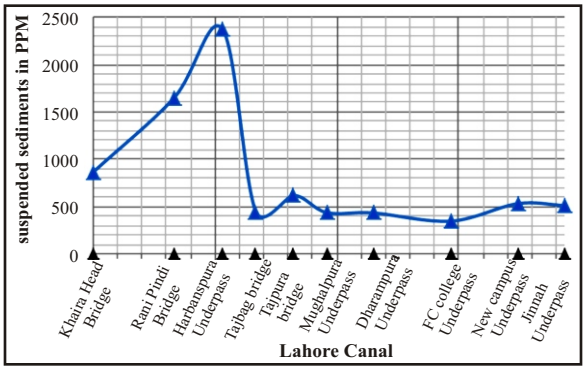

Fig. 3. Maximum Suspended sediment concentration on 12th April at Harbanspura underpass.

After the 5th week, that is after 12th of April the sediment concentration shows a rapid decline. 12th July and 2nd August that are 10th and 11th week (sets) again showed high concentration of suspended sediments as this was the monsoon season.

The allowable limits for various water quality parameters are given in TableV.

TABLE V
Limits for Various Water Quality Parameters

Water quality parameter	Unit	Range of values		
		Suitable	can be used	not suitable
Electrical conductivity (EC)	microS/cm	0-1000	1001-1250	>1250
Sodium Absorption Ratio (SAR)	meq/l	<6	6 to 10	>10
Chloride	meq/l	0-4.5		>4.5
pH		6.5-8.4		<6.5 &>8.4
Bicarbonates (HCO_3)	meq/l	<1.5	1.5-6	>6
Residual Sodium Carbonate (RSC)	meq/l	<1.25	1.25-2.5	>2.5

The normal range for irrigation water requirement by international and WAPDA standards is 6.5-8.4. From 15th February to 29th march, for 1st four sets/weeks of samples all pH values were within permissible range at all stations/RDs. Set 5 (5th week) on 12th April 2014 showed a minimum value of 5 pH at Tajpura Bridge. Value of 5 on pH scale shows acidic nature of the water. This is highly unsuitable for irrigation. Set 6 (6th week) showed alkaline water with high values of pH of 9.2 and 9.3 at FC college Underpass and Dharampura underpass respectively while a maximum value of 9.5 was on 24th May (7th week) at Khaira Head Bridge Fig. 4.

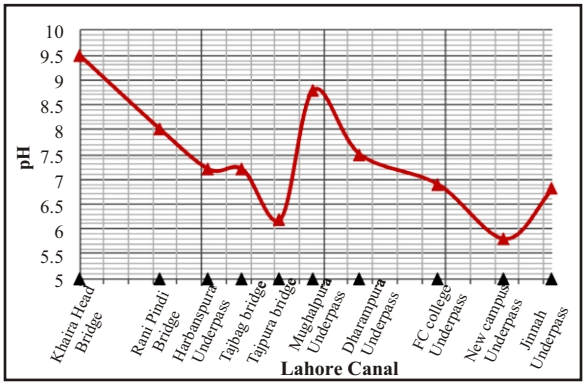

Fig. 4. pH variation on 24th May 2014

When water is of alkaline nature pH > 8, it may contain high level of bicarbonates concentration which in turn reduces the calcium and magnesium content that can have an impact on plant growth. While a pH of below 4 can cause soil acidification which can also cause plant damage. In this research the minimum value of pH is 4.6 was recorded on 21st June 2014 (9th week/set) at Harbanspura Underpass.

All the values of electrical conductivity for all weeks were well within the range specified of 0- 1250 microS/cm. Maximum value of 346 microS/cm was observed on 29th March 2014 (4th week) at Jinnah Underpass and minimum of 189 microS/cm on 21st June 2014 (9th week) at Tajpura bridge during the study period.

Maximum value of bicarbonates was 7.2 meq/l on 10th may 2014 (6th week sampling) at Khaira Head Bridge. Minimum value was 0.4 meq/l on same day at Dharampura Underpass. Most values were near 2 meq/l. The value of 7.2 meq/l was termed as unsuitable for irrigation by Soil and Water Testing Laboratory at Thokar Niaz Baig. Most stations showed declining values after 3rd week. After the 5th week of sampling i.e.during 6th and 7th week and onwards showed zero concentration of chloride for all stations. All values were within irrigation water quality guidelines.

Maximum concentration of calcium and magnesium was 4.8 meq/l on 1st March 2014 (2nd week sampling) at New Campus Underpass. While

minimum value was 1.3 meq/l on 15th Feb. 2014 (1st week) at Jinnah Underpass. Most values were near 2 meq/l. Overall trend was decrease in concentration with time.

The average temporal and spatial variation of suspended sediments and pH parameters is represented by taking average of respective values and the equations only represent the behaviour of the parameters within the reach of the canal for the months from February to September, 2014. Most variation was of suspended sediment and pH concentration whereas rest of the parameters were in limits.

Average spatial and temporal suspended sediment variations are related by the following given Equations 1 & 2:

$$S_s = 3E\text{-}12D^3 - 2E\text{-}06D^2 + 0.5585D - 46547$$

Where S_s is the avg. spatial suspended sediment concentration in PPM and D represents the reach length in m.

$$S_t = -0.0005T^3 + 0.1341T^2 - 7.307T + 218.47$$

Where, S_t is the avg. temporal suspended sediment concentration in PPM and T represents the time in days

Average spatial and temporal pH variation are related by the following given Equations 3 & 4:

$$P_s = -2E\text{-}14D^3 + 1E\text{-}08D^2 - 0.0037D + 319.32$$

Where, P_s is avg. spatial pH concentration and D represents the reach length of Lahore Branch canal in m.

$$P_t = 0.0035T^3 - 0.0699T^2 + 0.2184T + 7.4666 \quad (4)$$

Where, P_t is the avg. temporal pH concentration and T represents the time in days.

These equations (1-4) only represent the behavior of suspended sediments and pH for this research only. These relationships are poor and should not be used for research purposes.

A. Comparison between canal water quality and waste water quality from pipes

For this purpose data of discharges from drainage/sewer pipes was measured by filling a cube of 7 inches/side using a stop watch and samples were taken for chemical parameter analysis at these locations. Samples could not be collected from other sites as most of the pipes were not flowing. The recorded discharges from these pipes are given in Table VI.

In this table values of EC, RSC and bicarbonates for the pipe discharges exceed the limits for irrigation requirement and hence are deemed unsuitable for irrigation purposes. The canal water near these pipe locations showed chemical parameters were within the specified limit.

The total dissolved solids (TDS) have a relationship with the salinity of water [xiv]. We can get TDS from EC by a multiplication factor of 0.64 to get PPM of TDS.

For example, the TDS for pipe at Station 9 Ranipindi Bridge are 1562.88 ppm, which is 1.56 grams/litre of water. However, when it is mixed with canal water the TDS in canal water is 168.32 ppm, which is 0.168 grams/litre of water. Hence the TDS concentration of canal water with respect to TDS from waste water of pipe is reduced by 89.23 % and is only 10.76 % of original concentration.

Waste water may have affected the canal water quality at some places but this effect is negligible and the mixing of polluted water has no impact on overall water quality of the canal.

B. Comparison between pH of current canal water and previous studies

In the previous studies of water quality conducted in 2011 [x-xi] and later on in 2014 [xii], the range of pH values along the length of Lahore canal were within the normal range for irrigation water requirement by International and WAPDA standards i.e. 6.5-8.4. However, in this research the values of pH were within range for 1st four weeks of sampling. For 6th set of sampling on 10th May showed mostly "basic" nature of water at different locations and 10th set of samples on 12th July showed "acidic" nature. A comparison of these results is shown in Table VII.

C. Comparison between suspended sediment & pH of canal water

Various types of rocks and soil can release acidic and alkaline compounds into the water. In the presence of calcite ($CaCO_3$), carbonates (HCO_3) are released into the water causing the alkalinity of the water in contact with soil/rock. When sulphide minerals (pyrite or fool's gold "FeS_2") are present, water and oxygen react with these minerals to form sulphuric acid (H_2SO_4). This causes the water in contact to become acidic in nature. Drainage water from forests and marshes is often slightly acidic in nature because decaying vegetation produces organic acids. Since rain water itself is slightly acidic, because of that monsoon rain water of this canal become acidic in nature Fig. 5.

The high concentration of suspended sediments at Harbanspura was may be due to water entering from storm drain pipes just upstream of Harbanspura. The stream power was not enough and the sediments were deposited just before Taj Bagh Bridge.

TABLE VI
WATER CHEMICAL PARAMETER DATA FOR DRAINAGE/SEWER PIPE FALLING INTO THE CANAL AND CANAL WATER

Station	sample	Q ft^3/s	EC µS/cm	Ca+ Ma meq/l	Na meq/l	Bi-carbonate meq/l	Cl meq/l	RSC meq/l	SAR meq/l	pH	Remark
9	pipe	0.0135	2442	8.5	15.9	15.2	4.1	6.7	7.7	6.9	Unfit
9	Canal	402	263	2.6	0	2.2	0.2	0	0	6.9	Fit
1.33 km D/S of 9	pipe	0.0152	2035	6	14.3	12	3.2	6	8.2	7.3	Unfit
L/S 1km U/S of 8	pipe	0.0189	2120	7	14.7	13	4.4	6	8	8	Unfit
8	canal	402	264	2.6	0	2.1	0.3	0	0	6.6	Fit
0.73 km D/S of 8	pipe	0.018	2400	6.6	15.1	13.4	3.7	6.4	7.9	6.5	Unfit
7	canal	402	254	2.4	0	2	0.3	0	0	6.7	Fit

TABLE VII
pH VARIATION COMPARISON WITH PREVIOUS STUDIES

Location	Station	pH concentration (limit 6.5-8.4)					
		This research (2014)			Tayyaba et al.(2011)	Tahir et al. (2011)	Ansari et al. (2014)
		1st week	6th week	10th week			
Khaira Head Bridge	10	7.9	9.1	5	7.76		
Rani Pindi Bridge	9	7.8	7.8	5.5	7.74		7.4
Harbanspura Underpass	8	7.7	6.4	5	7.69	6.9	7
Tajbag Bridge	7	7.5	6.6	5			
Tajpura Bridge	6	7	7.1	6.4			
Mughalpura Underpass	5	7.8	8.3	6	7.45	6.7	7.2
Dharampura Underpass	4	7.9	9.3	6.3	7.53		7.5
FC College Underpass	3	7.9	9.2	6.3	7.63		
New Campus Underpass	2	7.9	8.8	6.1	7.54		7.3
Jinnah Underpass	1	7.9	7	6.1			

D. Bed deposits in the canal

The depth of bed deposits were measured during canal closure in January. Deposits were mostly comprised of sand sized particles and sludge from waste material entering the canal. Fig. 6 depicts that most of the waste material was entering between Rani Pindi bridge and Tajpura Bridge. Apart from sand deposits, different types of materials were thrown into the canal, which included things such as: bottles, handis, ladies purses and other house hold items. Waste water from different pipes was stagnant in some reaches/sections of the canal. The maximum bed deposits of 762 mm on right side and 609.6 mm on center and left sides were measured at upstream of Tajpura bridge.

Generally, the average depth of deposited material was about 152.4 mm. The grain size distribution of bed sediment deposits varied from smallest particle size of 0.088mm to a max particle size of 0.35 mm. These particle sizes classify the deposits as sand fraction. This range of sand fraction deposits was similar for all stations

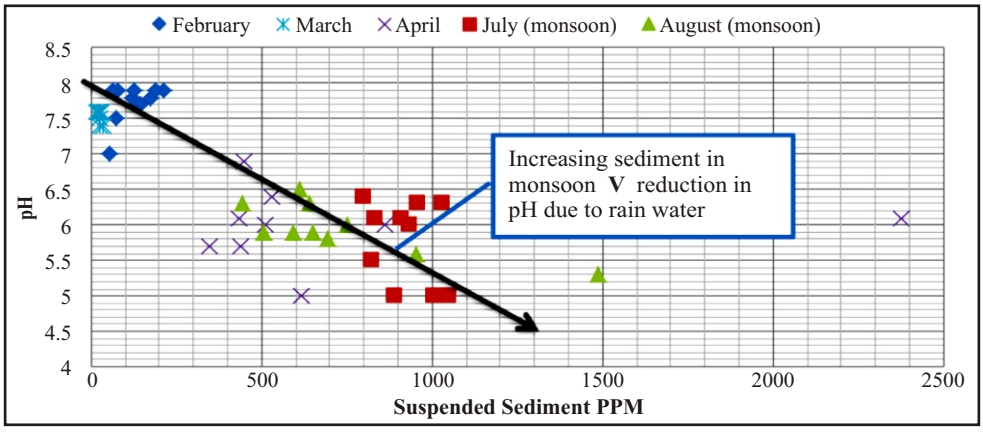

Fig. 5. Increase in suspended sediment concentration and reduction in pH - a function of monsoon season.

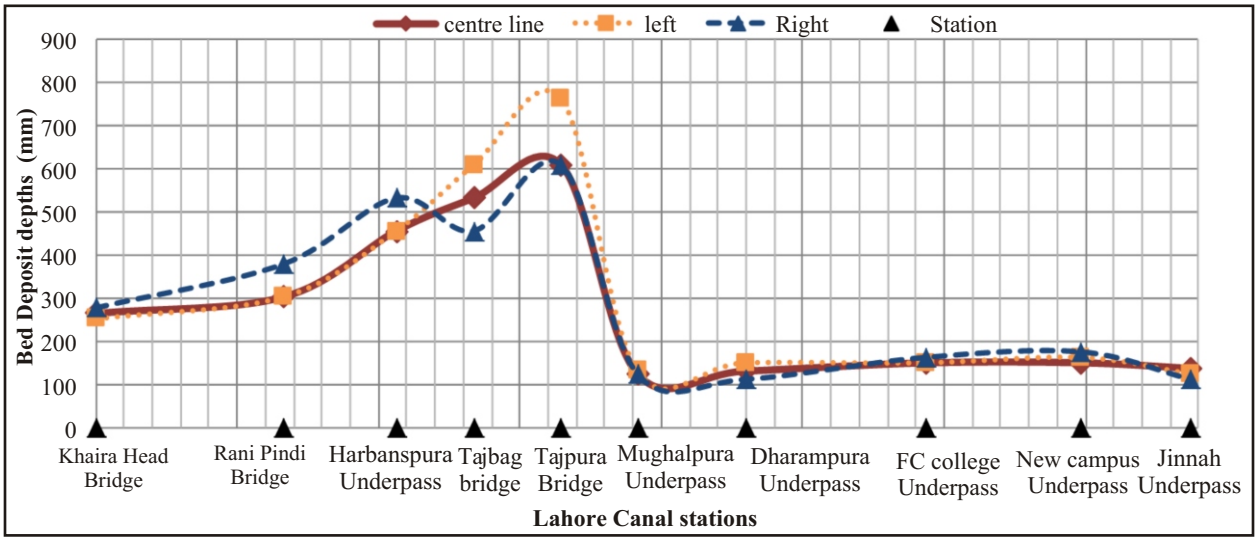

Fig. 6. Bed deposits along the canal with maximum deposits near Tajpura Bridge

VII. Conclusions

The suspended sediment samples were collected at specific sites and timings according to schedule. They were submitted to ISRIP for testing. After testing of samples for suspended sediment concentration, the results were collected. By observation and measurement during canal closure, the sand bed deposits were found maximum between Harbanspura and Tajpura Bridge partly due to short distance from the canal intake. Overall deposits may be classified as of sandy type- dominated by sand particles.

Sediment concentration was at its peak on 12th April 2014 and during the monsoon season (Jul-Aug 2014) and measured maximum near Harbanspura due to water entering from storm water pipes upstream of Harbanspura Underpass. Variation of suspended sediment concentration was independent of addition of waste water. Irrigation water quality of samples varied from being basic to acidic in nature due to sediment input with pH value ranging from 9.5 to 4.6. In general the quality of 58 % of samples canal water was found good for irrigation during dry period. Other chemical parameters were within limits by Irrigation department and FAO.

For reach between Rani Pindi and Tajbag Bridge, addition of waste water from sewer pipes had no effect on the water quality of canal related to irrigation.

The results showed that only suspended sediments and pH trends vary inversely proportional to each other but pH of canal water has no effect on suspended sediment concentration. It is the suspended sediment concentration which is affecting the pH of canal water. Any relationship between suspended sediment and other water quality parameters could not be developed as variation of suspended sediment was not following any direct and indirect relationship to variation of other water quality parameters other than pH.

VIII. Recommendations

In order to improve data quality and thus results further water sampling should be done on daily basis instead of alternate weeks. Likewise, the number of cross sections/stations should be increased.

Although sewage water has not been found deteriorating the water quality however further detailed data should be collected for comprehensive results.

Furthermore, water should also be tested for trace metals as industrial waste is being dumped into this canal that may include trace metals which are harmful for irrigation purpose.

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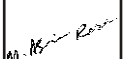
1	Mr. Muhammad Asim Raza (Main /Principal Author)	Literature review, data collection, statistical analysis, manuscript writing and interpretation of results.	
2	Mr./Dr./Prof. Muhammad Ashiq Kharal (2nd Author)	Proposed topic, basic study design, methodology, referencing and quality insurer