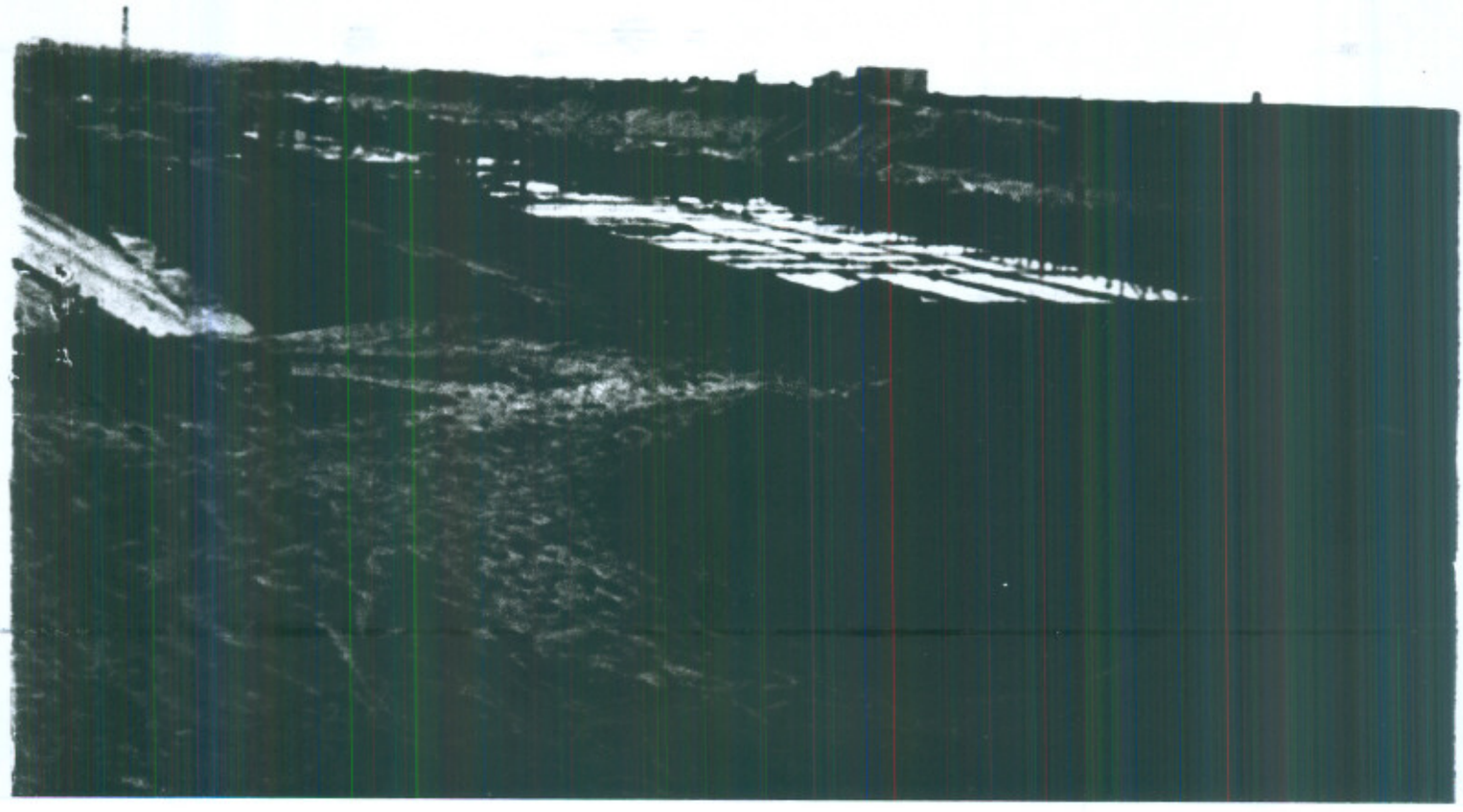
Engineering News

A Quarterly Journal of the Pakistan Engineering Congress

Vol: 42 July - December 2005 No: 6 & 7





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COVER PHOTO

Taunsa Barrages Emergency Rehabilitation and Modernization Project
Top : Concreting in Progress for Silt Excluder in U/S Right
Bottom : A General View of Down Stream Area of the Sub-Weir Construction

47th YEAR OF PUBLICATION

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ON OTHER PAGES

IN THIS ISSUE

EDITORIAL

☆ The urgency and need for Remodelling of Barrages 3

NEWS

☆ Welcome to New Members 4

TECHNICAL VIEWS

☆ Prediction of Water Quality of Indus River Downstream of Ghazi using QUAL2K Model 5
- *Muhammad Jamil & Prof. Dr. Muhammad Latif*

☆ Environmental Impacts of Ghazi Barotha Hydropower Project on River Indus and Surrounding Areas 23
- *Engr. Ghulam Ali Soomro & Dr. Allah Bakhsh Sufi*

☆ An Introduction to Constructed Wetlands (Reed Beds) Sustainable Low Cost Wastewater Treatment Plants 31
- *Engr. Mian Iftikhar Ahmed*

☆ Application of Remote Sensing Techniques for Conserving Scarce Water Resources : A Case Study from Pakistan 34
- *Engr. Abdul Shakoor, Engr. Naveed Alam & Engr. Muhammad Nadeem Asghar*

☆ Applications of Membrane Separation Technology in Textile Mills 43
- *Engr. Zeeshan Nawaz, Prof. Engr. Naeem A. Sheikh & Engr. Kashif Sagheer*

☆ Environmental Impacts of Polluted Effluents on Human Health 50
- *Engr.Muhammad Shariq Ahmed*

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The urgency and need for Remodelling of Barrages

Pakistan inherited from the British a wonderful and productive canal system, which has no parallel in its extensiveness and engineering prowess. It is a life line for the farmers and boon to the country's economy. In fact it sustains life, not only for the farming community but also generates industrial activities by meeting water needs. Any damage or efficiency loss will directly reflect on GNP. Without the canal system this part of the world could not make much progress. This is a huge and gigantic water management system which consists of 14 Barrages, 11 link canals, 24 water distribution systems with a stretch of 23,200 miles irrigating 22 million acres of land in Pakistan.

As obvious, the important parts of each system is a Barrage to raise the level of water in a river, a canal to carry the water to the farmer's neighbourhood and water courses to carry the water further to the land intended for farming. The system is a body with Barrage as the head and canals and courses like blood arteries and veins. Any damage, any where, is certain to affect the quality of life of the system and, as a result, humans benefiting from it.

Major part of the canal system was built early in the last century and needs regular and continuous maintenance to get optimum flows, moving. Repair and remodelling of Barrages is part of that effort. It is a matter of great satisfaction that the governments have initiated remodelling work on some of them. Taunsa Barrage is one of those.

It is a huge structure permitting and regulating million cusecs of water to its fullest capacity. The Barrage was built in 1958 and diverts over 28,000 cusecs of water to D. G. Khan, Muzaffargarh and Taunsa-Punjnad Link Canals. In the absence of this Barrage 2.3 million acres of land will stay dry. Beside diversion of water the Barrage provides a deck for road, railway line and numerous cable transmission lines. It must be preserved and kept in efficient working conditions to maintain linkage on the two sides of the river and avoid hundreds of thousands of farming families to starve.

For the work to be accomplished in time, the engineers and workers are toiling hard with one main objective i.e. restoring the structure to its optimum capacity and benefit profile. Their work is to be encouraged and commended. Section of the press, however, has reported misgivings by some people that remodelling work, particularly of Taunsa Barrage is meant to deprive lower riparian of their share of water. It must be clear that remodelling of Dams and Barrages has nothing to do with share allocation. It is an absolute technical requirement to keep the structure in working order to its original capacity and use. This Barrage needs remodelling to reduce silt deposition in canals and enhance safety of both upstream and downstream parts of the structure.

The distrust and misgivings must be replaced by trust and confidence. Those who matter in government and public should enhance the public confidence in institutions of rightful distributions of resources and efficient operations and maintenance of systems. People making irrelevant remarks and statements must avoid creation of tensions amongst various parts of the country. A group of engineers on behalf of the Pakistan Engineering Congress has visited the on-going work of Taunsa Barrage and appreciate the diligence of all the workers and professionals. The Congress expects that funding and support by the Government and public to the project continues and the project achieves timely completion.

WELCOME TO NEW MEMBERS

The Executive Council of the Pakistan Engineering Congress approved Membership of the following new members in to the Congress fold. The Engineering News congratulates all of them and welcomes them to PEC

Members admitted on 24-09-2005

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4 Engr. Shan Ahmad
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25 Engr. Yousaf Mahmood
26 Engr. Mujeeb Raza Khan Warsi
27 Engr. M. Shoaib ur Rehman Chatta

Members admitted on 10-12-2005

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PREDICTION OF WATER QUALITY OF INDUS RIVER DOWNSTREAM OF GHAZI USING QUAL2K MODEL

By

Muhammad Jamil & Prof. Dr. Muhammad Latif

ABSTRACT

The Water and Power Development Authority (WAPDA) has recently implemented the Ghazi-Barotha Hydropower Project (GBHP) on the Indus River to utilize the hydraulic head for power generation that is available between the tailrace of the Tarbela Dam and the confluence of the Indus River with Haro River. For this purpose a 52 km long concrete-lined power channel was constructed to divert the flow from barrage to a power complex. The inflow to the barrage pond will consist almost entirely of releases from Tarbela dam. During the low-flow period (from early October to mid-May), when Tarbela releases will be less than the channel capacity of 1,600 cumecs, a reduced flow of only 28 cumecs will be released D/S of the barrage into the Indus River.

The increase of contaminants concentration due to reduced flows may restrict the use of river water for aquatic life especially fish. In this paper, an effort was made to model the behavior of contaminants transport in River Indus from D/S of the Ghazi to the confluence of Indus River with Kabul River (about 40 km stretch). For this purpose QUAL2K model developed by USEPA employed.

For simulation purposes three scenarios were developed to study the worse conditions of water quality in Indus River in the low flow period. Scenaro-1 was run for low flow of 28 cumecs (990 cusecs) with the present conditions (2002 data) of wastewater quantity and quality. In Scenario-2, flow was the same but wastewater quantities were projected upto 2063 with same wastewater quality as in 2002. In case of Scenario-3, it was assumed that the wastewater quality will be further deteriorated to the extent that the BOD value will be in the range of 80 mg/l in the project life i.e. 2063. The river flow and wastewater quantities were kept same as in case of Scenario-2. The model results are showing that the DO and BOD will remain within the permissible limits (i.e. DO >4mg/l and BOD <8mg/l) in case of all three scenarios.

In case the BOD value of wastewater quality further increased above 80 mg/l as at the time of feasibility study of the project it was above 400 mg/l, the quality of the Indus River floodplain will deteriorate and it may endanger to the aquatic life. To keep the BOD value of wastewater in the range of 80 mg/l proper mitigations and management plans have to be evaluated, which may include provision of Wastewater Treatment Facilities like Treatment Plants for Industrial Estates and big Towns/Cities along the drains/nullas and Oxidation Ponds for the relatively small towns/villages which are directly disposing off their wastes in the rivers. In case of villages/towns which are sufficiently away from the river and these are disposing off their sewages into the drains/nullas, to keep the BOD below 80 mg/l, Reed-Bed Lagoons and Reed-Bed Channels may be provided.

If the Sarhad Development Authority (SDA) developed Industrial Estate and even BOD value will keep in the range of 80 mg/l, the river water quality may be affected. In that case release of excessive water at D/S of newly constructed barrage (U/S of Ghazi) will be readily available mitigation measure.

1. INTRODUCTION

Water is prerequisite for life and development. This is the reason that from early age of the humanity, most of the population was initially settled along the rivers and streams. Every use of water generates wastewater. Natural streams are always considered as an easy way to dispose off many kinds of effluents. The wisdom behind this practice is that the wastes are diluted and washed away as well as diluted by the stream water and the same are not visible at the dumping sites.

The natural stream/river water contains substances derived from the environment, both natural and man-made. The amount of these constituents in water determines its quality. Consequently, sampling the water and measurements of the concentrations of various

constituents can quantify the water quality. Such information about river water quality can be vital for determining the suitability of water for various purposes, such as domestic agricultural and industrial uses, sustenance of aquatic life and other recipients.

It is believed that only proper way for determining the quality of water, is by chemical analysis of water samples. However, other questions might arise such as understanding the relationships between the water quality parameters and contents, prediction of water quality, estimating the impacts of river pollution and water quality management. Such problems cannot be solved by mere chemical analysis and it is here that models can be used to assist in proper management. Basically, river water quality models are tools for analyzing, extrapolating and predicting water quality.

2. GHAZI BROTHA HYDROPOWER PROJECT (GBHP)

The Water and Power Development Authority (WAPDA) of Pakistan has recently implemented the Ghazi-Barotha Hydropower Project on the Indus River with the financial assistance of the World Bank and other international donor agencies. The Project was planned to utilize the hydraulic head for power generation that is available between the tailrace of the Tarbela Dam and the confluence of the Indus River with Haro River. In this reach the Indus River drops by 76 m in a distance of 63 km (GBHP Report on Supplementary Environmental Studies, PHC, 1992). This is solely a power generation project with an installed capacity of 1450 MW. The Project has three main components i.e. a barrage located about 7 km downstream of Tarbela dam forming a pond, a 52 km long concrete-lined power channel to divert the flow from barrage to a power complex, which is located near the confluence of Indus and Haro rivers (Figure 1).

There are number of villages close to the banks of the river downstream of the newly constructed barrage U/S of Ghazi, which have no proper drainage system and their wastewaters either discharge directly into the river or soak into the ground and reaches the river indirectly through percolation (GBHP Report on Supplementary Environmental Studies, PHC, 1992). The other nearby villages and towns, which are relatively away from the river, discharge their wastewaters into the natural streams, ultimately joining the river.

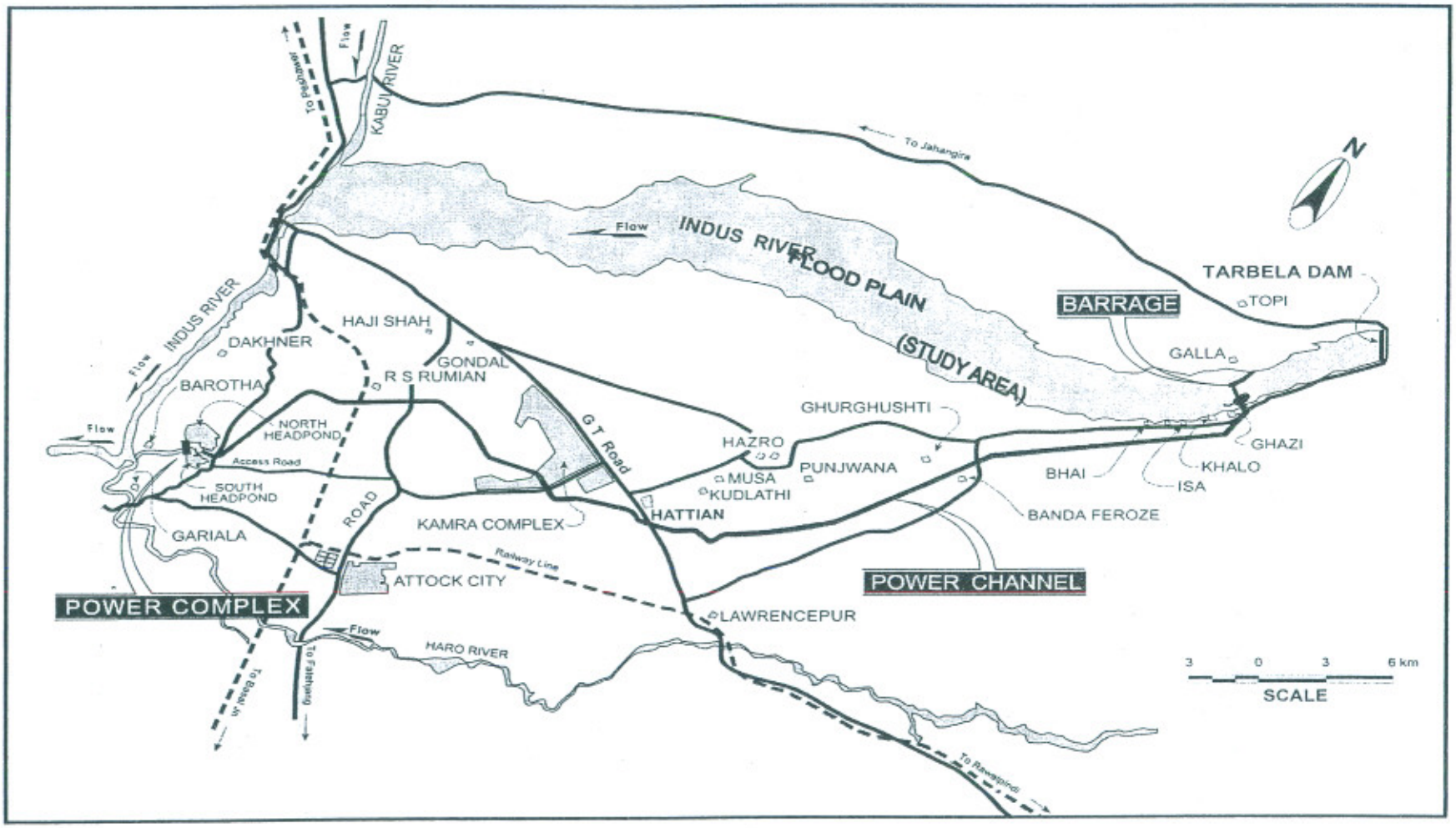
The flow to the power channel of GBHP will consist of release from Terbela Dam. During the low-flow period (from early October to mid-May), when Tarbela releases shall be less than the channel capacity of 1,600 cumecs (about 56,450 cusecs), it will not only result in reduction in the flows in the power channel but also less water will be available for releasing into the river downstream of the barrage. These releases may reach to almost nil during early 20 days of January. However, WAPDA has ensured a minimum release of 28 cumecs (about 990 cusecs) during this period. (GBHP Report on Supplementary Environmental Studies, PHC, 1992). It was apprehended that the water quality of Indus Floodplain will be adversely affected by the wastewater, which is being disposed off into the river particularly during low flow period.

The increase of contaminant's concentration due to reduced flows may pose a threat to the aquatic life especially fish. Keeping in view the alarming situation of the contaminants in river, an effort was made to model the behavior of contaminants transport in River Indus from D/S of Ghazi to the confluence of Indus River with Kabul River (about 40 km stretch). For this purpose QUAL2K model developed by USEPA was used.

3. DESCRIPTION OF THE STUDY AREA

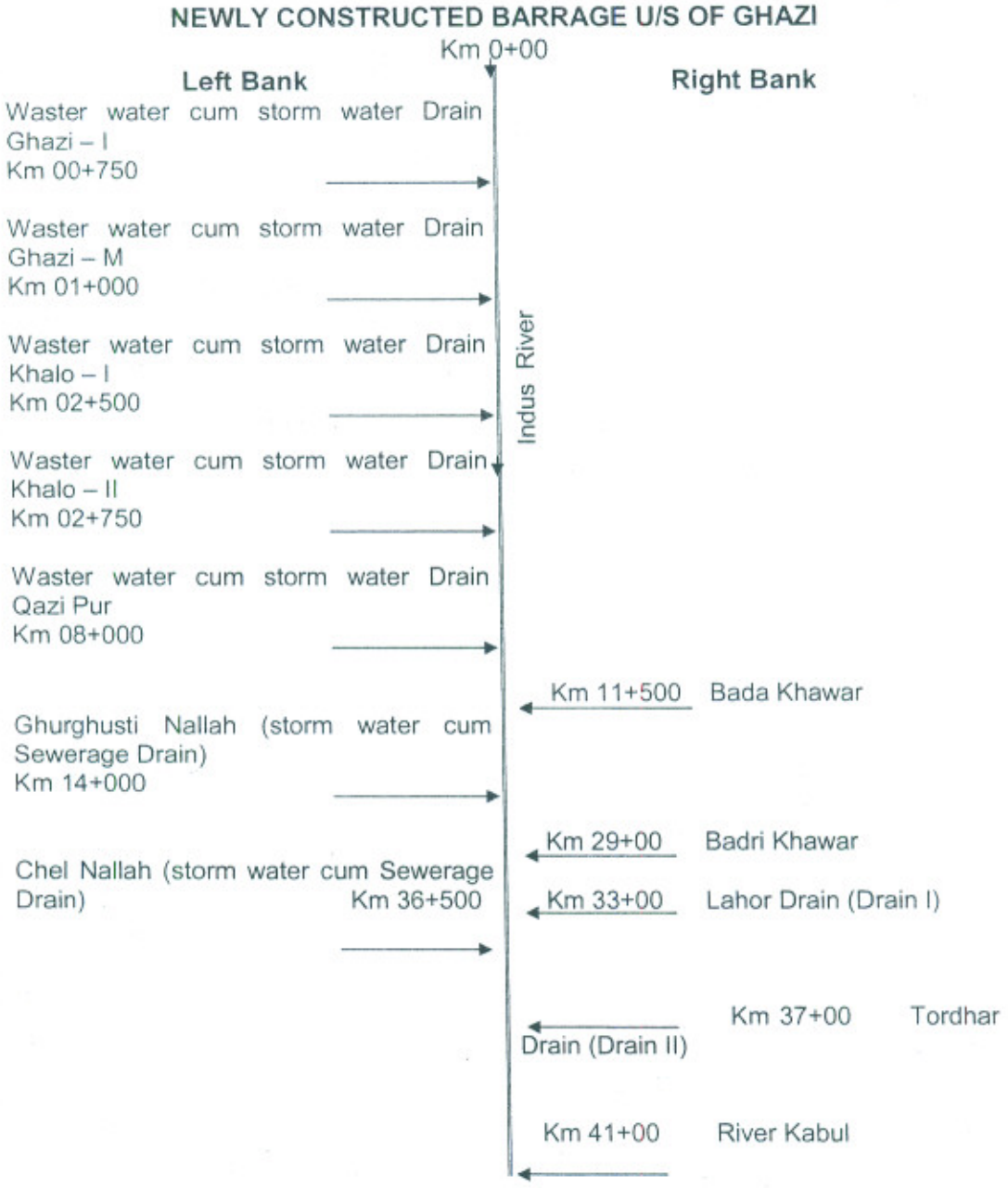
For the present study, River Indus was selected considering change of its present status by diverting the discharge of river from Ghazi to Brotha through a channel. For this purpose a reach of about 41km between Ghazi to the point of confluence of River Indus with Kabul was selected. The study area is shown in Figure 1. There are seven wastewater cum storm-water drains on left bank and four on right bank of the river, which are disposing off effluents into the river in the selected reach. These drains join the river at different reaches starting from

Fig 1: Ghazi-Barotha Hydropower Project Layout



00+750 km and terminating at about 37+000 km. A line diagram of the proposed study reach is shown in Figure 2.

Fig. 2: Schematic Presentation of the Selected Reach of River Indus



4. AN OVERVIEW OF PREVIOUS STUDIES

Environmental Assessment at Feasibility Stage

Environmental assessment of the project was started at feasibility stage and report was prepared at the completion of the Stage I of Engineering Study in August 1991, which presents the results of the environmental assessment of the Ghazi-Brotha Hydropower Project. The objectives of this report were to:

- Provide a comprehensive record of the baseline conditions of the project area, covering socio-economic and cultural aspects of the local populace and physical environmental condition of the project area and its surroundings,
- Describe the project features, and
- Analyse their effects on the baseline conditions (PHC, August 1991).

At this stage to check the quality of river water sampling was carried out at seven sites in the river during high flows (August) and low flows (December). The results indicated that the river water was slightly alkaline as its pH was varying from 7.6 to 8.0 at various locations. The ion concentration and total dissolved solids were within the desirable limits for human consumption. The BOD of Indus River samples was between 3 to 12 ppm, and coliform counts were high.

Report on Supplementary Environmental Studies

Supplementary Environmental Studies were carried out in the period from October 1991 to January 1992 and comprised the following:

- Ecology of the Indus River Flood Plain
- River Water Quality
- Public Health
- Animal Health
- Indus River Gorge and
- Archaeological surveys (PHC, 1992)

During these supplementary environmental studies, existing situation of the villages along the river stretch were studied in detail to assess the present water supply and wastewater disposal facilities, and to evaluate the socio-economic conditions for the prediction of future trends.

Water sampling was carried out in November 1991 to measure the quality of water at river water, ground water and wastewater/sewage. The results of tests on wastewater/sewage samples taken at Ghazi, Khalo and also at WAPDA colony, where sewage collection and treatment facilities were existing but where the sewerage treatment works was not operational, showed that BOD lies in the range of 315 to 435 mg/l (PHC, 1992)

Supplementary Environmental And Social (SES) Study For Management of Indus Flood Plain And Water Releases

Although most of the environmental effects on the water quality of floodplain were covered in the above studies, even at some national and international forums it was highlighted that there would be some adverse effects on river water quality during low flow period. In response to this, and on the emphasis from the local office of an international non-government organization (NGO), the World Bank desired to repeat the study.

The study is still in progress but the draft report has been submitted to World Bank for comments. The broad objective of the study was to resolve outstanding issues as related with the Project operation (WAPDA, 2003).

For this study, water samples were collected from river and other storm water channels/drains by WAPDA. Table 1 depicts the discharges of drains measured on monthly basis for a year around. The table also includes the date and time when the discharge measurements were carried out in each month.

Table 1: Discharge Measurements of Potential Sources Joining Indus River in the Study Area (2002)

(Discharge in Cumecs)

Period		Potential Sources of Left Bank (Wastewater Drains/Nullahs)							Potential Sources of Right Bank (Nullahs/Drains)					
		Ghazi-I	Ghazi-M	Khalo-I	Khalo-II	Qazipur	Ghurghushti	Chel	Bada Khawar	Gadoon Amazai I	Gadoon Amazai II	Badri Khawar	Drain -I	Drain II
Sep. 2002	Date	09/02/2002	09/11/2002	09/02/2002	09/11/2002	09/02/2002	29/8/02	09/03/2002	09/05/2002	09/06/2002	09/06/2002	09/10/2002	Not Measured	
	Discharge	**0.0028**	**0.016**	**0.004**	**0.009**	**0.0051**	**1.06**	**0.929**	**0.03**	**0.0212**	**0.049**	**2.73**		
Oct. 2002	Date	10/04/2002	10/04/2002	10/04/2002	10/04/2002	10/04/2002	10/07/2002	10/08/2002	No Discharge has been observed	18/10/02	18/10/02	16/10/02	19/10/02	19/10/02
	Discharge	**0.0046**	**0.0102**	**0.0019**	**0.0014**	**0.003**	**0.262**	**0.3468**		**0.0267**	**0.0804**	**2.93**	**0.74**	**0.1093**
Nov. 2002	Date	11/09/2002	11/09/2002	11/09/2002	11/09/2002	11/09/2002	11/07/2002	11/07/2002		11/02/2002	11/02/2002	11/06/2002	13/11/02	13/11/02
	Discharge	**0.0036**	**0.0056**	**0.0028**	**0.0035**	**0.0034**	**0.21**	**0.188**		**0.0062**	**0.084**	**2.42**	**1.07**	**0.181**
Dec. 2002	Date	18/12/02	18/12/02	18/12/02	18/12/02	18/12/02	14/12/02	14/12/02		21/12/02	21/12/02	20/12/02	22/12/02	22/12/02
	Discharge	**0.00088**	**0.0026**	**0.00028**	**0.0026**	**0.0017**	**0.145**	**0.142**		**0.005**	**0.057**	**2.196**	**0.972**	**0.241**
Jan. 2003	Date	23/1/03	23/1/03	23/1/03	23/1/03	23/1/03	13/1/03	15/1/03		24/1/03	24/1/03	23/1/03	24/1/03	24/1/03
	Discharge	**0.0024**	**0.0038**	**0.0005**	**0.0005**	**0.002**	**0.347**	**0.245**		**0.006**	**0.065**	**2.25**	**0.375**	**0.126**
Feb. 2003	Date	02/03/2003	02/03/2003	02/03/2003	02/03/2003	02/03/2003	02/01/2003	02/01/2003		02/04/2003	02/04/2003	02/04/2003	02/04/2003	02/04/2003
	Discharge	**0.0013**	**0.003**	**0.00098**	**0.00098**	**0.0013**	**0.333**	**0.282**		**0.0067**	**0.017**	**1.58**	**0.301**	**0.058**
Mar. 2003	Date	03/12/2003	03/12/2003	03/05/2003	03/05/2003	03/05/2003	03/05/2003	03/11/2003		03/11/2003	03/11/2003	03/10/2003	03/10/2003	03/10/2003
	Discharge	**0.0068**	**0.0049**	**0.0018**	**0.0107**	**0.0021**	**0.444**	**0.409**		**0.0011**	**0.041**	**2.65**	**1.29**	**0.49**
Apr. 2003	Date	04/12/2003	04/12/2003	04/12/2003	04/12/2003	04/12/2003	04/10/2003	04/09/2003		04/11/2003	04/11/2003	04/11/2003	04/09/2003	04/09/2003
	Discharge	**0.00143**	**0.0043**	**0.00187**	**0.00093**	**0.0028**	**0.309**	**0.308**		**0.00198**	**0.0386**	**1.65**	**0.70**	**0.375**
May 2003	Date	05/02/2003	05/02/2003	05/02/2003	05/02/2003	05/02/2003	05/03/2003	05/03/2003	No Discharge has been observed	05/08/2003	05/08/2003	05/05/2003	17/5/03	17/5/03
	Discharge	**0.001**	**0.0053**	**0.0013**	**0.00065**	**0.0025**	**0.252**	**0.333**		**0.0022**	**0.014**	**1.85**	**0.676**	**0.106**
Jun. 2003	Date	06/03/2003	06/03/2003	06/03/2003	06/03/2003	06/03/2003	06/02/2003	06/02/2003		06/05/2003	06/05/2003	06/04/2003	19/6/03	19/6/03
	Discharge	**0.0014**	**0.0282**	**0.00042**	**0.00042**	**0.0021**	**0.23**	**0.199**		**0.0071**	**0.014**	**1.8**	**0.7**	**0.12**
Jul. 2003	Date	07/08/2003	07/08/2003	07/08/2003	07/08/2003	07/08/2003	07/03/2003	29/7/03	12/7/03	12/7/03	12/7/03	7/7/03	29/7/03	29/7/03
	Discharge	**0.002**	**0.011**	**0.00053**	**0.00053**	**0.0025**	**0.388**	**0.141**	**12.13**	**0.0039**	**0.0103**	**1.83**	**0.75**	**0.102**
Aug. 2003	Date	08/07/2003	08/07/2003	08/07/2003	08/07/2003	08/07/2003	08/06/2003	08/06/2003	11/8/03	08/04/2003	08/04/2003	08/11/2003	20/7/03	20/7/03
	Discharge	**0.00114**	**0.0136**	**0.00073**	**0.000365**	**0.0032**	**0.302**	**0.724**	**1.52**	**0.0011**	**0.034**	**5.32**	**1.38**	**0.415**
Sep. 2003	Date	09/02/2003	09/02/2003	09/02/2003	09/02/2003	09/02/2003	09/02/2003	09/11/2003		09/01/2003	09/01/2003	09/10/2003		09/10/2003
	Discharge	**0.001**	**0.0127**	**0.001**	**0.001**	**0.0054**	**0.252**	**0.444**		**0.009**	**0.01**	**3.41**		**0.321**

The samples were taken in high-flow and low-flow state of the streams/river to determine variation of contaminants. The physical testing however remained continued with the activity of discharge measurements. Table 2 and 3 provides the water quality results for the samples collected for left and right banks in high and low flow conditions.

5. MODEL DESCRIPTION AND DATA COLLECTION

The enhanced stream water quality model QUAL2K or Q2K (Chapra and Pelletier, 2003) represents a modernized version of the QUAL2E or Q2E (Brown and Barnwell, 1987). The model permits simulation of several water quality constituents in a branching stream system. The conceptual representation of a stream used in the Q2K formation is a stream reach that has been divided into a number of sub-reaches or computational elements equivalent to finite differences.

QUAL2K is a comprehensive and versatile stream water quality, model. It can simulate up to 26 water quality constituents in any combination desired by user. The main constituents including temperature, conductivity, inorganic suspended solids, dissolved oxygen, detritus, slow CBOD, fast CBOD, dissolved organic nitrogen, ammonia nitrogen (NH4), nitrate, nitrogen (NO3), dissolved organic phosphorus (DOP), inorganic phosphorus, phytoplankton, bottom algae, pathogen, alkalinity, pH, TSS, NH3, Arbitrary non-conservative constituents, etc. The model has 17 worksheets of which 14 are used to enter data while 3 are output

The main data requirements for model is the discharge in each river reach, the river cross-sections at different points, bed slope of the river and water quality of main stream and tributaries. The main data used in the model included:

- River discharge
- River cross-sections
- River bed slope
- River water temperature
- Wind velocity
- Shade
- Cloud cover and
- Water quality data.

The cross-sections of the River Indus for selected reach were available at 43 points between barrage and point of confluence of Indus River with Kabul River, which were obtained from Pakistan Hydro Consultants (PHC, 2002). The selected cross-sections, which were used for the present study, were plotted with the help of computer showing the water levels in different creeks. Only that part of the cross-section was used in model where water has been found in the creek. For given reach, an average cross-sections has been taken. The discharge for reach was also known, so velocity was calculated for every reach. The latitude and longitude of the area were taken from Atlas of Pakistan (1992). The other relevant data was collected from WAPDA Environmental Cell (WEC), 2003. For the present study the parameters selected for the model simulation include DO and BOD as the wastewater, which is being disposed off into the river.

Table 2: Physical, Chemical and Bioilogical Test Results of River and Drainage Waters of the Study Area (High-Flow Period- September 2002)

Sr. No.	Name of Sample	Temp °C	pH	E.C µs/cm	DO Ppm	TSS ppm	TDS ppm	BOD ppm	COD ppm	Cl ppm	Fe ppm
1	Indus River 30 m u/s of Ghazi Drain Outfall	17.9	8.54	170	8.9	1.5	125	0	0	14.5	0.11
2	Ghazi Wastewater Drain	24.7	7.27	676	3.1	10.5	349	57	191	15	0.01
3	Indus River 30 m d/s of Khalo Drain Outfall	19.1	8.37	167	8.1	0.5	165	0	5	14.5	0.1
4	Indus River 30 m u/s of Ghurghushti Nullah Outfall	22.5	8.1	425	6.7	0.5	272	0	0	21.5	0.05
5	Ghurghushti Nullah (storm water cum sewerage Drain)	19.2	8.68	181	9	0.5	123	0	0	14	0.08
6	Indus River 30 m d/s of Ghurghushti Nullah Outfall	21.5	8.51	180	8.8	1.5	167	0	0	21.5	0.01
7	Indus River 30 m u/s of Chel River/Nullah	19.3	7.98	201	8	4.5	98	0	0	16.5	0.14
8	Chel River/Nullah (storm water cum sewerage Drain)	23.3	7.99	511	6.7	4.5	322	0	14	25.5	0.09
9	Indus River 30 m d/s of Chel River/Nullah	17.8	8.03	176	9.1	5	96	7.7	NA	10	0.15
10	Gadoon-Amazi Eastern Drain	20.5	6.76	609	0.5	124	259	32	NA	34	0.16
11	Gadoon-Amazi Western Drain	19.6	6.94	695	0.6	17.5	314	78	374	41	0.2
12	Bada Khawar Nullah	No flow in Bada Khwar was available at the time of sampling.									
13	Indus River 30 m d/s of Bada Khawar Outfall	18	7.3	263	7.9	3.5	119	0	4	10	0.14
14	Indus River 30 m u/s of Badri Khawar Nullah Outfall	18	8.57	197	9.1	1	242	5.5	NA	20	Nil
15	Badri Khawar Nullah	20	8.66	506	7.2	3.5	329	0	0	31	Nil
16	Indus River 30 m d/s of Badri Khawar Outfall	18	8.68	499	8.4	5	463	6.6	NA	26.5	Nil
PEPA Standards*		=<3°C	6-9			200	3500	80	150	1000	2.0

Source: WAPDA (2003)
*As per Statutory Notification of August 2000
NA: Not Available

Table 3: Physical, Chemical and Biological Test Results of River and Drainage Waters of the Study Area (Low-Flow Period -January 2002)

Sr. No.	Name of Sample	Temp °C	pH*	E.C µs/cm	DO ppm	TSS ppm	TDS ppm	BOD ppm	COD ppm	Cl ppm	Fe ppm
1	Indus River 30 m u/s of Ghazi Drain Outfall	13.7	8.2	242	8.6	1.5	140	6.0	NA	6	0.05
2	Ghazi Wastewater Drain	14.6	7.45	685	3.9	133.0	340	66	107.0	58.0	0.37
3	Indus River 30 m d/s of Khalo Drain Outfall	15.2	8.68	326	7.8	0.5	150	6.0	33.0	11.0	0.04
4	Indus River 30 m u/s of Ghurghushti Nullah Outfall	11.2	8.82	260	8.3	0.5	170	15	17.0	10.0	Nil
5	Ghurghushti Nullah (storm water cum sewerage Drain)	14.5	7.88	393	6.3	0.5	110	15.7	NA	6.0	Nil
6	Indus River 30 m d/s of Ghurghushti Nullah Outfall	12.5	8.3	365	7.3	0.5	170	12.3	NA	10.0	Nil
7	Indus River 30 m u/s of Chel River/Nullah	11.5	8.55	259	8.7	0.5	110.0	3	NA	9	Nil
8	Chel River/Nullah (storm water cum sewerage Drain)	10.3	8.06	447	6.9	0.5	200	6.0	16	18.0	0.12
9	Indus River 30 m d/s of Chel River/Nullah	12.3	8.51	267	8.5	1	120	1.5	NA	8.0	Nil
10	Gadoon-Amazi Eastern Drain	10.3	7.7	784	5.4	608	440	111.0	687.0	52.0	1.69
11	Gadoon-Amazi Western Drain	20	8.65	582	5	9.5	290	112.0	354	49.0	0.18
12	Bada Khwar Nullah	No flow in Bada Khwar was available at time of sampling.									
13	Indus River 30 m d/s of Bada Khawar Outfall	11.7	8.2	230	7.5	1.0	130.0	3	115.0	8	0.01
14	Indus River 30 m u/s of Badri Khawar Outfall	The outfall of Chel Nullah was cut off from the river creek.									
15	Badri Khawar Nullah	11.7	8.2	531	7.9	0.5	300.0	4.5	41.0	19	-
16	Indus River 30 m d/s of Badri Khawar Outfall	13.4	8.68	284	8.5	0.5	180.0	0	0	12.0	Nil
	PEPA Standards*	=<3°C	6-9			200	3500	80	150	1000	2.0

Source: WAPDA (2003)

*As per Statutory Notification of August 2000
NA: Not Available

6. MODEL INPUT

According to model requirements, the selected river reach of 41 km was divided into computational elements of different lengths. The total selected length of the river was divided into 7 reaches as shown in Table 4. Each reach is of 5kms long except reach nos. 4 and 7, which are 10 kms and 6 kms long respectively. Reach 1 has four wastewater–cum storm water drains namely Ghazi-I at km 00+750, Ghazi-M at km 01+000, Khalo-I at km 02+500 and Khalo-II at km 02+750. Reach 2 contains one drain i.e. Qazi Pur at km 08+000. Reach 3 has two drains i.e. Bada Khawar at km 11+500 and Ghurghusti Nullah at km 14+000. In reach 4, there is no any kind of drain joining the river that's why it is named as plane reach. In reach 5, there is only one drain i.e. Badri Khawar at km 29+000. Reach 6 also contains one drain known as Lahor Drain at km 33+000. The last reach no. 7 has two drains i.e. Todhar Drain at km 36+500 and Chel Nullah at km 37+000.

Table 4: Distribution of Study Reach into Different Computational Elements

Reach No.	Reach Name	Distance Covered (kms)
1	Ghazi-Khalo Reach	0 to 5
2	Qazi Pur Reach	6 to 10
3	Bada-Ghurghusti Reach	11 to 15
4	Plane Reach	16 to 25
5	Badri Reach	26 to 30
6	Lahor Reach	31 to 35
7	Todhar-Chel Reach	36 to 41

7. MODEL CALIBRATION

The model was calibrated for low flow using river discharge data during January 2002. The wastewater discharges were taken for the same month of January 2002. The selected water quality parameters, i.e. DO and BOD were used to simulate for the selected reach of the river. The model was made to run only for low flow discharge because at high flow there would be insignificance effect on the water quality of the river floodplain from induction of the wastewater effluents, as high river flow will dilute these pollutions. So the model was not calibrated for high flow discharge.

The average discharge observed during January 2002 in the river floodplain was 297 cumecs (10,500 cusecs), which was used for model calibration. The DO and BOD values at 30 m d/s of different point sources observed during January 2002 that were used to compare the model out put values for caliberation purposes are given in Table 5.

Table 5: Measured Water Quality Parameters at 30 m D/S of Different Point Sources in the Study Area (January, 2002)

Site	DO (mg/l)	BOD (mg/l)
Ghazi	8.6	6.0
Khalo	7.8	6.0
Bada Khawar	7.5	3.3
Lahor	8.7	3.0
Chel	8.5	1.5

Source: WAPDA (2003)

The data used for mode calibration included DO, BOD, water temperature and other water quality parameters provided in Table 3. The other main data used for model calibration was:

- Bed Slope 0.002 m/m, as there is a drop of 76 m in a reach of 63 km (WAPDA, 2003).
- Manning's 'n' 0.1 (as recommended in "Documentation and Users Manual" for natural streams).
- Average wind velocity in the month of January 1.28 m/s (WAPDA, 2003).
- Upstream and Downstream Latitude and Longitude values of reaches (Atlas of Pakistan, 1992).
- Average Hourly air temperature for the month of January as 13.70 C° (WAPDA, 2003).
- Shade values were taken zero percent as per site conditions and users manual recommendations.
- Bottom Algae was taken as 20 percent as per site conditions and model manual instructions.
- Cloud Cover was taken as 25 percent as per site conditions and model manual instructions.

The model was made to run for calibration purposes by selecting the other parameters to be used by the model as per guidelines provided in the manual for the model users.
The comparison of DO and BOD measured and calculated values is presented in Table 6 and graphically are shown in Figure 3.

Table 6: Comparison of Observed and Calculated DO and BOD Values at Different locations in the study area

Location	Measured DO (mg/l)	Calculated DO (mg/l)	Measured BOD (mg/l)	Calculated BOD (mg/l)
Ghazi	8.6	8.55	6.0	5.38
Khalo	7.8	8.50	6.0	5.30
Bada Khawar	7.5	8.27	3.3	4.46
Lahor	8.7	7.50	3.0	2.98
Chel	8.5	7.30	1.5	2.58
Average	**8.22**	**8.02**	**3.9**	**4.14**

Average deviations w.r.t. the observed DO and BOD were calculated as under:

Average Deviation in DO:

$$\text{Avg. DO Deviation} = \frac{(\text{Avg. Observed DO} - \text{Avg. Calculated DO}) * 100}{\text{Avg. Observed DO}}$$

$$= \frac{(8.22-8.02)*100}{8.22}$$

$$= +2.4\ \%$$

Similarly,
Average Deviation in BOD:

$$\text{Avg. BOD Deviation} = \frac{(\text{Avg. Observed BOD} - \text{Avg. Calculated BOD}) * 100}{\text{Avg. Observed BOD}}$$

$$= \frac{(3.9 - 4.14) * 100}{3.9}$$

$$= -6.1\ \%$$

As the above values are within the acceptable limits, therefore the model stands calibrated.

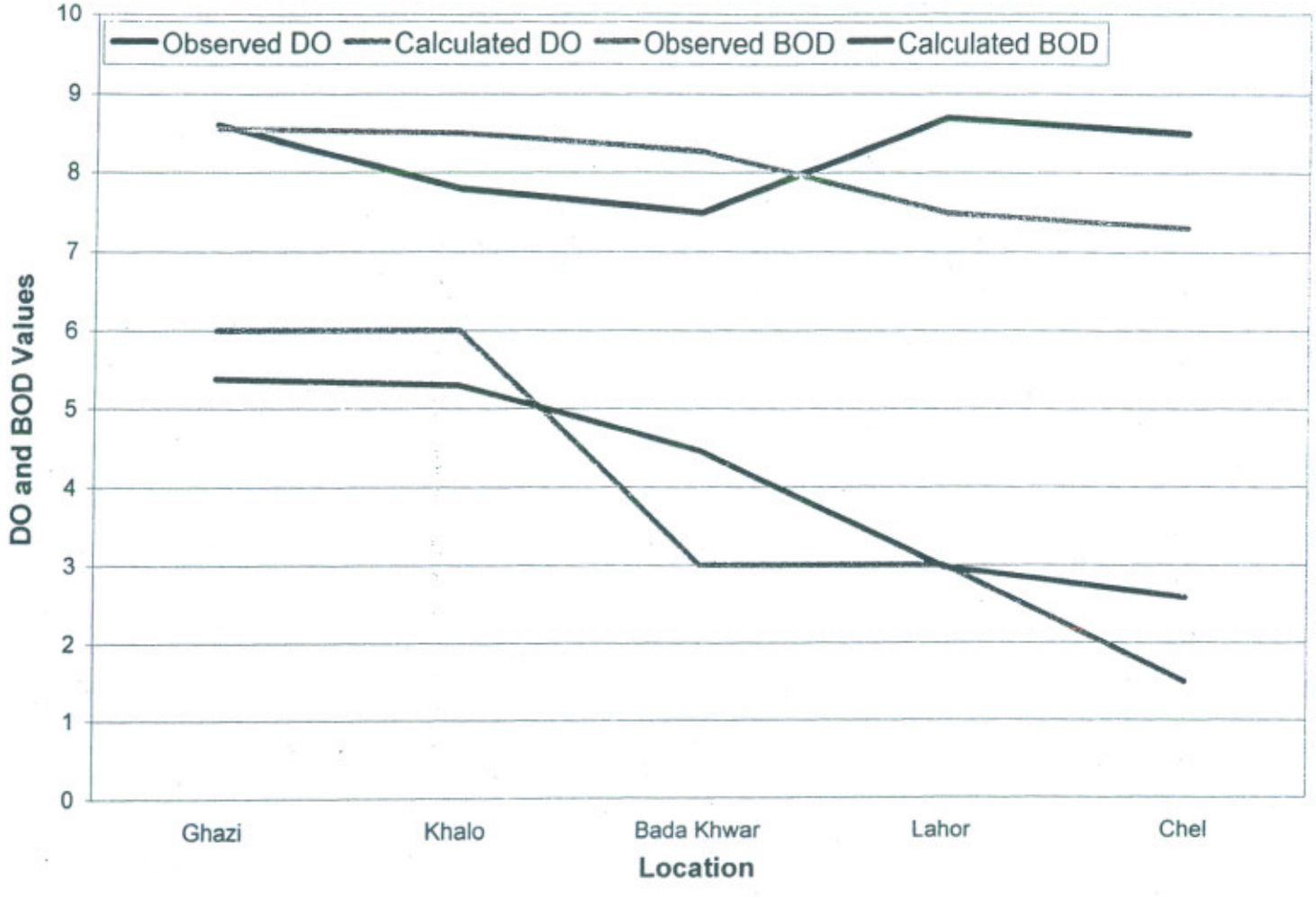


Fig. 3: Graphical Representation of Observed and Calculated DO and BOD Values

8. APPROPRIATE WATER QUALITY CRITERIA

One of the important parameter relating to the river water quality is dissolved oxygen. Aquatic life will be adversely affected if the dissolved oxygen is not within the prescribed limits or there is excessive concentration of heavy metals. However, the wastewater quality results show that there is no significant contribution of heavy metals. Therefore, the decision to be based on DO concentration, minima and not on average concentrations arises from various considerations. Deleterious effects on fish seem to depend more on extremes than on averages. For example, the growth of young fish is shown markedly if the oxygen concentration falls to 3 mg/l for part of the day, even if it rises as high as 8 mg/l at other times (Bahzad, 2002).

The Australian Water Quality Guidelines proposes that DO should not be permitted to fall below 6 mg/l or 80-90 % saturation (Bahzad, 2002), this being determined over at least on diurnal cycle. This figure is recommended based on the studies conducted in Victoria Australia, which showed that DO concentrations below 5 mg/l are stressful to many species. The experts recommend that a DO concentration of 4mg/l should be maintained in the fresh water streams because the aquatic life is reasonably protected at 4 mg/l (Bahzad, 2002). To maintain the DO level within permissible limit, it is desirable that BOD concentration in river water be kept low. The European Community has given a maximum BOD limit for aquatic life (particularly fish) as 3.o to 6.0 mg/l where as USSR standards are strict and allow a maximum BOD of 3 mg/l only (Bahzad, 2002).

Pak EPA has no maximum and minimum limits of DO and BOD for aquatic life as such. But it is restriction from EPA that the wastewater should be treated to bring BOD of the effluents up to 80 mg/l before discharging it into natural stream when enough water is available for its dilution by 10 times (NEQS, 1997).

Based on above discussions, BOD values were taken in the rage of 8 mg/l and DO should not be less than in 4 mg/l for the purpose of simulation of different scenarios.

9. MODEL SIMULATIONS

Scenario -1

In this scenario, the present condition i.e. in the year 2002 has been checked when there will be minimum flow of 28 cumecs (990 cusecs). The wastewater discharges with their DO and BOD inputs are shown in Table 7.

The water quality data was not available for a number of drains/ nullahs. So water quality data for the drains like Ghazi-M, Khalo-I, Khalo-II and Qazipur were assumed to be of similar nature as measured in case of Ghazi-I Drain. Similarly, for Lahor and Todhar drains, water quality was assumed to be the same as in case of Badri Khawar. While in case of Bada Khawar Nullah, the water was not available at the time of water discharge measurements in January 2002. However, two industrial estates Gadoon-Amazi Eastern and Gadoon-Amazi Western are disposing of their wastewater into Bada Khawar Nullah at a distance of about 13 Km upstream of its outfall into the Indus River. For assessment under adverse condition the discharge as well as wastewater quality data was used which was the sum of both industrial estates for Bada Khawar assuming that all wastewater is discharging into the river.

It may be noted that model allows the simulation of two forms of carbonaceous BOD to represent organic carbon. These forms are a slowly oxidizing form (CBODs) and a rapidly oxidizing form ($CBOD_f$). Since, we have not the separate values for CBODs and $CBOD_f$, ultimately we used the BOD values for CBODs assuming that it also covers the time of fast

oxidizing material. So the model output values for CBODs are the representing values of the BOD.

Scenario -2

In this scenario the river flow was the same as 28 cumecs but the discharge of the drains/nullahs was projected for the year 2063. The reason for projection of the wastewater discharge upto the year 2063 was that the project life of Ghazi Brotha Hydropower is for 60 years. The quality of the wastewater was assumed to be the same as in Scenario 1. The projected wastewater quantity and quality used for model input in Scenario- 2 is also given in Table 7.

Scenario -3

This scenario was the same as Scenario- 2 with only difference that the BOD of wastewater was assumed to falling in the range of 80mg/l in project life. which is the worst case. The assumption for BOD upto 80 mg/l was based on the EPA restriction that the wastewater should be treated upto 80 mg/l BOD before discharging it into the natural steam and natural stream should has the discharges for ten times dilution. The projected wastewater discharge for the year 2063 and quality of the wastewater used for model input in Scenario-3 is given in Table 7.

It may be noted that the BOD value was taken for Bada Khawar is the same as in case of Scenarios-1 and 2 due to reason that it is already over 80 mg/i i.e. 111.5 mg/l.

Table 7: Wastewater Discharge and Water Quality data used for Model input under Selected Scenarios- 1,2&3

Site	Scenario-1			Scenario-2			Scenario-3		
	Discharge for the year 2003 (cumecs)	DO Model Input (mg/l)	BOD Model Input (mg/l)	Discharge for the year 2063* (cumecs)	DO Model Input (mg/l)	BOD Model Input (mg/l)	Discharge for the year 2063 (cumecs)	DO Model Input (mg/l)	BOD Model Input (mg/l)
Ghazi-I	0.0024	3.9	66	0.0086	3.9	66	0.0086	3.9	80
Ghazi-M	0.0038	3.9	66	0.0135	3.9	66	0.0135	3.9	80
Khalo-I	0.0005	3.9	66	0.0042	3.9	66	0.0042	3.9	80
Khalo-II	0.0005	3.9	66	0.0042	3.9	66	0.0042	3.9	80
Qazipur	0.002	3.9	66	0.0110	3.9	66	0.0110	3.9	80
Ghurghushti	0.347	6.3	15.7	0.8632	6.3	15.7	0.8632	6.3	80
Chel	0.245	6.9	6.0	1.156	6.9	6.0	1.156	6.9	80
Bada Khawar	0.071	5.2	111.5	0.071	5.2	111.5	0.071	5.2	111.5
Badri Khawar	2.25	7.9	4.5	2.707	7.9	4.5	2.707	7.9	80
Lahor Drain	0.375	7.9	4.5	0.545	7.9	4.5	0.545	7.9	80
Todhar Drain	0.126	7.9	4.5	0.3006	7.9	4.5	0.3006	7.9	80

*Source: WAPDA 2002.

10. RESULTS OF THE SCENARIOS

Table 8 depicts the results of Scenarios 1, 2 and 3 for values of DO and BOD.

Table 8: Comparison of the Results of Scenarios 1, 2 & 3

Reach Label	Distance (km)	Scenario 1		Scenario 2		Scenario 3	
		DO (mg/l)	BOD (mg/l)	DO (mg/l)	BOD (mg/l)	DO (mg/l)	BOD (mg/l)
Barrage	0.00	8.60	6.00	8.60	6.00	8.60	6.00
Ghazi-Khalo	2.50	8.84	4.67	8.84	4.71	8.83	4.72
Qazipur	7.50	8.90	3.65	8.89	3.69	8.89	3.71
Bada-Ghurghushti	12.50	8.67	3.37	8.61	3.58	8.54	5.18
Plan	20.00	8.75	2.27	8.69	2.41	8.45	3.47
Badri	27.50	8.65	2.63	8.57	2.17	8.04	8.30
Lahor	32.50	9.00	1.64	8.93	1.75	8.05	7.36
Todhar-Chel	38.00	9.27	1.33	9.16	1.50	7.89	7.81
Tail	41.00	9.27	1.33	9.16	1.50	7.89	7.81

As clear from the above table that the DO values are almost same in first two Scenarios and there is a minor variation in case of Scenario-3.The DO values are much higher than permissible limits of 4 mg/l, so it can be assumed that there will be no danger to aquatic life due to availability of DO in river even during reduced flow, projected wastewater for the year 2063 and worst BOD of sewage up to 80 mg/l.

In case of BOD, the values are same in Scenarios-1 and 2. However, the values are higher in case of Scenario- 3 as compared to other two scenarios. But the values are almost within permissible limit of 8 mg/l for reduced flow, projected wastewater discharges and worst condition of BOD up to 80 mg/l. So, based on above results it can be assumed that there will be no adverse effect on aquatic life of the river during life of the Ghazi Brotha Hydropower Project.

11. COMMENTS AND DISCUSSION

Model DO Output Values

It may be observed from Table 8 that the DO values from barrage to downstream are in the range of 8.60 mg/l to 7.90 mg/l, which are almost same as compared to general observations made through sampling as provided in Table 3. As per Table 3, the DO values are 8.6 mg/l at barrage and downstream of Chel Nullah i.e. 8.5 mg/l. It may be noted that at reduced flow of 28 cumecs, projected wastewater quantity and worse wastewater quality of upto 80 mg/l BOD, the model out put DO and observed DO by sampling are almost same which may be due to reason that the reduced water flow pattern in the river was taken as the same as observed during October 2002 to May 2003 at the time of river survey when the flow was varying from 297 cumecs to 770 cumecs. Since it was assumed that at reduced flow conditions the water will flow in the same creeks as observed in river survey of October 2002 to May 2003, the cross sectional area of the reduced flow is presumably more and depth of flow is lesser than the actual condition that will prevail when the discharges of the river are 28 cumecs. Ultimately, the

chance of reaeration, oxygen inhabitation, photosynthetically available radiation is more than the actual, thus the values of DO have increased accordingly. Basically it is not possible to predict exact path of flow, which will be followed by the reduced flow, it may require a detailed hydraulic model study.

Model BOD Output Values

It may also be observed from Table 8 that the BOD value is higher at downstream of barrage i.e. 9 mg/l and it goes on decreasing further downstream and it remains as 1.85 and 1.86 mg/l in Scenarios 1 & 2 and 7.81 mg/l in Scenario 3, even though there are a number of drains/nullahs discharging their effluents into the river. This situation may be due to several reasons. One main reason is that at upstream of the barrage there are three main sewage outfalls on Left Bank, which are discharging pollutants of Main Terbela Colony, Sanober Colony and Sobra City of WAPDA into the river. Similarly, on Right Bank there are two sewage outfalls, which are contributing the pollutants of Powerhouse Colony WAPDA and GIK Institute. All these colonies and institute have their effluent treatment plants and it is assumed that the BOD value of the pollutants will be in the range of 80 mg/l. The second reason of the barrage side higher value of the BOD may be due to stagnant water of the impoundment area as it has less chance of reaeration and radiation due to higher depth of the water. Thirdly, the reason for less value of BOD on downstream side is that the quantities of the effluents are small and their quality is not much deteriorated. However, incase of scenario-3 where the BOD value of wastewater quality was assumed to be in the range of 80 mg/l, the BOD value of river floodplain is higher than barrage. Fourthly, the riverbed downstream is mostly gravely thus a lot of turbulence is encountered in the flows, which results effective assimilation of pollutants.

Assumptions of Scenario- 3

At simulation of Scenario- 3, it was assumed that the BOD of wastewater would be in the range of 80 mg/l as per EPA standards. This will be the case if the wastewater is treated accordingly before discharging it into the river. The samples collected at the time of Feasibility Study at Ghazi and Khalo drains were showing that the value of BOD was over 400 mg/l. During last few years, the local population has constructed Septic Tanks and Soakage Pits in their houses, due to this facility the quality of wastewater is relatively better. But ultimately the capacities of the septic tanks and soakage pits will be over and then the quality of wastewater may again deteriorate. The Local Administrations are providing proper flush systems even to the rural areas. If such flush system was provided in the study area, the quality of wastewater will further deteriorate and it may cross the range of 80 mg/l as assumed in Scenario-3. So there will be need of some mitigation and management plan to keep the BOD within permissible limits.

Some drains/nallas e.g. Ghurghashti, Chel, Bada Khawar and Badri Khawar, carry wastewater from far away and most of the water do not reach up to the river due to seepage into the ground and causes the ground water contamination. If in these villages/towns, which are contributing their wastewater into these near by drains/nullahs were also provided the flush system and the drains were lined, the contribution of wastewater of these drains will be much higher to the river as assumed in the Scenario-3. Due to higher water quantity and worst quality of the drains/nullahs wastewater, the quality of the river water may deteriorate. So there will be a need of some management plan for wastewater treatment of those villages/towns, which are even far away from the river but may affect the river water quality.

Future Industrial Development of the Area

Sarhad Development Authority (SDA) is planning to develop an Industrial Estate about 5km downstream of the Ghazi village. For this purpose the basic infrastructure has already been

developed by the SDA. If this industrial estate is developed, its wastewater will also affect the river water quality. So there will be need of some management plan to save the river water quality from further deterioration.

12. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Depending upon the model results and the discussions, it may be concluded that:

- Under present conditions of quality and quantity of wastewater and minimum flow of 28 cumecs the DO and BOD values remain within permissible limits.
- Under minimum flow conditions of 28 cumecs and projected wastewater quantity for the year 2063, the DO and BOD values will remain within the permissible limits.
- Under minimum flow conditions, projected wastewater for the year 2063 and assumed wastewater quality in the range of 80 mg/l, the DO and BOD values will still remain within the permissible limits.
- The pattern of the minimum flow in the river may require to be established to obtain the exact values of the DO and BOD in all three scenarios.
- When capacities of the septic tanks and soakage pits are over or some flush system was provided for the household in the concerned towns/villages, the quality of the wastewater is liable to further deteriorate and it may cross the limit of 80 mg/l. Under such scenario some mitigation and management plan will be required to keep the river water quality within permissible units.
- Besides providing flush system for the households in concerned towns/villages, if the drains/nullahs carrying sewage water of these villages in to the river are also lined, the quantity of the wastewater will increase, resulting contribution of increased quantity of pollutions. Therefore, the management plan will require consideration of this aspect as well.
- If the Sarhad Development Authority developed the Industrial Estate at 5 km downstream of Ghazi, the wastewater from Industrial Estate may deteriorate the river water quality and it will also require some mitigation and management plan.

Recommendations

With reference to above conclusions, the following recommendations are made to establish the river flow pattern; to mitigate the adverse effects and to evaluate the management plans to ensure the river water quality remains within the permissible limits.

Hydraulic Model Study

It is recommended that a proper Hydraulic Model Study should be conducted to establish the river flow pattern during the reduced flow. It will help to assess the values of DO and BOD near to practical situation and to determine which creeks will be severally affected due to reduced flow.

Wastewater Treatment Facilities

To keep the BOD values of the effluents in the range of 80 mg/l in the project life, the treatment facilities like treatment plants for big cities/towns and oxidation ponds for relatively small towns may be provided. Similarly the option for provision of Reed-Bed Lagoons and Reed-Bed Channels may also be adopted, as it may prove very economic and effective solution.

Release of Excessive Amount of Water From Barrage to the River

If the Industrial Estate was constructed by the Sarhad Development Authority, then along with construction sophisticated wastewater treatment plant to keep the BOD less than 80 mg/l, release of excessive amount of water based on water quality modeling will be required to mitigate the effects on water quality of the Indus River Floodplain.

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Water Trivia

- It takes 100,000 gallons of water to manufacture one automobile.
- A cow must drink 4 gallons of water to make 1 gallon of milk.
- It takes 30-40 gallons of water to fill a bathtub.
- It takes 50 glasses of water to grow enough oranges to make one glass of orange juice.
- It takes 10-15 gallons of water to wash dishes by hand.
- Ten inches of melted snow equals about one inch of water.
- 122 gallons of water are needed to produce one loaf of bread.
- It takes 2,500 gallons of water to produce one pound of beef.
- You can live about one month without food, but only a few days without water.
- 75% of all rain and snow fall directly back into the ocean and other bodies of water without touching land.
- A 5 minutes shower uses 25-50 gallons of water.
- Brushing your teeth for 2 minutes while running water takes 6 gallons.
- 9 to 12 gallons of water are used in a dishwasher.
- It takes 10 gallons of water to make one serving of a soda.
- About ¾ of the human body is water.
- Growing a day's food for 1 adult takes about 1,700 gallons of water.
- A typical household uses about 100 gallons of water per day per person.
- You can drink more than 4,000 glasses of tap water for the same cost as a 6 pack of soda.
- Families turn of water faucets about 70 times a day.
- Washing a load of clothes uses about 50 gallons of water.
- About 9 gallons of water are used to process one can of fruit.
- Making a hamburger, fries, and soda uses 1500 gallons of water. (raise potatoes, grain, cattle)
- Over 42,000 gallons of water are needed to grow and prepare the food for a typical Thanksgiving dinner for eight. This is enough water to fill a 30' by 50' swimming pool.
- 2/3 of the water you use at home you use in the bathroom.
- Watermelon is 93% water.
- Tomatoes are 90% water.
- Potatoes are 80% water.
- Ear of corn is 70% water.
- An elephant is 70% water.

(Compiled by : Mian Iftikhar Ahmad, Water, Sanitation and Environmental Consultant

ENVIRONMENTAL IMPACTS OF GHAZI BAROTHA HYDROPOWER PROJECT ON RIVER INDUS AND SURROUNDING AREAS

By

Engr. Ghulam Ali Soomro[1] and Dr. Allah Bakhsh Sufi[2]

ABSTRACT

WAPDA being an esteemed organization of the country is involved in development of Water and Power Sector Projects. Ghazi Barotha Hydropower Project is another huge hydropower generation project in the country after Tarbela. The barrage to feed power channel of Ghazi Barotha Power Station are built over River Indus 7 Km down of Tarbela Dam. The project has been constructed to utilize the hydraulic head for power generation that is available between the tailrace of Tarbela Dam and the confluence of Haro River. In this reach river Indus drops by 76 m in distance of 63 Km. This is solely a power generation project with an installed capacity of 1450 MW.

The purpose of this paper is to assess the negative impacts on the River Indus due to the construction of GBHP as Water of river Indus will be diverted to the power channel and the river Indus flows go to its lowest in low flow season. The reduction in river flow may change the ecology of the river - belas and people dependant on river water. In this context a study was made to keep the negative environmental impacts as low as possible and suggest mitigation measures to reduce negative impacts and provide enhancement measure to compensate the losses to be sustained by the area people and maintain the social life alongwith the ecology of the area less disturbed. The study demonstrated that the project is technically sound, economically viable and has limited environmental and social impacts on the area overall and specific the belas and people dependant on the Indus Water from Tarbela downstream upto confluence of Kabul River.

1) INTRODUCTION

Ghazi-Barotha Hydropower Project (GBHP) is a three-pronged project. The main barrage is constructed on the Indus River about 7 km downstream of Tarbela Dam. The Project is planned to utilize the hydraulic head for power generation that is available between the tailrace of the Tarbela Dam and the confluence of the Indus River with Haro River. In this reach the Indus River drops by 76 m in a distance of 63 km. This is solely a power generation project with an installed capacity of 1450 MW. The average annual energy output will be about 6,600 GWh.

The Project has the three components including; (i) a barrage located about 7 km downstream of Tarbela dam, forming a pond (with a surface area of 1,140 ha and a storage capacity of 65 M cu m), this will allow some re-regulation of the peaking discharges from Tarbela and divert water (ii) into 52 km long concrete-lined power channel, with a full water carrying capacity of 1,600 cumecs, located along the left bank of the Indus River with a uniform gradient of 1:9600, and (iii) a power complex is located near the confluence of Indus and Haro rivers. It comprises a fore bay, a spillway, 2 head ponds of 25 M cu.m capacity, intake, 5 penstocks, 5 power generating units with a total installed capacity of 1450 MW, switchyard and a 2-km long tailrace channel to carry water back into the Indus River. The map of project area is shown as Figure-1.

WAPDA Environmental Cell (WEC) was entrusted to evaluate survey and monitor the project in the perspective of environmental impact on the project area. This paper is a part of main EIA of Ghazi Barotha Hydropower Project.

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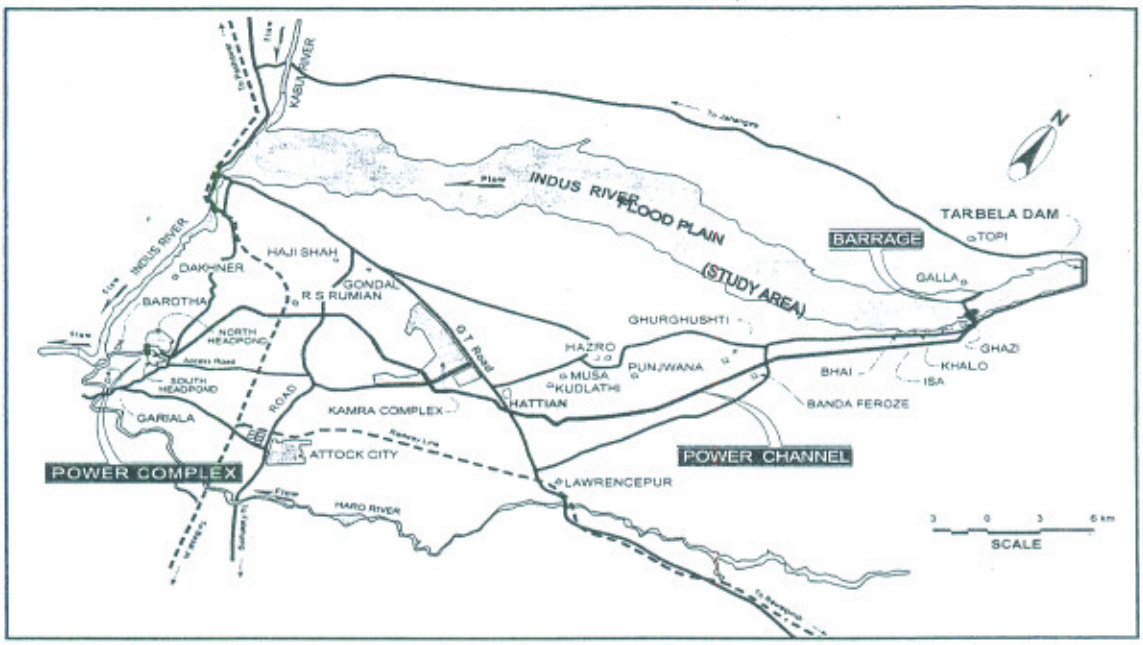


Figure 1 - Ghazi Barotha Hydropower Project Layout

2) OBJECTIVES

The diversion of water into power channel will result in the reduction of Indus flows downstream the barrage upto the confluence of Kabul River. The reduction in river flows during low flow season may change the ecology of the river's adjacent belas and people dependent on river water. GBHP project being of National Importance needed be studied thoroughly for environmental concerns of the area. The main objective of the study was to keep the negative environmental and social impacts as low as possible.

3) SCOPE

The main environmental and social issues/concerns with their mitigation measures are discussed as follows:

3.1 Interruption in accessibility

The bridges on power and tailrace channels at appropriate locations have been provided to provide accessibility of villagers to land and other resources.

3.2 Safety Hazards

Due to its configuration and high flow velocity, the Power channel poses a hazard to the public life safety. Therefore, measures have been adopted to control the access of people to the water in the channel by providing fence and running a safety awareness campaign for the communities. As a lifeguard for the people who drop into the channel by accident, safety gadgets like floating booms and handrails have been provided at 500 m intervals.

3.3 Effect on the groundwater resources during construction and operation of the Project

On the basis of available information, it was apprehended that the Project might affect the groundwater regime. There are three areas of special concerns. These include (a) along the left and right banks of Indus River from Tarbela up to its confluence with the Kabul River, (b) along the power channel, and (c) around the power complex.

3.4 Effects on Resources of Indus Floodplain

The diversion of water into the power channel resulted in the reduction of Indus flows downstream of the barrage up to the confluence of Kabul River. Surveys and studies were carried out to evaluate the effects of reduced flows on rive rain ecology, fisheries, and social and economic setting of the habitants of villages located along the banks of the river. The aspect of river water pollution by the effluent contributed from villages located along the riverbanks was also studied.

The study has shown that the effect of the Project on rive rain ecology will be minimal, particularly on vegetation of belas, which are higher than the flood level. A change in plant succession may occur on belas presently inundated occasionally. The grasslands are expected to .be replaced by vegetation of advanced succession. This will compensate the loss of ecosystem in the barrage pond due to impoundment.

The reduction in river flows during low-flow season may affect the small-scale fisheries in the reach between the barrage and up to the confluence of Indus and Kabul Rivers. However, an effectively managed fishery at the barrage pond will offset any loss.

Downstream of the barrage, no use is made of river water for irrigation purposes. Similarly, consumptive and non-consumptive use of river water by the villages along the riverbanks is rare, and is in the form of watering the livestock, washing and some sewage disposal. To meet this requirement adequate compensation water will be provided through releases from the barrage. Should there be further water need of communities, the Project will provide tubewells to supplement the water requirement.

At present, the Indus River is eroding the lands of the villages on the left bank downstream of the barrage site. A provision in the design of the barrage has been made to significantly reduce the attack. This included the provision of a separation dyke downstream of the barrage between standard bays and under sluices for about 3 km. In addition to this, the Project has reclaimed the left bank of the Indus River for about 4 km in the region of Ghazi, Khalo and Isa villages.

3.5 Mitigation Measures

Following mitigation measures were adopted;

a) Analyzing and Planning the Alternative Release Patterns from the Barrage,
b) Description of Potential Impacts on Physical, Biological and Socioeconomic Environment of the area,
c) Costs and Benefits under various Scenarios of Water Releases,
d) Physical Mitigation Measures,
e) Biological Mitigation Measures,
f) Socioeconomic Mitigation Measures,
g) Special Mitigation for Right and Left Bank Indus River Discharges; including; (i) Pollution Prevention Measures, (ii) Pollution Abatement Measures, and (iii) Recommended Enforcement Program, and
h) Impact Evaluation.

3.6 Management Plan for the Indus Floodplain

This component includes a management plan to allow river water for the sustained use of the Indus floodplain and belas under the water discharge regime to be adopted by the Project. *Inter alia*, this also includes the following aspects:

a) Establishment of a set of management goals objectives developed with input from local communities;

b) Identification of a series of complementary management measures that allow for sustainable use of a diversity of area within the floodplain and belas;
c) A proposed cooperative management structure that may include the establishment of an independent authority subject to the supervision of representatives from Federal Government, including WAPDA, Punjab and NWFP Provincial Governments, Local Governments and national/local non-government organizations;
d) Review of various approaches, which may be adopted to support community-based management of these resources;
e) An active monitoring program that would be linked to the overall monitoring program for the Project, including the monitoring program for water releases;
f) An emergency release procedure for additional water releases into the floodplain to meet special environmental and social requirements; and
g) Monitoring of two major right bank tributaries, viz., Bada and Badri Khwars.

3.7 Environmental and social monitoring program

A transparent monitoring program was prepared and implemented by WAPDA Environmental Cell (WEC). The aspects on which emphasis include; (a) Monitoring Program for the Indus River Discharges, (b) Pollution Abatement Measures, and (c) Recommended Enforcement Program.

4) BIOLOGICAL RESOURCES

4.1 Flora

Overall 127 species including 11 trees, 13 shrubs, 83 herbs, 2 sedge, 1 rush and 18 grass species were identified from different Belas as listed below:

There are 11 species of **tree** among these species, *Dalbergia sissoo* (sheshum) is used to extract timber whereas the other species are used as firewood. *Acacia modesta, Acacia nilotica* and *Zizyphus mauritiana* provide browse for goats and to some extent sheep during lean periods when no other feed is available. Due to extensive cutting, *Dalbergia sissoo* is locally under threat. There are 13 species of the **shrubs**, *Zizyphus nummularia* is browsed by goats and sheep. There are 83 **herbs** in total; only few herbs are palatable for a variety of grazing animals. There are only two kinds **sedges**; cattle and buffaloes graze both these species. There are total 18 Species of **grasses** from which *Cynodon dactylon and Chrysopogon serrulatus* are the important grazing species.

4.2 Fauna of the Study Area

The survey team is of the view that even if the Ghazi Barotha Hydropower Project was not implemented, the wildlife and their habitats within floodplains are subject to non-sustainable utilization and cannot withstand the pressure. There is hardly any pristine habitat or important species left within the project area, which may be threatened with the project interventions. There might be some pristine habitats; rich in fauna diversity, existing long time ago, but the historic record of these are not available.

A total of 121 bird species and 12 of mammal species were found in the study area. At present, the Wild Boar and Asiatic Jackal is the most common among the mammals; they are widely distributed in the belas where enough cover is available to provide shelter. Among the reptiles, at few places the presence of freshwater turtles, seen only once, was reported but none was sighted during the present study. Similarly, the presence of snakes was also reported but none was recorded. Such habitats usually have the Indian Monitor Lizards, which was recorded only twice.

Out of the total 121 bird species, sixty-three were observed during the present survey. Of these, 34 bird species are common as surveyed in 1991-92 and the present survey. About 29 species are additional that were identified in 1991-92, which could not be observed during this survey. Similarly, there are another 29 species of birds, which were not found in both

surveys, but there presence in this reach is possible as described in the paper of T.J. Roberts. As such, the complete list of the bird species comes to about 121. Out of these, 61 are migratory and 60 are resident. Again out of these, 18 species are in abundance, 56 are common and 18 less common and 29 are rare.

Of the total list of the bird species, only one specie, i.e., White-eyed Pochard (*Aytha nyroca*) is listed on International Union for Conservation of Nature (IUCN) Red List in category of Lower Risk, near threatened (LR/nt). This specie was not recorded in any of the surveys conducted for the project, but reportedly uses the same Indus flyway Route for migration. Similarly, there are 28 species protected by the Wildlife Departments of NWFP & Punjab, and 31 species listed in Common Migratory Species Appendix II.

The common birds include the House Crow, House Sparrow, Common Myna and Bank Myna. These species are associated with the belas, which have enough tree cover. The other species of such belas are Spotted Little Owlet, Common Cuckoo, Black Winged Kite, Black Kite, Red Vented Bulbul, White Cheeked Bulbul, Hoopoe, Collard Dove, Little Brown Dove, Red Turtle Dove and Common Starling. Similarly, the belas occupied with the *Saccharum*, are the habitat for Warblers, Black Drongo, Grey and Black Partridges, Indian Silver Bill, Bee-eaters, Indian Tailor Bird, Indian Baya, Pied Bush Chat, Rose-ringed Parakeet, Black Redstart, Indian Tree-pie and Jungle Babbler.

The oxbow lakes, seasonal marshes, main creek and its different channels, and stony belas with less vegetative cover are the main habitats for the migratory waterfowl which spend winter in the habitat or are the passage migrants in such areas. These include different species of *Anatidae*, Herons, Egrets, Gulls, Cormorants, Terns, Grebes, and many species of waders. White Breasted Kingfisher and Pied Kingfisher are also the species of such habitats. The preference of birds in different habitats is because of their life style and food habits.

4.2 Fish Fauna of the Study Area:

In order to assess the fish fauna, besides sampling with nets at different sites in the study area information was collected from fishermen, market dealer and from local consumers. Preserved samples from experimental and commercial netting were identified and examined in the laboratory thoroughly. Their relative occurrence has also been assessed from the available data. Total 25 species were found during the survey. List of commercially important Fish Fauna in study area is enlisted in Table-1. It also gives the relative proportion of different species that normally fishermen had in their catch.

Table 1
Fish Fauna in Project Area

Sr. No.	Name	Local Name	Relative Proportion
Indigenous species			
1.	*Schizothorax plagicstomus*	Mullah	50%
2.	*Labeo dero*	Tarki	05%
3.	*Orechromus mossambica*	Tilapia	03%
4.	*Mastacembelus armatus*	Balm	01%
5.	*Tor putitora*	Mahaseer	10%
Cultivated Species			
6.	*Cyprinus carpio*	Gulfam	22%
7.	*Cirrhinus mrigal*	Mori, mrigal	05%
8.	*Labco rohita*	Rohu	02%
9.	*Hypothalmichthys molitrix*	Silver carp	02%

4.4 Aquatic Biodiversity of the Study Area

The river-water samples collected from different reaches of the study area were subjected to macro and microscopic study for identification of macro- and micro-organisms that make the part of the food of fish fauna. The commonly occurring Phytoplankton, Zooplanktons and Benthos are as given below:

4.4.1 Phytoplankton

About 13 species of phytoplankton are identified in the study area. These include: (i) **Chlorophyta:** including *Chlorella* spp, *Scenedesmes* spp, *Spirogyra* spp, *Volvox* spp, *anacystis* spp, *Botrydium*, *Pediastram* spp, *Chlorella* spp); (ii) **Bacillariophyta:** including Diatoma, Synedra, *Cyctotella* spp, *Melosira* spp, *Pinnularia* spp, Eugelana spp; (iii) **Chlroysophyta:** including *Dinobriyons* spp; and (iv) **Myxophyta:** including *Oscillatoria* spp, *Nostoc* spp.

4.4.2 Zooplankton (Microscopic organisms)

About 15 species of zooplankton have been identified dominated by cladocerans and copepods, which become source of food and the nutrients for different fish species.

4.4.3 Benthos

Few bottom samples were collected from down stream of Ghazi barrage and were studied in laboratory in order to identify the organisms. Muddy samples from bottom revealed only four species of Benthos. These include; (i) Tubifex spp; (ii) Chirnomas spp; (iii) Pisidium spp, and (iv) Corethra spp.

5) DEMOGRAPHIC DATA

5.1 Population

Study area has experienced an accelerated population growth rate during the last decade. Since last official Census of year 1981 compared to official Census of year 1998 and 2003, the population growth rate per annum is calculated at 3.0 percent in district Swabi and 2.2 percent per annum in each District Attock and Haripur. Applying the same growth rate, the total population in the study area has increased from 138,544 in year 1998 to 156,665 in year 2003. Review of past data depicts that population increased in Punjab and NWFP as well as in the study area is at sliding scales. Thus, declining growth rates has been assumed for estimating the population for the forthcoming years in the project area. It is assumed that the growth rate will slide 10% in a decade, except in village Khalo and Ghazi, where considering many other factors including high rate of migration from these villages, high rate of remittances from abroad converting living style urbanized etc., lower growth rate of 1.51% per annum is estimated. Tehsil-wise increase in the population is summarized in Table-2.

Table 2
Population in Numbers

Tehsil*	Yr 1998	Yr 2003	Yr 2010	Yr 2020	Yr 2025
Ghazi	19,468	21,365	24,343	29,321	32,171
Attock	54,482	60,418	69,832	85,749	94,948
Swabi	64,594	74,882	92,095	123,768	166,334
Total	**138,544**	**156,665**	**186,270**	**238,838**	**293,453**

**Includes the villages of the Tehsil that form the part of the Study Area*

5.1 Population Distribution

The population in the study area is unevenly distributed in its three regions. Currently, the area falling in district Swabi (including areas of both Tehsils) has the maximum population of about 74,882, whereas, the area of Tehsil Ghazi has the minimum population as 21,365.

5.2 Population Density

Population density has been calculated for Tehsil Swabi, Tehsil Ghazi and Tehsil Attock. According to official Census of year 1998, population density in Tehsil Ghazi comes to 414 persons per sq. km, whereas for the year 2003 it is worked out as 454 persons per sq km as compared to population density of 267 per sq km in NWFP. The population density in Tehsil Swabi in year 1998 was 298 persons per sq km, whereas during year 2003 it has been worked out as 494 persons per sq km. The high-density rate in Tehsil Swabi is its' high growth rate as 3% per annum. The population Density in Tehsil Attock in year 1998 was 186 persons per square km.

5.3 Sex Ratio

As per Census of year 1998, the sex ratio in the three Tehsils of the study area is as against 100 males there are 101 females in Tehsil Ghazi, 105 females in Tehsil Attock and 102 females in Tehsil Swabi.

5.4 Literacy Rate and Religion

According to Census of year 1998, the maximum literacy rate is in Ghazi up to 54%, followed by 42% in Attock and 34% in Swabi. The literacy rate at national level was 44% in year 1998, which is 52% in year 2003. More than 99% population is Muslim in the study area.

5.5 Household Size

The average household size is highest in Tehsil Swabi and has been worked out as 7.8 persons per household followed by Tehsil Attock as 6.5 persons per household and in Tehsil Ghazi as 6.3 persons per household. The average household size in NWFP and Punjab is 6.9 persons per household as compared to average size in Pakistan as 6.8 persons per household.

6) RESULTS/DISCUSSION

The main effect of the barrage will be the partial redirection of the flow in the Indus River. During the high-flow season, the river downstream will receive the major portion of the releases from Tarbela. During periods of low flow, compensation flows will be released from the barrage to maintain aquatic ecosystems and provide local users access to water. Groundwater inflow-outflow relationships along the river will be slightly altered, with additional inflow from the pond upstream of Ghazi and, during the dry season, increased outflow to the river downstream. Reduction of flow in the river is not expected to affect the local livestock, as substantial pools will still remain. The total cattle herd of approximately 15,000 head consumes less than 0.01 cumecs for drinking. The effect of the project on flora and fauna of the riverain area will be minimal. The loss in riverain ecosystem in the barrage pond is expected to be balanced by the development of an aquatic ecosystem in this reach and an increase in the riverain ecosystem downstream of the barrage due to reductions in flood peaks.

Downstream of the barrage, the effect, if any, will be limited to the braided channel zone of the Indus River. The most probable effect may be a change in plant succession. Riverain fisheries may be affected by the reduction in dry season flows, affecting mostly part-time

fisherman. A recent study of the potential for the development of fisheries has shown that the existing fishery resources can be considerably enhanced by stocking fish species in the barrage pond and establishment of fisheries in the head-ponds at the power complex.

The intermittently flooded islands and floodplain vegetation support spares wildlife populations, including wild boar which is considered a pest. These populations are not expected to see significant reduction in habitat with reduced flows in the river. The channel alignment does not pass through or near any forest reserves or natural areas. The shores of the head-ponds will be a convenient source of water for wildlife.

7) CONCLUSIONS

Minimal water requirements for diluting wastewater discharged into the Indus River have been evaluated, based on conservative criteria. The water required for dilution is estimated at 28 cumecs, this will be provided downstream of the barrage throughout the Project life. This will be monitored and supplemented as necessary.

- Existing WAPDA sewage treatment works discharging into the river upstream of the barrage site will be renovated. A study has been carried out to define the remedial measures required. A new sewerage system including proper treatment works will be provided for Ghazi-Khalo sewage.
- With effective management, the barrage pool fisheries are expected more than to replace the loss of riverain fisheries downstream of the barrage. Fishery resources are being enhanced by stocking fish species in the head-ponds.

8) RECOMMENDATIONS

1. A regular programme of water quality analysis is recommended to be ensured that compensation water releases are sufficient to maintain dry season water quality in the river downstream of the barrage. Groundwater aspects should be monitored which include recharge from the barrage pond, changes in groundwater levels caused by the power channel, and seepage from the head-ponds.

2. The ecosystem of the braided channel zone should also be monitored to assess the change in plant succession. The monitoring programme which includes monitoring of fish, other aquatic species, birds and other wildlife in the barrage pond, the Indus River below Ghazi, and the head-ponds and adjacent habitat near the power complex are also recommended.

3. A regular monitoring for post project period for a period of at least 5 years is advisable and recommended to assess any further negative impacts in all project area and propose possible remedies etc.

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AN INTRODUCTION TO CONSTRUCTED WETLANDS (REED BEDS) SUSTAINABLE LOW COST WASTEWATER TREATMENT PLANTS

By

Engr. Mian Iftikhar Ahmad*

The use of "conventional" wastewater treatment technology (trickling filters and activated sludge) in developing countries has often been unsuccessful due to high cost, complex operating requirements and expensive maintenance procedures. Typical examples of such projects are wastewater plants in Islamabad and Karachi. Actually the conventional systems, such as trickling filters and activated sludge plants were developed to address the concerns about organic pollution of natural water bodies in western temperate climates, rather than the reduction of organic matter as well as pathogens which is often a priority in developing countries.

Pakistan, being a developing country cannot and should not follow the western technology blindly but needs the use of "appropriate technology". Appropriate technology is defined as a treatment system which meets the following criteria :

Affordable : Total amount costs, including capital, operation, maintenance and depreciation are within the user's ability to pay.

Operable : Operation of the system is possible with locally available labour and support.

Reliable : Effluent quality requirements can be met consistently.

Currently there are a limited number of appropriate technologies for small communities, which should be considered by a community and their designers. These include conventional and non-conventional systems such as stabilization ponds or lagoons, slow sand filters, land treatment systems, and wetlands (natural or constructed).

The non-conventional systems often utilize 'ecological' treatment mechanism (such as aquatic systems or wetlands) and do not have the mechanical parts or energy requirements of conventional systems. Waste Stabilization Ponds are one such solution but sometimes are constrained by land availability, topography, and are not environment friendly. In such locations, natural or constructed wetlands (Reed Beds) could provide an alternative technology.

It is what we call a LOW technology, rather than HI TECH because it is essentially simple, cheap and sustainable. Because they achieve a natural balance, well designed reed bed systems will more or less look after themselves. They do not need much power, they do not need any chemicals, they need very little maintenance, and the water leaving such a system can be very clean – certainly clean enough to pass the National Water Quality Standards.

A well designed reed bed system needs both aquatic plants and special water movement. The main plants used is still the Common reed (Phragmites karka – Nari), Cattail (Typha australis – Dab) and Vetiver grass (Khus). Almost all these aquatic plants are available in natural wetlands, along rivers, canals, water courses, and water logged areas in Pakistan.

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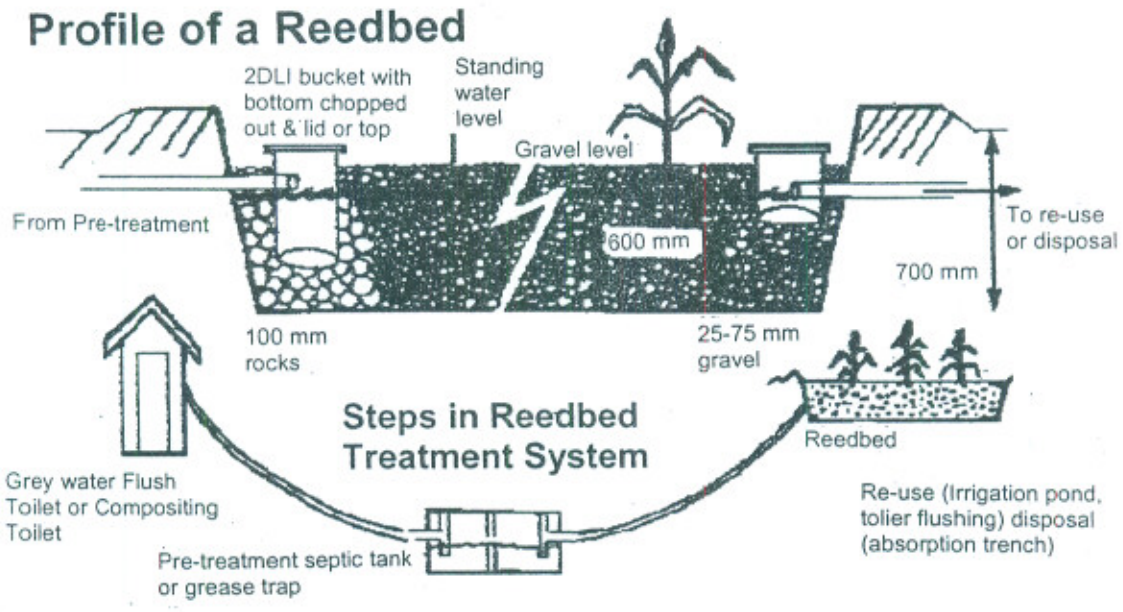
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The constructed wetlands (Reed Beds) utilize horizontal flow system, vertical flow system or combination of both. The horizontal system includes 'free water surface (FWS)' wetlands and 'vegetated submerged bed (VSB)' wetlands. The vertical system invariably uses VSB system. The required land area depends on the wastewater flow. However, in the rural setting, the horizontal system requires about 1.0 square meter / person (or population equivalent in case of an industry) and the vertical system even less than that.

A working reed bed system can be designed as a public area like a park with water cascades, bridges, shallow pools with fish, and small islands for birds. There is no smell, no flies, no noise, no chemicals, and no machines. The only regular maintenance work is harvesting the reeds once a year and occasional weeding (without poisons !)

There is potential for the combination of reed beds with a methane process in which the bulk of sludge is removed by settlement and fed to a methane digester to produce energy, and the supernatant is then cleaned with reed beds. This may becomes a practical solution for systems in urban areas.

In flat areas like large towns can be split up into segments, each served by a separate reed bed system. However, this is more difficult to arrange (but not impossible), for villages or towns in a valley, where the drainage pattern is already decided by the local relief.



For the technically minded, there is a 98% reduction in BOD (Biological Oxygen Demand) and SS (Suspended Solids). Reed bed system is low capital cost, low maintenance, sustainable and environment friendly. In practice they very much look after themselves.

In rural communities, inadequate budgets and poor access to equipment, supplies and repair facilities preclude proper operation and maintenance (O & M). Reed bed systems are ideal for rural area, coastal communities, highway motels, petrol stations, tourists, housing colonies and many industries especially in environmentally sensitive areas. Reed bed technology can be used for 'on site' as well as 'off site' wastewater treatment. In the case of an industry, each industry can construct its own reed bed within or outside its premises, or a group of industries can share a common reed bed system.

For having trouble free operation over a long time, the influent to the reed beds should be free from suspended solids. This can be attained by a course screen and the conventional

primary settling tank. Alternatively, following a course screen, a shallow anaerobic pond having floating aquatic plants such as duckweed and water hyacinths can be used as primary settling tank.

The Reed bed treatment system was developed by Professor Kickuth of Kassel University, Germany in 1973 and is being successfully used for the treatment of domestic and industrial wastewaters for the last many years in Australia, Indonesia, India, Israel, Maldives, Oman, Egypt, Denmark, Netherlands, England, Germany, USA and Canada.

The constructed wetlands (Reed Beds) have great promise in Pakistan and should be extensively used for the treatment of domestic as well as for industrial wastewater.

OBITUARY

May their souls rest in Peace

1. Fateha was offered at the sad demise of the veteran Engr. Rana Allah Dad Khan Past President of Pakistan Engineering Congress (1992-1994) at the Executive Council meeting of the Congress on 28th January, 2006. He passed away on 23-12-2005.

   Engr. Rana Allah Dad Khan graduated from the Punjab College of Engineering & Technology Lahore in Mechanical Engineering in 1945.

   Instead of joining Govt. service. He opted to establish his own Industry. For acquiring practical training and experience he went to Bombay and obtained valuable experiences in automobile industry from Bombay Garage Ltd. in 1946. He joined Kandawala & Company in 1947 for the same purpose. For advance training, he proceeded to England and obtained valuable training in his field of endeavor.

   He established Rana Motors Ltd. Lahore in 1948 & Rana Tractors Ltd. in 1964 (Now Millat Tractors Ltd. Nationalized by Government in 1971)

   As President of the Pakistan Engineering Congress his contribution in running the affairs of the Congress is memorable. He never missed any meeting of the Executive Council or any event organized by the Congress. God Al-Mighty may rest his soul in eternal peace.

2. Engr. Altaf-ur-Rehman, a former Chief Engineer (Dams Safety Organization) WAPDA passed away on 25-12-2005. He did B.Sc. (Civil Engineering from Maclagan Engineering College (Now University of Engineering & Technology, Lahore) in 1949. He got Post Graduation Diploma in Soil Mechanics from Imperial College, London in 1963. He was conferred with Pride of Performance by WAPDA. Also awarded life time achievement Award by Pakistan Geo-Technical Society in 2006, May God bless his soul.

APPLICATION OF REMOTE SENSING TECHNIQUES FOR CONSERVING SCARCE WATER RESOURCES : A CASE STUDY FROM PAKISTAN

By

Engr. Abdul Shakoor[1], Engr. Naveed Alam[2], Engr. Muhammad Nadeem Asghar[1]

ABSTRACT

Pakistan, which was once a water surplus, is now a water deficit country according to Malin Falkenmark criteria. The conventional wisdom of managing canal water supplies, which usually results in over- or under-irrigation, is not sufficient to meet the challenge of water demand in future. This paper introduces the use of modern tools like Remote Sensing (RS), Geographic Information Systems (GIS) and CROPWAT to improve the management of the existing irrigation systems. This study was conducted for the Pehure High Level Canal (PHLC) and the Upper Swat Canal (USC) system in the North Western Frontier Province (NWFP) of Pakistan. Crop identification at distributary level was made from multi-temporal Remote Sensing satellite images, using various image processing techniques, such as supervised, unsupervised classification and spectral mixture analysis. Cropped areas were calculated for each individual crop from these classified images, and then crop water requirement at distributary level was estimated using CROPWAT. Assuming all other parameters of the CROPWAT model optimistic, the calculated crop area was of major concern. The supervised classification with support of unsupervised classification and ground truth information has proven to be the best option and cost-effective technique for calculating the actual cropped area. The results of this study can be used while devising guidelines for water managers to release the canal supplies based on crop water requirement. This practice will help in avoiding wastage of canal water at farm level, which can be optimally used for increasing irrigated areas and crop productivity in the area.

INTRODUCTION

Water is an important natural resource on the earth and plays a vital role in every aspect of life. The sources of consumable water are mainly groundwater, rainfall and surface water bodies like river, ponds and lakes, but the competitors are too many like domestic, agriculture, infrastructure and industrial sectors. The agricultural sector is the major consumer of water and land resources. Seckler et al. (1998) estimate that around 70 percent of all water used each year produces 30 to 40 percent of the world's food crops on 17 percent of all arable land. With the limited availability of natural resource made it mandatory to use them optimally, so that the need of each sector will be fulfilled with justification. More knowledgeable management is essential for improving crop production per unit of water from the field level up to entire basins.

There are many approaches that are made to conserve water, but they are not the only complete way to get sustainable growth. There is further need for a comprehensive strategy for utilizing the water resources in such a way that they can be used for long time with minimum degradation when exploited in their optimal capacity. But we lack accurate information on the conditions of irrigation system, making performance hard to quantify (Molden 1997). As a result when technical interventions are made, the effects on the actual performance of the irrigation system are difficult to describe. Financial investments intended to improve productivity and make efficient use of good quality irrigation water can be economically justified if progress become measurable phenomenon.

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The task of providing that information on scales ranging from farm field to command and entire water basins is far from trivial. Distinct spatial variations cropping pattern, cropping conditions, soil moisture status and micrometeorology all occur within an irrigation scheme. Although information on irrigation practices can be acquired by conventional field visits, survey methodologies usually differ from survey to survey. Moreover, field data become outdated because changes in land and water management occur frequently (Bastiaanssen, 1998). However, the Remote Sensing (RS) from space can regularly provide objective information on agriculture and hydrological conditions of large land surface areas as well as small ones. Geographic Information Systems (GIS) approach is an advanced tool for manipulating such information in an efficient way. In this study, efforts were made to introduce the use of modern tools like RS, GIS and CROPWAT for improving management of the existing irrigation systems.

MATERIALS AND METHODS

STUDY AREA

The existing Upper Swat Canal and Pehure High Level Canal Project are located in Malakand Agency, Swabi, Charsaddah, Mardan and Nowshehra districts of NWFP in Pakistan. The area lies from 72^0 05' to 72^0 49' North, 33^0 99' to 34^0 10' East (see Fig 1) and is bounded: in the Northwest by the Swat River and Malakand Hill, to the Northeast by the Swabi hills and Tarbela Reservoir, to the Southwest by the Lower Swat Canal command, and to the Southeast the Pehur Main Canal (existing lift canal from below Tarbela Dam) and the Indus River.

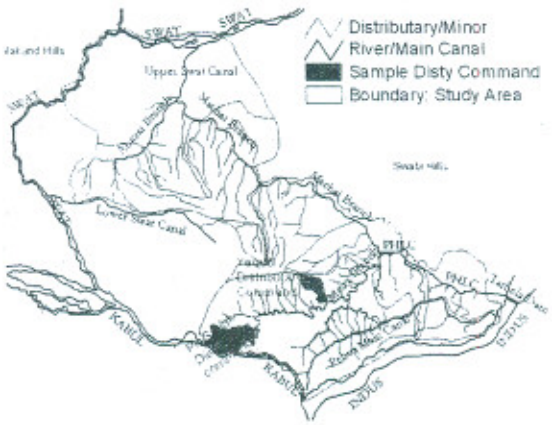


Figure 1: Study Area, Pehur High Level Canal (PHLC) and Upper Swat Canal Systems (USC)

Agriculture in the area is either rain fed or in the command of Upper Swat Canal System, restricted by shortage of irrigation supplies. Average annual rainfall as reported by three rain stations (Gohati, Jagganath and Shabazghari) in the area, is 830 mm, 755 mm and 675 mm respectively. Most of the rains are concentrated during months July and August of the year but overall, the area falls in rain fed zone of the country. Maize, Wheat, Sugarcane and Tobacco are the main crops grown in the irrigated areas while Maize, Wheat and Groundnuts are the main crops in rain fed areas. For this research two distributaries (Pir Sabak and Yaqubi) from the study area were selected. All the information was collected, managed and analyzed for these two sample distributaries.

LAND COVER CLASSIFICATION

The remote sensing data used in this study was Landsat ETM with 30-meter spatial resolution and panchromatic band having spatial resolution of 15 meter. A spectral characteristic comparison of the images acquired at different times of the year showed that period from late Feb to early April is most appropriate for *rabi* crop identification and early August to late September for *kharif* crop with Landsat ETM data (Zhao et al., 2002). In this study three dates were chosen, i.e., April 8, 2002; September 2, 2002 and February 18,

2003. During this time the relevant thematic maps of the study area were prepared to support the crop identification from satellite images. First, each frame of TM images was geometrically corrected with ERS Panchromatic 5 meter spatial resolution, which was already ortho-rectified to Lambered Conformal Conic (LCC) co-ordinate system, with a resultant estimated root mean square error (RMSE) of less than one pixel. Second, based on the statistical characteristics of different ETM bands and through visual evaluation, a standard false color composite of ETM bands 4, 3 and 2 was conducted. A land cover classification was performed for both the *rabi* and *kharif* season. The land cover classification will be used as input for crop water requirement calculations.

Rabi Season 2001-02

A Landsat ETM image of Aril 8, 2002 was used to identify crops in the *rabi* season. The crop classification was performed using a series of consecutive unsupervised classification steps. The unsupervised classification has been carried out on the basis of ISODATA clustering algorithm. The ISODATA algorithm assigns pixels to the nearest cluster, based on spectral distance. The algorithm is iterative in that it repeatedly performs an entire classification and afterwards recalculates the new statistics of the clusters.

The recalculated means of the every cluster are the basis for the new iteration, in which all pixels are assigned again to the nearest cluster. The process ends when certain number of pixels is not assigned to a different cluster. A value of 100% was used in this exercise, which means all pixels have to be assigned to some cluster. The number of clusters has to be fixed beforehand.

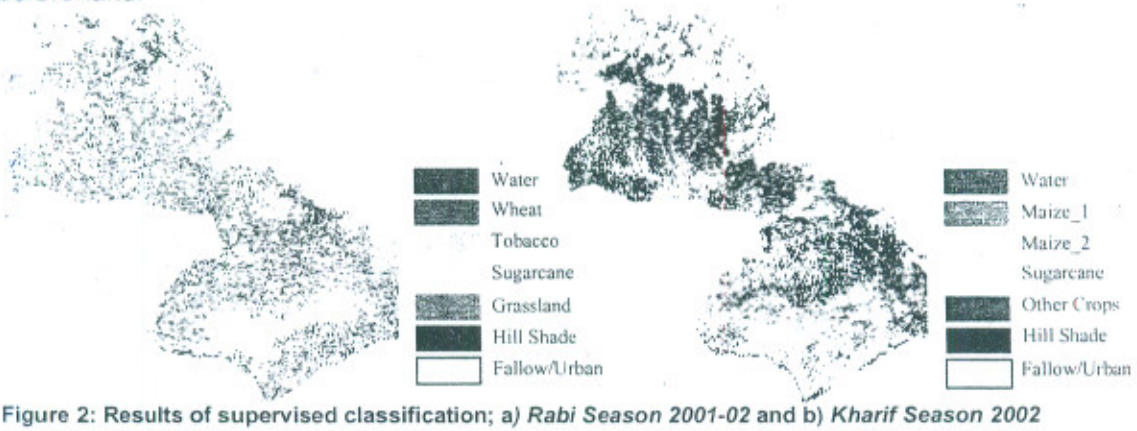


Figure 2: Results of supervised classification; a) *Rabi Season 2001-02* and b) *Kharif Season 2002*

Three ISODATA clustering attempts were performed, using respectively 5, 15 and 30 clusters. The ISODATA clustering with 5 classes was used to separate bare soil, village or settlement areas, water and vegetation. The ISODATA results with large number of clusters were used to separate different vegetation classes. A field campaign farmers interview was to collect the information about crops in various seasons, cropping pattern and irrigation practices and sources of irrigation. A spatial database was developed based on this campaign. This database was used to assign ISODATA clustering results to land cover classes. The result of the classification is presented in Fig 2(a). The major crop grown during *rabi* season is Wheat with other crops e.g. Tobacco and sugarcane, which are already on the ground during April, so are included for this classification attempt. The spectral features of other crops, which were identified in the field campaign but were not distinctive enough to be separated by the algorithm, were reported as "other vegetation" class.

The accuracy of classification depends on several factors; such as the spectral separability of the land cover classes, heterogeneity of the land surface, and the extent of field truth. The accuracy of the current classification is aggravated by the fact that the agricultural plots have a small size and most ground truth samples originate from a limited area. More ground points will improve the accuracy of the classification. The total area under wheat has been

classified as being 1505 acres in Pir Sbak distributary command area against crop assessment figures of Irrigation department (secondary Areas) to levy revenue.

Table 1: Accuracy statement of Supervised classification of satellite image for various crops.

Class Name	Reference Total	Classified Totals	Correctly Classified	Producers Accuracy	Users Accuracy
Wheat	52	50	47	90.38%	94.00%
Maize	69	69	63	91.30%	91.30%
Tobacco	96	98	91	94.79%	92.86%
Sugarcane	100	101	78	78.00%	77.23%
Other_vegetation	54	55	33	61.11%	60.00%

Kharif season 2002

The Landsat ETM of September 2002 was used to perform crop classification for identification of *kharif* season crops. The same ISODATA clustering methodology as applied for *rabi* season, was used for the September image. Similar database was developed as for *rabi* season, to interpret the clusters of the ISODATA. Despite that such dataset is not sufficient to cover the range of field conditions, the database has been used for the interpretation of the ISODATA results. In general crop classification has an accuracy of 85 percent if the ground truth data collection is complete (Bastiaanssen et al., 2003) so in this study it is expected to be lower.

The final result of land cover classification is presented in Fig 2(b). The crops in *kharif* season are Tobacco, Maize and Sugarcane. Crop areas were calculated from the classified images. Table 1 and Table2 represent the comparison of areas for various crops classified from the satellite image with Secondary data, the areas obtained from record of Department of Irrigation (DoI).

To compare the results of supervise classification with sub-pixel classification results, a spectral mixture analysis technique, Linear Spectral Unmixing (LSU) was tested in this case. The results of LSU apparently look very encouraging but unfortunately, due to lack of sufficient ground truth data the accuracy of results could not be tested. consequently, the results will not be used in calculation of water requirements for the crops in the study area.

CALCULATION OF CROP WATER REQUIREMENT

CROPWAT was used to calculate the water requirement of various crops grown in the study area. CROPWAT is a program that uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration and is meant as a practical tool to help agro-meteorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. Calculations of crop water requirements and irrigation requirements are carried out with inputs of climatic and crop data.

The Gohati station is located at an elevation of 375.2 m, latitude 34.10 ° N and longitude 72.25° E. The average 30 years data (1961-90) of Gohati station (NWFP province) regarding different meteorological variables—wind speed, sunshine hours, maximum and minimum temperatures, relative humidity and rainfall were utilized in CROPWAT for the calculation of reference evapotranspiration (Et_o) of both the distributaries.

DISTRIBUTARY WATER SUPPLY

Two sample distributaries Pir Sabak and Yaqubi were selected for this research. The main features of the sample distributaries are depicted in table 2.

Table 2: Main features of two sample distributaries

Distributary	Length of the Distributary (Km)	Design Discharge (liter/Sec)	Water Allowance (Liter/Sec/ha)
Pir Sabak	16	2379	0.699
Yaqubi	5	991	0.699

Historical data of distributary flow was recorded on daily basis at head of the distributaries. Gauge values were recorded daily and discharge was calculated using K-D Formula.

$$Q = KD^n$$

Where D is depth of flow, K is co-efficient which is mostly dependant on cross sectional area that is influenced by backwater from downstream regulating structures and n is an exponent that is largely dependant on geometric shape of the cross section (Vehmeyer et al., 1998).

Gauge measurement data is available from year 2000 to date. For this study, data for year 2002 was used. Discharge was calculated on daily basis to average ten daily basis for the whole year.

RESULTS AND DISCUSSIONS

Fig 3 shows the classified image of September 2002, clipped to the command areas of two sample distributaries (Pir Sabak and Yaqubi). Accuracy report (see Table 1) shows that Wheat, Maize and Tobacco are classified with reasonable high accuracy but Sugarcane has low value. There are number of reasons for the low accuracy of Sugarcane. Most important is that Sugarcane is area specific and is not cultivated through whole study area. Also the ground truth information was not enough to validate sugarcane results. Secondly, field survey has revealed that sometime Sugarcane is planted earlier than its actual date, mixed with some other crop e.g. Tobacco, wheat etc. This practice makes it difficult for remote sensing image to differentiate two crops. Also during April the condition of Tobacco and Sugarcane is such that soil reflectance is significantly mixed with crop and resulting spectral response of two crops is much similar. For September image Sugarcane is likely to mix with Maize. Overall accuracy of September image is 80.80% as compared to 78.60% for April image.



Figure 3: Classified image September 2002, clipped to command area of sample distributary; a) Pir Sabak distributary b) Yaqubi distributary

Crop Area Calculations

Gross command area of Pir Sabak is greater than that of the Yaqubi (crop assessment of DoI *kharif 2002*). But if we take a look at the statistics of secondary* areas, it reveals that total cultivated area for Pir Sabak is 2952 acres which is less than total cultivated area of Yaqubi, 3053 acres. Contrarily, the classified image showed that cropped area of Pir Sabak is greater than that of Yaqubi. The reason for this difference is that some area in Pir Sabak

* The data or information collected from Department of Irrigation (DoI)

distributary command which is in fact cultivated but not irrigated by canal water but instead, is irrigated by some other means e.g. pumping of underground water or rain fed etc. Only those areas, which are irrigated with canal water, are included in the statistics for the assessment of crops conducted by DoI therefore causing difference. This is one possible reason for discrepancy of the crop areas yielded by classified image from secondary areas of Pir Sabak distributary. Values of Maize, wheat and Tobacco are comparable for Yaqubi distributary (see Table 4) except for the Sugarcane, which differs significantly from secondary areas statistics. The reason for this difference is unaccountable cropped areas, which are irrigated with sources of water other than crop or illegal irrigated areas. Also, mix plantation of sugarcane together with other crops e.g. wheat, tobacco etc in the same field, may cause problem for satellite image to distinguish between two crops thus causing discrepancy. Therefore crop areas reported by DoI cannot be taken as representative of cropped area in the sample distributary command. Also, crop condition may aggravate the classification results. The comparison of areas calculated from classified satellite image with that from department of Irrigation (DoI) is shown in Table 2&3.

Table 3: Results of crop classification for *Rabi 2001-02* and *Kharif 2002*, for Pir Sabak distributary.

Land Cover	Calculated Area (Acres)	Secondary Area (Acres)
Wheat	1505.42	1618.11
Maize	3634.82	1319.33
Tobacco	1073.16	270.92
S_Cane_Rabi	3432.91	295.31
S_Cane_Kharif	5203.15	295.31
Other_Vegetation	1158.68	1273.35

Table 4: Results of crop classification for *Rabi 2001-02* and *Kharif 2002*, for Yaqubi distributary.

Land Cover	Calculated Area (Acres)	Secondary Area (Acres)
Wheat	870.96	805.02
Maize	1418.44	1966.74
Tobacco	646.72	984.91
S_Cane_Rabi	984.42	241.04
S_Cane_Kharif	1089.51	241.04
Other_Veg	1501.61	1273.35

Crop water requirement and supply

Crop water requirement was calculated using reference evapotranspiration (ET_0) value obtained from CROPWAT model and area of each crop calculated from classified satellite image for sample distributary. The ET_0 and rainfall average value for the study area derived from 30 years data, is shown in Figure 4. The average reference evapotranspitaion is 3.48 mm/d and it varies from 0.84 mm/d to 6.23 mm/d as shown in the Figure 4. The total rainfall in the area was 831 mm, the maximum of which occurs in August (232 mm). About 56% of total rainfall occurs in three months namely July, August and September. The crop water demands (ET_c) were calculated for both the sample distributaries based on a detail survey of both cropping intensities and cropping patterns. The values of ETc were calculated using reference evapotranspiration (ET_o) and crop factors (K_c). The average crop water demand of sugarcane was 1439 mm followed by tobacco (642 mm) and wheat (322 mm). The crop water demands for maize was 204 mm.

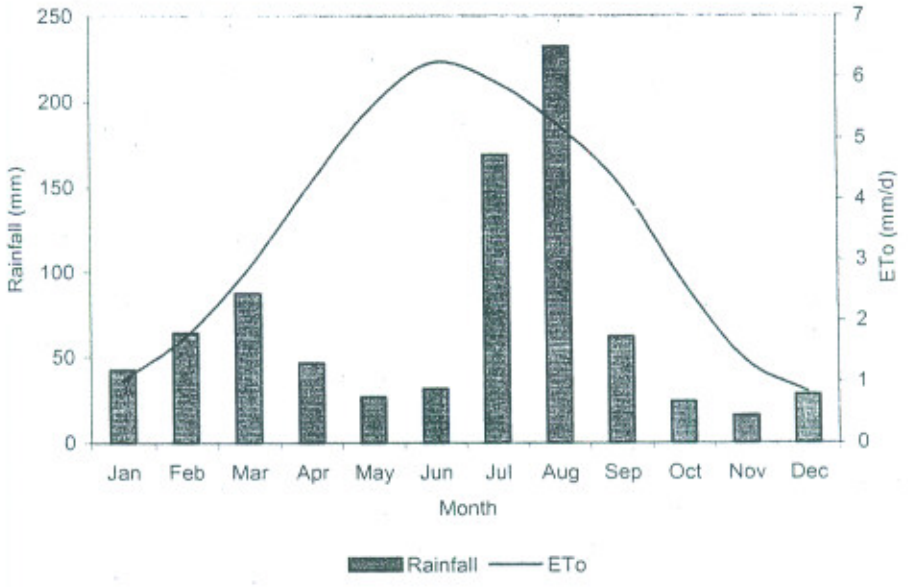


Figure 4: Variation in reference evapotranspiration and rainfall based on 30 years (1961-1990) average data

The sowing period of each crop was staggered into 4 blocks, which ranges over one month approximately. Similarly harvesting period spans over one month. Actual ET was calculated for this extended period of each crop to better compensate the effect of rainfall and locate optimistic value of reference ET_0. This can help in locating the sowing period of crop for which smaller amount of water is required. Accordingly, total area of the crop was distributed over four different periods of crop growth. This method of calculating actual ET considers the realistic effect of rainfall on resulting values of ET. Finally, crop water requirement was calculated on daily basis and then averaged on 10 daily basis. Water requirement obtained this way is not specific to any spatial location within command of distributary instead its calculation is based on various stages of the crop growth. Bastiaanssen et al 2003 used Surface Energy Balance Algorithm for Land (SEBAL) to calculate ET_0 value for each pixel of the satellite image by making direct use of satellite image radiance values. Temporal images can be used if water requirement is needed to calculate for growth stages of a particular crop during its growth period.

Water supplies of the sample distributaries were calculated from daily basis to 10 daily basis and then plotted to compare with water requirement of the distributary. The comparison of demand and supplies of the two sample distributaries is shown in Figure 5. It is evident from Figure 5 that water demand is higher than water supplies from January till beginning of September, but late in September the water demand falls shorter and water supplies rises up and becomes greater than demand. These supplies are based on only from Maira Branch[*] and supply from PHLC will supplement for the water demand. This type of chart will help water managers to take important decisions about releases of water from PHLC[*] to Maira. Such seasonal plots developed on daily basis can be much useful for efficient management of water supplies. The surplus water can either be saved or used to increase irrigated area and cropping intensity in the command of the distributary, consequently increasing yield and water productivity of the study area.

[*] Maira Branch canal is originating from tail of Machi Branch canal. At RD 242 PHLC will confluence with Maira.

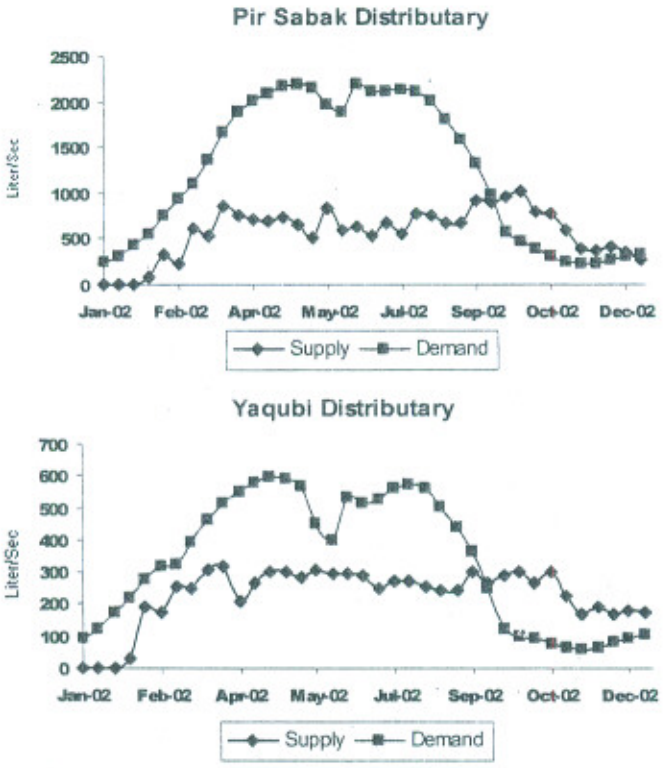


Figure 5: Demand and supply comparison of sample distributaries.

Presently, it is normal practice in the study area and also all over the Pakistan that water demand is calculated based on culturable command area (CCA) and cropping intensity of the distributary. Normally during *rabi* season cropping intensity is less therefore less water is required so less supply from head of distributary as compared to *khrif* season. Since this supply does not vary significantly within the season but crop water demand decreases significantly. As is clear from figure 5 that water supply becomes higher than water demand during *rabi* season, therefore farmers tend to either over irrigate the land resulting into water logging problem, or simply waste water into drains. Therefore the surplus water can be saved and utilized for irrigating additional areas. By using the methodology developed in this research crop water demand at field or distributary level can be calculated and compared with supply which can be helpful in decision making for effective water planning and management.

CONCLUSIONS AND RECOMMENDATIONS

For water managers it is important to have all necessary information (spatial and temporal) about crop and crop growth, irrigation practices, crop pattern, and water resources. Conventional techniques are not sufficient to provide all such information on large scale for planning and policy making purpose. Modern technologies of data acquisition and management for example remote sensing and GIS has proven their worth to provide timely and reliable information about various phenomena of earth. Water is global problem and vital to manage especially for developing agrarian countries like Pakistan. This research provides a tool for water resource planning and management at distributary level.

For better water resources management the accurate relationship between water demand and water supply must be realized and established. Accurate crop identification is important to know about actual demand of water in the area. This study has revealed that remote sensing information along with sufficient amount of ground truth data can be useful in identification of various crops with reasonably high accuracy. Therefore accurate cropped

area can be calculated from remote sensing image. Comparison of water supply with water demand showed that there is extra water during *rabi* season, which can be saved and used to increase irrigated areas and enhance crop productivity in the area. Water managers can adopt the methodology developed in this research as a tool for water planning and management. More detailed planning at field level can be made if advanced remote sensing models like Surface Energy Balance Algorithm for Land (SEBAL) are used. Also accurate areas can be calculated by using spectral mixture analysis techniques, which can provide estimates of crop fraction within pixel. In addition to all this modern irrigation practices and resource conservation technologies will be helpful for improving water use efficiency and overall conservation of water resources.

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APPLICATIONS OF MEMBRANE SEPARATION TECHNOLOGY IN TEXTILE MILLS

By

Engr. Zeeshan Nawaz[1], Prof. Engr. Naeem A. Sheikh[2] and Engr. Kashif Sagheer[3]

ABSTRACT

Membrane separation technology is evolving as a solution to the many problems a mill may be experiencing. Membranes can provide a solution in such areas as: color removal, BOD reduction, salt reduction and reuse, PVA (Polyvinyl Alcohol) recovery, and latex recovery. Membrane technology is unique in that it can provide a return on investment as a solution to pollution abatement. Membrane solutions are generally in keeping with the Clinton/Gore philosophy of pollution prevention is better than waste treatment. Capital investment is competitive with conventional end of pipe treatment because membrane technologies have become more of a commodity, and because a point source strategy can be employed. In many cases, valuable products can be reclaimed and reused, adding to an overall cost reduction.

1.0 INTRODUCTION

The textile industry is characterized by using a large quantity of chemicals and huge quantities of water;

- Detergents and caustic chemicals are used to remove dirt, grit, oils and waxes.
- Bleach is used to improve whiteness and brightness.
- Dyes, fixing agents and many inorganics are used to provide the brilliant array of colors the market demands.
- Size is added to improve weaving.
- Oils are added to improve spinning and knitting. Latex and glues are used as binders.
- A wide variety of specialty chemicals are used such as softeners, stain release agents and wetting agents also.

These chemicals become part of the product; many of the chemicals perform a necessary function, but are removed from the fabric. State authorities (Environmental Protection Agency, Ministry of Environment, etc.) and local municipalities have begun to target the textile industry to clean up the wastewater that is being discharged from the textile mills. Regulators are looking closely at toxicity due to high salt, the ever present BOD (biochemical oxygen demand), non-destructible COD (chemical oxygen demamd), heavy metals, and color of the effluent. As the mill comes up for a new discharge permit, many are finding that the effluent being discharged threatens permit renewal.

Membrane stages are integrated into the plant as either modified batch or continuous stages in series operations. Modified batch systems utilize a continuous feed, produce a continuous permeate of clean water, but the concentrate is produced batch wise as shown in Figure 1. Feed and bleed continuous operations take a constant feed rate and produce permeate and concentrate at constant rates. Modified batch operations are generally less expensive because of higher average fluxes and less hardware.

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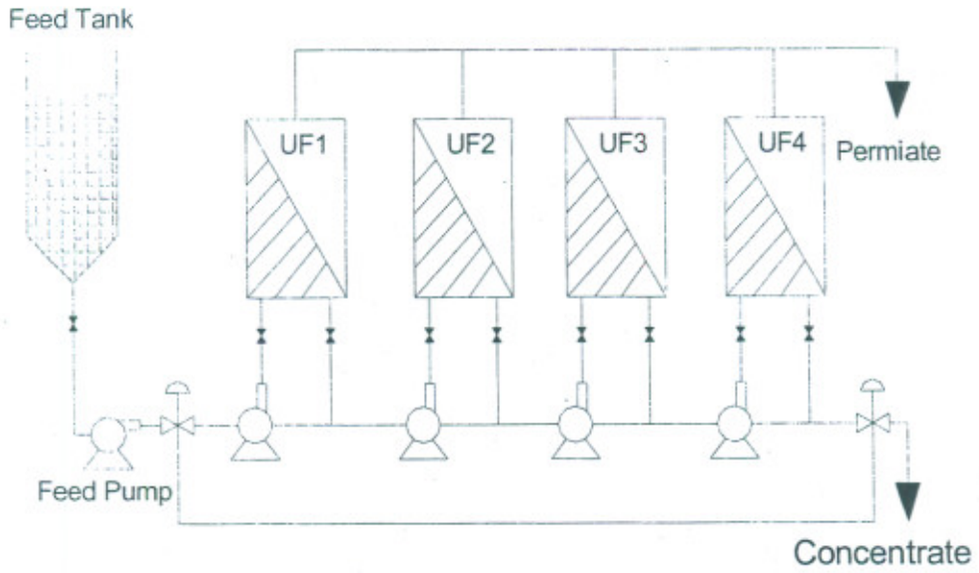


Fig. 1: Stage wise membranes in series

2.0 BASIS OF MEMBRANE TECHNOLOGY

Membrane operation is characterized by the flux, or flow rate per unit area of membrane, and by its retention or the percent of each solute species which does not pass through the membrane. There are two keys to membrane filtration which differentiate membrane application from conventional filtration.

1. The membranes are asymmetric with the small side of the pore facing the feed. This feature minimizes the pressure drop across the membrane, and eliminates any tendency to plug the membrane.
2. All membrane systems operate with a strong cross flow over the surface of the membrane.

Cross flow limits the build up of a filter cake (or concentration polarization layer in membrane lingo) to a few microns. The solutes, whose sizes are greater than the pore size of the membrane, are retained and concentrated forming a liquid stream called the concentrate or retentive. Water and solutes smaller than the pores pass through the membrane and are called permeate.

For purchasing a membrane separation system there are three major considerations:

- What type of membrane best suits my needs?
- What configuration of the membrane and operating conditions will best balance capital costs, operating costs and ease of operation?
- How is the membrane system integrated into my plant?

This section will give some guidance in making the process choices. The processes differ in the pore sizes.

2.1 Micro-Filtration (MF)

Micro-filtration is used to separate colloids from polymers with pores of 0.1 to 1 micron. MF will typically show 91% reductions in turbidity or silt density index. Typical applications are

clarification of juices and clarification of sugar solutions. Microfiltration membranes are made of several polymers including poly ether suifone, poly vinylidiene fluoride and poly sulfone. Ceramic, carbon and sintered metal membranes have found market, where extraordinary chemical resistance or where high-temperature prosess is necessary. As a rule of thumb, the smaller the pore sizes the higher the operating pressure, the capital investment and the operating cost. MF (micro-filtration) and UF (ultra-filtration) operate at 20 to 100 psi transmembrane pressures (P_{tm}) and velocities over the membrane surface of 1 to 10 meters/set. Typical fluxes for UF and MF are 20 to 400 gallons/sq ft/day (GFD).

2.2 Ultra-Filtration (UF)

Ultrafiltration is used to separate polymers from salts and low molecular weight materials, with pores of 0.001 to 0.1 micron. Turbidity is greatly reduced by 99+%. Polymers are retained for reduced TOC (total oxygen content), BOD (biological oxygen demand) and COD (chemical oxygen demend). A wide range of molecular weight cutoffs are available from 1000 to 500,000 daltons. Typical applications are haze stability in juices, concentration of paint, whey protein concentration and concentrating stable oily water emulsions. UF (ultra filtration) is an excellent means to remove metal hydroxides, reducing the heavy metal content to 1 ppm or less. Additional water can be added to wash salts and monomer out in a process known as diafiltration. UF membranes are mostly polymeric.

2.3 Nano-Filtration (NF)

Nanofiltration is used to separate sugars and divalent salts from water and monovalent salts. NF has found wide application for water softening. It also is demonstrating an ability to decolorize solutions. NF modules are extremely sensitive to fouling by colloidal material and polymers. For this reason extensive pretreatment is required. UF makes an excellent pretreatment substitute by eliminating the polymer addition, chlorine disinfectant and mixed media prefiltration. Nanofilters operate at 300 to 600 Psi P_{tm}, with velocities of 20 to 100 cm/set. Typical NF flux rates are 5 to 30 GFD.

2.4 Reverse Osmosis (RO)

RO (reverse osmosis) is used to remove almost everything from the water. NaCl and simple sugars show 98% or better retention by the membrane. Like NF (nano filtration), RO (reverse osmosis) is very sensitive to fouling and must be carefully pretreated. Virtually all NF (nano filtration) and RO membrane are thin film composite membranes. The operating conditions which influence productivity and rejection are transmembrane pressure, solute concentration and recirculation flow rate. The strong cross flow which limits the buildup of a filter cake results in expected operational characteristics.

In most applications increasing the transmembrane pressure does not necessarily increase flux. This is because the filter cake responds to the increased convection of solute to the membrane surface by increasing the thickness of the cake. The cake thickness is primarily controlled by the velocity of the cross flow. Increasing velocity generally increases the flux by increasing the rate at which the filter cake is swept away and reducing the cake resistance. Increasing concentration typically decreases flux because of the increase in convection to the membrane surface. The P_{tm} in RO (reverse osmosis) was typically about 500 to 1000 Psi, with cross flows of 20 to 100 cm/set. The range of typical RO fluxes is 5 to 15 GFD.

3.0 FOULING OF MEMBRANES

There are two types, colloidal flocculation or inorganic scaling above the membrane surface and adsorption of organics to the membrane. Fouling layers are removed by appropriate cleaning procedures and regeneration process. The most common procedures are caustic detergent for removal of dirt, oils and colloidal material, acids for metal hydroxides, and oxidizing agents for adsorbed organics.

4.0 APPLICATIONS

Membrane separation technology offers several varied types of textile manufacturing or different sites in one industry with reference to subheadings 4.1 to 4.7 covering many aspects of textile processing. These applications are unique because they provide a return on investment while abating wastewater treatment problems. The following are some of the important uses of membrane technology in textile mills.

4.1 Scouring Operations

Scouring operations generate large BOD (biochemical oxygen demand), oil and grease loadings on the sewer system. Heavy metals in cotton goods sometimes cause a problem also. UF (ultra filtration) retains and concentrates the emulsion to 30-50% oil which can be economically hauled away. At these concentrations the O/W emulsion supports combustion and can be used as fuel. Heavy metals are reduced to their solubility limit, usually less than 3 ppm. Scouring operations are best with ceramic or hollow fiber membranes. The best process mode for batch scouring operations is modified batch and shown in Figure 3. The driving force in this application is pollution control. Reuse of permeate is possible, along with the heat savings. Water reuse gives a two year payback if the water price is Rs. 50 / 100 gal.

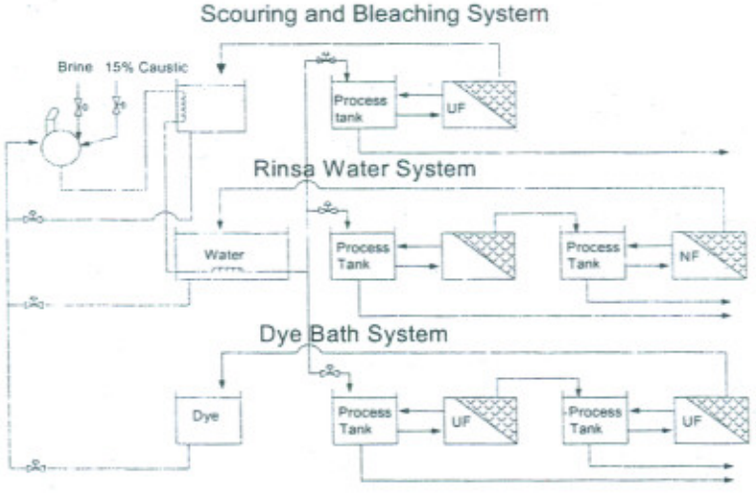


Fig. 2: Recycling of Jet Dyeing Machine Water

4.2 Latex Recovery

In general, latex is mixed with an extender such as calcium carbonate and used as the binder in carpet manufacturing. The waste stream is too dilute to reuse and is discarded causing an aesthetics and BOD (biochemical oxygen demand) / COD (chemical oxygen demand) problem. Latex recovery by UF (ultra filtration) is a standard operation for the many latex manufacturers and users. Latex recovery produces several principal benefits. A two year payback from latex recovery is possible from a 0.5-1% latex waste stream. Latex recovery benefits are: decreased purchase of latex and BOD (biochemical oxygen demand) reduction.

4.3 Dyestuffs

The dye which presents an aesthetics problem in waters used for recreation, heavy metals incorporated in the dye, and the salt which can present a toxicity problem when discharged to small streams. NF (nano filtration) / UF (ultra filtartion) are capable of completely separating many dyes such as: vat, acid, premetallized, dispersed and direct dyes from the

brine. Some dye manufacturers use UF to wash excess salt out of the dyes. NF can be used to separate fiber reactive dyes and cationic dyes from the salt. The salt is recovered for reuse, and the dye can be discarded and shown in Figure 2. Salt recovery from the dye bath alone has 50% returns on investment while reducing 92% salt toxicity by about 77%. A system to remove color and recover salt from fiber reactive dyeing has a two year payback if the water price including purchase, sewer charges were about Rs. 30 / 100 gal.

4.4 Printing

The printing operation uses large quantities of water for continuously washing the rubber belts. The wastewater is laden with fine pigments and polymeric binders giving the stream high color and BOD (biochemical oxygen demand). UF (ultra filtration) membranes remove the color and the binder. The clean permeate has an 85% reduction in BOD (biochemical oxygen demand) and 99% reduction in color. The water can be recycled back to the print machine for reuse and shown in Figure 3. The best membrane for this application is the one inch FEG tube used in a modified batch mode. It readily handles the high viscosity at the end of the run. It can be mechanically cleaned with a sponge ball or pig.

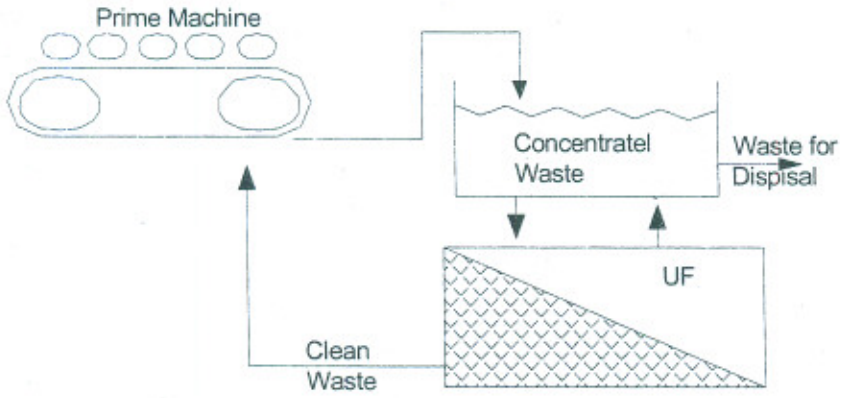


Fig. 3: The Printing Process

4.5 Pre-Treatment of Feed Water

Quality of water is paramount in high quality dyeing processes. Hollow fiber UF (ultra filtartion) removes color bodies which interact with the dye and compete for sites on the cloth. It also removes the colloidal material which causes spotting. Nanofiltration is an excellent alternative to ion exchange or green sand water softening. Many communities use NF to soften, decolorize and eliminate bacteria and viruses from the drinking water supply.

4.6 Recovery of Indigo Dyes

Indigo dye is only 76% fixed onto the fabric with the remainder being washed away. In the quinone form it is highly insoluble in water and can be readily concentrated by UF. The concentrate can be blended with fresh Indigo, reduced with hydrosulfite and caustic and reused. The best configuration for this application is the 1 inch tube. It has exceptionally long life of several years. The high cross flow velocity gives high stable fluxes keeping system and operating cost low.

4.7 PVA Size Recovery

PVA size recovery has long been used in large, integrated weaving plants to recover and concentrate the size from the desizing bath as shown in Figure 4. Size recovery can be used economically on small streams to remove the size from desizing baths. The size can be

hauled off as waste and the hot permeate can be recycled back to the desizing bath. Poly (acrylic acid) and polyester sizes can be recovered this way also. Cost savings are generated from lower PVA (polyvinyl alcohol) purchases, lower BOD (biochemical oxygen demend) surcharges, heat recovery, and water reuse.

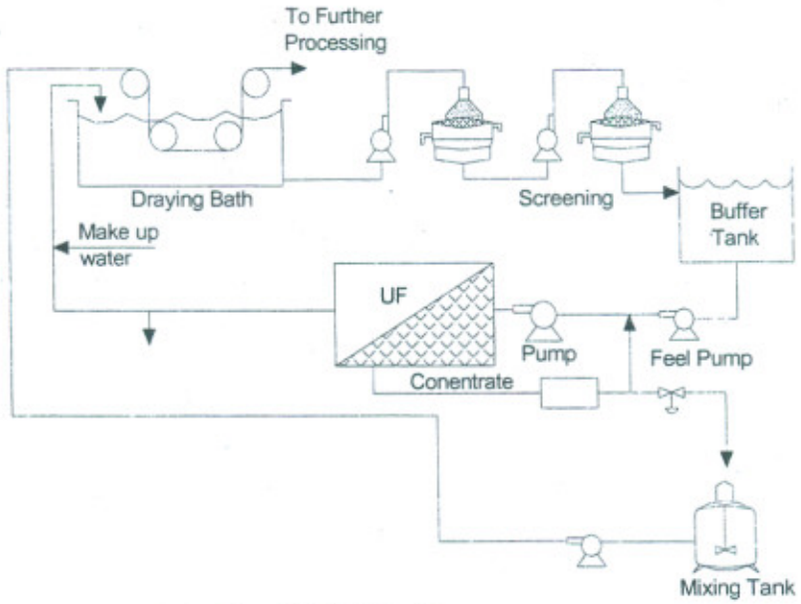


Fig. 4: PVA Size Recovery

5.0 CONCLUSION

The textile mills are advancing toward novel and hybrid operation. Strategically placed membrane technology will play an important role in recovering chemicals which used to go to the sewer, and in providing the high quality water needed to produce top quality goods the first time and every time. Membrane technology has many cost effective applications in the textile mills which are as follows:

- The ability to recover materials,
- Recycle water reducing fresh water needs and wastewater treatment costs,
- The use of a point source approach for minimum capital costs,
- Small disposal volumes which minimizes recurring waste disposal costs,
- Reduction of regulatory pressures,
- Improved heat recovery systems.

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ENVIRONMENTAL IMPACTS OF POLLUTED EFFLUENTS ON HUMAN HEALTH

By

Engr. Muhammad Shariq Ahmed*

ABSTRACT

One of the major environmental problems confronting Pakistan is water pollution. Human health is being affected by water pollution. The major sources of pollution for surface and groundwater resources are municipal sewage and industrial wastewater. The indiscriminate discharges of untreated sewage and industrial effluents into the water bodies have affected not only the water quality but also human health. Groundwater is also being contaminated by the discharge of untreated sewage into land. Water pollution is responsible for water borne diseases such as hepatitis, dysentery, typhoid, cholera, paratyphoid fever etc. This paper presents a general overview of the wastewater pollution in Pakistan, an evaluation and a specific reference to Lahore city and the effects on human health. Finally, sustainable treatment methods have been proposed to mitigate the water pollution problem.

The analysis of water bodies at wastewater discharge points shows depletion of Dissolved Oxygen (DO) and high levels of E. Coli. There is an evidence of groundwater pollution in many areas due to the discharge of wastewater on open land. To protect the water sources from contamination, appropriate treatment methods/treatment technologies have also been discussed in this paper. In the end conclusion and recommendations are given.

1) INTRODUCTION

High population growth rate coupled with rapidly expanding industrial sector has significantly deteriorated the human environment in Pakistan. Large quantities of municipal and industrial wastewaters are being discharged into natural bodies of water without any treatment giving rise to serious surface and ground water pollution problems. The major uses of the fresh waters in Pakistan are irrigation, municipal water supplies, and industrial use. The quality of fresh water for these beneficial uses is being adversely affected due to the indiscriminate discharge of wastewater effluents into the water bodies. The discharge of municipal and industrial wastewater is heavily taxing the oxygen resources of the rivers and thus threatening the aquatic life. Heavy metals and toxic compounds of this wastewater are a threat to human health.

2) POLLUTION SOURCES

Major pollution sources of surface water include municipal sewage, industrial effluents, storm water and agricultural runoff.

2.1 Municipal Sewage

Municipal wastewater from almost all the major cities in Pakistan is being discharged untreated into the rivers, thus adversely affecting their Dissolved Oxygen (DO) levels. Domestic sewage contains pathogenic bacteria and E-coli, which poses serious risk to human health. These bacteria in the sewage include *Salmonella typhosa*, *S. Paratyphoid*, *Shigella*, *Microbacterium and Vibrio*. Pathogenic viruses include entero viruses, reo-viruses, rotaviruses, adeno viruses and hepatitis viruses. In Pakistan, at places where potable water

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is not available, Surface water is also being used for drinking purpose without any treatment. Moreover, in urban areas where potable water system is available, due to the poor maintenance and lack of resources, cross-connections have worsened the conditions. As a result, diseases like dysentery, typhoid and gastroenteritis are prevalent in these areas. The total municipal pollution loads in term of Biochemical Oxygen Demand (BOD) for the five major receiving rivers are presented in Table 1.

Table-1
Municipal Wastewater Flows and Pollution Loads actually Discharged/Projected to be discharged into rivers of Punjab [1]

Water Body	Year 2000	
	Flow (m^3/s)*	Load BOD (T/d)**
Indus River	6.98	150
Jhelum River	0.82	15
Chenab River	10.71	225
Ravi River	23.43	500
Sutlej River	3.66	70
Total	45.6	960

*m^3/s = Cubic meter per second, **T/d = Tones per day

2.2 Industrial Effluents

Industrial wastewater from all the industries also finds its way to the receiving water bodies. These pollutants includes inorganic matter, detergents, heavy metals such as arsenic, cadmium, chromium, mercury, nickel, lead and zinc apart from other hazardous chemicals from various industries. These heavy metals and other inorganic compounds cannot be neutralized biologically and thus remain in the water bodies and enter into the food chain through animals. These metals are extremely dangerous to the human health. Table 2 summarizes the sources and impacts of heavy metals on human health.

Table-2
Sources and Health Effects of some Heavy Metals (SHO, 1992, 1984) [2]

Parameter	Source* Industry	Health Effects	WHO Guidelines Values (mg/l)**
Arsenic	2, 3, 4, 5, 6, 7	Acute poisoning of nervous system leading to coma and death for higher doses. Chronic poisoning leads to general muscular weakness, loss of appetite and weight, gastro-intestinal disturbances and sometimes skin cancer.	0.01
Cadmium	2, 3, 4, 5, 6, 7, 8	Acute effects in the form of severe gastro-intestinal upsets. Chronic poisoning produces proteinusia and formation of kidney stone. Increased risk of prostate cancer.	0.005
Chromium	1,2,3,4,5,6, 7,8,9,10	Liver cirrhosis, nephritis Gastro intestinal muscasa. Possibilities of digestive tract cancer	0.05
Lead	1,2,3,4,5,6, 7	Cumulative general metabolic poison. Tiredness, lassitude, irritability and anaemia. Behavior changes in children.	0.01
Mercury	1,2,3,4,5,6, 7,8	Neurological and renal disturbances cause gonad toxic and mutagenic effects. Disturbs the cholesterol metabolism	0.001
Nickel	1,4,5	Asthma, Dermatitis, Fever	0.2

* Following are the major industries in Pakistan:

1. Pulp and paper manufacturing
2. Inorganic Chemicals, Petrochemicals
3. Alkalies, chlorine, Inorganic chemicals
4. Fertilizers
5. Petroleum Refinery
6. Steel Works Foundries
7. Non-ferrous Metal Works, Foundries
8. Motor Vehicles, Aircraft Electroplating
9. Textile
10. Leather

** mg/l = milligram per liters

If contaminated water is consumed by animals like cows, goats, these harmful contaminants can also be transmitted to humans. Fish for example, may accumulate mercury and cadmium in very high concentrators and can results in dreadful diseases if consumed by humans. It is rightly feared that people in Pakistan are suffering from various diseases through aquatic food consumption.

Many industries discharge their effluents on land to ultimately affect the groundwater quality. A typical case is that of Kasur where around 240 tanneries have been discharging their untreated effluents into a pond dumping around 1250 kg/day of poisonous chromium to pollute the groundwater for a long time. Many cases of gastro- intestinal disorders have been reported from the area. Similar are the conditions at Muridke and Lahore - Sheikhpura Road where many industries throw their wastes on the land to form a stagnant pool. Groundwater contamination is also affected by leachates of improper sanitary land fills in the vicinity of major urban centers thus threatening the health of nearby communities drawing groundwater for domestic use.

Table 3 presents the total industrial wastewater flow along with pollution load in terms of BOD of major Punjab industries.

Table-3
Industrial Wastewater Flow and Pollution Load Discharged into Rivers of Punjab [1]

Water Body	Year 2000	
	Flow (m^3/s)	Load BOD (T/d)
Indus River	1.35	135
Jhelum River	0.38	30
Chenab River	2.86	220
Ravi River	4.65	385
Sutlej River	1.68	170
Total	**10.92**	**940**

2.3 Agricultural Pollution / Use of Pesticides

Pesticides pollution poses a significant threat to the human health. The use of pesticides in Pakistan has increased from 3,677 tons per year in 1981 to 43,373 tons per year is 1995 [3]. Improper use of pesticides has resulted in poisoning and deaths.

In Pakistan, fertilizer runoff consisting of Nitrates, Phosphates goes into the natural bodies of water and deteriorates the water quality. Also run off of pesticides leads to contamination of surface water. The agricultural run off consisting of fertilizers run off (N, P) has produced eutrophication problem in rivers. So control of fertilizer run off and pesticide pollution is a major factor controlling water pollution.

2.4 Case Study – Ravi River Pollution

The River Ravi receives wastewater from the city of Lahore through a number of discharge points without treatment. Based on year 2000 figures, at present 28.08 m^3/s of wastewater with BOD of 885 T/d (2000 figures) are being discharged directly into the river. It is estimated that the wastewater flows and BOD will increase to 37.68 m^3/s and 1105 T/d respectively by the year 2010 [4].

Deg Nullah, which carries the industrial wastewaters from Kala Shah Kaku and other industries along its way, joins the river through U.C. Canal. Kala Shah Kaku Industrial Complex has about 149 industrial establishments. Major polluting industries from this area contribute about 27.2 T/d of BOD to Deg Nullah [5]. Some industries at Lahore Sheikhpura road also discharge their wastewaters into the Nullah. Total BOD being discharged into the Ravi River through Deg Nullah is estimated to be 42.9 T/d. [1].

Hudiara Nullah receives more municipal and less industrial discharges. More than 13 industries of numerous types are discharging their effluents into it. They contribute liquid wastes such as textile mill waste, chemical waste, sugar mill waste and so on. The estimated BOD pollution lands from the point sources are of the order of 65 tons/day (1995 figures), which are roughly 13% of the anticipated pollution loads into the Ravi river [2].

3) EFFECTS OF WATER POLLUTION

Following are some of the major effects of water pollution.

3.1 Human Health Effects

Municipal wastewater usually contains many bacteria, viruses, protozoa, parasitic worms and other infectious agents that cause human diseases. Typhoid, cholera, dysentery, polio and infectious hepatitis are some of the more common diseases caused by bacteria or viruses that are transmissible through contaminated food and water due to unsanitary disposal of municipal wastes. This is apparent from the high incidence of infections and parasitic diseases in the country. Approximately 60 percent of the infant deaths have been related to these diseases.

Many industrial wastewaters contain chemicals with toxic, carcinogenic and physiological effects on man. The drinking water supplies from the polluted water bodies can pose serious health risks. Inorganic constituents of greatest cases to public health include cadmium, chromium, lead, selenium, mercury, fluorides and nitrates besides organic compounds many of which are carcinogens.

3.2 Ecological Effects

Various pollutants in the municipal, industrial and agricultural wastewaters affect the receiving water bodies in different ways. The biodegradable organic matter, normally measured in terms of BOD, is the main sink of DO in surface waters while oil and grease and synthetic detergents interfere with the oxygen transfer and thereby reduce the rate of oxygen absorption. Dissolved Oxygen is used by most organisms living in healthy aquatic ecosystems. The depletion of dissolved oxygen causes fish and other forms of oxygen –

- Pollution prevention measures along with the provision of wastewater treatment facilities are required for effective water pollution control. The use of clean technologies in manufacturing process should be encouraged through well targeted policies. For wastewater treatment, appropriate technology suited to the local conditions should be employed.

- Reuse of wastewater for irrigation purpose after adequate treatment needs to be promoted. This can supplement irrigation water in addition to providing nutrients for plant growth and reducing surface water pollution.

- There is a need to initiate regular monitoring programmes for natural water sources to build data base and to evaluate the effects of control measures. Research and development activities are also needed to be promoted. Necessary funds should be provided for laboratory equipment and trained staff for this purpose.

- Public opinion plays an important role in making pollution control a success. Mass media should be used to promote general awareness and appreciation of environmental issues.

- To safeguard the environment and protect public health from harmful effects of municipal & industrial wastes, there is need to adopt proper control measures and policies to prevent the introduction of harmful substances into the environment.

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