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Physico-Chemical Environment of Coastal Areas in the Vicinity of Lbod And Tidal Link Drain in Sindh, Pakistan after Cyclone 2a

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***Abstract*—**This paper presents the results of preliminary assessment of water quality along the coastal areas in the vicinity of Left Bank Outfall Drainage (LBOD) and Tidal Link Drain (TLD) in Sindh province after the cyclone 2A occurred in 1999. The water samples were collected from various RDs of Tidal Link Drain and lakes during September 2001 to April 2002 and were analysed for salinity, nitrite, phosphate, ammonia, silicate and suspended material in water. The results of the study showed considerable variations in water quality depending upon the location along the coast in the vicinity of LBOD and RDs. The salinity ranged between 4.39–65.25 ppt in Tidal Link Drain samples whereas 2.4–38.05 ppt in samples collected from lakes. The values of suspended material at various RDs of Tidal Link Drain ranged between 56.6–2134 ppm and at the lakes between 68–297 ppm. The data of continuous monitoring at RD–93 showed the range of PO_4 (8.6–25.2 µg/l), SiO_3 (554.96–1462 µg/l), NO_2 (0.557.2–25.2 µg/l) and NH_3 (9.38–23.62 µg/l). The concentration of nutrients in water samples collected from different RDs was found in the range of PO_4 (10.85 to 11.47 µg/l), SiO_3 (1624 to 2635.08 µg/l), NO_2 (20.38 to 44.8 µg/l) and NH_3 (24.08 to 26.6 µg/l). Sindh coastal areas which situated at the north-western boundary the Arabian Sea are highly vulnerable to flood damages due to flash floods during SW monsoon or impact of sea level rise and storm surges coupled with cyclones passing through Arabian Sea along Pakistan coast. It is hoped that the obtained data in this study would act as a database for future investigations and monitoring of LBOD and Tidal Link Drain coastal waters.

***Keywords*—**Tidal Link Drain, Salinity, Nutrients, Nitrite salts, Coastal areas.

I. Introduction

ON 21st May 1999, cyclone 2A has been hit the south eastern coastal areas of Sindh province-Pakistan and the catastrophic effect of this cyclone resulted in severely damaging the Tidal Link. The banks of Tidal Link were partially washed away and breaches occurred at 56 locations. Similarly Kadhan Pateji Outfall Drain (KPOD) suffered six breaches and the whole system failed to sustain the storm water [1].

Left Bank Outfall Drain (LBOD) project is designed for the integrated development of irrigation and drainage on the left bank of River Indus. The Sukkur Barrage prevents productive land from going out of production due to increased waterlogging and salinity [2]. The main purpose of LBOD is to remove and safely drain saline water to the sea at Shah Samando Creek and provide complementary drainage and irrigation improvements over a 580,000 ha area on the left bank of River Indus [3]. Also LBOD project implemented to drain out excess seepage water seeped from the irrigation canals and resulting in waterlogged lands in Nawabshah, Sanghar and Mirpurkhas districts.

The Tidal Link is 41 km long and passes through a series of large shallow interconnected lakes where the water in these lakes is considerably less saline than seawater. Tidal Link Drain most southerly section of the LBOD came into operation in 1995 to evacuate about 3 million tons of salt and 0.7 million acre-feet of drainage annually into the sea [4] & [5].

Before construction of the tidal link canal, the spinal drain discharged into Pateji and Shakoor lakes, later on, with completion of the drainage network the water inflows increased and it became necessary to connect KPOD to the sea through tidal link canal and allow effective disposal under a wide range of discharge. The overloading of LBOD drains during the July 2003 storms had a huge increase on the impacts of heavy rains that caused severe damage. Also the LBOD outlet system could not handle the effects of the large volume of storm water runoff that resulted from the large, intense monsoon season rain storms like those that have occurred in 1994, 1999 and 2003 [6]. According to the [6] conditions of the outfall system do not provide the hydrological, environmental and social functions that were considered at the design stages. The LBOD-KPOD can now be described as a “new river” that is forming an estuary and is an integral part of creek formation into the coastal area. The Tidal Link has encouraged the sea to approach the land and now the tidal fluctuations are visible in the KPOD. This situation will continue, and its progress is not predictable. Adapting to this new situation requires continuous hydraulic and environmental monitoring.

It was reported that the performance of the drainage systems constructed in Pakistan was not up to the expectations. This could be due to poor designing,

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construction, operation and maintenance of these systems [7]. However, to improve the efficiency of the systems there is a need to develop a cost effective technology to new situations so that maximum benefits can be drawn from the investments on such drainage projects. It has been reported that due to cyclones and proximity of Arabian Sea, majority of Sindh coastal areas are vulnerable to flood damages [8]. Also [9] have discussed geological hazards along the Sindh coast and reported that cyclones may have different environmental impacts at different locations along the coast. The cyclone of 1999 caused serious damage in terms of lives and property in Thatta and Badin districts; it wiped out 73 settlements, with over 75,000 houses destroyed [1]. For the management of cyclones and other natural disasters, Government of Sindh has established the Provisional Disasters Management Authority (PDMA). In addition to that also there is National Disasters Management Authority.

The main purpose of the study was to monitor the physicochemical conditions of water quality of the saline water drained through LBOD into the Shah Samando creek of Indus Delta and may act as a database for future investigations and monitoring of LBOD and Tidal Link Drain waters.

II. Material and Methods

A. Sample Collection

Samples of water were collected from various stations in the vicinity of LBOD and Tidal Link Drain waters. The samples were collected from all locations by using the standard sampling methodology [10]. Glass bottles of one-liter capacity were used for the sampling of water for general environmental parameters. For collection and preservation of nutrient samples, 100 ml capacity High Density Polyethylene (HDPE) bottles were used. The nutrient samples immediately after collection were placed in a cooler filled with ice, delivered to the lab and kept frozen until processing.

B. Sample Analysis

The water samples were transported to the National Institute of Oceanography (NIO), Chemical Oceanography and Marine Environment Laboratory within very short time after collection and analysed various environmental parameters by using the international accepted protocols.

The temperature of surface water at the sampling site has been measured by using laboratory thermometer. The salinity of water samples was analysed using the OSK 2058 T.S SALINOMETER (Japan). The tidal observations were recorded at the site by using Seabird SBE-26 USA. The current measurements also were recorded at the site. The Current Meter Anndreaa RCM-718 (Norway) was used to record the maximum and minimum speeds of the current.

Spectrophotometer Shimazdu UV-260 (Japan) was used for the analysis of nutrient samples. The major nutrients (NO_2, PO_4, SiO_3, and NH_3) in water were analysed as described by [11]. Ammonia was determined by treating the saline water in an alkaline medium with hypochlorite and phenol in the presence of sodium nitroprusside which acts as catalyzer. Then the blue indophenols colour formed with ammonia was measured using spectrophotometer. Nitrite was determined by diazotizing with sulphanilamide and coupling with N-(1-naphthyl)-ethylenediamine to form a highly colored azo dye which can be measured spectrophotometrically.

For the analysis of suspended matter, 300ml water sample was filtered through a glass fiber filter (GF/F, 0.7m) and the retained material was dried at 100 ºC. After 2 hours of drying the suspended matter was determined by weighing and subtracting the weight of the filter from the total weight [10].

III. Results And Discussion

A. Surface water temperature

The temperature data collected at every 3 hours interval during the study period at RD-93 was analysed and monthly averages are presented in Table 1. The average annual water temperature data shows that minimum temperature ranged from 7.0ºC to 26.5ºC and maximum water temperature ranged between 27 to 41ºC. Seasonal variation is quite indicative in temperature data. The surface water temperature measured during December 2001–February 2002 show that the minimum range was 7–11ºC and the maximum range was 27–30ºC, which was the coolest period of the year. After the winter season the temperature gradually increased and reached a maximum of 41ºC during May 2002.The higher temperatures were found during March to September, when the average minimum range was 18.5–26.5 ºC and the average maximum range was between 36-41ºC.

TABLE 1
Monthly average of surface water temperature of Tidal Link Drain at RD-93

Month	Temperature ºC	
	Minimum	Maximum
September 2001	26.5	36.0
October 2001	21.5	37.5
November 2001	14.0	35.0
December 2001	11.0	30.0
January 2002	09.5	27.5
February 2002	07.0	30.0
March 2002	18.5	37.5
April 2002	20.5	38.5
May 2002	23.0	41.0
June 2002	26.2	36.5
July 2002	26.5	38.5
August 2002	26.0	37.0

B. Salinity

The high saline seawater from Shah Samando Creek which previously was detected up to RD-125 and RD-95 has been extended up to RD-38 and possibly beyond [12]. Salinity was measured at different stations of RDs during September 2001, March and April 2002 and results are shown in Table 2.

During September 2001 the values of salinity at RD-38, RD-0 and RD-26 were 16.47 ppt, 4.39 ppt and 5.5 ppt

respectively. Results showed that salinity at RD-38 was higher than the salinity of RD-0 and RD-26, which may be due to sea water intrusion through Shah Samando Creek because RD-38 is nearer to sea as compared to RD-0 and RD-26.

During March-April 2002, 18 RDs were visited which represent the complete Tidal Link Drain. The salinity in RDs water found to be in the range of 25.8 to 65.52 ppt as compared to 7.0-45.5 ppt during 1996-97 [13] for Tidal Link Drain. The lowest salinity value (25.8 ppt) was recorded at RD-20 during April 2002 and the highest salinity value (65.52 ppt) was recorded at RD-42 during April 2002.

It was appeared from many relevant literatures that there is no any fixed standard available for salinity and other environmental parameters for the LBOD construction.

TABLE II
SALINITY VALUES AT VARIOUS RDS OF TLD DURING SEPTEMBER 2001, MARCH AND APRIL 2002

Date	Station	Salinity (ppt)
Sept-01	RD -38	16.47
Sept-01	RD 0	4.39
Sept-01	RD+26	5.5
March-02	RD -154	51.28
March-02	RD -144	50.5
March-02	Shah Samando	50.84
March-02	RD -138	51.28
March-02	RD -125	52.54
March-02	RD -125	51.54
March-02	RD -114	52.04
March-02	RD -104	55.08
March-02	RD -93	53.98
March-02	RD -70	52.96
March-02	RD - 61	55.76
March-02	RD -55	56.94
March-02	RD -80	53.22
April-02	RD -42	65.52
April-02	RD -47	55.78
April-02	RD -26	57.28
April-02	RD -18	61.28
April-02	RD -39	50.28
April-02	RD 20	25.18
April-02	RD 0	25.85

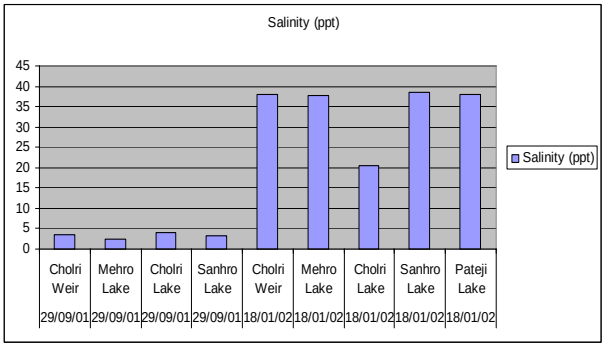

Fig. 1 Values of salinity at various lakes in the vicinity of LBOD

The survey of the four lakes (Sanhro, Mehro, Cholri and Pateji) in the study area was undertaken during September 2001 and January 2002.

The range of salinity of water was between 2.4–38.05 ppt. The lowest salinity was recorded at Mehro Lake during September 2001, which could be due to fresh water drained into lakes during rainy season. The highest salinity value was recorded at Cholri weir station during January 2002 (Figure 1). This high concentration could be due to the influence of sea water in the area.

Rising in the salinity level in the Dhands, has caused a big change in the ecosystem for example, birds and waterfowl suffered, distinctive vegetation is being lost, and a major decrease in yields and species composition of the fishery has been occurred [14].

C. Tidal height and current measurements

The monthly tidal data collected at RD-93 during September 2001-August 2002 show that the tidal height was found in the range of 0.2 to 4.86 meter. The records of tidal observation show that the tidal height in September 2001 was found in the range of 0.25 to 3.1 m where as from October to December 2001 the tidal height was observed between 0.2-4.4 m. The tidal height of 0.5-4.2 m was recorded during January–March 2002. The onset of South West (SW) monsoon starts in May and the influence of monsoon was observed on regime and the tidal height was found in the range of 0.72–4.56 m.

The tidal height recorded during July-August 2002 which is early SW monsoon also indicated rise in water levels. The tidal height was observed in the range of 0.62- 4.04 m. Current measurements were carried out at RD-93 five times during Septeember2001–August 2002. In addition to this, current was also measured at RD –38 during October 2001.

The summary of results obtained for current speed measurement is presented in Table 3. Current measurements of the water flowing in Tidal Link Drain during September 2001 at RD-93 showed that the current speed maximum during ebb tide and the current speed of 90 cm/sec was recorded. During flood tide the speed of water current was found in the range of 50-70 cm/sec.

The current measurements at RD-93 during January 2002 indicated a maximum flood water of 180 cm/s and the minimum flood water of 83 cm/sec. During ebbing, water current speed was observed in the range of 150-180 cm/sec.

TABLE III
CURRENT MEASUREMENT AT RD –93 AND RD-38 DURING 2001-02

Stations	**Month**	**Flood cm/sec**	**Ebb cm/sec**
RD – 93	Sept. 2001	50 – 70	60 – 90
RD – 38	Oct. 2001	18 – 48	45 – 75
RD – 93	Jan. 2002	83 – 100	150 – 180
RD – 93	Feb.2002	20 – 80	30 – 180
RD – 93	June 2002	36 – 160	83 – 180
RD – 93	August 2002	53 – 83	83 – 140

During February 2002 current speed of flood water was recorded in the range of 20-80 cm/s and ebb water current speed was recorded in the range of 30-180 cm/sec. The current speed at RD-93 during June 2002 was observed in the range of 36-160 cm/sec during flooding. In August 2002 flood water current speed was recorded between 53 - 83 cm/sec and ebb water current speed was recorded between 83-140 cm/s. The speed of water current measured at RD-38 during October 2001 indicated flood water current and the observed speed was 18-48 cm/sec and ebb water current speed was recorded between 45-75 cm/sec.

D. Nutrient

Major nutrients (NO_2, PO_4, SiO_3, and NH_3) were analysed to gather some information which play major role in coastal water productivity. It was reported that excess nutrient supplies from increased sedimentation due to changes in land use, atmospheric deposition, agricultural fertilizer runoff and other anthropogenic sources, can have adverse effects on wetland ecosystems [15].

Table 4 presents the average values of nutrients at RD-93. The monitoring of phosphate at RD-93 during September 2001, October 2001 and August 2002 revealed that concentration of phosphate ranged from 8.06 μg/l to 33.55 μg/l. The concentration of phosphate in Tidal Link during September and October 2001 ranged from 8.06 to 14.45 μg/l and during August 2002 the concentration of phosphate ranged from 20.46 to 33.55 μg/l. The concentration of PO_4 at RD-38, RD-96 and RD-0 during September 2001 was 10.85, 11.16 and 11.47μg/l respectively (Table 5) which is similar to that of RD–93. The concentration of PO_4 in Cholri Lake and Sanhro Lake during September 2001 was 19.84 μg/l and 13.02 μg/l respectively. The concentrations of phosphate at Cholri Lake and Shah Samando Creek were lower as compared to the results presented by [16].

TABLE IV
AVERAGE VALUES OF NUTRIENTS AT RD –93 DURING SEPTEMBER, OCTOBER 2001 AND AUGUST2002

Date	NO_2 μg/l	PO_4 μg/l	SiO_3 μg/l	NH_3 μg/l
Sep-01	1.1124	12.4515	1042.85	35.36
Oct-01	2.977583	10.8904	903.8359	63.5145
Aug.-02	17.4922	24.9922	930.308	24.88975

The range of silicate concentration at RD-93 during September 2001, October 2001 and August 2002 was between 554.96–1462.4 μg/l. The lowest concentration (554.96 μg/l) was recorded on 8 August 2002 at 1800 hours and the highest concentration (1462.4 μg/l) was recorded on 9 August 2002 at 1200 hours.

The observations of silicate at RD-38, RD-96 and RD-0 during September 2001 were between 1624–2635.08 μg/l as shown in Table 5. The lowest concentration (1624 μg/l) was recorded at RD-38 and the highest concentration (2635.08 μg/l) was recorded at RD-0. The concentration of silicate in Dhands during September 2001 is presented in Table 5. The silicate concentration at Sanhro Lake was found to be 2470 μg/l and 2724 μg/l at Cholri Lake. The concentration of NH_3 at RD-39 was found between 9.38 to 123.62 μg/l and the concentration average found to be 35.36 and 63.5145 during September and October, 2001 and 24.889 during August 2002 as shown in Table 4.

The concentration of Ammonia during September 2001 at RD-38, RD-98 and RD-0 was 24.08 μg/l, 26.6μg/l and 25.2 μg/l respectively. The concentrations of NH4 at Sanhro Lake during September 2001 were found 65.8 μg/l, whereas it was found 107.96 μg/l at Cholri Lake as shown in Table 5.

The range of NO2 was 0.5574–25.2 μg/l. The lowest value (0.5574 μg/l) was recorded on September 2001 and the highest value (25.2 μg/l) was recorded on October 2001. The concentrations of NO2 at RD-38, RD-96 and RD-0 during September 2001 ranged between 20.38–44.8 μg/l. The lowest value (20.38 μg/l) was recorded at RD-96 and the highest value (20.38 μg/l) was recorded at RD-0. The nitrite concentration was 1.45 μg/l at Sanhro Lake whereas it was 0.574 μg/l at Chorli Lake as shown in Table 5.

TABLE V
VALUES OF NUTRIENTS AND NITRATES AT VARIOUS RDS AND LAKES DURING SEPTEMBER, 2001

Date	Stations	NO_2 μg/l	PO_4 μg/l	SiO_3 μg/l	NH_3 μg/l
29/09/01	RD -96	20.38	10.85	2528.4	26.6
30/09/01	RD -38	52.2	11.16	1624	24.08
30/09/01	RD 0	44.8	11.47	2635.08	25.2
30/09/01	Cholri Lake	1.45	19.84	2724	103.96
30/09/01	Sanhro Lake	0.574	13.02	2470	65.8

E. Suspended Material

The concentration of suspended material at various RDs in Tidal Link Drain during September 2001, March 2002 and April 2002 ranged between 56.6–2134 ppm as shown in Table 6. The minimum concentration (56.6 ppm) was recorded at RD-104 during March 2002 and the maximum value (2134 ppm) was recorded at RD+26 during September 2001.

The values of suspended material at RD-98, RD-104 and Shah Samando Creek were also found higher than the other stations because of rapid erosion at RD-98 and RD-104 and mixing of Tidal Link Drain water with sea water at Shah Samando Creek.

The concentration of suspended material in the water of Dhands during September 2001 and January 2002 was found in the range of 68 – 297 ppm as shown in Table 7. The minimum value (68 ppm) was recorded at Cholri Weir station during September 2001 and the maximum value (297 ppm) was recorded at Mehro Lake.

The values of suspended matter at lakes were found less than those found at Tidal Link Drain due to less erosion in Dhands area.

TABLE VI
SUSPENDED MATERIAL AT VARIOUS RDS IN LTD

Date	Stations	Suspended material (ppm)
30/09/01	RD -38	103.6
30/09/01	RD 0	163
30/09/01	RD+26	56.6
22/03/02	RD -154	460
22/03/02	RD -144	990.6
22/03/02	Shah Samando	1579.6
23/03/02	RD -138	619
23/03/02	RD -125	847
23/03/02	RD -125	1062.6
24/03/02	RD -114	858
24/03/02	RD -104	2134.6
24/03/02	RD -93	728.6
25/03/02	RD -70	512.6
25/03/02	RD - 61	576.6
25/03/02	RD -55	463.3
25/03/02	RD -80	697.3
12/4/2002	RD -42	594
12/4/2002	RD -47	926
13/04/02	RD -26	606
13/04/02	RD -18	663
13/04/02	RD -39	1399
14/04/02	RD 20	250
15/04/02	RD 0	535

TABLE IV
SUSPENDED MATTERS AT VARIOUS DHANDS

Date	Stations	Suspended material (ppm)
29/09/01	Cholri Weir	68
29/09/01	Mehro Lake	297
29/09/01	Cholri Lake	87.33
29/09/01	Sanhro Lake	143.6
18/01/02	Cholri Weir	88
18/01/02	Mehro Lake	90.3
18/01/02	Cholri Lake	82.3
18/01/02	Sanhro Lake	90.3
18/01/02	Pateji Lake	129.6

IV. CONCLUSION

The data collected during this study showed that after cyclone 2A due to breaches in the Tidal Link Drain the seawater intrusion increased considerably (25.8-65.52ppt) as compared the salinity range found prior to cyclone range (7.0-45.4) as reported by [13]. The data collected for suspended material in the water flowing through Tidal Link Drain generally show higher concentration. It has been observed from the data that the concentrations of PO_4, NO_2 and NH_3 were in the normal range for all samples collected from Tidal Link Drain and Lakes but the concentration of SiO_3 was found higher than other nutrients. This is possibly due to run off from water containing higher concentrations of silicate in comparison to nitrate and phosphate.

From the results of this study we can conclude that the high levels of salinity and suspended material may be due to the impacts of cyclone and LBOD design defects.

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REFERENCES

[1] Alagha, S. K., "Environmental Monitoring of Tidal Link Drain-LBOD and its Adjoining Coastal Areas", ME Thesis, Institute of Environmental Engineering and Management, Mehran University of Engineering and Technology, Jamshoro, Pakistan, 2004.

[2] Memon, M.K. and Sohag, M.A., "Project Planning, Implementation and its constraints". In: Proceedings of Symposium on Left Bank Outfall Drain (LBOD) Project and Its Impacts. Organized by Institute of Irrigation and Drainage Engineering, and Institute of Environmental Engineering and Management, at Mehran University of Engineering and Technology (MUET) Jamshoro, Sindh on 29 November, 1997 and sponsored by MUET and WAPDA (South Zone), Water Wing Hyderabad, pp. 1-8, 1997.

[3] Hasnain, S. M., Jone, C. R. C., Bradford, M. G., "Tube well Drainage within LBOD: Implementation Difficulties, Solutions and Achievements", In: Proceedings of Symposium on Left Bank Outfall Drain (LBOD) Project and Its Impacts. Organized by Institute of Irrigation and Drainage Engineering, and Institute of Environmental Engineering and Management, at Mehran University of Engineering and Technology Jamshoro, Sindh on 29 November, 1997 and sponsored by Mehran University of Engineering and Technology, Jamshoro and WAPDA (South Zone), Water Wing Hyderabad, Pages 59-68, 1997.

[4] Hall, A.C.J., "The Uses of Remote Sensing on LBOD", In: Proceedings of Symposium on Left Bank Outfall Drain (LBOD) Project and Its Impacts. Organized by Institute of Irrigation and Drainage Engineering, MUET and Institute of Environmental Engineering and Management, MUET at Mehran University of Engineering and Technology Jamshoro, Sindh on 29 November, 1997 and sponsored by Mehran University of Engineering and Technology, Jamshoro and WAPDA (South Zone), Water Wing Hyderabad, pp. 19-25, 1997.

[5] Robboy, R. and Sirichany, D., "Left Bank Outfall Drain Project Tackling Pakistan's Waterlogging and Salinity Problems", Available online at www.worldbank.org, 1997.

[6] World Bank (South Asia Region, Agriculture and Rural Development) , "Review of the performance of the Left Bank Outfall Drain Stage I (KPOD, DPOD, Tidal Link and Cholri weir)", Report of the World Bank International Panel of Experts, 2005.

[7] Muhammad, S. and Ali, A., "Effect of Farm Drainage System on Crop Production", Pakistan Journal of Water Resources, Vol. 12(1), pp. 1-8, 2008.

[8] Rehman, H. and Battarai, R., "Modelling and socio-economic impact analysis of floods in coastal cities under sea level rising scenarios: A case study of Karachi, Sindh Pakistan", pp.29-36, 2005. In: Proceeding of the International Symposium on Floods in Coastal Cities under Climate Change Conditions, Thailand, 2005.

[9] Inam, A., Rabbani, M. M., Mehmood, K., Ali, S.M., Tebrez, S.M., Danish, M., Sheikh, S.A., "Geological Hazards along Sindh Coast with Special References to Karachi Coast", Pak. J. Oceanography 3(1):37-50, 2007.
[10] Food and Agriculture Organization of the United Nation (FAO), "Manual of Methods in Aquatic Environment Research. Part–I Method for Detection, Measurement and Monitoring of Water Pollution", 1975.
[11] Parsons, T. R.; Maita, Y.; Lalli, C. M., "A Manual of Chemical and Biological Methods for Sea Water Analysis", Pergamon Press, New York, 1984.
[12] National Institute of Oceanography (NIO), "Annual Physical Monitoring report", 2004, Karachi.
[13] National Institute of Oceanography (NIO), "Hydraulic Monitoring of Tidal Link Drain, Final Technical Report", June 1998, Karachi.
[14] Schneider, A. K., "National Drainage Program project in Pakistan", International Rivers Network (IRN) Comment on the Inspection Panel Report and Management response, 2006.
[15] Sayed, M.F., and Abdel-Satar, A.M., "Chemical Assessment of Wadi El-Rayan Lakes-Egypt", American- Eurasian J. Agric. & Environ. Sci., 5(1): 53-62, 2009.
[16] Khuhawar T. M. J., Khuhawar M. Y., Mastoi, G.M., "Chemical Assessment of Water Quality at KPOD and Tidal Link of LBOD Project", In: Proceedings of Symposium on Left Bank Outfall Drain (LBOD) Project and Its Impacts. Organized by Institute of Irrigation and Drainage Engineering, and Institute of Environmental Engineering and Management, at Mehran University of Engineering and Technology Jamshoro, Sindh on 29 November, 1997 and sponsored by Mehran University of Engineering and Technology, Jamshoro and WAPDA (South Zone), Water Wing Hyderabad, pp. 53-58, 1997.