ENVIRONMENTAL ASSESSMENT OF WASTEWATER DISPOSAL ON MOURI RIVER AT KHULNA: AN APPLICATION OF GIS

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ABSTRACT

Rivers are the blessing on earth as they serve humans with ample fresh water supply. The purpose of the present study focuses on the combination of the GIS mapping, to indicate the status of pollution status in the sketch of River Mouri and the existing scenario of Mouri River. The daily wastewater disposed on the Mouri River was measured from boyra area drain as 1617 m^3 and annually the volume becomes 590278 m^3 which turned down the river water blackish in color and odorous. In this investigation the value of Turbidity, Dissolved Oxygen (DO), Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total suspended solid (TSS), Total dissolved solid (TDS), Chloride, Iron, Hardness, were found to exceed the permissible limit. The experimental values of DO and BOD were found to be analogous with simulation values. At present, the flow rate of Mouri River has becoming smaller due to obstruction by sluice gates in various locations. Furthermore, the river land areas have been used in different purposes such as construction of mud-roads, houses etc. by local community. The Mouri River water is highly polluted with biodegradable organic matters and seems totally unsuitable for fisheries development.

Keywords: *Dissolved oxygen simulation, GIS mapping, Mouri River, waste-load discharge*

1. INTRODUCTION

Bangladesh is a country of rivers which is situated along with the Ganga–Brahmaputra–Meghna delta and their tributaries. The rivers are main source of surface water in Bangladesh however the modern urbanization, industrialization, technological developments and multi-use of water deteriorated and deteriorating river water quality day by day.Water is essential for drinking, for growing food, for washing, and it is also important for many of the pleasant recreational aspects of life (Reeve, 2002). Water is absolutely essential not only for human beings, but also for animals, plants and all other living things. Water pollution may be caused by different municipal waste and industrial effluent. Now a day's water pollution has proven to be a very serious and visible form of environmental contamination as water bodies are used indiscriminately as dumps (Francis, 1994). In South Asian countries such as Nepal, India and Bangladesh pollution of rivers is severe and critical near urban stretches due to huge amounts of pollution load discharged by urban activities (BIWTA, 2006).

Khulna, the third largest city of Bangladesh, has been developed as an industrial as well as an administrative center. The importance of environmental quality in Khulna city in particular has recently attracted a great deal of interest. The population density of this area in 1991 was about 663340, in 1998 about 847580 in 2001 about 1172831 and was 1400689 in 2007 estimation (KCC, 2010). Water and land, the vital resources of life are increasingly being polluted in this area. The wastewater produced by the city people are dumped in the Mouri River, flowing at the North West side of the Khulna city, which separates the Domuria upazila from Khulna. Mouri River acts as a wastewater disposal site for the Khulna city (Huda and Chowdhury, 2004). This indiscriminate disposal of domestic and municipal wastewater causes a severe environmental pollution in the river environment and change in ecosystem (Olajire and Imeokparia, 2000). The river runs through various agricultural lands and by side of the main city and finally falls into the Shidsa River near Badamtala which starting fused point is in Rayer Mohal (Khan *et. al*., 2003). The disposed waste load in some location is so high that the river water quality has been significantly deteriorated in physical, chemical and biological aspects.

In the recent years, the Geographic Information System (GIS) is considered as effective tool in wastewater management as it enables the large volume data handling much easier (Gemitzi *et. al*., 2007). Effective decision making and planning is upgraded by the application of GIS. Environmental condition in various portions of river can be easily represented by GIS mapping. Pollutant concentrations represented by the mapping process help to

making decision to control the wastewater pollution in the river for achieving environmental sustainability. The objectives of the study is to investigate the quality of river water at different sampling stations and participate GIS Mapping to identify the likely pollution loading in various portions of the Mouri river. BOD and DO play important role for the growth of plant and animals in the water was also predicted from the waste load discharges simulation model . The possible application of this study is for the decision makers to introduce optimum treatment engineering controls at points of interests, prior to its disposal into River Mouri to prevent the ecological damages and protect human health.

2. METHODOLOGY

2.1 Study Area and Sampling Sites

The River Mouri is originates in Dakatia Beel and enters into Khulna metropolitan city, and receives the untreated municipal and industrial wastewater through main six municipal drains outfalls of the city. Finally, selected six sampling stations, located at each wastewater outfall point (Table 1). The working stations were established with more and less similar distances from the drainage openings to the Mouri River. Six different stations were selected at 1.5 Km interval.

Table 1: Description of the sampling location

Station No	Sampling Locations	GPS Coordinates	
		Latitude	Longitude
1	Rayer Mohal	$89^0$31'4.62''E	$22^0$50'7.68''N
2	Shashanghat	$89^0$31'46.25'' E	$22^0$49'36.15''N
3	Gollamari bridge	$89^0$32'11.31''E	$22^0$48'53.41''N
4	Nirala grave yard	$89^0$32'25.38''E	$22^0$48'4.89''N
5	Ten gate	$89^0$32'24.08''E	$22^0$47'10.98''N
6	Lobonchora	$89^0$32'54.33''E	$22^0$46'6.47''N

2.2 Quantity of Wastewater

The quantity of wastewater discharged in Mouri River from Boyra municipal drain is calculated. First the floating velocity of the flow is calculated and then calibrates it to obtain the actual velocity. Then the diameter of the drain and the flow depth is measured using a tape and a stick. After that using simple principal of geometry the area of flowing water is calculated. Finally the quantity of wastewater discharged in river water is calculated by using the following formula, Q= Av where, Q= Quantity of wastewater discharged in Mouri River (m^3/sec.); A= Area of water flowing in the (m^2); and V= Velocity of wastewater flowing in the drain (m/sec.)

2.3 Calibration of Floating Velocity

To determine the average velocity of stream the calibration of floating velocity is required. To serve this purpose average velocities for different floating velocities are determined in the laboratory. Then a floating velocity vs. average velocity graph is plotted. From this graph a equation for determining average velocity is derived. Using this equation the average velocity of the stream is determined.

2.4 Sample Collection

Samples were collected from six different stations at morning (7-9 am). Water samples were kept and preserved in 250ml plastic and glass bottles after collection. Samples were collected and analysed for a period of 6 months from February to July.

2.5 Analysis of Various Water Quality Parameters

The measured and analysed water quality parameters involved both the physical and chemical parameters. The parameters are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), Sulphate, Chloride, Nitrate, total suspended solid (TSS) and total dissolved solid (TDS). DO and BOD was analysed using digital DO meter while Chloride was analysed by titration method. Nitrate was analysed by Cadmium reduction method and Sulphate was analysed by USEPA method 375.4.

2.6 GIS mapping

The GIS Mapping of the different pollutants at the wastewater outfalls, to assess the pollutant loads discharged into River Mouri from six wastewater outfalls of Khulna and relative contamination of different portions of River Mouri, downstream to each outfall point was done using ArcGIS 10.1. The probable effective areas of each outfall points were identified by dividing the river area into segments. Both mean pollutant concentrations and pollution load value at wastewater outfalls were considered as for the segments and represented two parameters in a map by different colour composition.

2.7 Prediction of Dissolved Oxygen Profile

To predict waste load profile the physical characteristics of the river such as depth of flow, velocity of flow, with of river at that section was determined. Then the BOD and DO was found by laboratory experiment and the temperature of the water was measured by using a mercury thermometer. Then these parameters are placed in the equation and found the desired profile. To check the validity the water sample was collected from selected sampling stations and laboratory tests for BOD and DO were done. Then these values were compared with the values found by prediction.

3. RESULTS AND DISCUSSION

3.1 Quantity of Wastewater

The study has been undertaken to estimate the waste load discharges from Boyra area to Mouri river and hence assessing the impacts on water quality. To determine the quantity of wastewater several physical parameters were measured. These parameters are tabulated in the Table 2.

Table 2: Physical parameters of municipality drain

Parameters	Unit	Quantifying value
Distance traveled by ¾ filled bottle, s	m	1.735
Time to travel, t	Sec.	23
Diameter of drain	m	0.9144
Flow depth in the municipality drain	m	0.238

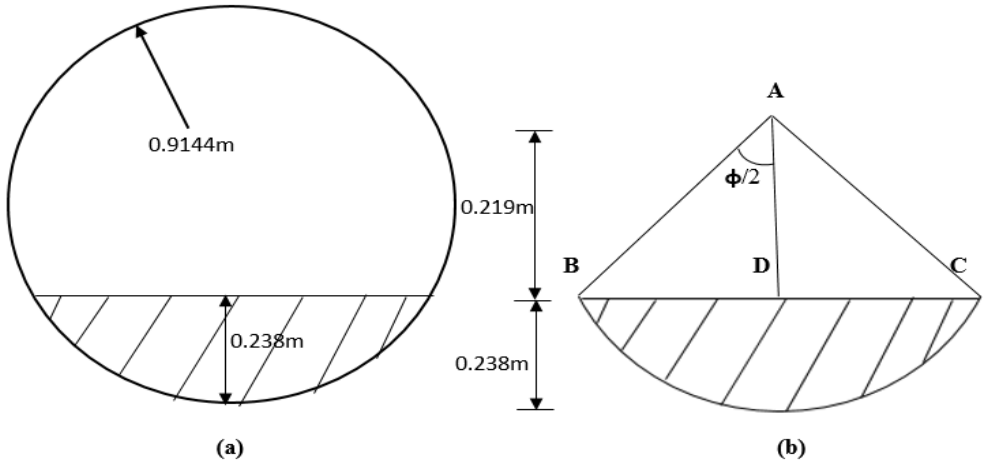


Figure 1: Physical parameters of municipality drain

Now to calibrate this floating velocity with the average velocity, several average velocities were measured against several different floating velocities in the tilting flume at the hydraulics laboratory of the Department of Civil Engineering, KUET. The floating velocities and corresponding average velocities are shown in Table 3.

Table 3: Calibration of floating velocity

Floating velocity,(m/sec)	Average velocity,(m/sec)
0.01	0.05
0.13	0.23
0.19	0.25
0.24	0.36
0.35	0.48

Then a graph was plotted (Figure 2) between mean velocity and floating velocity. From this graph an equation for calculating average velocity was determined and using the graph the average velocity was found.

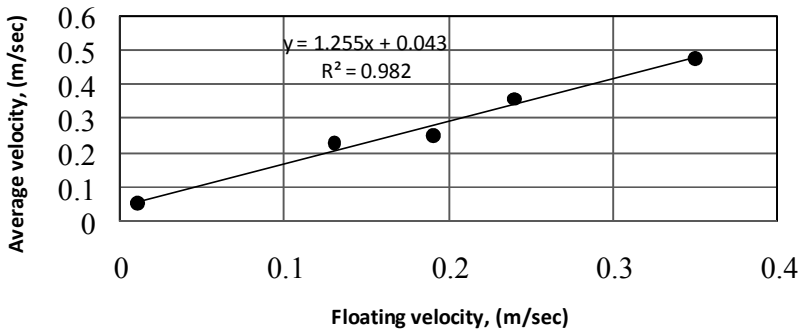


Figure 2: Graph for floating velocity vs Average velocity

Thus, quantity of wastewater discharge in six wastewater drain outfalls was shown in table 4.

Table 4: Flow rate (m^3/day) at different wastewater drain outfalls

Sampling Locations	Flow Rate(m^3/day)
Rayer Mohal	1538.76
Shashanghat	1617.12
Gollamari bridge	2146.64
Nirala grave yard	2482.42
Ten gate	1384.32
Lobonchora	1848.26

3.2 Physicochemical characteristics of the wastewater

Results of the wastewater analyses for the samples collected from the six wastewater outfalls of the city of Khulna (Table 5), revealed that the chloride and sulphate were found within the permissible limits of the Bangladesh Drinking standard (DoE, 1997) at all the six wastewater outfalls.

Table 5: Water quality parameter of test value and Bangladesh Drinking standard (BDS) value

Sample No.	Parameters (mg/L)	Rayer Mohal (1)	Shashan ghat (2)	Gollamari Bridge (3)	Nirala grave yard (4)	Ten gate (5)	Lobon-chora (6)	BDS (mg/L)
1.	DO	3.84	3.52	0.57	0.65	1.05	1.68	6
2.	BOD_5	9.49	10.45	8.58	5.60	3.46	2.27	0.2
3.	COD	97	106	83	79	72	65	4
4.	Chloride	549	368	745	634	423	326	150~800
5.	TDS	1288	1240	1480	1365	1164	985	1000
6.	TSS	352	400	324	368	434	496	10
7.	Nitrate	41.4	51.5	35.5	38.5	55.5	62.8	10
8.	Sulphate	61	42	72	64	36	31	400

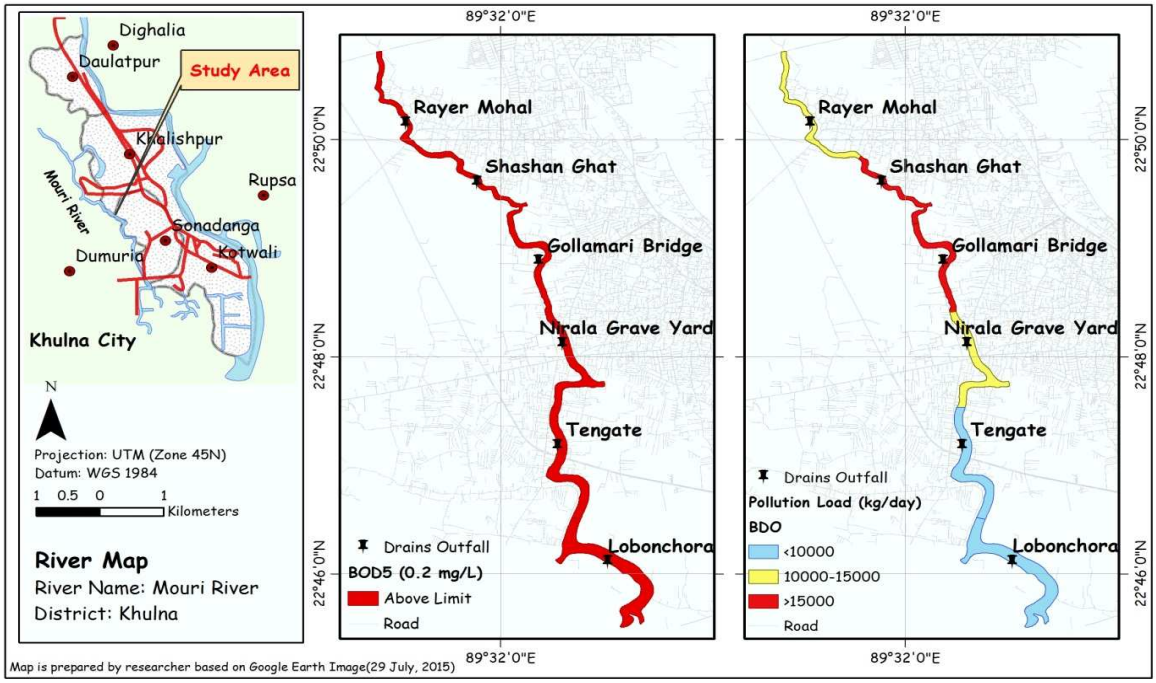
However, the biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), dissolved oxygen (DO), total suspended solid, total dissolved solid and nitrate throughout the study period, at all six wastewater outfalls of Khulna were exceeding the Bangladesh Drinking standard (DoE, 1997) permissible limits.

3.3 Pollutant Load Assessment

The pollutant load assessment of the study (Table 6) revealed that although few pollutants, discharged into River Mouri are relatively low in concentrations at one wastewater outfall point as compared to other wastewater outfalls and in some cases even within the permissible limits of Bangladesh Drinking standard (DoE, 1997) but have high pollutant load.

Table 6: Unit pollutant load (Kg/day) of study parameters at wastewater outfalls of Khulna

Parameter	Rayer Mohal Drain Outfall (kg/day)	Shashan ghat Drain Outfall (kg/day)	Gollamari Bridge Drain Outfall (kg/day)	Nirala grave yard Drain Outfall (kg/day)	Ten gate Drain Outfall (kg/day)	Lobonchora Drain Outfall (kg/day)
BOD_5	14603	16899	18418	13901	4790	4200
COD	149260	171415	178171	196110	99670	120140
Chloride	844779	595100	1599245	1573854	585570	602533
TDS	1981923	2005229	3177030	3388500	1611350	1820540
TSS	541643	646848	695510	913530	600790	916740
Nitrate	63705	83282	76210	95570	76830	116071
Sulphate	93864	67919	15456	15887	4984	5730



(a) (b)

Figure 3: (a) Mean BOD Concentrations (b) BOD Pollution Load at Wastewater Outfall of Khulna discharging into River Mouri.

3.4 Simulation of the Dissolved Oxygen Profile

The Boyra municipal drain discharges effluent to the Mouri river at Shashanghat point. In this point the worst conditions are occurs in summer months when the stream flow is low and water temperature are high. Under these conditions, measurements are made in the laboratory and in the field to determine the characteristics of the wastewater and the streams flows. The measured parameters, BOD and DO profile are given in Table 7, 8 and Figure 4.

Table 7: Measured parameters at wastewater discharge points

Parameters	Unit	Measured values
Width of river	m	13.718
Flow depth of river	m	1.9812
Average velocity of river water	m/sec	0.0117
Flow rate of wastewater	m^3/d	1617.12
Flow rate of river water	m^3/sec	0.318
Temperature of stream water	^oC	26.5
DO of wastewater	mg/l	1.45
DO of river water	mg/l	3.52
BOD of wastewater	mg/l	23.7
BOD of river water	mg/l	10.45
K_1	1/d	0.301568
K_2	1/d	0.439805

Table 8: Predicted DO and BOD profile

Distances, x (km)	Time, t=x/u	DO(mg/l)	BOD(mg/l)
0	0	3.52	10.45
1.5	1.4851	0.80	6.65
3	2.9702	0.39	4.23
4.5	4.4553	0.80	2.69
6	5.9404	1.42	1.71

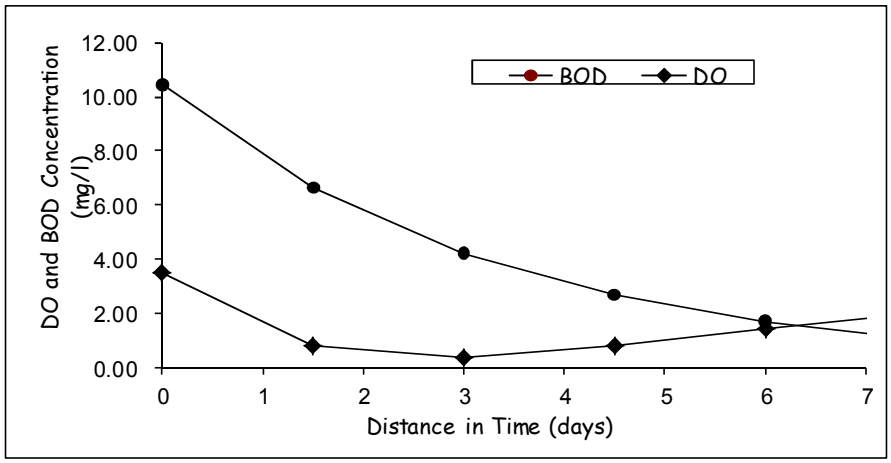


Figure 4: Predicted DO and BOD profile by using Streeter-Phelps equation (Standard)

3.5 Validation of Simulated Profile

The actual field measurements and predicted profile are shown in Table 9 and Figure 5, 6.

Table 9: Values of BOD and DO from mathematical model and actual field measurements

Location	Predicted DO(mg/L)	Field DO(mg/L)	Predicted BOD(mg/L)	Field BOD(mg/L)
Shashanghat(0km)	3.52	3.52	10.45	10.45
Gollamari bridge(1.5km)	0.80	0.57	6.65	8.58
Nirala grave yard(3 km)	0.39	0.65	4.23	5.6
Ten gate(4.5 km)	0.80	1.05	2.69	3.46
Lobonchora(6 km)	1.42	1.68	1.71	2.27

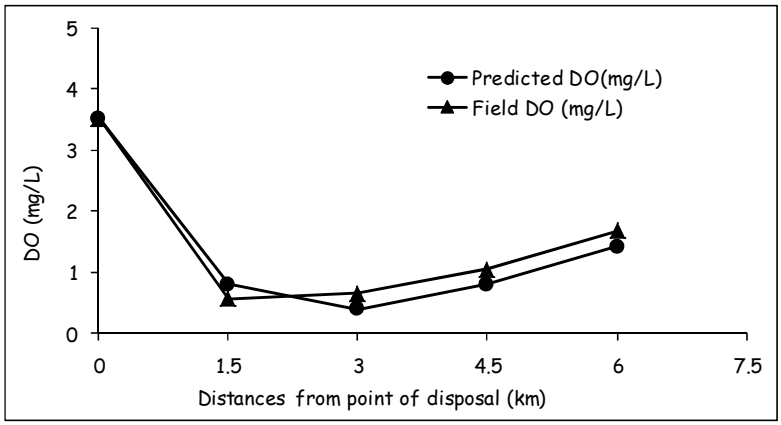


Figure 5: Variation of predicted dissolved oxygen with field experimental values

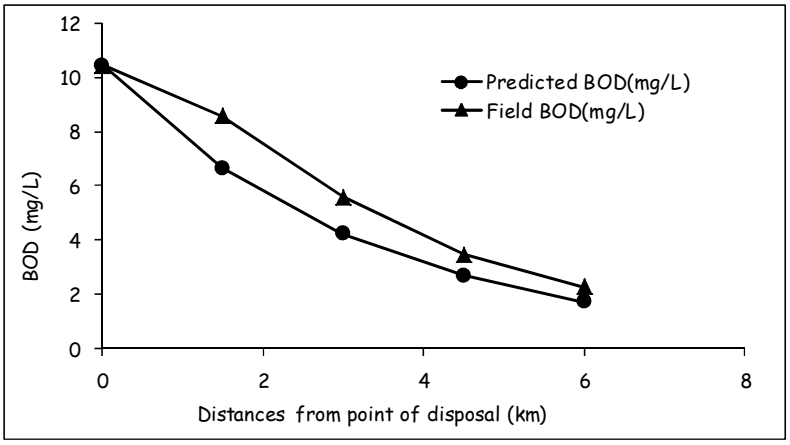


Figure 6: Variation of predicted BOD with field experimental values

From the graphs there are some variations of predicted BOD and DO values with the test results. These variations may occur as there was some time variance between sample collections and performing the tests in the laboratory. On the other hand, the stream was not in ideal plug flow condition. This may leads to this variance. But the variation is less so that the model can be used for quick predictions.

This profile is useful to predict the BOD load and the dissolved oxygen concentrations in a natural stream. However this model has some limitations. The equation is based on the assumption that there is one source of BOD when there may actually be several different point or nonpoint source of BOD. Again algal respiration in the absence of sunlight, nitrification processes that increases the oxygen demand and the presence of sludge deposits in pool areas can all account by the formulas used to derive oxygen sag curves. Further, the mathematics assumes steady-state conditions all along a river channel. Because such steady-state conditions would indeed be rare.

4. CONCLUSIONS

The daily wastewater disposed on the Mouri River was measured from boyra area drain as 1617.12 m3 and annually the volume becomes 590278 m3 or 155.93*106 gallons which turned down the river water blackish in color and odorous. The quality of wastewater was also assessed and the quality parameters were far beyond the standard limits. This wastewater also contains some portion of solid wastes such as plastics bags, paper, tin cans and broken glasses which blocks the river water and increases the pollution.

Mouri River acts as the main dumping site of wastage of Khulna city and this makes the environment of the river totally degraded and unsuitable. The water quality was tested at six stations of Mouri River and at all stations the water quality parameters failed to fulfill the required safe limit. In some stations, the dissolved

oxygen is below 2mg/L so that the environment is unsuitable for the aquatic lives. The river water contamination should be minimized in such a manner that can reduce the adverse effect on river resources. A suitable mechanism for controlling the volume of wastewater discharged into the river should be developed. The failure of the development of such mechanisms may cause a total destruction of the environment of Khulna city in general and the riverine ecosystem.

Finally the profile of dissolved oxygen and BOD load for the Mouri River stream was predicted from the developed model. This profile was validated by field experiment and there was no significant deviation.

REFERENCES

BIWTA Bangladesh Tide Tables, Tidal Research and Computer, Department of Hydrology, Bangladesh Inland Water Transport Authority (BIWTA), Dhaka, 2006.

Demography of Khulna City, Khulna City Corporation (KCC), 2010.

DoE, The Environment Conservation Rules (ECR, 1997), Department of Environment, Ministry of Environment and Forest, Bangladesh.

Francis, C. H. 1994. Accumulation and disponibilidad de metals pesados en suelos regados conagus residualses en Distrito de Riego 03,Tula, Hgo. Rev. *Inter. Contam. Ambient,* 10:15-21.

Gemitzi, A., Tsihrintzisb, V. A., Christouc, O., & Petalasb, C., *Use of GIS in sitting stabilization pond facilities for domestic wastewater treatment*, Journal of Environmental Management, 82(2), 155–166 (2007).

Huda, M. k. and Chowdhury, M. A., GIS Modeling of Industrial Effluent Impacts on River Water of Khulna City, 2004.

Khan, F., Husain, T. and Lumb, A., Water quality evaluation and trend analysis in selected water sheds of the Atlantic region of Canada, Environmental Monitoring & Assessment, 88, pp 221–242, 2003.

Olajire, A. A. and Imeokparia, F. E., Water Quality Assessment of Osun River: Studies on Inorganic Nutrients, Environmental Monitoring and Assessment 69, pp. 17-28, 200

Reeve, N. 2002. Introduction to Environmental analysis. John Willey and Sons limited, England.