Journal of Civil Engineering
The Institution of Engineers, Bangladesh
Vol. CE 24, No. 1, 1996

POLLUTION ASSIMILATION CAPACITY OF BURIGANGA RIVER

Mohammad Rezaur Rahman and Md. Yunus Rana [1]

ABSTRACT : The Buriganga River receives partially treated sewage effluent, sewage polluted surface runoff and untreated industrial effluent of Dhaka city. Already the minimum dissolved oxygen, the prime indicator of water quality, have been found to be less than the desirable level at certain sections of the Buriganga river. Early implementation of efficient management practices will save the Buriganga river from the fate of many rivers in different parts of the world. Before developing management program it is necessary to investigate the assimilative capacity of the rivers. The basic objectives of this study is to investigate the assimilative capacity of the Buriganga river. It has been seen that Buriganga river has considerable pollution assimilation capacity. Current pollution load will therefore pose no problem if they are properly managed using existing facilities. If tannery units at Hazaribag are shifted to Savar as proposed by the Government then additional loads can be discharged through Pagla Sewage Treatment Plant without violating water quality standards.

KEY WORDS : Buriganga, pollution assimilation, effluent management.

INTRODUCTION

The river Buriganga encompasses the south-western periphery of the Dhaka City. The river receives partially treated sewage polluted surface run off and untreated industrial effluent, sewage polluted surface runoff and untreated industrial effluent. Already the minimum dissolved oxygen, the prime indicator of water quality, have been found to be less than the desirable level at certain sections of the Buriganga river during certain periods of the year. Rapid urban expansion and industrialization in Dhaka City are inevitable and should not be discouraged considering the need for fast development of the country. However, this development will in turn result in more degradation of Buriganga water quality. An appropriate management practice need to be developed and implemented in order to keep resultant degradation of water quality within tolerable limit.

Early implementation of efficient management practices will save the Buriganga river from the fate of many rivers in different parts of the world. Indian Supreme Court ordered closure of 190 factories near the Ganges river (The Telegraph, Sept 13, 1993). Such desperate attempts to clean up the river incurs considerable socio-economic cost which can be easily avoided by being foresighted in the first place.

Before developing management program it is necessary to investigate the assimilative capacity of the rivers. Department of Environment (DOE, 1992) considers the assimilation capacity of Bangladeshi rivers to

1 Institute of Flood Control and Drainage Research Bangladesh University of Engineering and Technology Dkaka 1000, Bangladesh

be large. However they did not quantify this assimilation capacity. The basic objectives of this study is to investigate the assimilation capacity of the Buriganga river but within a substantially modest and limited framework. Suggestions have been made how the assimilation capacity of Buriganga river can be best utilized.

Many assumptions were made in this study to keep things simple and in perspective. Major assumptions that were made are (i) assimilation of pollution in this study implies assimilation of biological oxygen demand (BOD) load; (ii) only dissolved oxygen (DO) was taken as the water quality indicator; (iii) Influence of only BOD on DO was taken under consideration; (iv) steady state assimilation of BOD was assumed; (v) one dimensional analysis would be representative.

WATER QUALITY TREND OF BURIGANGA RIVER

DOE (1992) analyzed cumulative data for three parameters namely total solid, DO, and BOD from 1984 to 1992 for the Buriganga river. Although in general, the parameters are within acceptable limits the water quality has been shown to follow a downward trend. BOD is approaching 3 mg/1 for both dry and wet seasons. During the dry season, DO has fallen below 5 mg/1. In the wet season it has fallen below 6 mg/1. Both domestic and industrial wastes find its way into the river Buriganga, Hazaribag station being the most polluting station. DO at Hazaribag can be as low as 2 mg/1 in May while the standard value for DO in surface water in Bangladesh is at least 4 mg/1 (DOE, 1991).

PREVIOUS STUDIES

A number of studies on Buriganga river water quality has been carried out so far (for example, Mohammed, 1988; Karim, 1992; SEATEC, 1988; JICA, 1987; Azad, 1994). They have all expressed concern about the deteriorating quality of Buriganga river. However so far no study has been carried out solely on how to manage the Buriganga river water quality. Ahmed (1993) provided some insight regarding the benefits of a management program by showing the improvement in DO content of Buriganga river during dry season if current effluent discharge from Hazaribag is discontinued.

HYDRAULICS OF THE BURIGANGA RIVER

Hydraulically, the Buriganga is not an isolated river. Many other rivers are hydraulically connected with the Buriganga and influence the flow of the Buriganga. It is hydraulically connected with the Balu, the Dhaleswari, the Kaliganga, the Karnatali, the Lakhya, the Tongi khal and the Turag. The network of the river system hydraulically connected with the Buriganga is shown in Figure 1. Upstream end of the Buriganga is at 11 km down from the Mirpur bridge and downstream end is at Hariharpara. Total length of the Buriganga river is 17 km. Average width of the river around Dhaka city is nearly 500 m. Average flow during wet season (May to October) is about 700 cumec and average flow during dry season (November to April) is about 140 cumec.

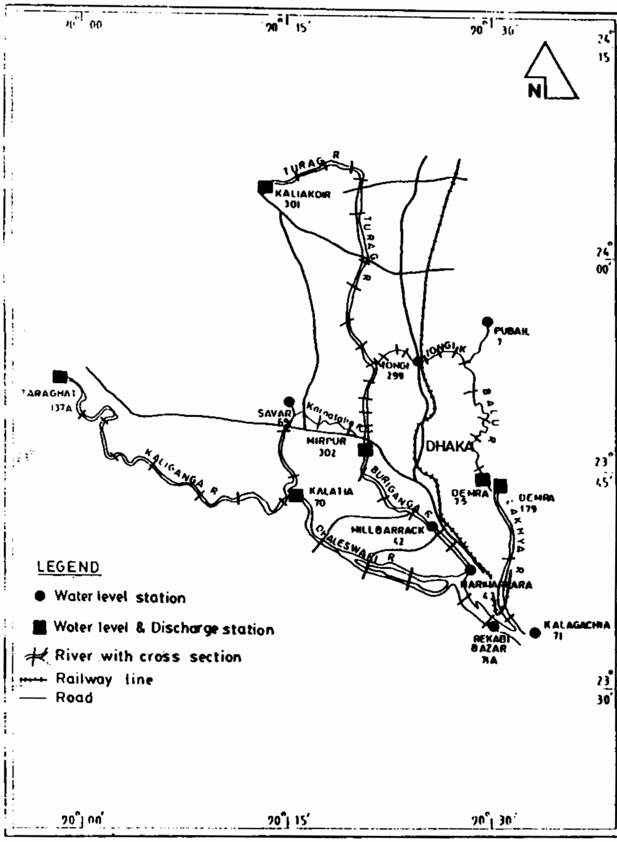

Figure 1: The Buriganga river system

Fig 1. The Buriganga River System

HYDRAULIC MODEL CALIBRATION AND VERIFICATION

In this research project, a widely used software called Mikell has been used for river flow investigation. The details of model description, data used, model setup and model calibration and verification has been shown in Rahman and Rana (1994). Model was calibrated for hydrological year 1989-90 and 1990-91. The main calibration parameter is Manning roughness coefficient of the rivers. A range of roughness coefficient from 0.03 to 0.04 was used to calibrate the model. Optimum roughness coefficient is obtained by best fitting of model estimated water level against observed one. This was done by trial and error. Model calibration and verification indicate that performance of this model in reproducing water level is satisfactory. So, model computed discharges and velocities will be representative.

WATER QUALITY MODEL

DO is the prime indicator of the water quality. In this study impact on DO due to pollutant load in terms of BOD was investigated. In any water quality management program for a river, the objective should be to maximize the use to assimilative capacity of the river keeping the water quality acceptable. Such objective and constraint were used in this study.

Gils (1991) suggests that management program should use such models which are easily interpretable to the decision makers. In this study, impact on DO due to BOD load was investigated using the widely used Streeter-Phelps equation as shown below :

$$D=\frac{k_1 L_o}{K_2-k_1}\left(e^{-k_1 t}-e^{-k_2 t}\right)+D_o e^{-k_2 t}$$

Where,	D	=	DO deficiency
	k_1	=	BOD reaction rate constant
	k_2	=	reaeration rate constant
	L_o	=	BOD load
	D_o	=	initial DO deficiency
	t	=	time

Although its shortcomings (major among them is the assumption of steady state assimilation of the pollutant load) have been widely discussed, this model is still the common method for simulating instream assimilation. Relative ease of computation, a long history of use and the absence of alternative formulations which are superior over a range of conditions are probably responsible for this precedent (EPA, 1985). Ahmed (1988) also considers that for planning pollution control measures during dry season when flow regime of the Buriganga river is more well defined, this simplified model is adequate. Mohammed (1988) expressed similar opinion.

ASSESSMENT OF ASSIMILATIVE CAPACITY

The reach of Buriganga between Hazaribag and Dhaleswari confluence was considered. The distance between Hazaribag and Dhaleswari confluence is 15 km and this reach was subdivided into 15 segments each 1 km long.

The following linear program was formulated to determine the loads that can be allowed through Hazaribag, Dholai Khal and Pagla outfall

Maximize $L_H + L_D + L_p$

Subject to

$$IL_{H1} * L_H + L_{D1} * L_D + IL_{p1} * L_p <= DOD_1$$
$$IL_{H2} * L_H + L_{D2} * L_D + IL_{p2} * L_p <= DOD_2$$
$$IL_{H3} * L_H + L_{D3} * L_D + IL_{p3} * L_p <= DOD_3$$
$$IL_{H4} * L_H + L_{D4} * L_D + IL_{p4} * L_p <= DOD_4$$
$$IL_{H5} * L_H + L_{D5} * L_D + IL_{p5} * L_p <= DOD_5$$
$$IL_{H6} * L_H + L_{D6} * L_D + IL_{p6} * L_p <= DOD_6$$
$$IL_{H7} * L_H + L_{D7} * L_D + IL_{p7} * L_p <= DOD_7$$
$$IL_{H8} * L_H + L_{D8} * L_D + IL_{p8} * L_p <= DOD_8$$
$$IL_{H9} * L_H + L_{D9} * L_D + IL_{p9} * L_p <= DOD_9$$
$$IL_{H10} * L_H + L_{D10} * L_D + IL_{p10} * L_p <= DOD_{10}$$
$$IL_{H11} * L_H + L_{D11} * L_D + IL_{p11} * L_p <= DOD_{11}$$
$$IL_{H12} * L_H + L_{D12} * L_D + IL_{p12} * L_p <= DOD_{12}$$
$$IL_{H13} * L_H + L_{D13} * L_D + IL_{p13} * L_p <= DOD_{13}$$
$$IL_{H14} * L_H + L_{D14} * L_D + IL_{p14} * L_p <= DOD_{14}$$
$$IL_{H15} * L_H + L_{D15} * L_D + IL_{p15} * L_p <= DOD_{15}$$

$$L_H', \quad L_D \text{ and } L_p \quad >= 0$$

Where L_H is the allowable load at Hazaribag (H)

L_D is the allowable load at Dholai khal (D)

L_p is the allowable load at Pagla (P)

$IL_{H}/_{D}/_{pi}$ is the impact coefficient due to H/D/P at distance i

DOD_i is the allowable deficiency in DO at distance i

Impact coefficients $IL_{H/D/pi}$ are the impacts on DO at distance i due to a 1 mg/1 discharge of BOD load at discharge point H/D/P. The impact coefficients were calculated using Streeter-Phelps equation. BOD aeration rate constants (K_1) were taken form Ahmed (1988). O' Connor and Dobbin's (1958) formula as reported in EPA (1985) was used to estimate k_2.

DOD_i is the DO deficiency that can be allowed at a distance of i km without violating the water quality standard set by DOE. DOE (1991) set a standard of 4-6 mg/1 of DO for surface water.

EXISTING POLLUTION DISCHARGE

Browder (1992) indentified four main pollutant discharge routes into the Buriganga. These routes and respective pollutant loads are shown in Table 1.

Table 1. Pollutant discharge routes along Buriganga and loads

	Discharge routes	Pollutant loads (BOD tons/day)
1	Hazaribag Tanneries	15
2	City drains along the river	10
3	Dholai Khal	35
4	Pagla Sewage Treatment Plant Outfall	5

SIMULATION OF WATER QUALITY

Since dry season is critical from water quality consideration, therefore, in this study only dry season flow was considered. The DO profiles under existing pollutant discharge pattern corresponding to 20% (80 cumec), 30% (110 cumec), 40% (130 cumec) and 50% (140 cumec) flow are shown in Figures 2, 3, 4 and 5 respectively. An initial DO level of 6 mg/l was assumed from available literature and temperature of 20° Celsius was considered.

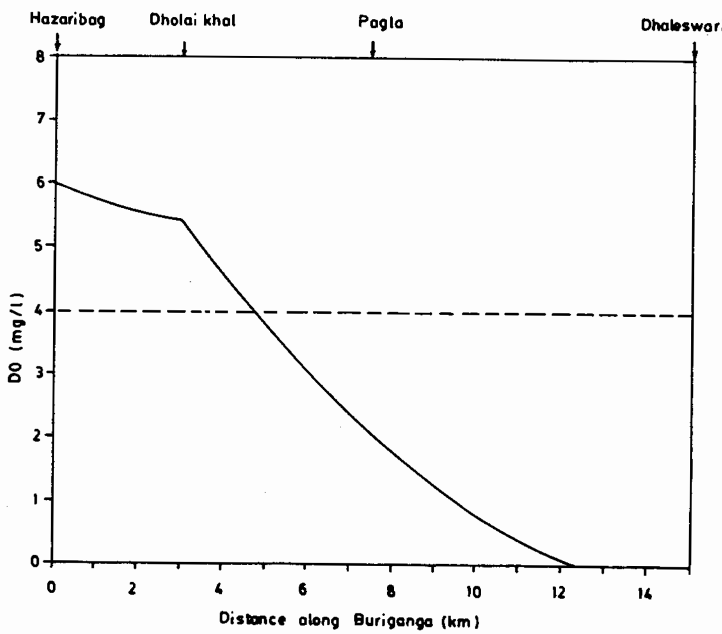

Fig 2. DO Profile Corresponding to 20% Flow During Dry Season

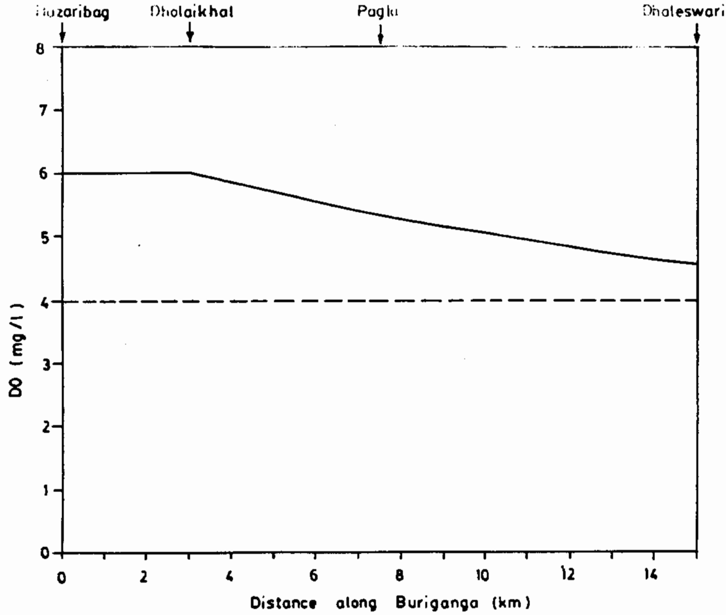

Fig 3. DO Profile Corresponding to 30% Flow During Dry Season

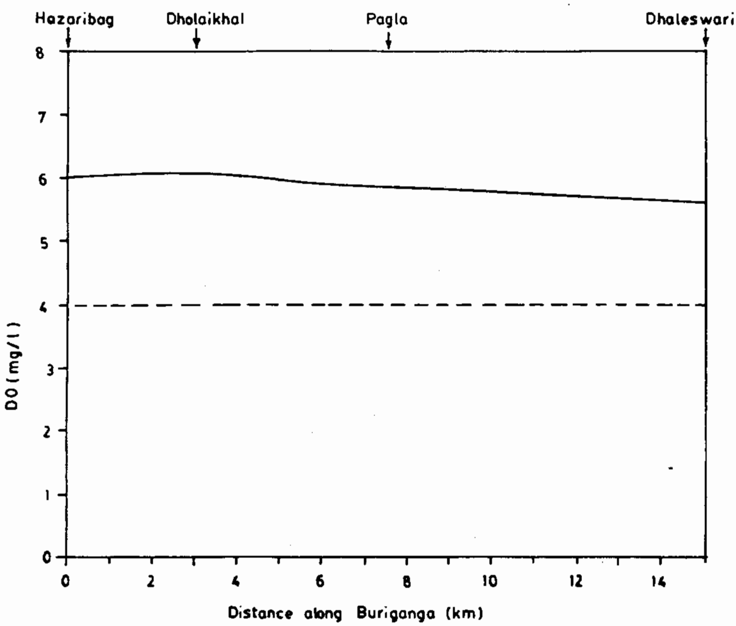

Fig 4. Do Profile Corresponding to 40% Flow During Dry Season

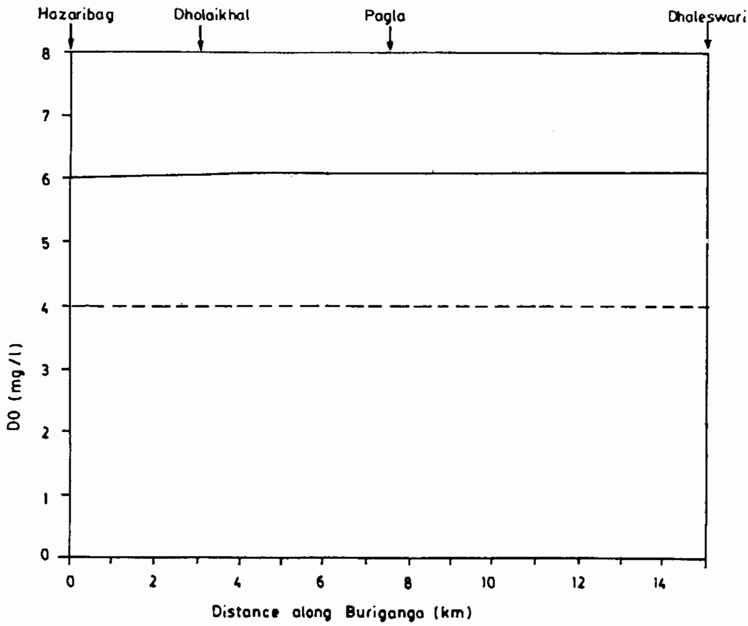

Fig 5. DO Profile Corresponding to 50% Flow During Dry Season

It is seen that DO goes down below generally acceptable level of 4mg/1 for considerable length for 20% flow. DO level improves considerably for 30% flow and for flow greater than 30% virtually there is no problem.

No management program will accommodate flows of all probabilities. There will always be ceratin probability of water quality violation. In this study, a 20% violation of water quality has been considered as an acceptable level of violation. Therefore assimilative capacity corresponding to 20% level of flow was investigated.

DOE (1991) has yet to fix a definite standard but has proposed a DO standard of 4-6 mg/1 for recreational water in Bangladesh. Therefore the maximum allowable load corresponding to 20% flow under different alternative scenarios regarding water quality standard that is 4, 5 and 6 mg/1 were calculated. The result is as shown in Table 2.

Table 2. Maximum allowable loads for alternative DO standards corresponding to 25% flow.

Do standard (mg/1)	L_H (BOD t/d)	L_D (BOD t/d)	L_P (BOD t/d)
4	0	0	27.5
5	0	0	18.7
6	0	0	9.8

It is seen that Buriganga can assimilate considerable load if they are discharged from Pagla. Whereas current discharge from Pagla is 5 t/d, Buriganga can assimilate 27.5, 18.7 and 9 t/d corresponding to 4, 5 and 6 mg/l of DO standard respectively. The calculated allowable discharges provide valuable information to decision makers. For example by lowering the standard from 6 to 5 mg/l of DO, Buriganga river can absorb additional load of 8.9 tons/day of BOD. On the other hand, lowering the DO standard from 5 to 4 mg/l, Buriganga can assimilate another 8.9 tons/day of BOD. Such information helps decision makers in setting the DO standard considering the need of development.

Current discharge of 35 t/d through Dholai khal and 10 t/d through city drains need to be totally discontinued. This is a helpful indication in the sense that such discharge can be easily diverted to Pagla through existing sewerage network. Such rerouting is desirable from public health point of view, will improve water quality and will not sacrifice maximum utilization of assimilative capacity of Buriganga. This is equally true for all alternative DO standards.

To do so, however, capacity at Pagla need to be expanded. Currently, Pagla is treating 20 t/d and after treatment, discharging 5 t/d. If another 45 t/d is rerouted to Pagla then capacity need to be expanded to 65 t/d. After treatment, the allowable discharges will be as shown in Table 2.

It is also seen from Table 2 that maximum utilization of Buriganga assimilative capacity does not allow any discharge from Hazaribag. Although it is feasible and more importantly appropriate to divert flow from Dholai Khal and city drains to Pagla and dispose it there after treatment, it is not feasible to divert industrial wastes from Hazaribag to Pagla STP as Pagla treatment plant is for biological wastes and it is not appropriate to mix industrial waste with biological waste. Therefore another run was made to see what is maximum load that can be allowed through Hazaribag and the result is as follows :

Table 3. Allowable loads for alternative DO standards allowing discharge from Hazaribag.

Do standard (mg/l)	L_H (BOD t/d)	L_D (BOD t/d)	L_P (BOD t/d)	Total (BOD t/d)
4	15.0	0	7.1	22.1
5	10.1	0	5.0	15.1
6	3.6	0	5.0	8.6

It is seen from comparing the Tables 2 and 3 that considerable load has to be sacrificed in order to allow discharges through Hazaribag. For example, to maintain a DO standard of 4 mg/l, only 22.1 t/d of BOD can be discharged instead of 27.9 t/d of BOD if discharge from Hazaribag is allowed. Even then, existing discharge of 15 t/d from Hazaribag needs to be reduced to 10.1 t/d and 3.6 t/d if DO standard is set at 5 mg/l and 6 mg/l respectively. This indicates the necessity of a treatment plant at Hazaribag. Loads at Hazaribag can not be diverted to Pagla as Pollutant characteristics of Hazaribag is different due to its industrial nature. The Government has recently decided to create a leather processing zone at Savar. If that is so then leather units at Hazaribag will be shifted to Savar. In that case the loads at Hazaribag will be reduced to zero. In such scenario, the allowable loads will be as in Table 2.

For flows more than 20%, considerable loads can be accommodated even keeping the loads from Hazaribag at 15 t/d. The loads corresponding to DO standard of 4 mg/1 are shown in the following table.

Table 4. Allowable loads for various flows for DO standards of 4 mg/1

flow in %	L_H (BOD t/d)	L_D (BOD t/d)	L_P (BOD t/d)	Total (BOD t/d)
30	15.0	0	71.1	86.1
40	15.0	0	174.5	189.5
50	15.0	0	408.5	423.5

It is seen that loads are considerably more than current discharge. So even if the population increases and pollution load increases proportionately, no problem regarding water quality is expected at these levels of flows, if such loads are properly managed.

CONCLUSIONS

Assimilative capacity of Buriganga river has been assessed in this study albeit within a substantially modest and limited framework. Many assumptions were made to keep things simple and in perspective. Such simplifying assumptions are not expected to change the general conclusions. However the results of this study need to be interpreted in the light of the assumptions.

It has been seen that Buriganga river has considerable pollution assimilation capacity. Such assimilation capacity provides considerable opportunity for proper management of Buriganga river water quality.

Either a treatment plant at Hazaribag or shifting of tannery units to Savar will allow further utilization of the assimilation capacity of Buriganga river. A treatment plant at Hazaribag is necessary not only to manage the BOD load but also to treat the chromium contents of the discharges from Hazaribag tanneries.

REFERENCES

Ahmed, M. Feroze (1993), "Sector Review : Industry," Environmental Management Training Project, Instructors' manual, DanEduc Consulting and Pathmark Associates Ltd.

Ahmed, M. Feroze (1988), Effect of Polluting Discharges on the River Buriganga, Water Pollution Control in Asia, ed. Thongchai Panswad, et. al. Pergamon Press.

Azad, A.K. (1994), Water Quality Modelling of Mizing Zones of Rivers for Multiple Outfalls, M.Sc. Thesis, Department of Civil Enger., BUET, September.

Browder, Greg J. (1992), Final Report for Water Quality Management Task, July.

Department of Environment (DOE) (1992), Report on Water Quality of Selected Rivers in Bangladesh for 1990-91 and Pollution Trend Since 1984.

Department of Environment (DOE) (1991), Environmental Quality Standards for Bangladesh.

Environmental Protection Agency, USA (1985), Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition).

Gils J. A. G. van and D. Argiropoulos (1991), Axios River Basin Water Quality Management, Delft Hydraulics.

JICA (1987), Study on Storm Water Drainage System Improvement Project in Dhaka City.

Karim, Md. Abdul (1992), Impact of Greater Dhaka City Flood Protection Works on the Environment with Specific Reference to Industrial Waste Disposal, M. Sc. Thesis, Department of Civil Eng., BUET.

Mohammed., Kazi Noor (1994), Characterization, Treatment and Disposal of Sewage of Dhaka City, M.Sc. Thesis, Department of Civil Engg., BUET.

Rahman, M.R. and Md. Yunus Rana (1994), Management of Buriganga River Water Quality under Alternative Scenarios, RO1/94, IFCDR.

SEATEC International Company Ltd., Thailand (1989), Bangladesh Industry and Environment Industrial Pollution Control Component.