

APPLICATION OF SENSITIVITY ANALYSIS IN SELF PURIFICATION OF THE SURMA RIVER, BANGLADESH

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ABSTRACT

The rivers which flow through a city show an appreciable decline in water quality but they are often difficult to specify the exact cause of deterioration. Also the treatment of pollution of river is very troublesome. This study finds the treatment efficiency of the Surma River by its self purification capacity due to the pollution through discharges of choras (small canal), industrial wastewater discharges, and human excreta disposal. The sensitivity analysis by Streeter-Phelps Oxygen-sag equation is used to find the treatment efficiency and the corresponding sensitivity values for some selected pollution parameters were also determined. The Java software was used to find the treatment efficiency and to show the relation between treatment efficiency and those selected parameters.

Key words: Surma River, Sensitivity analysis, Self purification capacity, Streeter-Phelps Oxygen-sag equation, river pollution.

I. INTRODUCTION

Water is the fluid of life not only for human beings but also for any living organism. The fresh liquid water sources on land surfaces and in the ground constitute only 1% of the total water on earth. The main sources of water in Bangladesh are surface waters in rivers, reservoirs, lakes, canals and ponds, and the ground water in deep and shallow aquifer (Ahmed and Rahman, 2003). In the ground water, presence of arsenic and iron are excessive almost all over Bangladesh. The rivers, main source of surface water, are also polluted day by day. Most of the big cities and settlements have developed near the rivers and urbanization becomes the main reason for contamination for these rivers (DoE, 2001). The study by Hossain

(Hossain, 2003) showed that surface water quality of the rivers of the country had been deteriorating further and further due to continuous pollution. For Bangladesh the concerns over water quality are due to (i) industrial pollution near major urban centers (ii) faecal contamination throughout the country (iii) contamination by agro-chemicals, though still not so severe (iv) saline intrusion in coastal areas (v) suspended sediments, largely from the upper catchments outside Bangladesh (Muyan and Mamun, 2003).

Cities located on the bank of rivers tend to discharge their wastewater – treated or untreated, into the rivers. Phenomenal increase in pollution of river water due to discharge of wastewater from cities is a cause of concern to the pollution

regulators (4th World Water Forum, 2006). Industries located near the river discharge their effluent in river water which contain huge amount of biodegradable and non-biodegradable wastes and heavy metals. Poor people dispose their excreta into the river. Increase in pollution of river waters due to discharges of wastewater from cities through choras, industries and human wastes are causing concern to the environmentalist. The treatment and disposal of intercepted and diverted wastewater are expensive. Presently many industries construct their effluent treatment plant which reduces the strength of waste significantly. According to the present day practice, no decision on the extent of treatment of the city wastewater is taken considering the assimilative capacity of the recipient river water. There exists no merit in considering the recipient rivers which get dry during summer months every year, but the Surma River flows all the year round. The water quality parameters of the Surma River, wastes of different choras and the wastes coming from human excreta which are discharged into the river are also tested. The study area was Sunamganj to Kanaighat through Sylhet city, Bangladesh.

The concept of water quality is fundamental to the study of environmental engineering and water resources because they explore the relation between water requirements and the form and extent of permissible departure from purity. This is inextricably linked with the term pollutants/pollutions. A substance (either natural or man-made) becomes a pollutant only when it is introduced at a level or in a form that upsets the normal functioning of an ecosystem, or that affects human or animal health. In stream water pollution control, the main objective is to assess the system complies with the maximum pollutant releases, allowed from point and non-point source pollution; so that pollutant levels in the receiving streams meet the water quality standards.

To calculate the degree of wastewater treatment for a single city wastewater by self-purification of the recipient river water, computer simulation is done using the classic Streeter-Phelps Oxygen-Sag equation taking all the possible parameters except temperatures of river water and ambient air. To find the trend of individual parameter and to compare the effect of pollution on river water, a computer program is developed by using language 'Java'.

II. LITERATURE REVIEW

Self Purification Capacity is the waste assimilation capacity of river mainly by DO (dissolved oxygen) without any chemical use. Here BOD₅ (biochemical oxygen demand), DO, water flow, de-oxygenation and re-aeration rate, DO deficit etc. are used but COD (chemical oxygen demand), Coliform, and NH₃ are not used.

Sensitivity analysis is applied to simplify models, investigate the robustness of model predictions, as an element for quality assurance. It is common in physics and chemistry, in financial applications, risk analysis, signal processing, neural networks and any area where models are developed. In environmental engineering, computer environmental models are increasingly used in a wide variety of studies and applications. For example global climate model, waste water treatment plant on a river flows, or for assessing the behavior and life length of bio-filters for contaminated waste water, optimal experimental design of non-linear estimation for chemical kinetics (Wikipedia).

Pandey et al. applies sensitivity analysis for a five-compartment marine ecosystem. They have studied sensitivity analysis to derive non-linear model of the variables such as photosynthesis, coefficients of inter-compartmental energy transfers, mortality and respiration losses. Computation of the expressions and comparison of the models have been carried out through a computer program written in 'C' language. They further analyzed sensitivity in terms of DO and toxicity and applied the models to Peel and Harvey estuaries (Pandey et al., 1994).

Sensitivity analysis is also applied to investigate the uncertainty of propagation by factors in a flood damage model into the model outputs and explores the importance of factors. Uncertainty reduction in the most influential factors identified by the Morris method is proposed as a means to reduce the uncertainty in model outputs. In this way the risks of making a wrong decision could be reduced (Xu and Mynett, 2006).

Sincock et al. derived a water quality simulation model for river systems and they checked the validity of the model performing sensitivity analysis. The essential framework of the model proved to be sound and calibration and validation performance was generally good. However some

supposedly important water quality parameters associated with algal activity were found to be completely insensitive, and hence non-identifiable, within the model structure, while others (nitrification and sedimentation) had optimum values at or close to zero (Sincock et al., 2003).

Mazumder applies sensitivity study to the river pollution parameters. He applied sensitivity analysis to find the effect of individual water quality parameter through a computer program by using 'C' language (Mazumder, 2000).

Many researchers work on water quality of the Surma River. Alam et al. analyzed the water quality of the Surma River and developed phosphorous and ammonia-nitrogen model (Alam et al., 2007). Chowdhury and Ali assessed phosphate and ammonia-nitrogen at different locations of the Surma River and compared their concentrations with Bangladesh standard of ECR 1997 for the use of various purposes (Chowdhury and Ali, 2006). The present work applies sensitivity analysis on river which is first time in Bangladesh.

III. SELECTED WATER QUALITY PARAMETERS

The selected water quality parameters are:

- BOD5 of wastewater in mg/L prior to treatment where wastewater fall (P1)
- Wastewater falls in the river in cu m/day (Q1)
- Allowable dissolve oxygen (DO) deficit in mg/L at the critical DO deficit location in the river downstream of the discharge of the treated wastewater from the city (DAI)
- River water flow in cu m/day (Q)
- BOD5 in mg/L of river prior to receiving wastewater (F1)
- DO deficit in mg/L in river water prior to receiving wastewater (E1)
- De-oxygenation rate constant of the river water in day⁻¹ (K11)
- Re-aeration rate constant of the river water in day⁻¹ (K21)
- DO deficit in mg/L in treated wastewater (T1)

IV. EQUATIONS FOR CALCULATING SELF PURIFICATION CAPACITY

The treatment efficiency of the river is obtained using the following sequence of equations based on

the classic Streeter-Phelps Oxygen-sag equations (Streeter and Phelps, 1925). Extensive iterations are required for the determination of treatment efficiency of river.

D1 = DO deficit in mg/l in the in the river water after receiving the city wastewater

$$= E1(1 - \frac{Q1}{Q}) + \frac{(T1 * Q1)}{Q} \dots\dots\dots (1)$$

L1BAR = BOD (5-day) in mg/l in river water on receiving untreated city wastewater

$$= F1(1 - \frac{Q1}{Q}) + \frac{(P1 * Q1)}{Q} \dots\dots\dots (2)$$

$$L1 = \frac{L1BAR * (P1 * Q1)}{(100 * Q1) * EPSILON} \dots\dots\dots (3)$$

Where, EPSILON is the treatment efficiency in percent.

Evaluating D1, L1BAR and L1 using Equations (1), (2) and (3) putting in equation (4) the value of TC can be obtained.

$$TC = \dots\dots\dots (4)$$

$$(\frac{1}{K21 - K11}) * \log((\frac{K21}{K11})^{(1 - (D1 * (K21 - K11)) / (L1 * K11))})$$

Putting TC in equation (5) DC can be evaluated.

where,

DC = DO deficit at the critical location in the river downstream of the city wastewater discharge

$$DC = [(\frac{K11}{K21 - K11}) * (EXP(-K11 * TC) - EXP(-K21 * TC))] \dots (5)$$

$$* K1 + D1 * EXP(-k21 * TC)$$

$$DC = ALFATC * L1BAR + D1 * (-k21 * TC)$$

Replacing L1 by LABAR from equation (3) in above we obtain

$$DC = ALFATC * L1BAR + D1 * EXP(-K21 * TC) - ALFATC$$

$$* ((P1 * Q1) / (100 * Q)) * EPSILON$$

$$DC = UO - U1 * EPSILON \dots\dots\dots (6)$$

Where,

$$ALFATC =$$

$$((K11 / K21 - K11) * (EXP(-K11 * TC) - EXP(-K21 * TC)))$$

$$\therefore U_0 = ALFATC * L1BAR + EXP(-K21 * TC)$$

$$U1 = ALFATC * ((P1 * Q1) / (100 * Q))$$

Putting DC as DAI, EPSILON can be solved as

$$EPSILON = (U0 - DC) / U1 \dots\dots\dots (7)$$

Since equations (3), (5) and (6) are depended on EPSILON. One needs to assign a numerical value to EPSILON from equation (7). The iterative

process of solving continues till the difference between the two values of EPSILON is less than 0.1. A program was developed by language 'Java' for this iterative process.

V. TESTING RESULTS

The wastewater parameter of different choras and point sources of human waste disposal were tested from May 2007 to April 2008 at an interval of one month. The following values of waste water are combined values for domestic and excreta of human:

- a) BOD5 of wastewater prior to treatment, P1 = 200 - 300 mg/L
- b) Wastewater falls in the river, Q1 = 70000 - 200000 cu m/day
- c) Allowable dissolved oxygen (DO) deficit, DAI = 3.0 - 3.5 mg/L
- d) River water flow, Q = 700000 - 2000000 cu m/day
- e) BOD5 of river prior to receiving wastewater flow, F1 = 6 - 13 mg/L
- f) DO deficit in mg/L in river water prior to receiving wastewater, E1 = 1.7 - 2.8 mg/L
- g) De-oxygenation rate constant of the river water, K11 = 0.15 - 0.30 day⁻¹
- h) Re-aeration rate constant of the river water, K21 = 0.55 - 0.70 day⁻¹ and
- i) DO deficit in mg/l in treated wastewater, T1 = 3.0 - 8.0 mg/L

The above data was used particularly for drawing the graph of those parameters against the self purification capacity (treatment efficiency by river itself) of river. The optimum values were used for the calculation of self-purification capacity which occurs most of the time of the year:

- a) P1 = 220 mg/L
- b) Q1 = 100000 cu m/day
- c) DAI = 3.0 mg/L
- d) Q = 1000000 cu m/day
- e) F1 = 10 mg/L
- f) E1 = 2.0 mg/L
- g) K11 = 0.20 day⁻¹
- h) K21 = 0.60 day⁻¹ and
- i) T1 = 4.0 mg/L

VI. PROGRAM DEVELOPMENT AND RESULTS

A program was developed by language 'Java'. Treatment efficiency or self-purification capacity of the Surma River using optimum values of the parameters, $\epsilon = 67.45$ percent. The relation between individual parameter and treatment efficiency are also found from the program (the following figures actually drawn by Microsoft Excel using the data found from the software) which is shown in Fig- 1 to 9.

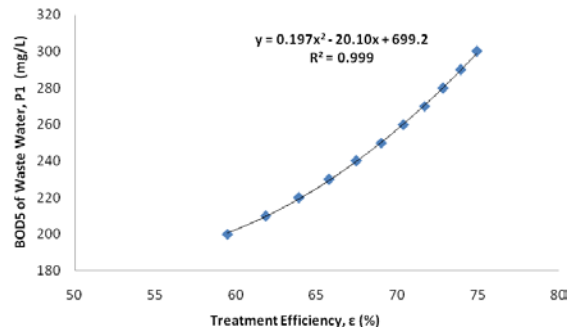


Fig- 1: BOD5 of Wastewater vs. Treatment Efficiency

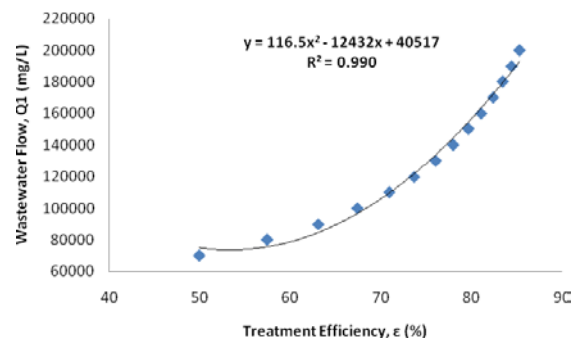


Fig- 2: Wastewater Flow vs. Treatment Efficiency

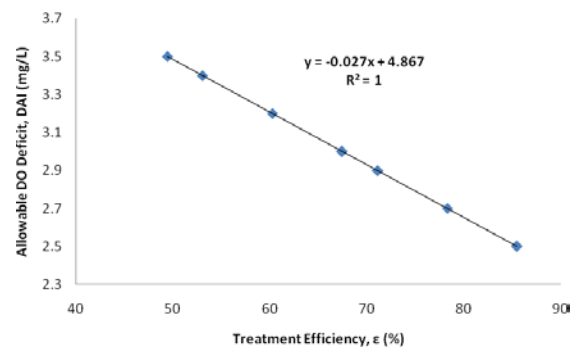


Fig- 3: Allowable DO Deficit vs. Treatment Efficiency

Self-purification Capacity

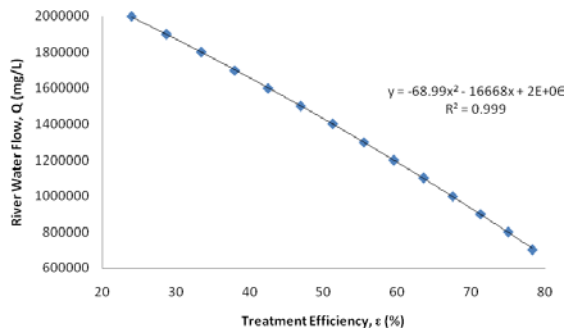


Fig- 4: River Water Flow vs. Treatment Efficiency

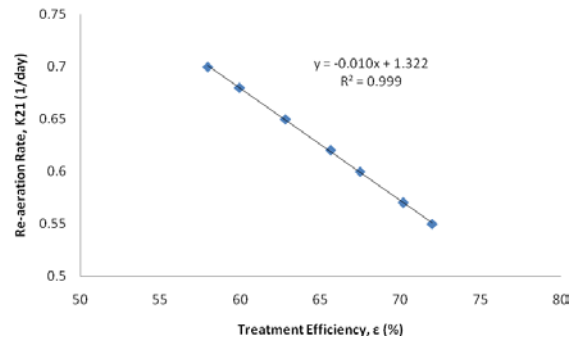


Fig- 8: Re-aeration Rate vs. Treatment Efficiency

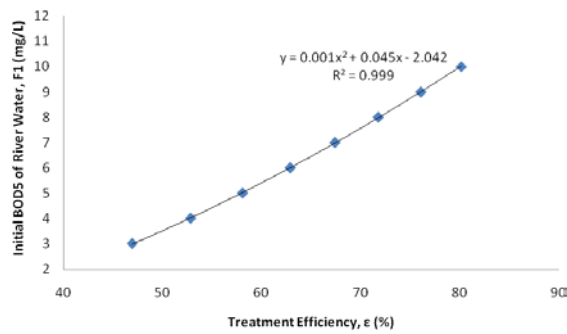


Fig-5: Initial BOD₅ of River Water vs. Treatment Efficiency

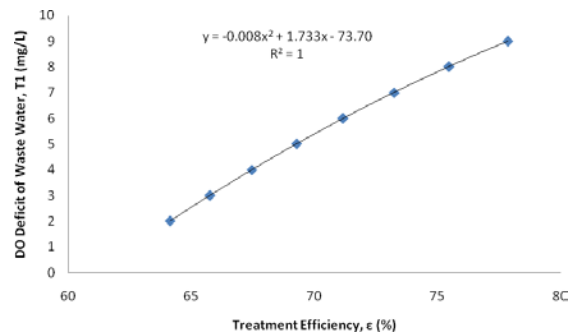


Fig- 9: DO Deficit of Waste Water vs. Treatment Efficiency

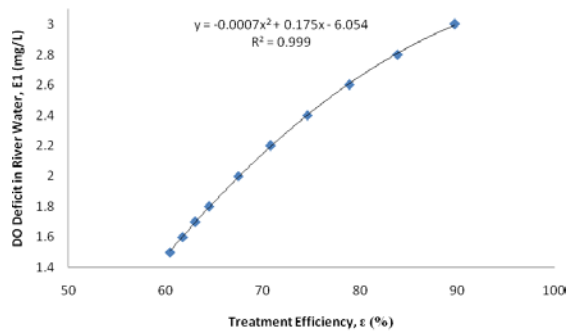


Fig- 6: DO Deficit in River Water vs. Treatment Efficiency

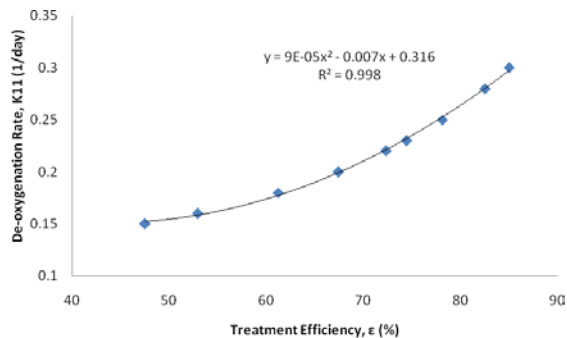


Fig- 7: De-oxygenation Rate vs. Treatment Efficiency

VII. SENSITIVITY ANALYSIS

The extent of variation for each parameter to cause an unit percentage change in treatment efficiency is the sensitivity factor of that parameter. From the graphical presentation, a mathematical relationship and correlation coefficient have been obtained for different parameters with treatment efficiency. It was done by Microsoft Office-2007, so that a parameter can be expressed as a polynomial of treatment efficiency.

The polynomial relationship for different parameters with treatment efficiency are assumed as $P = f(\epsilon)$; where P = Particular Parameter and ϵ = Treatment Efficiency. Now, the sensitivity for a parameter be

$$\left(\frac{dp}{d\epsilon} \right)_{\epsilon=\epsilon'} = f'(\epsilon')$$

Where ϵ' = is the treatment efficiency for a given set of parameter before any type of variation. It refers to as the slope of a polynomial curve at $\epsilon = \epsilon'$. The polynomial expression and the respective sensitivity equation i.e. $(dp/d\epsilon)$ for various parameters and also the values of sensitivity are shown in table-1.

Table 1: Result of Sensitivity Analysis

Parameter	Polynomial Expression $P = f(\epsilon)$	Sensitivity Equation $(dP/P\epsilon) = f'(\epsilon')$	Sensitivity Value for $\epsilon' = 67.45\%$
P1	$0.197x^2 - 20.10x + 699.2$	$0.394 \epsilon' - 20.10$	6.48
Q1	$116.5x^2 - 12432x + 40517$	$233 \epsilon' - 12432$	3283.85
DAI	$-0.027x + 4.867$	-0.027	-0.027
Q	$-68.99x^2 - 16668x + 2E+06$	$-137.98 \epsilon' - 16668$	-25975
F1	$0.001x^2 + 0.045x - 2.042$	$0.002 \epsilon' + 0.045$	0.178
E1	$-0.0007x^2 + 0.175x - 6.054$	$-0.0014 \epsilon' + 0.175$	0.08
K11	$9E-05x^2 - 0.007x + 0.316$	$1.8 * 10^{-5} \epsilon' - 0.007$	-0.006
K21	$-0.010x + 1.322$	-0.01	-0.01
T1	$-0.008x^2 + 1.733x - 73.70$	$-0.016 \epsilon' + 1.733$	0.6538

The sensitivity value of each parameter of above table indicates their influences on water body. These are explained below:

The sensitivity of wastewater flow (Q1) is just 8 times that of river water (Q). The sensitivity of wastewater flow is 507 times less significant to BOD5 in wastewater (river water). Hence the city dwellers must be reduced to put the organic pollutant, less kitchen waste and road side garbage in the city water or surface drain. The owner of industry must construct environmental treatment plant for treating the industrial waste before disposal of effluent in the river. Also disposal of human excreta in the river must be protected. Then improvement of river water is possible because they contain huge amount of BOD5.

The sensitivity of DO deficit in waste water (T1) is about 65 times less than that of a sensitive parameter like re-aeration rate (K21). However, the de-oxygenation rate (K11) is about 0.6 times less sensitive than the re-aeration rate (K21). So Surma Rive is not hazardous with respect to de-oxygenation rate constant.

BOD5 (F1) and DO deficit (E1) in mg/L of river water prior to receiving the city wastewater, industrial effluent and human excreta are beyond the control of designer. But the other two needs to consider and these are allowable DO deficit at the location in the river downstream of city wastewater discharge (DAI) and re-aeration rate (K21).

VIII. CONCLUSION

Since the sensitivity of wastewater which falls into the river is 507 times to that of river water. It suggests that the wastewater is more polluted than the river water. So, it is the collective responsibility

of city dwellers, owners of industry and those people who dispose their excreta in Surma River for conservation of the Surma River and thereby generation of less wastewater. Generally, once a pollution trend sets in, it accelerates day by day. So, there is a possible risk of serious water quality deterioration in future. The proper authority should take necessary steps to maintain the satisfactory water quality and ensure the flow of the Surma. Some steps could improve the river water quality like proper dredging, discharging domestic and industrial effluents after proper treatment and building up awareness about river pollution to the surrounding community.

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