SIMULATION AND MULTIOBJECTIVE OPTIMIZATION FOR RIVER WATER QUALITY MANAGEMENT

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SIMULATION AND MULTIOBJECTIVE OPTIMIZATION FOR RIVER WATER QUALITY MANAGEMENT

By

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Submitted
in fulfillment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

to the

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Dedicated to

My Parents,

Wife

and daughters

Mishtu and Manu

CERTIFICATE

This is to certify that the thesis entitled **"*Simulation and Multiobjective Optimization for River Water Quality Management*"**, submitted by **Mr. D. L. Parmar** to the **Indian Institute of Technology Delhi** for the award of Doctor of Philosophy, is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion has reached the requisite standard, fulfilling the requirements for the said degree. The results contained in this thesis have not been submitted, in part or full, to any other university or Institute for the award of any degree or diploma.

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ABSTRACT

Many rivers, especially in developing countries are getting polluted because of increased wasteload emanating from urban areas coupled with a lack of appropriate water quality management plans involving systematic effluent and stream regulation norms based on modeling studies and diverse objectives. Although, many pollution abatement efforts have been initiated but no tangible results could be obtained in effectively controlling the river pollution. The last two decades have witnessed increasing use of simulation and optimization models for improved understanding river systems that help decision makers in developing plans to maintain them. But, these models have largely focused on wastewater treatment alone as a method of pollution abatement. In the present study, it was, therefore thought, worthwhile to attempt various combinations of abatement measures (such as wastewater treatment, flow augmentation and diversion) using simulation models and developing wasteload allocation models taking into account the diverse objectives of various stakeholders to river water quality problems.

The present study is aimed at (i) Conceptualizing scenarios based on various pollution abatement measures, (ii) investigating water quality using the QUAL2E simulation model under baseline conditions and conceptualized scenarios, (iii) assessing the sensitivity of water quality to model parameters and abatement measures, (iv) developing wasteload allocation models for the diverse objectives of users and stakeholders, (v) applying simulation and wasteload allocation models for water quality management in the Delhi stretch of the river Yamuna, India. The analysis is limited to point sources with BOD and DO only as the water quality parameters. The QUAL2E model was calibrated and validated using field data obtained from secondary sources before the application of the model to the study area. The

reaeration constant, K_2 used in the model was calculated using a predictive equation developed in this study. Thereafter, data for the period March-June 2005 is used for simulating the water quality under baseline conditions and scenarios. A total of 34 scenarios characterizing different levels of wastewater treatment, flow augmentation, and drain diversion considered individually and in combination were conceptualized, and simulation was carried out for these scenarios. Three different cases, namely,viz, Case A: Existing layout with fifteen drains discharging into the Delhi stretch of the river Yamuna between Wazirabad barrage and Okhla barrage; Case B: Layout after diversion of the first i.e. Najafgarh drain (D1); and Case C: Layout after diversion of all fourteen (D2 to D15) drains other than the Najafgarh drain were considered. Further, sensitivity analysis was carried out to study the effect of model parameters and different abatement measures on the performance of the model. The sensitivity analysis was carried out for the "best practical scenario" to see the efficacy of the scenario for adoption by the planners. The next part of the study deals with the development of the multiobjective wasteload allocation models. A total of two single objective and three models were formulated. These are a) least cost model (LCM), b) cost-equity model (CEM), c) cost-assimilative capacity model (CAM), d) cost-equity-assimilative capacity model (CEAM), e) cost-flow augmentation model (CFAM). The cost functions for wastewater treatment and flow augmentation have been developed as regression relationships by using the SPSS software. The response of water quality to waste loads was quantified using the transfer coefficients calculated using the QUAL2E model. The models were applied to the Delhi stretch of the river Yamuna. Solutions were obtained using NIMBUS Web based software.

Results obtained for Case A reveal that when wastewater treatment is adopted as a pollution abatement measure, the DO criterion is satisfied after tertiary treatment. If flow augmentation is attempted, a total flow of 90 m^3/s is needed. When wastewater treatment is tried in combination with flow augmentation, 57.5 and 21.6 m^3/s of flow are required with primary and secondary treatment, respectively. The layout under Case B and C requires at least secondary and tertiary treatment, respectively. Also, quite high flows of 40 m^3/s and 74.2 m^3/s are required in case B and case C, respectively. Thus, out of the three layouts, the existing layout i.e. Case A seems to be the most feasible. Results of sensitivity analysis reveal that K_1 and K_3 are the most significant model parameters and the water quality is most sensitive to the method of wastewater treatment.

Optimal solutions for LCM reveal that a minimum cost of Rs. 660.16 million per year will be incurred in the Delhi stretch of the river Yamuna to meet the dissolved oxygen of standard of 4 mg/l. For the CEM, a cost of Rs. 787.26 million per year is required to attain an inequity value of 3.06. For the CFAM model under Case I, a cost of Rs. 725.71 million per year is incurred with a flow augmentation of 1.8 m^3/sec. For case II, a cost of Rs 679.82 million per year is incurred with a negligible flow of 0.00001 m^3/sec. Thus joint optimization of flow augmentation and wastewater treatment show that the least cost solution when the cost of flow augmentation is considered actually results for the case of no flow augmentation. It is an interesting and useful finding as two models converge in a least cost formulation. This implies that flow augmentation is not an economically feasible option for the Delhi stretch of river Yamuna. The findings of this study would be useful to the decision makers in implementing policies and solutions for improving the water quality in the river Yamuna up to the desired level.

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