TOWARDS AN INTEGRATED POLLUTION MANAGEMENT APPROACH FOR THE BURIGANGA RIVER IN BANGLADESH

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By

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma at any university and that to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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Md. Ashiqur Rahman
Sydney, 30 March, 2011

I dedicate this work to my dear parents who have been strongly encouraging and eagerly awaiting to see the success of my studies.

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Abstract

Water pollution management in the Buriganga River, which encompasses the south-western periphery of the capital city Dhaka, has been a major concern for the Government of Bangladesh at least for the last two decades. Several policies based on direct regulatory measures have been adopted by the government in different times to address this issue. In spite of this, no significant improvement in the river water quality has been achieved. In addition, an updated, detailed and systematic analysis of water quality along the full length of the river has not been conducted for some time.

Hence, this research aimed to postulate a new management system to control pollution in the Buriganga River based on a recently conducted qualitative and quantitative assessment of river water and wastewater that are discharged into the river. The study also aimed to evaluate the existing system for river pollution control and to determine the economic costs that are likely to result under alternative policy instruments for pollution mitigation, such as, uniform reduction, uniform taxes and tradable permit system. In the study, a conceptual framework was recommended for an integrated pollution management approach in the Buriganga River.

The river water quality was found to be unacceptable (as per the standards set by the Department of Environment in Bangladesh) for the parameters such as dissolved oxygen (DO), biochemical oxygen demand on five days (BOD_5), chemical oxygen demand (COD), ammonia-nitrogen (NH_3-N) and chromium (Cr) during both dry (low flow condition) and wet (high flow condition) seasons and for electrical conductivity in water (EC_w) during only dry season. For the river water, the average concentration of DO ranges between 0.9 mg/L in dry and 2.8 mg/L in wet season, BOD_5 between 34.5 mg/L in dry and 2.5 mg/L in wet season, COD between 60.1 mg/L in dry and 17.2 mg/L in wet season, EC_w between 661 µS/cm in dry and 83 µS/cm in wet season, NH_3-N between 4.1 mg/L in dry and 3.3 mg/L in wet season, Cr between 0.06 mg/L in dry and 0.07 mg/L in wet season. Temperature, pH, phosphate-phosphorus (PO_4-P) and lead (Pb) were found within the DOE acceptable limits in both dry and wet seasons. Moreover, along the length of the river, relatively higher ambient concentration of BOD_5, COD, NH_3-N and Cr was

observed at Kholamora station for both dry and wet seasons compared to four other selected stations (receptor points) along the river.

The study established that the water of the Buriganga River is polluted by a combination of wastewater from both municipal and industrial sources, located within its basin area, which are discharged through three main drainage channels. The wastewater was found hypoxic to anoxic in most cases associated with very high concentration of BOD_5, COD, EC_w, Cr and NH_3-N compared to the guidelines. For the incoming wastewater, the minimum and the maximum average concentration (including three major discharge points) of BOD_5 ranges between 251.0 to 1003.4 mg/L, COD between 378.9 to 1261.1 mg/L, EC_w between 458.9 to 3939.3 µS/cm, Cr between 0.02 to 13.3 mg/L and NH_3-N between 4.1 to 83.5 mg/L throughout the year. The average BOD_5 pollution loading rates for the three major discharge points at Rayerbazar sluice gate, Shahidnagar drainage outlet and Pagla Sewage Treatment Plant (PSTP) effluent outfall were estimated as 83, 71 and 32 tons/day respectively.

The study identified that the existing command and control (CAC) based regulatory approaches to pollution management for the Buriganga River are not functioning effectively. The compliance and enforcement of these regulatory measures are not satisfactory, which contributes to continuing pollution problems. The present pollution control measures do not provide any economic incentives for pollution prevention and adoption of new technologies. Despite the provisions made within the national policies, no specific role has been outlined to ensure the effective contribution of Non-Government Organisations/Community Based Organisations for pollution control. However, the current study found that the local community is willing, and has the potential, to directly participate in the pollution control process of this river.

The research used a spreadsheet based decision support tool in order to conduct a simulation exercise for evaluating the economic efficiency of the several alternative pollution abatement policies, while meeting specific water quality targets. The method generated empirical estimates on costs of BOD_5 reduction from three major discharge points in the Buriganga River using three alternative policies. The results from the simulation exercise showed that application of the approaches based on economic incentives (uniform tax or tradable permit system) could achieve significant cost savings (up to about 50 per cent) for BOD_5 pollution control in the Buriganga River in contrast to the CAC based approach (uniform reduction system). Further, considering the prerequisites for the tradable permit system and the marginal difference of economic benefit to be gained from this system compared to the uniform tax system, it is recommended that at this stage the uniform pollution tax system with revenue recycling should be considered as an effective alternative policy for water quality improvement in the Buriganga River.

Finally, through this interdisciplinary study a conceptual framework of an integrated pollution management system for the Buriganga River was developed taking into account the state of water quality, the weaknesses encountered in the present system, the empirical evidence of the potential benefits from economic incentive based approaches to regulating pollution and from the experiences of river pollution management in other countries. The integrated management framework was recommended by combining appropriate pollution control instruments which encourages coordination of different stakeholders, public participation and application of economic incentive based measures. The proposed new approaches (economic incentive and community involvement) do not replace the present regulatory measures (particularly the ambient water quality standards) but they rather complement them.

The research also proposed a set of policy initiatives that should be implemented within the integrated management framework. It would necessitate legislative changes to incorporate a legal basis for pollution taxing. The legal reform should incorporate the scope to vary the emission tax rate from time to time and/or to impose strict regulations in short notice in case of emergency situation. In this context, legal agreements between polluters and regulatory authorities could be formed in order to ensure the proper collection of pollution taxes. The study also suggested the strengthening of organisational capacity at the cost of aborting the involvement of multiple government authorities, in favour of a single authority that would be invested with full power and responsibility for pollution control in the Buriganga River. Hence it was recommended that a *Buriganga River Management Authority* be established, to work under the supervision of the Ministry of Environment and Forests (MOEF). This agency could be assigned with legislative power and would hold sole responsibility to manage and coordinate all activities related to pollution control and conservation of the Buriganga River.

Moreover, the study noted the significant positive contributions of community participation and commitments towards managing the pollution problem of the Buriganga River and the catalytic role it could play. With this end in view, the proposed integrated approach recommended formulating a standard procedure and guideline for water quality monitoring by community groups to ensure ease and efficiency of their work. In addition, necessary training programs should be directed by experts in the field to equip in the community for this purpose. Giving the community a responsible role in monitoring and recording failures and improvements could provide the necessary focus of attention and impetus required to resolve the Buriganga River pollution problem. Application of economic incentive based instruments and continual disclosure of information were also recommended in the study. The study concluded that a sustainable pollution management system for the Buriganga River could be achieved by bringing together all the stakeholders concerned at a local level and by applying appropriate pollution control measures along with the suggested set of policies.

Publications and presentations from the thesis

Rahman, M.A., 2010. 'An evaluation of river pollution control system in Bangladesh: moving towards an integrated approach', *Proceedings of the 11th APRU Doctoral Students Conference 2010*, 11-16 July 2010, Universitas Indonesia, Depok, Indonesia.

Rahman, M.A. and Ancev, T., 2010. 'Possible application of economic incentives for water conservation: a case study on the Buriganga River, Bangladesh', *Proceedings of the International Conference on Knowledge Globalization-2010*, ISBN 978-984-33-1691-2, pp. 304-12, 8-10 May 2010, North South University, Dhaka, Bangladesh.

Rahman, M.A., Ancev, T. and Al Bakri, D., 2010. 'Alternate management strategies for reduction of BOD along the river, Buriganga, Bangladesh', *Proceedings of the Water Management Conference 2010: Upgrading technology and infrastructure in a finance-challenged economy*, pp. 467-492, 23-26 March 2010, The U.S. Society for Irrigation and Drainage (USCID), Sacramento, California, USA.

Rahman, M.A., and Al Bakri, D., 2010. 'A Study on Selected Water Quality Parameters along the River Buriganga, Bangladesh', *Iranica Journal of Energy and Environment*, vol. 1, no. 2, pp 81-92.

Rahman, M.A., 2010. 'Pollution control in the river Buriganga, Bangladesh: CAC or EI based approach?', A poster presentation at the *Centenary Research Symposium*, 4th June 2010, Faculty of Agriculture, Food and Natural Resources (FAFNR), The University of Sydney, Australia.

Rahman, M.A., 2009. 'A Review of Management Instruments for Water Pollution Control: sustainable options for the river Buriganga, Bangladesh', *The International Journal of Interdisciplinary Social Sciences*, vol. 3, no. 11, pp. 55-67.

Rahman, M.A., 2009. 'Healthy existence of rivers for sustainable development: a case study on the river Buriganga, Bangladesh', An oral presentation at the *AusAID Annual Conference*, 27 November 2009, The University of Sydney, Australia.

Rahman, M.A., Al Bakri, D. and Ancev, T., 2008. 'Towards a framework for integrated industrial effluent management system: a case study on the river Buriganga, Bangladesh', *Proceedings of the International Conference on Environment-2008*, 15-17 December 2008, Engineering Campus, Universiti Sains Malaysia, Penang, Malaysia.

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ABBREVIATIONS

ANOVA	Analysis of Variance
ANU	The Australian National University
ANZECC	Australian and New Zealand Environment and Conservation Council
APHA	American Public Health Association
AusAID	Australian Agency for International Development
BAPA	Bangladesh Paribesh Andolon
BELA	Bangladesh Environmental Lawyers’ Association
BIWTA	Bangladesh Inland Water Transport Authority
BOD	biochemical oxygen demand
BOD_5	biochemical oxygen demand on five days
BRMA	Buriganga River Management Authority
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAC	Command and Control
CBO	Community Based Organisation
CEGIS	Centre for Environmental Geographical Information Services
CGA	Central Ganga Authority
COD	chemical oxygen demand
CRP	Clean River Program
Cr	chromium
d	day
DCC	Dhaka City Corporation
DEC	Department of Environment and Conservation
DG	Director General
DO	Dissolved oxygen
DOE	Department of Environment
DWASA	Dhaka Water Supply and Sewerage Authority
EC_w	electrical conductivity in water
ECA	Environment Conservation Act
ECC	Environmental Clearance Certificate
ECR	Environmental Conservation Rules
EI	Economic incentive
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EPB	Environmental Protection Bureau
EPCO	Environmental Pollution Control Ordinance
EQS	Environmental Quality Standards
ETP	Effluent Treatment Plant
EU	European Union
GAP	Ganga Action Plan
GEMS	Global Environment Monitoring System
GPD	Ganga Project Directorate
hr	hour
IWM	Institute of Water Modelling
JBA	Jamuna Bridge Authority
km	kilometer
LBL	Load Based Licensing
LGED	Local Government Engineering Department

m	meter
mg/L	Milligrams per Litre
ml	millilitre
m^3/sec	cubic meter per second
MAC	Marginal Abatement Cost
MLD	million litre per day
mm	millimeter
M/E	Mechanical and Electrical
MOEF	Ministry of Environment and Forests
MOI	Ministry of Industries
MTR	Marginal Tax Rate
MWR	Ministry of Water Resources
NBR	National Board of Revenue
NEMAP	National Environmental Management Action Plan
NEP	National Environmental Policy
NGO	Non-Government Organisation
NWP	National Water Policy
NRCD	National River Conservation Directorate
NSW	New South Wales
NH_3-N	ammonia-nitrogen
OECD	Organisation for Economic Co-operation and Development
O_2	oxygen
O&M	Operation and Maintenance
PAC	Public Accounts Committee
Pb	lead
PO_4-P	phosphate-phosphorus
PSTP	Pagla Sewage Treatment Plant
RAJUK	Rajdhani Unnayan Kartripakkha (Capital Development Authority)
SARA	San Antonio River Authority
SIA	Social Impact Assessment
SME	Small to Medium Enterprise
sq. km	square kilometre
SWOT	Strengths, Weaknesses, Opportunities and Threats
TAC	Total Abatement Cost
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
Temp	temperature
TMDL	Total Maximum Daily Load
UNEP	United Nations environment Programme
USA	United States of America
USEPA	United States Environmental Protection Agency
US$	United States Dollar
WARPO	Water Resources Planning Organisation
WPCO	Water Pollution Control Ordinance
%	percentage
^{0}C	degree celsius
µS/cm	micro Siemens per centimetre