8.1 Major findings and conclusion

8.1.1 Introduction

This research work has conducted an interdisciplinary study in order to quantify the pollution problem in the Buriganga River and to suggest possible solutions with management strategies. The study has developed an integrated approach with a combination of policy instruments, which would be most appropriate for pollution management in the Buriganga River. The conclusions drawn from this research are discussed below:

8.1.2 Poor state of water quality in the Buriganga River

The results showed that the Buriganga River water quality is not acceptable as per DOE standards for the parameters such as DO, BOD$_5$, COD, NH$_3$-N and Cr during both dry and wet seasons, and for EC$_w$ during the dry season. However, the data confirmed that parameters such as temperature, pH, PO$_4$-P and Pb, are still within acceptable limits in both dry and wet seasons in the river. The overall mean values of parameters for the Buriganga River are presented in Table 8.1.

Along the length of the river, the highest ambient concentration of BOD$_5$, COD, NH$_3$-N and Cr was observed at receptor point 2 (Kholamora) for both dry and wet seasons. This was most likely due to the impact of very high concentration of incoming polluted water, being discharged from the Rayerbazar sluice gate. This is the nearest (2 km) wastewater discharge point from the Kholamora receptor point. This information indicates that the pollutants are not being diluted or assimilated (during both high and low flow conditions of the river) within the two km downstream travel distance. Similar situation was also observed at other receptor points of the river indicating to the probability that the river
receives pollution beyond its assimilative capacity. No discernible improvements in water quality parameters were observed at different receptor points though their locations longitudinally varied from 0.5 to 5.5 km from the nearby wastewater discharge points.

Overall, it can be concluded from the observed data that the river (from upstream to downstream) is in a very dire situation, particularly from the perspective of DO concentration, which is alarmingly lower than the acceptable level. This is most likely due to the emission of biodegradable organic matter from industrial liquid effluent and untreated municipal wastewater. Therefore, immediate attention with a sustainable management system is required in order to control the discharge of such pollution into the river. Otherwise, the healthy existence of this river would be strongly compromised in both dry and wet seasons.

8.1.3 Excessive pollution loading in the Buriganga River

This research also assessed the quality of wastewater and pollution (in terms of BOD₅) loading discharged into the Buriganga River. The study showed that the water of the Buriganga River is polluted by the mixed type of wastewater from both municipal and industrial sources, located within its drainage 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 DOE guideline. For the incoming wastewater, the minimum and the maximum average concentration (including three major discharge points) of BOD$_5$ ranged 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.

The composition of the wastewater indicated that it is being discharged into the river with partial or no treatment. These results further implied the need of pollution reduction from the discharge points. The average BOD$_5$ pollution loading rates for the three discharge points were estimated at 83, 71 and 32 tons/day from Rayerbazar sluice gate, Shahidnagar drainage outlet and PSTP effluent outfall respectively. The total loading of BOD$_5$ was calculated at 186 tons/day whereas, the simulation exercise result showed that a total maximum loading of up to about 85 tons/day could be acceptable in order to get a minimum DO concentration of 5mg/L in the river water. It was concluded that these excessive pollution loading rates have to be decreased in order to increase the ambient DO concentration at various points of the river.

8.1.4 Current management system for river pollution control is inadequate

The research found that a number of policies and regulations with a fairly comprehensive set of legislations are currently in place for pollution management in Bangladesh, which are also applicable for the Buriganga River. The existing management system focuses on CAC based direct regulatory measures and emphasises on expensive technological solutions for the surface water quality problem. However, the state of compliance and enforcement of the regulatory measures are not satisfactory, leading to persistent pollution. There are weaknesses within the organisational capacity for successful implementation of pollution control regulations and programs. In addition, lack of information disclosure raises questions on the transparency and the accountability of the present system and limits participation of interested stakeholders in pollution control. Moreover, there is no provision within the present system to provide any economic incentive to the pollution emitters for pollution mitigation and adoption of new technologies. Despite the provisions made within the national policies, no action program has been developed to ensure the effective contribution of NGOs/CBOs for pollution
control, although evidence shows that the local community is willing and has the potential to directly participate in the process.

This research found that in the current system too many organisations and agencies are involved to control the pollution of this river. A major limitation was identified as the absence of a single authority with sole responsibility to coordinate the efforts of different organisations and programs towards controlling the pollution problem. This has led to a blame culture giving rise to organisational inefficiency. The research established that a shift to a new paradigm is necessary by involving relevant stakeholders and incorporating alternative pollution control measures to restore the health of the Buriganga River.

8.1.5 Pollution taxation with revenue recycling as a preferred policy instrument

A spreadsheet based decision support tool was used to evaluate the economic efficiency of alternative pollution abatement policies, while meeting specific water quality targets. The method generated empirical evidence on costs of $\text{BOD}_5$ reduction (in terms of load) from the discharge points in the Buriganga River using three alternative pollution abatement policies. The basic outcome from the simulation exercise was that a uniform pollution tax system or a tradable ambient permit system (EI based approaches) could have significant cost savings (up to about 50 per cent) for $\text{BOD}_5$ pollution control in the Buriganga River in contrast to the uniform reduction system (CAC based approach).

However, considering the prerequisites for the tradable permit system and the marginal difference of economic benefit to be gained from this system compared to the taxation system, it is concluded that a pollution tax system should be considered as a preferred policy for water quality improvement in the Buriganga River. It is apparent from the study that the pollution taxation system will attain the same goal as a uniform reduction system but with significantly lower abatement costs. This study proposes that the revenue raised from the pollution taxation system is recycled and returned to the same pollution emitters as refunds in proportion to their emission reduction. This would ensure better success for the implementation of the pollution taxation system.
8.1.6 Integrated approach with inclusion of various stakeholders

The research has developed a conceptual framework of an integrated approach for pollution management in the Buriganga River by identifying a blend of policy instruments appropriate for the Bangladesh context. It was found that effective participation from community in terms of water quality monitoring and application of EI based instrument (pollution taxation with revenue recycling) would ensure the healthy existence of the Buriganga River.

However, it is important to note that the suggested paradigm shift of the pollution control system with the new strategies (economic incentive and community involvement) do not intend to replace the present regulatory measures (particularly the ambient water quality standards), rather they are intended to complement them. The new approach proposes to regulate the concentration of pollutants at the receptor points and the pollution load at the discharge points. This will pave the opportunity to provide economic incentives to the pollution emitters who take appropriate measures to mitigate their pollution. It is evident that this reform necessitates legislative changes, strong organisational capacity, disclosure of information and public participation.

Consequently, this research also recommends the formation of a separate entity proposed to be called the Buriganga River Management Authority (BRMA), which will be assigned with sole responsibility to control pollution in the Buriganga River. The major tasks of this authority would be to set water quality standards, conduct monitoring at effluent discharge points and perform load based pollution assessment. It would also formulate policies for water conservation, enforce regulations and develop protocol for river water quality monitoring by CBOs and NGOs. In addition, this authority would be responsible for sharing water quality and pollution related information. This proposed authority would act as an apex body to coordinate the activities of various stakeholders and facilitate the implementation of alternative pollution control measures for the Buriganga River.
8.2 Limitations and scope of this research

In the context of a developing country like Bangladesh, there are limitations in the availability of consistent long term data on river flow, water quality parameters, pollution load as well as lack of cooperation from pollution mitigation organisations and transparency of information on policy documents. The present interdisciplinary study was conducted keeping all these factors in perspective and some specific limitations of this research are discussed below:

- In order to quantify the pollution in the Buriganga River, this research focused on major point source discharges. To get even more precise view of the overall pollution situation, the non-point (diffuse) sources could also be considered. However, this was beyond the scope of the research work reported in this thesis, as modelling of non-point source pollution would have required significant shift in the research focus.

- The river is subject to low to semi-tidal influences which were not taken into account when assessing the river water quality. Quantifying the effects of tidal influences would require collection of more frequent water samples during specific diurnal periods. This would have enabled to acquire precise scientific knowledge on the constitution of river water in terms of various parameters. However, this was not possible under the scope of the current study and it does not affect the outcome of this research because this study focused on the seasonal (dry and wet) variation of water quality rather than on the daily variation.

- The flow rates of incoming wastewater can vary within the day. A continuous measurement with a current meter could be conducted to capture the fluctuation of wastewater flow rates. In this study the flow rates were calculated manually through velocity-area method, which did not take into consideration the possibility of fluctuation of incoming wastewater flow in the river. However, the results on the wastewater flow rates derived using this method was sufficiently precise for the purpose of this research work and to draw conclusions.
• In the absence of effluent treatment plants in two of the three major wastewater discharge sources, the pollution abatement costs were constructed based on available engineering manuals. It would be ideal to work with observed data on abatement costs but as the data were unavailable due to absence of abatement installations, this research reverted to engineering cost estimates.

• An integrated approach with a combination of policy instruments for pollution mitigation in the Buriganga River was developed on the basis of results on economic assessment of BOD\textsubscript{5} reduction. The incorporation of other parameters such as COD, NH\textsubscript{3}-N, EC\textsubscript{w} and Cr in the economic analysis would have broadened the significance of the study, but was not undertaken due to data limitations. In addition, the conceptual framework from this study was developed based on BOD\textsubscript{5} reduction. Therefore, incorporation of other parameters was beyond the scope of this study.

8.3 Recommendations for further research and investigations

The following issues may be considered for further research and investigation in the field of river pollution management in the Buriganga River:

• A study on developing a depth wise profile of water quality parameters in the river, where water samples need to be collected from different depths (such as 3 m, 7 m, 10 m) of the river. Sampling of river sediments could also be included in such study. These would provide valuable information to interpret the state of aquatic ecosystem of the river due to the impact of pollution.

• A study on the methodology of developing a ‘river water quality index’ (Canter 1996) for the Buriganga River. Following Canter (1996) a procedure could be developed to categorise a large quantity of water quality data on different parameters, with the primary purpose being to simplify such data so as to make it useful to decision makers and various interested groups.
An investigation on land use pattern and individual pollution sources within the drainage basin of the Buriganga River (river catchment based study) could be useful to estimate the amount of pollution discharged into the river through the application of DSS-IPC (Decision Support System for Integrated Pollution Control) model (Lvovsky 1999 and Sebastian et al. 1999). The model results could be compared with the observed results in order to generate a precise data base on pollution loading rates into the river.

Studies on estimating the amount of pollutants generated by non-point or diffuse sources (as mentioned in section 3.3.2) and their impact on the Buriganga River.

A study for quantifying the state of pollution and the assimilative capacity of the river during both low and high flow periods using 1-D water quality models (Thomann and Mueller 1987). The observed data on river water quality presented in this research could be used for developing, calibrating and verifying the model.

A study on developing procedures for community monitoring of river water quality in order to establish an accurate database on the state of the river. A uniform sampling technique and standard testing procedures could be developed with clear guidelines on timing, locations and frequency of sampling.

Studies on community environment values on river water and their preparedness to participate in relation to protecting the river from pollution.

Investigations on empirical evidence on the relative administrative and transaction costs of different pollution abatement measures.

Application of the proposed conceptual framework as a pilot project and determination of the effectiveness of management actions.