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Restoring water quality in the polluted Turag-Tongi-Balu river system, Dhaka: Modelling nutrient and total coliform intervention strategies

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HIGHLIGHTS

- First application of a WQ model to the Turag-Balu River System in Bangladesh
- Model of TC and nutrients illustrates the serious pollution problems in the river.
- Pollution control is possible with sufficient effluent treatment.
- Flow augmentation can dilute discharges in low flow conditions.

GRAPHICAL ABSTRACT

The study is set in the Dhaka region of Bangladesh close to the confluence of three rivers, the Ganga, the Brahmaputra and the Meghna, which dominate the hydrology of the Delta system of the Bay of Bengal. Home to millions of people, the Delta system is driven by hydrology, the pollution from 30,000 factories discharge into the river systems, sea level rise and climate change. Pollution creates a major threat to the people of Bangladesh.

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ABSTRACT

River water quality in rapidly urbanising Asian cities threatens to damage the resource base on which human health, economic growth and poverty reduction all depend. Dhaka reflects the challenges and opportunities for balancing these dynamic and complex trade-offs which goals can be achieved through effective policy interventions. There is a serious problem of water pollution in central Dhaka, in the Turag-Tongi-Balu River system in Bangladesh with the river system being one of the most polluted in the world at the moment. A baseline survey of water chemistry and total coliforms has been undertaken and shows dissolved oxygen close to zero in the dry season, high organic loading together with extreme levels of Ammonium-N and total coliform in the water. Models have been applied to assess hydrochemical processes in the river and evaluate alternative strategies for policy and the management of the pollution issues. In particular models of flow, Nitrate-N, Ammonium-N and indicator bacteria (total coliforms) are applied to simulate water quality in the river system. Various scenarios are explored to clean up the river system, including flow augmentation and improved effluent treatment. The model results indicate that improved effluent treatment is likely to have a more significant impact on reducing Ammonium-N and total coliforms than

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flow augmentation, but a combined strategy would greatly reduce the pollution problems in the Turag-Tongi-Balu River System.

1. Introduction

Environmental pollution in large rapidly developing delta cities is a major problem responsible for over 12.6 million deaths annually according to the World Health Organization and UNICEF (Prüss-Üstün and Corvalán, 2006). Deltas have some of the highest population densities in the world with often poor and vulnerable residents (Nicholls et al., 2016). The presence of high population numbers, unsanitary conditions, poorly regulated industrial discharges and untreated domestic effluents has ensured that many urbanised delta rivers are highly polluted. These factors also pose a significant health threat to people using the rivers, groundwaters and associated water supply systems (Pimentel et al., 2007; Vörösmarty et al., 2010). Similar to urban rivers systems in other rapidly industrializing developing countries, the rivers of Dhaka City, Bangladesh, are heavily impacted by the scale and intensity of economic growth. While Greater Dhaka is a major engine of growth for Bangladesh, representing 40% of GDP production, high levels of pollution, over-abstraction of ground water, and inefficient use means that the Turag-Tongi-Balu river system in central Dhaka (Figs. 1 and 2) receives a huge load of domestic and industrial effluent. New industrial developments and townships enhance these pollution loads with devastating impacts on river water quality. In this paper we assess the impact of nutrient and faecal pollution in the Turag-Tongi-Balu River system and consider the mass balance of chemical constituents in the river system.

We have utilised a dynamic process based flow and water quality model INCA (Integrated Catchment Model, Whitehead et al., 1998a, 1998b, 2016, Wade et al., 2002a, 2002b, 2002c) to simulate the behaviour of the catchment and river system. Water quality modelling is a useful technique to improve our understanding of the spatial and temporal dynamics of nutrients and faecal pollution (total coliforms) in a river system, and can be used to explore the potential effects of different management and hydrological change scenarios on river water dynamics. Two management strategies have been considered in this study, namely, the introduction of effluent clean up technologies for key discharges along the river and the alteration of water flows in the upper Turag so as to increase the flows of water in low flow conditions. This study presents the first integrated flow and water quality model of pollution risks in urban Dhaka and aims to guide and support government efforts to systematically regulate pollution in the Dhaka region. The designation of rivers in Greater Dhaka as Ecologically Critical Areas (ECAs) by the Ministry of Environment and Forestry creates a foundation for future restoration activities (MoEF, 2010).

2. The Turag-Tongi-Balu catchment system

The city of Dhaka, capital of Bangladesh, is located in the centre of the country, north of the confluence of the River Padma (combined Ganga and Brahmaputra) and Meghna. The Turag-Tongi-Balu Rivers are part of a complex peripheral system of rivers surrounding Dhaka, as shown in Fig. 1. Seasonal flow variability in this river system is related to the region's climate, characterised by a hot pre-monsoon summer season (March to May), a rainy monsoon season (June to September), a post-monsoon autumn season (October to November), and a dry winter season (December to February) (WARPO, 2004; Shahid, 2010). The Turag River is fed by runoff coming from a predominantly agricultural area located upstream, as well as from other rivers such as the Bangshi River and the Brahmaputra River, and flows into the Buriganga River, in the South of Dhaka. Land use is changing rapidly in the peripheries of Dhaka, with multi-spectral satellite data showing rapid conversion from agricultural cultivated land to urban land uses along Tongi Khal over the past few decades (Dewan and Yamaguchi, 2009; Dewan et al., 2012). Improved sanitation coverage in this new urban area is currently low, with the drainage system used as a combined sewerage system in a large portion of the area, presenting a source of microbial contamination of the river system. Precise estimates of effluent loads from various sources along the river are unavailable, in part due to the rapid pace of change which means that data is quickly outdated. Dhaka is one of the most densely populated cities in the world, home to approximately sixteen million people, of which less than 25% are served by sewage treatment facilities (Islam et al., 2015). In the last twenty years, a convergence of unregulated industrial expansion, rural-to-city migration, overloaded infrastructure, unclear institutional responsibility for water quality management and ineffective enforcement of environmental regulations have all taken their toll on surface water quality. Though there are plans for a number of sewage treatment

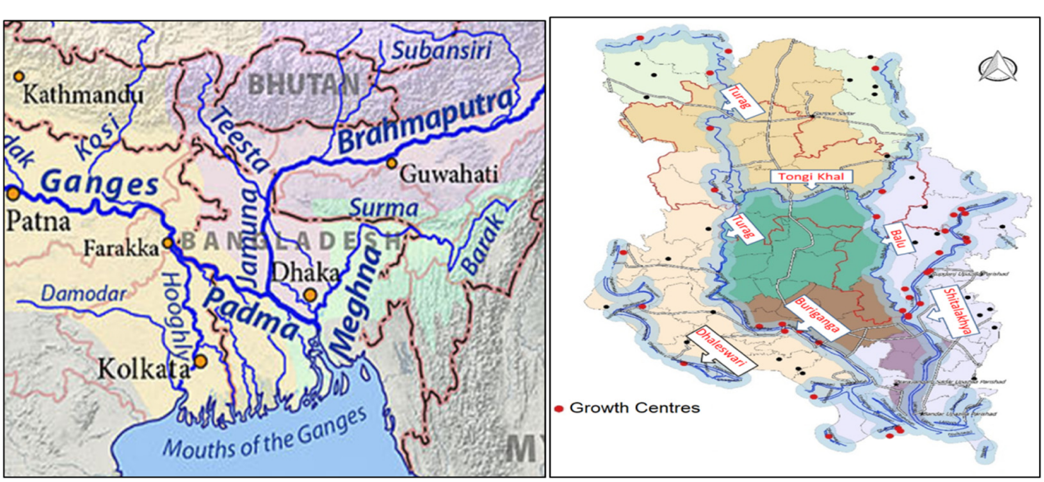

Fig. 1. Maps showing Ganges, Padma, Brahmaputra and Meghna Rivers feeding into the Bangladesh Delta (left) and details of the Turag-Tongi-Balu River System around Dhaka City (green/brown Zone) on the right hand map. Red dots on right map shows areas of rapid growth and development in Dhaka. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)