Photo: Alex Fischer

Monitoring and modelling river water quality to protect Dhaka's river system

Story of change: Key findings & emerging impacts

Summary

- The Ready Made Garment (RMG) industry in Bangladesh is one source of pollution into Dhaka's heavily contaminated rivers.
- Industrial pollution together with domestic waste damages rivers, estuaries and coastal waters with serious impact on the health and livelihoods of people who live nearby.
- REACH has created river system models to evaluate domestic and industrial effluents in Bangladesh and Ethiopia, and contributed to the development of a new water quality monitoring network in Dhaka.
- The models have also been used to assess mitigation measures for river clean-up, both for a government-led USD 20 billion mitigation scheme in Dhaka, and for industry, to inform potential investment in water treatment measures
- Since 2019, Primark, the Alliance for Water Stewardship (AWS) and the Partnership for Cleaner Textiles (PaCT) representing many of the major international RMG companies, have been collaborating with the REACH programme to understand and respond to pollution from their factories.

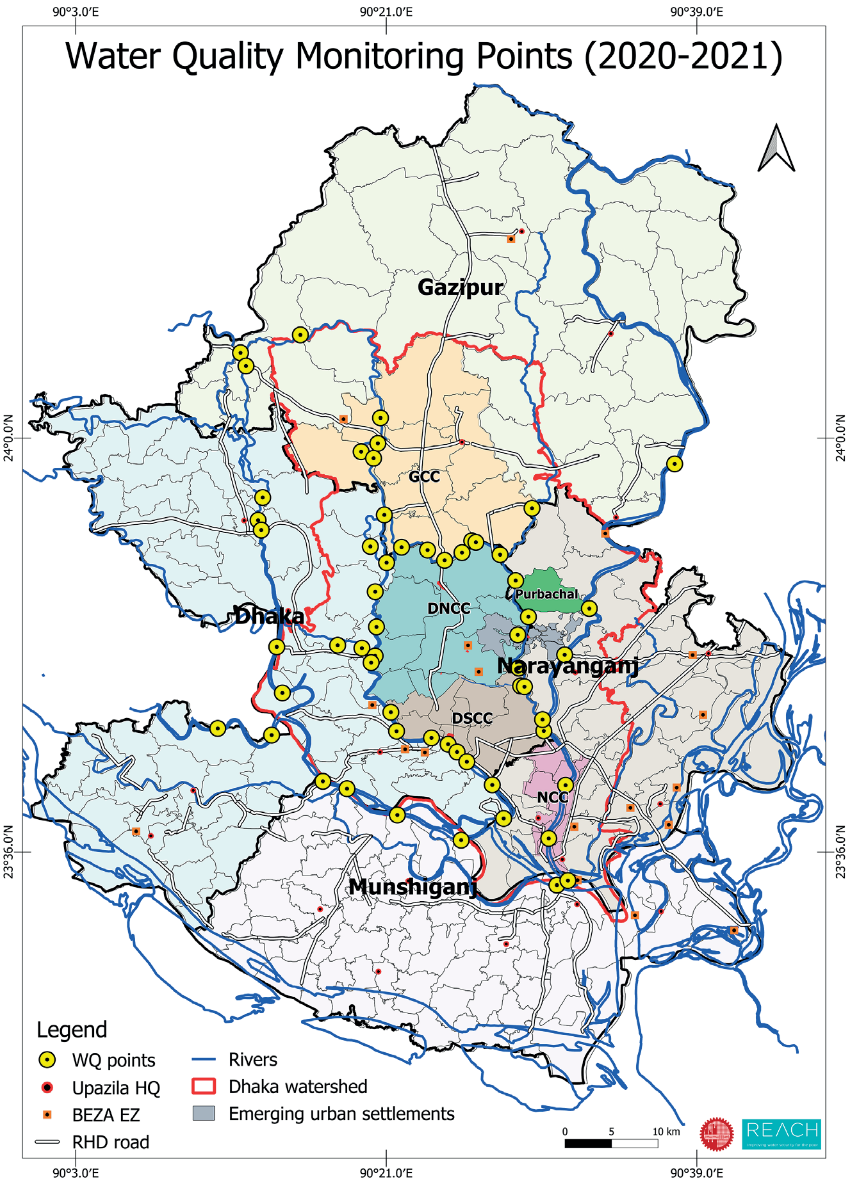
Alliance for Water Stewardship | 2030 Water Resources Group | Hosted by World Bank Group Water | University of Oxford | REACH Improving water security for the poor | UK International Development Partnership | Progress | Prosperity

Introduction

River water quality is a topic of rapidly growing concern for sustainable and equitable development in the city of Dhaka, Bangladesh. Over the last two decades, water quality has dramatically decreased due to major increases in industrial and domestic effluent and waste being allowed to enter rivers without adequate treatment. REACH research has highlighted significant social inequalities in pollution exposure, with low-income residents and workers along the riverbanks using the contaminated waters daily for their domestic, productive and recreational uses.

Drawing on a 5-year system-wide river water quality monitoring programme, the REACH Programme has established an advanced water quality modelling system that can allow decision-makers to assess the potential impacts of current activities and future growth and mitigation strategies on river health. REACH's data and models are providing the means to optimise and prioritise planned investments, thus supporting policy and practice for industry, government and donors.

Figure 1: Map of Greater Dhaka watershed showing locations of sampling points.



Advancing the science of river health and social inequalities

Developing a river water quality monitoring system for Greater Dhaka

REACH has established the first comprehensive water quality monitoring system for 12 rivers or canals with a total length of 283 km in the Greater Dhaka watershed (Figure 1). Monthly analysis of physiochemical parameters, organics and microbial concentrations from 58 sampling points over five years (2017-2021) has provided the means to assess the seasonal and spatial impacts of untreated domestic and industrial wastewater discharge, particularly by the ready-made garment and tannery industries. This also included a one-off analysis of 17 heavy metals at each of the sampling points. Data from this river water quality monitoring is available in a public online dashboard hosted by Tableau.

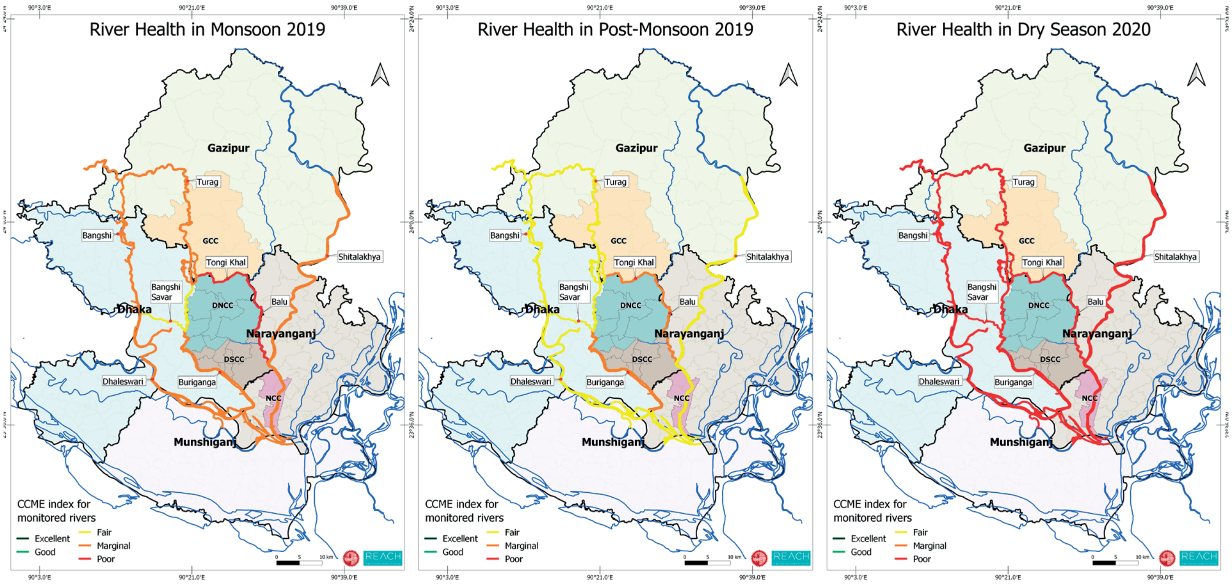
Findings show that during the low flow conditions that prevail from December to April, dissolved oxygen throughout the river system falls below the minimum threshold essential for sustaining aquatic life. The anoxic conditions in the waters and sediments can result in some metals from bound sediments and gases such as methane, ammonia, and hydrogen sulphide, being released. During monsoon, when the river levels rise, owing to the combined effect of upstream flows from the Himalayas and localised rainfall within the basin, the dissolved oxygen rises, and the concentrations of most organic and inorganic pollutions fall to meet national guidelines. The best condition is observed in the post-monsoon season as flushing of the floodplains and rivers in monsoon results in lower sediment and cleaner water, with the pollution plume travelling further downstream (Figure 3).

The Bishwa Ijtema, an annual congregation of Muslims along the banks of the Tongi Khal, served as a natural experiment to test the impact of human activity on river health (Figure 2). An analysis of heavy metals before and after the Ijtema in January 2018 showed an overall increase in concentrations. This was due to combined effects of decreased river flow, resuspension of sediments caused by the disturbance of riverbed during Ijtema preparatory work, and subsequent dissolution of metals due anaerobic condition. A bacterial biosensor was developed to understand the toxicity of these combinations of heavy metals on living organisms (Rampley et al., 2019).

Figure 2: The huge Ijtema tent on the banks of one of Dhaka's rivers.

Photo by Jubair1985 , CC BY-SA 4.0, via Wikimedia Commons

Figure 3: River health of Greater Dhaka during 2019 – 2020 based on a Water Quality Index comprising 15 parameters, namely temperature, pH, electrical conductivity, dissolved oxygen, oxidation reduction potential, turbidity, colour, alkalinity, iron, ammonia-nitrogen, nitrate, phosphate, sulphide, sulphate and chloride.



Interestingly, despite the overall increase in metal concentrations, the simultaneous dumping of organic waste resulted in lower availability of free ions, which in turn lowered the toxicity in the samples collected during the Ijtema.

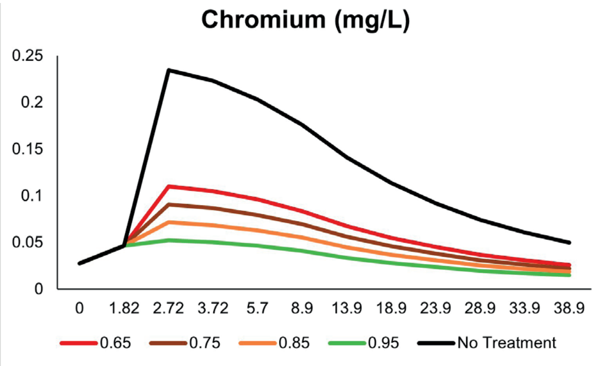
Developing an Integrated catchment model (INCA) to evaluate impacts of industrial activities and mitigation interventions

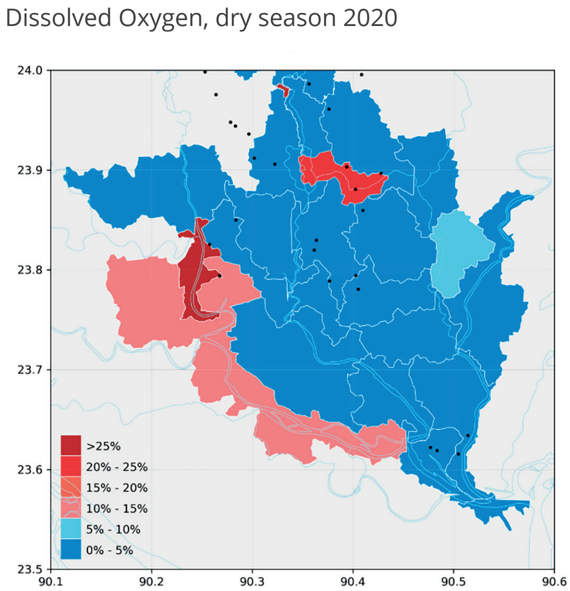
REACH has developed an Integrated catchment model (INCA) for the Greater Dhaka watershed, simulating river flows, nitrate, phosphate, ammonia, sediments, pathogens and heavy metals (chromium, cadmium, copper, zinc, lead, arsenic, manganese and cobalt). The model is dynamic (daily) and process based, capturing the underlying hydrological, chemical and biological processes acting on rivers and catchments. It has been used to understand the relative contribution of textile and tannery effluents along different reaches of the river system, and evaluate the potential impacts of pollution mitigation strategies (Bussi et al., 2023, Whitehead et al., 2018).

The model demonstrated that the relocation of the tannery industry from Hazaribagh to a purpose-built estate in Savar has contributed to increased pollution of the Dhaleswari River as the centralised effluent treatment plant is only partially functional (Whitehead et al., 2019). Proper treatment can substantially reduce the concentrations of chromium downstream (Figure 4).

Since 2019, REACH has been collaborating with Primark, the Alliance for Water Stewardship (AWS) and the Partnership for Cleaner Textiles (PaCT), representing many of the major fashion brands, to understand and respond to pollution from their factories. Through this collaboration, managers and water quality specialists from the ready-made garment industry have contributed to an INCA modelling exercise which shows the significant but varied impacts of effluents discharged on dissolved oxygen in the sub-catchments (Figure 4), highlighting the need to improve discharge quality and match government initiatives in a positive way to reduce the industry's pollution footprint.

Figure 4: Impacts of the Savar Tannery Discharges on Chromium in the Dhaleswari River system under different treatment scenarios (Source: Whitehead et al., 2021. CC by 4.0) and the impacts of Garment Industry on Dissolved Oxygen Levels (right). Black dots indicate factory locations.



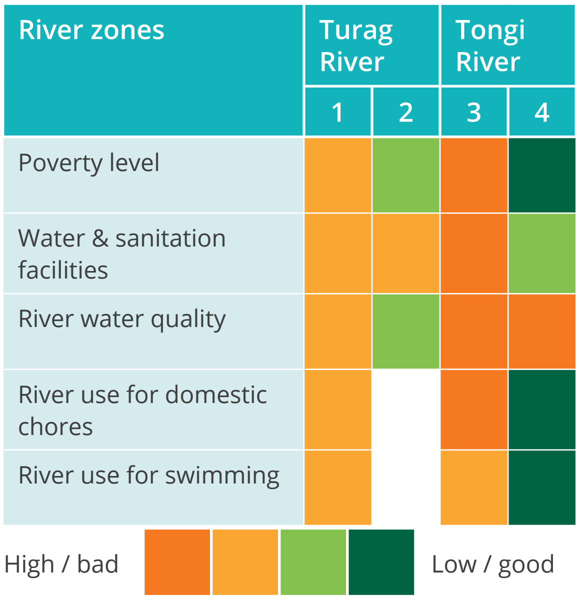


Understanding social inequalities in pollution exposure

REACH conducted household surveys and direct observation of river use behaviour along a 25km stretch of the Turag River and Tongi Khal in northern Dhaka to explore the social inequalities in pollution exposure (Hoque et al., 2021; Figure 5). Findings showed that low-income riverbank residents and casual workers use the river water daily for their domestic and productive purposes, with observed gender differences in types and location of activities across seasons.

Along densely populated slums, women and girls were seen washing clothes and dishes at the river due to lack of adequate water services. Small-scale productive activities, including dyeing denim, washing fish baskets or plastic sheets, collecting plastic waste and fishing, were also observed close to market places or boat terminals. Men, women and children used the river for personal washing and bathing, which increased significantly in the wet season when the river is perceived to be cleaner.

Figure 5: Qualitative assessment linking water quality, socio-economic conditions, and direct contact with river across the four study zones Source: Hoque et al., 2021. CC by 4.0



Remote sensing, coupled with population data, estimated more than a million people being at risk of monsoon flooding, which brings in toxic pollutants closer to settlements and croplands. Communities downstream of the tannery estate along the Dhaleswari River expressed significant concerns about the decline in crop productivity in the past few years, owing to soil degradation and increased insect infestation which they ascribed to untreated tannery wastewater. Similar concerns were expressed by communities downstream of Konabari RMG cluster along the Turag River and Tongi Industrial cluster along the Tongi Khal where degradation of floodplains affected crop agriculture and endangered the once rich aquatic eco-system known for abundant floodplain fisheries resources.

Using science to inform policy and practice

Guiding planned government and donor investments for river clean-up

REACH's water quality monitoring work provided a comprehensive analysis of pollution dynamics and river health in Dhaka and has contributed to the design of a new enhanced water quality monitoring network with 20 automated stations installed across Dhaka's rivers. This is being set up by the Department of Environment (DoE) with investment from the World Bank. The monitoring system can be integrated with modelling work to assess future interventions and provide lead time to safeguard critical infrastructure. This would require additional investment to support the integrated modelling and data platform.

The INCA model enables decision-makers to assess the impacts of planned interventions under the USD 20 billion 'Umbrella Investment Programme' (UIP) being pursued by the Government of Bangladesh with financing from the World Bank. The UIP has 35 priority projects to clean up the Dhaka rivers by 2041, including the construction of 12 new sewage treatment plants (STPs).

The modelling indicates that these STPs will reduce phosphorus and ammonia and improve dissolved oxygen levels along Tongi Khal, while nitrate concentrations are likely to remain unchanged due to their generation from upstream agricultural areas (Bussi et al., 2023). Other hotspots across Dhaka will show comparatively less improvement due to high levels of industrial discharges. The modelling also recommended changes in the current priority list and schedule regarding commissioning of the STPs. These results were presented at the Greater Dhaka Restoration Workstream meeting chaired by Secretary, LGD in July 2023. The Secretary, LGD, is also the chairperson of the LGD implementation committee for UIP.

Building capacity of government and industry stakeholders

REACH has been actively engaged in capacity building for students, government partners and industry stakeholders in Bangladesh, and also in Ethiopia where INCA models have also been developed (Whitehead et al, 2021). In Bangladesh, three water quality modelling course have been delivered to train students and teaching staff at BUET, as well as professionals from the government's Department of Environment, Dhaka Water Supply and Sewerage Authority, Bangladesh Water Development Board, Local Government Division, Department of Public Health and Engineering, and City Corporations, who are actively engaged in the World Bank's Umbrella Investment Programme (Figure 6).

Similar trainings were also held for students in Ethiopia and staff at local basin development and water authorities. The courses provided the INCA modelling software, along with instructions on how to use it and apply it to other catchments. At a workshop in Addis Ababa stakeholders requested trial setup on the model on the Blue Nile and rivers in the Lower Rift Valley. An online course, written by Prof Paul Whitehead, is also available at www.omb.co.uk/courses.

Scaling out

To demonstrate the applicability of the water quality modelling globally, the INCA model has been used in Ethiopia to evaluate rising salinity levels in the Awash River and Lake Beseka and the changing nitrate and phosphorus conditions downstream from intensive agriculture and rising populations. Moreover, the model simulated the concentrations of heavy metals in the Awash River just downstream of Addis Ababa where new tanneries discharge unregulated and untreated waste into the river system. Here some urgent planning and policy work is needed to control these discharges. As in Bangladesh, countering this requires skilled stream and river management and harnessing of resources to manage downstream pollution.

Selected outputs

Research articles

Bussi, G., Shawal, S., Hossain, M.A., Whitehead, P.G. and Jin, L. (2023). Multibranch modelling of flow and water quality in the dhaka river system, Bangladesh: Impacts of future development plans and climate change. *Water*, 15 (17): 3027. doi: 10.3390/w15173027

Hoque, S.F., Peters, R., Whitehead, P., Hope, R. and Hossain, M.A. (2021). River pollution and social inequalities in Dhaka, Bangladesh. *Environmental Research Communications*, 3 (9): 095003. doi: 10.1088/2515-7620/ac2458

Rampley, C.P.N., Whitehead, P.G., Softley, L., Hossain, M.A., Jin, L., David, J., Shawal, S., Das, P.,Thompson, I.P., Huang, W.E., Peters, R., Holdship, P.,Hope, R. and Alabaster, G. (2019). River toxicity assessment using molecular biosensors: heavy metal contamination in the Turag-Balu-Buriganga river systems, Dhaka, Bangladesh. *Science of the Total Environment*, 134760. doi: 10.1016/j.scitotenv.2019.134760

Whitehead P.G., Mimouni, Z., Butterfield, D., Bussi, G., Hossain, M.A., Peters, R., Shawal, S., Holdship, P., Rampley, C.P.N., Jin, L. and Ager, D. (2021). A New Multibranch Model for Metals in River Systems: Impacts and Control of Tannery Wastes in Bangladesh. *Sustainability*, 13(6): 3556. doi: 10.3390/su13063556

Whitehead, P.G., Bussi, G., Hossain, M.A., Dolk, M., Das, P., Comber, S., Peters, R., Charles, K.J., Hope, R. and Hossain, S. (2018). Restoring water quality in the polluted Turag-Tongi-Balu river system, Dhaka: Modelling nutrient and total coliform intervention strategies. *Science of the Total Environment*, 631: 223-232. doi: 10.1016/j.scitotenv.2018.03.038

Figure 6: Training courses in Bangladesh and Ethiopia (Source: REACH).

Whitehead, P.G., Bussi, G., Peters, R., Hossain, M., Softley, L., Shawal, S., Jin, L., Rampley, C., Holdship, P. and Hope, R. (2019). Modelling heavy metals in the Buriganga River System, Dhaka, Bangladesh: Impacts of tannery pollution control. *Science of the Total Environment*, 697: 134090. doi: 10.1016/j.scitotenv.2019.134090

REACH water quality research and model development in Ethiopia's Awash Basin can also be explored at www.reachwater.uk/resources

Other

REACH Impact video – Managing River Water Security. www.reachwater.uk/impact-videos

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Story of change themes

- Groundwater
- Land
- Coasts
- Gender
- Schools
- Services
- Health
- Climate
- Cities
- Basins

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