Chemosphere 165 (2016) 1–9

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Monitoring of metal pollution in waterways across Bangladesh and ecological and public health implications of pollution

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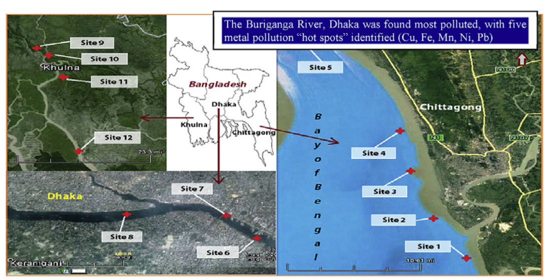
HIGHLIGHTS

- Detected eight trace/heavy metals (Cd, Cu, Fe, Mn, Ni, Pb, U, Zn) on a regular basis in waterways across Bangladesh.
- Seven metal pollution "hot spots" have been identified across waterways of Bangladesh.
- Five "hot spots" were found in the Buriganga River, Dhaka.
- Metal pollution may cause significant impacts on water quality, biodiversity, food security, human health and livelihoods.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 March 2016
Received in revised form
7 August 2016
Accepted 25 August 2016
Available online 8 September 2016

Handling Editor: Martine Leermakers

Keywords:
Heavy metals
Artificial mussels
Metal "hot spots"
Bangladesh
Buriganga River
Chittagong
Dhaka
Khulna
Pollution implications

ABSTRACT

Using innovative artificial mussels technology for the first time, this study detected eight heavy metals (Cd, Cu, Fe, Mn, Ni, Pb, U, Zn) on a regular basis in waterways across Bangladesh (Chittagong, Dhaka and Khulna). Three heavy metals, viz. Co, Cr and Hg were always below the instrumental detection levels in all the sites during the study period. Through this study, seven metal pollution "hot spots" have been identified, of which, five "hot spots" (Cu, Fe, Mn, Ni, Pb) were located in the Buriganga River, close to the capital Dhaka. Based on this study, the Buriganga River can be classified as the most polluted waterway in Bangladesh compared to waterways monitored in Khulna and Chittagong. Direct effluents discharged from tanneries, textiles are, most likely, reasons for elevated concentrations of heavy metals in the Buriganga River. In other areas (Khulna), agriculture and fish farming effluents may have caused higher Cu, U and Zn in the Bhairab and Rupsa Rivers, whereas untreated industrial discharge and ship breaking activities can be linked to elevated Cd in the coastal sites (Chittagong). Metal pollution may cause significant impacts on water quality (irrigation, drinking), aquatic biodiversity (lethal and sub-lethal effects), food contamination/food security (bioaccumulation of metals in crops and seafood), human health (diseases) and livelihoods of people associated with wetlands.

1. Introduction

Contamination of aquatic systems with metals through discharges from mining, industrial and agricultural activities may

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http://dx.doi.org/10.1016/j.chemosphere.2016.08.121
0045-6535/

render water unsuitable for irrigation, drinking water, livestock drinking, agriculture, fisheries and aquaculture (Hossain and Islam, 2004; Kibria et al., 2010a). Metal pollution may affect ecosystem biodiversity, eliminate sensitive native species or reduce species abundance through reproductive impairment and increased incidence of diseases (Wu et al., 2007; Kibria et al., 2012). Previous studies have revealed that fertilizers, farm manures, fungicides, effluents from sewage, pulp and paper mills, waste incineration, refineries, urban and storm water run-off, agricultural run-off, acid mine drainage, iron and steel production, land fill and petroleum industry are the principal sources of metal pollution in the aquatic environment (Marcotullio, 2007; Kibria et al., 2010a).

Many rivers, estuaries and coastal areas of Bangladesh seemed to be heavily contaminated with agricultural, domestic, industrial effluents (e.g. from farming, sewage, landfills, paper mills, dyeing industries, textile mills, oil refineries, tanneries, fertilizer factories, ship breaking yards) (Hossain, 2010). A very recent study found that the Karnafuli River estuary and adjacent coastal area of the Bay of Bengal, Bangladesh are highly polluted by high risk metals (Kibria et al., 2016). The water of the Buriganga River passing through the capital city Dhaka, Bangladesh is extremely polluted, is black in color (Saifullah et al., 2012), and low in dissolved oxygen level (0.722–1.204 mg/L) (Rahman and Al Bakri, 2010). The rivers in the Khulna areas are also reported to be highly polluted (Sabbir et al., 2010; Ahmed et al., 2015). In general, pollution from domestic, industrial, agrochemicals and oil and grease are major threats to water quality of marine and coastal areas of Bangladesh (UNEP, 1986; Hossain and Islam, 2006).

The typically high temporal and spatial variabilities of metals in the aquatic environment make it necessary to take water samples frequently in order to provide a statistically valid estimate. But the efforts and analytical costs required often becomes a major obstacle for comprehensive metal pollution studies over large areas, especially in Bangladesh. The 'Artificial mussel' (AM) technology developed recently has been shown to provide a cost effective tool for trace/heavy metal monitoring in freshwater, estuarine and marine environments, and is also able to provide a time-integrated estimate for comparison over large geographic areas (Wu et al., 2007; Leung et al., 2008; Degger et al., 2011; Gonzalez-Rey et al., 2011; Kibria et al., 2010b; Kibria et al., 2012, 2016; Claassens et al., 2016). For the first time, this study used the AM technology to assess threats and risks posed by trace metals to various beneficial water uses including water quality, biodiversity and human health in the most polluted rivers, estuaries and coastal areas of the Bay of Bengal (BoB), Bangladesh. The current study focused on trace/heavy metal pollution monitoring in waterways of the three most impacted regions of Bangladesh (Chittagong, Dhaka, and Khulna) with the following objectives.

The objectives of the current study were:

- To use "Artificial mussels" (AM) passive sampling devices for determining the temporal and spatial variation of eleven metals (Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn, and U) in the river, estuary and coastal area of Bangladesh.
- To identify 'hot spots' of metal pollution in the river, estuary and coastal area of Bangladesh.
- To evaluate the likely implications of pollution on ecological and public health

2. Materials and methods

2.1. The study area

Twelve sampling sites were selected for monitoring of trace/heavy metals, covering coastal area of **Chittagong**, the Buriganga River of **Dhaka**, and the Bhairab, Rupsa and Pasur river estuaries of **Khulna** of Bangladesh (Fig. 1 and Table 1). These sites were chosen based on a preliminary survey to identify and locate low, medium and highly impacted sites (known to be polluted from agricultural, domestic, and industrial effluents including farming, sewage, landfills, paper mills, dyeing industries, textile mills, oil refineries, fertilizer factories, ship breaking yards; see Table 1). **Chittagong** is the second largest city, industrial centre and the main sea port of Bangladesh. About 144 industrial units discharge untreated solid wastes and liquid effluents containing, persistent organic and inorganic substances and toxic metallic compounds into the Karnafuli River estuary and surrounding coastal water bodies (BOBLME, 2011). **Dhaka** is the Capital of Bangladesh. The Buriganga River (also known as the Old Ganges) receive wastes from textiles, pharmaceuticals, cement, rubber, chemicals, pulp, fertilizer, leather, tanneries, metals, steel and re-rolling mills, petroleum refineries, plastic industries, dyeing, glass, paper boards, oil and lubricant spillage from mechanized vessels, domestic/city and other solid wastes. Every day, 4500 t of solid waste and 22,000 L of toxic wastes are released into the Buriganga River by the 200 tanneries in the Hazaribagh and Rayerbazar area (Brady, 2014). **Khulna** is the third largest industrial city of Bangladesh and is the second largest seaport of Bangladesh. The Bhairab, Rupsa and Pasur are the three most polluted rivers in the Khulna region that receive wastes from news print mills, Khulna city and merchant ships, oil tankers and marine vessels, agriculture, fish farming, refineries, jute mills, Power Companies, cement factories, and ports.

2.2. Artificial mussel (AM)

Artificial mussels (AM) (an innovative continuous pollution monitoring passive sampling device) were used to sample and monitor trace/heavy metals in waterways of Bangladesh following Wu et al. (2007); Kibria et al. (2012). The 'AM' collects or accumulates metals through a diffusion barrier onto a sorbent medium. The device (AM) consists of non-permeable Perspex tubing (60 mm × 25 mm) in which 200 mg Chelex-100® resin (50–100 mesh from Bio-Rad) is suspended in 8 mL seawater/freshwater inside the tubing. Both ends of the tubing are further capped by a layer of polyacrylamide gel (thickness: 1 cm) to protect the gel from possible mechanical damages. Water diffuses through the polyacrylamide gel into the chelax-100 (metal binding agent) from which the complexed metals can later be extracted. After several weeks, the chelating agent is sampled to determine its metal content (Wu et al., 2007; Kibria et al., 2012). The merits of using AM compared to bio-monitors and spot/grab sampling for trace metals/heavy metals are given in Kibria et al., 2010a and 2010b.

2.3. Deployment, retrieval and analysis of AM

Field deployment of AMs includes placing of AMs (three replicate AM per site) in a plastic basket (with 10 mm opening for exchange of water) and retrieval at the end of a four weeks' interval. The experiments/research ran for three months (three deployments; March–May 2014; dry period). Deployment and retrieval procedures were carried out following Kibria et al. (2016). The AM samples were analyzed following methods described in Wu et al. (2007); Kibria et al. (2012).

2.4. Water quality

Water quality (WQ) comprising temperature, pH, salinity, conductivity, TDS, hardness and dissolved oxygen were measured