Annals of Bangladesh Agriculture
Journal homepage: bsmrau.edu.bd/aba

ORIGINAL ARTICLES

Water quality and the presence of metals in crustaceans (*Sartoriana spinigera)* and mollusks (*Pila globosa*) close to an urban waste landfill in Kodda at Gazipur

Md. Nurunnabi Mondal[1*], D. M. Rokibul Hoque Siddiqui[1], Israth Jarin Promi[1], Md. Emranul Ahsan[1], Tasrina Rabia Choudhury[2] and Shaifa Abrarin[3]

[1]Department of Fisheries Management, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh
[2]Analytical Chemistry Laboratory, Chemistry Division, Atomic Energy Centre Dhaka, Bangladesh Atomic Energy Commission, Dhaka 1000, Bangladesh
[3]Institute of National Analytical Research and Service (INARS), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhanmondi, Dhaka 1205, Bangladesh

ARTICLE INFO

Keywords:
Water quality, heavy metal, metalloids, *Sartoriana spinigera*, *Pila globosa*, waste landfill.

Received : 30 November 2023
Revised : 23 December 2023
Accepted : 30 December 2023
Published : 30 December 2023

Citation:
Mondal, M. N., D. M. R. H. Siddiqui, I. J. Promi, M. E. Ahsan, T. R. Choudhury and S. Abrarin. 2023 Water quality and the presence of metals in crustaceans (*Sartoriana spinigera*) and mollusks (*Pila globosa*) close to an urban waste landfill in Kodda at Gazipur. *Ann. Bangaldesh Agric*. 27(2): 175-189.

ABSTRACT

Degradation of water and sediment quality along with other aquatic ecosystem components, due to urban waste is a significant concern that demands attention. Despite of the multifaceted use of the Konabari area within the Gazipur City Corporation of Bangladesh, limited studies have assessed the health of the floodplain ecosystem adjacent to urban waste landfills in Kodda. This research focuses on evaluating water quality parameters and the presence of metals and metalloids in water, sediment, and biota (invertebrates) in the lowland floodplain near the Kodda municipal landfill in Gazipur district. In December 2022, thirteen composite samples, including water, sediment, crustaceans (*Sartoriana spinigera*), and mollusks (*Pila globosa*), were collected from the designated sampling site. Surface and sub-surface (0–15 cm depth) water were collected using a water sampler for water quality analysis, and the presence of heavy metal and metalloid content of the water, sediment, crabs, and mollusks were analyzed using an atomic absorption spectrometer. The results indicated dissolved oxygen concentrations ranging from 0.30 to 5.81 mg/l (mean 3.1±2.37 mg/l). Certain locations directly affected by waste discharge exhibited alarmingly low dissolved oxygen levels (~0.71 mg/l), coupled with elevated temperatures and phosphate (PO_4^{3-}) content (2–7.4 mg/l). The scarcity of heavy metal concentrations (<0.0677 mg/l) in water may be attributed to the constant flow of water preventing metal accumulation in the flowing water. However, sediment analysis revealed significantly higher concentrations (mean±Sd) of Fe (15240±1211 mg/kg), Mn (1122±180 mg/kg), Cu (44±5.5 mg/kg), Cr (28±3.2 mg/kg), Ni (39±2.4 mg/kg), As (3.7±0.89 mg/kg), and Zn (72±3.95 mg/kg) compared to other studies in various locations. Crustacean (Crab) samples showed concentrations of Cr, As, Pb, Cd, Zn, and Cu exceeding recommended permissible limits. *Pila globosa* emerged as an effective ecological bioindicator of aquatic pollution, with concentrations of Cr, Mn, Ni, Cu, Zn, and Pd exceeding recommended limits. Despite eco-environmental indices suggesting low to moderate contamination, the heavy metals and metalloids study indicated degradation of ecosystem health triggered by urban waste discharge. Consequently, the study recommends proper waste treatment in landfills and their transformation from open dumps to scientifically managed controlled waste landfills.

[*]**Corresponding Author:** Department of Fisheries Management, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. Email: nurunnabi@bsmrau.edu.bd

https://doi.org/10.3329/aba.v27i2.72545

Introduction

Urbanization, industrialization, population growth, and other human-induced stressors contribute to the deterioration of the quality of water, sediment, and other aquatic ecosystem components. Excessive use of pesticides, fertilizers, fungicides, and various chemicals by farmers, cultivators, and nearby residents further creates compound contamination in water bodies. The non-biodegradable contaminants, particularly trace metals and their compounds, pose persistent challenges (Singh *et al*., 2014). So, to assess the aquatic environmental health of a specific habitat, one can analyze water quality parameters and the presence of metals and metalloids in water, sediment, and biota.

The lowland floodplain located at the confluence of the Bongshai and Turag Rivers holds significant importance for Konabari, Baimail, and Mirpur residents in the Gazipur City Corporation. The local population utilizes the floodplain for various purposes, including fishing, small-scale pen culture, waterway navigation, crop and vegetable production, and household activities. A major concern for the region is the impact of effluent from the Kodda municipal landfill. The Kodda area hosts the largest waste dumping facility under the Gazipur City Corporation, handling a substantial amount of waste, approximately 2500 metric tons per day, making it the largest city corporation in Bangladesh (Anik *et al*., 2018; Akand, 2020; Haque *et al*., 2023). This waste, which includes medical waste, is deposited in open landfills (Kodda municipal landfills) without treatment.

The contaminants from the landfill leachate disperse throughout the surrounding environment, reaching the Bongshai-Turag River over the adjacent floodplain area. This landfill is considered a significant point source of contamination for the Turag River and, subsequently, the Buriganga River around the capital city of Dhaka, Bangladesh. Numerous studies have highlighted the severe water, sediment, and biota contamination in the Turag and Buriganga Rivers (Islam *et al*., 2015a; Islam *et al*., 2015b; Ahmed *et al*., 2015; Ahmed *et al*., 2016). Despite of the extensive contamination findings in these rivers, research in this specific area has been limited. Therefore, there is a critical need for comprehensive research in this locality.

Metals and metalloids from different sources (natural and anthropogenic) continuously enter the aquatic environment, creating a significant risk that threatens environmental and human health. Organisms (fish, crustaceans, mollusks, etc.) assimilate metals by ingesting particulate material suspended in water, ingesting food, adsorption on tissue and membrane surfaces, and ion exchange. As a result, they may accumulate large amounts of metals from the aquatic environment (water, sediment). The accumulation rate is dependent on both the rate of uptake and elimination (Guven *et al*., 1999; Tasrina *et al*., 2022a). Besides fish, invertebrate species, especially crustaceans and mollusk, have close contact with water and sediment. They are the group of organisms whose interactions are noted to forecast the state of a certain system. Numerous species of them are employed as bioindicators (Boening, 1999; Davies-Coleman and Palmer, 2004). They are an important component in the trophic structure and can survive a diversity of environmental conditions. Therefore, in this study, two invertebrate species (*Sartoriana spinigera* and *Pila globosa*) were selected to determine heavy metals and metalloids in their body. However, the research objectives were to investigate water quality parameters and to determine the presence of heavy metals and metalloids in water, sediment, crustaceans, and mollusks to evaluate the floodplain ecosystem close to an urban waste landfill.

Materials and Methods

Study site and sample collection

This research was performed in the lowland floodplain near Kodda municipal landfill in Konabari in the Gazipur district of Bangladesh (Fig. 1). The area is adjacent to the Bongshai-Turag River junction. The location was inundated 6–7 months a year due to the rainfall and the Bongshai-Turag River water flow. During the dry season, some parts of the area are used for crops and vegetable production. Some land is used for the production of fodder. The water is used for culture and capture of fish, navigation, and household purposes. The area is impacted by contaminants from urban landfills (Kodda municipal landfill, Fig. 1), as it is adjacent to the location. The Gazipur City and later Gazipur City Corporation (established in 2013) (Haque *et al*., 2023) have dumped urban waste in this landfill. The waste dumped at this site includes domestic waste, hospital and nursing waste, construction and demolition waste, slaughterhouse waste, industrial waste, and waste from agriculture (Anik *et al*., 2018; Akand, 2020). During the monsoon, these solid wastes are flowed and flooded around the location through the river, rain, and runoff waters. However, due to the unabated waste dumping, this floodplain area's ecosystem health was degraded, and the area's residents are the worst sufferers.

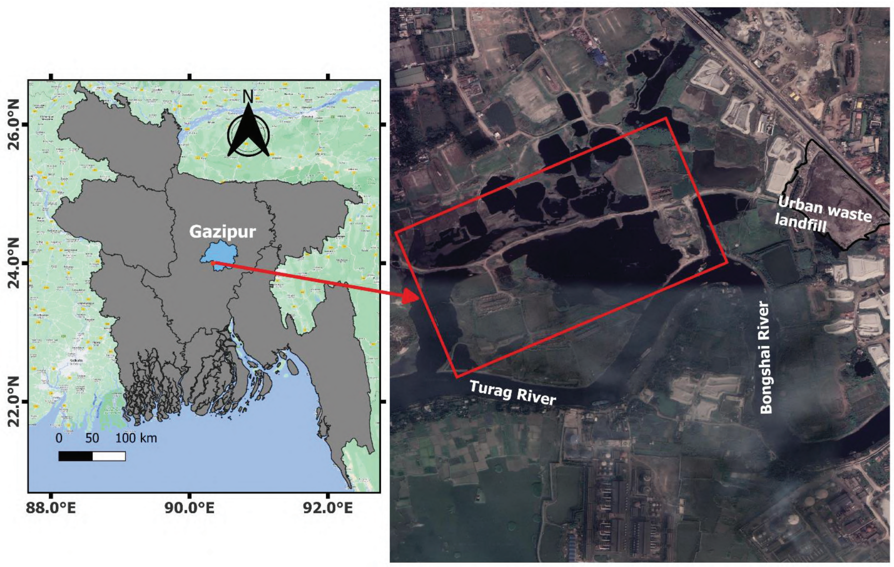

Fig. 1. The map shows the sampling site of this study. The left-side map shows the sampling site in the Gazipur district of Bangladesh. The rectangle (red color) on the right-side map indicates the sampling area covered in this research.

Water, sediment, crustacean (*Sartoriana spinigera*), and molluscan (*Pila globosa*) samples (a total of thirteen samples, seven water samples for water quality analysis and six samples for heavy metals and metalloids analysis) were collected from the sampling site (Fig. 1) in December 2022. The coordination of the sampling sites was identified and recorded using Global Positioning System (GPS). Surface and sub-surface (0–15 cm) water were collected from the seven sampling points for water quality analysis. Three samples of water were taken from each sampling site using a water sampler of 0.5 L capacity. They were subsequently mixed to make a composite sample and stored in a polyethylene bottle as one sample (0.5 L). Before sampling, the polyethylene bottles (intake and new) were cleaned with deionized water and air-dried in the laboratory. During sampling, bottles were pre-washed with sampling water (three times), filled with the desired samples, and immediately sealed to avoid air exposure. The collected samples were kept cold in an ice box. Sediment samples were collected using sediment corers up to 5 cm deep from the surface of the sediment to access less disturbed sediment. Before collecting each sediment sample, the sampling corer was washed with deionized water and rinsed several times to avoid contamination. Similar to the water sample, three sediment samples were collected from each site. They were subsequently mixed to make a composite sample. After collection, the sample was sealed in polyethylene zipper bags with proper labeling and kept in an ice box (Hasan *et al*., 2023). Then, the samples were transported to the laboratory. In the study area (Fig. 1), the local fishermen captured fish using underwater traps. During fishing, they also caught crabs and mollusks in addition to fish. The crab and mollusk samples were collected from the local fisherman directly on the sampling site. The scientific name, photograph, and description of the invertebrate (*Sartoriana spinigera* and *Pila globosa*) samples are given in Table 1 and Fig. 2. For robust analysis, five individuals of crabs were mixed together to make a composite crab sample. Similarly, five individuals of mollusks were mixed together to make a composite molluscan sample. After collection, all the samples were transported to the laboratory on ice and stored in the refrigerator at 4 °C for future study.

Table 1. The scientific, English, and local names, habitats, and parts were excluded before sample preparation for analyzing the selected crustacean and mollusk species shown in the table.

Scientific name	English name	Local name	Habitat	Parts excluded for the analysis
Sartoriana spinigera (Wood-Mason, 1871)	Wood Meson crab	Tele Kankra	River, swamps, floodplain, caves, mud soil wetland, caves	Viscera and outer hard shell
Pila globosa (Swainson, 1822)	Apple snail	Gol Shamuk	River, floodplain, lake, marshes, wetland, and low saline brackish water	Outer shell and viscera

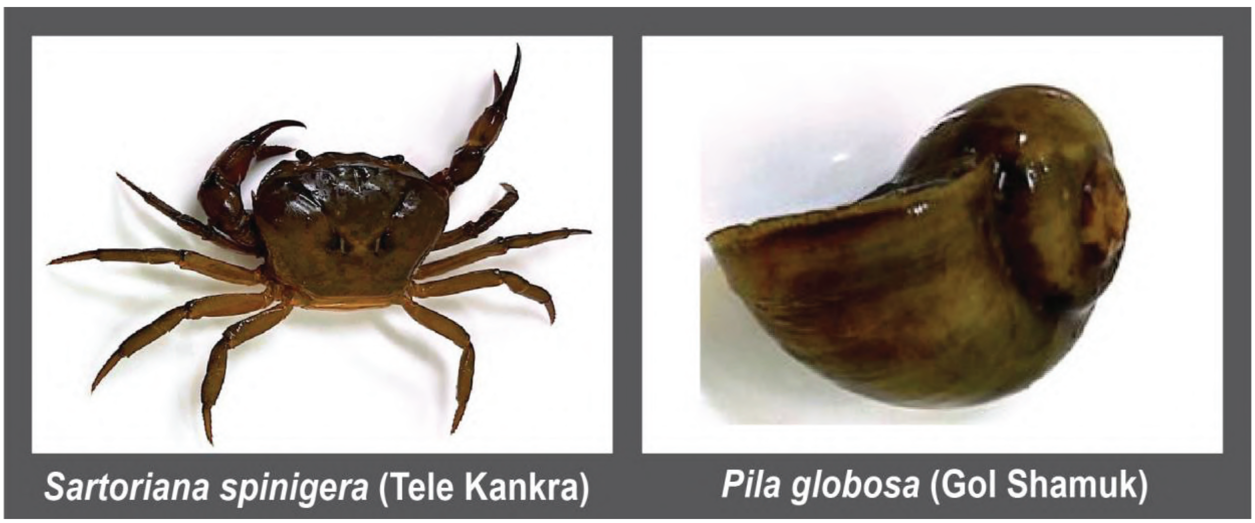

Fig. 2. Photograph of crustacean (*Sartoriana spinigera*) and mollusk (*Pila globosa*) species used for the analysis of the heavy metal and metalloid.

Sample preparation for analysis

In the laboratory, the water samples were filtered using glass microfiber filter paper (Whatman GF/F, 47 mm diameter) with a vacuum pump and stored in the refrigerator in the dark until laboratory analysis. The collected sediment samples in the laboratory were first air-dried at room temperature and then oven-dried at 105 °C (Ahmad and Goni, 2010). Then, it was ground, homogenized, and stored in the polyethylene zipper bags for analysis. The crustacean and molluscan samples were thoroughly washed with deionized water, and the viscera and outer shell were removed (Table 1). After being thoroughly washed with deionized water, the samples were dried in an oven (JSON-100, JS Research Inc. Korea) at 60–70 °C till a constant weight was achieved. A stainless-steel grinder was used to grind the dry samples and pass them through a sieve.

Water quality parameters

A portable pH meter (Hanna) was used to measure pH on the spot. Similarly, a dissolved oxygen (DO) and temperature meter (HACH HQ30d) were used to measure the dissolved oxygen and temperature in the sampling site during sample collection. The nutrient analysis including analysis of nitrate, nitrite, and inorganic phosphate (APHA, 1998; Hach Company, 2012) were conducted in the Laboratory of the Department of Fisheries Management, BSMRAU. The nitrate, nitrite, and inorganic phosphate (Reactive Orthophosphate) were analyzed using a spectrophotometer (HACH, DR6000, USA) (Scor-Unesco, 1966; Parsons *et al*., 1984; Grasshoff *et al*., 2009). The nitrate concentration was measured following the cadmium reduction method (Parsons *et al*., 1984) using NitraVer 6 and NitriVer 3 reagent powder pillow. The nitrite was measured following the USEPA Diazotization Method (Scor-Unesco, 1966), using a NitriVer 3 reagent powder pillow. The phosphorus concentration was measured, following the USEPA Ascorbic Acid Method (Scor-Unesco, 1966) using a PhosVer 3 Phosphate reagent powder pillow. The absorbance was measured by a spectrophotometric method (APHA, 1998; Hach Company, 2012).

Heavy metal and metalloid analysis

The metal content of the water, sediment, crab, and molluscan samples were analyzed at the ISO/IEC 17025 accredited laboratory of the Institute of National Analytical Research and Service (INARS), Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh. The metalloid concentration was analyzed in the Analytical Chemistry Laboratory (accredited on ISO/IEC 17025: 2017 for heavy metals in water, fish, shrimp, soil, sediment, food, vegetables, biological matrices) Chemistry Division, Atomic Energy Centre Dhaka, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. About 6 g of finely ground dried powder sediment, crab and molluscan samples, and 100 ml of water samples were used for heavy metal and metalloid analysis. The samples were digested using analytical-grade concentrated reagents such as HNO_3 (nitric) and $HClO_4$ (perchloric) acid and deionized water (18.2 MΩ cm at 25 °C). The sample's heavy metals concentration was measured by an atomic absorption spectrometer (AAS, model: AA240 FS, Varian, Australia). The analysis of metals was performed following the method described by Ahsan *et al*. (2019) and Akbor *et al*. (2020), as well as the standard methods described by APHA (1998).

Eco-environmental indices analysis

Contamination factor (CF)

The contamination factor (CF) (Hakanson, 1980) was determined using the following formula:

$$CF = \frac{\text{Cn}}{\text{Bn}}$$

Where, Cn and Bn are the measured and background elemental concentrations in sediment, respectively.

Degree of contamination (CD)

The degree of contamination (CD) was evaluated and computed by the following equation (Hakanson, 1980; Akbor *et al*., 2020; Backman *et al*., 1998)

$$\text{CD}=\sum_{i=1}^{n} CFi$$

Where CF*i*, is the contamination factor.

Biota-sediment accumulation factor (BSAF)

The biota-sediment accumulation factor was computed using the following equation (Ahsan *et al*., 2019):

$$BSAF = \frac{C_b}{C_s}$$

Where, C_b and C_s are the metal concentration in the biota and sediment, respectively.

Statistical analysis

R(https://cran.r-project.org/bin/windows/base/) (version 4.3.0), RStudio (version 2023.09.1+494), and ggplot2- based R packages (https://cran.r-project.org/web/packages/ ggplot2/index.html) were used in this study for statistical analysis of collected data.

Results and Discussion

Water quality parameter assessment

A detailed summary of measured water quality parameters such as dissolved oxygen (DO), temperature, pH, phosphate (PO_4^{3-}), nitrite (NO_2^-), and nitrate (NO_3^-) are shown in Table 2. The DO concentration ranges from 0.30 mg/l to 5.81 mg/l. Dissolved oxygen is an essential water quality parameter for most chemical and biological processes in the water column and aquatic life. Like terrestrial animals, fishes and other aquatic organisms need oxygen to live. In this study, the dissolved oxygen concentrations in the three locations (LFW-1, LFW-4, and LFW-7) were alarmingly low: 0.30, 0.25, and 1.59 mg/l, respectively. Among these three locations, LFW-1 received municipal waste discharge directly from the landfill sites, and LFW-4 and LFW-7 received municipal waste discharge in addition to other wastewater, such as industrial, domestic, and agricultural waste. Besides, the watercolor of the locations was very dark like inky, highly turbid, and pungent in odor. The area's alarmingly low dissolved oxygen condition creates a detrimental and lethal situation for fish and other aquatic life. Nahar *et al*. (2017) mentioned that industrial and urban discharge alarmingly lower (in some locations, down to 0.1 mg/l) the dissolved oxygen concentration in the Buriganga River, which hinders aquatic life. According to environmental conservation rules (ECR) and environmental quality standards (EQS), in a healthy inland water body, fish can maintain their growth and survive properly if the dissolved oxygen concentration is above 5 mg/l (ECR, 1997; Bhatnagar and Singh, 2010; DoE, 2016). The temperature range was 23.0–26.6°C. In a sub-tropical country, the temperature range in this study was within the acceptable limit for aquatic life like fish (ECR, 1997; DoE, 2016; Singha *et al*., 2018). However, elevated temperature in water might cause variations in dissolved oxygen concentration. This study found high temperatures and lower dissolved oxygen concentrations in the LFW-1, LFW-4, and LFW-7 locations (Table 2). The concentration of pH ranges from 7.4 to 8.1. Based on the pH values, the water in the study area was slightly alkaline. According to the standard pH value (6.5–8.5) of inland surface water by environmental conservation rules (ECR, 1997), the pH ranged in this study was within the permissible limit.

The phosphate (PO_4^{3-}) concentration ranges from 0.17 mg/l to 7.38 mg/l; the mean was 2.64 mg/l (Table 2). The PO_4^{3-} value in the 6 locations and the mean were within permissible limits based on ECR (ECR, 1997). However, in the location LFW-4, the PO_4^{3-} concentration was higher (7.38 mg/l) than the ECR permissible limit (6 mg/l). This is probably due to the excessive use of phosphate fertilizer or other agricultural practices in the surrounding agricultural lands and due to considerable surface runoff from agricultural fields and agricultural waste-based municipal landfill discharge to the location. The nitrite (NO_2^-) concentration ranged from 0.003–0.392 mg/l, and the mean was 0.064 mg/l, which was within the acceptable range (ECR, 1997; Islam *et al*., 2019). In this study, the NO_3^- concentration ranges from 0.42 to 9.93 mg/l with a mean of 2.59 mg/l. Although the range was within the permissible limit based on ECR (ECR, 1997) and WHO (WHO, 1984), however, according to BSTI (Bangladesh Standard and Testing Institute) (BSTI, 2001), the NO_3^- value (9.93 mg/l) in the location LFW-1 exceeded the acceptable limit (4.5). This may be due to the surface runoff or leachate from municipal waste that contains high concentrations of nitrate fertilizer or agriculture-related waste.

Table 2. The physicochemical water quality parameters such as DO (mg/l), temperature (°C), pH, phosphate (PO_4^{3-}, mg/l), nitrite (NO_2^-, mg/l), and nitrate (NO_3^-, mg/l) of the study site

Sample No.	Sample type	Latitude	Longitude	DO (mg/l)	Temp. (°C)	pH	PO_4^{3-} (mg/l)	NO_2^- (mg/l)	NO_3^- (mg/l)
LFW-1	Surface water	23.9984881	90.3408803	0.30	26.2	8.1	3.16	0.392	9.93
LFW-2	Surface water	23.9984820	90.3406744	5.81	23.0	8.0	0.17	0.026	4.10
LFW-3	Surface water	23.9976409	90.3393051	5.37	24.6	7.9	0.44	0.006	1.63
LFW-4	Surface water	24.0009828	90.3384798	0.25	27.9	7.4	7.38	0.011	0.79
LFW-5	Surface water	23.9985617	90.3356733	4.76	25.7	7.6	0.48	0.003	0.48
LFW-6	Surface water	23.9995463	90.3350334	3.47	25.4	8.1	4.90	0.004	0.42
LFW-7	Surface water	23.9956337	90.3349968	1.59	26.6	7.6	1.96	0.008	0.78
Maximum				5.81	27.9	8.1	7.38	0.392	9.93
Minimum				0.30	23.0	7.4	0.17	0.003	0.42
Mean				3.1	25.6	7.8	2.64	0.064	2.59

Concentration and distribution of heavy metals and metalloids

Heavy metals Cr, Fe, Cu, Ni, Mn, Co, Zn, Pb, and Cd and metalloids As can be hazardous and may enter human and other animals' bodies through the food chain (Tasrina *et al*., 2022b). Therefore, it is crucial to know their content and distribution in the different components of the ecosystem and trophic structure. In this study, a total of 10 heavy metals and metalloids (Cr, Mn, Fe, Co, Ni, Cu, Zn, As Pb, and Cd) were measured from each water, sediments, crustacean (*Sartoriana spinigera*), and molluscan (*Pila globosa*) samples (Table 3).

Table 3. Heavy metal and metalloid in the water, sediment, crab (*Sartoriana spinigera*), and mollusk (*Pila globosa*) sample from the sampling site (floodplain) adjacent to the urban waste landfill.

Sample	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Pb	Cd
Water (mg/l)	<0.0004	0.0071	<0.0677	<0.0021	<0.0022	0.016	0.0408	0.0325	<0.0012	<0.0003
Sediment (mg/kg)	27.9	1122.3	15240	20.17	38.99	43.88	71.86	3.664	13.055	<0.0051
Crab (mg/kg)	<0.0077	163.28	164.72	<0.0403	1.65	52.71	192.83	0.596	0	<0.0058
Mollusk (mg/kg)	6.61	669.63	1678.9	1.92	6.90	219.01	370.43	0.650	0.775	0.1357

Note: mg/l = milligram per litter, mg/kg = milligram per kilogram; Crab, Mollusk, and sediment samples were analyzed on dry matter (dr.mt.) weight basis; < indicate the value was calculated based on the threshold determination limit of the metal by the instrument (AAS).

In this study, the concentration (mg/l) of six heavy metals, such as Cr, Fe, Co, Ni, Pb, and Cd, in the water samples was below the detection limit (BDL) of the instrument used for measurement (AAS). The other four metals (Mn, Cu, Zn, and As) concentrations in the water samples were 0.0071 mg/l, 0.016 mg/l, 0.0408 mg/l, and 0.0325 mg/l, respectively. The pattern of heavy metal concentration in the water samples was Zn>As>Cu>Mn (Table 3). The deficient concentration of heavy metals in water may be attributed to the fact that the water in the study site is constantly flowing, and metals cannot be accumulated in one place in the flowing water. However, from the measured metals, Mn and Cu were below the permissible limit according to the WHO (0.4 mg/l) (WHO, 2017) and ECR (0.1 mg/l) (ECR, 1997) guidelines based on drinking water quality. Although the concentration of Zn and As were below the permissible limit by ECR (5 and 0.05 mg/l, respectively), the limit exceeded the WHO (0.01 and 0.01 mg/l, respectively) recommended values (WHO, 2017). The slightly elevated concentration of Zn and As may be due to the contamination of the aquatic environments from urban wastefill. Because pollutants from wastewater cannot be entirely removed by even the most sophisticated wastewater treatment facilities, some substances end up in the background (Banaee and Taheri, 2019).

The metal and metalloid (Cr, Mn, Fe, Co, Ni, Cu, Zn, As, and Pb) content in the collected floodplain sediment samples were 27.9, 1122.3, 15240, 20.17, 38.99, 43.88, 71.86, 3.664, and 13.055 mg/kg (dr. mt.), respectively. Like water, the Cd content was the least abundant (below the detection limit) in the sediment. Ahmed *et al*. (2009) also found the least abundant Cd concentration in the water and sediment samples during their study in the open water ecosystem. However, the order of the heavy metal and metalloid concentrations in the sediment samples was Fe>Mn>Zn>Cu>Ni>Cr>Co>Pb>As (Table 3). The most noticeable differences between the heavy metals and metalloid concentrations in water and sediment are the much higher concentration

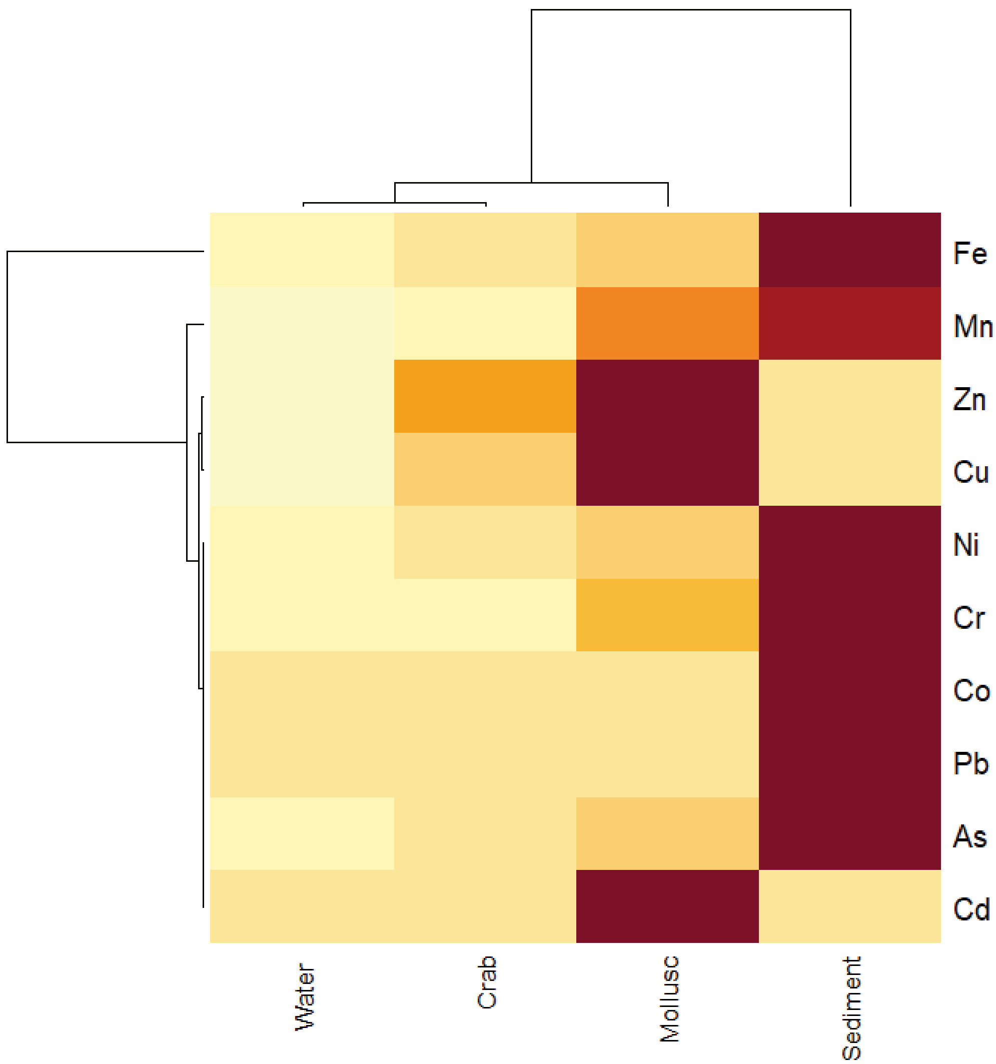

Fig. 3. The Heatmap among the measured heavy metals and metalloids from the water, sediments, crab, and mollusk samples from the floodplain area near the Kodda urban waste landfill.

of all the metals and metalloids in sediment than in water. The relation among the heavy metals and metalloids in the water, sediment, crab, and mollusk in the heatmap in Fig. 3 was also noticed. It is due to the sediment accumulation of runoff metals and metalloids from urban waste landfills and other sources. Among the elements, Fe and Mn concentrations were excessively high, ranging from 14383–16096 and 995–1250 mg/kg, respectively, on a dry weight basis. Excessive Fe comes into the aquatic environment from natural geological sources, industrial wastes, domestic discharge, and byproducts, and the Mn content comes into the sediment from fertilizers, battery manufacturing, the garment industry, varnishes and fungicides, and livestock feeding supplements (Mohiuddin *et al*., 2015). In comparing the heavy metal and metalloid content with other research in a similar manner, it found that Fe and Cu concentrations were greater than the Buriganga river sediment as studied by Mohiuddin *et al*. (2015) and Ahmad *et al*. (2010), respectively. The Cr, Ni, and As concentration in the sediment in this study was much higher than the Buriganga river sediment studied by Akbor *et al*. (2020) and the Mn, Cu, and Zn in the Chalan Beel wetland ecosystem studied by Salam *et al*. (2021).

Benthic crustacea such as crab (*Sartoriana spinigera*) may be sensitive to metal pollution because they live in the bottom sediments where chemical contaminants are mainly stored. They serve as valuable indicators of the degree of pollution in surface sediment (Ololade *et al*., 2011). Since crab legs are frequently immersed in surficial sediments, they may be better able to absorb metals from the sediment. As a result, it is more prone to sedimentation and is anticipated to have elevated metal levels (Zhao *et al*., 2012). In this study, the heavy metals and metalloids such as Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Pb, and Cd accumulated in the edible muscles (Table 1) of the species were measured by AAS. The concentration of the metals Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Pb, and Cd were <0.0077 mg/kg, 163.28 mg/kg, 164.72 mg/kg, <0.0403 mg/kg, 1.65 mg/kg, 52.71 mg/kg, 192.83 mg/kg, 0.596 mg/kg, 0 mg/kg, and <0.0058 mg/kg, respectively on the dry weight (dr. wt.) basis. The concentration of the elements varies according to the order Zn>Fe>Mn>Cu>Ni>As>Co>Cr>Cd>Pb (Table 3). Among the measured elements in the species (*Sartoriana spinigera*), the concentration of Zn was greater, and the concentration of the elements Cr, Co, Pb, and Cd was below the instrument's detection limit (AAS). The elevated concentration of Zn can be explained by the fact that Zn and Cu are essential for crabs to survive physiologically, and they are highly accumulated in the majority of the food that crabs eat, such as debris and tiny benthic organisms. According to the FAO guidelines (FAO, 1983) the concentration of Cr, As, Pb, and Cd in crab was 1 mg/kg, 1 mg/kg, 0.5 mg/kg, and 2 mg/kg, respectively on the dry weight basis (dr. wt). However, measured concentration of these heavy metal and metalloid were not exceed the permissible limits. In contrast, Zn and Cu concentration (mg/kg) exceed the acceptable limit according to the EU guidelines (EU, 2006)

Pila globosa is widely distributed geographically. They are critical in maintaining healthy aquatic ecosystems (Jahan *et al*., 2001). They are also excellent ecological indicators of water pollution. In this study, *P. globosa* were selected because they are a reliable contamination biomarker and biomonitor of water pollution to assess the health of the aquatic ecosystems (Bhattacharya *et al*., 2016). The heavy metal and metalloid concentrations of the analyzed mollusk samples (Table 1) were Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Pb, and Cd, and the values were 6.61, 669.63, 1678.9, 1.92, 6.90, 219.01, 370.43, 0.65, 0.775 and 0.1357 mg/kg, respectively in dry matter basis (Table 3). The order of concentration of the metals and metalloids in the apple snail was Fe>Mn>Zn>Cu>Ni>Cr>Co>Pb>As>Cd. According to the measured concentrations, the Fe and Mn concentrations were higher than other elements, similar to the Fe and Mn concentrations on the sediment samples. Therefore, the excess amount of Fe and Mn in the species (mollusk) might have accumulated from sediment, as these two elements' concentrations were also much higher in the sediment samples (Table 3). The heatmap (Fig. 3) also showed it. In the sediment, these metals accumulated from municipal runoffs, industrial waste disposal, steel industry, battery manufacturing, effluent discharge, chemical plants, untreated waste from tanneries, and chemicals and dye from textile industries. Although most of the analyzed elements in this study support the idea that heavy metals in *Pila globosa* were accumulated from sediment, there was an exception for Cu, Zn, and Cd. Because these element concentrations in the sediment were lower than *Pila globosa* (Table 3 and Fig. 3), since *Pila globosa* is a filter-feeder, they can absorb heavy metals from inorganic particulate matter and sediment, water, detritus, and food. So, these elements may enter the *Pila globosa* through the food chain. A previous study conducted in the wetland ecosystem found that the heavy metals Cr, Mn, Fe, Ni, Cu, Zn, Pd, and Cd concentrations in the *Pila globosa* were 1.7, 4.735, 2065.837, 1.390, 34.7357, 1.534, 0.193, and 0.280 (mg/kg dr.wt.), respectively (Menon *et al*., 2023). Except for Fe and Cd, all the values were much lower than in this study, indicating that ecosystem health degraded due to heavy metals and metalloid pollution in the study area. That is also supported if compared with standard permissible limits of these elements given by FAO (FAO, 1983) and WHO (WHO, 1991) data. The FAO and WHO permissible limits of heavy metals and metalloids (Cr, Mn, Fe, Ni, Cu, Zn, As, Pd, and Cd) of mollusk were 1 (FAO, 1983), 1 (WHO, 1989), 100 (FAO, 1983), 0.5 (WHO, 1991), 30 (FAO, 1983), 40 (FAO, 1983), 1 (FAO, 1983), 2 (FAO, 1983), and 1 (FAO, 1983) (mg/kg dr. wt.), respectively. The values found in the present study exceed these standard permissible limits (FAO and WHO) except As, Pd, and Cd.

Eco-environmental indices evaluation

Eco-environmental risks were evaluated using geostatistical indices to identify the cause and degree (geogenic or anthropogenic) of heavy metals and metalloid pollution. For this, indices like contamination factor (CF), degree of contamination (CD), and Biota-sediment accumulation factor (BSAF) (Table 4 and Fig. 4) were estimated following previous studies (Ahsan *et al*., 2019; Kumar *et al*., 2020).

Table 4. The values of the eco-environmental indices (contamination factor (CF), degree of contamination (CD)

Sample	Contamination factor (CF)								CD
Sediment	Cr	Mn	Ni	Cu	Zn	As	Pb	Cd	
	0.31	1.32	0.57	0.88	0.41	0.24	0.19	0.01	3.93

The analyzed contamination factor **(**CF) values for the measured heavy metals and metalloids like Cr, Mn, Ni, Cu, Zn, As, Pb, and Cd were 0.31, 1.32, 0.57, 0.88, 0.41, 0.24, 0.19, and 0.01, respectively. CF<1 means low contamination, 1≤CF<3 means moderate contamination, 3≤ CF<6 means considerable contamination, and CF≥6 means very high contamination (Hakanson *et al*., 1980). The average CF values for all metals were organized in the order of Mn (1.32: moderate contamination) > Cu (0.88: low contamination) > Ni (0.57: low contamination) > Zn (0.41: low contamination) > Cr (0.31: low contamination) > As (0.24: low contamination) > Pb (0.19: Low contamination) > Cd (0.01: low contamination). According to the contamination factor, most of the elements CF values except Mn were < 1, indicating a low degree of contamination (Table 4). The area's low to moderate level of contamination might be attributed to absorbing a substantial volume of industrial, municipal, and residential effluent from nearby urban waste landfill sites. Hakanson *et al*. (1980) mentioned that CD values<8 indicate a low degree of contamination. The estimated degree of contamination (CD) value for the heavy metals and metalloids was 3.93 in this study, which suggested that the area possesses a low degree of contamination. Among the measured heavy metals and metalloids, the Cu, Zn, and Cd BSAF values of both samples (crab and mollusk) exceed 1 (Fig. 4), indicating a higher level of Cu, Zn, and Cd accumulation in the *Sartoriana spinigera* and *Pila globosa* species from sediment.

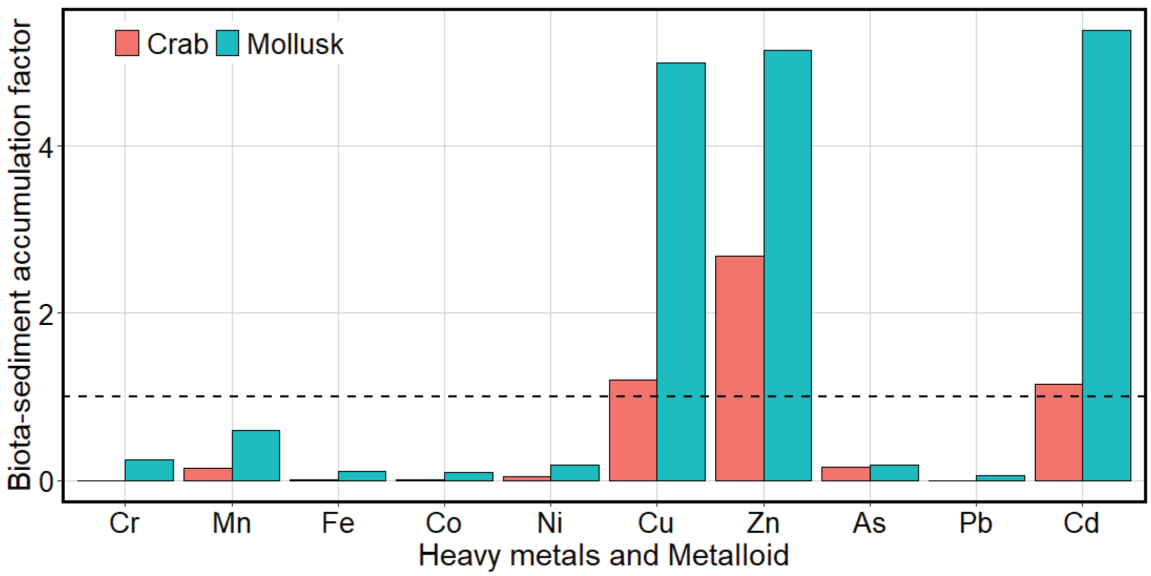

Fig. 4. Biota-sediment accumulation factors (BSAF) of crab and mollusk. The horizontal dashed line indicates the values equal to 1.

Conclusion

This comprehensive study explores the health of ecosystems by examining water quality parameters and the presence of metals and metalloids in water, sediment, and biota (crustacean and mollusk) collected from floodplain ecosystems affected by municipal urban waste. The findings indicated that, among the water quality parameters, the dissolved oxygen (DO) concentration was detrimental to aquatic life in certain locations, with significantly low levels. Additionally, areas with degraded DO content exhibited elevated temperature and phosphate levels. While other analyzed water quality parameters (pH, nitrite, nitrate) remained within acceptable limits, the compromised DO levels, heightened temperature, and increased phosphate content potentially threatened various aquatic species, including fish.

The concentration of heavy metals in water, including Cr, Fe, Mn, Co, Ni, Cu, Zn, As, Pb, and Cd, remained within permissible limits. However, in sediment, the concentration of these elements notably escalated, with higher levels of Cr, Mn, Fe, Ni, Cu, Zn, and Pb compared to other locations in various studies. The order of heavy metal and metalloid concentrations in sediment samples was Fe>Mn>Zn>Cu>Ni>Cr>Co>Pb>As; for crabs, it was Zn>Fe>Mn>Cu>Ni>As>Co>Cr>Cd>Pb, and for mollusks, it was Fe>Mn>Zn>Cu>Ni>Cr>Co>Pb>As>Cd. Cr, As, Pb, Cd, Zn, and Cu in crabs and Cr, Mn, Fe, Ni, Cu, Zn, As, Pd, and Cd in mollusks exceeded standard permissible limits.

Eco-environmental indices suggested that the ecosystem exhibited low to moderate contamination. At the same time, the biota-sediment accumulation factor indicated substantial accumulation of Cu, Zn, and Cd in crabs and mollusks from sediment. Given that the area is impacted by contaminants from municipal waste landfills and is utilized by residents for various purposes, this study recommends regular monitoring and evaluation of the ecosystem to ensure its overall health.

Acknowledgments

The authors are grateful to the Department of Fisheries Management (FMG), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh; the Institute of

National Analytical Research and Service (INARS), Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh; and the Analytical Chemistry Laboratory, Chemistry Division, Atomic Energy Centre, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh for laboratory assistance. The authors also acknowledge Mr. Md. Zahidul Islam, Mr. Md. Saju, and Mr. Md. Sohidul Islam for their help in collecting the samples.

Authors contribution

M. N. Mondal carried out the planning, designing, conceptualization, sample collection and preparation, preliminary manuscript writing, mapping, Figs, and tables. D. M. R. H. Siddiqui and I. J. Promi, preliminary manuscript draft writing, interpretation, communication, and assisted in sample collection. M. E. Ahsan Eco-indices calculation and data calculation, interpretation. T. R. Choudhury and S. Abrarin carried out laboratory analysis and data calculation.

References

Ahmad, J. U. and M. A. Goni. 2010. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. *Environ. Monit. Assess.* 166(1–4): 347–57.

Ahmad, M. K., S. Islam, S. Rahman, M. R. Haque and M. M. Islam. 2010. Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. *Int. J. Environ. Res*. *4*(2): 321-332.

Ahmed, M. K., M. A. Baki, G. K. Kundu, M. S. Islam, M. M. Islam, and M. M. Hossain. 2016. Human health risks from heavy metals in fish of Buriganga river, Bangladesh. *Springer Plus* 5: 1697.

Ahmed, M. K., M. A. Baki, M. S. Islam, G. K. Kundu, M. Habibullah-Al-Mamun and S. K. Sarkar. 2015. Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. *Environ. Sci. Pollut. Res*. 22: 15880–15890.

Ahmed, M. K., S. Ahamed, S. Rahman, M. R. Haque and M. M. Islam. 2009. Heavy metals concentration in water, sediments and their bioaccumulations in some freshwater fishes and mussel in Dhaleshwari River, Bangladesh. *Terr Aquat Environ Toxicol*, *3*(1): 33-41.

Ahsan, M. A., F. Satter, M. A. B. Siddique, M. A. Akbor, S. Ahmed and M. Shajahan. 2019. Chemical and physicochemical characterization of effluents from the tanning and textile industries in Bangladesh with multivariate statistical approach. *Environ. Monit. Assess.*191(9).

Akand, A. B. S. 2020. The wase mountains of Gazipur. The Daily Star. https://www.thedailystar.net/city/news/the-waste-mountains-gazipur-1980321 (Accessed on 22 November 2022).

Akbor, M. A., M. M. Rahman, M. Bodrud-Doza, M. M. Haque, M. A. B. Siddique, M. A. Ahsan and M. K. Uddin. 2020. Metal pollution in water and sediment of the Buriganga River, Bangladesh: an ecological risk perspective. *Desalination Water Treat*, 193: 284-301.

Anik, M. A. H., A. R. Shishir, P. Islam, S. N. Naila and I.M. Chowdhury. 2018. Sustainable solid waste management through 3R strategy in Gazipur City. *Int. J. Environ. Waste Manag*. 22(1–4): 228–38.

APHA, 1998. Standard Methods for the Examination of Water and Wastewater, 12th ed. American Public Health Association, Washington, DC, USA 1268 P.

Backman, B., D. Bodiš, P. Lahermo, S. Rapant and T. Tarvainen. 1998. Application of a groundwater contamination index in Finland and Slovakia. *Environmental geology*. *36*: 55-64.

Banaee, M. and S. Taheri. 2019. Metal bioaccumulation, oxidative stress, and biochemical alterations in the freshwater snail (Galba truncatula) exposed to municipal sewage. *J. Adv. Environ. Heal. Res.* 7(1): 8–17.

Bhatnagar, A. and G. Singh. 2010. Culture fisheries in village ponds: a multi-location study in Haryana, India. *Agric. Biol. J. North Am.* 1(5): 961–8.

Bhattacharya, P., S. Swarnakar, A. Mukhopadhyay and S. Ghosh. 2016. Exposure of composite tannery effluent on snail, *Pila globosa*: A comparative assessment of toxic impacts of the untreated and membrane treated effluents. *Ecotoxicol. Environ. Saf.* 126: 45–55.

Boening, D. W. 1999. An evaluation of bivalves as biomonitors of heavy metals pollution in marine waters. *Environ. Monit. Assess.* 55(3): 459–70.

BSTI, 2001. Bangladesh Standards and Testing Institute, BDS1240, 2001.

Davies-Coleman, H. D. and C. G. Palmer. 2004. The use of a freshwater mollusc, Burnupia stenoch0rias (Ancylidae) as an ecotoxicological indicator in whole effluent toxicity testing. *Proc. 2004 Water Inst. South. Africa Bienn. Conf. 2004;(May):* 309–15.

DoE, 2016. Surface and groundwater quality report 2016. Natural Resource Management and Research Wing, Department of Environment, 2017.

ECR, 1997. The Environment Conservation Rules 1997. Government of the People's Republic of Bangladesh. Ministry of Environment and Forest, 1997.

EU, 2006. Maximum levels for certain contaminants in foodstuffs, Official Journal of the European Union, L 364/5.

FAO, 1983. Compilation of legal limits for hazardous substance in fish and fishery products. Food Agric. Organ. 464, 5–100. FAO fishery circular.

Grasshoff, K., K. Kremling and M. Ehrhardt. 2009. *Methods of Seawater Analysis* (Wiley, 2009).

Guven, K., C. Ozbay, E. Unlu and A. Satar. 1999. Acute lethal toxicity and accumulation of copper in Gammarus pulex (L.) (Amphipoda). *Turk J Boil* 23: 513–521.

Hach Company, 2012. Water Analysis Handbook Hach Company, seventh ed. U.S.A, Loveland, Colorado.

Hakanson, L. 1980. Ecological risk index for aquatic pollution control, a sedimentological approach. *Water Res* 14: 975–1001.

Haque, N. M. Z., I. Hossain and A. K. M. M. Haque. 2023. Assessing the role of urban-local government in providing environmental services: A case study of Gazipur City Corporation in Bangladesh. *South Asian J. Dev. Res. [Internet].* 3(2): 89–107.

Hasan, M. R., M. Anisuzzaman, T. R. Choudhury, T. Arai, J. Yu, M. F. Albeshr and M. B. Hossain, 2023. Vertical distribution, contamination status and ecological risk assessment of heavy metals in core sediments from a mangrove-dominated tropical river, *Mar. Pollut. Bull.*, 189.

Islam, M. S., M. K. Ahmed, M. Habibullah-Al-Mamun and S. Masunaga. 2015a. Assessment of trace metals in foodstuffs grown around the vicinity of industries in Bangladesh. *Journal of food comp. and anal.* 42: 8–15.

Islam, M. S., M. K. Ahmed, M. Raknuzzaman, M. Habibullah-Al-Mamun and S. Masunaga. 2015b. Metal Speciation in Sediment and Their Bioaccumulation in Fish Species of Three Urban Rivers in Bangladesh. *Arch. Environ. Contam. Toxicol.* 68: 92–106.

Islam, M. S., R. Afroz and M. B. Mia. 2019. Investigation of surface water quality of the Buriganga river in Bangladesh: laboratory and spatial analysis approaches. *Dhaka University Journal of Biological Sciences*. *28*(2): 147-158.

Jahan, M., M. Akhter, M. Sarker, M. Rahman and M. Pramanik. 2001. Growth ecology of *Pila globosa* (Swainson) (Gastropoda: Pilidae) in simulated habitat. *Pakistan J. Biol. Sci.* 4: 581–584.

Kumar, A., M. Cabral-Pinto, A. Kumar, M. Kumar and P. A. Dinis. 2020. Estimation of risk to the eco-environment and human health of using heavy metals in the Uttarakhand Himalaya, India. *Applied Sci.* 10(20), 7078.

Menon, M., R. Mohanraj, V. B. Joemon and A. P. Rv. 2023. Bioaccumulation of heavy metals in a gastropod species at the Kole wetland agroecosystem, a Ramsar site. *Journal of Environ. Manag. 329*: 117027.

Mohiuddin, K. M., M. M. Alam, I. Ahmed and A. K. Chowdhury. 2015. Heavy metal pollution load in sediment samples of the Buriganga river in Bangladesh. *Journal of the Bangladesh Agricultural University, 13*(452-2016-35862): 229-238.

Nahar, M. S., M. N. Mondal, M. F. Hasan, J. Shahin, M. A. Haque and A. Nishii. 2017. Geochemical Color Maps of the Dhaka Water, Bangladesh—New Map Presentations for Toxic Metals and Isotopes. *Journal of Geos. and Environ. Prot.* 5(03): 134.

Ololade, I. A., L. Lajide, V. O. Olumekun, O. O. Ololade and B.C. Ejelonu. 2011. Influence of diffuse and chronic metal pollution in water and sediments on edible seafoods within Ondo oil-polluted coastal region, *Nigeria. J. Environ. Sci. Heal. - Part A Toxic/Hazardous Subst. Environ. Eng.* 46(8): 898–908.

Parsons, T., Y. Maita and C. Lalli. 1984. A manual of chemical and biological methods for seawater analysis. Pergamon, Oxford sized algae and natural seston size fractions. *Mar. Ecol. Prog. Ser.* 199: 43–53.

Salam, M. A., M. A. Alam, S. L. Paul, F. Islam, D. C. Shaha, M. M. Rahman and T. Islam. 2021. Assessment of Heavy Metals in the Sediments of Chalan Beel Wetland Area in Bangladesh. *Processes* 9: 410.

Scor-Unesco, W. 1966. Determination of photosynthetic pigments. *Determination of Photosynthetic Pigments in Seawater*. 9–18.

Singh, N. K. S., M. Sudarshan, A. Chakraborty, C. B. Devi, T. B. Singh and N. R. Singh. 2014. Biomonitoring of Fresh Water of Loktak Lake, *India. Eur. J. Sustain. Dev*. 3(1): 179–88.

Singha C., S. Chandan, N. C. Roy and A. Chowdhury. 2018. Observation of fish production and availability of aquatic inhabitants under pen culture in Chatol beel floodplain. *Inter. Jourl. Fishe. Aqua. Res.* 3(3): 61-68.

Tasrina, R. C., T. Islam, A. R. M. T. Islam, M. Hasanuzzaman, A. M. Idris, M. S. Rahman, E. Alam and A. M. S. Chowdhury. 2022a. Multi-media compartments for assessing ecological and health risks from concurrent exposure to multiple contaminants on Bhola Island, Bangladesh, *Emerg. Contam.*, 8, 134-150.

Tasrina, R. C., J. Ferdous, M. M. Haque, M. M. Rahman, S. B. Quraishi and M. S. Rahman. 2022b. Assessment of heavy metals and radionuclides in groundwater and associated human health risk appraisal in the vicinity of Rooppur nuclear power plant, Bangladesh, *J. Contam. Hydro.*, 251, 104072.

WHO, 1984. Guidelines for Drinking Water Quality. 1984. 51 P.

WHO, 1989. Heavy Metals Environmental Aspects. Environment Health Criteria. No. 85, Geneva, Switzerland.

WHO, 1991. World Health Organization), Nickel, Nickel Carbonyl and Some Nickel Compounds, Health and Safety Guide No 62 (Geneva).

WHO, 2017. Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Geneva: World Health Organization. License: CC BY-NC-SA 3.0 IGO.

Zhao, S., C. Feng, W. Quan, X. Chen, J. Niu and Z. Shen. 2012. Role of living environments in the accumulation characteristics of heavy metals in fishes and crabs in the Yangtze River Estuary. *China. Mar. Pollut. Bull. Elsevier Ltd*. 64(6): 1163–71.