Pollution, 4(3): 459-469, Summer 2018
DOI: 10.22059/poll.2018.246483.344
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Health Risk Assessment of Chromium-Accumulated Fish and Vegetables at Gulshan Lake of Bangladesh: A Case Study

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Received: 23.11.2017 Accepted: 10.02.2018

ABSTRACT: The present study evaluates health risk assessment for inhabitants who are exposed to chromium in fishes and vegetables of the Gulshan Lake. In the fish, chromium concentration has amounted to 2.2 to 149.7 mg/kg, while in vegetables leaf and vegetables stem it has been 5.6 mg/kg and 12.0 mg/kg, respectively. What is more, in sediment it has been 179.5 to 308 mg/kg and in water, 4.0 to 16.9 mg/l. Higher accumulation of chromium (149.7 mg/kg) has been found in a fish species, relatively most affordable for poor people, called Pangas (*Pangasius pangasius*). Therefore, due to consumption of this fish the resultant non-cancer health hazard indices to people, living nearby Gulshan Lake has been almost 10 times greater than those induced by safe average daily dosages of the respective chemical. Vegetable pathway is still safe in terms of non-carcinogenic health hazard but may be very likely to act as an additive. It is therefore important to immediately take some remedial measures to not only reclaim Gulshan Lake but prevent any further pollution also.

Keywords: Fish; Pangas (*Pangasius pangasius*); water spinach (*Ipomoea aquatic*); lake sediment; Neutron Activation Analysis (NAA)

INTRODUCTION

Gulshan Lake in the city of Dhaka, which has once been used as a retention pond during heavy downpour and recreational purposes, has now worsened rapidly due to noxious effects on hydrophytes, fish species, and bottom sediment from toxic chemical wastes. These chemicals mainly originate from textile and dying industries, situated in the nearby Tejgaon industrial area and all sewerage wastes coming from the areas of Gulshan, Baridhara, Kalachandpur, Nadda, Shaorabazar, and Godaraghat get mixed in this lake (Quraishi et al., 2010). PMF (Positive Matrix Factorization) and CF (Contamination Factor) have successfully identified the major sources of metals (Pb, Cr, As, and Cd) from tannery, paint, municipal sewage, textiles, and agricultural activities in water as well as sediment

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samples of different rivers in Bangladesh (Bhuiyan et al., 2014; Ali et al., 2016). Pollution Load Index (PLI), geo-accumulation (Igeo), and degree of contamination (Cd) from previous studies have revealed that most of the sediment samples were moderately to heavily contaminated by heavy metals of urban rivers in developing countries (Banu et al., 2013; Islam et al., 2015). Chemicals that are derived from industrial effluents, released following the generation of corrosion inhibitors, pigments containing metals (Galvin, 1996), or other sources ultimately find their way into different water bodies and can produce a wide range of toxic effects in aquatic organisms, from single-cell species to whole populations of more complex creatures (Mathis and Cummings, 1973; Bernet et al., 1999). Elevated concentrations of heavy metals have been observed in the soil and crops, cultivated in Lihe River Watershed of Taihu Region, and their potential health risk assessment has turned out to be quite significant for local inhabitants when ingested (Chen et al., 2017). Among all toxic metals in the environment, chromium is a relatively scarce one, the occurrence and amounts of which are thereof generally very low in aquatic ecosystems (0.001 to 0.002 mg/l) (Moore and Ramamoorthy, 1984; DWAF, 1996). However, from the aforementioned sources natural water may receive much chromium, which then becomes a pollutant of aquatic ecosystems, getting accumulated in aquatic organisms (Srivastava et al., 1979; Madoni et al., 1996; Hadjispyrou et al., 2001; Mortuza et al., 2005; and Mohinuzzaman et al., 2013).

The process whereby an organism concentrates metals in its body from the surrounding medium or food, either through absorption or ingestion, is known as bioaccumulation (Forstner and Wittmann 1981). According to Heath (1991), fish can regulate metal concentration to a certain limit, after which bioaccumulation occurs. Bioaccumulation of metal within an organism results from the interactions of various factors like physiological (growth, weight loss, absorption, and accumulation), chemical (metal concentration, speciation, and bioavailability), and environmental ones (temperature and food concentration) (Casas and Bacher, 2006; Holdway, 1988). According to USEPA-IRIS (Integrated Risk Information System) (2010) database, ingestion of chromium in human body from varieties of chromium-accumulated food like fish, vegetables, grains, fruits, or yeast poses non-carcinogenic potential health risk and can develop cancer to some extent in case the metal is inhaled. So, there is a need to accurately quantify the toxicological risk of chromium to the residing populations in the contaminated environment. But there have been very few works in Bangladesh till date to address this issue. Among these works, numerous researchers (Kamal et al., 1999; Rahman and Hossain, 2008) have illustrated the pollution status of rivers around Dhaka city and some (Ahmed et al., 2005 and Quraishi et al., 2010) have worked on pollution level of water and sediment of the Gulshan Lake. Bioaccumulation of chromium in vegetables and consequent health risk has been investigated for both adults and children, showing that there was no risk to local population from dietary intake of these vegetables. Accumulation of heavy metals (V, Cr, Mn, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sb, Ba, and Pb) determined by ICP-MS (Induced Coupled Plasma Mass Spectrophotometry), ICP-OES (Induced Coupled Plasma Optical Emission Spectrophotometry), AAS (Atomic Absorption Spectrophotometry), and associated human health risk have been examined in different fish species, crustaceans, and shellfish from lakes, rivers, bays, and estuaries (Ahmed et al., 2015; Kaya et al., 2017; Plavan et al., 2017; Thakur & Mhatre, 2015). In most cases, it has been suggested that consumption of fish at that accumulation level was safe, though continuous and excessive use for a long time with its cumulative effects is likely to incur cancer risk.

Nevertheless, in previous studies a certain fish species, known as *Pangasius pangasius*, as well as a certain kind of vegetable, called *Ipomoea aquatic*, have not been investigated; neither have Instrumental Neutron Activation Analysis (INAA) been used. Therefore, this study has dealt with physico-chemical properties of Gulshan Lake water and chromium accumulation in fishes, vegetables, and soil in order to assess the risk of adverse health effects on human exposure to chromium through fish and vegetable pathways.

MATERIAL AND METHODS

Gulshan Lake (Fig. 1), situated in the north-eastern side of Dhaka city, is a semi-natural freshwater lake, occupying an area of about 210 acres. It was planned and dug out of the low lying land in the Gulshan-Baridhara residential areas to provide the residents with an environment-friendly landscape (Anwar et al., 2002). The depth of the lake in summer ranges from 4m at the margins to 9m in the center; however, in winter these numbers fall to 1m and 6m, respectively. Many drains and gullies discharge into the lake (Ahmed et al. 2005). The lake has multiple uses such as fishery, boating facility, washing, and bathing purposes to slum people (many slums are situated in Gulshan). Biodiversity accounts for 2 vegetation types in the watershed area, 15 fish species (6 cultured species and 9 natural ones), and 6 aquatic macrophytes. Still about 150 tons of various fish species are cultivated in this lake as of now, 70% of which are Pangas (*Pangasius pangasius*), thanks to its high growth rate and no additional food required except for the sewerage waste coming from surrounding area. What is more, huge amount of vegetables such as Water Spinach (*Ipomoea aquatic*) are naturally grown in this lake and are regularly sold in the local market.

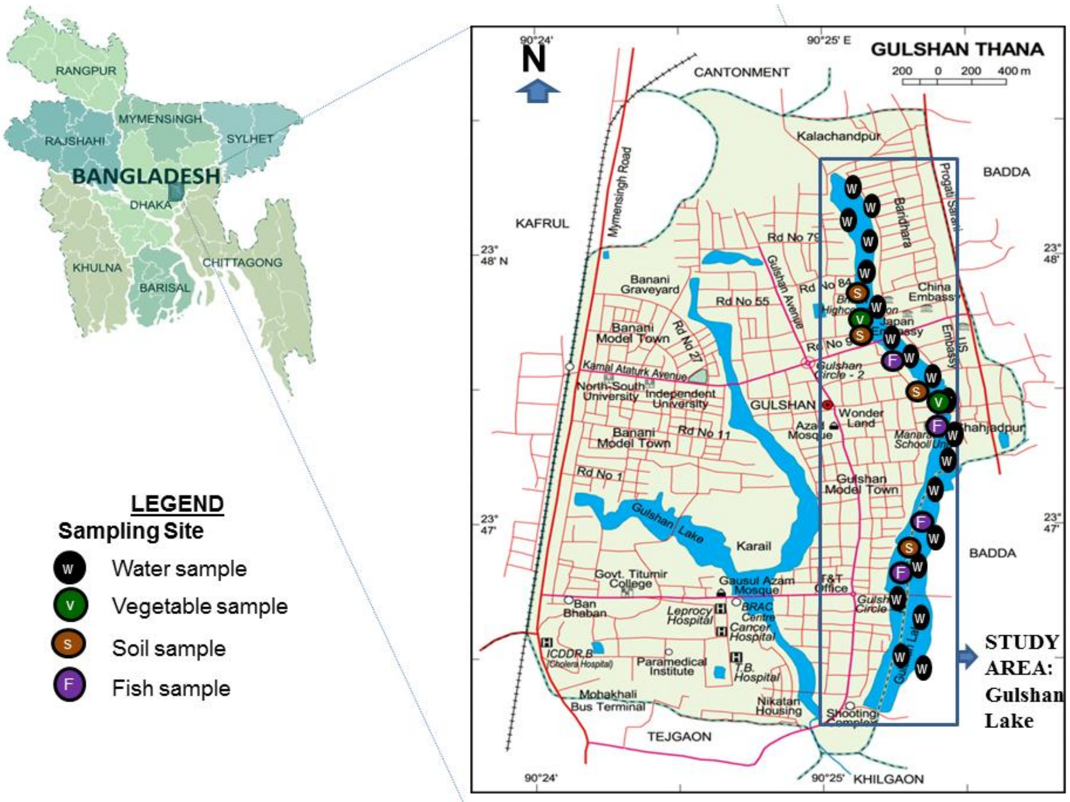

Fig. 1. Map of study area

For this research, 5 fish species named *Catla catla* (local name: Catol), *Oceochromis mossabica* (local name: Tilapia), *Cirrhinus mrigala* (local name: Mrigal), *Pangasius pangasius* (local name: Pangas), and *Hypophthalmichthys nobilis* (local name: Silver Carp), 1 leafy vegetable, called *Ipomoea aquatic* (Water Spinach), 19 water samples, and 3 sediment samples were collected from different locations of the lake. Sediments and water samples were kept in prewashed plastic containers (100 ml), the former being taken from below 2-3 cm of water-sediment interface where the lake was 4ft in depth. All these samples got transferred to the laboratory immediately, there to be measured for physico-chemical properties of water (Temperature, pH, TDS, Turbidity, EC, DO, and BOD) by means of standard procedures (APHA, 1998). Once the physico-chemical properties of water were evaluated (Table 1), only 4 water samples were randomly selected for chromium detection out of all 19 water samples, which had almost the same properties. These then got acidified (with 4ml/liter of HNO_3) and were stored in refrigerator.

After being washed with distilled water, the fish samples were dissected and only the muscle parts were taken with the help of a stainless steel stiletto. All the muscle samples were separately oven-dried to a constant weight of 105±20°C, each to be ground to powder with the aid of a mortar and pestle and then preserved in a desiccator for further analysis. Water spinach samples were thoroughly cleaned under tap water and then distilled with deionized water, then to be cut into small pieces with a stainless steel knife into leaf and stem parts. The raw vegetables sample were dried in an oven at 80ºC for 2-3 days and the resultant dried samples were then powdered and preserved in a desiccator for NAA. Approximately, 50 g of each sediment sample got dried in an oven at 110°C, and their moisture content was determined. The dried samples were then ground for 20 min in an automatic agate mortar and pestle grinder to produce homogenous powders, the particles of which were below 63µm in size. However, four water samples, taken for determination of chromium, were evaporated in the oven at 80^0C with 1g cellulose powder and got heated until a constant weight of residues was obtained. The final dried residue samples were grounded in mortar and pestle, thence to be kept in a desiccator until target preparation.

Instrumental Neutron Activation Analysis (INAA) was employed to determine the chromium content of the designated samples. Powdered and dried samples (100 mg for sediment and 150 mg for vegetables, fish, and water), as well as standard IAEA-Soil-7, IAEA-1633b, and IAEA-SL-1 were enclosed in a polyethylene capsule, placed at the center of the reactor by a pneumatic tube and irradiated for 40 min. The irradiated samples were allowed to cool for 3 weeks, and then emitted gamma-ray intensities were measured for each sample, using an HPGe detector associated with a computer-based Canberra S-100 Multi-Channel Analyzer (MCA) master board packages. The spectra for samples and standards were analyzed both manually and by means of HYPERMETPC software and finally concentrations of chromium were measured. The results obtained for samples were in good agreement with the certified values. For example deviation of experimental values for chromium in IAEA-1633b and IAEA-SL-1 was only 1% and 0%, respectively, compared to the certified value.

RESULTS AND DISCUSSION

The present study investigated some physico-chemical properties of Gulshan Lake water (19 sampling points) so as to recognize environmental factors for bioaccumulation, like temperature, TDS, turbidity, pH, EC, DO, and BOD, with Fig.

2 illustrating their values. Temperature, TDS , turbidity, and pH values of Gulshan Lake water were not very high, ranging from 25.7 to 29.6 (^{0}C), 1.7 to 2.3 (g/l), 24-81 (FTU), and 6.6 to 7.3, respectively. Values of the remaining parameters, namely EC and DO, were very alarming, considering the national standard level (Table 1). Their values ranged between 4190 and 5460 (μs/cm) and between 0.9 and 2.3 (mg/l), respectively. However, the matter of great concern was that the mean of measured EC and DO values was almost twice greater and 3.6 times lesser than the standard values of these parameters for lake environment, respectively (Table 1).

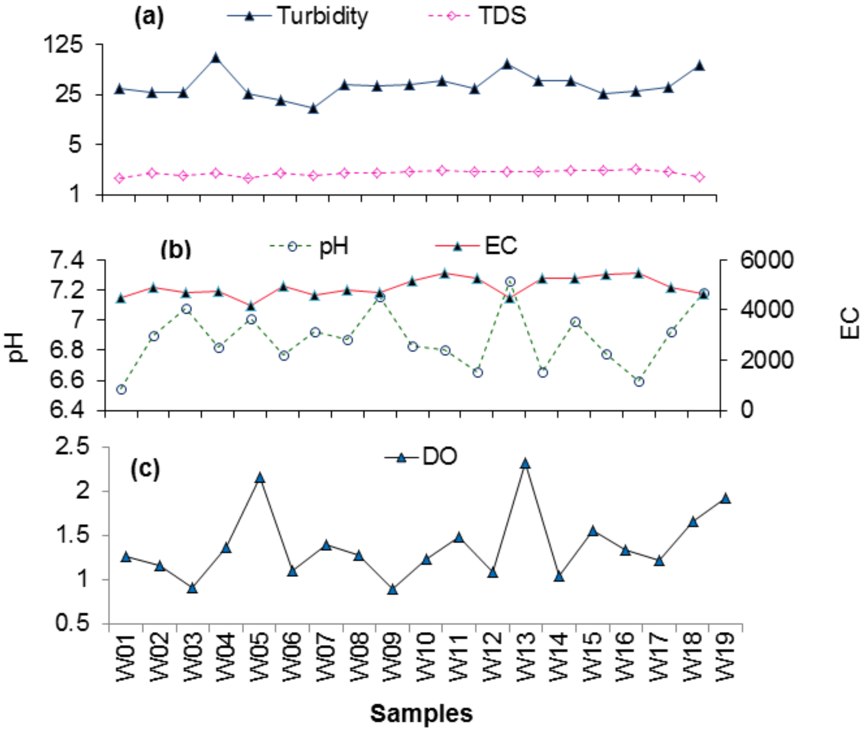

Fig. 2. Illustration of various physic-chemical parameters of watersamples; (a) pH and EC values (b) Turbidity and TDS values (c) DO values

Table 1. Standard values for lake water

Parameter	Standard
pH$^{(a)(b)}$	6.5 - 8.5
EC (μs/cm) $^{(c)}$	2250
DO (mg/l) $^{(a)(b)}$	≥5

$^{(a)}$ National standard of inland surface water (lake) usable for fisheries (DoE, 2003)

$^{(b)}$ National standard of inland surface water (lake) usable for recreational activity (DoE, 2003)

$^{(c)}$ National standard of inland surface water (lake) usable for irrigation activity (DoE, 2003)

Chemical factors, contributing to bioaccumulation, such as metal concentration (chromium) in water and sediment, got investigated as well, showing higher concentrations that ranged within 3.95-16.94 mg/l and 179.47-308.1 mg/kg, respectively (Table 2), considered higher than what may be identified for typical unpolluted systems. It is evident that the concentration of chromium in water was the highest where various nearby textiles and dyeing industries discharged untreated effluents (Quraishi et al., 2010) into Gulshan Lake. Though no specific standard limit has been set for chromium concentration in various compartment like water and sediment of lake (unpolluted) in Bangladesh, Moore and Ramamoorthy (1984) reported that dissolved concentration of chromium in unpolluted lakes and rivers generally varies between 0.001 and 0.002 mg/l. Ramoliya et al. (2007) illustrated that chromium level in sediments varies greatly and depends on composition of parent rock from which the sediment is originally formed and –to some extent—on the chromium, dissolved into water from this chromium-rich sediment. But, pollutants might not enter into the water from the soil; instead they may come from various nearby industrial sources, in which once they enter the lake, they get distributed into various compartment of water body, like surface water, aquatic organisms, or bottom sediment. Results (Table 2) showed that bottom sediment contained significant amounts of chromium, several times greater than the chromium in surface water. Seenayya and Prahalad (1987) also found similar results, reporting that chromium concentration in surficial sediments of Husainsagar Lake of India was several fold greater than the surface water. During the sampling phase in this work, it was observed that the lake water was slightly greenish in color, indicative of high planktonic presence. The plankton probably adsorbed chromium from water to a significant extent and their sinking to the bottom of the lake resulted in substantial enrichments of this metal in bottom sediment. Similar evidence was also found by Seenayya and Prahalad (1987). Moreover, in the current work, the industrial and domestic waste inputs to the lake caused a sharp drop in dissolved oxygen content, which might be due to the activity of sulphate-reducing bacteria. This situation can be reduced, removing chromium (+6) by reducing it to chromium (+3) and ultimately increasing the particulate matter (Seenayya and Prahalad, 1987). Moore and Ramamoorthy (1984) found out that the dominating fraction of chromium in freshwater would be in the particulate matter.

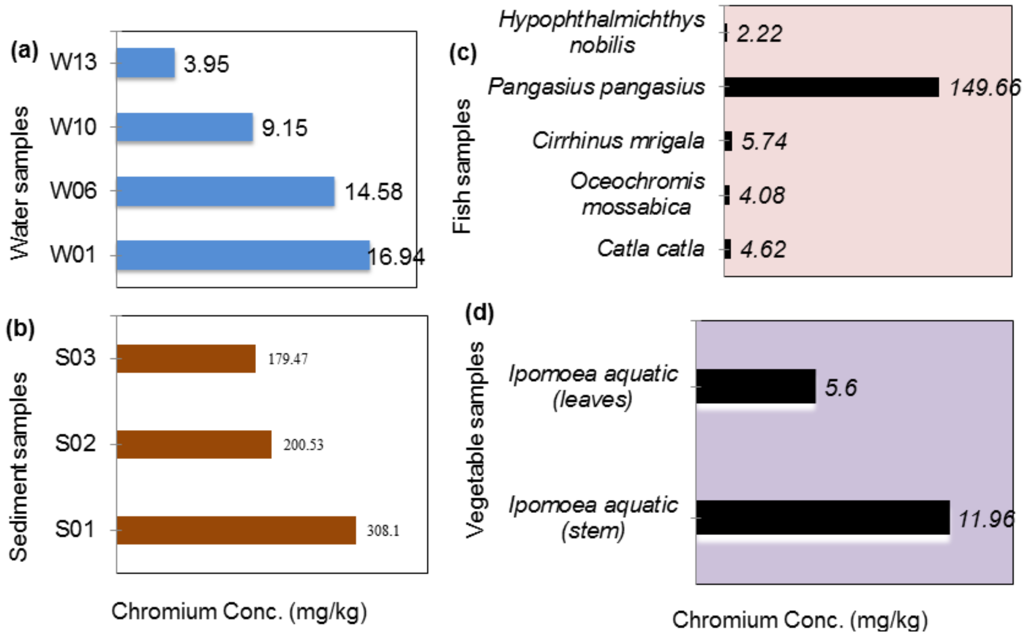

Fig. 3. Concentrations of Chromium (Cr) in Lake (a) water; (b) sediment; (c) fish and (d) vegetable samples.

Table 2. Concentrations of Chromium in water and sediment of Gulshan Lake

Compartment of lake	Sample	Conc. of Cr (^{a})
Water	W01	16.94
	W06	14.58
	W10	9.15
	W13	3.95
Sediment	S01	308.1
	S02	200.53
	S03	179.47

(^{a}) Unit (water sample mg/l and sediment sample mg/kg)

Chromium accumulation of five fish species was found with the results, showing that chromium in these fish species varied from 2.22 to 149.66 mg/kg (Fig. 3) on dry weight basis with *Pangasius pangasius* enjoying the lion's share among these species. When fish or other organisms are exposed to elevated levels of metal in an aquatic environment, they can absorb the bioavailable metals directly from the environment via various exposure routes like gills, skin (fish), root system (hydrophytes), or through ingestion of contaminated water or food. Thus, bioaccumulation of metal differ in various organ or tissue of the fish such as the kidney, liver, gill, skin, and muscle (Al-Kahtani, 2009; Nussev et al., 2000; Ramoliya et al., 2007). To illustrate this with an example, Javed (2005) investigated the bioaccumulation of Zinc in *Catla catla* and *Cirrhinus mrigala* and found that these fish species accumulate Zinc in their various organs non-uniformly, with the muscle part containing the least amount of Zinc. Eleven trace elements (Zn, Mn, Cu, Fe, Cr, Ni, Co, Hg, Pb, Cd, and As) were determined in the muscles of six fish species (*Scardinus knezevici*, *Alburnus scoranza*, *Cyprinus carpio*, *Rutilus prespensis*, *Anguilla Anguilla*, and *Perca fluviatilis*), collected from Skadar Lake (Rakocevic et al., 2017). In this study, the total metal accumulation was found the highest in roach and the lowest in perch, while European eel was found to accumulate more arsenic than other fish species. But the present research investigated chromium only in the muscle part of the designated fish species, as muscle is the main edible part of fish (Nussev et al. 2000). Ramoliya et al. (2007) reported that chromium in aquatic ecosystem follows a trend similar to its transfer from soil to water and ultimately to living organisms. Therefore, comparatively, chromium in water retained in low level. Moreover, based on the food habit of these fish species, it was summarized that algae, plankton, hydrophytes, protozoa, crustacean, wastes, and sediments are the main essential foods, required at various amounts, depending on the species, themselves, or the size. From the discussion it was evaluated that the reason behind bioaccumulation of chromium in these fish species was in favorable conditions.

However, water spinach (*Ipomoea aquatic*) is abundantly grown in Gulshan Lake and is very cheap, tasty, nutritious, and preferred by every class of people in the city. This species contained varied amounts of chromium in its different parts, e.g., stem of water spinach contained 11.96 mg/kg, while 5.60 mg/kg of chromium gathered in the leaves. Moreover, various hydrophytes are used as phytoremediation of heavy metals in polluted water (Lone et al., 2008); therefore, hydrophytes might be one of the major sources of heavy metal accumulation in human body.

Lee et al. (2005) demonstrated the basic framework to assess the health risk of an adult farmer, who resided in Songcheon gold-silver mine area and was exposed to arsenic and other heavy metals in the contaminated soils and water. Here, however, this basic framework was used to assess the health risk of an adult human who resided in the Gulshan Lake area and was exposed to chromium in contaminated fish and vegetables. Among the studied fish species, the maximum chromium was accumulated in *Pangasius pangasius,* mostly consumed by poor people (slum people) for its relatively cheap price. Thus it was regarded as the fish pathway, whereas leaves became the vegetable pathway, since they are the most edible part of leafy vegetables. Water, though a major pathway for ingestion of contaminant object in human body, was not considered in the current case, because the people in slum mostly used water supply from the city pipe water distribution system for domestic purposes. The dosage of the exposures may be estimated by the expected quantities of toxicants in the ingested fish and vegetables. The average daily dose (ADD) of the contaminant via the identified pathways (i.e., fish ingestion and vegetables pathways) indicated the quantity of chemical substances, ingested per kilogram of body weight per day (Kolluru et. al., 1996 and Paustenbach & Reilly, 2002) that:

$$\mathrm{ADD} = \frac{\mathrm{C} \times \mathrm{IR} \times \mathrm{ED} \times \mathrm{EF}}{\mathrm{BE} \times \mathrm{AT} \times 365} \qquad (1)$$

where C is the concentration of the contaminant in the environmental media (mg/kg); IR, the ingestion rate per unit time (mg/day); ED, the exposure duration (years); EF, the exposure frequency (days/year); BW, the body weight of the receptor (kg); AT, the average time (years) equal to the life expectancy; and 365, the year-to-day conversion factor. Table 3 shows the principal exposure factors, taken into account, to carry out the risk assessment calculations.

The outcome of ADD estimations for chromium with the two exposure pathways, namely fish pathway and vegetable pathway, was 3.0×10^{-2} and 1.0×10^{-3} mg/kg/day, respectively. The average daily intakes of chromium via the fish pathway were approximately 30 times greater than those of vegetable ingestion pathway.

Table 3. Exposure factors for an adult, residing in Gulshan Lake

Factor/Parameter	Symbol	Unit	Residential	Data source
Exposure Duration	ED	Years	30	USEPA, 1997
Exposure Frequency	EF	Days/year	350	USEPA, 1997
Averaging Time	AT	Years	66	National Standard (DoE, 2003)
Body Weight	BW	Kg	60	National Standard (DoE, 2003)
Ingestion Rate				
Fish	IR_f	Kg/day	0.028	Aquaculture News (2008)
Vegetables	IR_v	Kg/day	0.025	FAO (2011)

Due to the exposure of harmful chemicals, toxic risks can also be referred as non-carcinogenic harms. The extent of the harm is indicated in terms of a hazard quotient (HQ):

$$\mathrm{HQ} = \frac{\mathrm{ADD}}{\mathrm{R_f D}} \qquad (2)$$

where the R_fD is the reference dose, the estimate of the highest dose that can be taken every day over a prolonged time period without causing an adverse non-cancer effect. The R_fD value for chromium was 0.003 mg/kg/day, derived from USEPA-IRIS (2010) database. But when more than one potential toxicant is present, the interactions must be considered and toxic risks, due to potentially-hazardous substances present in the same media, are assumed to be additive. According to Kolluru et al. (1996) and Paustenbach & Reilly (2002), the HQs values of all hazardous substances are then summed up to achieve the overall toxic risk, the hazard index (HI) (HI = $\sum HQ_i$; I = 1….n). They also described that if the calculated HI is less than 1.0, the non-carcinogenic adverse effect due to this exposure pathway or chemical can be neglected. But this research considered one chemical and, based on Equation 2, HQ values for fish and vegetables pathways were almost 10 and 0.4, respectively. So, HI value for fish pathway was obviously higher than 1.0, if other toxic substances may or may not be present. For vegetable pathway, HI value may or may not be higher than 1.0 in the presence of other substances; therefore, there was a good chance of non-carcinogenic risk in the exposure of chromium via fish pathway and minimal risk through ingestion of vegetables.

CONCLUSION

Chromium level in water and sediment was higher than admissible limit, hence fish and vegetables accumulated chromium in their bodies through bioaccumulation from this polluted environment. Among the investigated fish, *Pangasius pangasius* (local name, Pangas), accumulated chromium in their muscle part significantly. *Ipomoea aquatic* (Water spinach) also absorbed chromium in the order of stem, followed by leaf. ADD value of chromium via the fish pathway was about 30 times higher than those of vegetable ingestion pathway. The outcome of the risk assessment showed that toxic risk (Hazard Index) of chromium for exposure of individuals (adult human), residing in Gulshan Lake area, was significantly higher due to their exposure from *Pangasius pangasius* fish taken from this lake. Consumption of *Ipomoea aquatic* of Gulshan Lake might not be very significant to develop non-carcinogenic health risk, but act as an additive in total health risk of more than one toxic chemical. So, the total information, gained from this research, was worrisome in the view of health implications for the population who depend on Gulshan Lake for their fish and/or vegetables' requirements. As a result, in view of the possible risks to health of human population, it is suggested to monitor chromium loads or pollution status of Gulshan Lake very closely.

Acknowledgement

Authors are very much grateful to the Director of Reactor and Nuclear Physics Division (RNPD), Institute of Nuclear Science and Technology (INST), and Atomic Energy Research Establishment (AERE), Savar, Dhaka, for his kind permission for using the laboratory.

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