Assessment of heavy metal concentration in edible fish muscle and water sample collected from different location in Chittagong: a public health concern

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Abstract

Introduction. The research was carried out to investigate the concentration of heavy metals in fish and water samples collected from different locations of Chittagong District, Bangladesh.

Materials and methods. The concentrations of heavy metals including Cr, Cu, Ni, Pb and Fe in sea water and marine fishes (pama croaker, bombay duck and rat-tail anchovy) were detected by using Air / Acetylene Flame Atomic Absorption Spectrophotometer along Chittagong City areas, Bangladesh.

Results and discussion. The mean concentration of heavy metals were found in water in the range as Cr 0.0138–0.0789 mg/L, Cu 0.0014–0.0284 mg/L, Ni 0.0259–0.2519 mg/L, Pb 0.0109–0.1596 mg/L and Fe 0.2176–1.787 mg/L. The analysis of water samples showed that the distribution of heavy metals in the order of magnitude as Fe > Ni > Pb > Cr > Cu. The variation might be due to location, level of contamination in water through industrial effluents and anthropogenic activities. While the mean concentration of heavy metals were found in all fish samples in the range as Cr 3.2039–16.3495 mg/Kg dry wt., Cu 1.5589–4.5848 mg/Kg dry wt., Ni 0.1101–1.9029 mg/Kg dry wt., Pb 0.4373–2.7638 mg/Kg dry wt. and Fe 30.9599–108.780 mg/Kg dry wt. The distribution of heavy metals in fish samples analyzed were in the order of magnitude as Fe > Cr> Cu> Pb> Ni. The analysis showed that magnitudes of heavy metal were more or less similar with other researchers. The variation might be due to metal accumulation in fish and various fish species living in the same water body but different level of contamination in water. Among all samples, 17% fish samples had excess amount of Cr whereas acceptable limit is 15.0 mg/kg for fish. Mean concentrations of Pb in all fish samples were 17% below detection level, 33% optimum and 33% higher than the maximum permitted concentrations (1.5 mg/Kg). Fe in all fish samples were 33% below, 17% optimum and 50% higher than the maximum permitted concentrations (43 mg/Kg) recommended by FAO/WHO.

Conclusions. Most of the fish species studied are safe to be consumed. Therefore, this study is proposed to draw the attention of health and environmental authorities in need for appropriate regulatory framework.

Introduction

Fish, as human food, are considered as a good source of protein, polyunsaturated fatty acids (particularly omega-3 fatty acids), calcium, zinc (Zn), and iron [1]. Due to the lower cost and higher nutritive value, it is one of the most important sources among the food products of animal origin [2,3]. In future, seafood will be an vital source of food protein and the safety for human consumption of products from aquaculture is of public health interest [4].

Heavy metals are an important source of food contamination and health hazard. The main threats to human health are associated with exposure to arsenic, cadmium, lead and mercury and copper. Absorption of heavy metals through food has been shown to have serious consequences on health– such as kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, bone fracture, cancer and death [5].

Heavy metals are contaminants in the aquatic environment as well as became toxic health threat for human. Fish play important role in condensing the toxicity of heavy metals which have a great ecological significance due to their cumulative behavior and toxicity [3].

The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal [6,7]. The aim of this study was to assess the levels of some heavy metals in water and fish specimens caught from different localities in Chittagong coastal area, Bangladesh. Public health importance and the hazardous toxic effects of these heavy metals and fish contamination with these were discussed.

Materials and methods

Collection of water samples

The water samples were obtained from 12 sampling stations established along 5 regions (Figure 1). The sampling stations were chosen based on an experimental scheme design following human activities in the area. These regions are main fishing centers of Chittagong, Bangladesh and also, a variety of industries and touristic centers are concentrated in these regions. Following the large volume of population and industries located there, the five regions were selected to measure the heavy metals concentrations in water samples during summer season (Table 1).

Table 1

List of sampling stations for water collection from Chittagong, Bangladesh

Sampling station Code	Regions
W_1	Majhir Ghat
W_2	
W_3	Firingi Bazar
W_4	
W_5	Sea-resource Ghat
W_6	
W_7	Chaktai Khal
W_8	
W_9	Uttar Kattoli
W_{10}	
W_{11}	Uttar Kattoli Pond
W_{12}	

Collection of fish specimens

Pama croaker (*Otolithoides pama*), bombay duck (*Harpadon nehereus*) and rat-tail anchovy (*Coilia ramcarati*) were collected from four different market in Chittagong Metropolitan area, Bangladesh (Table 2). Twenty fish of each species were collected from each market. The fish were washed with deionized water and wrapped separately in acid washed polyethylene bags and were stored frozen at -20°C until analysis.

Materials

All reagents used in this work (HNO_3, NaOH, HCl, KI, $HClO_4$, K_2CrO_4, $NaBH_4$, acetylene and argon gas) were of analytical grade and purchased from Merck (Germany).

Table 2

List of market for fish collection in Chittagong, Bangladesh

Location	Fish Samples code		
	Pama croaker	Bombay duck	Rat-tail anchovy
Market 1	P_1	B_1	R_1
Market 2	P_2	B_2	R_2
Market 3	P_3	B_3	R_3
Market 4	P_4	B_4	R_4

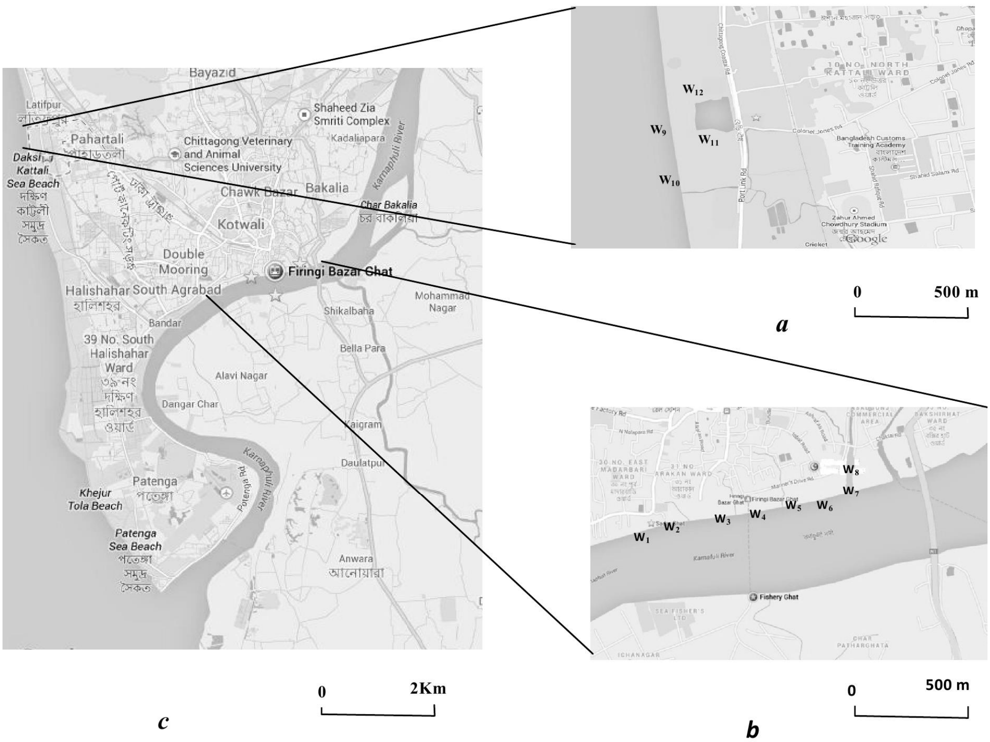

Figure 1. Location map of the study areas (Source: Google map, 2018)

Preparation and analysis of water samples

The water samples were preserved by the addition of 1 ml of concentrated nitric acid per liter until the time of analysis. The analysis of water samples was carried out according to American Public Health Association [8]. They were filtered through 0.45 μ membrane filter. The required volume (100 ml) of the filtrate was used to measure heavy metal levels in water samples by using Air/ Acetylene Flame Atomic Absorption Spectrophotometer.

Preparation and analysis of fish specimens

Fish samples were allowed for thawing and the skin of the fish was removed using a plastic knife to avoid metal contamination. The muscles of fish were taken into pre-acid washed crucibles and they were homogenized separately. The weight of each homogenized sample was recorded. Then the samples were kept in a drying oven at 100° C for more than 24 hrs until a constant weight was observed. The dried samples were then ground into a fine powder using a porcelain motor and a pestle. Powdered fish tissues were digested using a dry ashing procedure [9]. They were filtered through 0.45 μ membrane filter. The required volume (100 ml) of the filtrate was used to measure heavy metal levels in water samples by using Air/ Acetylene Flame Atomic Absorption Spectrophotometer.

At each step of digestion processes, acid blanks were prepared in order to ensure that the samples and chemicals used were not contaminated. They were analyzed by atomic absorption spectrophotometer. Each set of digestion has its own acid blank and was corrected by using its blank.

Each standard solution was measured 3 times and the mean were plotted. A blank solution of distilled water was used to check accuracy of the standard solutions and it was run after every 10 samples.

The metal content will be calculated using the formula:

$$C = \frac{C_{AAS} \cdot V}{W}$$

where C – concentration (mg Kg^{-1}or ppm dry wt.)

C_{AAS} – concentration of the element through AAS (ppm)

V – volume made up

Data Analysis

The data obtained from the experiments were statistically analyzed for find out mean and standard deviation among the various samples in triplicate. Data were analyzed using the software, IBM SPSS Statistics, version 20 at the 0.05 level.

Results and dscussion

Heavy metal in sea water

The Mean concentrations and associated standard deviations of Cr, Cu, Ni, Pb and Fe in sea water are presented in Table 3. The mean concentration of heavy metals were found in water in the range as Cr 0.0138–0.0789 mg/L, Cu 0.0014–0.0284 mg/L, Ni 0.0259–0.2519 mg/L, Pb 0.0109–0.1596 mg/L and Fe 0.2176–1.787 mg/L. The distribution of heavy metals in water samples analyzed were in the order of magnitude as Fe > Ni > Pb >

Cr > Cu. Ismail and Saleh (2012) [10] detected heavy metals of water in the order of Fe > Cu, whereas concentrations Pb was below the detection limit. According to El-Kattan (2018) [3], the contents of heavy metals in water were in the order of degree as Cr > Cu > Pb > Fe. Kumar *et al.* (2013) [12] also found heavy metal concentrations in Ennore creek sea water decreased in the order of Cu > Cr > Ni > Pb. The analysis showed that magnitudes of heavy metal were more or less similar with Ismail and Saleh (2012) [10] reported but differ from Ambedkar and Muniyan (2012) [11] and Kumar *et al.* (2013) [12]. The variation might be due to location, level of contamination in water through industrial effluents and anthropogenic activities.

Table 3

Concentration of heavy metal in sea water*

Sampling station Code	Cr (mg/l)	Cu (mg/l)	Ni (mg/l)	Pb (mg/l)	Fe (mg/l)
W_1	0.0530±0.0034	0.0251±0.0038	0.0259±0.0091	0.1555±0.0130	1.140±0.0340
W_2	0.0252±0.0234	0.0188±0.0053	0.0384±0.0017	0.1596±0.0204	1.270±0.0586
W_3	0.0303±0.0244	0.0163±0.0039	0.2350±0.0064	0.0118±0.0013	1.196±0.0387
W_4	0.0138±0.0123	0.0284±0.0060	0.2519±0.0035	0.0109±0.0054	1.280±0.0206
W_5	0.0518±0.0173	0.0119±0.0070	0.0568±0.0039	0.1379±0.0141	1.252±0.0179
W_6	0.0789±0.0197	0.0081±0.0057	0.0815±0.0026	0.1313±0.0241	1.342±0.0431
W_7	0.0310±0.0060	0.0183±0.0034	0.2007±0.0007	0.0265±0.0039	1.787±0.0088
W_8	0.0168±0.0058	0.0259±0.0021	0.2024±0.0026	0.0129±0.0060	1.325±0.0063
W_9	0.0237±0.0096	0.0035±0.0019	0.1179±0.0049	0.1196±0.0117	0.3382±0.0150
W_{10}	0.0304±0.0230	0.0036±0.0013	0.1348±0.0044	0.1033±0.0190	0.2848±0.0084
W_{11}	BDL	0.0014±0.0001	0.1770±0.0037	0.0976±0.0049	0.3475±0.0303
W_{12}	BDL	BDL	0.1998±0.0024	0.0662±0.0336	0.2176±0.0106

* Values are mean ± standard deviation of triplet determinations; BDL=Below Detection Level

The highest concentration level of Cr was found in W_6 (0.0789 mg/L), while the least concentration was detected in W_4 (0.0138 mg/L). But Cr was found below the detection level in pond water. Cu content in W_4 (0.0284mg/L) was higher followed by lowest in W_{11} (0.0014mg/L). In pond water sample (W_{12}) Cu was analyzed below the detection limit. The highest Ni content was found 0.2519 mg/L in sample W_4 and lowest value 0.0259 mg/L for sample W_1. The maximum concentration of Pd was observed in W_2 (0.1596 mg/L) whereas minimum concentration was observed in W_4 (0.0109 mg/L). The level of Fe was detected highest in sample W_7 (1.787 mg/L) and lowest in W_{12} (0.2176 mg/L).

Kumar *et al.* (2013) [12] studied on the heavy metal content in sea water and showed that the Cu ranged from 45.29 to 51.02 mg/L, Cr 11.60 to 15.75 mg/L, Ni 12.01 to 15.69 mg/L and Pb 4.10 to 6.20 mg/L. Ambedkar and Muniyan (2012) [11] analyzed Cr, Cu, Pb and Fe content in water. They found 0.70± 0.026 mg/L Cr, 0.50 ±0.025 mg/L Cu, 0.46 ± 0.018 mg/L Pb and 0.32 ± 0.015 mg/L Fe in water. The analysis detected that all water samples were lower Cu, Cr, Ni and Pb content than the range reported by Kumar *et al.* (2013) [12] and Ambedkar and Muniyan (2012) [11] but higher Fe content was found than Ambedkar and Muniyan (2012) [11]. Accumulation of heavy metals in the aquatic environments have been associated with urban runoff, sewage treatment plants, industrial effluents and wastes, mining operations, boating activities, domestic garbage dumps and agricultural fungicide runoff [13].

Heavy metal in sea fish

The Mean concentrations and associated standard deviations of Cr, Cu, Ni, Pb and Fe in sea fish (pama croaker, bombay duck and rat-tail anchovy) are presented in Table 4. The mean concentration of heavy metals were found in all fish samples in the range as Cr 3.2039–16.3495 mg/Kg dry wt., Cu 1.5589–4.5848 mg/Kg dry wt., Ni 0.1101–1.9029 mg/Kg dry wt., Pb 0.4373–2.7638 mg/Kg dry wt. and Fe 30.9599–108.780 mg/Kg dry wt. The distribution of heavy metals in fish samples analyzed were in the order of magnitude as Fe > Cr> Cu> Pb> Ni. Jezierska and Witeska (2006) [14] detected heavy metals in live fish usually follow the ranking: Fe > Pb > Cu > Cd > Hg. According to Ambedkar and Muniyan (2012) [11], the contents of heavy metals in the all fish organs analyzed were in the order of Cr > Cu > Pb > Fe. The analysis showed that magnitudes of heavy metal were more or less similar with Jezierska and Witeska (2006) [14] reported but differ from Ambedkar and Muniyan (2012) [11]. The variation might be due to metal accumulation in fish and various fish species living in the same water body with different level of contamination in water.

Table 4

Concentration of heavy metal in sea water fish*

Fish Sample Code	Cr (mg/Kg dry wt.)	Cu (mg/Kg dry wt.)	Ni (mg/Kg dry wt.)	Pb (mg/Kg dry wt.)	Fe (mg/Kg dry wt.)
P_1	5.8931±0.4799	2.9826±0.0519	1.2259±0.0201	1.5247±0.1430	34.3399±0.7788
P_2	3.6049±0.0702	4.0512±0.0246	1.1303±0.0509	1.7494±0.1561	78.4812±0.6901
P_3	5.7798±0.6082	2.8343±0.0615	1.0733±0.0423	1.5914±0.2352	30.9599±0.6071
P_4	3.5654±0.4884	4.0548±0.0246	1.1680±0.0588	1.6669±0.1727	79.2792±0.1692
B_1	3.2039±0.2504	2.8581±0.0246	1.9029±0.0217	1.9964±0.0859	39.0306±0.7464
B_2	4.1452±0.4207	2.1553±0.0292	0.8601±0.0469	0.5675±0.0489	34.9958±0.2801
B_3	3.2842±0.3392	2.6436±0.0292	1.7545±0.0491	1.5193±0.2173	37.5378±0.2475
B_4	4.3846±0.4186	2.1408±0.0604	0.7716±0.0073	0.4373±0.1759	35.079±0.2426
R_1	16.3495±0.480	4.5848±0.3676	0.9126±0.1773	2.7638±0.3460	108.780±1.778
R_2	9.7973±0.3718	1.6085±0.1129	0.1101±0.0915	BDL	91.913±4.043
R_3	16.1246±0.584	4.1436±0.1514	0.5969±0.1071	2.5346±0.8953	106.618±1.289
R_4	8.1584±0.3056	1.5589±0.3856	0.1459±0.1077	BDL	92.822±0.914

* Values are mean ± standard deviation of triplet determinations; BDL=Below Detection Level

The highest concentration level of Cr was found in P_1 (5.8931 mg/Kg dry wt.), B_4 (4.3846 mg/Kg dry wt.) and R_1 (16.3495 mg/Kg dry wt.) in pama croaker, bombay duck and rat-tail anchovy respectively. Contamination levels of heavy metal in fish are normally compared to the permissible limits recommended by Food and Agriculture Organization (FAO) and World Health Organization (WHO) [15]. In this research, 17% fish samples had excess amount of Cr among all samples whereas acceptable limit is 15.0 mg/kg for fish according to [15,16]. Furthermore, chromium is also more harmful in its lower oxidation state (III). Chromium and chromates are potential carcinogens [17].

The maximum concentration of Cu was observed in P_4 (4.0548 mg/Kg dry wt.), B_1 (2.8581 mg/Kg dry wt.) and R_1 (4.5848 mg/Kg dry wt.) in pama croaker, bombay duck and rat-tail anchovy respectively. Mean concentration of Cu in fish samples was lower compared with FAO/WHO (1984) [15] permissible level (20 mg/Kg). Though copper is an essential element that serves as a cofactor in a number of enzymes systems and necessary for the synthesis of hemoglobin, very high intake of Cu can cause adverse health problems for most living organism [18].

The level of Ni was detected highest in sample P_4 (1.1680 mg/Kg dry wt.), B_1 (1.9029 mg/Kg dry wt.) and R_3 (0.5969mg/Kg dry wt.) and lowest in P_3 (1.0733 mg/Kg dry wt), B_4 (0.7716 mg/Kg dry wt.) and R_2 (0.1101 mg/Kg dry wt.) in pama croaker, bombay duck and rat-tail anchovy respectively. According to the FAO/WHO (1984) [15] maximum permissible concentration is 80 mg/Kg for Ni in fish muscle. In this study, Ni concentration for all studied fish species was lower than FAO/WHO standard [15].

Pb content in P_2 (1.7494 mg/Kg dry wt.), B_1 (1.9964 mg/Kg dry wt.) and R_3 (2.5346 mg/Kg dry wt.) were higher in pama croaker, bombay duck and rat-tail anchovy respectively. It was found that mean concentrations of Pb in all fish samples were 17% below detection level (BDL), 17% below, 33% optimum and 33% higher than the maximum permitted concentrations (1.5 mg/Kg) recommended by FAO/WHO [15]. Lead toxicity is known to cause musculo-skeletal, renal, ocular, neurological, immunological, reproductive and developmental effects [11].

The highest Fe content was found in sample P_4 (79.2792 mg/Kg dry wt.), sample B_1 (39.0306 mg/Kg dry wt.) and Sample R_1 (108.780 mg/Kg dry wt.) while the lowest value was found 30.9599 mg/Kg dry wt. in sample P_3, 34.9958 mg/Kg dry wt. in sample B_2 and 91.913 mg/Kg dry wt. in sample R_2 for pama croaker, bombay duck and rat-tail anchovy respectively. It was found that mean concentrations of Fe in all fish samples were 33% below, 17% optimum and 50% higher than the maximum permitted concentrations (43 mg/Kg) recommended by FAO/WHO [15]. Excess amount of iron causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness [17].

The presence of heavy metal in the fish sample might be due to untreated industrial discharges, sewage effluents, illegal waste dumping activity, nearby chemical fertilizer industries, domestic wastes and some anthropogenic activities.

Conclusion

Metal has a variety of unpleasant effects, which can impact individual health and produce different harmful changes in human. Knowledge of heavy metal concentrations in sea water and marine fishes are important in order to regulate the consumption of fish. The distribution of heavy metals in water samples analyzed were in the order of magnitude as Fe > Ni > Pb > Cr > Cu. On the other hand, among the metals analyzed in fish muscle, Cr, Pb and Fe were with the highest concentration, while Cu and Ni had the lowest level according to FAO/WHO (1984) [15]. Though the results reveal some higher heavy metal content in fish, it is important to examine the metal concentration in fish through constant monitoring. The metal contaminants perhaps pose little hazard to human for fish consumption. Therefore, future studies should focus on health risks posed by metal contamination in the other biological factor along with seasonal variations.

References

1. Chan H. M., Trifonopoulos M., Ing A., Receveur O., Johnson E. (1999), Consumption of freshwater fish in Kahnawake: risks and benefits, *Environmental Research*, 80(2), pp. 213–222.
2. Darwish A.M., El- Mossalami M.K., El- Bassiony R.A. (2003), Quality assurance of some fatty fishes, *Assuit Veterinary Medical Journal*, 49 (98), pp. 79–96.
3. El-Kattan, Y.A., Nahla, A. Abo-El Roos. (2008), Levels of some heavy metals in River Nile water and Oreochromis niloticus fish at Menoufia Governorate, *Egyptian Journal of Comparative Pathology & Clinical Pathology*, 21(1), pp. 64–75.
4. WHO, (1999), *Food safety issues associated with products from aquaculture, Report of a Joint FAO/NACA/WHO Study Group*, World Health Organization Technical Report Series 883, pp. 1–55.
5. Jarup L. (2003), Hazards of heavy metal contamination, *British Medical Journal*, 68, pp. 167–182.
6. Saeed S. M., Shaker I. M., (2008), Assessment of heavy metals pollution in water and sediments and their effect on *Oreochromis niloticus* in the northern delta lakes, Egypt, *8th International Symposium on Tilapia in Aquaculture*, pp. 475.
7. Santos, I. R., Silva-Filho E. V., Schaefer C. E., Albuquerque- Filho M. R., Campos. L. S. (2005), Heavy metals contamination in coastal sediments and soils near the Brazilian Antarctic Station, King George Island, *Marine Pollution Bulletin*, 50, pp. 85–194.
8. A.P.H.A. (American Public Health Association) (1985), *Standard methods for examination of water and waste water*, 16th Ed. Washington, D.C.
9. Jorhem, L., (1993), Determination of metals in foodstuffs by atomic absorption spectrometry after dry ashing: NMKL interlaboratory study of Pb, Cd, Zn, Cu, Fe, CR and Ni, *Journal of AOAC international*, 76, pp. 798–815.
10. Ismail I., Saleh M. I., (2012), Analysis Of Heavy Metals In Water And Fish (*Tilapia Sp.*) Samples From Tasik Mutiara, Puchong, *The Malaysian Journal of Analytical Sciences*, 16 (3), pp. 346–352.
11. Ambedkar G., Muniyan M. (2012), Analysis of heavy metals in water, sediments and selected freshwater fish collected from gadilam river, tamilnadu, india, *International Journal of Toxicology and Applied Pharmacology*, 2(2), pp. 25–30.
12. Kumar C.S., Jaikumar M., Robin R.S., Karthikeyan P., Kumar C.S., (2013), Heavy Metal Concentration of Sea Water and Marine Organisms in Ennore Creek, Southeast Coast of India, *The Journal of Toxicology and Health*, 103, pp. 192–201.
13. Alemdaroglu T., Onur E., Erkakan F. (2003), Trace metal levels in surface sediments of lake Manyas, Turkey and Tributary River, *International Journal of Environmental Studies*, 60, pp. 287-298.
14. Jezierska B., Witeska, M. (2006), *The metal uptake and accumulation in fish living in polluted waters; Soil and Water Pollution Monitoring, Protection and Remediation* Springer, pp. 3–23.
15. FAO/WHO (1984), *List of maximum levels recommended for contaminants by the Joint FAO/WHO Codex Alimentarius Commission. Second Series CAC/FAL*, Rome, pp. 1–8.
16. FEPA (Federal Environmental Protection Agency) (2003), *Guidelines and standards for Environmental Pollution Control in Nigeria*, pp. 238.
17. Patil G., Ahmed I., (2011), Heavy metals contamination assesment of kanhargaon dam water near chhindwara city, *Acta Chimica and Pharmaceutica Indica*, 1(1), pp. 7–9.
18. Sivaperumal P, Sankar T V, Nair Viswanathan P.G. (2007), Heavy metals concentrations in fish, shellfish and fish products from internal markets of India visàvis international standards, *Food Chemistry*, 102, pp. 612–620.