Estimation of Toxic Metal intake through food and potential risk on the inhabitants in the vicinity of Sundarban areas, India

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Abstract
Present study highlighted the exposure level of toxic heavy metals lead (Pb), cadmium (Cd) and arsenic (As) in some essential food items along with assessment of degree of uptake through food consumption and to forecast any effect during long term consumption of the contaminated food stuffs throughout the life period of the people from remote and rural areas of Sundarbans. Study revealed that the level of occurrence of toxic metals followed the order Pb > As >Cd exactly similar to that of the earth crust implying on the probable sources. Among the foodstuffs, cereals comprising of rice and wheat contributed maximum load of these toxic metals to an adult through consumption during the life period followed by vegetables (Potato, Moong and Spinach) and fish (average of Rui and Parse).

On comparing with the Provisional Tolerance Daily Intake (PTDI) values as prescribed by WHO, it was observed that the metals Cd and As contributed less percentage (17.0 to 28.0%) showing no potential harmful effect on consumption. In contrast, accumulation of Pb through consumption of these foodstuffs contributed 3.6 times higher than the values as prescribed and may cause the harmful effects to the local people. Hence, proper management action must be implemented immediately to these rural areas by awareness as well as by supplying hygienic food items to those innocent inhabitants near the periphery of Sundarbans.

Keywords: Foodstuffs, Toxic metals, Distribution and uptake, Potential risk, Inhabitants, Sundarbans.

Introduction

The presence of toxic metals and metaloids such as lead (Pb), cadmium (Cd) and arsenic (As) in our immediate environment is a great concern because these metals have neither any bio-chemical role to play nor can be transformed and destructed in nature[1,2]. These are termed as metals, largely originating from various types of anthropogenic activities by the human beings and are distributed all around us in our immediate environment[3-6]. The peculiar characteristics of toxic metals are that these are not static but become dynamic by the influence of natural agents of physical, chemical and biological origin. It results in distribution and accumulation of toxic metals in all environmental segments of air, water, soil and biotic lives[7-13].

It is well known that among the biota, the animal community does not know how to prepare food and hence they entirely depend on plant community which is grown through the uptake of nutritional substances from these contaminated water, soil and air. In this way, toxic metals ultimately undergo partioning to the biological groups through food chain[12]. Human beings are placed at the top of biological niche in the ecosystem and are more vulnerable to be affected by the consumption of toxic metal contaminated food items.

Besides, toxic metal contamination may also occur due to irrigation with contaminated water[5,7,9] continuously and deposition of industrial and vehicles emission on vegetable surface[7,11]. These are also responsible to cause harmful effects and ultimate health hazards with many unusual manifestations[14-16]. Long term consumption of contaminated vegetables may be responsible for chronic accumulation of toxic metals that may disrupt various biochemical processes and cause cardiovascular, nervous, kidney and bone diseases[17,23].

In the light of the above facts, an attempt has been made through this study to highlight the level of accumulation of toxic metal in food, to calculate the daily intake value and finally, to predict any possible harmful effect on human through consumption of contaminated food.

Material and Methods

Sampling: The leafy vegetable samples like spinach, root vegetable such as potato and moong dal were collected from local market. Similarly, two cereals grains like rice and wheat were also included in the study. Rice (Oryza sativa) is the seed of grass species paddy and is the oldest cereal grain in the world. It is a staple food for more than the half of world's population. On the other hand, wheat is also a cereal grain produced from a type of grass (triticum) that is grown and used world-wide. Fish samples of Rui and Parse were also collected from local fresh water ponds from the fisherman. All these samples were kept cool in icebox during the transportation to the laboratory.

Analytical procedures: The food samples were repeatedly washed with de-ionized water to remove any extraneous materials and dried in air oven at 105^0C for 24 hours. The dried samples were ground in a mortar and passed through 200- mesh sieve and kept in polythene bags. Fish samples

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from the ice box were brought out and dissected by using plastic knife. The muscles were dried, ground and homogenized. Accurately weighed aliquots of 1 g of food samples were digested according to USEPA[25] methods and metal analysis for Cd, Pb and As was carried out using Atomic Absorption Spectrophotometer ((AAS model: Agilent Technology 200 Series AA) with graphite furnace atomizer. A sample blank was always prepared following the same sequence of digestion procedure and the element analysis was performed against the blank.

The settings of AAS were followed in accordance with those as recommended by the manufacturer. A standard curve was prepared with each analysis. Precision and accuracy were assessed with standards and the AAS detection limits of Pb, Cd and As are 0.05, 0.002 and 0.001 mg/l respectively. All the food samples were analyzed for the duplicate so that validation of the experimental output could be done properly. All the results were expressed in terms of mg/kg or ppm as dry weight. During the metal analysis, only the analytical grade chemicals and standard solutions were used in the study. The use of super quality distilled water was mandatory. All glass wares and containers were neatly cleaned, rinsed with super quality grade water several times and air dried before the use.

Estimation of daily intake (DI) of these metals by human in adult was calculated by multiplying the respective concentration in each types of foodstuff by the weight of that foodstuff group consumed by an average individual as follows:

$$DI = ((FU \times C)/BW) \times 10^{-3}$$

where FU is the daily food uptake rate (g/ person/day), C is the estimated metal concentration in food samples (µg/g dry weight), BW is the average body weight (60 kg for an adult) and 10^{-3} is the conversion factor. The consumption rates of the foodstuffs as mentioned in the Household Consumption of Various Goods and Services in India 2011–12 (MOSPI)[24] were used.

Results and Discussion

Heavy Metal Concentrations in Different Food components: Lead is a non-essential heavy metal and endures many adverse health effects including neurotoxicity and nephrotoxicity [14]. Pb in the present food samples (Table 1) ranged from the minimum of1.26 $\mu g.g^{-1}$ as recorded in Spinach to the maximum of 2.95$\mu g.g^{-1}$. Cadmium results impaired kidney function, poor reproductive capacity and hypertension, tumorous and hepatic dysfunction[15]. Moreover, cadmium toxicity may result in genotoxicity, endocrine disruption, oxidative damage and disruption of ion regulation[16]. Cd varied within 0.05 to 0.08 $\mu g.g^{-1}$ and As ranged from 0.05 to 0.31. The degree of distribution of Cd followed the order of spinach > fishes > rice = wheat > moong dal. Arsenic exposure can also affect almost all organ systems including the dermatologic, cardiovascular, nervous, renal, hepatobilliary, gastro-intestinal and respiratory systems[17].

Highest values of As were registered in the flesh of fishes followed by potato, spinach and rice and ranged from 0.05 to 0.32 $\mu g.g^{-1}$. The codex maximum limit[18] for As in rice and polished rice have been ascribed as 200 µg/kg and 400 µg/kg respectively. The limit of Pb content in cereal grains and pulses is prescribed for 200 µg/kg and for Cd as 100 µg/kg. In the present study, the levels of Pb were found always higher in all the food components than the codex limit. In contrast, Cd levels were about ten times lower than this limit.

In general, the level of occurrences of toxic metals followed the order Pb > As > Cd. This is exactly similar in abundance to those present in surface soil and this indicated the more probable sources of these toxic group of metals from soil surface leaching, especially to those food components (rice, wheat, moong seed, potato and spinach) that are produced from contaminated agricultural land or irrigation water and the aquatic bodies where fishes are growing.

The metal levels in fishes in Bangladesh varied a lot occasionally with higher level even than the present study[21].The average Pb values of all the plant types in this study (1.0-3.2 µg.g-1) showed higher than the FAO/WHO guidelines[19] (0.5-1.0 µg.g-1) and the WHO/ EU[20] range of 0.1-0.3 $\mu g.g^{-1}$. However, an elevated concentration of Pb (70.66 mg/kg) in the leaves of the red Indian spinach was reported from Kolkata market[2].

Table 1
Level of distribution of toxic metals in food components (average of duplicate)

S.N.	Sample Description	Unit	Cadmium (Cd)	Lead (Pb)	Arsenic (As)
1.	Parshe Fish	µg/g	0.05	1.37	0.10
2.	Rui Fish	µg/g	0.07	2.62	0.32
3.	Rice (Cereal grains)	µg/g	0.03	2.95	0.06
4.	Moong Dal (lentils), vegetable	µg/g	0.04	2.36	0.05
5.	Wheat (Cereal grains)	µg/g	0.06	2.82	0.07
6.	Potato (vegetable)	µg/g	0.05	2.25	0.11
7.	Spinach (Vegetable)	µg /g	0.08	1.26	0.07

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Concentration of Heavy Metals in Different Foodstuff Groups: The estimated daily intakes of heavy metals through consumption of foods decreased in the order of Pb > As > Cd in any of these food items (Table 2). Comparatively higher degree of bioaccumulation of Pb in the present samples may originate from contaminated soils or from aerial depositions of industrial and vehicular emissions or storage. The sources of elevated levels of As could be due to both natural and anthropogenic reasons. The use of arsenic enriched fertilizers and pesticides in paddy cultivation is known to contribute to the bioaccumulation of this metal in rice [22]. Among the various food items, rice contributed maximum amount of any of these toxic metals per day (Cd-0.12, Pb- 15.8, As- 0.33µg per kg body weight) followed by potato (Cd - 0.05, Pb- 2.25, As- 0.11µg per kg body weight).

However, the least level contribution was recorded in favor of moong, lentil vegetable with Cd- 0.001, Pb- 0.05 and As- 0.0015µg per kg body weight. The maximum intake of the metals came from the consumption of cereal (rice 330.7 and wheat 44.8 g/day), vegetables (potato126.4, spinach 33.9 and moong 1.27g/day) and fish (26.83 g/day) as these were the most consumed food items used by humans. The intake of lead from the consumption of food items could be of health concern to the adult population.

Furthermore, in order to get more clear idea about the difference in uptake of heavy metals, an attempt has been made to categorize all the above food items of table 1 into three broad food groups like cereals comprising of rice and wheat, vegetables with potato, spinach and moong (lentil) and fishes. Respective metal contributions of each of the food items were summed up except in fishes where average constituents of Rui and Parse were considered presented in table 3. The percentage contribution of heavy metals from different foodstuff group (Fig. 1) distinctly highlighted a distinct variation among different toxic metals and followed the order Cereals > Vegetables > Fishes. These were Cd- 67.85, Pb- 64.95 and As-51.35% by cereals, Cd- 19.57, Pb- 28.35 and As-24.35% by vegetables and the remaining were contributed by fishes.

Thus, the cereals containing only rice and wheat items could be assigned as the major group of toxic metal contributor and together with vegetables, it accounted for 93.3% of total Pb, 87.42% of total Cd and 75.67% for total As intake through consumption. Consequently, the heavy metal levels in these foodstuffs should be given more emphasis.

Health Risk Assessment of Heavy Metals uptake: From the present study, it was revealed that an adult consumed13.84 µg /d for Pb, 0.37 µg /d for As and 0.28 µg /d for Cd through consumption of these food groups on comparing with Provisional Tolerable Daily Intake (PTDI) value which is obtained from the Provisional Tolerable Weekly Intake[25] (PTWI) as recommended by the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). It was observed that the calculated levels of uptake of both Cd and As were below the acceptable limit of PTDI of 1.0 and 2.14 µg per kg body weight per day respectively (Table 3). This indicates that no harmful effect would be observed for the people by these extents of intake level of toxic metals.

In contrast, uptake of Pb was found 3.4 times greater (13.84 µg/kg body weight) than the prescribed limit per day (3.57 µg / kg body weight) that would no doubt pose a great health concern to the inhabitants on consumption of these food items.

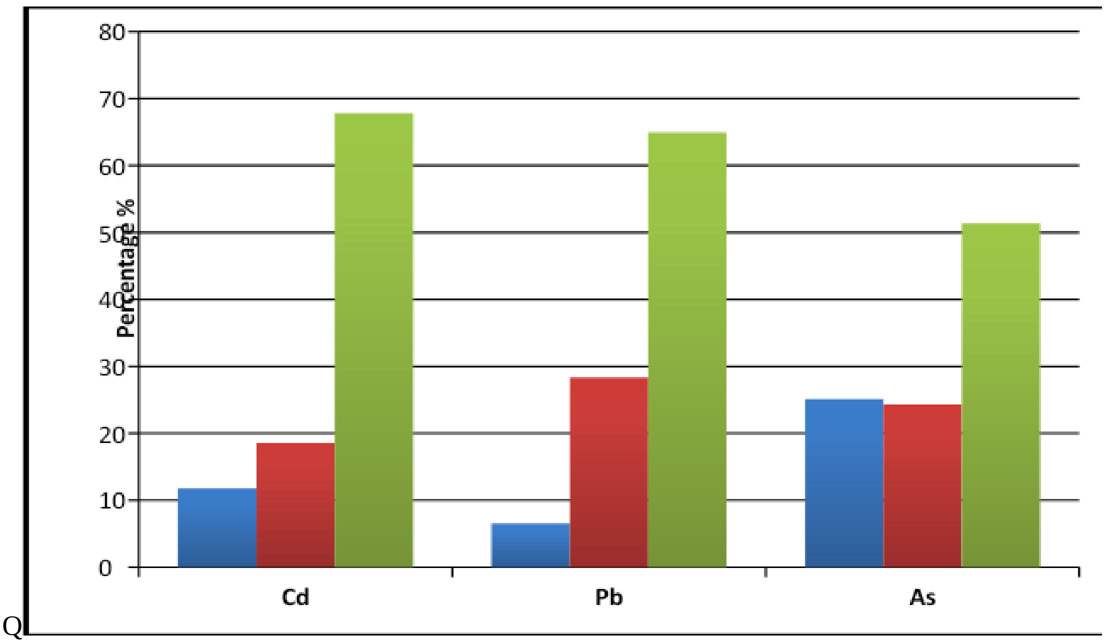

Figure 1: Percentage contribution of different heavy metals (Cd, Pb and As) through consumption of various food items (fishes, vegetables and cereals)

Table 2
Daily Intake of Metals through food consumption in microgram (µg) per kg body weight

S.N.	Sample Description	Cadmium (Cd)	Lead (Pb)	Arsenic (As)
1.	Parshe Fish	0.022	0.61	0.045
2.	Rui Fish	0.030	1.17	0.14
3.	Rice (Cereal grains)	0.16	16.26	0.33
4.	Moong Dal (lentils), vegetable	0.001	0.05	0.0015
5.	Wheat Cereal grains	0.04	2.11	0.052
6.	Potato (Vegetable)	0.11	4.74	0.23
7.	Spinach (Vegetable)	0.04	0.71	0.045
8.	PTDI (µg) per kg body weight.)	1.0	3.57	2.14

Table 3
Daily Metal intake through consumption of various food groups (µg/kg body weight).

S.N.	Sample Description	Cadmium (Cd)	Lead (Pb)	Arsenic (As)
1.	Fishes (Average)	0.026	0.90	0.09
2.	Cereals	0.12	8.99	0.19
3.	Vegetables	0.052	3.95	0.09
4.	Total	0.20	13.84	0.37
5	PTDI (µg/kg body weight/day)	1.0	3.57	2.14
6	DIM/ PTDI (Ratio)	0.28	3.87	0.17
7	PTWI(µg/ kg body weight/week)	7.0	25	15

In addition, it is also known that the diets with inadequate amounts of nutritional elements enhanced absorption of lead. Besides, long periods of fasting[25] are also known to facilitate Pb absorption to a large extent. Again, as heavy metal bioaccumulation increases in nutrition-deprived state, rural people with higher prevalence of under nutrition are at a greater risk of heavy metal toxicity.

Thus, proper remedial action should be early implemented through awareness to the local people providing suitable alternatives to decrease the potential health risks of heavy metals to humans via consumption of these toxic heavy metal contaminated foods.

Conclusion

Present study was undertaken to highlight the level of distribution and degree of bioaccumulation of toxic metals of Pb, Cd and As through consumption of some very essential foods like cereals (Rice and Wheat), vegetables (Potato, Spinach and Moong dal) and fish (average of Rui and Parse). These foods are very common and largely consumed by the local inhabitants of Sundarban areas. In all, the food materials toxic metal content of Pb was higher than As and the lowest was recorded for Cd. This could be due to proportionate exposure of these metals through agriculture and food processing practices. Among the food items, cereals contributed maximum amount of toxic load followed by vegetables and fish. The extent of toxic metal accumulation through food consumption by an adult also followed the same sequence of order like Pb >As > Cd.

The reason could mainly be due to relatively higher amount of uptake of cereals than vegetables and fish. The extent of bioaccumulation of Pb per day per kg body weight was recorded significantly higher (3.5 times) than the tolerable limit of PTDI as prescribed by World Health Organization (WHO) and no harmful effect might be witnessed by the accumulation of Cd and As in the local people immediately. However, adequate alternate arrangements of food selections or food productions are urgently needed to protect the health status of the people living in these remote and rural areas.

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References

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

2. Banerjee D., Kuila P., Ganguly A. and Ray L., Market basket survey for chromium, copper, lead and cadmium in some vegetables from different shopping malls in Kolkata, India, *EJEAF Che*., **9(7)**, 1190–1195 **(2010)**

3. Chakraborti C., Kundu S.K., Ghosh P.B. and Choudhury A., A preliminary study on certain trace metals in some plants and animal organisms from mangrove of sundarban, India, *Mahasagar*, **26(1)**, 17-20 **(1993)**

4. Codex Alimentarius, Commission, Report of (CACR), the Eighth Session of the Codex Committee on Contaminants in Foods, In Proceedings of the Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission 37th Session, Geneva, Switzerland, December **(2014)**

5. Das A. and Das A., Heavy metals in common food items in Kolkata, India, *Euro-Mediterr J Environ Integr*, **3**, 1 **(2018)**

6. De T.K., De M., Das S., Roy R. and Ghosh P.B., Level of heavy metal in some edible marine fishes of Mangrove dominated tropical estuarine areas of Hooghly river, North-east coast of Bay of Bengal, India, *Bull. Environ. Conta. Toxicol*., **85(4)**, 385-390 **(2010)**

7. Dzantiev B.B., Renieri E., Sfakianakis D., Alegakis A.A., Safenkova I.V., Buha A., Matovic V., Tzardi M., Divanach P., Kentouri M. and Tsatsakis A., Nonlinear response to waterborne cadmium exposure in zebrafish. An in vivo study, *Environ. Res*., **157**, 173–181 **(2017)**

8. EU, Commission regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs, *Official Journal of European Union*, L364/5 **(2006)**

9. FAO/WHO, Evaluation of Certain Food Additives and Contaminants; World Health Organization, Technical, Report Series No.837, WHO, Geneva, Switzerland **(1993)**

10. Gercia-Leston J., Mendez E., Pasaro B. and Laffon B., Genotoxic effects of lead: an updated review, *Environ. Int*., **36**, 623–636 **(2010)**

11. Ghosh P.B. and Choudhary A., Copper, Zinc and Lead in the sediment of Hooghly estuary, *Environ. Ecol*., **7**, 427-430 **(1989)**

12. Ghosh P.B. and Mandal S., Degree of partitioning of heavy metals in different environmental segments of a sewage-fed fishery pond at East Kolkata Wetland, India – A case study, *International Journal of Chemical and Environmental Sciences*, **1(1)**, 7-14 **(2019)**

13. Ghosh P.B., Saha T. and Bandyopadhyay T.S., Distribution of Lead, Cadmium and chromium in the waste water of Calcutta canals, *Res. J. Chem. Environ*., **4(3)**, 33-36 **(2000)**

14. IPCS, International programme on chemical safety, environmental health criteria, WHO, Geneva, 165 **(1995)**

15. Ministry of Statistics and Programme Implementation (MOSPI), Government of India, Report no. 558/68/1.0/2 **(2014)**

16. Mukherjee P., Das P. and Ghosh P.B., The extent of Heavy metal Pollution by Chemical Partitioning and Risk Assessment Code of Sediments of Sewage-fed Fishery Pond at East Kolkata Wetland, a Ramsar Site, India, *Bulletin of Environmental Contamination and Toxicology*, **108**, 731–736 **(2022)**

17. Mukherjee S., Mukhopadhyay K., Bishnu A., Ghosh P.B. and Saha Tapan, Distribution of Heavy Metals in tea leaves and soil in some tea estates of the Dooars region of West Bengal, Conference, 7th All India People's Technology Congress, Organized by Forum of Scientists, Engineers & Technologists (FOSET), Kolkata, India, 321-324 **(2009)**

18. Rattan R.K., Datta S.P., Chhonkar P.K., Suribabu K. and Singh A.K., Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and ground water-a case study, *Agric Ecosyst Environ*, **109**, 310–322 **(2005)**

19. Renner R., Arsenic and lead leach out of popular fertilizer, *Environ Sci Technol*, **38**, 382 **(2004)**

20. Sarkar S., Ghosh P.B., Sil A.K. and Saha T., Heavy metal pollution assessment through comparison of different indices in Sewage-fed Fishery pond sediments at East Kolkata Wetland, India, *Environ. Earth. Sci*., **63(5)**, 915-924 **(2010)**

21. Sengupta S., Chatterjee T., Ghosh P.B. and Saha T., Heavy metal accumulation in agricultural soils around a coal fired Thermal Power Plant (Farraka) in India, *J. Environ. Science & Engg*., **54(4)**, 299-306 **(2010)**

22. Sengupta S., Chatterjee T., Ghosh P.B., Sarkar S. and Saha T., Heavy metal contamination in leaves of Mangifera indica around a coal fired thermal power plant in India, *Journal of ecology and the Natural Environment*, **3(14)**, 446-454 **(2011)**

23. Sharma R.K., Agarwal M. and Marshall F., Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India, *Ecotoxicol Environ Saf*, **66**, 258–266 **(2007)**

24. Tchounwou P.B., Patlolla A.K. and Centeno J.A., Carcinogenic and systemic health effects associated with arsenic exposure-a critical review, *Toxicol. Pathol*., **31**, 575–588 **(2003)**

25. USEPA, Framework for metal risk assessment, EPA 120/R-07/001 **(2007)**

26. WHO/FAO, Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission, 13th Session **(2007)**.

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