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A Survey of Toxic Metal Concentrations in Food Chain Level at Rajshahi District Area in Bangladesh

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Abstract: ***This study reports the base line levels of some potentially toxic heavy elements such as. Pb, Cd, Mn and Cr in 21 locally grown vegetables including rice variety. Vegetable and rice samples were collected from Mohanpur upazila area of Rahshahi district. The samples were collected and digested with HNO_3 and H_2O_2. The total concentrations of heavy metals (Pb, Cd, Mn and Cr) in vegetables and rice were determined using a flame Atomic Absorption Spectrophotometer (AAS). The concentration of lead obtained from the minority of the vegetables collected from the studied area surpassed the maximum recommended limit of the metal for two samples in the edible part of the vegetables. The rests are within the limit Cd, Mn and Cr concentrations in all the collected samples are found within the recommended limit.***

Keywords: Vegetables, Heavy metals, Toxicity, Food contamination, Food safety

1. Introduction

Heavy metals contamination is a major issue in environmental pollution in all over the world. In Bangladesh, it is a challenge. There are many types of vegetables and crops grow around this area. The soil of the locality is suitable for cultivation. Ground water is used for irrigation purposes to produce crops and vegetables. The produced vegetables are good qualities and exportable to various countries of the world.

Today the most commonly anticipated problem is the contamination of soil with toxic metals. Well-documented metallic constituents include Pb, Cd, Cr, Mn etc. which have significant adverse effects on crop productivity. The toxic metals may be absorbed by plants grown in contaminated soil, which then accumulate in human/animals eating those plants sometimes reaching to chronic toxic levels. Uptake of trace elements via the roots of plants is generally the prime pathway of absorption and must be appreciated in order to understand the effects of pollutants upon the environment. It is thus conceivable that even a small additional “pollution” component can pose a public health hazard under some circumstances. In Bangladesh, very little attention has been given to the accumulation of heavy metals in soil, water and food products such as vegetables, cereals, fruits etc.

Therefore, we have considered it important to check the distribution of Pb, Cd, Cr and Mn in soil, groundwater and some indigenous foodstuffs around Mohanpur upazila , Rajshahi district in Bangladesh. It is also important to note that local villagers produce a lot of vegetables. Bangladesh is an agriculture-based country. Most of the people are farmers of our country. They are producing a lot of foodstuffs in their fields. Every year Bangladesh exports foodstuffs in the USA, UK and EU countries and it earns a lot of foreign currency. Recently UK and EU countries measured the arsenic concentrations in foodstuffs that are imported from Bangladesh [1]. They also reported that the levels of trace element (Pb, Cd, Mn, Cr etc) in vegetables of Bangladesh were higher than those of their countries. So, they are now somewhat regret to import vegetables from Bangladesh. As a result we are about to deprive of a lot of foreign currency.

Our overall objective has been to determine heavy metal concentration load in vegetables grown in Mohanpur upazila area of Rajshahi, Bangadesh and to propose the future possible mitigation measures in order to reduce the impact associated with the health risks of the people, whether local people or the above mentioned section of the world population is being exposed to high concentrations of toxic elements in their diet.

2. Experimental Method

2.1. Materials

Trace element grade 65% w/w HNO_3. Trace element grade 30% w/w H_2O_2.

2.2. Method:

The samples were dried and thoroughly homogenized, then ground to pass a 100-mesh pore size sieve. For each digestion, 1 gram of dried powder sample was taken into the appropriate digestion vessels. 10 ml of 65% w/w HNO_3 and 2 ml of 30% w/w H_2O_2 were added to sample into digestion vessel (500 ml) and the samples were heated continuously at a temperature slowly raised up to 120 ± 5 °C for two hours. After cooling, the digest solutions were filtered with filter paper (Whatman no. 42), diluted with double distill water and finally made volume up to 50 ml. Then the sample solutions were ready for analysis by Atomic Absorption Spectrophotometer (AAS). The Atomic Absorption Spectrophotometer was arranged to determine the cadmium concentrations in collected vegetable samples A cadmium lamp of the wavelength 228.87 nm was used.

Total cadmium concentration in mg/kg $=\frac{d}{c}\times v$

Where, d = Reading of AAS in ppm, c = Sample weight taken (dry wt. basis), v = Volume of sample (after digestion).

The collected vegetable samples were digested by standard methods in order to measure the quantity of lead, cadmium, chromium and manganese. All samples were analyzed in duplicate and the results reported are the averages of these two. Blanks were prepared for all digestions, while two controls were also run during the analysis. The instrument calibration standards were made by diluting the standard (1000 ppm) supplied with AAS. An atomic absorption spectrophotometer (Shimadzu Corporation, JAPAN) was employed to determine Pb, Cd, Mn and Cr.

3. Discussion

Figure 1 shows Map of the Mohanpur upazila area of Rajshahi, Bangladesh

Figure 1: Map of Mohanpur Upazila, Rajshahi, Bangladesh

Lead

The total lead concentrations in all the vegetables studied through AAS are shown in Figure 2. The concentrations are reported as milligrams of total lead per kilogram of edible parts of vegetables (dry wt. basis). The maximum permissible limit of lead in vegetables is 7.2 mg/kg (dry weight basis) as recommended by WHO [2] as shown in Table 1.

Results incorporated in Table-2 indicate that lead content in the studied vegetable samples are ranged from 3.332 to 19.931 mg/kg with a mean value of 11.631 mg/kg. Among the analyzed vegetables, radish (Raphanus sativus) and brinjal (Solanum melongena) show a very high level of lead i.e. 19.918 and 11.384 mg/kg, respectively.

Muhammad Haleem khan et al.[3,4] studied the lead content in foodstuff samples of “Gujranwala” city (a lead affected area in Pakistan). The food categories containing the mean lead concentrations were vegetables ranging from (15.75 to 22.8 mg/kg), that include potato (19.30 mg/kg), tomato (22.84 mg/kg), onion (15.75 mg/kg), spinach (21.0 mg/kg) and chilies (15.75 mg/kg) respectively.

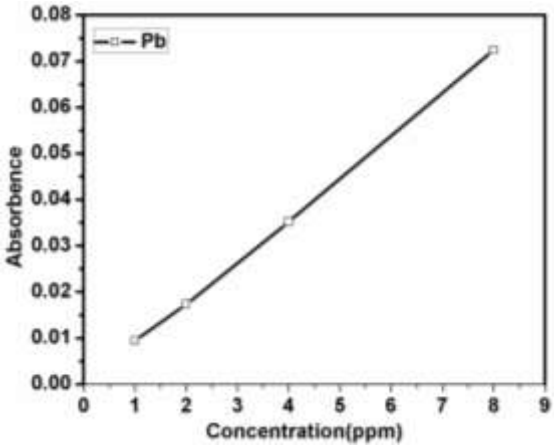

Figure 2: Calibration curve for lead by AAS

Our results are fairly comparable with these mentioned above. It is to be noted that radish and brinjal show exceptionally higher Pb concentrations. It is concluded from the present results that the vegetables under study except radish and brinjals are safe for human consumption in terms of lead concentration. However, vegetables of the study area are quite safe for human consumption in terms of cadmium concentration.

Cadmium

The total cadmium concentrations in all the vegetables studied are shown in Table 2. One can observe from the table that the concentrations of Cd in vegetable samples are ranged from 0.00 to 0.2405 mg/kg.

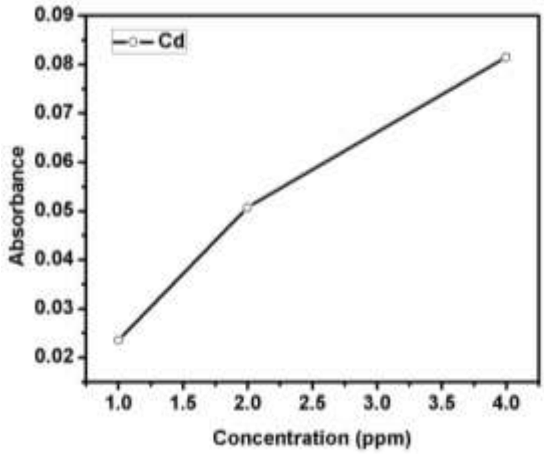

Figure 3: Calibration curve for Cadmium by AAS

It is reported that the recommended value of cadmium in all foodstuffs for Bangladesh is 6 mg/kg (dry weight basis) [5]. A critical examination of Figure 3 and Table-2 reveals that the cadmium concentrations in vegetables of the studied area are within the recommended value. The mean concentration of cadmium in vegetables is 0.241 mg/kg. Moreover, the above data reveals Cd concentration within permissible limit in the vegetables studied. Cd is released into the environment as a result of incineration or disposal of Cd containing product such as plastic containers, break linings, rubber tires, and as a byproduct in the refining of other metal primarily. Present results show that Cd levels in the vegetables studied are ranged from 0.00 to 0.241 mg/kg which is within the recommended limit. It indicates that also soil in the area contains low concentration of Cd. Hence Cd levels in the vegetables grown in the area would be low as expected as observed. From these results, it can safely be said that the vegetables of the area are suitable for human consumption in terms of cadmium contamination.

Manganese

Manganese is an essential nutrient that is important for normal processes in the body, though adverse health effects have been noted at higher doses [6]. Excessive manganese exposure, predominantly reported in adults exposed occupationally via inhalation, has been associated with adverse central nervous system effects [6].

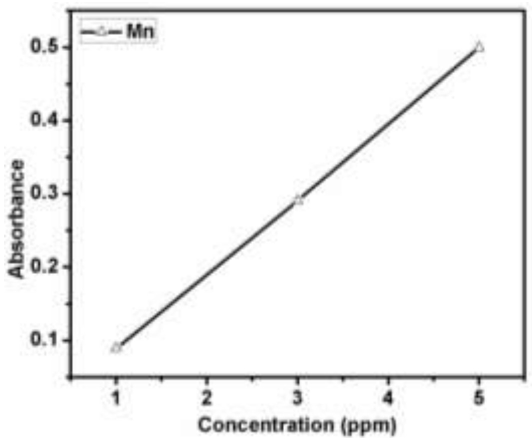

Figure 4: Calibration curve for Manganese by AAS

There are two forms of manganese in the environment. Manganese may be found in cereals, leafy vegetables, fruits, and fruit juices. Manganese is an essential nutrient. Elevated intake of manganese above recommended amounts may be of concern in some dietary situations.

The obtained results on total manganese concentrations from all vegetable samples are summarized in Table-2 which is expressed as milligram of total manganese per kilogram.

From the Table-2, it is seen that the concentrations of manganese in vegetable samples varied from 0.180 to 2.727 mg/kg.

From WHO recommendation [7] the normal limit of manganese in foodstuffs varies from 15 to 100 mg/kg. The present results show that the concentrations of total manganese in collected vegetable samples are within the normal limit. The results from the Figure 4 and Table-2 one can infer that the vegetables are free from manganese contamination and are safe for human consumption.

Table 1: WHO recommended limit of toxic metals in Asia.

Name of metals	Limit mg/kg
As	1
Pb	7.2
Cd	6
Mn	15-100
Cr	0.366

Generally manganese and manganese compounds are used to make steel, used in some pesticides and used as anti-knock agents in gasoline. It can be released from mining and smelting operations, during welding, and from coal-or oil-burning factories or power plants. The studied area is far from the industrial places or any mining places and that’s why the study area are free from manganese and hence the vegetables.

Around Dhaka city in Bangladesh a study was conducted [8] to investigate the heavy metal of soil and vegetation of the industrial zone. Soils, grass, rice and arum collected from industrial sites were analyzed. The concentrations of total manganese are ranged from 106 to 577 mg/kg. In the present study analyzed vegetable samples show Mn concentration (Table-2) below well the above mentioned result.

Chromium

The presence of chromium metal in the environment has been a great concern to scientists and engineers because of its toxic nature and other adverse effects on receiving food. Chromium metal is generally refractory and cannot be degraded or readily detoxified biologically.

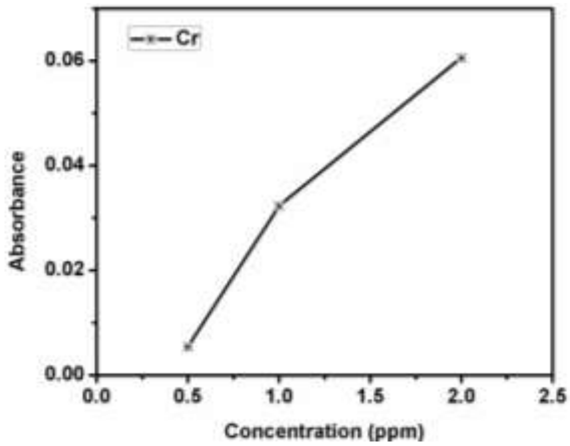

Figure 5: Calibration curve for Chromium by AAS

Results reveal that the total Cr concentrations in vegetables are remaining in the range 0.0907 to 0.305 mg/kg. The recommended limit of Cr in the foodstuffs is 0.36 mg/kg [3] as shown in Table-2 and Figure 5 respectively.

The results indicate that none of the foodstuffs investigated here is burdened with chromium. A critical examination of the results shows that the concentration of chromium in all the vegetables lies under the maximum permissible limit. Hence the collected vegetables examined were quite safe for human consumption in terms of chromium concentration.

Kuskwam [9] studied the concentration of Cr in vegetables. Lettuce shows or concentration ranging from 0.78mg/kg to 1.68 mg/kg. The concentration of chromium at different vegetable farms were distributed as follows: Lettuce from 0.76 mg/kg in ZE to 1.08 mg/kg in KU; Swiss chard from 0.57 mg/kg in BU to 0.68 mg/kg in KL; Ethiopian Kale from 0.57 mg/kg in ZK to 0.76 mg/kg in BU and Carrot had mean concentration of 0.52mg/kg at Burayu farm.

Compared to above data it is clear that the concentration of chromium in the studied area is comparatively low and is not alarming to all living beings.

Overall Discussion

Most of the laboratory research on biosorption of heavy metals indicated that no single mechanism is responsible for metal uptake. In general, two mechanisms are known to occur, viz. 'adsorption', which refers to binding of materials onto the surface and 'absorption', which implies penetration of metals into the inner matrix95. Either one of these or both of the mechanisms might involved in the transportation of metals into the plant body. Accumulation of these heavy metals in vegetables could be attributed to the use of contaminated ground water for their cultivation. It is seen from Table-2 that the concentrations of Cd, Mn and Cr and for maximum samples Pb are within the permissible limits [11-12].

The data of studied 21 vegetables including rice, results show that only two of the collected samples, radish and brinjal contain Pb concentration that exceeds the maximum permissible concentration (mpc) and others contain under the range of permissible limit.

The highway crosses through the studied area, the vehicles passing through this road might release some lead (Pb) compounds into the air and then into the soil or water. This may be uprooted to the plants or vegetables for biological transformation or absorption. Presumably some of the samples thus contain lead that exceeds the higher permissible limit. However the concentrations of Cr, Cd and Mn in the studied 21 vegetables including rice are within the safe limit in terms of health status.

From the overall results of the present investigation, one can draw the conclusion that apart from Pb concentrations in all the vegetables (except radish and brinjal) studied are quite safe for human consumption.

The present author has information [13] that a considerable amount of vegetables are on sale in the United Kingdom and EU countries and imported from Bangladesh. Recently Rmalli [14] reported that these foodstuffs provide an additional source of arsenic in the diet. However present results evidence that many of the vegetables grown in the studied area are free of toxic metal concentrations and might be exportable to world markets without existing any health hazards. There are different fertilizers in the market, which are usually used in the vegetables growing fields. Many fertilizers are produced without any restriction. These fertilizers may contain different kinds of heavy metals [15]. Sometimes they get exceed the bearable limit of the soil. As zinc sulphate generally provide the heavy metals such as Mn, Cd, Pb, Zn and many other heavy metals in the soil while growing the vegetables and foodstuffs. It is evident from the above discussion that various trace/heavy metals might mix with the agricultural soils along with the nutrients. From the imbalanced application of fertilizers, the soils may be overburdened with toxic and other elements that might be transmitted from soil to the crops to humans.

Some foodstuffs consume the heavy metals in their stalk which are rejected to the fields. Consequently using same fertilizer and production of same foodstuffs in the same fields it may accumulate the higher concentration of heavy metals in the soil and from that the next production may highly contaminated. As mentioned earlier that the highways are flowing beside the study area. A number of automobiles are running everyday through these ways. These aspects should also be taken into consideration while explaining the presence of toxic/heavy metals particularly lead in water bodies, soils, vegetables and crops in the study area.

Table 2: Concentration of Pb, Cd, Mn and Cr in collected vegetables samples

Sample No.	Name	Pb	Cd	Mn	Cr
1	Potato	4.450	0.750	0.308	0.141
2	Arum tuber	3.334	0.074	0.354	0.101
3	Basil	4.228	0.057	0.167	0.091
4	Wax gourd	4.450	0.063	0.559	0.101
5	Banana	3.334	0.00	0.290	0.128
6	Cauli-flower	6.453	0.046	0.139	0.138
7	Cucumber	4.228	0.020	0.723	0.121
8	Ribbed gourd	4.228	0.058	0.401	0.118
9	Spinach	3.894	0.037	0.142	0.114
10	String bean	4.228	0.092	0.966	0.128
11	Beans	4.005	0.012	0.854	0.108
12	Radish	19.915	0.075	0.344	0.128
13	Brinjal	11.348	0.012	0.903	0.145
14	Teasle gourd	3.334	0.012	0.299	0.134
15	Papaw	4.116	0.023	0.367	0.208
16	Lady's finger	4.562	0.012	0.603	0.118
17	Palwal	5.118	0.017	0.318	0.302
18	Cabbage	5.340	0.006	2.727	0.124
19	Bitter gourd	4.895	0.023	0.325	0.158
20	Tomato	5.674	0.241	0.677	0.124
21	Rice	5.674	0.152	0.180	0.114

*All toxic metals were measured by mg/kg as unit

Although there is no clear evidence about Pb dietary transfer, many studies have demonstrated that diet is the most important root of toxic metal accumulation in aquatic animals and food choice influences body burden of metals100-101.

4. Conclusion

A study was performed on the status of toxic heavy metals in some foodstuffs (vegetables, rice etc.), commonly consumed in Bangladesh (and likely to be exported in the USA, EU countries) were examined by using Atomic Absorption Spectrophotometry (AAS) technique. A total of 21 foodstuff samples including 20 different vegetables and one kind of rice sample were collected from different agricultural fields of Mohanpur upazila area of Rajshahi district in Bangladesh.

The lead concentration of all samples of the study area ranged between 3.332 to 19.931 mg/kg (Table-5.2). Lead level in vegetables more than 7.2 mg/kg is not suitable for edible purpose. The present results reveal that major samples contain lead less than 7.2 mg/kg. Generally the maximum permissible limit of cadmium in vegetables is 6 mg/kg . The cadmium level in all samples of the study area ranged between 0.00 to 0.241 mg/kg (Table-2), which is within the permissible limit. The mean concentration of cadmium in vegetables is 0.120 mg/kg. Moreover, the above data reveals comparatively low concentration of Cd in the vegetables studied.

The collected vegetables including rice have contained minute quantities of manganese. The Manganese level of all vegetables in the study area ranges from 0.180 to 2.727 mg/kg (Table-2). The Manganese limit for vegetables is specified 103 as 15 to 100 mg/kg. Therefore, the manganese values of all samples were found to be within the desirable limits. So all vegetable samples under the present investigation are free from manganese hazards.

The baseline levels of potentially toxic trace metals namely Pb, Cd, Mn and Cr in vegetables consumed by the inhabitants of Rajshahi district as well as all over the country have been measured. The levels of Pb, Cd, Mn and Cr were significantly lower in vegetables whereas, only two vegetable samples have shown higher values of Pb. Because of unavailability of data regarding trace metal level in food commodities of the district, the measurement reported herein will help in monitoring and improvement to population hygienic conditions. Important soil properties might affect the bioavailability of metals by binding them and limit the plants towards metal uptake. Due to high clay content in the Mohanpur upazila area the phyto availability of the metals might be limited. The factors and sources responsible for uptake of trace metals such as environmental conditions, availability of trace metals from soil, nature of vegetables might be an efficient interceptor of metals of agriculture related chemicals, method of applications and processing need to be handled carefully. The data showed here might be useful for health status evaluation and in considering the ultimate effects on the population of Bangladesh.

Acknowledgments

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