J. Environ. Sci. & Natural Resources, 11(1&2):227-234, 2018 ISSN 1999-7361

The Urgency of Studies on Cadmium Manifestation (Cd) in Food Chain

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Abstract

Cadmium (Cd) is a heavy metal which is not essential for human body. Cadmium enters into human body mainly through food consumption. Besides industrial wastes, phosphate fertilizers contain Cd which accumulates gradually in agricultural lands. To produce high quantity of food for about 160 million people of Bangladesh, agricultural lands need to be applied huge amount of fertilizes including TSP which add Cd to soils. It has been reported that in rice grains the cadmium concentrations were the highest in Bangladesh and Srilanka where the per capita rice intake is high, from a survey on four continents of 12 countries. The intake of these Cd containing foods may ultimately increase the Cd concentration in human kidneys and livers which might be related to the enhanced kidney patients in Bangladesh. There is lot of toxic effects of excess Cd on humans. The present review illustrates the urgency of further studies of Cd in Bangladesh.

Keywords: Cadmium, Food chain, Human health

Introduction

Bangladesh is one of the most densely populated countries in the world (BBS, 2006). Agriculture plays an important role in the revival of Bangladesh national economy (Ayoub, 1999). The quality of the soil determines the nature of plant ecosystems and the capacity of land to support animal life (Wild, 1996). Agricultural soil contamination with heavy metals through the repeated use of untreated or poorly treated wastewater from establishments and application of chemical fertilizers and different types of pesticides is one of the most severe environmental problems in Bangladesh (Rahman *et al*., 2012). Throughout the world, soil ecosystem has been contaminated with different types of heavy metals by various human activities and movement of metals in food chain has become human health hazard (Zahir *et al.,* 2009). Cadmium is a 67th most abundant element which has a density of 8.64 g/cm^3 at 20^{0}C, a melting point of 320^{0}C, and a boiling point of 767^{0}C. It is a silver-white, lustrous and ductile metal. The atomic number is 48 and atomic mass is 112.4 (Merian, 2004). Major groups of heavy metals including Cd have been shown in Table 1.

Table 1. Major groups of heavy metals

Major groups	Heavy metals	Reference
Less toxic	Tin (Sn) and Aluminum (Al)	(Raikwar *et al.,* 2008)
Highly toxic	Mercury (Hg), Lead (Pb) and Cadmium (Cd)	
Essential	Copper (Cu), Zinc (Zn), Cobalt (Co), Chromium (Cr), Manganese (Mn) and Iron (Fe)	
Non-essential	Barium (Ba), Aluminum (Al), Lithium (Li) etc.	

Among the highly toxic metals, cadmium is one of the most important to consider because of its potential to enter into the human food-chain and its ability to accumulate in organs (ATSDR, 2008b). The most recent study suggests that around 300,000 USA workers involved in various cadmium based industries were estimated to be at elevated risk of cadmium exposure (ATSDR, 2008b). The increased emissions of cadmium resulting from various sources, combined with its persistence in the environment, and its relatively rapid uptake in crops, combine to make cadmium the fifth most toxic metal to animals and the fourth most toxic metal to plants (Muneer *et al*., 2011). The average concentration of cadmium in the lithosphere (crust and uppermost solid mantle) is 0.098 mg/kg (Heinrichs *et al*., 1980). In USA, around 300,000 workers involve in Cd based industries were estimated to be elevated risk of Cd exposure (ATSDR, 2008b). Cd is also present as an

impurity in several products, including phosphate fertilizers, detergents and refined petroleum products, metal based pesticides, industrial emissions, transportation, harvesting process (Ali *et al.,* 2013).

Unsafe food in the world

Food adulteration has become a global issue and the problem is not ignoring the human rights for safer food. Various kinds of food are commonly adulterated include fruit, vegetables, milk, fishes, sweet mates, rice, wheat, meat, soft drink, juice powder, baby and so on (Mahfuz, 2014). The problem of adulteration persists at every level of food from preparation to consumption. Most of the food manufactures and restaurant owners and also so forth are all involved in this unethical practice of adulteration. Foods are adulterated by using several exaggerated chemicals and toxic artificial colors. Fig. 1 shows the pathways of our food being contaminated.

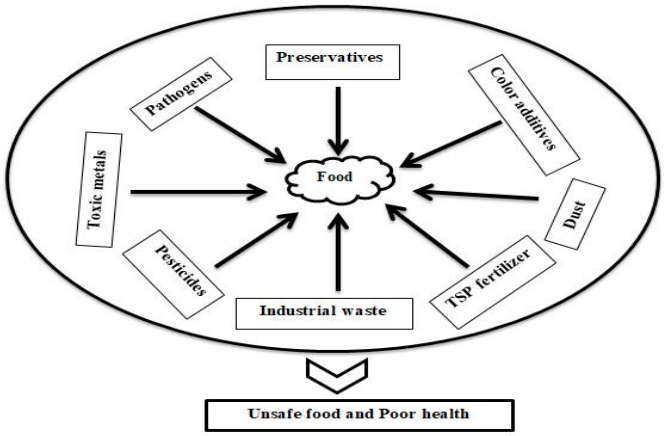

Fig. 1. Pathways of unsafe food in the world

Addle and perishables foods are stored, sold and serve to consumers. Uses of poisonous chemicals in perishable foods are explicit in highest degrees which are endangering the lives of the people (Derek, 2015). Our future generation will be seriously affected with vulnerable physical and mental growth inflicted by food adulteration.

Cd concentration of soils in Bangladesh

The amount of Cd in soils depends on various factors such as soil components and the amounts added in the soil over time through atmospheric deposition etc. (Flora *et al*., 2011). Soil pH and organic matter also influence Cd accumulation (Kirkham, 2006). Studies suggest that soil pH decreases the amount of Cd intake by the plants increases (Page *et al*., 1987). The highest total Cd was found to be 3.15 ε g/g in Chorfasion (Bhola) and it was followed by Ishardi (5.23 ε g/g), Kaligonj(2.89 ε g/g), Lalpur (2.39 ε g/g), Dumuria (2.4 ε g/g) and Asasuni(2.43 ε g/g). The lowest Cd value was found 1.38 ε g/g in Tangail Sadar which was identical to Botiaghata (1.51 ε g/g) and Madhupur (1.64 ε g/g) (Akter *et al.,* 2013). Table 2 shows the heavy metal concentrations of Bangladesh.

Table 2. Heavy metal concentrations (µg/g) in the collected soil samples of different areas of Bangladesh (Begum *et al.*, 2014)

Heavy metals	Dhaka City Area (Sultana, 2010)	Industrial Sites of Gazipur (Sumi, 2010)
Pb	3.84	75.00
Ni	<0.002	12.50
Cr	32.25	100.0
Cd	0.52	0.20

The Cd concentrations were found in the soils of Dhaka Aricha highway, Savar, Bangladesh 3.99±1.85 mg/Kg (Aktaruzzaman *et al*., 2013). The Cd concentrations were found 0.32 to 0.54mg/kg in tannery effluent contaminated soil in Dhaka (Mottalib *et al.*, 2016). The Cd concentrations were found 0.49-4.89 mg/ kg in surface soils of Chittagong city (Alamgir *et al.*, 2015). The Cd concentrations were found 0.005-0.055 mg/kg in sediments of six freshwater wetlands of greater Dhaka district (Alam *et al.*, 2018). The Cd concentrations were found ranged from 2.33 to 1.5 mg/kg and 0.75 to 2.10 mg/kg in dry and wet season, respectively at Hazaribagh area (Mondol *et al.,* 2017). The Cd concentration values of all soil samples were found to be ranged in between 1.07 to 1.5 mg/kg (0-15 cm) and 0.567 to 0.933 mg/kg (16-30 cm). The mean values of Cd concentration were recorded 1.25 and 0.71 mg/kg at the top soils and subsoils, respectively. The highest value of Cd (1.5 mg/kg) was observed in the agricultural land where spinach was grown and the lowest concentration of Cd (0.57 mg/kg) was observed agricultural land where potato was grown (Saha and Hossen, 2018).

Cd concentration of different vegetables in Bangladesh

Vegetables are part of daily diets in many households forming an important source of vitamins and minerals required for human health (Thomson and Kelly, 1990). The daily vegetable consumption by an adult of Bangladesh is 130 g (Islam *et al.,* 2005). The concentrations of these trace elements in vegetables may vary depending on the inherent (varieties, maturity, genetics, and age) and environmental (soils, geographical locations, season, water source and use of fertilizers) conditions of plants and animals and on methods of handling and processing (Pennington and Calloway, 1973). An average man accumulates as about 30 mg Cd in his body by the age of 50 years. Refined foods, water foods, water pipes, coffee, tea, coal burning and cigarettes are the most important source of Cd (Raikwar*et al.,* 2008). In 1989, the FAO/WHO Joint Expert Committee on Food Additives (JECFA) set the Provisional Tolerable Weekly Intake (PTWI) for cadmium at 7 ε g/kg/week, corresponding to 1 ε g/kg/day (WHO, 1989). Fig. 2 shows the heavy metal concentrations in vegetables in Bangladesh.

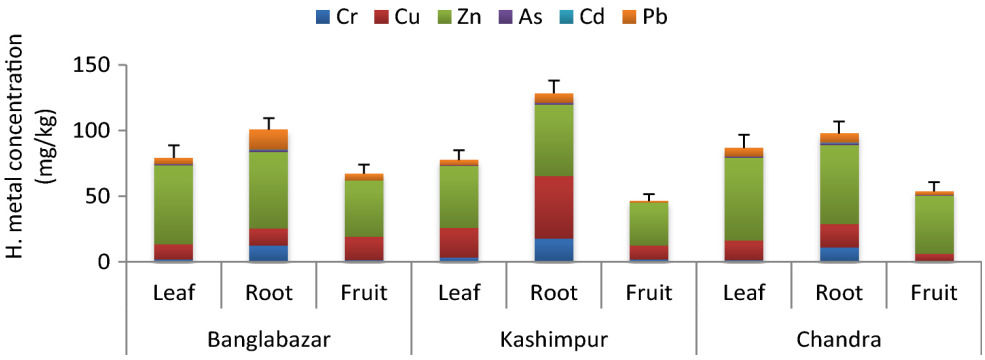

Fig. 2. Heavy metal (H) concentration of vegetables in the industrial area of Bangladesh (Ahmed *et al.,* 2018)

The Cd concentrations were found <0.1 mg/kg in potato, amaranths, spinach amaranths, carrot, cabbage, tomato, and brinzal at Pakshi union, Ishwardi, Pabna (Tasrina *et al.,* 2015). The average Cd concentrations were found in amaranths, radish and cauliflower 2.545mg/kg at Ruppur, Pabna district (Jolly *et al.*, 2013). The Cd concentration in leafy vegetables (Red spinach) was found 0.180-2.305 mg/kg along the Dhaka Aricha Highway, Savar (Aktaruzzaman *et al.*, 2013). The largest number of Bangladeshi food and non-food samples investigated for their Cd content. High Cd levels were detected in leafy vegetables (mean 31 [SD 29] ε g/kg). Of these vegetables, lalshak (Amaranths tricolor) contained the highest Cd level (303 ε g/kg [wet weight]; mean 100.5 [SD 95] ε g/kg) (Al Rmalli *et al.*, 2012). The cadmium level (dry wt.) was the highest in spinach with a range of 0.559 to 1.400 µg/g followed by tomato with a range of 0.630 to 1.303 µg/g and cauliflower having 0.506 to 0.782 µg/g (Naser *et al.*, 2009). In Porabari union, Tangail; the Cd concentration values of all vegetables sample were found to be ranged in between 0.053 to 0.143 mg/kg. The highest value of Cd concentrations in vegetables 0.143 mg/kg in (Amaranths) land and the lowest value of cadmium concentration in vegetables were 0.053 mg/kg in (Cauliflower and Zucchini) land (Saha and Hossen, 2018).

Cd concentration in rice in Bangladesh

Heavy metal contamination in paddy soils is one of the most serious problems facing rice production and soil management in Asian countries. In the world, especially in Latin America, the East, and South Asia, the Middle East and the West Indies rice is one of the most important staple foods which are the staff of life for 3 billion people (Stone, 2008). It also provides about 30% of the dietary energy and 20% of the dietary protein in Asia (WHO, 2002). However, rice may contain significant amounts of contaminants such as arsenic (As), cadmium (Cd) and lead (Pb) (Meharg *et al.,* 2013). The irrigated rice samples collected from Mymensingh exhibited the highest Cd concentration (mean 0.080 mg/kg), which was threefold higher than Saltha (0.024 mg/kg) and between the two rice seasons, the difference of Cd concentration was small and also the Cd level of rice samples depending on the varieties ranged from 0.007-0.297 mg/kg; however, the majority varieties had Cd concentration below 0.05 mg/kg (Jahiruddin *et al.,* 2017). Table 3 shows the maximum permissible level of heavy metals in rice.

Table 3. Maximum permissible Level (MPL) of heavy metal in rice (Magamage *et al.*, 2017)

Metal Type	As	Cd	Pb	Hg	Se
MPL (ppm)	0.2	0.2	0.2	0.1	0.3

The Cd levels over 260 rice samples across 12 districts of Bangladesh in the range of <0.005-1.31 mg/kg, with the mean of 0.099 mg/kg (Meharg *et al.*, 2013). In the study of Bangladesh Rice Research Institute (BRRI) they found that 8/86 samples of industrial field rice were highly contaminated with cadmium(>0.07 mg/416.01 g) and they also found 21/76 market samples of rice contained greater amount than the risk level of daily intake of cadmium (Hezbullah *et al.,* 2016). The Cd concentration of rice grain showed significant difference among various contaminated soils. The mean Cd values in rice grains were 0.98, 0.10, 0.22 and 0.36 mg/kg dry weight for city sewage; tannery, fertilizer factory and cement factory soil, respectively. The Cd concentration in straw and root also varied significantly among the soils. The Cd concentration ranged from 2.73 to 6.91 mg/kg in straw and 3.50 to 27.91 mg/kg in root (Kibria, 2012) reported that. The Cd concentration of four rice varieties (Minicat, BRRI 28, BRRI 29, Swarna) from field and market were found between 2.93-5.67, 3.66-9.55, 0.16-0.57, 0.19-0.93 mg/kg respectively (Uddin *et al., 2017)*. In Porabari union, Tangail; the Cd concentration values of all rice (BRRI 28) samples were found to be ranged in between 0.057 to 0.097 mg/kg and also the mean values of Cd concentration in rice were recorded at 0.071 mg/kg (Saha and Hossen, 2018) (Fig. 3).

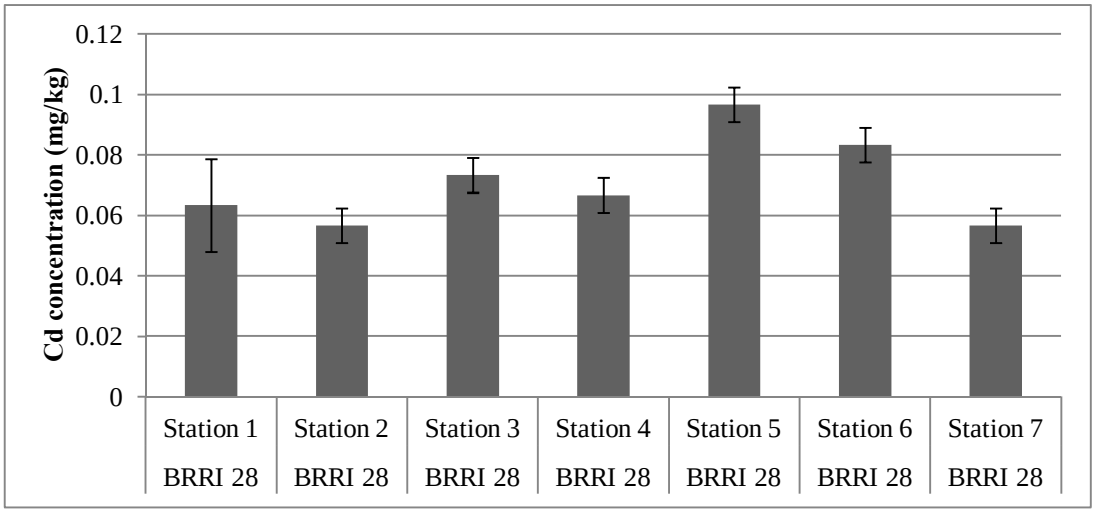

Fig. 3. Cadmium (Cd) concentrations in Rice at Porabari Union, Tangail (Saha and Hossen, 2018)

Number of kidney patients and dialysis expenditure in Bangladesh

Around 20 million people currently suffer from kidney disease in Bangladesh and among which 800,000 require dialysis (Farhin, 2017). One in every seven people in the country has been suffering from kidney diseases and 40,000 die of longtime kidney failures annually (The Daily Star, 2019) and also reported that the rate of chronic kidney disease has now increased to 18 percent from 9 percent during the period (The Daily Star, 2019). National Health Bulletin 2016 showed that among the top causes of death at medical college hospitals in 2015, kidney disease was placed sixth. The government run dialysis centres take Tk 400 for a single dialysis, but the facilities are not adequate and also a single dialysis costs about Tk 1,600-5,000 at private facilities, while a patient need two-three dialysis in a week. According to Kidney Foundation, against the yearly need of 20,000 kidney transplantations, about 100 kidneys are transplanted in the country a year (Kabir, 2019).

Effects of Cd on human health

Cadmium is denominated mostly for its high toxicity to animals and humans (Merian, 2004). Cadmium has a biological half-life between 15-30 years, which causes its accumulation in the blood, kidney, liver, and the reproductive organs (Flora *et al.,* 2011). Fig. 4 shows the Transfer of Cadmium in the human food chain and its health effect.

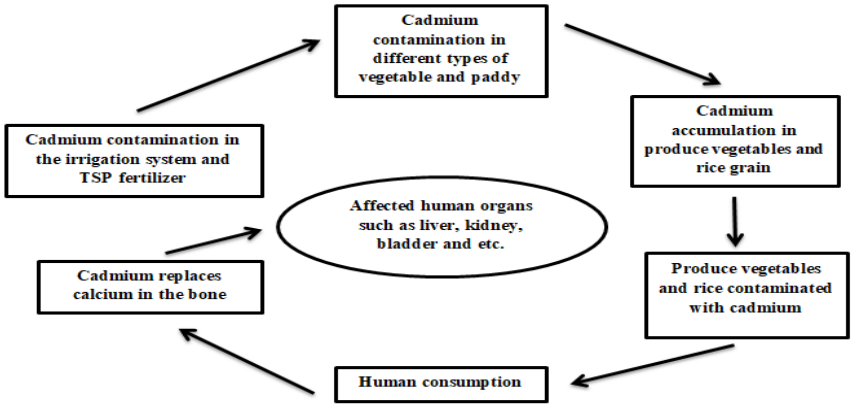

Fig. 4. Transfer of Cadmium in the human food chain and its health effect

Sewage sludge or household leachate used for irrigation and it also increases the average Cd in soil and different types of vegetable (Gholami*et al.,* 2011). It causes various health-related problems in humans through accumulation in different organs. Cd enters through ingestion and inhalation in the human body (Cadmium Working Group, 2011b). The acute effects of this metal can be seen in the respiratory and digestive tracts (Merian, 2004). The toxic effects of excess Cd on humans are hypertension, emphysema, carcinogenic changes (mainly kidney and prostate), skeletal deformation and low reproductive function (Kabata-Pendias and Mukherjee, 2007). Cadmium exposure may increase important manifestations of cardiovascular disease Environmental exposure to Cd is associated with significantly increased stroke and heart failure prevalence(Peters *et al.,* 2010). The Environmental Protection Agency (EPA) has established maximum containment levels for cadmium in drinking water at 5 µg/l (ATSDR, 2008).

Conclusions

Cadmium concentration in Bangladesh soils and rice has been observed higher than the permissible limits. The source of Cd in soils and rice are mostly from industrial activities and triple super phosphates used in agricultural lands. The number of kidney patients is increasing in Bangladesh. We assume that this might be due to the high concentration of Cd in foods which are consumed by the inhabitants. Bangladesh is spending a large amount of money for kidney patients. If proper awareness program and action could be taken, this could discourage people to apply excessive phosphate fertilizers to soils. This will reduce the excessive intake of Cd by human being. Further lab works are warranted to find out the way of reducing the input of Cd in agricultural soils.

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