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Review

Heavy metal contamination of food in a developing country like Bangladesh: An emerging threat to food safety

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This review paper highlighted possible ways of heavy metal contamination of food chain in a developing country like Bangladesh as it is considered an emerging threat for food safety. The review paper was prepared over a period of six months by searching and collecting data of various studies done in Bangladesh from original articles of many national and international journals. Also, data were taken from related review articles of many journals and websites. The review showed that arsenic, cadmium, chromium and lead are the four major threats for heavy metal contamination of food chain in Bangladesh. Pollution of surface water, agricultural soil by unscientific industrial effluent disposal and application of chemical fertilizers, pesticides are the major ways of heavy metal contamination. Consumption of these heavy metals with food above safe limit causes various organ dysfunctions including cancer.

Key words: Heavy metal, food contamination, food safety.

INTRODUCTION

Heavy metals constitute a very heterogeneous group of elements which are widely varied in their chemical properties and biological functions. The term "heavy metal" can be defined as metals which have specific weights more than 5 g cm^{-3} (Raikwar et al., 2008). The term heavy metal has been called a "misinterpretation" in an International Union of Pure and Applied Chemistry (IUPAC) technical report due to its contradictory definitions and lack of a "coherent scientific basis". Thus, an alternative term "toxic metal" has been proposed, but

no consensus of exact definition exists either (Mandal and Ahmed, 2013). They do not degrade or are not destroyed; they generally do not breakdown into less harmful constituents. They accumulate where they are released. As trace elements, some heavy metals are essential to maintain the metabolism of human body. However, at higher concentrations they can lead to poisoning. Some heavy metals like mercury, cadmium and lead are highly toxic in nature (Ahmed et al., 2012).

Heavy metals can be classified into four major groups

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on their health importance:

Essential: Copper (Cu), Zinc (Zn), Cobalt (Co), Chromium (Cr), Manganese (Mn) and Iron (Fe). These metals are called micronutrients and are toxic when taken in excess of requirements.

Non-essential: Barium (Ba), Aluminum (Al), Lithium (Li) etc.

Less toxic: Tin (Sn) and Aluminum (Al).

Highly toxic: Mercury (Hg), Lead (Pb) and Cadmium (Cd).

Heavy metals are also called trace elements due to their presence in trace (10 mg/kg) or in ultra-trace (1µg/kg) quantities in the environmental matrices. Heavy metal pollution can originate from natural and anthropogenic sources. Activities such as mining, smelting operation and agriculture have contaminated extensive area of world (Raikwar et al., 2008).

Heavy metal contamination of the environment is a major problem especially for the growing medium sized cities in developing countries primarily due to uncontrolled pollution levels driven by causative factors like industrial growth and heavy increase in traffic using petroleum fuels. Heavy metal contamination may occur due to factors including irrigation with contaminated water, the addition of fertilizers and metal based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale (Ali et al., 2013).

With the increased urbanization and industrialization, there has been a rapid increase in the municipal waste water (sewage water and industrial effluents) which in turn has intensified the environmental pollution. Pollution of river causes the degradation of biodiversity. Heavy metals contamination creates problem in those species, specially the fishes which survive in polluted rivers and this problem is directed toward the health damage of human with the consumers of fishes (Ahmed et al., 2012).

Agricultural soil contamination with heavy metals through the repeated use of untreated or poorly treated wastewater from industrial establishments and application of chemical fertilizers and pesticides is one of the most severe ecological problems in Bangladesh (Rahman et al., 2012). Plants grown in polluted environment can accumulate heavy metal at high concentration causing serious risk to human health when consumed (Naser et al., 2012).

Food safety is a scientific discipline describing handling, preparation and storage of food in ways that prevent food borne illness. Safety of food chain can be broken by both contamination and adulteration of food in different steps of the cycle. Unsafe food causes many acute and life-long diseases, ranging from diarrheal diseases to various forms of cancer (Mridha, 2013). It is well understood that the whole population of Bangladesh is slowly poisoned through all types of agricultural,

dairy, poultry, fishery, packaged, bottled and canned food etc (Hezbollah, 2014). The increasing demand of food safety has accelerated research regarding the risk associated with consuming food contaminated by heavy metals (Ali et al., 2013).

ARSENIC CONTAMINATION IN BANGLADESH

Arsenic is a natural component of the Earth's crust. It can be found in soil and water that have interacted with arsenic rich rocks. Arsenic can also be introduced into the ground water anthropogenically through the application of the arsenic rich herbicides and pesticides that are frequently use on agricultural lands.

Arsenic contaminated ground water was first documented in 1984 (Khalequzzaman et al., 2005). Arsenic contamination of ground water is a major public health concern in Bangladesh and elsewhere (Khan et al., 2010). The presence of arsenic in ground water has been reported in many countries, like Argentina, Chile, China, India, Japan, Mexico, Mongolia, Nepal, Poland, Taiwan, Vietnam and USA. The World Health Organization (WHO) ranked this calamity as "the largest poisoning of a population in history in the year 2000 (Bhattacharya et al., 2010). Chronic toxicity of arsenic in humans from arsenic contaminated drinking water occurs in 61 of 64 districts in Bangladesh, affecting millions of people. The maximum permissible level of arsenic in drinking water recommended by the World Health Organization is 10 µg/L (WHO, 2008) and in Bangladesh, it has been adjusted to 50µg/L by the local authorities (Khan et al., 2010).

Arsenic contaminated ground water is used for irrigation as well as cooking, and it is likely that the last 30 years of irrigation have led to diffuse contamination of land throughout the districts relying on arsenic contaminated ground water. Thus, soil-crop-food transfer, as well as cooking and direct ingestion of drinking water may be among the major exposure pathways of arsenic transfer (Alam et al., 2003). The arsenic contaminated rice may be considered a catastrophic situation in South-East Asia where concentration of arsenic in underground water is high, and rice being the staple food.

Khan et al. (2010) in their study in Bangladesh found that raw rice contained higher concentration of arsenic compared to raw vegetables. The epidemiological studies show that the chronic arsenic poisoning can cause serious health effects including cancers, melanosis, hyperkeratosis, restrictive lung disease, peripheral vascular disease (black foot disease), gangrene, diabetes mellitus, hypertension, and ischemic heart disease etc. Arsenic seems to be a cancer promoter rather than a cancer initiator (Bhattacharya et al., 2010).

A survey showed that arsenic related diseases resulted in 9136 deaths per year and 174 disability-adjusted life years (DALYS) among people who were exposed to

arsenic concentrations of above 50 µg/L, and this constituted about 0.3% of the total burden of disease in Bangladesh (Alam et al., 2003).

CADMIUM CONTAMINATION OF FOODS IN BANGLADESH

It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride) or sulphur (cadmium sulphate) (Raikwar et al., 2008). Cadmium (Cd) is a heavy metal that has received considerable concern environmentally and occupationally. Cd has a long biological half-life mainly due to its low rate of excretion from the body. Thus, prolonged exposure to Cd will cause toxic effect due to its accumulation over time in a variety of tissues, including kidneys, liver, central nervous system (CNS) and peripheral neuronal systems (Wang and Du, 2013).

It is almost absent in the human body at birth, however accumulates with age. An average man accumulates as about 30 mg cadmium 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 cadmium (Raikwar et al., 2008). There are several other sources of human exposure to Cd, including employment in primary metal industries, production of certain batteries, some electroplating processes (Wang and Du, 2013).

Approximately 0.001% of cadmium in the body is excreted per day, mostly in urine. Such extremely low excretion rate of cadmium is due to a lack of an active biochemical mechanism for elimination coupled with renal reabsorption (Satarug and Moore, 2004). In 1989, the FAO/WHO Joint Expert Committee on Food Additives (JECFA) set the provisional tolerable weekly intake (PTWI) for cadmium at 7 µg/kg/week, corresponding to 1 µg/kg/day (WHO, 1989).

In a study by 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). They also found 21/76 market samples of rice contained greater amount than the risk level of daily intake of cadmium (Hezbollah, 2014). Another study in Bangladesh found high cadmium level in leafy vegetables especially "lal shak" (*Amaranthus tricolor*) (303 µg/kg), in rice (37.2 µg/kg) and in puffed rice (Al-Rmali et al., 2012).

A study in Ruppur, Pabna district found high cadmium in Amaranthus, Radish and cauliflower, and Hazard Quotient (HQ) value for cadmium was 2.543 which is above the safe value (Jolly et al., 2013). Another study in the region of Dhaka Aricha highway, Savar, Bangladesh found high cadmium (3.99±1.85 mg/Kg) in studied soil samples along with high level in vegetable samples (1.00±0.68 mg/Kg) (Aktaruzzaman et al., 2013).

Chronic exposure to low level cadmium has been associated with a number of pathologies, such as end-stage renal failure, early onset of diabetic renal

complications, osteoporosis, deranged blood pressure regulation and increased cancer risk (Satarug and Moore, 2004). Epidemiological and experimental studies have linked the occupational Cd exposure with lung cancer and other cancers such as the prostate, renal, liver, hematopoietic system, urinary bladder, pancreatic, testis and stomach cancers. Exposure to Cd also severely affects the function of the nervous system, with symptoms including headache and vertigo, olfactory dysfunction, parkinsonian-like symptoms, slowing of vasomotor functioning, peripheral neuropathy, decreased equilibrium, decreased ability to concentrate and learning disabilities (Wang and Du, 2013).

CHROMIUM CONTAMINATION OF FOODS IN BANGLADESH

Chromium is a polyvalent element, found naturally in the air, soil, water and lithosphere. Chromium can exist in several chemical forms displaying different oxidation states from zero to six, but in the natural environment, only trivalent chromium Cr (III) and hexavalent chromium Cr (IV) are stable. Cr (IV) is a carcinogen and a potential soil, surface water and ground water contaminant, while its reduced trivalent form is much less toxic, insoluble and a vital nutrient for humans.

Cr (III) occurs naturally in the environment and is an essential nutrient required by the human body. It is used on a large scale in many different industries, including metallurgical, electroplating, production of paints and pigments, tanning, wood preservation, pulp and paper production (Shadreck and Mugadza, 2013).

Chromium salt (particularly chromium sulphate) is the most widely used tanning substances today. Currently more than 90% of global leather production of 18 billion sq. ft is through chrome-tanning process (Belay, 2010). Tannery effluent is ranked as the primary pollutant among all industrial wastes. Approximately 40 heavy metals and acids are used for processing raw hides. Only 20% of the total chemicals used during tanning are absorbed by leather, whereas the rest is released as waste. Solid wastes generated by the tannery industry contain appreciable amounts of toxic metals, which are converted to protein concentrate and used as poultry feed in Bangladesh (Islam et al., 2014).

In Bangladesh, among the routes of chromium ecotoxicity, feeds and fertilizer production from tanned skin-cut wastes is the most direct one leading to food chain contamination. The tanning industries of Hazaribagh, Bangladesh are processing some 220 metric tons of hide a day with an associated release of 600 to 1000 Kg of tanned skin-cut waste (SCW) resulting from per ton processed hide. The SCW are protein-rich and are unscientifically used to produce protein-concentrates for poultry and fish feeds and organic fertilizer. In view of the facts, a huge migration of chromium can ensue into poultry products, fish and vegetables, and further bio-

magnify into food chain (Hossain et al., 2009). The U.S. National Academy of Sciences has established the Recommended Daily Allowances for chromium as 50 to 200 $\mu\text{g}/\text{day}$ for adult men and women (Shadreck and Mugadza, 2013). A study by Bangladesh livestock research institute (BLRI) found high chromium (0.53 to 0.96 ppm) in all milk samples of both brand and local vendors compared to the IAEA values (0.22 to 0.29ppm) (Hezbollah,2014).

Another study with poultry egg found mean chromium content of a single egg to be 23.3809 μg which exceeds adequate daily dietary intake of children up to 8 years of age as well as corresponds to major part for other age groups. Chromium content was higher in albumin than in yolk (Hossain et al., 2009). A study with "Stinging Catfish" of Turag river of Dhaka found high chromium (1.46mg/Kg) in fish body (Mandal and Ahmed, 2013).

A study with vegetable samples grown at Gazipur district of Bangladesh showed that the accumulation concentration of chromium (21.9-22.9 $\mu\text{g}/\text{g}$) was higher than the maximum allowable level set by world health organization (WHO) (1.3 $\mu\text{g}/\text{g}$) (Naser et al., 2012). Inhalation of Cr (VI) has been shown to cause perforation of the nasal septum, asthma, bronchitis, pneumonia, inflammation of the larynx and liver and increased incidence of bronchogenic carcinoma while exposure due to dermal contact of Cr (VI) compounds can induce skin allergies, dermatitis and dermal corrosion (Shadreck and Mugadza, 2013). Cr (VI) is a powerful epithelial irritant, and also considered a human carcinogen (International Agency for Research on Cancer, 1990).

LEAD CONTAMINATION OF FOODS IN BANGLADESH

Lead (Pb) is ubiquitous, and one of the earliest metals discovered by the human race (Flora et al., 2012). It is the most common industrial metal that has become widespread in air, water, soil and food (Raikwar et al., 2008).

Lead is regarded as a potent occupational toxin, and its toxicological manifestations are well known. The non-biodegradable nature of lead is the prime reason for its prolonged persistence in the environment. Human exposure to lead occurs through various sources like leaded gasoline, industrial processes such as lead smelting and coal combustion, lead-based paints, lead containing pipes or lead-based solder in water supply systems, battery recycling, grids and bearings etc. Lead contamination in soils has been seriously emphasized in recent years since this metal is very toxic for human and animals. Pb enters human or animal metabolism via the food chain (Rahman et al., 2012). A study with fish and water of Turag river found high lead in water samples (0.1169 \pm 0.041 ppm) (Maximum allowable concentration is 0.05 ppm) and "Lia fish" (*Lamellidens corrianus*) (3.8656 \pm 1.041 mg/kg) (FAO standards-0.10 mg/kg)

(Mandal and Ahmed, 2013). Another study with samples from central market of Rajshahi, Bangladesh found high Pb in fish "Major carp" (*Catla catla*) (Saha and Zaman, 2013).

A study by Bangladesh Rice Research Institute (BRRI) showed that one sample of rice collected from industrial field of Narayanganj district have a very high amount of lead (0.242ppm) (Hezbollah,2014). Another study with water and plants samples from area around Tejgaon industrial area of Bangladesh found the level of Pb to be much higher than the permissible levels of WHO and USPH standard at all locations during both wet and dry season (Mondol et al., 2011). A study in Samta village of Jessore district of Bangladesh found high lead level in vegetables like ghotkol, elephant foot, bottle ground leaf and stem amaranth (1.689, 0.967, 0.987 and 0.831 $\mu\text{g}/\text{g}$ respectively).

Considering the average daily intake of fresh vegetables per person per day is only 130 g, all the vegetables grown at Samta had Pb concentrations that would be a health hazard for human consumption (Alam et al., 2003). Acute toxicity is related to occupational exposure, and is quite uncommon. Chronic toxicity on the other hand, is much more common and at blood level of about 40 to 60 $\mu\text{g}/\text{dL}$ (Flora et al., 2012). Peripheral motor neuropathy is seen as a result of chronic high level lead exposure. It has been associated with miscarriages and low birth weights of infants (Gidlow, 2004).

Lead directly affects the hematopoietic system through restraining the synthesis of hemoglobin by inhibiting various key enzymes involved in the heme synthesis pathways. It also reduces the life span of circulating erythrocytes by increasing the fragility of cell membranes (Flora et al., 2012). The International Agency for Research on Cancer has concluded that the evidence for the carcinogenicity of lead in humans is inadequate (Gidlow, 2004). Both chronic and acute lead poisoning causes cardiac and vascular damage with potentially lethal consequences including hypertension and cardiovascular disease (Flora et al., 2012).

CONCLUSION

Heavy metal poisoning of food is a nerve racking issue for developing countries like Bangladesh. Unscientific waste disposal technique and injudicious application of chemical fertilizer or pesticide is one major cause of soil and surface water contamination with heavy metal. These heavy metals are taken up by the plants grown on the contaminated soil and fish of contaminated water bodies. Human taking these contaminated plants or fish are at risk of heavy metal intoxication. Poultry sector is another threat for heavy metal intoxication for Bangladeshi people. It is time for policy maker to take appropriate action to protect people from this threat of food safety. Large scale study on human is needed to actually find out heavy metal related illness. To date, studies on human in

Bangladesh were done only for arsenic intoxication. Other heavy metal related illness incidence should be documented by large scale studies.

Conflict of Interests

The authors have not declared any conflict of interests.

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