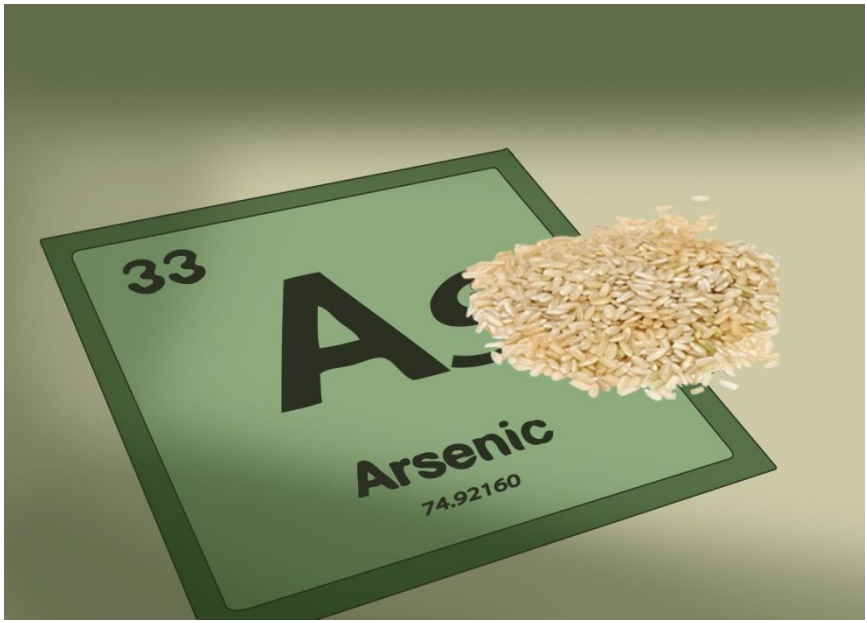

Screen foodstuffs for arsenic; Avoid or reduce the intake of food containing high concentration of arsenic

Chapter

9

〖Food with Low Arsenic Level〗

Food alone can contribute more than one-third of the total arsenic intake in arsenic endemic area (Huq, 2008) whereas drinking water contributes the rest two-third. This situation is observed in Bangladesh. Similar situation is thought to be in India. Therefore, necessary measure must be taken to reduce the intake of arsenic contaminated food or to take low arsenic contaminated food. However, unlike drinking water, the task to taking food low in arsenic is difficult to implement. In addition, the focus on the risk of consuming arsenic through drinking water and airborne workplace exposure are more highlighted than that of food. It may be due to failure of identification of health problem following chronic intake of arsenic contaminated food.

Seafood is an important source of arsenic intake. For example, it is about 90% of daily arsenic intake in the United States (Gunderson, 1995), 70% in Canada

(Dabeka et al., 1993), and 60% in Japan (Tsuda et al., 1995). In addition, Japanese consume seaweed which also contains arsenic. The amount of inorganic arsenic in seafood is very low. Most of them are in organic form. There is no reported case of poisoning following intake of high arsenic contaminated seafood. It is considered that ingestion of complex organic arsenic is safer than inorganic arsenic. In addition, the lethal dose of arsenic varies in rat (Table 9.1).

Table 9.1 *Median lethal dose of some arsenic species in rat.*

Species	Dose (mg/kg)
Arsine	3
As^{III}	14
As^{V}	20
MMA	700-1,800
DMA	700-2,600
Arsenocholine	6,500
Arsenobetaine	>10,000

The important sources of inorganic arsenic containing foods are rice, grains and flours (Schoof et al., 1999). In addition, rice has the tendency to bind with inorganic arsenic while washed or cooked with arsenic contaminated water.

In arsenic endemic areas, the use of arsenic contaminated water for irrigation has lead to the accumulation of arsenic in surface soil lead to bioaccumulation of arsenic in edible plants and crops (Bundschuh et al., 2012).

Arsenic is present in most of the foodstuffs. The estimated average daily dietary intake of arsenic in different countries is not known. However, it is estimated to 25-75 g/day by US adults.

9.1 Rice

Rice is the staple food for over half of the world's population. Over 90

percent of the world's rice is produced and consumed in the Asian region by 6 countries (China, India, Indonesia, Bangladesh, Vietnam and Japan) comprising 80% of the world's production and consumption. The people in Bangladesh and India (West Bengal) consume on average 450 g (range 400 to 650 g) of uncooked rice per person per day (Duxbury et al., 2003). Daily rice consumption per person by Japanese or Korean is 165 g or 185 g. Indian and Chinese consume low amount of rice in comparison to the people of Myanmar, Vietnam and Bangladesh (Table 9.2).

The concentration of arsenic in rice considered to be safe ranges from 82 to 202 μg (Zavala & Duxbury, 2008). In arsenic endemic area, rice is contaminated with arsenic. The extent of arsenic contamination depends on the amount of arsenic in soil and irrigated water. When a person in arsenic endemic area consumes arsenic contaminated rice along with arsenic-contaminated drinking water (4 L/day), including vegetables with a high arsenic content, is sufficient to cross the maximum allowable daily level (MADL) limit of 220 μg/day (Correl et al., 2006).

Table 9.2 *Daily consumption of rice per person in 2010.*

Country	Daily consumption (g/day)
China	251
India	208
Indonesia	414
Bangladesh	441
Vietnam	465
Myanmar	578
Thailand	285
Philippines	267

(Source: FAO)

Speciation of rice is also estimated. Inorganic arsenic and DMA dominate in raw rice (Zavala et al., 2008). The proportion of inorganic arsenic in total

arsenic in rice ranges from 11% to 93% (Torres-Escribano et al., 2008).

Our target is to reduce arsenic consumption through foodstuff in arsenic endemic area. Initial screening of foodstuffs for arsenic in arsenic endemic area is the first step.

There are currently no regulations that are applicable to inorganic arsenic in food in the USA and EU. Only China has set a regulatory limit in food at 150 μg per kg of rice. In October 2005, the Ministry of Health of China adopted a new food safety standard on arsenic in foods (Table 9.3). This standard, specified for a variety of food products, has been set for inorganic arsenic, and not for total arsenic. This is an important step as it recognizes that total arsenic in foods is not appropriate for evaluating food safety.

Table 9.3 *Chinese food safety standard for inorganic arsenic (mg/kg) in foodstuffs.*

Foodstuff	Inorganic arsenic (mg/kg)
Rice	0.15
Flour	0.10
Other cereals	0.20
Vegetables	0.05
Fruit	0.05
Poultry	0.05
Egg	0.05
Milk powder	0.25
Fresh milk	0.05
Beans pulses	0.10
Fish	0.10
Algae	1.50
Shellfish	0.50

A study shows the amount of arsenic in rice bought from markets in UK that had been grown in America, Europe, India, and Bangladesh. An average of 260 μg/kg arsenic was found in US rice. The rice imported from India showed a low

amount of 50 μg arsenic per kg, whereas from Bangladesh it was about 150 μg arsenic per kg.

The total arsenic content of 150 paddy rice samples collected from different areas of Bangladesh. Arsenic concentrations varied from 10 to 420 μg/kg at 14% moisture content. Rice yields and grain arsenic concentrations were 1.5 times higher in the boro rice (cultivated winter season) than the aman rice (during summer or monsoon season), consistent with the much greater use of groundwater for irrigation in the boro season. Mean values for the boro and aman rices were 183 and 117 μg/kg, respectively. The variation in arsenic concentrations in rice was only partially consistent with the pattern of arsenic concentrations in drinking water tube wells. Processing of rice (parboiling and milling) reduced arsenic concentrations in rice by an average of 19%. Human exposure to arsenic through rice would be equivalent to half of that in water containing 50 μg/kg for 14% of the paddy rice samples at rice and water intake levels of 400 g and 4 L/cap/day, respectively (Duxbury et al., 2003).

9.1.1 Raw and Cooked Rice

In Bangladesh, the raw rice is contaminated with arsenic with highest levels of 1.8 mg/kg (Meharg & Rahman, 2003) (Table 9.4). Although the amount of arsenic in rice varies that may be due to inadequate number of samples, area from which it is collected and method of estimation.

There are two varieties of rice: uncooked rice (atap chal; local language) and cooked rice (sidha chal; local language). Bangladeshi like to eat sidha chal. Sidha chal means the paddy rice, collected from the field, is cooked with water. Then it is dried. It is again cooked before intake as boiled rice. When the paddy is cooked with high concentration of arsenic contaminated water twice, once at the processing of rice and another just before intake as boiled rice (Misbahuddin,

2003), then there are more accumulation of external arsenic into the rice. This rice contains its organic acid and external inorganic arsenic. However, boiling of rice for 5 min will reduce the arsenic concentration by 20% and for 25 min the concentration will reduce by 65% (Chakravarty et al., 2003). Cooking may affect the intake of arsenic through foodstuff (Bae et al., 2002).

A rice sample (with undetectable amount of arsenic) showed arsenic in the cooked rice (bhat) when it was cooked with arsenic-contaminated water. The quantity of arsenic was higher when water and rice were cooked so that all the water was absorbed by the rice by the time it was well-cooked (Huq et al., 2006). Bangladeshi cook rice with more amount of water and when the rice was well-cooked, the liquid starch was decanted. This method is a better method to reduce arsenic in rice.

Cooked rice collected from households during the field survey showed concentrations of arsenic from 0.11 to 0.36 mg/kg (Huq & Naidu, 2003). Another study shows that the content of arsenic ingested by a person from cooked rice is 0.124 mg from 460 g of rice (Chakravarty et al., 2003).

Different strains of rice show different degrees of arsenic uptake, and arsenic levels in rice are affected by concentration in irrigation water and soils.

Table 9.4 *Amount of total arsenic in raw rice.*

Authors	Number of samples	Amount of arsenic (μg/kg)	
		Range	Average
Khan et al., 2007	84	65-1,824	878
Meharg and Rahman, 2003		58-1,830	496
Ali et al., 2002	12	50-1,520	480
Smith et al., 2006	46	46-1,110	358
Das et al., 2004	10	40-270	136

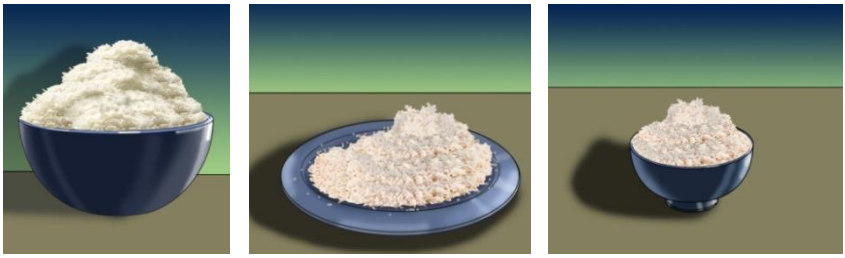

Figure 9.1 *Amount of rice in bowl in the past (left), in plate at present (middle) and in pot in future (right).*

Now the question is how to reduce the intake of arsenic through rice. There may be some suggestions. For example, three to four decades ago Bangladeshi preferred to eat bowl full rice (Figure 9.1). Now-a-days they prefer to eat plateful rice. In order to reduce the arsenic load, they should take potful rice. Total arsenic content of raw rice may be reduced 35 to 45% in cooked rice after rinse washing of raw rice and cook with high volume (6: 1, water: rice) of water (Raab et al., 2009). It may be adviceable to rinse rice in water until water runs clear. Then cook rice in excess water than usual. The diet should not be consumed every day. If possible, in the individual diet, rice should not be included every day. Everything depends on the motivation of people.

Arsenic is known to cause oxidative stress. On the other hand, rice contains hundreds of antioxidants. Although rice in arsenic endemic area has quite high amount of arsenic as well as antioxidants.

9.2 Vegetable

One of the important items of Bangladeshi dish is curry which contains a lot of water. If someone uses arsenic contaminated water, then there is chance of more intake of arsenic. Among the vegetables, leafy vegetables contain relatively low concentration of arsenic (Table 9.5). Potato contains low concentration of arsenic.

Table 9.5 *Speciation of arsenic in rice and vegetables from two arsenic-exposed areas of Bangladesh.*

Foodstuffs	*Local name*	*Number of samples*	*Speciation of arsenic in foodstuffs (µg/kg)*			
			Inorganic	*MMA*	*DMA*	*Total*
Raw rice	Chaal	75	296.3	222.5	363.4	882.2
Non-leafy vegetables						
Amaranth stem	Data	39	166.0	144.4	309.0	619.4
Arum stem	Kachur data	40	229.7	323.1	410.1	962.9
Dhundal	Dhundal	9	214.7	241.7	182.2	638.6
Egg plant	Begoon	42	252.6	191.6	449.1	893.3
Lady's finger	Dherosh	42	211.6	155.9	318.0	685.5
Papaya (green)	Kacha pepe	45	177.9	220.5	282.5	680.9
Pumpkin	Kumra	2	0	331.4	433.5	764.9
Ridge gourd	Jhingha	11	141.2	89.3	486.0	716.5
Snake gourd	Chichinga	22	270.3	121.6	294.7	686.6
Roots and tubers						
Taro	Kachur lata	34	377.6	232.3	533.5	1143.4
Arum root	Maan kachu	16	274.4	149.8	706.7	1130.9
		Leafy vegetables				
Amaranth leaf	Data shak	34	39.1	134.3	284.8	458.2
Arum leaf	Kachu shak	45	369.3	230.6	534.4	1134.3
Halancha leaf	Halancha leaf	22	196.0	130.2	348.1	674.3
Indian spinach	Pui shak	73	227.7	157.5	386.0	771.2
Jute leaf	Paat shak	10	212.1	98.4	321.8	632.3
Kalmi leaf	Kalmi leaf	3	62.3	0	49.2	111.5
Potato leaf	Alu shak	5	249.8	128.7	326.5	705.0
Pumpkin leaf	Kumra shak	26	225.3	193.4	365.9	784.6

(Misbahuddin et al., 2007)

On the other hand, high concentration of arsenic is found in arum (Misbahuddin et al., 2007). Arum is a common vegetable in rural Bangladesh for easy to cultivate and available throughout the whole season. Several varieties of arum are available and different parts are usually consumed. The higher values of arsenic in arum may be due to the use of contaminated water from hand pump tube well for its cultivation in the home garden. More than 150 mg/kg of arsenic has been found to be accumulated in arum.

Vegetables (Green papaya, red amaranth, bottle gourd leaf, potato, ripe tomato, green chili, etc) that are growing in the garden and receiving irrigation with arsenic-contaminated water have significantly higher levels than those grown in unaffected areas (Chakravarty et al., 2003).

Williams et al. (2006) analyzed total arsenic in vegetables, roots and tubers, pulses, and spices and found values up to 1.59 mg/kg dry weight in fruit vegetables and 0.79 mg/kg dry weight in leafy vegetables.

In an arsenic endemic area, it is impossible to eat any vegetable after estimating its arsenic level. Some vegetables like arum may be avoided. In reality, it is difficult to avoid the intake of arum by the poor Bangladeshi leaving in rural arsenic endemic area.

There are some vegetables which have compound(s) that can reduce the body arsenic load. These vegetables are amaranth and spinach. Corn also contains compound that can reduce arsenic in arsenic loaded rats. People in arsenic endemic area may be encouraged to eat these vegetables.

9.3 Soup

Liquid pulse is very popular in India and Bangladesh. They include it in their dietary manu every day. Pulse retains about 91.2% of arsenic when cook in arsenic contaminated water.

9.4 Salad

Green leafy vegetables are preferred by the Bangladeshi as salad. These are usually containing low amount of arsenic.

We cannot avoid the intake of rice instead encourage the people of endemic area for low intake of rice. The total calorie can be replaced by shifting the diet habit of potato, maize, etc.

9.5 Fruits

Arsenic was detected in all juices available in USA market. 32% demonstrated arsenic levels are nearly at or above the drinking water exposure limit of 10 ppb.

On a dry weight basis, some vegetables have much higher levels of arsenic than rice. However, a typical Asian diet includes much more rice than vegetables, so intake from rice remains the principal arsenic exposure through food.

Meanwhile, in a bid to reduce the amount of arsenic taken up by rice, researchers are attempting to design rice plants that do not absorb as much arsenic.

The proportion of inorganic arsenic ingested through food may be significant, even when the arsenic concentration of drinking water is higher than 50 ppb. For example, a recent study conducted in Mexico, where the concentration of arsenic in drinking water was as high as 400 ppb, found that even so 30% of inorganic arsenic intake came from food (DelRazo et al., 2002).

In conclusion, people of arsenic endemic area must change the food habit in order to reduce intake of arsenic from foodstuffs. For example, Bangladeshi must change their diet manu like combination of rice (small amount), chapati, dal, vegetable, boiled corn, boiled bean, and yogart (Figure 9.2). In 1960's, Koreans ate 600-800 g of cooked rice per meal. Korean has changed their dietary contents.

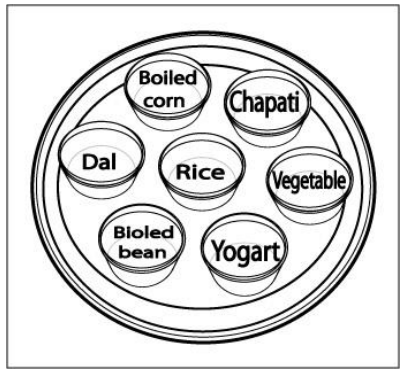

Figure 9.2 *Dietary manu for Bangladeshi.*

9.6 Questions to be Raised

1. In an arsenic endemic area, the arsenic contaminated hand pump tube wells are marked with red color in order to encourage the people not to drink that water. What measure can be taken in case of arsenic contaminated foodstuff?

2. Unlike water intake, it is not possible to estimate the arsenic content of any food before intake.

3. Most of the epidemiological studies show a close relationship between arsenic intake through water and the development of symptoms. So, is there any role of arsenic from food source?

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✶ Myth

Do not eat shrimp/prawn when taking 'vitamin C'.