What are Safe Levels of Arsenic in Food and Soils?

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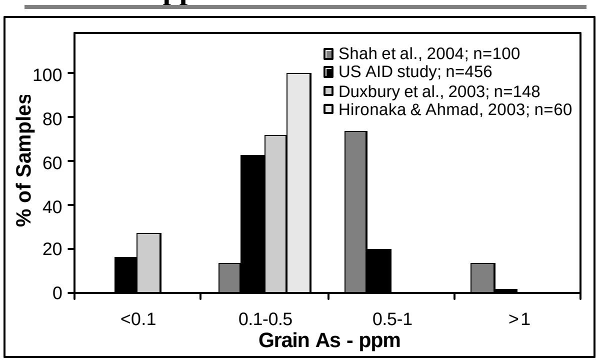
Abstract

A perspective on arsenic "safety" in food and soils in Bangladesh is provided by using current limits or standards for arsenic (As) that have been established by various countries and organizations. Approaches to setting standards for Bangladesh using some of these values are discussed.

One approach to determining safe levels of As in food is by comparison to safety standards for drinking water. This comparison is made on the basis of inorganic As species as these are considerably more toxic than organic As species. Rice is considered by itself because of the large intake of rice in the Bangladesh diet (~ 450g/adult/day or 80% of caloric intake). With an adult daily intake of 450 g rice and 4L of water, equivalent intakes of inorganic As from these two sources occur at As levels of 550 and 110 ppb As in rice for water standards of 50 ppb (Bangladesh) and 10 ppb (WHO and many western countries), respectively. This calculation assumes that 80% of the As in rice is inorganic (Williams et al., this symposium) and that the bioavailability of As in rice is similar to that in water (demonstrated in a pig feeding study; Naidu [personal communication]). Several countries, including the UK and Australia, currently use a 1 ppm limit for arsenic in food and this is often cited as a "safe"level for rice. This value is clearly too high for the Bangladesh level of rice consumption.

An alternative strategy in establishing As standards for both drinking water and rice is to consider the combined dietary intake of inorganic arsenic from these sources, rather than evaluating each individually. In 1989, the FAO and WHO jointly established a provisional tolerable dietary intake of 0.015 mg inorganic As/kg body weight/week, or 130 µg/day for a 60 kg adult. This level is already exceeded by the intake of 200 µg/day from drinking 4 L of water containing 50 ppb As. A tolerable limit for intake of inorganic As has not been established for Bangladesh, but how this could be used to evaluate dietary As intake from rice and water at daily intakes of 450 g and 4 L, respectively, is illustrated in the table for a 200 µg/day inorganic As intake limit.

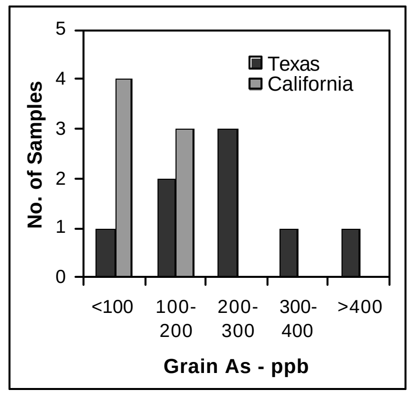
Scenario	Max. Acceptable As (ppb)	
	Rice	Water
Sources equal	277	25
Water 10 ppb	444	10



The distribution of arsenic in raw rice grain from various studies with fairly large numbers of samples is shown in the figure. Overall 22% of the samples exceeded 0.5 ppm (500 ppb), indicating that inorganic arsenic intake from rice will exceed that from water at the 50 ppb level in a significant number of instances. It is noted, however, that this conclusion is strongly influenced by the data from Shah et al., which is all from Chapai Nawabganj Sadar. Other studies are from a variety of areas across Bangladesh that represent varying levels of environmental As contamination.

A survey of total As in rice purchased in the USA (Ithaca and Syracuse, NY) found that the average As concentration of rice consumed in this part of the USA was 107 ppb, or one-third of that consumed in Bangladesh. Rice produced in the USA contained an average of 181 ppb, with substantial differences between California and Texas. One sample from Texas contained 753 ppb As. Rice samples from Bangladesh, India and Pakistan had unusually low As contents and were all aromatic types. The per capita exposure to inorganic As in rice is estimated to be 32x higher in Bangladesh than in the USA (using more representative data for As in Bangladesh rice [340 ppb], differences in per capita intake and differences in inorganic As percentages between rice grown in Bangladesh and the USA [Williams et al., this symposium]).

Country	**No. of Samples**	**Mean As ppb**	**Country**	**No. of Samples**	**Mean As ppb**
Argentina	1	136	Korea	2	45
B'gladesh	3	46	Lebanon	1	169
Bhutan	1	32	Pakistan	3	33
China	2	146	Spain	2	186
Egypt	2	32	Thailand	9	93
Greece	1	114	USA	22	181
India	16	37	V'nzuela	12	84
Italy	7	158	**TOTAL**	**84**	**107**
				Median	**84**

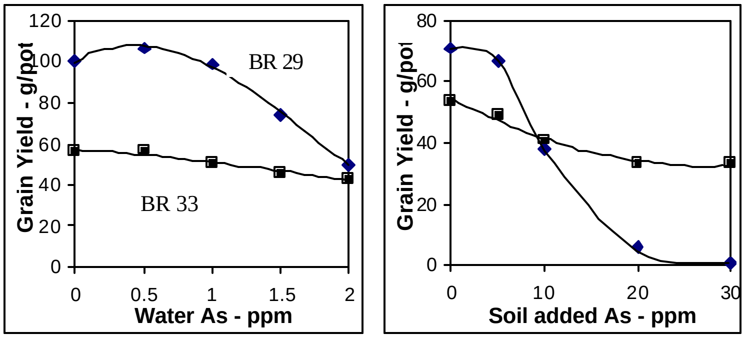


Arsenic intake in Bangladesh from food sources other than rice is minimal, with the possible exception of vegetable and root crops. Unfortunately, reports of consumption data for these foods as well as their As content vary widely, making it impossible to derive arsenic intake data with any degree of confidence. A systematic approach is needed to evaluate the importance of dietary intake of arsenic from vegetable and root crops.

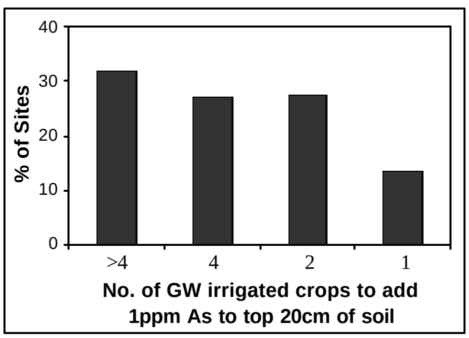
The question of what is a safe level of arsenic in soil is considered from the following perspectives:

- Phytotoxicity to rice (agricultural sustainability and food security)
- Ingestion (human health)
- Leaching to groundwater (environmental and human health)
- Variability in soil characteristics (a safe level in one soil may be unsafe in a different soil)

Pot studies (Jahiruddin et al, 2004; Khan, this symposium) have shown that levels of As (arsenate) in irrigation water above 1 ppm, and raising soil As content by more than 5 ppm, reduce the yield of Br 29 rice, the most productive boro season variety. These treatments also showed residual effects on BR 33 rice in the following Aman season. An interaction between arsenic and phosphate additions to soil was observed with P inputs increasing As toxicity and grain As content.



Constructed from data in Jahiruddin et al., 2004.

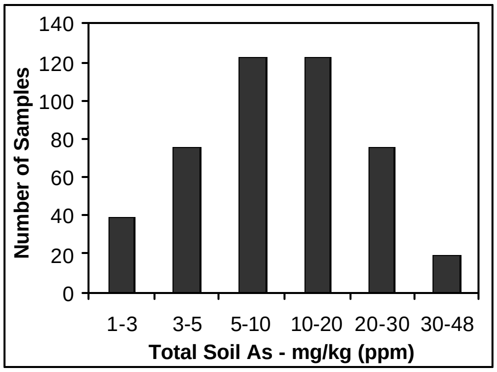


It is uncertain that adding As to soil immediately before doing an experiment duplicates the behavior of contaminated As soils, which have gone through many redox cycles. Nevertheless, addition of As at levels that reduce rice yields in pot experiments will occur quite quickly given the quality of irrigation water in Bangladesh. Without losses, As in the top 20 cm of soil will be increased by 5-10 ppm in 10 crops (years) at 41% of the 456 irrigation well sites in the US-AID study.

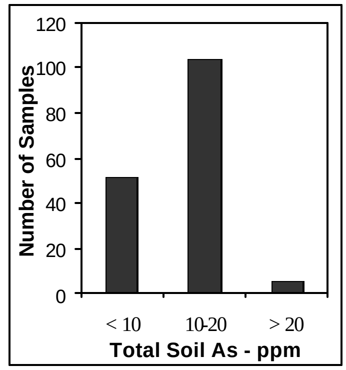
There are no federal regulations limiting soil As levels in the USA. However, the US Environmental Protection Agencies (EPA) superfund risk model gives a value of 0.43 ppm total soil As for a cancer risk of 1 in 10^6 for exposure by *soil ingestion*. This has created an interesting situation for regulation of soil As by individual States as the average background As level in USA soils is ~ 5 ppm. State standards for remedial action vary tremendously, but many require this when soil As is above the natural background, which is often less than 10 ppm. Background soil As levels have been shown to vary with soil type (Chen et al, 2002), which is sometimes considered in evaluations of soil contamination. Soil As standards in other countries (Canada, UK, Netherlands, Australia) are generally in the 10-20 ppm range for agricultural use of soils.

Total soil As in the top 15 cm of Bangladesh soils was above 10 ppm for 48% and 65% of the 456 sites in the 2002 US-AID study and 161 sites in Shah et al. (2004), respectively.

Similarly, 21% and 4% were above 20 ppm. Lower soil As levels were reported by Huq et al. (2003) for a 24 upazila study; average values > 10 ppm were found in only 3 upazila while 18 upazila were <5 ppm. A nationwide map of soil As (M. Miah, this workshop) will provide a better perspective on soil As levels, but it is clear that there is cause for concern from both agricultural sustainability and human health perspectives.



US-AID, 2002 study



Shah et al. 2004

Establishment of soil As limits based on the potential for leaching to groundwater is not very developed. Wenzel et al., (2002) derived upper limits of ~200 and 1000 ppm total soil As for protection of groundwater at the 10 and 50 ppb As levels, respectively, in Austria. The USA EPA uses a "toxicity characteristic leaching procedure" (TCLP) to determine the As leaching potential of potential hazardous wastes, including contaminated soils. This procedure uses a dilute acid extraction with a 1:20 soil to solution ratio and concentrations of As > 5 ppm in the extracting solution indicate that the soil requires remediation. A soil can only fail this test when its total As level greater than 100 ppm. These studies suggest that leaching of As from soils to groundwater is unlikely to be a problem in Bangladesh. However, leaching of As from flooded and reduced paddy soils has been little studied (A. Khan, this symposium).

It is important to consider whether the safety standards used by developed countries are appropriate for the Bangladesh context where there are multiple severe health and environmental issues. Therefore there is a need for Bangladesh to establish it's own safety standards for arsenic in food and soils. These standards will depend on acceptable risk levels, tempered by what is achievable. In considering standard development, it is clear that potential impacts of As on food security and direct human exposure to arsenic are both important for human health outcomes.

References

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