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Arsenic intake and dietary risk assessment of coriander (*Coriandrum sativum* L.) leaves in the Gangetic basin of West Bengal

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Abstract

Field experiments were conducted at farmers' field in Nadia district of West Bengal during winter seasons of 2008–09 and 2009–10 to evaluate the varietal tolerance and arsenic (As) accumulation of different coriander cultivars and As intake and dietary risk assessment of leaves. Results revealed that As accumulation in different plant parts was in the order, root > leaf > stem. Ingestion of significant proportion of inorganic As through consumption of coriander was observed which posed a risk of 36.0% of Provisional Tolerable Weekly Intake.

Keywords: arsenic, coriander, gangetic basin, risk assessment

Introduction

Arsenic (As) contamination in groundwater is the maximum in Bangladesh, followed by West Bengal, India (Sanyal 2005). Studies have shown that the contribution of food-chain towards As pollution in humans is manyfold greater than that of drinking water (Díaz *et al.* 2004). Although the principal crops like cereals, oilseeds etc. drew attention of the researchers, fruits and vegetables cannot be ignored as far as As contamination through food chain is concerned (Hossain 2006; Kundu *et al.* 2012). It was also observed that leafy vegetables contained higher As levels as compared to ground vegetables and cereals (Arain *et al.* 2009; Lieo *et al.* 2005) on dry-weight basis. Leafy vegetables accumulated much higher content of heavy metals as compared to other vegetables because leafy vegetables have large surface area (Itanna 2002). It was also reported by Abedin *et al.* (2002) and Hossain (2006) that the use of As rich irrigation water affected root growth, plant height and crop yield.

In this context, a thorough understanding of As-plant-soil interaction is necessary in order to examine plants grown in soils contaminated with high concentration of As and irrigated with As contaminated groundwater as well as entry of As in food chain. Rice-based cropping system is predominant in this state; however, rice grown in monsoon is not a major problem since metal concentration is diluted and consumption of contaminated groundwater for irrigation is less. The winter and summer crops, on the other hand, are mainly irrigated through contaminated ground water from shallow tube wells and are of real concern.

In West Bengal, coriander is mainly cultivated and consumed as leafy vegetable. Following *Kharif* rice, cultivation of short duration coriander in the month of October–November is a popular practice in the gangetic basin of West Bengal. Relatively drier season for coriander cultivation poses the threat of As contamination through irrigation from contaminated groundwater sources. The situation becomes more vulnerable when such leafy vegetables are consumed fresh (uncooked). Keeping this in view, the present investigation was undertaken to study As accumulation in coriander, determine relative proportions of such contamination in plant parts and explore varietal preferences for As accumulation.

Materials and methods

The experiment was conducted at farmers' field in Nonaghata (latitude 22°57'N, longitude 88°33'E), Block-Haringhata, District-Nadia, West Bengal, India during *Rabi* of 2008–09 and repeated during 2009–10. The experimental site has subtropical humid climate with an average rainfall ranging between 1250 mm to 2500 mm and mean minimum and maximum temperature were 13°C and 39°C respectively. The experimental soil is silty clay loam in texture having pH 7.26, organic carbon 0.49%, available nitrogen 181 kg ha^{-1}, available phosphorus 37 kg ha^{-1} and available potassium 145 kg ha^{-1}, which were estimated following standard methods (Jackson 1967). As content in the irrigation water and soil of the experimental site were 0.105 mg L^{-1} to 0.124 mg L^{-1} and 9.57 mg kg^{-1} to 9.73 mg kg^{-1} in 1st and 2nd year, respectively.

The experiment was laid out in randomized block design with four replications. Five selected coriander varieties (Surabhi, Bliss, Anand, Sadhana and a local cultivar) were tested in two consecutive years in the same experimental site.

Coriander was planted in mid October of 2008 and repeated again in 2009 with a spacing of 30 × 10 cm, seed rate 10–15 kg ha^{-1} and recommended dose of fertilizers (60: 20: 20 kg NPK ha^{-1} through urea, single super phosphate and muriate of potash respectively. Well decomposed farmyard manure was applied as basal along with ½ N and full dose of P and K at the time of final land preparation and rest ½ dose N was top-dressed after weeding. Irrigation was given immediately after sowing and life-saving irrigation was given at 3rd day of sowing and subsequent irrigations were applied once in seven to ten days. Arsenic contaminated shallow tube-well (STW) water was used as the source of irrigation.

Plant samples were taken at different stages *viz*., early vegetative and vegetative stage. The plant samples were washed with tap water, followed by washing through ultrapure de-ionized water. The root, stem and leaves were collected separately and cut into small pieces. The samples were then dried, ground and kept in properly-labelled containers.

Plant sample (1 g) was digested with tri-acid mixture (HNO_3: H_2SO_4: $HClO_4$: 10:1:4, v/v) until a clear solution was obtained. The digest was filtered using Whatman No. 42 filter paper. 10 mL of the filtrate was taken in 50 mL volumetric flask, to which 5 mL of concentrated HCl and 1 mL of mixed reagent [5.0% KI (w/v) + 5.0% ascorbic acid (w/v)] were added, kept for 45 minutes to ensure complete reaction and the volume was made up to 50 mL. The total As content in the solution was determined by using atomic absorption spectrophotometer (AAS).

A dietary exposure assessment is the process of estimating how much of a food chemical a population or population sub group consumes. Dietary exposure to (or intake of) food chemicals is estimated by combining food consumption data with food chemical concentration data. The process of doing this is called dietary modeling (Xue *et al.* 2010).

$$\text{Dietary exposure} = \text{food chemical concentration} \times \text{food consumption}$$

The dietary intake and the risks associated with the As contamination of food materials were assessed in per cent of Provisional Tolerable Weekly Intake (PTWI) of the contaminant and PTWI of Arsenic is 15 µg/ body weight (900 µg for an adult of 60 kg body weight) as described by WHO (2000).

Analysis of variance method (Gomez & Gomez 1976) was used for statistical analysis. The significance of different sources of variation was tested by error mean square with the help of Fisher's 'F' test at probability level of 0.05. For comparison of 'F' value and computation of critical different (CD) at 5.0% level of significance, Fisher and Yates tables were consulted (Fisher & Yates 1963).

Results and discussion

Arsenic accumulation in coriander

Results showed that accumulation of As in edible parts of coriander varied from 0.21 to 0.91 mg kg^{-1}, across the growth stages and cultivars (Table 1). Abbas *et al.* (2010) reported accumulation of 0.031±0.0028 mg kg^{-1} in coriander in Sindh province of Pakistan which is not a traditional As contaminated area. Arain *et al.* (2009) made an assessment of As loading in coriander (and other vegetables) irrigated by lake water having As contamination beyond WHO permissible guideline in southern Sindh province of Pakistan and observed As accumulation in coriander leaves to the tune of 0.985±0.145 mg kg^{-1} on a dry weight basis. The geogenic As contamination of the underground water in gangetic West Bengal is relatively similar to the contaminated lake basin areas of Sindh, Pakistan.

The relative proportion of As accumulation in different plant parts is shown in Fig. 1. Roots registered the largest share of total As load in plant biomass as compared to the other parts.

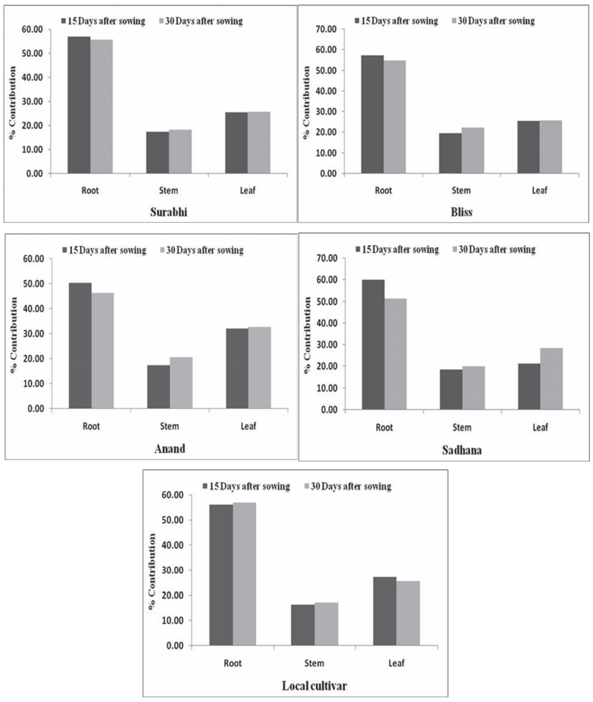


Fig. 1. Contribution of different plant parts to total arsenic accumulation in coriander cultivars

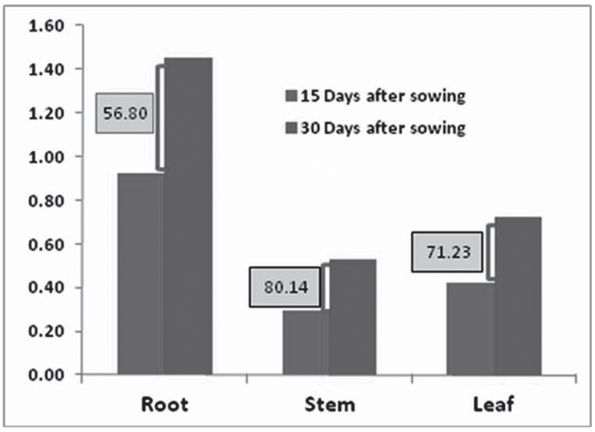
As accumulation was in the order of root > leaf > stem regardless of the cultivars tested and time of sampling [15 or 30 days after sowing (DAS)]. Such findings are quite consistent with the general observations on distribution of As in plant parts and was found to be in the order: below ground parts > aerial parts (Sanyal 2005). Roots and tubers generally have the highest As concentration, with the skin having higher concentration than the inner flesh (Peryea 2001).

Table 1. Arsenic accumulation (mg kg^{-1}) by different plant parts of coriander cultivars at different stages (pooled data)

Cultivar	15 Days after sowing			30 Days after sowing		
	Root	Stem	Leaf	Root	Stem	Leaf
Surabhi	1.07	0.33	0.48	1.73	0.57	0.80
Bliss	0.85	0.29	0.34	1.30	0.53	0.54
Anand	0.61	0.21	0.39	0.99	0.44	0.70
Sadhana	0.87	0.27	0.31	1.23	0.48	0.68
Local cultivar	1.23	0.36	0.60	2.01	0.61	0.91
S.Em (±)	0.06	0.02	0.03	0.07	0.03	0.04
CD (Pd" 0.05)	0.19	0.05	0.09	0.22	0.08	0.12

STW As=0.105 mg L^{-1} (2008); 0.124 mg L^{-1} (2009) Soil total As=9.57 mg kg^{-1} (2008); 0.124 mg kg^{-1} (2009)

The As accumulation levels (Fig. 2) was observed to increase with the advancement of growth and increase in As load was maximum in coriander stem (80.14%) and edible leaf (71.23%). Chaturbedi (2006) reported that As toxicity varied widely with plant genotypes probably due to varietal differences in As translocation and phytoextraction potential. In our study cv. Bliss was found to accumulate least As and locally grown cultivar the highest.



Figures in the boxes indicate per cent changes in As accumulation at 30 days after sowing over 15 days after sowing of coriander

Fig. 2. Per cent change in arsenic accumulation with advancement of growth of coriander (average of selected cultivars were considered in pooled observations of 2008 & 2009)

Arsenic intake and dietary risk assessment

In risk assessment, exposure estimates are compared with 'reference health standards', where available, to assess the potential risk to health associated with changes to the food supply (Xue *et al.* 2010). According to WHO (1981), 1.0 μg of inorganic As per day may give rise to skin lesions within a few years. It was also reported that in fruits and vegetables, inorganic As accounted for approximately one-half of the total As (Schoof *et al.* 1999). Ingestion of significant proportion of inorganic As (325 μg/week/adult) through consumption of coriander was observed through the present investigation which poses a risk of 36.0% of PTWI which is much beyond the WHO permissible limit but still quite low as compared to As contaminated rice (Table 2).

Coriander accumulated higher As (910 μg kg^{-1}) in edible portion (leaf) than irrigated rice (357 μg kg^{-1} grain). However, the risk associated with dietary exposure to As contaminated coriander (36.0% of PTWI) was much less than rice (217.0% of PTWI) which is due to less consumption of the former, though the level of As ingestion through coriander far exceeded the WHO permissible limit for clinically safe food item. Such food items which are relatively less consumed, are largely ignored in toxicological investigations and demand due attention of the researchers.

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Table 2. Arsenic intake and dietary risk assessment

Samples	Weekly consumption	Max. total As conc. (μg kg^{-1})	Max. weekly total As intake (μg)	Max. weekly inorganic As intake (μg)	PTWI (%)
Coriander (Leaf)	700 g	910	650	325	36.11
Rice**	10965 g**	357**	3910.94**	1955.45**	217.22**

**Final Report of "Total diet study in West Bengal" (2010)

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