Beyond the wells: role of diet on arsenic induced toxicity in exposed populations of Bihar, India

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ABSTRACT: Drinking water is the major route of arsenic exposure but dietary factors can modulate the arsenic induced toxicity. We aim to determine the dietary correlates of arsenic exposure and factors that can act as host defense. As a part of an on-going research project here, we present with the preliminary findings from survey of a study population with known arsenic exposure from drinking water in Bihar, India.

1 INTRODUCTION

Arsenic levels in drinking water as high as 1900 $\mu\text{g L}^{-1}$ has been recently detected in one of the villages from arsenic affected districts (18 out of 38) of Bihar where more than 10 million people are facing contamination from drinking water (Thakur & Gupta, 2006). Diet is known to modulate the risk of arsenic induced toxicity, for example diet rich in gourds and root vegetables along with increased diversity of food is found to reduce the risk of arsenical skin lesions (Pierce *et al.*, 2010). On the other hand, malnutrition, which is highly prevalent in Bihar (NFHS, 2016), is known to increase susceptibility of arsenical skin lesions (Mazumder *et al.*, 2011). The aim of this study is to determine the dietary correlates of arsenic induced toxicity in Bihar.

2 METHODS

2.1 Study area

Samples (N=42) were collected from residents of arsenic contaminated areas (reported concentration $>10 \mu\text{g L}^{-1}$) from Bhagalpur (Rannuchak and Nandgola), Banka (Rajpura and Kakna), Saran (Sabalpur) and Patna (Haldi Chapara) districts of Bihar, India as a part of ongoing Nutri-SAM project.

2.2 Data collection

After taking informed consent, data on socio-economic, nutritional and health status were collected using questionnaires. Food consumption pattern and nutrient intake was determined using food frequency questionnaire and 24-hour recall methods, respectively. Nutrient content was calculated using Indian Food Composition Table – 2017 (Longvah *et al.*, 2017). Blood, water, hair, rice (raw and cooked), wheat and potato samples were collected and

arsenic content was estimated by Atomic Absorption Spectrophotometer (PerkinElmer PinAAcle 900 T) using APHA protocol.

2.3 Statistical analysis

Descriptive data as mean $\pm$ standard deviation along with comparison tests, association and correlations are presented using SPSS (IBM, version 22) and Stata (version 11.2, StataCorp, USA).

3 RESULTS AND DISCUSSION

3.1 Demographic and nutritional status

There were significant demographic differences between male and female participants (Table 1) along with difference in nutrient intake. Overall, 23% participants were underweight, 14% were overweight and 9% were found to be obese. Most of the participants were married, having extended family (more than six members) but had a common kitchen. None consume alcohol (prohibited by law in Bihar), but 38% were found to take some form of tobacco such as *gutkha* or chewing leaves.

Table 1. Demography and nutrient intake (mean $\pm$ SD).

	Overall	Male (n = 20, 48%)	Female (n = 22, 52%)	p value
Age (years)	52 $\pm$ 16	58 $\pm$ 17	46 $\pm$ 15	0.018
BMI (kg m^{-2})	22.9 $\pm$ 6.6	20.5 $\pm$ 3.4	25.2 $\pm$ 7.0	0.010
W/H Ratio	0.8 $\pm$ 0.07	0.89 $\pm$ 0.02	0.85 $\pm$ 0.01	0.169
Blood Pressure (normal %)	76	75	77	0.863
Energy (kcal d^{-1})	1667 $\pm$ 655	1928 $\pm$ 628	1430 $\pm$ 127	0.012
Protein (gm d^{-1})	51 $\pm$ 18.5	58 $\pm$ 4	43 $\pm$ 4	0.006
CHO (gm d^{-1})	281 $\pm$ 114	332 $\pm$ 24	234 $\pm$ 21	0.004
Fat (gm d^{-1})	48.5 $\pm$ 28.0	52.8 $\pm$ 7.1	44.7 $\pm$ 5.1	0.357
Dietary fibre	41.1 $\pm$ 22.1	49.1 $\pm$ 5.0	33.8 $\pm$ 4.2	0.023

Table 2. Summary of arsenic concentrations.

Sample (N, unit)	Mean	S.D	Maximum
Water (42, $\mu\text{g L}^{-1}$)	33.86	34.99	107.0
Blood (26, $\mu\text{g L}^{-1}$)	12.32	24.77	104.78
Hair (23, $\mu\text{g kg}^{-1}$)	807.62	689.76	2480.40
Raw rice (41, $\mu\text{g kg}^{-1}$)	50.98	194.65	1257.50
Cooked rice (18, $\mu\text{g kg}^{-1}$)	139.61	386.16	1654.50
Wheat (33, $\mu\text{g kg}^{-1}$)	175.57	158.01	567.50
Potato (33, $\mu\text{g kg}^{-1}$)	248.05	205.56	826.00

Table 3. Correlates of skin manifestation.

	Yes (n = 10, 24%)	No (n = 32, 76%)	p value
Gender (number)	M = 5; F = 5	M = 15; F = 17	0.863
Age (years)	48 $\pm$ 17	53 $\pm$ 16	0.415
BMI (kg m^{-2})	22 $\pm$ 3	23 $\pm$ 6	0.781
W/H Ratio	0.85 $\pm$ 0.04	0.88 $\pm$ 0.08	0.575
Energy (kcal d^{-1})	1820 $\pm$ 942	1619 $\pm$ 548	0.403
Protein (gm d^{-1})	52 $\pm$ 23	50 $\pm$ 17	0.712
CHO (gm d^{-1})	323 $\pm$ 170	268 $\pm$ 91	0.191
Fat (gm d^{-1})	53 $\pm$ 24	36 $\pm$ 29	0.504
Dietary fibre	43 $\pm$ 32	40 $\pm$ 18	0.646
Water ($\mu\text{g kg}^{-1}$)*	39 $\pm$ 40	32 $\pm$ 33	0.562
Raw rice ($\mu\text{g kg}^{-1}$)*	156 $\pm$ 413	21.3 $\pm$ 25.4	0.065
Wheat ($\mu\text{g kg}^{-1}$)*	355 $\pm$ 161	97 $\pm$ 66	0.000
Potato ($\mu\text{g kg}^{-1}$)*	616 $\pm$ 111	166 $\pm$ 106	0.000
Blood ($\mu\text{g kg}^{-1}$)*	73 $\pm$ 44	7 $\pm$ 15	0.000
Hair ($\mu\text{g kg}^{-1}$)*	1301 $\pm$ 686	525 $\pm$ 528	0.007

*Measured arsenic concentrations.

67% of the respondents were found to skip breakfasts every day and only 14% had four or more meals a day. The main sources of nutrients were cereals such as wheat and rice with 87% participants having pulses every day. Milk intake in the study population was 67% and 9.5% consumed curd every day. Most of participants consume green leafy, roots and tubers and other vegetables everyday whereas only 17% had fruits regularly. Use of refined sugar was common (81%) while *jaggery* and carbonated beverages were consumed occasionally.

3.2 Arsenic, diet and health

The overall arsenic concentration (Table 2) in drinking water was less than the Indian permissible limit of $\mu\text{g L}^{-1}$ but higher than the WHO limit of $10 \mu\text{g L}^{-1}$ and Saran district had the highest concentration ($n = 14$; mean $\pm$ SD: $44 \pm 38 \mu\text{g L}^{-1}$; max: $107 \mu\text{g L}^{-1}$). Arsenic in food items (rice, wheat and potato) was not correlated with concentrations in drinking water. This could be because either the food is sourced from markets or the water used for irrigation is different to water used for drinking.

There was no significant difference in demography and nutrient intake between participants with skin manifestations (pigmentation or lesions, a hall mark for arsenic toxicity, 24%) compared to participants without skin symptoms (Table 3).

Participants with skin manifestations had significantly high concentrations of arsenic in blood and

Table 4. Association between arsenic in food and in biomarkers.

Arsenic in	Blood		Hair	
	r	p	r	P
Water	-0.20	0.32	0.69**	<0.001
Cooked rice	0.93**	<0.001	0.49	0.17
Wheat	0.59**	0.007	0.16	0.52
Potato	0.93**	<0.001	0.53*	0.03
Energy intake/day	0.43*	0.02	-0.14	0.54
Protein intake/day	0.38	0.05	-0.14	0.55
CHO intake/day	0.49*	0.01	-0.04	0.85
Dietary fiber intake/day	0.40*	0.04	-0.12	0.59

were consuming higher arsenic from food items significantly so for wheat and potato (Table 3).

Though there was no relationship between drinking water and blood arsenic, statistically significant positive correlation was found between arsenic in cooked rice, wheat, potato, energy intake, protein intake, carbohydrates intake, dietary fiber intake and arsenic in blood. A strong relationship between water and hair arsenic was observed and statistically significant positive correlation was observed between arsenic in water and potato with arsenic in hair samples (Table 4).

4 CONCLUSIONS

Arsenic in food items (wheat and potato) and nutrient intake is found to be related with blood arsenic levels and the blood arsenic is found to be significantly higher in participants with skin manifestations, compared to those without any skin symptoms. Both potato and wheat are found to be significant route of arsenic exposure in this population. This is a part of an ongoing study and further results will be presented at the conference.

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REFERENCES

- Longvah, T., Ananthan, R., Bhaskarachary, K. & Venkaiah, K. 2017. Indian food composition table. *National Institute of Nutrition (ICMR), Hyderabad, India*.
- Mazumder, D.G. & Dasgupta, U.B. 2011. Chronic arsenic toxicity: studies in West Bengal, India. *Kaohsiung J. Med. Sci.* 27(9): 360–370.
- NFHS. 2016. State fact sheet-Bihar. Ministry of health and family welfare, *Government of India*. 1–4.
- Pierce, B.L., Argos, M., Chen, Y., Melkonian, S., Parvez, F., Islam, T., Ahmed, A., Hasan, R., Rathouz, P.J. & Ahsan, H. 2010. Arsenic exposure, dietary patterns, and skin lesion risk in Bangladesh: a prospective study. *Am. J. Epidemiol.* 173(3): 345–354.
- Thakur, B.K. & Gupta, V. 2016. Arsenic concentration in drinking water of Bihar. *J Water Sanit. Hyg. Dev.*, 06(2): 331–341.