

# 1 Nutritional status of children in arsenic exposed and non-exposed areas in Bangladesh

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### Abstract

A cross-sectional study was conducted on 600 children (age 5-14 years) of arsenic exposed (mean concentration of arsenic- 203  $\mu\text{g}/\text{l}$  of tube well water) and non-exposed (28  $\mu\text{g}$  arsenic/l of tube well water) areas in Bangladesh to find out any difference in the nutritional status. Nutritional status of children was assessed by z-scores of weight for age, height for age and weight for height and also using 5<sup>th</sup> and 85<sup>th</sup> percentiles of the body mass index (BMI) for age. Dietary history of children showed almost similar intake of carbohydrate, energy, protein and fat in both groups. BMI of the children was found to be strongly associated with the arsenic level of the tube well water used by the families ( $\chi^2 = 10.228$ ,  $p < 0.01$ ). Thinness (low BMI for age) was found more among the children of exposed area (49.0%) than that of non-exposed one (37.7%). Comparatively children with normal BMI was found to be more in non-exposed area than in exposed area and the difference was found to be significant ( $\chi^2 = 9.759$ ,  $p < 0.01$ ). Similarly weight for age z-score measurements showed that the children in the exposed area were more underweight than those of the non-exposed area ( $\chi^2 = 7.891$ ,  $p < 0.05$ ). Height for age z-score measurements showed that the children in the exposed area were more stunted than those of non-exposed area ( $\chi^2 = 6.676$ ,  $p < 0.05$ ). Weight for height z-score measurements showed that the children in the exposed area were

more underweight than those of non-exposed area ( $\chi^2 = 6.388$ ,  $p < 0.05$ ). The study suggests that arsenic exposure through contaminated drinking water had negative impact on the nutritional status of children.

## **Introduction**

Bangladesh in recent times passing a crucial moment due to arsenic toxicity in ground water (Smith et al., 2000b). Prolonged consumption of water containing high concentration of arsenic affects on health (IPCS, 2001; Rahman et al., 1998; Rahman et al., 1999). The effect is directly related to arsenic concentration of drinking water and duration of contaminated water intake. Others factors such as sensitivity, nutritional status of the individual, genetic cause, immunity etc also may have roles to increase toxic effect of arsenic (Chen et., 1988). Dietary regimens that reduce methylation capacity, such as protein malnutrition may have a role in explaining individual variation in susceptibility to cell damage and carcinogenicity (Chen et., 1988).

Bangladesh is a high-density populated country in the world with low socio-economic condition and prevalence of morbidity due to malnutrition 3.32 per 1,000 (Statistical Pocket Book of Bangladesh, 1993). Infectious disease associated with malnutrition has loaded the health problem of the people of this country. Arsenicosis, an emerging public health issue, has overloaded this public health problem.

There is evidence that people of poor socio-economic condition are more prone to arsenicosis. Therefore, it is assumed that poor nutritional status of the people may favor the toxicity to arsenic. Zhang et al., (1996) showed that persons having accumulation of arsenic in their serum loose their normal nutritional status gradually. It is presumed that differences in nutrition, socio-demographic characteristics, behavior, or a predisposition for quickly metabolizing inorganic arsenic may be responsible for the disease. Poor nutritional status of adult may increase an individual's susceptibility to chronic arsenic toxicity (Milton et al., 2004). The children of 5-14 years comprise 26.5% of the total population (Statistical Pocket Book of Bangladesh, 1993). They are the future generation of the nation. So, it is an important task to explore the relationship between nutritional status of children and arsenic toxicity. Prevalence of neutropenia and lymphocytosis was observed in patients with chronic exposure to high levels of arsenic in water (Islam et al., 2004). However, arsenic-induced skin lesions are

observed among Atacamenos people in Northern Chile despite good nutrition (Smith et al., 2000a).

The study attempts to provide information about the nutritional status of both the arsenic exposed and non-exposed group of children. The community will be benefited if we know the cause whether arsenic contaminated water plays any role on the nutritional status of our children. In addition, these findings may help formulate preventive measures and possible interventions for nutritional risk factors.

### **Materials and Methods**

*Study area:* The study was conducted in both arsenic exposed (Sonargoan Upazilla of Narayanganj District) and non-exposed (Sirajdikhan Upazilla of Munshigonj District) areas in Bangladesh. These sample Upazillas were selected by multistage stratified simple random sampling method. The sample villages were selected by the guideline of the Directorate of Public Health Engineering (DPHE) report. Finally arsenic exposed and non-exposed village were selected by determining the arsenic level of drinking water.

*Duration of study:* The study was conducted during April 2005 to May 2006.

*Study population:* Six hundred children of 5-14 years of age were included. Exposed group of children were those who drank water from the tube wells having arsenic level  $>50 \mu\text{g/l}$ . On the other hand, non-exposed group of children were those who drank water from the tube wells having arsenic level up to  $10 \mu\text{g/l}$ .

*Development of questionnaire:* A questionnaire was developed to collect information on socio-demographic characteristics, dietary practice, duration of water used, daily consumption of water of children, arsenic level of tube well water and other sources of drinking water. The questionnaire was pre-tested and validated before finally used at the field level.

*Interviewers:* Before data collection by the interviewers were trained by the authors on various aspects of data collection including questionnaire. A supervisor was selected to supervise the overall field work. After completion of training the interviewers collected data from the fields.

*Ethical issue:* At the beginning of interview objectives of the study were briefly discussed among the respondents. It was also informed that the authors would maintain confidentiality of everything and the collected information would be used for research purpose only. The interview started after getting verbal consent of the respondent.

*Collection of data:* The questionnaire was filled up by interview of the mother. Data collection was carried out in two phases:

*Listing Phases:* This phase included listing of all households in the sample villages, identification of subjects (i.e. children of 5-14 years) and listing of tube wells in sample villages.

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*Interviewing Phages: Children and their mothers were interviewed. Face to face interview was carried out through a pre-tested questionnaire to collect information.*

After completion of interview, anthropometric measurements (height and weight) were taken.

**Weight:** *A bathroom weighing scale was used to take weight. Each child was asked to stand on the weighing scale with minimum clothing, without shoes, any weight in hand or touching or catching things. Three measurements were taken for each child and the mean was recorded.*

**Height:** *Height of each child was measured by a centimeter tape fixed vertically to a wood made frame wall exactly at the floor level. The height was recorded in a standing position of the subject without foot wear, feet together, knees straight and heel, buttocks and shoulder blades in contact with the vertical wall. Three measurements were taken for each child and the mean was recorded.*

*Collection of samples:* We collected samples of drinking water for analysis of arsenic level. A 100 ml bottle was supplied to each patient to bring drinking water during the next visit. All these samples were properly labeled with the identification number of the corresponding patients.

*BMI:* BMI was calculated using the available weight and height by the following formula:

$$\text{BMI} = \frac{\text{Weight in kg}}{(\text{Height in m})^2}$$

*Formula for calculation of Z-score:* In this study z-score of weight for age, height for age and weight for height were used to assess the different aspects of nutritional status of the children. Z-scores were calculated by the following formula-

$$\text{Z score} = \frac{(\text{Individual value}) - (\text{median value of reference population})}{\text{Standard deviation value of reference population}}$$

Standard deviation value and median value of reference population were calculated by transforming the original NCHS reference data.

$$\text{WAZ} = \frac{(\text{Observed weight}) - (\text{median weight of reference for given age and sex})}{\text{Standard deviation of reference population}}$$

$$\text{HAZ} = \frac{(\text{Observed height}) - (\text{median height of reference for given age and sex})}{\text{Standard deviation of reference population}}$$

$$\text{WHZ} = \frac{(\text{Observed weight for height}) - (\text{median weight for height of reference for given sex and height})}{\text{Standard deviation of reference population}}$$

The z-score of weight for age, height for age and weight for height were categorized by the following cut off level to determine the nutritional status of the children.

*Weight for age: Z score (WAZ)*

<- 3SD: severely underweight; <-2SD to - 3SD: moderately underweight; +2 to - 2SD: normal weight

*Height for age: Z score (HAZ)*

<- 3SD: severely stunted; <- 2SD to - 3SD: moderately stunted; +2 to - 2SD: not stunted

*Weight for height: Z score (WHZ)*

<- 3SD: severely wasted; <- 2SD to - 3SD: moderately wasted; +2 to - 2SD normal

*Assessment of daily water consumption:* Daily consumption of water by each child was measured by asking the number of glasses of water the children drunk per day according to the sample glass. The sample contained about 250 ml of water.

*Dietary assessment:* Dietary intakes of the children were assessed using 24-hours recall method and details of all foods and drinks. Consumed foods and drinks by the children were recorded. The participants were shown various utensils such as measuring cups, spoons, glasses and plates to get nearest approximation of the amounts of food consumed. The serving weight of different food items was calculated. Equivalent raw food weight was calculated by using a conversion table for Bangladeshi foods formulated by the Institute of Nutrition and Food Science, University of Dhaka (Ali and Pramanic, 1999).

*Estimation of arsenic:* NIPSOM arsenic test kit was used for determination of arsenic content of tube well water. Fifteen percent of sample of tube well water who had arsenic level >50 µg/l was reconfirmed by atomic fluorescence spectrometry at the Department of Occupational and Environmental Health, NIPSOM.

*Analyses of data:* All the data which were collected from the field and data of 24-hours food habits were entered into the computer for analysis using SPSS software program. 24-hours recall data were analyzed at the Institute of Nutrition and Food Science, The University of Dhaka.

## Results

Age distributions of the studied children of both arsenic exposed and non-exposed areas were almost similar except in the age group 80-99 months and 140-159 months (Table 1). In arsenic exposed area 31% of the children were between 80-99 months and 10% between 140-159 months old, while those of non-exposed area were 22% and 17% respectively.

Sex distribution of the children of both the areas was also almost same. It was found that in both the areas male was little higher proportion compared to female.

In arsenic exposed area 40.6% families had monthly income of Tk. 1,001-3,000. Fifty five percent families had monthly income of Tk. 3,001-6,000 and rest (4.7%) had income more than Tk. 6,000 per month. Similar picture

**Table 1:** Age, sex of the studied children and their parents' monthly income

<i>Characteristics</i>	<i>Number of children in</i>	
	<i>Arsenic exposed area</i>	<i>Arsenic non-exposed area</i>
<i>Age (months)</i>		
60-79	76	79
80-99	94	67
100-119	45	49
120-139	44	44
140-159	29	51
>159	12	10
<i>Sex</i>		
Male	152	154
Female	148	146
<i>Parents' monthly income (in Taka)</i>		
1,001-3,000	122 40.6%	133 44.3%
3,001-6,000	164 54.7%	162 54.0%
>6,000	14 4.7%	5 3.7%

of monthly income was observed in non-exposed area. About 44.3% had monthly income of Tk. 1,001-3,000, 54.0% had monthly income of Tk. 3,001-6,000 and 3.7% had monthly income more than Tk. 6,000 per month. No significant difference in monthly income of parents between the two Upazillas was observed.

Table 2 shows the average amount of principal nutrients taken by the study children per day. Independent sample t-tests were performed to find out any difference of mean intake of principal nutrients. It was observed that there was no significant difference of intake of nutrients by the children between the two areas.

Children of arsenic exposed area used tube well water as a source of drinking water in 99.3% cases (Table 3). Only 2 (0.7%) children in the exposed area used pond water for drinking purpose. River water and pond water

were used for cooking purpose (83.6%). On the other hand, all the children in arsenic non-exposed area used tube well as the source of drinking water. Among the arsenic non-exposed families 68 (22.7%) used pond water and river water for cooking purposes.

**Table 2:** Amount of principal nutrients taken per day by the children

<i>Principal nutrients</i>	<i>Arsenic exposed area</i>	<i>Non-exposed area</i>	<i>p value</i>
Total weight (g)	533 ± 282	530 ± 240	>0.05, df = 598
Energy (kcal)	1,018 ± 448	1,012 ± 394	>0.05, df = 598
Protein (g)	33 ± 28	30 ± 24	0.212, df = 598
Fat (g)	9 ± 8	11 ± 22	0.124, df = 598
Carbohydrate (g)	224 ± 76	222 ± 76	>0.05, df = 598

Data are Mean ± SD

Regarding purification of drinking water it was seen that all the families in non-exposed used it directly without using any method of purification. One family (0.3%) in arsenic exposed area used water for drinking purpose after boiling and one family (0.3%) purified it with alum (Table 3).

**Table 3:** Sources of drinking and cooking water as well as method of purification

<i>Study area</i>	<i>Source of drinking water</i>		<i>Source of cooking water</i>		<i>Purification of drinking water</i>		
	<i>Pond</i>	<i>Tube well</i>	<i>Tube well</i>	<i>River</i>	<i>Directly</i>	<i>Boiling</i>	<i>Using alum</i>
Exposed	2	298	49	251	298	1	1
	0.7%	99.3	16.3%	83.6%	99.3%	0.3	0.3
Non-exposed	0	300	232	68	300	0	0
	0.0%	100.0%	77.3	22.6%	100.0%	0.0%	0.0%
$\chi^2 = 2.007, p = 0.157$			$\chi^2 = 247.301, p < .001$		$\chi^2 = 2.007, p = 0.367$		

Children of arsenic exposed and non-exposed areas were selected after water analysis of the drinking water. Out of 300 water samples in exposed area, 188 had arsenic level >50 µg/l (Table 4). In non-exposed area 293 samples had arsenic level <50 µg/l. The mean (± S.D) level of arsenic tube well water in arsenic exposed area was 203 ± 177 µg/l whereas it was only 28 ± 18 µg/l in non-exposed area.

BMI of children according to arsenic level of drinking water was studied (Table 5). Out of total 320 children with normal BMI 229 were from the families having drinking water used arsenic level  $<50 \mu\text{g/l}$ . The relationship

**Table 4:** Arsenic level of water samples

Arsenic level	Number of water samples in			$\chi^2$ and p value
	Arsenic exposed area	Non-exposed area	Total	
$<50 \mu\text{g/l}$	112	293	405	$\chi^2 = 248.896$ $p < 0.01$ , $df = 2$
50 $\mu\text{g/l}$ and above	188	7	195	

of BMI with level of drinking water was found to be statistically highly significant at  $<0.01$  level.

**Table 5:** BMI of children according to arsenic level of drinking water

Arsenic level	BMI group percentile wise			Total	$\chi^2$ and p value
	Low	Normal	High		
$<50 \mu\text{g/l}$	92	200	8	300	$\chi^2 = 43.0154$ $p < 0.01$
50 $\mu\text{g/l}$ and above	168	120	12	300	
Total	260	320	20	600	

BMI was calculated to see the nutritional status of the children in both areas. It was found that in the non-exposed area 37.7% of the children were suffering from low BMI for age (thinness) which was 49.0% in the exposed area (Table 6). The numbers of children with normal BMI were 141 and 179 in the arsenic exposed and non-exposed areas respectively. The difference was found to be statistically significant.

**Table 6:** BMI group of the children

BMI group percentile based	Number of children in		$\chi^2$ and p value
	Arsenic exposed area	Non-exposed area	
Thinness (low BMI for age)	147 49.0%	113 37.7%	$\chi^2 = 9.759$ , $p < 0.01$
Normal BMI for age	141 47.0%	179 55.9%	
Overweight (high BMI for age)	12 4.0%	8 2.7%	

Underweight status of the children was calculated by weight for age z-score measurements (Table 7). It was seen that except one in exposed group none of children in non-exposed group had severe underweight. Out of 52 children with moderate underweight, 35 were in exposed group and 17 in non-exposed group. Among the rest 547 children who were with normal weight for age z-score measurements, 264 were in the exposed group and 283 were in the non-exposed group. The difference was found to be statistically significant.

**Table 7:** Underweight (chronic malnutrition) status of the children

	<i>Number of children in</i>		$\chi^2$ and p value
	<i>Arsenic exposed area</i>	<i>Non-exposed area</i>	
Severe underweight	1 0.3%	0 0.0%	$\chi^2 = 7.891, p < 0.05$
Moderate underweight	35 11.7%	17 5.7%	
Normal	264 88.0%	283 94.3%	

Stunting status of the study children was calculated by height for age z-score measurements (Table 8). It was seen that out of 36 severely stunted children 24 were in the exposed group. Out of 141 children with moderate stunting 77 were in exposed group and 64 in non-exposed group. Rest (423) of the children who were with normal nutritional status according to height for age z-score measurements, 199 were in the exposed group and 224 were in the non-exposed group. The difference was found to be statistically significant.

**Table 8:** Stunting (chronic malnutrition) status of the children

	<i>Number of children in</i>		$\chi^2$ and p value
	<i>Arsenic exposed area</i>	<i>Non-exposed area</i>	
Severe stunting	24 8.0%	12 4.0%	$\chi^2 = 6.676, p < 0.05$
Moderate stunting	77 25.7%	64 21.3%	
Normal	199 66.3%	224 74.7%	

Wasting status of the studied children was calculated by weight for height z-score measurements (Table 9). It was seen that 4 children with severe wasting were from the exposed group while in non-exposed group none had

severe wasting. Out of 30 children with moderate wasting 19 were from the exposed group and 11 were from the non-exposed group. Among the rest 566 children who were with normal nutritional status according to weight for height z-score measurements, 277 were from the exposed group and 289 were from the non-exposed group. The difference was found to be statistically significant ( $\chi^2 = 6.388$ ,  $p < 0.05$ ).

**Table 9:** Wasting status of the children

	Number of children in		$\chi^2$ and p value
	Arsenic exposed area	Non-exposed area	
Severe wasting	4 1.3%	0 0.0%	$\chi^2 = 6.388$ , $p < 0.05$ df = 2
Moderate wasting	19 6.3%	11 3.7%	
Normal	277 92.3%	289 96.3%	

Table 10 shows the types of latrine used by the families. Septic tank type sanitary latrines were used by 19.0% of the children in exposed area; while in arsenic non-exposed area 29.3% used it. Water seal latrines were used by 37.7% and 36.7% of the children in arsenic exposed area and non-exposed area respectively.

**Table 10:** Distribution of respondents according to type latrine they used

Type of latrine used	Study area	
	Arsenic exposed	Non-exposed
Septic tank	57 19.0	88 29.3
Water seal	113 37.7	110 36.7
Sanitary not closed	29 9.7	14 4.7
Non-sanitary fixed	99 33.0	88 29.3
Open air	2 0.7	0 0.0

## Discussion

The present study shows that BMI of the children was found to be strongly associated with arsenic level of drinking water. Thinness of the children was more in the arsenic exposed area. In this study the food intake of the children were studied by 24-hour recall questionnaire. BMI of the studied children found correlation with intake of five important nutrients. The average amount of principal nutrients taken by the studied children per day of both the areas was assessed. Independent sample t-tests were performed to find out any difference. It was observed that there was no significance difference of intake of nutrients by the children between the two areas.

A study conducted by Mazumder (1998) revealed that nutritional status in adults indicated by lower weight, shorter height or lower BMI might be associated with arsenicosis.

On the other hand, a study carried out by Ahmad (2002) to find out the effects of chronic arsenic exposure on nutritional status of children (6-12 years) in a selected area of Bangladesh found that no statistically significant difference in terms of weight, height, weight for age between exposed and non-exposed group of arsenic contaminated water except height for age.

In this study, nutritional status in terms of stunting, wasting and under nutrition among of children had significant association with arsenic exposed and non-exposed areas. Similar finding was observed by Minamoto et al., (2005) in there study carried out in rural Bangladesh.

Variability in susceptibility to arsenic toxicity may be related to nutritional status. Arsenic is methylated to monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) via one-carbon metabolism, a biochemical pathway that is dependent on folate. Folate, total homocysteine, and other factors involved in one-carbon metabolism influence arsenic methylation (Gamble et al., 2005). The percentage of DMA in urine was positively associated with plasma folate and negatively associated with total homocysteine. Conversely, percent MMA was negatively associated with folate and positively associated with total homocysteine; percent inorganic arsenic was negatively associated with folate. Dietary protein deficiency enhances the developmental toxicity of inorganic arsenic, possibly by impairment of arsenic methylation (Lammon and Hood, 2004). Low intake of calcium, animal protein, folate, and fiber may increase susceptibility to arsenic-caused skin lesions (Mitra et al., 2004).

From the above findings of the current study it can be concluded that there was significant difference of nutritional status of the children between of exposed and non-exposed areas. The study revealed that the children of exposed area had lower nutritional status compared to that of non-exposed area.

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### **References**

- Ahmad TS. Effects of chronic arsenic exposure on nutritional status of children (6-12 years) in a selected area of Bangladesh. In: Research studies on health impact of arsenic exposure. Dhaka, Bangladesh Medical Research Council, 2002, pp 396-97.
- Ali SMK, Pramanic MMA. Conversion factors and dietary calculation. Dhaka, Institute of Nutrition and Food Science, The University of Dhaka, 1999.
- Chen J, et al. Atherogenicity and carcinogenicity of high-arsenic well water: multiple risk- factors and related malignant neoplasm's of black foot disease. *Arteriosclerosis*. 1988; 8: 452.
- Gamble MV, Liu X, Ahsan H, Pilsner R, Ilievski V, Slavkovich V, Parvez F, Levy D, Factor-Litvak P, Graziano JH. Folate, homocysteine, and arsenic metabolism in arsenic-exposed individuals in Bangladesh. *Environ Health Perspect*. 2005; 113: 1683-88.
- IPCS. Arsenic and arsenic compounds. *Environmental health criteria* 224. 2<sup>nd</sup> ed. Geneva, World Health Organization, 2001, pp 7-8.
- Islam LN, Nabi AH, Rahman MM, Khan MA, Kazi AI. Association of clinical complications with nutritional status and the prevalence of leukopenia among arsenic patients in Bangladesh. *Int J Environ Res Public Health*. 2004; 1: 74-82.
- Lammon CA, Hood RD. Effects of protein deficient diets on the developmental toxicity of inorganic arsenic in mice. *Birth Defects Res B Dev Reprod Toxicol*. 2004; 71: 124-34.

- Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, Smith AH. Arsenic level in drinking water and the prevalence of skin lesions in West Bengal, India. *Int J Epidemiol.* 1998; 27: 871-7.
- Milton AH, Hasan Z, Shahidullah SM, Sharmin S, Jakariya MD, Rahman M, Dear K, Smith W. Association between nutritional status and arsenicosis due to chronic arsenic exposure in Bangladesh. *Int J Environ Health Res.* 2004; 14: 99-108.
- Minamoto K, Mascie-Taylor CG, Moji K, Karim E, Rahman M. Arsenic-contaminated water and extent of acute childhood malnutrition (wasting) in rural Bangladesh. *Environ Sci.* 2005; 12: 283-92.
- Mitra SR, Mazumder DN, Basu A, Block G, Haque R, Samanta S, Ghosh N, Smith MM, von Ehrenstein OS, Smith AH. Nutritional factors and susceptibility to arsenic-caused skin lesions in West Bengal, India. *Environ Health Perspect.* 2004; 112: 1104-9.
- Rahman M, Tondel M, Ahmad SA, Axelson O. Diabetes mellitus associated with arsenic exposure in Bangladesh. *Am J Epidemiol.* 1998; 148: 198-203.
- Rahman M, Tondel M, Ahmad SA, Chowdhury IA, Faruquee MH, Axelson O. Hypertension and arsenic exposure in Bangladesh. *Hypertension.* 1999; 33: 74-78.
- Smith AH, Arroyo AP, Mazumder DN, Kosnett MJ, Hernandez AL, Beeris M, Smith MM, Moore LE. Arsenic-induced skin lesions among Atacameño people in Northern Chile despite good nutrition and centuries of exposure. *Environ Health Perspect.* 2000a; 108: 617-20.
- Smith AH, Lingas EO, Rahman M. Contamination of drinking water by arsenic in Bangladesh: a public health emergency. *Bull World Health Organization.* 2000b; 78: 1093-103.
- Statistical pocket book of Bangladesh. 1999. p 3, 126, 363.
- Zhang X, Cornelis R, De-Kimpe J, Mees L, Vanderbiesen V, De-Cubber A, Vanholder R. Accumulation of arsenic species in serum of patients with chronic renal disease. *Clin Chem.* 1996; 42: 1231-37.

