Arsenic in Drinking Water and Pregnancy Outcomes

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We studied a group of women of reproductive age (15–49 years) who were chronically exposed to arsenic through drinking water to identify the pregnancy outcomes in terms of live birth, stillbirth, spontaneous abortion, and preterm birth. We compared pregnancy outcomes of exposed respondents with pregnancy outcomes of women of reproductive age (15–49 years) who were not exposed to arsenic-contaminated water. In a cross-sectional study, we matched the women in both exposed and nonexposed groups for age, socioeconomic status, education, and age at marriage. The total sample size was 192, with 96 women in each group (i.e., exposed and nonexposed). Of the respondents in the exposed group, 98% had been drinking water containing ≥ 0.10 mg/L arsenic and 43.8% had been drinking arsenic-contaminated water for 5–10 years. Skin manifestation due to chronic arsenic exposure was present in 22.9% of the respondents. Adverse pregnancy outcomes in terms of spontaneous abortion, stillbirth, and preterm birth rates were significantly higher in the exposed group than those in the nonexposed group ($p = 0.008$, $p = 0.046$, and $p = 0.018$, respectively). *Key words*: abortion, adverse pregnancy outcomes, arsenic, arsenicosis, preterm birth, stillbirths. *Environ Health Perspect* 109:629–631 (2001). [Online 15 June 2001]
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Bangladesh, an alluvial and deltaic land of 147,570 km^2, is prone to various natural disasters such as cyclones, floods, and droughts. Bangladesh had to face another environmental catastrophe in recent years arising from groundwater polluted with arsenic. This arsenic-polluted water posed a considerable threat to the country's safe water supply. Some 50 million people from 60 out of the country's 64 districts were at risk of arsenic poisoning (*1*,*2*).

The water supply in Bangladesh is primarily from groundwater sources. About 4 million tube wells (hand pumps) have been sunk into aquifers located at depths ranging from 40 to 300 ft, and sometimes even deeper, to tap underground water, which was assumed to be safe from bacterial contamination. With the primary aim of preventing cholera and other diarrheal diseases, the tube wells were installed all over the country by the government of Bangladesh and aid agencies, mainly UNICEF (the United Nations Children's Fund), since the late 1960s to provide safe drinking water through simple technology at a minimum cost. Unfortunately, the authorities did not foresee the possibility of geochemical contamination of groundwater including contamination by arsenic. Although the tube well program significantly reduced the burden of diarrheal diseases and saved millions of lives, it has turned into a major cause of a new tragedy.

In a fact-finding survey, the Department of Public Health Engineering first detected arsenic-contaminated groundwater in 1993 in the village of Chamagram in Baroghoria union, district of Nawabgonj, and reported that water samples from four tube wells contained arsenic at 0.059–0.388 mg/L. However, the first eight patients of arsenicosis were located by the Department of Occupational and Environmental Health, National Institute of Preventive and Social Medicine in 1994 in the same area (*1*–*4*).

Of the tube wells so far examined in the 60 districts, 50% contained arsenic at levels above the Bangladesh safe limit (0.05 mg/L); the highest concentration of arsenic detected in tube well water is 2.97 mg/L. Arsenic contamination has not yet been detected in tube well water in the terraced and hilly areas of Bangladesh. The age of the contaminated tube wells is commonly in the range of 3–18 years, and the contamination has been detected more in the tube wells installed at depths of 50–200 ft. It has been reported that 7,500 arsenicosis patients [melanosis or hyperpigmentation on covered parts of the body and/or bilateral palmoplantar keratosis/hyperkeratosis in addition to high levels of arsenic in drinking water (> 0.05 mg/L)] were identified in 40 districts distributed in 277 villages of 118 "thanas" (lowest administrative unit) (*1*,*5*). The prevalence of arsenicosis was higher among males than females. Most of the patients were in 20–40 years of age, and the youngest patient so far with arsenicosis was 4 years of age (*1*).

The arsenic contamination problem in Bangladesh is rapidly emerging. In December 1995 it was estimated that only 10 million people were at risk of arsenic exposure through tube-well water. Until 1995, the arsenic contamination situation in West Bengal, India, was believed to be the greatest arsenic disaster in the world (*2*). However, in the following years, arsenic contamination in groundwater in Bangladesh became apparent, and the situation is now considered as the largest in the world (*5*).

Arsenic affects people regardless of sex. It is a known carcinogen (*6*) and has mutagenic and teratogenic effects (*7*,*8*). Chronic exposure to arsenic may affect all of the organs and systems of the human body. Arsenic readily crosses the placental barrier and thus affects fetal development. Reproductive and developmental effects of inorganic arsenic on humans and on animal species have been reported (*9*–*12*). There is extensive documentation of reproductive and fetal developmental effects in a variety of animal species (*9*,*10*). In contrast, there are few reports about effects of arsenic in drinking water on human pregnancy outcomes (*13*,*14*). Higher spontaneous abortions (69.57/1,000 live births) and stillbirths (7.68/1,000 live births) were observed in the high arsenic area (where drinking water arsenic > 0.1 mg/L), compared to the control area (where drinking water arsenic < 0.1 mg/L); among controls, the rates for spontaneous abortions and stillbirths were 51.14/1000 live births and 2.84/1,000 live births, respectively (*13*).

Moreover, no published study is available on pregnancy outcomes in relation to arsenic exposure through drinking water in Bangladesh. Therefore, the aim of this study was to identify pertinent information regarding pregnancy outcomes of the women who were chronically exposed to arsenic through drinking water, and also to estimate the difference between the prevalence of adverse pregnancy outcomes in exposed and nonexposed groups.

Materials and Methods

Study design and area. We carried out a cross-sectional study in the village of Samta in thana Sharsha, Jessore district (located 520 km southwest of Dhaka), and in the village of Katiarchar in Sadar thana, Kishorgonj district (located 150 km northeast of Dhaka). We selected the exposed group from residents of Samta and the comparison group (i.e., nonexposed group) from residents of Katiarchar. The arsenic content of the tube wells used by the subjects in Katiarchar was ≤ 0.02 mg/L.

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Samta was an arsenic-affected village. Eighty-seven percent of tube wells in Samta had an arsenic content > 0.05 mg/L. Most (70.8%) tube wells had arsenic in the range of 0.2–0.45 mg/L. The average arsenic level was 0.240 mg/L and the highest concentration was 1.371 mg/L. The prevalence of arsenicosis was 10%. Among the arsenicosis patients, 52.6% were male and 47.4% female (*2*).

Study population and sample size. The study population was composed of married women of reproductive age (15–49 years) who previously had at least one pregnancy. The exposed group consisted of women who had been drinking arsenic-contaminated water (> 0.05 mg/L aresenic) for at least 5 years, whereas the nonexposed group consisted of respondents who had been drinking arsenic-safe water (i.e., < 0.02 mg/L aresenic). The subjects in the nonexposed group were matched for age, socioeconomic status (SES), education, and age at marriage. In calculating the sample size, we used the formula

$$n = z^2_{1-\propto/2}\{P_1\ (1–P_1) + P_2\ (1 – P_2\}/d^2$$

where z is the z-score and d (acceptable level of error) and P_1 and P_2 are the anticipated population proportions of adverse pregnancy outcome in exposed and nonexposed groups. Because available literature did not provide any estimate of the anticipated prevalence rates, we used 0.5 for P_1 and P_2 to provide the largest sample. However, we used a comparatively large value for error (d = 0.15) to keep the sample to a manageable size in our context of the study. Using the above formula and modalities (z = 1.96, $P_1 = P_2$ = 0.5, and d = 0.15,) the required sample size for each group was 86. In this study, we inflated the sample size by an arbitrary figure of 10 as a check against possible dropout; thus, the final sample size was 96. Therefore, we included another 96 respondents as the comparison group. As a result, we interviewed a total of 192 women, which increased precision slightly.

Data collection. We enlisted individuals fulfilling the criteria for inclusion in the study through house-to-house visits. We selected the required number of respondents by simple random sampling. Subsequently, researchers used a pretested combined-structure questionnaire and checklist to interview the selected respondents. At the beginning of the interview, the researcher explained the purpose of the study to each prospective respondent and obtained her verbal consent to participate in the study. We used arsenic concentrations in tube wells as listed in the Department of Occupational and Environmental Health database.

We collected information on the respondents' lifetime pregnancy history, which included the number of pregnancies, preterm births (live birth before completion of 8 months, or 37 weeks from the last menstrual period), live births, stillbirths, and spontaneous abortions (spontaneous expulsion of product of conception before completion of 5 months, or 22 weeks of gestation from the last menstrual period). During analysis we calculated stillbirth, spontaneous abortion, and preterm birth rates using the total number of live births as the denominator. Subsequently, we compared the pregnancy outcome events such as spontaneous abortions, still births, and preterm births in the exposed and nonexposed groups.

Results

Most (80.9%) of the respondents in the exposure and nonexposure groups were between 20 and 39 years of age. The mean age (± SD) of the respondents in both exposed and nonexposed groups was 31.7 ± 8.6 and 31.0 ± 7.6, respectively. Of the respondents in both groups, 53.6% married at 15–19 years of age. Among the 192 respondents, 64.6% had no schooling, and only 15.1% had secondary education or more. Of the total respondents, 51% came from middle socioeconomic status and 18.3% came from high socioeconomic status. Moreover, there was no statistically significant difference ($p > 0.05$) for socioeconomic status, age at marriage, or educational status among respondents in exposed and nonexposed groups (Table 1).

Of the respondents in the exposed group, 98% had been drinking water containing > 0.10 mg/L aresenic; 43.8% of these women had been drinking this water for 5–10 years, and the rest of the women had varying levels of exposure for > 10 years. In the exposed group, 22.9% had skin manifestation(s) due to arsenic toxicity.

The mean number of pregnancies, live births, stillbirths, spontaneous abortions, and preterm births were 3.74, 3.33, 0.18, 0.23, and 0.23, respectively, among the exposed group and 3.22, 3.07, 0.07, 0.07, and 0.08, respectively, in the nonexposed group (Table 2). In exposed and nonexposed groups, respectively, 89.1% and 95.5% of pregnancies ended as live births; the difference was statistically significant (z = 3.2; p = 0.002). Adverse pregnancy outcomes measured as spontaneous abortions, stillbirths, and preterm birth rates were 68.8, 53.1, and 68.8 per 1,000 live births, respectively, among the exposed group and 23.7, 23.7, and 27.1 per 1,000 live births, respectively, among the nonexposed group. We observed a statistically significant difference in the adverse pregnancy outcome rates ($p < 0.05$) when we compared the two groups (Table 3).

The pregnancy outcomes rates were higher among exposed women who had been drinking arsenic-contaminated water (> 0.1 mg/L) for > 15 years than among those who had been drinking arsenic-contaminated water for < 15 years. Rates of spontaneous abortions, stillbirths, and preterm births were 43.5, 43.5, and 47.8 per 1,000 live births, respectively, among those women who had been drinking arsenic-contaminated water for < 15 years, whereas the rates were 133.3, 77.5, and 122.2 per 1,000 live births, respectively, among those women who had been drinking arsenic-contaminated water for > 15 years. The observed difference was statistically ($p < 0.05$) significant (Table 4).

Discussion

In this cross-sectional study, we compared pregnancy outcomes in women exposed to

Table 1. Comparable variables among the exposed and nonexposed groups.

Variables	Exposed (n = 96)	Nonexposed (n = 96)	Significant difference
Mean age ± SD (years)	31.7 ± 8.6	31.0 ± 7.6	z = 0.59; $p > 0.05$
Mean age at marriage ± SD (years)	16.5 ± 0.58	16.6 ± 0.57	z = 0.36; $p > 0.05$
SES			
Low	31	28	χ^2 = 0.90; $p > 0.05$
Middle	50	48	
High	15	20	
Education			
None	60	64	χ^2 = 0.39; $p > 0.05$
Primary	21	18	
Secondary and above	15	14	

Table 2. Respondents by mean pregnancy outcomes.

Pregnancy outcome	Exposed	Nonexposed
Pregnancy	3.74 ± 1.8 (359)	3.22 ± 1.6 (309)
Live birth	3.33 ± 1.6 (320)	3.07 ± 1.6 (295)
Stillbirth	0.18 ± 0.69 (17)	0.07 ± 0.33 (7)
Spontaneous abortion	0.23 ± 0.57 (22)	0.07 ± 0.36 (7)
Preterm birth	0.23 ± 0.55 (22)	0.08 ± 0.28 (8)

Values shown are mean ± SD (n).

arsenic through drinking water (> 0.1 mg/L) to outcomes of women who were exposed to arsenic at levels < 0.02 mg/L. The groups were comparable in terms of age, age at marriage, level of education, and socioeconomic status, as these variables did not differ statistically.

The present study has all the limitations inherent to such a design. Higher allowable error (15%) used in sample size determination could have influenced the results. In Bangladesh, especially in the rural areas, the medical records system is still rudimentary and tests for confirmation of pregnancy are rarely available. In contrast, in rural Bangladesh, pregnancies are considered important and valued events of life, especially by the women; they prize each pregnancy and grieve over the loss when it occurs. Moreover, pregnancies and their outcomes are well remembered in terms of spontaneous abortions, preterm births, stillbirths, and live births as defined in this study.

In this study, rates of spontaneous abortion, stillbirth, and preterm birth were 2.9, 2.24, and 2.54 times higher, respectively, in the exposed group than in the nonexposed group (Table 3). These differences were statistically significant ($p = 0.008$ for spontaneous abortions, $p = 0.046$ for stillbirths, and $p = 0.018$ for preterm births). Statistically significant differences in rates of spontaneous abortion ($p = 0.0071$) and stillbirth ($p = 0.0283$) have also been observed in southeast Hungary in a population whose drinking water arsenic concentration exceeded 0.1 mg/L compared to a population whose drinking water arsenic concentration was < 0.1 mg/L (*13*). Aschengrau et al. (*14*) reported a high frequency of spontaneous abortions (1.7 times) among women of eastern Massachusetts who consumed a high level of arsenic (1.4–1.9 mg/L) through drinking water compared to women who consumed lower levels of arsenic.

Conclusion

In this study we observed that adverse pregnancy outcomes were more common among women who were chronically exposed to arsenic through drinking water. Arsenic pollution of groundwater has become a serious environmental health problem in Bangladesh. As revealed in this study, contamination is also a threat to healthy and safe pregnancy outcomes.

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Table 3. Adverse pregnancy outcomes per 1,000 live births among the respondents.

Pregnancy outcome	Exposed	Nonexposed	*z*-Score	*p*-Value
Spontaneous abortion	68.8	23.7	2.66	0.008
Stillbirth	53.1	23.7	2.00	0.046
Preterm birth	68.8	27.1	2.35	0.018

Table 4. Adverse pregnancy outcome rates (per 1,000 live births) by duration of drinking arsenic contaminated (> 0.1 mg/L) water.

	Duration of drinking arsenic-contaminated water			
Pregnancy outcome	< 15 Years	≥ 15 Years	*z*-Score	*p*-Value
Spontaneous abortion	43.5	133.3	3.0	0. 003
Stillbirth	43.5	77.5	2.0	0.046
Preterm birth	47.8	122.2	2.3	0.021