

Arsenic in Drinking water and Birth Outcomes:
A Study of the Bangladesh Integrated Nutrition Programme

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EXECUTIVE SUMMARY

This paper assesses the impact of arsenic (As) exposure on pregnancy outcomes in Bangladesh. A total of 261 villages from 3 highly As contaminated upazilas of two districts were selected for this study. The upazilas were Faridpur sadar of Faridpur district and Matlab and Shahrasti of Chandpur district. Data were collected from 742 women under 106 CNCs from 100 villages of Faridpur Sadar, 710 women from 55 villages under 80 CNCs of Matlab, and 737 women under 33 CNCs from 106 villages of Shahrasti upazila. Water samples were collected from the tubewells (TWs) where from the pregnant mothers were drinking water, at least during the year 2002 for analysis in the laboratory with Atomic Absorption Spectrophotometric (AAS) method.

A total of 2,189 women who gave births in 2002 participated in the study. Their mean age was 26.52 years, the mean duration of As exposure of the participants was 6 years, and the median was 7 years. The majority of them (72%) used As contaminated water (>50 ppb) for drinking purpose during their last pregnancies. The mean and median As concentration of the TW water of the study participants was 158.21 and 151 ppb respectively, ranging from non-detectable level to 668 ppb. Overall incidence of spontaneous abortion, stillbirth, premature birth, low birth weight, and neonatal death were found to be 23.3/1000 live birth, 26.95/1000 live birth, 42.49/1000 live birth, 113.75/1000 live birth, and 28.78/1000 live birth respectively. About 28% of newborn babies were malnourished (<2.5 kg of weight). No significant difference was observed between the two categories of As exposed and non-exposed babies. The majority of the mothers (72%) exposed to As at above 50 ppb gave normal births. A statistically significant difference was observed in the total pregnancy outcome status of the respondent mothers, particularly for low birth weight ($p<0.002$), premature birth ($p<0.006$), and abortion ($p<0.06$) when compared with As exposed and non-exposed groups, after adjustment for maternal education, age of mothers, antenatal care, parity, and household socioeconomic condition.

It seems from the study that the rate of adverse pregnancy outcomes including abortion, premature birth, low weight birth, still birth, and post-natal death of the mothers exposed to As above 50 ppb was higher than those of the mothers exposed to As below 50 ppb. However, these differences were not found to be statistically significant for mothers who gave first birth in the year 2002 in spite of drinking As contaminated water. In contrary, a significant difference was observed particularly for spontaneous abortion, premature birth, and low birth weight cases for the mothers who had previous pregnancy history including for the year 2002. Further study is needed to establish this finding by mapping the precise exposure assessment.

Keywords: Bangladesh; Arsenic; Abortion; Premature birth; Low birth weight; Still birth; Neonatal death Bangladesh

Abbreviations: OR, odds ratio; CI, confidence interval; PPB, parts per billion; atomic absorption spectrometry- AAS.

Introduction

Arsenic (As) is widely distributed in nature and mainly transported in the environment by water (1). As is an element possessing both metallic and nonmetallic properties. It is a well-known toxin to human and pests. The degree of its toxicity depends on the chemical form and specification. Humans are exposed to As through environmental, medicinal and occupational sources. The main source of As exposure for general population is ingestion of drinking water with high level of As. The World Health Organization (WHO) has revised its original guideline value for As in drinking water of 50 ppb (1) to a provisional guideline value of 10 ppb (2). According to Bangladesh government the scale limit of As in drinking water is up to 50 ppb (3).

As contamination of ground water has been reported from all over the world. Bangladesh is one of the most affected regions. To control different water borne diseases the Department of Public Health Engineering, Bangladesh (DPHE) with the assistance from UNICEF drilled millions of hand pump TWs. Through this initiative Bangladesh achieved remarkable success in providing safe drinking water to almost 97% of its rural population. But the recent discovery of As in groundwater has ruined this decade long success and access of safe drinking water has now dropped to almost 80% (14). To date, as 95% of the country's 130 million population rely on supposedly pathogen-free underground water, up to 57 million people in Bangladesh are estimated to have been chronically exposed to high concentrations of As (Figure 1). However, since decades of As exposure have already accrued, it is likely that a significant proportion of the exposed population will continue experiencing elevated risk of As-induced health problems. Even if further exposure could be successfully averted (albeit unlikely), an epidemic of As-induced cancers will still be almost inevitable in Bangladesh. Long-term studies from Taiwan showed that once chronically exposed, a population continues to experience elevated cancer risk for several decades after the exposure has ceased. A recent study estimated that the lifetime risks of death from As induced cancers in Bangladesh will at least double because of the As problem. Although it is yet to be systematically

investigated, the results have shown that there is wide inter-individual variability in the risk of As-induced health effects and their outcomes, especially for skin lesions that are already widely prevalent in Bangladesh.

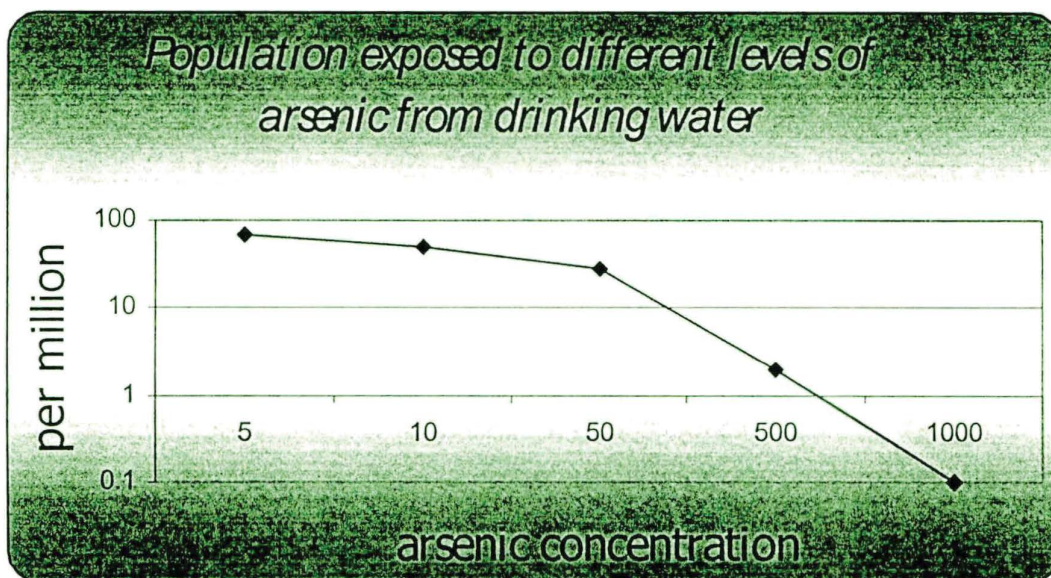


Figure 1: Population exposed to different levels of As from drinking water

Characteristic skin lesions (hyperpigmentation, hypopigmentation and Keratosis) are the hallmark of chronic high As exposure (8,11). The latency period for these skin lesions ranges from five to ten years, though shorter latency is possible. Melanosis may occur anywhere on the body, often showing raindrop like pigmentation or diffuse dark brown dappling especially marked in non-exposed parts of the body. Leucomelanosis follows the same distribution and may be present even in absence of melanosis. Keratoses are small, corn-like elevations, usually 0.4-1 cm in diameter and nodular, found on the palms and its lateral border, fingers and on the soles, heels and toes (12). Development of skin lesions and other symptoms depends on the concentration and duration of As exposure and possibly on nutritional and genetic factors (13). Inorganic As is a known carcinogen

and chronic exposure to As can cause cancer of skin and other internal human organs (14). Studies have shown that As also causes several non-malignant adverse health effects including weakness, edema, conjunctival congestion, diabetes mellitus, hypertension, adverse respiratory effects (11,15-17).

As exposure increases the incidences of spontaneous abortion, stillbirth, birth defects, and preterm birth in animals (5). Epidemiological studies in Taiwan, Chile, Argentina, and Bangladesh have shown that exposure to inorganic As from drinking water is associated with cancers of the skin, lung, bladder, and possibly other organs (14) and diabetes (7) was noted to be associated with consumption of As contaminated water. Several epidemiological studies have examined the associations between As exposure and multiple adverse pregnancy outcomes, including spontaneous abortion (11), still births (11)., A study from Chile reported significant association between As exposure and late fetal mortality [rate ratio (RR) = 1.7; 95% CI: 1.5, 1.9], neonatal mortality (RR=1.53; 95%CI:1.4, 1.7), and post neonatal mortality (RR=1.26, 95% CI:1.2,1.3) (19). A hospital-based case control study in Texas, USA reported an increase of stillbirths in relation to residential proximity of the participants to an arsenical pesticide production plant in Texas. Adverse pregnancy outcomes were also reported from Sweden. Increased frequency of spontaneous abortion among the worker living in the nearest community compared to the community living further away from a copper smelter was observed, the prevalence odds ratio for the women living nearest the smelter was 1.5. The birth weights of infants born to women living nearest the smelter (mean=3.39 kilogram) were lower than those living in the outlying communities. A study from Hungary reported an increased frequency of stillbirths and spontaneous abortion (prevalence odds ratio=2.7) from the south-eastern part where high level of As were found in the deep well drinking water. Slightly increased risk (prevalence odds ratio=1.3, 95% CI: 1.0,1.6) was reported from a case-control study conducted in Massachusetts USA (22). Excess spontaneous abortion, stillbirth and pre-term birth rates among the chronic As exposed population as compared to the unexposed population were first reported in Bangladesh in 2001. In this prevalence comparison study, the proportion of spontaneous abortion, stillbirth and pre-term birth rates were significantly higher in the exposed group compared to the

unexposed group ($p = 0.008$, $p = 0.046$, and $p = 0.018$, respectively). Several epidemiological studies have examined the associations between As exposure and multiple adverse pregnancy outcomes, including spontaneous abortion (10, 11, 23) still births (10,11) or specific birth defects. Although several human studies have been conducted to determine the association between chronic As exposure and adverse pregnancy outcome, the evidence remains inconclusive.

Not enough studies have been done in this regard in Bangladesh. This cross sectional survey included 2,189 eligible female participants who were exposed to varying As concentrations in drinking water. In this paper we present the reported incidence of spontaneous abortion, stillbirths and neonatal death among women consuming different concentrations of As in their drinking water.

This study attempted to assess the effect of As exposure on pregnancy outcomes in three upazilas of Bangladesh where Bangladesh Integrated Nutrition Programme (BINP) is collecting pregnancy related information for about last four years. BINP is a World Bank funded project aims to eliminate malnutrition in the country. In each upazila there are Community Nutrition Centers (CNC), the smallest unit of BINP. The female community nutrition promoter (CNP) from the same community runs the CNC. Each CNP is responsible for interviewing about 1,250 people. The Community Nutrition Organizers (CNO) monitored their work. The CNPs and CNOs are trained initially for one month and they receive daylong refresher training every month. The CNPs are provided with specific format for collection of data and they maintain hand written logbooks on mothers' and children's nutritional status. Different nutritional and health information during pregnancy and pregnancy outcomes and health education given to the mothers during pregnancy are also recorded by the CNPs. They provide nutritional supplementation to pregnant mothers as well. The weight of the newborns is measured by the CNP as early as possible just after birth. The weight of the baby is monitored up to two years of age.

Therefore, we found this a unique opportunity to look at the pregnant mothers and their outcomes and to link these information with their status of drinking water in order to see whether there was any effect of drinking As contaminated water with their birth outcomes who gave birth, particularly in the year 2002.

Objective of the study

The study aimed to explore the extent of the association between adverse birth outcomes and drinking As contaminated water during pregnancy. We specifically addressed the following issues to achieve the study objectives.

1. To know the status of association between exposure to As during pregnancy and spontaneous abortion, stillbirth, low birth weight, birth defects, child growth or neonatal death, and
2. To assess the status of dose-response relationship

Materials and methods

Study area

A total of 261 villages from three highly As contaminated upazilas of two districts were selected for this study. The upazilas were Faridpur sadar of Faridpur district and Matlab and Shaharasti of Chandpur district. Data were collected from 100 villages of Faridpur Sadar, 55 villages of Matlab and 106 villages of Shaharasti upazila. Before selecting Shahrasti upazila Banaripara was selected for this study. Later, we had to drop Banripara as majority of the villagers of this upazial shifted to safe water sources, mainly to deep hand TW option distributed by the government.

The three study upazilas were chosen from the BINP operated areas, which had higher level of As concentration in the TW water. The water of almost all the TWs in these areas were tested well ahead of starting this survey by the BAMWSP/ World Vision, an International non-governmental developmental organization.

Data collection and sampling technique

A total of 2,189 women who gave births during 2002 under community nutrition centers were selected randomly for interview. Twenty-one field enumerators and three supervisors were recruited. They got a three-day intensive training on how to conduct interview and to collect water samples for laboratory test.

The interviewers first went to the Health Nutrition and Population Programme-Nutrition Facilitation programme (HNPP-NFP) office of the selected upazilas. The interviewers collected the names of all CNCs under each upazila and selected the required number of CNCs using random table. The mothers who gave birth in 2002 were identified from the selected CNCs. The number of such mothers in each CNC was about 30. From each CNC 8-10 mothers were selected randomly. Data regarding pregnancy outcomes for the year 2002 (e.g. LMP, EDD, abortion, live births, still births, complications during pregnancy etc.), nutritional status of the mother, date of delivery, newborns birth weight, any neonatal deaths, health education given to the mother etc. were collected from CNCs logbooks. Later on, the respondent mothers were interviewed with the same questionnaire at their home after taking their consent and the correct information was marked in the questionnaire.

A detailed history of previous pregnancies of each respondent and their outcomes were collected. In some cases when mother could not recall any history of past pregnancy events properly assistance was sought from any of the senior members of the household, e.g. like mother in law or sisters in law who were present at the time of delivery. Any history of diabetes and hypertension of the respondent was taken. The interviewers took the height and weight of the respondent mothers and the babies who were born in 2002. Smoking history of the mothers and other household members was collected from the respondent mothers. The smoky condition of the kitchen was assessed from the closed or openness of the kitchen and what fuel they used for cooking. A list of the assets a family possesses was also collected. The educational level of both the respondents and her husband was collected. These data were not recorded at CNCs. A total of 2,003 water samples were collected from the TWs for laboratory analysis. There were 11 twin pregnancies, which were not included in the analysis.

Water samples were collected from the TWs where from the pregnant mothers were drinking water, at least during the year 2002 for analysis in the laboratory with Atomic Absorption Spectrophotometric method (AAS). The water samples were collected through acidified 100 ml plastic bottles. Each field enumerator interviewed at least four mothers, on average, per day. Data and water samples were collected in August–September 2003 and the data entry was completed in October–November 2003.

Supervision – as a part of quality control

Three supervisors monitored and supervised the field activities. Each supervisor re-interviewed at least three respondents per day. Besides, the supervisors used to sit every evening with the team members to review the activities of each day and to provide necessary suggestions for the next day work. Each supervisor supervised seven field enumerators in one upazila. The supervisors worked under the direct supervision of the Project Manager. At the end of every week, the water samples were sent to the laboratory in Dhaka for As test.

Laboratory validation

All the water samples were analysed in the Intronic laboratory. To evaluate the performance of Intronic results 10 known As standard of different concentrations were provided for analysis both at Intronic as well as to the US Geological Survey (USGS) for comparison. Results from both the laboratories matched perfectly. This indicates the high quality analysis performed by the Intronic Laboratory (Fig. 2).

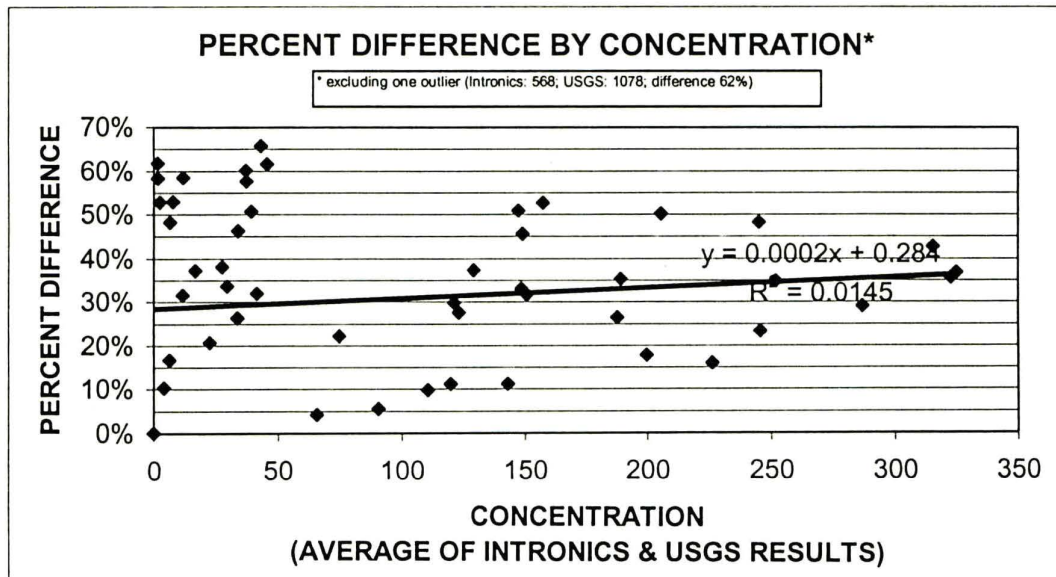


Figure 2: Comparative analysis of As test results (Intronics and USGS laboratory)

Measuring household wealth index

The approach used in developing household wealth index for this study has been developed by Filmer and Pritchett (24) who have shown that the wealth index performs as well as a more traditional measure such as household-size-adjusted consumption expenditures. A set of household level variables was identified to include in the construction of wealth index. These were *almirah* (wardrobe), table, chair, bench, watch, cot or bed, radio, television, and bicycle. Each of the variables was recorded into categorical dichotomous (yes/no) variable. Nine dichotomous variables were created and standardized. The principal component analysis was run with all constructed variables with certain criteria. The component score efficient matrix was multiplied by the standardized variables to produce factor scores which were termed as household wealth score. The wealth score was classified into quintile for this study.

Limitations

We encountered the following limitations during implementation of the project:

- i) We could not start and complete the field survey on time because of rainy season and floods in almost all the survey areas.
- ii) One sampled mother in Matlab refused to take part in the interview, as she was reluctant to talk about her deceased child as she gave birth of a still baby in 2002.
- iii) Community Nutrition Promoters (CNP) who keep the log books and measuring scale were not found at home in many places as the BINP project was not operating at that time. The majority of the poor CNPs were not keeping these instruments and log books at their home rather, they kept them in safe places, the houses of their relatively well-off relatives. As a result the interviewers had to spend long hours to find the CNPs and the materials.

Results and discussion

General description and socioeconomic characteristics of the study population

A total of 2,189 mothers who gave births in 2002 participated in the study. Their mean age was 26.52 years, and the mean duration of As exposure of the participants was 6 years, and median was seven years. The majority of them (72%) used As contaminated water (>50 ppb) for drinking purpose during their last pregnancies. The univariate distribution of variables on maternal education, and different other socio-economic variables are presented in Table1. Out of the study subjects, 520 (24%) did not receive any formal education. The mean number of pregnancies was 2.75 and the percentage of live births among the babies who were born in 2002 was 93%.

To assess economic condition of the mothers and whether it has any impact on the birth outcome status if compared with their drinking water exposure status, wealth ranking matrix was prepared using the quintal techniques. Here it is mentioned that more than 98% of the respondents were housewives. The wealth index was categorized into five different groups and the percentage of mothers in each group is presented within parenthesis: always deficit (19%), sometimes deficit (22%), always surplus (25%), sometime surplus (17), , and balance (17%). The different pregnancy outcome was found to be significant (at <0.05) when compared with the household wealth matrix.

The mean and median As concentration of the TW water of the study participants was 158.21 and 151 ppb respectively, ranging from non-detectable level to 668 ppb. Overall incidence of spontaneous abortion, stillbirth and premature birth, low birth weight, and neonatal death were found to be 23.3 /1000 live birth, 26.95 /1000 live birth, 42.49/1000 live birth, 113.75/1000 live birth, and 28.78/1000 live birth respectively.

Source of drinking water of the respondent mothers

To understand the issue of chronic As exposure and related pregnancy outcomes in our sampled mothers, we analysed all 2003 water samples in laboratory to detect As concentration. It was observed that source of drinking water of all the respondent mothers was TW and their mean As exposure age was 6 years with a highest exposure age of 26 years. Mean and median As concentration of the mothers drinking from these TWs was 158.21 ppb and 151.00 ppb respectively with a highest concentration of 668 ppb. According to the AAS results about 72% of the respondents were drinking As contaminated water (>50 ppb).

About new born babies

About 28% newborn babies were malnourished (<2.5 kg). No significant difference was observed between the two categories of As exposed and non-exposed babies. Out of the total new born babies for the year 2002 only 8 babies had physical deformation. The influence of As could not be established for this deformation. The types of physical deformations found were: cleft lip and cleft palate, anencephaly, microcephaly, and hydrocephalus, etc.

Distribution of mothers and their birth outcome status

i. Pregnancy outcome in 2002

Overall incidence of spontaneous abortion, stillbirth, premature birth, low birth weight, and neonatal death in 2002 were found to be 23.3/1000 live birth, 26.95/1000 live birth, 42.49/1000 live birth, 113.75/1000 live birth, and 28.78/1000 live birth respectively. The majority of the mothers (72%) exposed to As at above 50 ppb gave normal births. The risk of spontaneous abortion, stillbirth and neonatal death by maternal education, age, socioeconomic status, parity and history of receiving antenatal care during pregnancy were analyzed.

Results from the logistic regression analysis of spontaneous abortion, stillbirth, post-natal death, premature birth, and low-birth weight of the mothers who gave birth in the year 2002 are presented in Table 2. The tendency for comparatively increasing adverse pregnancy outcome, particularly for still birth, abortion, post natal death, and low birth weight was observed among mothers who were exposed to higher level of As contamination in their drinking water during the whole pregnancy period. But none of the differences was found to be statistically significant. Similarly, there was no significant difference observed in the birth outcome status of the mothers who had first issue in the

year 2002. Whereas, a statistically significant difference was observed in some birth outcome status such as, spontaneous abortion ($p=0.002$), premature birth ($p=0.001$), and low birth weight ($p=0.04$) of the mothers who had more than one pregnancy outcomes. Therefore, it can be said that parity was found to be significantly associated with the adverse pregnancy outcomes after adjustment for As exposure, maternal education, age, antenatal care and socio-economic status of the respondent mothers, which is consistent with other findings such as, prenatal exposure to acute high doses of As has resulted in miscarriage and early neonatal death (11).

ii. Total pregnancy outcome of the respondent mothers

Total pregnancy history of the respondent mothers was recorded (Table 3). A statistically significant difference was observed in the total pregnancy outcome status of the respondent mothers, particularly for low birth weight ($p<0.002$), premature birth ($p<0.006$), and abortion ($p<0.06$) when compared with As exposed and non-exposed groups, after adjustment for maternal education, age of mothers, antenatal care, parity, and household socioeconomic condition. This indicates that there is a statistically significant increasing risk is associated with increasing As exposure.

It was observed that As concentration level of 50 ppb appears to be a threshold level for still birth ($p<0.14$) and post-natal death ($p<0.15$) cases as no increased risk was observed with increasing As exposure. In spite of the significant difference in the birth outcome status of the total respondent mothers, it might be difficult to correlate the birth outcome status with drinking water exposure in the absence of past drinking water history, especially during previous pregnancy periods of the respondent mothers. However, to establish this link further investigation of the previous drinking water history of the respondent mothers needs to be examined carefully.

Conclusion and recommendation

It has already been documented that As is easily transferred to the fetus (18). High doses of As produce detrimental effects on the developing embryo in avian and mammalian species (19, 20). But in this study we did not find any effect on different pregnancy outcome status particularly for the birth outcomes during the cross sectional survey period. Apparently it seems that the rate of adverse pregnancy outcomes including abortion, premature birth, low weight birth, still birth, and post natal death of the mothers exposed to As above 50ppb was higher than those of the mothers exposed to As below 50ppb. However, these differences were not found to be statistically significant for mothers who gave first birth in the year 2002 in spite of drinking As contaminated water. One possible explanation for these different in pregnancy outcomes might be due to switching to As free waters; another possibility could be not drinking from As contaminated water sources on a continuous basis. Further study is needed to establish this finding by mapping the precise exposure assessment.

In contrary, a significant difference was observed particularly for spontaneous abortion, premature birth, and low birth weight cases for the mothers who had previous pregnancy history including for the year 2002. Similar to this, a statistically significant difference was also observed in various birth outcome status of the respondent mothers when their life time pregnancy outcomes were compared with As exposed and non-exposed groups. Therefore, it can be said that considering the pregnancy events in categorizing parity, the effects is significant and this is somewhat consistent with other findings of prenatal exposure to acute high doses of As that has resulted in miscarriage and early neonatal death (21).

Although a few studies have addressed the potential reproductive effects of As exposure in the vicinity of As emitting industries and via drinking water, the evidence is not conclusive (20). Recently, a retrospective study in Bangladesh (10) compared pregnancy outcomes in women exposed to fairly high (mean 240 $\mu\text{g/L}$) and low (below 20 $\mu\text{g/L}$) As concentrations in drinking water and found increased spontaneous abortions, stillbirths, and pre-term births. Parity was not included as a confounding factor in this study. Therefore, ascertainment of exposure could be questioned and outcomes were not clearly

defined. Although a relationship between ingested As and negative pregnancy outcome has so far only been reported in a limited number of studies from Taiwan, Sweden, Chile, and now in Bangladesh, it appears likely that there might be a causal relationship, which needs further attention. Various sources of exposure should be considered in future studies.

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Appendix: Tables

Table 1 Socioeconomic characteristics of the respondent mothers

Variable	Number	Percent
<i>Maternal education</i>		
No formal education	5573	44
Primary (grade 1 to grade 5)	6935	55
> Primary	106	1
<i>A Maternal (years)</i>		
<20	326	15
21-30	1402	64
>30	461	21
<i>Parity</i>		
1 – 2	1103	50
3 – 5	953	44
>5	133	6
Mean (SD)	3.72 (1.79)	
Live birth	3.48 (1.65)	
<i>Household Wealth Index</i>		
Always deficit	411	19
Sometime deficit	477	22
Balance	555	25
Sometime surplus	365	17
Always surplus	381	17

05/17/05
05/17/05

Table 2: Association between As contamination and pregnancy outcomes for the year 2002

Variable		Pregnancy outcome																	
participants		Spontaneous						Still birth						Postnatal					
		Abortion			Still birth			death			Premature birth			Low birth weight					
		No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†			
As concentration (ppb)		No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†	No. of Cases	OR†	95% CI†			
0-50		14	1	1	15	1	1	14	1	1	23	1	1	72	1	1			
>50		1548	73	1.0	43	51	1.03	109	75	1.0	69	72	0.83	106	127	1.07			
		1,578	37	0.56-1.98	149	1.04	0.56-1.89	335	1.001	0.4-1.3	138	1.45	0.50-1.36	283	1.26	0.8-1.45			
Total		2186	51		58			63			92			178					
Total		6008	223		200	2		444			210			410					
P value			0.779			0.65			0.14			0.74			0.46				
P value			0.067			0.14			0.15			0.006			0.002				

† OR, odds ratio; CI, confidence interval, adjusted for participant's education, age, antenatal care, parity, and household asset.

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