Water consumption patterns in rural Bangladesh: are we underestimating total arsenic load?

Abul Hasnat Milton, Habibur Rahman, Wayne Smith, Rupendra Shrestha and Keith Dear

ABSTRACT

Risk related to the ingestion of any water contaminants depends on many factors, including the daily per capita amount of consumed water relative to body weight. This study explored the water consumption pattern of a rural arsenic-affected population in Bangladesh. The study findings are likely to contribute to the risk estimation attributable to ingestion of arsenic and other drinking water contaminants. A total of 640 individuals participated in this cross-sectional study carried out in an arsenic-affected rural population in Bangladesh. In this study daily per capita water consumption for drinking purposes was found to be 73.04 ml/kg/d (range = 71.24–74.84 ml/kg/d), which is higher than for both the US and Taiwan populations. This difference in per capita drinking water consumption might contribute to much higher lifetime cancer mortality and other morbidity risks from arsenic among the Bangladesh population compared to either the US or Taiwan populations. Arsenic is also ingested through cooking water which, if considered, might increase the risk further. The findings of this study highlight the urgent need for a holistic water supply programme for Bangladesh, with special emphasis on the arsenic-affected population.

Key words | Arsenic, Bangladesh, water consumption, water supply

Abul Hasnat Milton (corresponding author)
Wayne Smith
Centre for Clinical Epidemiology and Population Health (CCEB),
The University of Newcastle, Level 3,
David Maddison Building,
Royal Newcastle Hospital, Newcastle,
NSW 2300, Australia
Tel.: +61 2 4923 6200
Fax: +61 2 492 36148
E-mail: *milton.hasnat@newcastle.edu.au*

Habibur Rahman
Arsenic Cell,
NGO Forum for Drinking Water Supply and Sanitation, 4/6, Block-E, Lalmatia, Dhaka-1207,
Bangladesh

Rupendra Shrestha
Keith Dear
National Centre for Epidemiology and Population Health (NCEPH),
The Australian National University, Canberra,
ACT 0200, Australia

INTRODUCTION

Information on the water consumption pattern of a population is essential in order to estimate the risk of adverse health effects attributable to any water contaminant. It is also crucial in developing a safe water supply programme for a population. Arsenic contamination of drinking water in Bangladesh has posed a threat to its safe drinking water supply programme (Smith *et al.* 2000). The success in providing safe drinking water to 97% of the rural population (UNICEF, 1998) through tube wells has been reduced substantially due to arsenic contamination of drinking water.

An estimated 6–11 million tube wells currently exist in Bangladesh. Of these tube wells, 27% and 46% of these tube wells are estimated to contain arsenic more than 50 μg/l ppb and 10 μg/l respectively (Kinniburgh & Smedley 2001). All these arsenic-contaminated tube wells cannot be declared abandoned in the present context of mass arsenic contamination of drinking water. Furthermore, tube well water could be used for all other purposes except drinking and cooking. Unless we achieve a suitable alternate safe water source for all-purpose use for a population, our priority should be to ensure safe water for at least drinking and cooking purposes.

This study explored the water consumption pattern of a rural arsenic-affected population. The study findings are likely to contribute to estimating the risk attributable to ingestion of arsenic and other drinking water contaminants. These findings may also be utilised in planning and developing a safe drinking water supply programme for Bangladesh.

METHODS

All the villages of the study area Lalpur and Bagatipara, two upazila (sub-districts) of Natore district (a north-western

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district of Bangladesh), were screened for arsenic in tube well water in 2001 by the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP). Villages of these two upazilas with 5 or more tube wells containing arsenic concentrations at 100 ppb or more were identified. After that, a pre-baseline survey was carried out among these 75 identified villages – 56 villages from Lalpur upazila and 19 villages from Bagatipara upazila – in order to construct a map of the villages manually indicating the location of the tube wells. Then a number of clusters of tube wells were identified on the map. Each cluster comprised three adjacent tube wells, on average. Nine households residing close to these clustered tube wells were then enlisted. Then 60 clusters of tube wells from 47 villages were randomly selected out of all the clusters from these 75 villages, preferably one cluster per village. In the case of two clusters in one village, they were selected from two opposite sides of the village.

A sampling frame containing the member list of the households with information on their demographics was prepared to select the eligible study participants. Nine households having at least one eligible participant were randomly selected from each cluster. In the case of any household having more than one eligible participant, one was randomly selected from them.

A total of 640 eligible participants were finally included in the study: 22 refused to participate in the study. Of the participants 218 were from dug wells, 216 from three-pitcher filters and 206 from control areas. So the participation rate for the study was 96.7%.

This cross-sectional study was carried out among the 640 adult (aged 15 years or above) participants in the study villages along with the baseline survey at the beginning of this study. A structured, pre-tested interviewer-administered questionnaire was used to collect information on the water consumption pattern through face-to-face interviews. Information on the water use pattern was obtained from the participants of the study. In some cases, information on water use for common purposes of the households was obtained from the participants with the help of a reliable adult member of the household.

Water uses for different purposes include drinking, cooking, bathing, domestic washing and other purposes. Domestic washing includes utensil cleaning, clothes washing and house cleaning. Other purposes include water used for toileting and cattle feeding.

To estimate the volume of water used for different purposes, interviewers carried a standard sized glass of size 250 ml and a pitcher of 20 l with them and asked the participants about the amount of water they use in terms of the glass for drinking purposes and the pitcher for cooking, bathing, washing and other domestic purposes. All analyses were performed using STATA software (STATA 2001).

RESULTS

A total of 640 individuals participated in this study. Water sources used for different purposes are present in Table 1. All the participants and 97.34% of the participants use shallow tube well water for drinking and cooking purposes, respectively. Of the total population, 89.22% use tube well water for domestic washing purposes and 79.40% are still dependent on groundwater for irrigation of agricultural land through either hand-operated or machine-operated tube wells.

Drinking-water-related detailed information is presented in Table 2. All the participants were drinking tube well water prior to the installation of the interventions. Of these, 11.41% of the participants use more than one tube well to collect drinking water. The mean depth of the tube well is 33.19 m, ranging from 11.27–60.96 m. The majority of the tube wells (89.22%) belong to private owners. All these privately owned tube wells are located on their own household premises. The lifetime mean duration of tube well water use is 21.78 yr.

The amounts of water used for different household purposes are presented in Table 3. Complete information on the amount of water used for different purposes was available for 628 participants. The daily mean amount of drinking water per capita is 3.53 l or 73.04 ml/kg/d. The daily mean amount of water per person used for cooking is 6.71 l or 139.14 ml/kg/d. For bathing, domestic washing, toileting and cattle feeding the daily amount of water required per person is 27.26 l, 12.18 l and 12.75 l, respectively. Per capita daily water consumption for all purposes is 62.47 l.

Table 4 presents the distribution of water intake for drinking purposes by different age groups as selected

Table 1 | Water sources for different purposes

Purpose of use	Water sources
Drinking ($n = 640$)	Shallow tube well = 640 (100%)
Cooking	Shallow tube well = 623 (97.34%)
	Others = 17 (2.66%)
Bathing	Shallow tube well = 377 (58.91%)
	Pond = 56 (8.75%)
	River = 37 (5.78%)
	Others = 15 (2.34%)
Domestic washing	Shallow tube well = 571 (89.22%)
	Pond = 56 (8.75%)
	Others = 13 (2.03%)
Irrigation purposes	Shallow tube well = 18 (5.37%)
	Machine operated shallow tube well = 220 (65.67%)
	Machine operated deep tube well = 28 (8.36%)
	Others = 69 (20.60%)

Table 2 | Drinking water use pattern

Variable	Frequency (%)
Current source of drinking water $N = 640$	640 (100%)
Households use more than one tube well $N = 640$	73 (11.41%)
Depth of the tube well (m) $N = 578$	Mean = 33.19 SD = 8.43 Range = 11.27–60.96
Type of ownership of the tube well $N = 640$	Private = 571 (89.22%) Government = 61 (9.53) Others = 81.25%)
Location of the tube wells $N = 640$	At own premises = 571 (89.22%)
	At neighbour's premises = 61 (9.53%)
	At other places = 8 (1.25%)
Lifetime mean duration of using tube well water for drinking purposes (yr)	Mean = 21.78 SD = 9.74
Lifetime mean arsenic exposure through drinking water	Mean = 7.66 SD = 8.32

percentiles for both sexes. No significant differences ($F = 1.80$, $p = 0.14$) were observed between the different age groups.

Table 5 compares the amount of per capita water consumption/kg body weight between males and females. No significant difference ($t = 1.03$; $p = 0.14$) is observed between males and females with respect to the daily amount of drinking water per kg body weight.

Cumulative distributions of daily per capita water consumption for drinking purposes in ml/kg/d for the different age groups of 15–24, 25–34, 35–44 and ≥45 yr for both sexes are presented in Figure 1.

DISCUSSION

In this study, all the study participants used shallow tube wells for drinking purposes. This finding is similar to the observation of 97% rural population having access to safe drinking water through tube wells (UNICEF 1998). For bathing and domestic washing, a large proportion of the study population still use water from unsafe sources such as ponds or rivers. Approximately 80% of the study population use underground water for the purpose of irrigation. This high proportion of participants using groundwater for irrigation purposes could be replaced in many places by abandoned surface water, thereby reducing pressure on groundwater resources in the future.

The mean depth of the tube wells is 33.19 m in the study area, with a range varying from 11.27–60.96 m, which is similar to the depth range of the majority of the tube wells in Bangladesh. According to a BGS survey, the depth of tube wells ranges from 10–50 m (Kinniburgh & Smedley 2001). Almost all the tube wells (89.22%) belong to private owners.

Table 3 | Amount of water used for different household purposes

Purpose	Per person daily consumption Mean (sd)	95% CI
Drinking (l/d)	3.53 (0.98)	3.45–3.61
Drinking (ml/kg/d)	73.04 (22.96)	71.24–74.84
Cooking (l/d)	6.71 (2.41)	6.52–6.89
Cooking (ml/kg/d)	139.14 (56.39)	134.72–143.55
Bathing (l/d)	27.26 (13.28)	26.22–28.30
Domestic washing (l/d)	12.18 (10.19)	11.81–13.69
Toileting and cattle feeding (l/d)	12.75 (12.09)	11.81–13.69
For all purposes (l/d)	62.47 (27.25)	60.33–64.61

This finding is consistent with the previous report of UNICEF which mentioned that, during the 1980s, UNICEF's support for installing tube wells decreased because the private sector was able to supply and install large numbers (UNICEF 1999).

The previous risk due to arsenic ingestion was estimated based on a water consumption estiamte of 2 l/d (Ershow *et al.*, 1991) and assuming a 70 kg person in the United States. In its earlier risk assessment, USEPA (1988) did not consider variability in water consumption per unit of body weight in the study populations when interpreting the epidemiological data on arsenic carcinogenicity in Taiwan or the dose–response relationship, although the per capita water consumption varies from population to population, imposing a varying degree of risk on different populations and sub-populations. In this study, per capita daily drinking water consumption for all ages and sexes is 3.53 l, which is similar to the male Taiwanese population result of 3.5 l/d (USEPA 1988) but higher than the previous EPA estimate of 2 l/d (Ershow *et al.* 1991). The daily intake of water per kilogram of body weight per person for this study population is 73.04 ml/kg/d (range = 71.24–74.84 ml/kg/d). This is close to, but still higher than, that for the Taiwanese population, which is approximately 40–60 ml/kg/d, much higher than the 21–28 ml/kg/d that US populations are estimated to consume (USEPA 2000).

Table 4 | Distribution of the water intake for drinking data as selected percentiles by age for both sexes (ml/kg/day)

Age group (yr)	Mean	Percentile 1%	5%	10%	25%	50%	75%	90%	95%	99%
15–24	73	35	45	51	60	69	82	99	112	151
25–34	72	31	41	48	57	69	82	98	111	133
35–44	72	34	45	48	57	67	86	96	109	133
≥45	78	23	35	46	56	75	93	123	133	185

$F = 1.80$; $p = 0.14$.

Table 5 | Amount (ml/kg/d) of drinking water by sex

Sex	Mean (sd)
Male	73.97
Female	72.07

$T = 1.03$. $P = 0.31$.

Males drink slightly more water per kilogram of body weight compared to females, but this is not statistically significant in our study. The assumption that males drink more water was used in the case of the Taiwanese population (USEPA 1988). Our study findings do not support this assumption. This may be partly due to inadequate access to drinking water for males, who are mostly engaged in farming in the fields. The current estimates on per daily capita water consumption are higher than the findings of a previously reported study in Bangladesh (Ahmed & Smith 1987). According to that study, daily per capita water consumption for drinking, cooking, clothes washing, utensil washing, bathing, and sanitary and other purposes were reported to be 2 l, 4 l, 8 l, 5 l, 12 l and 8 l, respectively. These differences may partly be due to differences in the calculation of the amount of per capita water consumption as the total household water

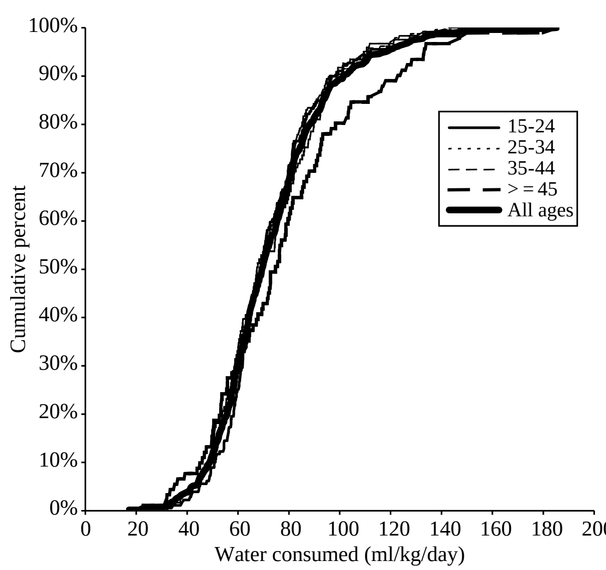

Figure 1 | Cumulative distributions of daily per capita drinking water consumption data by age.

amount was divided by the total number of household members. In the present study, information on per capita daily drinking and bathing water amounts was directly obtained from the study participants, while information on cooking, domestic washing and other purposes were collected on a household basis and later on were divided by the total number of household members. The previous study also did not include the water used for cattle feeding. Per capita daily water consumption may also have increased due to increased access to safe water through the tube wells.

No significant association ($r = 0.06$; $p = 0.19$) between socio-economic conditions (on the basis of monthly household income of the participants) and per capita water consumption for drinking purposes was observed. Although household monthly income is not adequate to measure the socio-economic conditions, this needs to be further studied in detail.

This study was carried out among the adult population only, although water consumption patterns are likely to vary among different sub-populations including infants, young children, pregnant, lactating or child-bearing women. It was also difficult to estimate precisely the amount of water for various purposes from different participants, despite an attempt by showing them a standard size of container. The study findings may not be representative for the water consumption pattern of the coastal and hilly areas where safe potable water is scarce. Nevertheless our study findings may be generalised for the majority of the arsenic-affected rural areas of Bangladesh. However, a larger study is recommended to consider different sub-populations and geohydrological areas.

CONCLUSIONS

Accurate estimates of water intake are mandatory before we can assess the likely health risks from community contaminated water. In a recent paper on cancer risk estimation in Bangladesh on the basis of Taiwan data showed that the lifetime risk of deaths from internal cancers among the population of Bangladesh would be more than doubled due to arsenic ingestion (Chen & Ahsan 2004). This estimated risk may be even higher in reality as the daily per capita water consumption for drinking purposes is higher and the prevalence of malnutrition is higher in the rural Bangladesh population compared to the Taiwanese population. In addition to arsenic contamination, higher concentrations of manganese, lead, nickel and chromium in drinking water, above the WHO guidelines, have also been reported from different parts of Bangladesh (Frisnie *et al.* 2002). This highlights the urgent need for a holistic water supply programme for Bangladesh, with special emphasis on the arsenic-affected population.

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