Arsenic Contamination in Groundwater and Foods and Its Psychosocial Effects on Rural Bangladeshi Children

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URL http://hdl.handle.net/10232/21278
Arsenic (As) is a metalloid, naturally and anthropogenically occurs in the environment (Smedley and Kinniburgh, 2002), and widely distributed in air, water, soils, plants and animals in variable concentrations. Bangladesh is grappling with the largest mass poisoning of a population in the human history because groundwater used for drinking has been contaminated with naturally occurring inorganic arsenic (Smith et al., 2000). It is estimated that of the 160 million inhabitants of Bangladesh around 80 million in 61 of 64 districts are at risk of drinking arsenic contaminated groundwater, and about 35 million people are taking arsenic contaminated groundwater exceeding the national safety level (50 µgL⁻¹) of Bangladesh. Alone with some well described physical effects arsenic has psychological such as anxiety, fear to death, reduction of cognitive function, etc. and social effects. The affected people have right to be free from arsenic poisoning and get back physical and mental health and honor, and trust to be accepted as members of the community. Thus, especial attention is needed to pay to the school going children, because they are growing and developing physically, mentally and socially, although mental development (intelligence quotient) is very hard to evaluate. Very few studies had been conducted on arsenic exposure and children’s intellectual function in Bangladesh. In the year of 2004 and 2007, Wasserman et al. studied on 6 years and 10 years old children. They found strong association between water arsenic and children’s nonverbal intelligence quotient (IQ). However, Calderon et al., 2001 found an association between verbal IQ and urinary arsenic of the Mexican children. On the contrary, there are very few studies on social implications and arsenic exposure (Hassan et al., 2005, Alam et al., 2002), and to date, there is scarcity of research on arsenic exposure and social competence (SC) of children. Moreover, there are some studies reported the arsenic contamination in food chain (Ohno et al., 2007, Das et al. 2004, Huq et al., 2006). In addition, the measurement of water used in cooking is indeed essential to evaluate the relative contribution of different arsenic sources on daily arsenic intake. The

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present study aimed to investigate the relationship between arsenic exposure on intelligence quotient (IQ) and social competence (SC) of children from early childhood to adolescence. Moreover, to assess the amount of food and water used in cooking in order to estimate the total daily arsenic intake.

In the present study, 720 children were randomly selected as subjects from Sonargaon thana located approximately 40 km southeast of Dhaka. The study subjects were divided into three age groups i.e. 4-5 years (early childhood), 9-10 years (late childhood) and 14-15 years (adolescence). They come from different villages. Most of inhabitants in Sonargaon thana depend mostly on subsistence farming for the daily food needs as opposed to market purchases. And most of the people drinking tube well water for accessing ground water in daily life fulfillment. The ground water polluted with severe arsenic poisoning. All children were persuaded to provide current drinking water and spot urine samples for the measurement of arsenic concentration in water [As]_w and urine [As]_u. Collected samples from each respondent were kept in a freezer and transported to Japan where they were kept at -30°C until element determination. Arsenic concentration was determined by inductively coupled plasma mass spectrometry (Agilent 7500ce ICP-MS, Agilent Technologies, Santa Clara, CA, USA) with an octopole collision/reaction cell. IQ was assessed by Raven’s standard progressive matrices (SPM) for 9 & 10 year and 14 & 15 year groups and Kaufman Brief Intelligence test (KBIT) 4 & 5 year group, and for measuring social competence, the Bengali version of Texas Social Behavior Inventory (TSBI) Form-A was employed (over 9 & 10 year groups). In order to evaluate the contribution of sources other than drinking water to arsenic exposure, the amount of water used during cooking of the most frequently consumed food according to the FFQ was measured. The amount of water used for cooking was measured with a food preparation survey on site. The amount of water used for food preparation was measured by visiting each household. In addition, rice samples were collected from different part of Bangladesh to determine the arsenic concentrations in rice as a source to total arsenic intake.

In general, the results indicated that most of the respondents came from families with poor socioeconomic status (low and low-medium income strata). Investigating the influence of socioeconomic status as confounding factor on arsenic contamination the one way ANOVA test was performed, and the result stated that [As]_u significantly differed by parental income (p<0.01 for 14 & 15 years, p<0.05 for 9 & 10 years and p<0.05 for 4 & 5 years age groups children). It suggests that socio-demographic conditions have an influence on arsenic exposure, and the respondents with poor socioeconomic status
are consuming highly arsenic contaminated tubewell water and individuals with higher income can take preventive measures. However, the influence of other socioeconomic indicators like education, sanitation and house type, etc. were insignificant on arsenic contamination ([As]_w). Arsenic exposure was negatively correlated with IQ in all three age groups (p<0.01 for 14 & 15 years, p<0.001 for 9 & 10 years and p<0.05 for 4 & 5 years age groups children). Regarding IQ, the effect of exposure was seen from 4 years old. Effect of arsenic was significant on IQ even after controlling for socioeconomic indicators such as parental occupation, income and education. SC significantly differed in the [As]_w groups (p<0.001 for 14 & 15 years, and p<0.05 for 9 & 10 years age groups children ). Moreover, a significant effect of [As]_w on the SC score was identified after controlling for the socioeconomic indicators. To identify other sources of arsenic, food consumption was assessed by weekly food frequency questionnaire (FFQ) and the 24-hour recall method. The FFQ survey results revealed that rice was consumed the most frequently (more than once daily), followed by daal (bean) soup and finally non-leafy vegetables (almost once a day), but fish, meat and eggs were consumed approximately once a week. Water intake per meal from cooked rice was estimated to be 629 ml/person, followed by daal soup (278 ml/person), and cooked vegetables (88 ml/person). Our results suggest that the water used for cooking is an important source of arsenic. Arsenic concentration in rice was high in highly contaminated areas. Arsenic intake from rice/day was almost equivalent to that from 2 liter drinking water/day. Food, especially rice, was another major source of arsenic intake. Arsenic concentrations in rice were high in highly contaminated areas.

「結論及び考察」
This study reports that the people in the present survey area are using water form highly arsenic contaminated tubewells. Socioeconomic status (SES), especially household income, was determined to have a dominant role on arsenic contamination. Water and urinary arsenic concentrations ([As]_w and [As]_u) were correlated with each other. Arsenic had an effect on IQ of children in all age groups and on SC of children in late childhood and adolescence. High concentration of [As]_w or [As]_u was associated with lowering the IQ percentile and score of SC. Because arsenic is neurotoxic (V.M Rodriguez et al. 2003). And arsenic can affect brain function of children through maternal exposure also. From the result we found that children from early childhood age, verbal and composite IQ were unaffected. The possible explanation for the differences observed across the age groups implies that there might have lower stability of estimates of children's intelligence at younger age (e.g., Bartels et al. 2002; Petrill et al.}

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2004). Moreover, the possible cause of not finding any association between arsenic exposure and aspects of verbal intelligence for early childhood age groups, in this study, might be the lack in development of higher cognitive function especially language and hearing. In one of the study, C.A Nelson, 2000 reported that the human brain development especially the higher cognitive function starts from birth to around 15 years old of children, and the language and sensory pathways (vision, hearing) are developed until 6 years old. Apparently, the younger children (4 & 5 years old) in the present survey felt shame to answer because it was an individual test. On the contrary, group tests were applied to measure the IQ of children who are from the age of late childhood and adolescence; they felt free to answer. However, we could not use the same SPM test among all the children from different representative groups because there is an age limitation of using SPM. In the present study, however, a stronger association was found for IQ with urinary arsenic than with the arsenic in tubewell water, and the existence of stronger association is more reasonable because urinary arsenic concentration reflects the total ingestion of arsenic from all possible sources.

Psychosocial state (worry, loneliness, negative evaluation by others) and brain function (IQ) may influence how one acts and thinks and this could in turn affect one’s SC. Moreover, arsenic may influence the executive functioning of brain and which can influence an individual’s ability to interact socially. SC is a multifaceted developmental process that begins in childhood (Hussong et al., 2005). Cognitive development plays a huge role in socialization. The way in which a child achieves social competence not only depends on how others identify him/her, but how that particular child identifies with his/herself. Cognitive developmental theory states that in order for social interactions to take place, a self-concept must first develop (Shaffer, 2005). One of the main developmental tasks during childhood is to achieve competence within social relationships. Many theories suggest that early influences in life are highly correlated with how well a child will later develop socially. External environment (such as neighborhood), childhood loneliness (social rejection due to arsenic exposure), school environment these factors of arsenic affected children can be influenced the SC.

Besides, the result also shown that the children who came from the family of having higher SES they possess higher scores in IQ percentile and as well as in social competence. In addition, hypothetically it seems that the children who are intellectually good, they are socially highly competent. So the children who are intellectually good they can solve the problem well and cooperate actively and self-esteem is high. By the way their social competence is high. Therefore, SC is important because it is associated
with many positive outcomes such as prosocial behavior and overall happiness as an adult/ person/an individual.

Rice is the staple food in Bangladesh and a large amount of water was used in cooking. Daily arsenic intake from raw rice was almost equivalent to that from 2 liters drinking water per day. In addition, although it is apparent that drinking water is the major source of arsenic for the population living in arsenic affected areas in Bangladesh, our results suggest that the cooking water and food especially rice are another sources of arsenic intake. Many reports have relied on the concentrations of arsenic in drinking water (Mazumder et al., 2008) as the surrogate of human exposure; however, the additional exposure through raw and cooked food should not be neglected. The biological dose indicators would neither give any information on the absolute intake level nor on the relative relevance of different arsenic sources, especially the importance of water versus food arsenic, which would be important in establishing risk assessment and in determining the priority for mitigation. In the present study, the relative contribution of arsenic sources to total arsenic intake was evaluated systematically by assessing the arsenic concentrations in drinking water and rice, and the proportion of water added in cooking.

Our findings can play an important role in facilitating the appropriate steps in the mitigation of arsenic poisoning from all possible sources, such as drinking and cooking water, which will thus reduce the total arsenic intake and, accordingly, improve rural livelihood in Bangladesh. The most important action in affected communities is the prevention of further exposure to arsenic by the provision of safe water supplies for drinking, food preparation and irrigation of food crops. Moreover, we hope that our findings will add a new sense of urgency to mitigate arsenic exposure in Bangladesh and other parts of the world where consumption of arsenic contaminated groundwater is prevalent. Finally, it is necessary to conduct more research in the early age group children (age < 4 & 5 year) in order to fully define the stage at which children are most vulnerable to arsenic exposure. Moreover, future research should focus on all possible sources of arsenic intake.

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