Bull Environ Contam Toxicol (2007) 79:293–296
DOI 10.1007/s00128-007-9206-7

Effect of Arsenic on the Onset of Menarcheal Age

Jaydip Sen · A. B. D. Chaudhuri

Received: 30 November 2006 / Accepted: 5 April 2007 / Published online: 1 August 2007

Abstract Ground water arsenic contamination is a major problem in the Bengal Delta plain. The present study investigates the effect of arsenic exposure on age at menarche in North 24-Parganas district, one of the worst affected districts. A higher mean menarcheal age of 12.50 years is reported from women residing in four arsenic affected villages in as compared to a control village (11.71 years). The differences in menarcheal age between three of the four affected villages and the control village are statistically significant ($p < 0.05$). The study indicates that arsenic exposure can have a negative effect on menarcheal age.

Keywords Menarcheal age · Arsenic contamination

Age at menarche is an important event of human growth that has interested the scientific community for decades. There has been considerable amount of published literature from different countries, including India, in this issue. Age at menarche is controlled by a number of factors such as genetics, birth-weight and rural-urban settings. It is now recognized that the widespread occurrence of high inorganic arsenic (As) in natural waters is a major global public health issue. The problem is acute in the Holocene alluvium and deltaic aquifers of the Bengal Delta Plain (Bangladesh and West Bengal, India). The magnitude of the problem can be understood in terms of the sheer population exposed (36 million) and geographical area covered (173×10^3 km^2). The As levels in the contaminated groundwater in this area is 50–3,200 μg L^{-1} as compared to the Indian National drinking water standard of 50 μg L^{-1} and WHO recommended provisional limit of 10 μg L^{-1}. This large-scale 'natural' high As content in groundwater poses a great threat to human health via drinking water (Bhattacharyya et al. 2003). Das et al. (1994) reported that six districts of West Bengal were the worst affected by this contamination. By the year 2003, the number of districts went up to nine (Rahman et al. 2003). Since then a number of papers have been regularly published which dealt with this groundwater contamination by As. Millions of cubic meters of groundwater contaminated with high levels of As are coming out from both the hand operated tube-wells, used by the villagers for their daily needs and shallow big diameter tube-wells, installed for agricultural irrigation and depositing on soil throughout the year. Hence there is also a possibility of soil contamination, which can in turn affect the food chain. It needs to be mentioned here that the element As commonly exists in groundwater in two species viz. arsenite [As(III)] which is the reduced state of inorganic As and arsenate [As(V)], which is the oxidized state of inorganic As. The As(III) form is more mobile, toxic and carcinogenic for living organisms.

Individuals exposed to As suffer from hyper-pigmentation and keratosis, weakness, anemia, burning sensation of eyes, swelling of legs, liver fibrosis, chronic respiratory disease, gangrene of toes, neuropathy, and skin cancer. In many cases, the individuals have been crippled, unable to work. In the recent past, there has been

J. Sen (✉)
Department of Anthropology, University of North Bengal,
P.O.: NBU, Raja Rammohunpur, 734 013 Dist. Darjeeling,
West Bengal, India
e-mail: jaydipsen@rediffmail.com

A. B. D. Chaudhuri
Department of Anthropology, University of Calcutta,
35 B.C. Road, 700 019 Kolkata, West Bengal, India
e-mail: adcanthro@caluniv.ac.in

an alarming rise in the number of such affected individuals. Many of them are now suffering from or have already died of cancer. Symptoms of chronic As toxicity develop between 6 months to 2 years or more of exposure. The time of onset depends on the concentration of As in drinking water, volume of intake, health and nutritional status of the individuals. The issue of good health and nutrition is very important. It has been reported that in West Bengal, populations suffering from malnutrition have increased susceptibility to As (Guha Mazumder et al. 1998).

It has now been well recognized that exposure to different toxic elements affects both prenatal and postnatal growth (e.g. Schell et al. 2006). Naturally the question arises whether the onset of menarcheal age is affected by As exposure. A thorough search of the existing literature yielded a paucity of studies on this issue, although very recently it has been suggested that exposure to organochlorine pollutants in utero and through mother's milk affects the onset of menarcheal age. It has also been observed that lead can have an effect on the age at menarche and is biologically plausible. Moreover, higher spontaneous abortions, stillbirths and birth defects have been reported among women exposed to arsenic through drinking water in the Bengal Delta Plain. Evidently, As contamination of ground water is indeed a major environmental and health problem. The problem is acute in nine districts of West Bengal, India. A detailed study spanning seven years was made in North 24-Parganas district, whose area and population were 4,093.82 km^2 and 7.3 million, respectively by Rahman et al. (2003). They reported that out of the 22 blocks of North 24-Parganas district, As has been found above the maximum permissible limit in ground water in 20 blocks and estimated that about 2.0 million and 1.0 million people were drinking As contaminated water above 10 $\mu g\ L^{-1}$ and 50 $\mu g\ L^{-1}$ level, respectively in this district alone.

Numerous studies have dealt with ground water levels of As and the health effects of As in different districts of West Bengal. Studies should now be initiated to understand whether consumption of As contaminated water has any negative effect of the onset of the age at menarche among the Bengalee populations residing in these affected areas. The Bengalee population comprises both the Bengalee Hindu Caste Population (BCHP) and the Bengalee Muslim Populations (BMP). Both these two populations are genetically identical (Das Chaudhuri et al. 1993). Keeping these issues in mind, the present study attempts to determine the age at menarche among the residents of five villages in North 24-Parganas district of West Bengal who are exposed to arsenic contamination through ground water.

Materials and Methods

Menarchael age was collected in 2004–2005 by the recall method from Bengalee female individuals (n = 280) residing in four As affected villages (Kamdebkati, Shimulpur, Raghabpur and Chandalhati) in North 24-Parganas district of West Bengal, India. The villages are subsequently referred to as A1, A2, A3 and A4. The data were compared with a control population (n = 70) residing in the village (Khajra) later referred to as C1. All these villages were covered under a community-based project to mitigate ground water As pollution in West Bengal. This project is being executed by a non-governmental organization ("Save The Environment") in collaboration with "All Indian Institute of Hygiene and Public Health" and "Indo-Canadian Environment Facility". Kamdebkati had a total of 268 tubewells out of which 239 were affected by As. The levels of As were 0.01–0.60 ppm. Simulpur had 251 tubewells out of 262 affected by As (0.01–0.54 ppm). Raghabpur had 59 tubewells affected out of 95 (0.01–0.08 ppm), while Chandalhati had 119 tubewells affected out of 136 (0.01–0.60 ppm). In Khajra, 107 tubewells were affected out of 116 (0.01–0.30 ppm). "Save The Environment" runs a special clinic for the As affected individuals of these villages in the area. Khajra was chosen as the 'control' primarily because no clinical cases of As exposure have been reported there. Moreover, a survey by "Save The Environment" has shown that individuals residing in Khajra have better food and nutrition. It is recognized that individuals having better nutrition do not develop As-related symptoms. The results were statistically analyzed using Systat.

Results and Discussion

Menarcheal data was collected from those female individuals who were born to families of these villages and as such experienced menarche while residing in these villages belonging to the Bengalee Population residing in a rural area where the predominant occupation was agriculture. This type of sampling was done to minimize the effects of certain parameters such as genetics and rural and urban settings. Means, standard deviations and ranges of the menarcheal age of the female individuals included in the present study are presented in Table 1. The average mean is 12.50 years. The means from the four affected villages are 12.72 years (A1), 12.80 years (A2), 11.96 years (A3) and 12.50 years (A4). The means are higher than the mean obtained from females residing in the control village (C1), which is 11.76 years.

The mean menarcheal age obtained in the present study are in broad agreement with those reported for Indian and

Table 1 Mean, standard deviation and range of menarchael age in the present study

Name of village	n	Mean (in years)	Standard deviation	Range (in years)
A1	70	12.77	0.83	10.00–15.00
A2	70	12.82	0.61	11.00–14.00
A3	70	11.96	0.71	11.00–14.00
A4	70	12.44	0.81	10.00–14.00
C1	70	11.71	0.85	10.00–13.00

Bengalee populations (BCHP and BMP). Sengupta et al. (1996) obtained the mean age at menarche was 12.23 years among Brahmin girls, 11.96 years among Kalita, 11.92 years among Kaibarta, 11.83 years for Ahoms and 11.94 years for Sonowal girls from Assam. Shukla et al. (1994) obtained a mean age of 13.56 years from Uttar Pradesh. Gupta and Jaiswal (1992) reported a mean age of 13.25 years from Jammu. The mean age at menarche as determined by retrospective recall was 13.00 years among Bangladeshi girls (Chowdhury et al. 2000). Sengupta et al. (1996) further reported a mean age at menarche of 12.10 years from Muslim girls from Assam. Haq (1984) obtained a mean age at menarche of 12.67 years among Muslim girls from neighboring Bangladesh. Among Bengalee Hindu girls, Chatterjee (1994) reported a mean menarcheal age of 13.37 years while Chatterjee and Mandal (1991) obtained a mean menarcheal age of 13.00 years. Other studies on the same population include that of Sen (1975) (mean = 12.48 years) and Sarkar and Roy Chowdhury (1968) (mean = 12.90 years).

As evident from Table 1, the individuals residing in the four arsenic affected villages (A1–A4) have a higher mean age at menarche than those residing in the control village (C1). To assess the statistical differences between the two groups, paired *t* test has been employed. The results of the *t* test show that there are statistical significant differences ($p < 0.05$; *df* 69) when the two groups (exposed and control) are compared. The *t* values are statistically significant ($p < 0.05$) for all the cases except for A3 versus C1. The t values are 11.95 for A1 versus C1, 10.63 for A2 versus C1, 1.93 for A3 versus C1 and 7.03 for A4 versus C1.

Studies on the effect of toxic elements and pollutants on the onset of menarcheal age are few in number. The studies of Axmon (2006) and Denham et al. (2005) indicated that exposure to organochlorine pollutants and toxic elements have negative effects on age at menarche. Aschengrau et al. (1989) reported higher spontaneous abortions among women exposed to As through drinking water. Recently, this has been corroborated by Ahmad et al. (2001), Milton et al. (2005) and Von Ehrenstein et al. (2006) who pointed out that spontaneous abortion and stillbirth were significantly higher in the As exposed group in Bangladesh. Kwok et al. (2006) reported a significant association between As exposure and birth defects in Bangladesh. Hence, it can be inferred that there is an increase in age at menarche due to exposure to pollutants and toxic elements and that As has an adverse effect on reproduction. However, the effect of As on menarcheal is yet to be effectively reported. The results of this study show that exposure to As through ground water can have an adverse effect on the age at menarche.

Acknowledgments The authors acknowledge the cooperation of "Save The Environment, Calcutta". The University Grants Commission, Govt. of India has supported the study financially (Grant No: F.PSW-022/03-04 dated 12.03.2004).

References

Ahmad SA, Sayed MH, Barua S, Khan MH, Faruquee MH, Jalil A, Hadi SA, Talukder HK (2001) Arsenic in drinking water and pregnancy outcomes. Environ Health Perspect 109:629–631

Aschengrau A, Zieler S, Cohen A (1989) Quality of community drinking water and the occurrence of spontaneous abortion. Arch Environ Health 44:283–290

Axmon A (2006) Menarche in women with high exposure to persistent organochlorine pollutants in utero and during childhood. Environ Res 102:77–82

Bhattacharyya R, Chatterjee D, Nath B, Jana J, Jacks G, Vahter M (2003) High arsenic groundwater: mobilization, metabolism and mitigation – an overview in the Bengal Delta Plain. Mol Cell Biochem 253:347–355

Chatterjee S (1994) Menarche, menopause and fertility in the Paschatya Vaidik women of West Bengal. Man India 74:271–278

Chatterjee S, Mandal A (1991) Physical growth pattern for girls (9–17 yr) from rural West Bengal. Indian J Med Res 94:346–350

Chowdhury S, Shahabuddin AK, Seal AJ, Talukder KK, Hassan Q, Begum RA, Rahman Q, Tomkins A, Costello A, Talukder MQ (2000) Nutritional status and age at menarche in a rural area of Bangladesh. Ann Hum Biol 27:249–256

Das D, Chatterjee A, Samanta G, Mandal B, Chowdhury TR, Samanta G, Chowdhury PP, Chanda C, Basu G, Lodh D, et al. (1994) Arsenic contamination in groundwater in six districts of West Bengal, India: the biggest arsenic calamity in the world. Analyst 119:168N–170N

Das Chaudhuri AB, Basu S, Chakraborty S (1993) Twinning rate in the Muslim population of West Bengal. Acta Genet Med Gemellol 42:35–39

Denham M, Schell LM, Deane G, Gallo MV, Ravenscroft J, DeCaprio Akwesasne AP (2005) Relationship of lead, mercury, mirex, dichlorodiphenyldichloroethylene, hexachlorobenzene, and polychlorinated biphenyls to timing of menarche among Akwesasne Mohawk girls. Pediatrics 115e:127–134

Guha Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, Smith AH (1998) Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. Int J Epidemiol 27:871–877

Gupta A, Jaiswal TS (1992) Age at menarche among three caste groups of Jammu city. Man India 72:463–467

Haq MN (1984) Age at menarche and the related issue: a pilot study on urban schoolgirls. J Youth Adolesc 13:559–567

Kwok RK, Kaufmann RB, Jakariya M (2006) Arsenic in drinking-water and reproductive health outcomes: a study of participants in the Bangladesh Integrated Nutrition Programme. J Health Popul Nutr 24:190–205

Milton AH, Smith W, Rahman B, Hasan Z, Kulsum U, Dear K, Rakibuddin M, Ali A (2005) Chronic arsenic exposure and adverse pregnancy outcomes in Bangladesh. Epidemiology 16:82–86

Rahman MM, Mandal BK, Chowdhury TR, Sengupta MK, Chowdhury UK, Lodh D, Chanda CR, Basu GK, Mukherjee SC, Saha KC, Chakraborti D (2003) Arsenic groundwater contamination and sufferings of people in North 24-Parganas, one of the nine arsenic affected districts of West Bengal, India. J Environ Sci Health A Tox Hazard Subst Environ Eng 38:25–59

Sarkar SS, Roy Chowdhury J (1968) The secular trend of menarchael age in the city girls of Calcutta. Man India 48:346–356

Schell LM, Gallo MV, Denham M, Ravenscroft J (2006) Effects of pollution on human growth and development: an introduction. J Physiol Anthropol 25:103–112

Sen T (1975) A study on the age at menarche of the urban Bengalee girls. A search of its secular trend. J Ind Anthrop Soc 10:173–179

Sengupta S, Gogoi G, Chetry HB (1996) Variation in menarcheal age of Assamese girls. J Indian Med Assoc 94:88–90

Shukla NB, Sharma SS, Bhusan S (1994) Age of menarche of urban and rural sport school girls. Man India 74:307–310

Von Ehrenstein OS, Guha Mazumder DN, Hira-Smith M, Ghosh N, Yuan Y, Winham G, Ghosh A, Haque R, Lahiri S, Kalman D, Das S, Smith AH (2006) Pregnancy outcomes, infant mortality and arsenic in drinking water in West Bengal, India. Am J Epidemiol 163:662–669