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Effect of Drinking Arsenic-Contaminated Water in Children

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Summary

Chronic arsenic toxicity due to drinking of arsenic-contaminated water has been a major environmental health hazard throughout the world including India. Although a lot of information is available on health effects due to chronic arsenic toxicity in adults, knowledge of such effect on children is scanty. A review of the available literature has been made to highlight the problem in children. Scientific publications on health effects of chronic arsenic toxicity in children with special reference to psychological issues are reviewed. The prevalence of skin abnormalities such as pigmentation change and keratosis, the diagnostic signs of chronic arsenic toxicity, vary in various arsenic-exposed children population in different regions of the world. The occurrence of chronic lung disease including pulmonary interstitial fibrosis has been described in arsenic-exposed children in Chile. Affection of intellectual function has also been reported to occur in arsenic-exposed children studied in Thailand, Bangladesh, and India. Methylation patterns of arsenic in children aggregate in families and are correlated in siblings, providing evidence of a genetic basis for the variation in arsenic methylation. Chronic arsenic toxicity due to drinking of arsenic-contaminated water causes significant morbidity in children resulting in skin lesions, lung disease, and defect in intellectual function.

Key words: Arsenicosis in children, Arsenic skin pigmentation, Intellectual defect, Keratosis

Introduction

Many aquifers in various parts of the world have been found to be contaminated with arsenic. Of these, the most noteworthy occurrences are in large areas of India, Bangladesh, Taiwan, and Northern China. Asian countries affected are Lao PDR, Cambodia, Myanmar, Pakistan, Nepal, and Vietnam. Other countries having reports of significant arsenic contamination of ground water are Hungary, Mexico, USA, Chile, and Argentina. In India over and above West Bengal, other states affected

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are Bihar, Uttar Pradesh, Jharkhand, and Assam.[1] There are sufficient evidence from human studies that chronic ingestion of inorganic arsenic causes cutaneous and systemic manifestations along with skin, bladder, and lung cancer in adults.[2]

Skin abnormalities such as pigmentation changes and keratosis have long been known to be hallmark signs of chronic arsenic exposure in adults. These lesions are the most common health effects found in populations exposed to arsenic-contaminated drinking water. Pigmentation and keratosis caused by arsenic are quite distinctive. The hyperpigmentation is marked by raindrop-shaped discolored spots, diffuse dark brown spots, or diffuse darkening of the skin on the limbs and trunk. Spotty depigmentation (leucomelanosis) also occurs in arsenicosis. Simple keratosis usually appears as bilateral thickening of the palms and soles, while in nodular keratosis, multiple raised keratotic lesions appear in palm and soles. Skin lesions pose an important public health problem because advanced forms of keratosis are painful, and the consequent disfigurement can lead to social isolation in the villages. In contrast to cancer which takes decades to develop, these skin

lesions are generally observed 5–10 years after exposure commences. Although limited epidemiological data exist, other reported clinical manifestations resulting from ingestion of arsenic-contaminated drinking water in adults include weakness, conjunctival congestion, hepatomegaly, portal hypertension, lung disease, poly neuropathy, solid edema of limbs, ischemic heart disease, peripheral vascular disease, hypertension, and anemia.[2,3]

Initial report of the nonmalignant pulmonary effect of chronic ingestion of arsenic by drinking arsenic-contaminated water was available from studies in children in Chile as early as in seventies. Rosenberg conducted autopsies on five children manifesting characteristic features of chronic arsenic toxicity, including pigmentation and/or keratosis. Lung tissue was examined in four of the five children, with abnormalities found in each and two having pulmonary interstitial fibrosis with mild bronchiectasis.[4] Arsenical skin lesions were reported in 144 school children in Antofagasta, Chile, during a cross-sectional survey in 1976. The investigators further reported that chronic cough was complained of by 38.8% of children with skin lesion compared with 3.1% of children with normal skin.[5]

The prevalence of skin manifestations in children due to drinking of arsenic-contaminated water was reported from epidemiological studies carried out in 1995–96 in South 24 Parganas, West Bengal, India. Pigmentation and keratosis were observed among boys and girls (age <9 years), who were exposed to arsenic above 50 mg/l although less compared with adults. Nine (1.7%) of 536 girls and 12 (1.9%) of 613 boys below the age of 9 years had pigmentation due to exposure of high level of arsenic in water. The number of subjects with keratosis was 1 (0.2%) and 3 (0.48%) in girls and boys, respectively.[6] In another study in West Bengal, India, 114 (3.7%) of 6695 children below 11 years had evidences of arsenical skin disease. In Bangladesh, 298 (6.11%) of 4877 children below 11 years were reported to have arsenical skin lesion due to drinking of arsenic-contaminated water.[7] However, higher prevalence of skin lesion due to consumption of contaminated groundwater was observed by Watanabe and others among 241 children (age 4–15 year) living in two rural villages in northern Bangladesh. The arsenic concentrations of the tube-well waters ranged from less than detection limit to 535 μg/L. Approximately half of the examined children exhibited dermatological symptoms with relatively obscured dose-response relationship; an observation suggesting that the

children were no less susceptible to the dermatological effects of arsenic than the adults living in the same communities. Proportion of the children with lower body mass index (BMI) significantly increased with increasing arsenic exposure level and the dose–response relationship was consistently observed among the subgroups.[8] The incidence of arsenicosis in children was found to be 12.2% in Inner Mongolia, China, when studied in a population of 728 subjects below 19 years who were exposed to arsenic.[9] Arsenic-specific skin lesions were reported in infants aged 6–18 months in China.[10] In a recent study carried out in Cambodia, higher incidence of arsenic-related skin lesion was also observed in children who were drinking arsenic-contaminated water.[11] Ten of 27 (37.04%) children below 16 years of age were found to show evidences of arsenical skin lesions. From the reports available in the literature, it appears that children are similarly affected as adults due to chronic arsenic exposure although the incidence of arsenic-related skin manifestation vary depending on various factors, which include dose and duration of exposure, nutritional status of children, and ethnicity.

The study report on children's intellectual function in the arsenic-exposed region of Thailand was available for review.[12] Chronic arsenic exposure assessed by hair concentrations was related to developmental retardation as judged by IQ measured by using the Wechsler intelligence scale test for children. Multiple classification analysis was conducted with data from 529 children aged 6–9 years who had lived in Ronpiboon district since birth. The percentage of children in the average IQ group decreased remarkably from 56.8 to 40.0 as the arsenic level increased. After adjusting for confounders, they observed a statistically significant relationship that arsenic could explain 14% of variance in children's IQ. The extent of arsenic exposure was difficult to assess. Hair concentrations were found to have an average of 2.42 mg/kg (range: 0.48–26.94 mg/kg) of arsenic, whereas normal was quoted as less than 1 mg/kg.

Another study was conducted on the effect of water arsenic exposure and children's intellectual function in Araihazar, Bangladesh.[13] It was found that exposure to arsenic from drinking water was associated with reduced intellectual function in Wechsler Intelligence Scale for children (WISC) III for children, in a dose–response manner after adjustment for sociodemographic covariates and water Mn. Children with water arsenic levels >50 mg/l achieved significantly lower performance

and full-scale scores than did children with water arsenic level <50 mg/l. The association was generally stronger for well water arsenic than for urinary arsenic. In a study of 720 children between 8 and 12 years of age in rural villages in Shanyin county, Shanxi province, China, it was found that the IQ scores of the children in the high-As group were the lowest. It is more significant that high concentrations of As affect children's intelligence and growth.[14]

A cross-sectional study of intellectual development was done in West Bengal on 351 children aged 5–15 years in families selected from a surveyed source population of 7683 people[15] in West Bengal, India. Intellectual function was assessed based on six subsets from the WISC, the total sentence recall test, the colored progressive matrices (CPM) test, and a Pegboard test. Information on sociodemographic factors was collected and height and weight were measured. Arsenic level in urine samples collected from the participants and water samples consumed by them were measured by AAS. Urinary arsenic concentrations stratified into tertiles showed an inverse trend with the vocabulary test scores, the object assembly test scores, and the picture completion test scores, adjusted for potential confounders. This corresponds to a relative reduction of the mean scores related to exposure in the upper tertile in the vocabulary tests of 12.6%, in the object assembly test of 20.6%, and in the picture completion test of 12.4%. Reduction in intellectual function scores, particularly the vocabulary and picture completion test scores, was associated with increased urine arsenic concentrations, but not with various measures of water concentrations. There was little evidence of an association between arsenic drinking water concentrations alone and intellectual function.[15] Current urine concentrations reflecting exposure from all sources appeared to be more relevant than peak, or cumulative exposure based on measurements of water sources. A study from Bangladesh reported that urinary arsenic may be a strong predictor of skin lesions than arsenic in drinking water in the population.[16]

The biotransformation of arsenic in humans occurs through the methylation process. Few data exist that link methylation patterns to arsenic-induced disease. In a study from West Bengal, it was reported that second methylation capacity in children is higher than adults, as the values of the DMA/MMA ratio is significantly (positive t-test) higher in children than adults (average 8.15 vs. 4.11) in the exposed group. That means that the second methylation step in the arsenic metabolic pathway is more active in children than adults. From these results, the authors suggested that children retain less arsenic in their body than adults does. From this study, the authors observed that children do not show skin lesions compared with adults when both are drinking same contaminated water.[17] However, observation of higher prevalence of skin lesion in some arsenic-exposed children in Bangladesh and also in China and Cambodia as presented earlier[8,9,11] suggest that other factors than age may also be related to methylation capacity in a child.

Various studies have been carried out to assess whether genetic polymorphisms cause variation in arsenic methylation with variation in arsenical disease manifestation. Family correlation studies assist in determining whether variations in methylation patterns may be caused by genetic polymorphisms. If genetic factors contribute to arsenic methylation capacity, family studies should demonstrate that siblings have a higher correlation of methylation activity than their parents. Chung et al.[18] conducted a study on methylation patterns in children in a small village in northern Chile situated in extremely dry desert environment where all of its residents shared the sole drinking-water supply to the village which contained high levels of arsenic. Eleven families were selected because of their long-term exposure to very high levels of arsenic in drinking water (735–762 μg/l). Each family consisted of a father, a mother, and two children. The authors measured urinary arsenic and its methylated metabolites for each participant ($n = 44$). The intraclass correlation coefficients showed that 13–52% of the variations in the methylation patterns were from being a member of a specific family. Family correlations were calculated for father–mother, parent–child, and sibling–sibling pairs. Methylation patterns correlated strongly between siblings [$r = 0.78$ for InAs/metAs, 95% confidence interval (CI), 0.34–0.94; $r = 0.82$ for MMA/DMA, 95% CI, 0.43–0.95] compared with lower correlations in father–mother pairs ($r = 0.18$, $r = −0.01$, respectively), after adjustment for total urinary arsenic, age, and sex. Family correlations were not notably altered when adjustments were made for specific blood micronutrients (methionine, homocysteine, folate, vitamin B6, selenium, and vitamin B_{12}) potentially related to methylation. The study substantiates that methylation patterns aggregate in families and are correlated in siblings, providing evidence of a genetic basis for the variation in arsenic methylation.[18]

Arsenicosis has a socioeconomic effect on children. Children affected by pigmentation and/or keratosis due to chronic arsenic toxicity discourage them from attending school for fear of ridicule. Very often when a family member, especially an earning male member develops arsenicosis, his treatment takes precedence over other expenses like children's schooling, which may be abandoned if the family cannot afford both. Children also may have to contribute to the family income, thus depriving them of education. Arsenicosis may force changes in responsibilities within and outside the home for victim as well as the rest of the family. The burden of the disease and its treatment as well have the impact on households and their coping strategies, which vary with the victim's occupation and earning capacity.

References

1. IARC (International Agency of Research on Cancer).Some drinking-water disinfectants and contaminants, including arsenic. Monographs on the Evaluation of Carcinogenic Risk to Humans.Vol.84. Lyon, France: WHO; 2004. p.227.
2. NRC (National Research Council).Arsenic in Drinking Water. Washington, DC: National Academy Press; 1999. P.83-149.
3. Guha Mazumder DN. Criteria for case definition of arsenicosis. In: Chappell WR, Abernathy CO, Calderon RL, Thomas DJ, editors. Arsenic Exposure and Health Effects (V). London: Elsevier Science Ltd.; 2003. p. 117-34.
4. Rosenberg HG. Systemic arterial disease and chronic arsenicism in infants. Arch Pathol 1974;97:360-5.
5. Borgoño JM, Vicent P, Venturino H, Infante A. Arsenic in the drinking water of the city of Antofagasta: Epidemiological and clinical study before and after the installation of a treatment plant. Environ Health Perspect 1977;19:103-5.
6. Guha Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, et al. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. Int J Epidemiol 1998;27:871-7.
7. Rahman MM, Chowdhury UK, Mukherjee SC, Mondal BK, Paul K, Lodh D, et al. Chronic arsenic toxicity in Bangladesh and West Bengal, India–A review and commentary. J Toxicol Clin Toxicol 2001;39:683-700.
8. Watanabe C, Matsui T, Inaoka T, Kadono T, Miyazaki K, Bae MJ, et al.Dermatological and nutritional/growth effects among children living in arsenic-contaminated communities in rural Bangladesh. J Environ Sci Health A Tox Hazard Subst Environ Eng 2007;42:1835-41.
9. Guo X, Fujino Y, Kaneko S, Wu K, Xia Y, Yoshimura T. Arsenic contamination of groundwater and prevalence of arsenical dermatosis in the Hetao plain area, Inner Mongolia, China. Mol Cell Biochem 2001;222:137-40.
10. Sun GF, Liu JY, Sun DJ, Luong TV, Wang LY. Endemic Arsenicosis: a Clinical Diagnostic Manual with Photo Illustrations. Bangkok: East Asia and Pacific Regional Office, United Nations Children's Fund; 2004. p. 17.
11. Mazumder DN, Majumdar KK, Santra SC, Kol H, Vicheth C. Occurrence of arsenicosis in a rural village of Cambodia. J Environ Sci Health A Tox Hazard Subst Environ Eng 2009;44:480-7.
12. Siripitayakunkait U, Vishudhiphan P, Pradipasen M, Vorapongsathron T. Association between chronic arsenic exposure and children's intelligence in Thailand.In: Chappell WR, Abernathy CO, Calderon RL, editors. Arsenic Exposure and Health Effects.Oxford, UK: Elsevier Science Ltd; 1999. p.141-9.
13. Wasserman GA. Water arsenic exposure and children's intellectual function in Araihazar, Bangladesh. Arch Environ Health 2004;4:223-34.
14. Wang SX, Wang ZH, Cheng XT, Li J, Sang ZP, Zhang XD, et al. Arsenic and fluoride exposure in drinking water: Children's IQ and growth in Shanyin county, Shanxi province, China. Environ Health Perspect 2007;115:643-7.
15. von Ehrenstein OS, Poddar S, Yuan Y, Mazumder DG, Eskenazi B, Basu A, et al. Children's intellectual function in relation to arsenic exposure. Epidemiology 2007;18:44-51.
16. Ahsan H, Perrin M, Rahman A, Parvez F, Stute M, Zheng Y, et al. Associations between drinking water and urinary arsenic levels and skin lesions in Bangladesh. J Occup Environ Med 2000;42:1195-201.
17. Chowdhury UK, Rahman MM, Sengupta MK, Lodh D, Chanda CR, Roy S, et al. Pattern of excretion of arsenic compounds [arsenite, arsenate, MMA(V), DMA(V)] in urine of children compared to adults from an arsenic exposed area in Bangladesh. J Environ Sci Health A Tox Hazard Subst Environ Eng 2003;38:87-113.
18. Chung JS, Kalman DA, Moore LE, Kosnett MJ, Arroyo AP, Beeris M, et al. Family correlations of arsenic methylation patterns in children and parents exposed to high concentrations of arsenic in drinking water. Environ Health Perspect 2002;110:729-33.