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ARSENIC POISONING AT TUBE WELL IN RED RIVER DELTA CASE STUDY AT SON DONG VILLAGE

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ABSTRACT

Arsenic (As) contamination in groundwater has been the crucial environmental problem in many regions in the world, particularly in Bangladesh and West Bengal, India. The problem in Red River delta has been recognized recently. During October 2003 to January 2004, a randomly survey of As concentrations in tube wells was conducted at Sondong village, near by Hanoi city by the west direction 25 km away. The relations between arsenic concentrations in tube wells and other parameters such as conductivity, red-ox potential, iron and phosphate concentrations were interpreted. The reductive environment is dominant with average value about -120mV. Iron concentrations are 6.5 mg/l and phosphate concentrations are 0.7 mg/l in average. Data from 54 water samples showed that arsenic concentrations ranged from 5 to 434 μg/l with mean value was 251μg/l. People at the local area have used sand filer tanks to eliminate iron from groundwater then arsenic was co precipitated by the iron hydroxide Fe(III) partly. But because iron concentrations are not high enough for total absorption the arsenic, arsenic concentrations in filtered water are still high as 81μg/l in mean value. So the people at that village exposure to quite high arsenic level both from filtered and raw groundwater. 204 hair and 50 urine samples were collected and analyzed for total arsenic concentration accordingly. Arsenic accumulations gain 1.71 mg/kg (0.16- 10.36 mg/kg) in hair samples compare to 0.25 mg/kg at reference site, 61.8% samples content higher than 1mg/kg of arsenic, that is toxic level referenced from WHO. Children younger than 15 years old tend to accumulate more arsenic than adults (average 2.53 mg/kg). Urinary arsenic concentrations are 146 μg/l (30-394 μg/l) at contaminated village compared to 77 μg/l at control one. The received data showed that the people at Sondong village are under high risk for arsenic toxicity. A mitigation solution should be suggested and applied to that area

Keywords: *arsenic, iron, ground water, tube wells, hair, urine,*

INTRODUCTION

Arsenic pollution in groundwater has been found in many parts of the world as Argentina, Mexico, USA, China, Taiwan, India, Bangladesh, Thailand and Vietnam (Berg et al. 2001, Chakraborti et al. 2002, Smedley et al. 2002). Arsenic in groundwater can be connected to natural weathering or biology reactions as in Argentina, Bangladesh, Vietnam, as well as anthropogenic reasons as mining activities in Thailand (Smedley et al. 2002). Chronic exposure to arsenic through drinking water is believed to connect to some severe health affects as carcinogen symptom at skin, lung, bladder or non cancer as melanosis and keratosis on hand or feet, cardiac and possibly diabetic diseases (Pershagen et al.1985). WHO has recommended the As value in drinking water to 10μg/L instead of 50μg/L as before since 1993. The calamity from arsenic poisonings in groundwater at Bangladesh and West Bengal, India has been discovered the last decade and the threaten to human health has become the worldwide concern. The arsenic pollution at groundwater could be heterogeneous or homogenous at small area. Geologist, chemists, hydrologist and microbiologists, etc still under investigate the reasons for the phenomenon. Predominant hypothesis used to explain the elevated arsenic concentration in anoxic condition at alluvial delta is the dissolving of arsenic absorbed to Fe oxyhydroxide mineral. The desorption processes are influenced by a number of factors such as pH, reductive potential, arsenic species ratios (As III/As V), other oxidations, water flow profile, etc. Arsenic can be released from sediment into ground water by trigger of strongly reductive condition, which is believed be controlled by microbial organic matters oxidation (Berg et al. 2001, Nickson et al. 2000).

In many Asian countries groundwater still is main source for drinking water without quality control especially at countryside area. As intake through contaminated drinking water was considered as major route for As accumulation into body. At epidemic region like Bangladesh and India, arsenic concentration in hair and urine are widely used as markers for chronic and recent exposure. A huge survey made by Chakraborti et al showed that 90% of 35.000 hair and urine samples collected from skin effected patients who live at heavy As contaminated area contained As elevated above normal level (Chakraborti et al. 2002, 2003). The similar data range was reported by (Anawar et al. 2002), As content in water, hair and urine from people at some Bangladesh provinces is in the range of 0.01-9 mg/L, 1.1-19.84 mg/kg and 0.05-9.42 mg/L for water, hair and urine respectively. Arsenic in urine and hair samples are considered as important indicators for arsenic chronicle and recent exposure

Some reports had confirmed that groundwater extracted through tube wells at some places in Northern alluvial delta by Red river, Vietnam contained quite high arsenic concentration (Berg et al, 2001, Nga et al. 2003). The found average arsenic concentration was 159 μg/l (WHO guideline value and Vietnamese standard is 10 μg/l in drinking water). Tens millions people have been using this groundwater source for drinking and irrigation purpose by millions of tube wells, which were partly built by support of UNICEF and other NGOs. Together with urbanization and industrial development, Hanoi city is expanding with faster rate than demanded clean water supply plans. People at new urban area possibly are using groundwater with high level of arsenic as drinking water. The number of such kind of tube well has been still increasing by time without any quality control. Yet the extension of the arsenic pollution and its effects to the environment and people's health still has not known. Hence the research on situation of arsenic pollution and health impact has been carried taking Sondong village as case study.

MATERIALS AND METHODS

Research site is Sondong village; it is located 25 km in the west direction from Hanoi city. 54 water samples from tube wells and filtered by sand tank were collected in the study, 204 people were recruited for hair and urine samples. Water samples from tube wells were collected in to acid washed clean plastic bottles after filtering through 0.45 m nitrocellulose acetate filter paper, the samples were acidified to pH <2 by HNO_3 concentrated and kept in cool place less than two week before measurement of arsenic and other relevant chemical element. (Standard methods, 1995)

Total arsenic in water, was analyzed by hydride generation-atomic absorption spectrometer (Shimadzu). Fe were determined by flame AAS -6800 (Shimadzu). 204 hair samples were cut at positions close to scalp and in the backside of head. Hair samples were washed carefully by neutral detergent and deionized water, dry at 60°C before analysis. 0.2 mg hair was digested by mixture of HNO_3 concentrated, H_2O_2 and in closed Teflon thimbles under microwave oven. Hair treated solutions were analyzed for total arsenic as the procedures applied to water sample (Rahman et al. 2002). Urine samples were collected into clean plastic bottles then stored at - 20oC before analyzed by HPLC-ICPMS. Procedure for analysis of arsenicals in urine was described in (Kubota et al. 2003)

RESULTS AND DISCUSSION

Arsenic and iron concentrations in groundwater and filtered water

Field-testing at the 54 households at Sondong village shows that the tube wells have been drilled since the year of 1993 till recently, among them 30% wells were made since the year of 2000. It means that nowadays people at countryside can have tube well at family scale with reasonable cost. The tube wells provide water for drinking, washing, bathing, and irrigation a small garden for in house vegetable consume. Well depth ranges from 24 to 54 m, and 40-45m is domain, according to hydrology records these water layers are belong to Holocene aquifer, that is popular for young aquifer at Red river delta.

Table 1. Field parameters for groundwater at Sondong village

	pH	Dissolved oxygen (mg/l)	Conductivity (μS/cm)	Re-dox potential (mV)	Temperature (°C)
Mean	7.20	0.28	618	-118	26
Max-Min	7.53-6.32	2.68-0.00	1138-283	+91 -164	27
Median	7.30	0.05	636	-126	24

Table 1 provided some other parameters; the groundwater at the village is reductive with low oxygen concentration and low redox potential. This condition founded by previous study at Hanoi area as well as other river deltas as in Bangladesh and West Bengal (Anawar et al. 2002, Berg et al. 2001, Trafford et al. 1999). Under the reductive condition arsenic absorbed at surface of iron oxide particles were dissolved or desorbed because Fe (III) had been oxidized to dissolved Fe (II).

Table 2 provides the arsenic, iron and phosphate concentrations in the groundwater. Arsenic contamination is very serious here, among tested well 100% ones contained arsenic higher than standard value (10μg/l), 41% well contains more than 200 μg/l, 11% well polluted with more than 400μg/l. The mean value is 251.6 μg/l, that is 25 times higher than recommended value for drinking water from WHO and Vietnamese Ministry of Health. The groundwater extracted from the tube wells looks a bit yellow after settle for a while in tank caused by $Fe(OH)_3$ precipitation.. People at the village do not want to use that raw groundwater for making tea or cooking, they used two layers sand filter tank to removal Fe without aware about the more toxic metal as arsenic. The simple system has eliminated partly arsenic from groundwater by sorption of arsenic onto $Fe(OH)_3$ particles which cover sand grains, these particles are precipitated after Fe(II) dissolved be oxidized by the air to Fe(III). But data research from Luzi et al. (2004) showed that when iron concentration in groundwater was higher than 12 mg/l then arsenic removal efficiency could reach 90%. Here in groundwater from Sondong village, Fe concentration is around 6 mg/l, that is one of reasons why arsenic concentrations still rather high in filtered water. Phosphate content higher than 1 mg/l often reduce the arsenic removal capacity of sand filter but it seems is not a case here because average phosphorous concentration at these sample is 0.7mg/l. This is clear that sand filter tank used for iron removal at this area should be optimized more for arsenic trap purpose. Using that filtered water for drinking purpose is very risk for human because as present at figure 1, arsenic concentrations in groundwater and filtered water show the proportion trend, more arsenic occurred in groundwater then more arsenic still stayed in filtered water. There are more than 50% of filtered water samples still contaminated with more than 50 μg/l of As (that is old standard value for drinking water at many countries). If the new standard value is considered (10 μg/l) then the situation would be worse. Awareness rising for people about toxicity of arsenic combined finding more safe water sources, as rainwater or community water supply should be applied at these villages.

Table 2. Arsenic, iron, and dissolved phosphate in tube well and filtered water

	Groundwater			Filtered water
	As (µg/l)	Fe (mg/l)	Dissolved P	As (µg/l)
Mean	251.6	6.5	0.7	81.1
Max-Min	433.8 - 4.7	24.7-0.1	4.3-0.0	305.1 - 0.3
Median	261.6	5.6	0.4	59.4

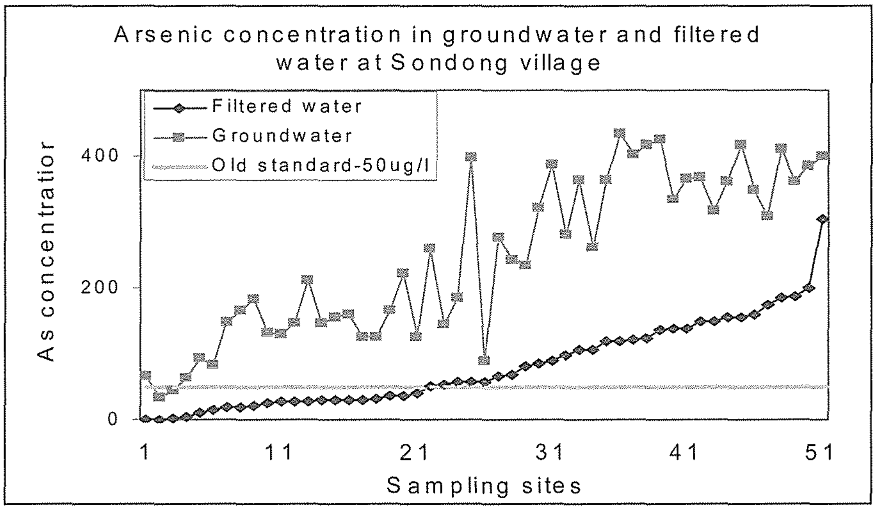

Figure 1. Arsenic contamination in groundwater and filtered water at Sondong village.

Arsenic accumulation in hair and excretion via urine

Arsenic is toxicant with many serious affects; people intake water polluted by high content of As for long time would be dead by cancer at skin, lung, or kidney as reported in Bangladesh, Taiwan. Exposure to low concentration of As for a long time can get illness with several diseases as skin hypo-hypertension, and possibly cardiac vascular, diabetes etc. or more specific with skin manifestation. The clinical manifestations of chronic arsenic toxic are dependent on host susceptibility, the dose, and the time course of expose (Pershagen et al. 1985,Chakraborti et al. 2002, 2003). In this study 204 people from Sondong village have agreed to provide their tube well water, hair and urine samples for total arsenic determination and results are present in table 3. In this study samples from Thuongcat village (northern Hanoi) were taken as control.

Table 3. Arsenic concentrations in water, hair, urine samples collected from Thuong cat and Sondong

	Ground water (µg/L)		Hair (mg/kg)		Urine (µg/g creatinine)	
	Thuongcat	Sondong	Thuongcat	Sondong	Thuongcat	Sondong
No. Samples	25	54	25	204	10	50
Range	<1-141	5-434	0.06-0.47	0.16-10.36	23.3-141.3	29.9-393.7
Average	9.6	251	0.25	1.71	76.9	146.4

The data clearly show that human samples from Sondong are accumulated higher arsenic concentrations compare with control samples from Thuongcat. Groundwater at Thuongcat has low arsenic concentration as 10 µg/l compare with 251 µg/l at Sondong. The result is that by using such arsenic contaminated water via drinking, bathing or vegetable consume, people at Sondong not only intake more arsenic at present as show at urine data (146.4 µg/g creatinine) but also bear a serious long term exposure as data from hair samples (1.71 mg/kg). 61% of hair samples contained more than 1ug/kg, which is reference value for arsenic toxicity at human. Among 45 children were tested for hair sample, the average value found 2.53 mg/kg of arsenic. This suggested a more susceptible to arsenic at children compare with adults. The assuming was showed at research of Concha et al (1998) by urine sample. Among 20 pregnancy women involved in the test, 50% of their hair samples contain higher than 1mg/kg arsenic.

According to reference from WHO document arsenic concentration in urine generally below 10μg/L in some Europeans where no arsenic exposure exists. Drinking well water with an As content exceeding 100μg/l gave an average urinary total As concentration of 178 μg/L. In people with no exposure to As the concentration of As in hair generally is 0.02-0.2 mg/kg.(Abernathy 2001). Considering the reference values from other studies as at Bangladesh, As concentration in urine is 120-200 μg/g creatinine (Watanabe et al, 2001), 798 μg/l (Chakraborti et al, 2003) or at China 71.4 μg/g creatinine (Shraim et al 2003), the data found at this study show that people at Sondong village still intake a certain amount of arsenic via ingest route, it could be from arsenic contaminated water or food. Our results from hair samples also indicate a moderately long term exposure to arsenic at Sondong community when compare with data found in Bangladesh, where arsenic in hair is 2.78 mg/kg (Chakraborti et al. 2003), from 1.1- 19.84 mg/kg (Anawar et al., 2002), 3.43 mg/kg (Samanta et al. 2004), and 7.99 mg/kg at China (Shraim et al., 2003).

Arsenic is normally found in higher concentrations in human hair and nail than other parts of the body. High As excretion in urine is indicative of continued As exposure. In study area people have used the water from tube well for about 2-10 years but not always for drinking and cooking because high iron concentration. In Red river delta people at rural area often collect and store rainwater during rainy season, that source of clean water were used for drink and prepare meal. But during the end of dry season when no more rain water left in tank people have to temporally use groundwater directly or after simple filtering. It means that it is not easy to calculate dose and exposure time for each individual. Definitive correlation between As concentrations in water, hair and urines samples can not be deducted because it is depended on other host related factors as exposure duration, age, sex, food consumption, etc.

CONCLUSIONS

Received data from the study has revealed that there is a definite arsenic contamination from groundwater, which is used as drinking source for people in countryside at some parts of Red river delta. Sand filter system at household scale can not always remove efficiency arsenic from raw water. Human health would be harmful affected if continuously using such contaminated water for drinking and cooking. Biomarkers as arsenic concentration in hair and urine provided evident for long term and recent exposure from people to arsenic. They could be used meaningful by public heath, environment awareness raising and water supply sectors in order to improve clean water requirement for 80% of national population in country side.

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References

1. Abernathy C.2001. Arsenic. Exposure and health effects. WHO.
2. American Public Health Association. (1995) *Standard methods for examination of water and wastewater.* 3, 20-51

3. Anawar H. M., J. Akai, K. M. G. Mostofa, S. Safiullah and S. M. Tareq, (2002). *Arsenic poisoning in groundwater: Health risk and geochemical sources in Bangladesh*, *Environment International*, 27 (7), 597-604.
4. Berg, M; Tran, H C; Nguyen, T C; Pham, H V; Schertenleib, R; Giger, W, (2001). Arsenic contamination of groundwater and drinking water in Vietnam: a human health threat. *Environmental Science & Technology*, 35 (13), 2621-2626.
5. Chakraborti D., Mohammad M. Rahman, Kunal Paul, Uttam K. Chowdhury, Mrinal K. Sengupta, Dilip Lodh, Chitta R. Chanda, Kshitish C. Saha and Subhash C. Mukherjee, (2002). Arsenic calamity in the Indian subcontinent; What lessons have been learned? *Talanta*, 58 (1), 3-22
6. Chakraborti, D., Mukherjee, S., C., Pati, S., Sengupta, M., K., Rahman, M., M., Chowdhury, U., K., Lodh, D., Chanda, C., R., Chakraborti, A., K., Basu, G., K. (2003) Arsenic Groundwater Contamination in Middle Ganga Plain, Bihar, India: A future Danger? *Environmental health perspectives*. 111, 1194-1201
7. Concha, G., Nermell, B., Vahter, M. (1998). Metabolism of inorganic Arsenic in Children with Chronic High Arsenic Exposure in Northern Argentina. *Environmental heath perspectives* .106, 355-359
8. Kubota R., Kunito T and Tanabe S.(2003). Occurrence of several arsenic compounds in the liver of birds, cetaceans, pinnipeds, and sea turtles. *Environmental Toxicology and Chemistry*. 2 (6), 1200-1207.
9. Luzi S, Berg M, Pham T.K.T, Pham H.V. and Schertenleb R. (2004). Household sand filters for arsenic removal-Technical report. EAWAG, www.arsenic.eawag.ch/publications
10. Nga T.T.V, Inoue M, Khatiwada N.R., Takizawa S., (2003). Heavy metal tracers for the analysis of groundwater contamination: Case study in Hanoi city, Vietnam. *Water Science and Technology: Water Supply*. 3 (1-2), 343-350.
11. Nickson R. T., J. M. McArthur, P. Ravenscroft, W. G. Burgess and K. M. Ahmed, (2000). Mechanism of arsenic release to groundwater, Bangladesh and West Bengal, *Applied Geochemistry*, 15 (4), 403-413.
12. Pershagen, G. (1985). 25. Higgins, I., Welch, K., Oh, M., Bond, G. & Hurwitz, P., Lung cancer mortality among men living nears an arsenic emitting smelter *05-31-02, http://www.inchem.org/documents/iarc/iarc/iarc835.htm.*
13. Rahman, L., Corns, W., T., Bryce, D., W., Stockwell, P., B. (2000). Determination of mercury, selenium, bismuth, arsenic and antimony in human hair by microwave digestion atomic fluorescence spectrometry. *Talanta*. 52, 833-843
14. Samanta G., Sharma R, Roychowdhury T, Chakraborti D., (2004). Arsenic and other elements in hair, nails, and skin-scales of arsenic victims in West Bengal, India. *Science of the Total Environment*. 326, 33-47.
15. Shraim, A., Cui, X., Li, S., Jack C. Ng, Wang, J., Jin, Y., Liu, Y., Guo, L., Li, D., Wang, S., Zhang, R., Hirano, S. (2003). Arsenic speciation in the urine and hair of individuals exposed to airborne arsenic through coal-burning in Guizhou, PR China. *Toxicology Letters*. 137, 35-48
16. Smedley P. L. and D. G. Kinniburgh, (2002). A review of the source, behavior and distribution of arsenic in natural waters. *Applied Geochemistry*, 17 (5), 517-568
17. Trafford J.M, *British Geological Survey*. Technical report WC/96/22.1999
18. Watanabe C, Inaoka T, Kadono T, Nagano M, Nakamura S, Ushijima K, Murayama N, Miyazaky K, Ohtsuka R. (2001). Males in rural Banladeshi communities are more susceptible to chronic arsenic poisoning then females: Analyses based on urinary arsenic. *Environmental health perspectives*. 109 (12), 1265-1270.