Arsenic in Irrigation Water: Spatial Variability of As Content and Selected Chemical Parameters - Comparison with BGS Data

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Introduction

In Bangladesh, groundwater from shallow depth is contaminated by naturally occurring As in 59 out of 64 districts (BGS/DPHE, 2001). Groundwater is used extensively in irrigation of rice, the staple food of Bangladesh, with 83% of the total irrigated area under rice cultivation (Dey et al., 1996). Large areas of Bangladesh have to rely on groundwater for irrigation of staple crops such as rice (Panaullah et al., 2003; Nickson et al., 1998). Irrigation with arsenic contaminated groundwater is leading to elevated levels of arsenic in paddy soils (Alam and Satter, 2000) which may lead to increased concentration of arsenic in rice (Meharg and Rahman, 2003; Duxbury at el., 2003), vegetables (Alam et al., 2003) and other agricultural products (Abedin, 2002a). The exact cause of arsenic release that is poisoning the ground water and soil is still poorly understood, and variability of arsenic in soil and water across the space is not clear. Moreover, there are diverse opinions about the exact cause of arsenic release and the variability in soil and water and strong disagreements on the source of arsenic in the ground water (Islam, 2003). Relatively little is known about the spatial variability of arsenic in soil. Arsenic in groundwater has been extensively studied by BGS (BGS, 2001) in relation to its implications on the health ecosystem and has established a huge database on arsenic and other chemical constituents of groundwater. On the other hand, the USAID funded Arsenic Project is assessing arsenic concentration in irrigation water and its impact on the food chain, particularly through rice. These studies have some common aspects such as arsenic concentration and chemistry of ground water. This current study aims (i) to determine the spatial variability of As and some selected parameters in shallow tube well (STW) water and (ii) to compare the results of data generated through Arsenic project funded by USAID with those using BGS data.

Methodology

The study used ground water data generated by Arsenic project and BGS in Faridpur Sadar Thana and south-west hydraulic zone of Bangladesh where sizeable geo-referenced database on As, Fe, Mn and P concentration in ground water are available. Faridpur is located in the alluvial and deltaic plain of Bangladesh which has been recognized as the most arsenic contaminated area, and detailed chemical analysis of ground water has been provided by both Arsenic Project and BGS. In south-west hydraulic zone, wide range of data has been collected by both the projects at the national scale**.** Data were analyzed by "Test kit" method in BGS and "Tri Acid method" in Arsenic Project.

Semivariograms were calculated to determine the spatial dependency of water As, Fe, Mn and P both for the surveys in Faridpur and south-west region by GS+ 5.3.2. Maximum lag distance and lag interval for the semivariance were determined iteratively to best fit the model having highest R^2, the lowest residual sum of squares (RSS) and spatial dependence close to unity. Kriging interpolation was performed to spatially describe the distribution of As, Fe, Mn and P concentration in irrigation water. Comparisons are made both in surface and tabular forms.

Results and Discussions

There is significant difference ($P<0.01$) in the average As level of the two data sets both in Faridpur and south-west hydraulic zone (Table 1). Average level of Mn of BGS data does not differ significantly from that of Arsenic project in both the locations (Table 1) but Fe and P concentrations were higher for BGS data in Faridpur. All the water parameters were highly variable with CV as high as 143% for As data generated by BGS and lowest 56% for Mn concentration determined by the Arsenic project both in Faridpur. The variability in data generated by BGS was, in general, higher than that generated by Arsenic project irrespective of locations. The higher variability in BGS data could be partially attributable to the use different agencies involved in analysis of the sample water. Arsenic concentration correlated positively with Fe and P but in general, have little to negative relationship with Mn.

The distribution of As was strongly positive skewed except for Arsenic Project data from Faridpur. This result suggests that the data are randomly distributed, that is, not normally distributed for the BGS data in Faridpur and in the south-west hydraulic zone; hence, the changes in value seemed to be independent of the respective sampling location. All other parameters were strongly positive skewed in south-west hydraulic zone and BGS in Faridpur. The coefficient of skewness of As, Fe, Mn and P in Arsenic project in Faridpur was very low. The frequency distribution can be regarded as being normally distributed, and this result indicates that dependence exists between change in value and increasing sampling distance. Semivariance is, therefore, developed with increasing distance between sampling points. Semivariance for As, BGS data in Faridpur and Arsenic project data in south-west hydraulic zone suggest spherical model while, BGS data in south-west hydraulic zone and Arsenic project data in Faridpur suggest exponential model with high R^2, the lowest residual sum of squares (RSS) and spatial dependence close to unity (Table 3). Semivariance of Arsenic project in Faridpur reaching the sill within the sampled scale, whereas in the other cases semivariance displayed a different trend. This suggests that for Arsenic project in Faridpur, the changes in value will be independent when their separation distance exceeds effective range 4890 meters and all other cases the samples will not be stochastically independent from each other within their scale value. The random distribution of the data points indicates a nugget effect, i.e. the variance is not spatially structured at the effective range (95160m for BGS Faridpur, 287700m for BGS SW and 27560m for Arsenic SW). However, spatial dependence could be exist below these ranges. Similarly, Fe, Mn and P in Arsenic project in Faridpur the semivariance models are Spherical, Exponential and Spherical respectively and hence the changes in value will be independent when their separation distance exceeds effective range 3110, 17490 and 3108 meters. Other cases spatial dependence could be exist below the ranges (For Fe, 36240m in Faridpur BGS, 633000m in sw BGS, 240468m in sw Arsenic. For Mn, 9630m in Faridpur BGS, 82300m in sw BGS, 125100m in sw Arsenic. For P, 40410m in Faridpur BGS, 591900m in sw BGS.

Spatial variability maps of As, Fe, Mn and P in ground water pumped through shallow tube well has been created for BGS and Arsenic project both for Faridpur and south-west hydraulic zone of Bangladesh and are presented in Fig. 1. Both BGS and Arsenic project data show that arsenic concentration is relatively higher in the south and south- eastern part of south-west hydraulic zone although the pattern of concentration varied between the two data sets. The situations were very different in Faridpur Thana, where Arsenic project data indicated that most of the area have high As concentrations, while for the BGS data As concentration were low (<50ppb) in most of the area. One of the reasons for the difference between the spatial variations exhibited by two data sets is that the sampling points of the two data sets were not the same. Other explanations are the difference in the analytical method and the involvement of several agencies in the analysis of samples in the case of the BGS data. The spatial relationship between As and the parameters are also supported to the relationship earlier mentioned.

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Table 1. Descriptive statistics and mean comparison of Arsenic Project and BGS data

Items	Arsenic Project				BGS			
	Faridpur							
	As	Fe	Mn	P	As	Fe	Mn	P
Mean	112.63	4.08	0.64	91.00	31.94	5.64	0.66	127.00
SD	67.36	2.57	0.36	56.90	45.72	4.92	0.72	106.00
Max	247.04	10.75	1.56	222.9	200.00	19.60	4.23	500.00
Min	13.24	0.15	0.01	3.40	1.00	0.05	0.04	20.00
Skewness	0.36	0.46	0.16	0.34	2.16	0.90	2.17	0.78
CV (%)	59.81	62.99	56.25	59.81	143.14	87.23	109.09	83.46

Items	Arsenic Project				BGS			
	Faridpur							
	As	Fe	Mn	P	As	Fe	Mn	P
t- value	9.13**	2.34*	0.21	2.50*				
SW Region								
Mean	87.30	4.56	0.45	-	121.70	3.85	0.52	1.26
SD	86.94	3.69	0.47	-	164.20	3.65	0.62	1.59
Max	530.31	18.41	2.35	-	1660.00	30.40	3.87	11.70
Min	0.30	0.02	0.02	-	0.00	0.00	0.00	0.00
Skewness	1.76	1.29	1.63		2.02	1.73	1.73	2.84
CV (%)	99.59	80.92	104.44		134.92	94.81	119.23	126.19
t-value	3.18**	1.79	1.32					

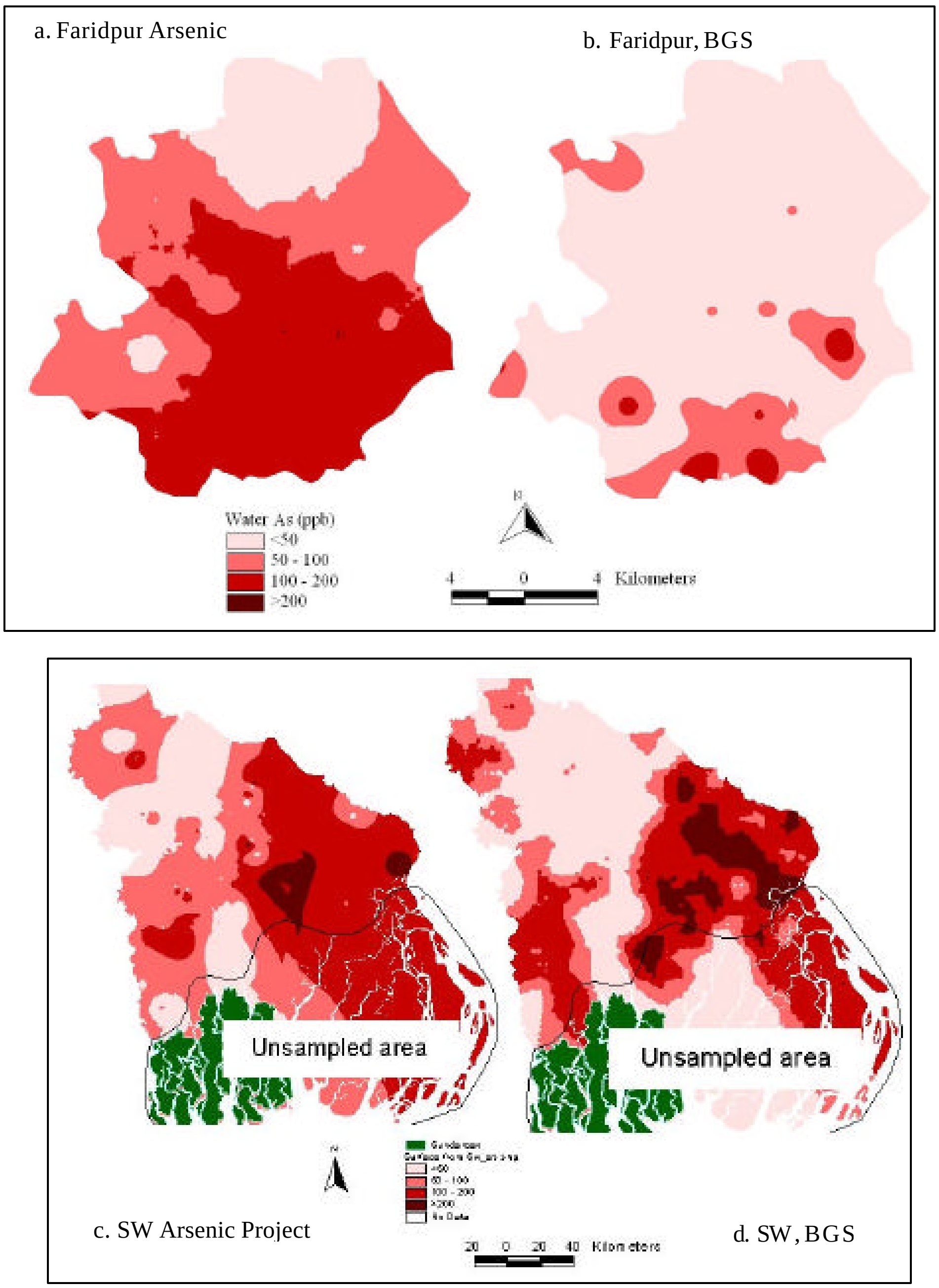

Figure 1 (a, b, c, & d). Spatial variability maps of As in ground water pumped through shalow tube well.