Water-Soil-Crop Arsenic Interrelationships

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Introduction

The chemical properties of irrigation water coupled with soil properties may have an influence on the variation of arsenic accumulation in paddy rice soils. Soil properties such as clay content, pH and redox conditions (Marin et al., 1993), ionic composition (Khattak et al., 1991), type and amount of organic matter (Mitchell and Barr, 1995) are considered to be the important variables for availability and phytotoxicity of plants to arsenic. However, our understanding of the factors that regulate arsenic accumulation in paddy soils and rice is quite limited. The objective of this paper is to develop multiple regression (MLR) models to predict arsenic content in paddy soils and rice grain and to assess which soil and water chemical characteristics are most highly related to arsenic contents.

Methods

Data from survey work by the USAID-funded project in the dry boro rice of 2002 were used to develop multiple regression models. Three hundred thirty samples each of water, soil and rice from Senbag, Faridpur, Paba, Brahmanbaria and Tala thanas were collected. Soil and grain arsenic were used as response variables in MLR models using soil and ground water properties (Table 1) as predictor variables. For adding or dropping predictors from the MLR models we calculated C_p statistics, which provides a convenient criterion for determining the most appropriate variables. We used S-plus (version 6.2 for windows) (Insightful Corp., 2003) for all statistical analyses.

Table 1. Description of variables used

Codes	***Variables Description***	***Unit***
WP	Irrigation water Phosphorous	ppm
WFe	Irrigation water Iron	ppm
WS	Irrigation water Sulphur	ppm
WAs	Irrigation water Arsenic	ppm
SpH	Soil pH	unit less
SOM	Soil Organic Matter	%
Clay	Soil Clay	%
SP	Soil Available Phosphorous	ppm
FeO	Soil Fe-oxide	ppm
SAs	Soil Total Arsenic	ppm
GAs	Rice Grain Arsenic	ppm

For developing the MLR model for soil and grain arsenic prediction, we hypothesized that at least one predictor variable among WP, WFe, WAs, SpH, SOM, SP and FeO was a significant explaining power on soil or grain arsenic. The initial MLR models are:

$$SAs = ß_0 + ß_1 WP + ß_2 WFe + ß_3 WS + ß_4 WAs + ß_5 SpH + ß_6 SOM + ß_7 Clay + ß_8 SP + ß_9 FeO + € _{(error)}$$

$$GAs = ß_0 + ß_1 WP + ß_2 WFe + ß_3 WAs + ß_4 SAs + ß_5 SpH + ß_6 SOM + ß_7 Clay + ß_8 SP + ß_9 FeO + € \text{ (error)}$$

Results

The Analysis of Variance on the initial model for soil arsenic showed that there is strong evidence that at least one of the predictor variables has a statistically significant influence on soil arsenic (p-value < 0.0001). The R^2 value indicates that all predictors (WAs, WP, WS, WFe, pH, OM, Clay, SP, FeO) explain 63.1% of the variation in arsenic concentration in paddy rice soils

Table 2. Coefficient Table of soil arsenic prediction model.

	Value	*SE*	*t value*	*Pr(>|t|)*
Intercept	-14.1	5.15	-2.73	0.0068
WAs	32.7	5.01	6.52	0.0000
WP	-2.34	0.686	-3.41	0.0007
WS	0.025	0.089	0.28	0.7762
WFe	0.397	0.106	3.73	0.0002
SpH	1.34	0.671	1.99	0.0473
SOM	-0.381	0.362	-1.05	0.2923
Clay	0.260	0.026	9.88	0.0000
SP	0.214	0.023	9.29	0.0000
FeO	0.0012	0.0003	3.90	0.0001

The relationships between soil arsenic and WAs, WP, WFe, SpH, Clay, SP and FeO were significant (Table 2). The relationship between soil arsenic and WS and SOM were not significant. We refitted the model without WS and OM, and examined the *Cp*-statistics values to determine whether they should be included. The *Cp*- statistics of WS and SOM were lower than that of the current model. Therefore, we dropped these two predictors from the initial MLR model.

The final MLR model for soil arsenic prediction was:

$$SAs = -14.8 - 2.3\ WP + 0.4\ WFe + 32.1\ WAs + 1.4\ SpH + 0.25\ Clay + 0.26\ SP + 0.001\ FeO$$

The Analysis of Variance on the initial model for grain arsenic showed that at least one of the predictor variables is statistically significant in explaining the response variable grain arsenic (p-value < 0.0001). The R^2 value indicated that all predictors (WAs, WP, WFe, SAs, pH, OM, Clay, SP, FeO) explained 42.4% of the variation in arsenic concentration of the rice grain.

Table 6. Coefficient Table of grain arsenic prediction model

	Value	**SE**	**t value**	**Pr(>|t|)**
Intercept	1.3022	0.1768	7.3668	0.0000
WAs	0.3159	0.1784	1.7703	0.0776
WP	0.0735	0.0237	3.0968	0.0021
WFe	0.0028	0.0037	0.7748	0.4390
SAs	0.0101	0.0019	5.3412	0.0000
SpH	-0.1533	0.0228	-6.7299	0.0000
SOM	-0.0162	0.0123	-1.3221	0.1871
Clay	-0.0006	0.0010	-0.6118	0.5411
SP	-0.0002	0.0009	-0.2161	0.8290
FeO	0.0000	0.0000	0.6793	0.4974

The relationships between grain arsenic and predictors SAs, WP, and SpH were significant, whereas, the predictors WAs, WFe, SOM, Clay, SP and FeO were not significant. The *Cp*- statistics of WFe, OM, Clay, SP and FeO were lower than those of the current model, and were dropped from the initial MLR model.

The final MLR model for grain arsenic prediction was:

$$GsAs = 1.3 + 0.4\ WAs + 0.08\ WP + 0.01\ SAs - 0.16\ SpH$$

Conclusions:

- WAs, WP, WFe, SpH, SOM, SP and FeO explained 63% of the total variation in arsenic accumulation in paddy rice soil.
- WAs, SAs,WP and SpH explained 42.4% of the total variation in rice-grain arsenic.

References:

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