Concentrations of arsenic and other metals in agricultural soils of Bangladesh

Mohammad Mahmudur Rahman[A,B] and Ravi Naidu[A,B]

[A]Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes campus, South Australia 5095, Australia, Email mohammad.rahman@unisa.edu.au
[B]Cooperative Research Centre of Contamination Assessment and Remediation of the Environment (CRC-CARE), P.O. Box 486, Salisbury South, South Australia 5106, Australia, Email ravi.naidu@crccare.com

Abstract
To ascertain the magnitude of arsenic (As) and other metals contamination in soils of agricultural lands, a preliminary study has been carried out from an As affected area of Bangladesh. The agricultural irrigation system of Bangladesh is completely reliant on groundwater. Large amounts of As and other heavy metals are added to agricultural soils due to the irrigation. A total of 20 agricultural land soils were analyzed by using inductively coupled plasma mass spectrometry (ICP-MS) for As and other metals following microwave assisted digestion. National Institute of Standard and Technology (NIST) standard reference material (SRM) 2711 (Montana soil) was analyzed to validate the results of As and other metals. Results from these studies show slight elevation of As in surface soils relative to background concentrations with no effect of irrigation on other metals. Further studies with a larger sample size are needed for detailed assessment of the effect of ground water irrigation on heavy metal content of agricultural soils.

Key Words
Groundwater, irrigation, microwave digestion, ICP-MS.

Introduction
Naturally elevated levels of As have been detected in the groundwater of Bangladesh. Groundwater is the primary supply of potable water for Bangladeshi inhabitants. In addition, As contaminated groundwater is generally used for agricultural irrigation. So, it is likely that huge quantity of As is pumping out with groundwater in As-affected regions and falling on agricultural irrigated lands. Therefore, it is probable that As is entering in human food chain. Accumulation of As in food crops pose potential health threats to humans. A number of studies have already been reported on As concentrations of Bangladeshi soils. Ahsan *et al.* (2009) recently reported that the range of As in floodplain soils from Faridpur district of Bangladesh was 18-65 mg/kg whereas the range of As in Dhamrai soils was 3.1-8.9 mg/kg. Another study showed that As levels of rice field soils were much higher compared to those in the non-contaminated areas (Saha and Ali, 2007). Ullah (1998) reported that irrigation with groundwater increased the levels of As in soil up to 83 mg/kg. The As content in soils ranged from 1.27–56.68, 3.18–54.77, 1.27–50.95, 1.27–39.48 and 3.18–35.66 mg/kg in Chapainawabganj Sadar, Kustia Sadar, Bera, Ishurdi and Sarishabari thanas of Bangladesh, respectively (Alam and Sattar 2000). This study reports a preliminary assessment of As and other metals content in agricultural soils of Bangladesh to determine the degree of contamination.

Materials and method
The soil samples were collected from the agricultural lands of Bangladesh during 2004. A microwave digestion system (Model: MARS 5, CEM) was used for the digestion of soil samples. The USEPA method 3051 was followed for sample digestion. ICP-MS (Agilent Technologies, Tokyo, Japan, model 7500c) was used for the determination of As and other metals. National Institute of Standard and Technology (NIST) standard reference material (SRM) 2711 (Montana soil) was used to validate the results of As and other metals. The values of soil pH and EC were given elsewhere (Rahman *et al.* 2009).

Results and discussion
Concentrations of As and other metals in agricultural soils
The analytical results of As and other metals in Montana soil showed that experimental values are very close to the certified values (Table 1). Concentrations of As and other metals in soil from each individual agricultural land are summarized in Table 2. The mean, median and range of As and other metal concentrations are presented in Table 3. The mean and median As concentrations of soils were 6.9 µg/g and 6.8 µg/g, with a range of 2.3-11.9 µg/g. Arsenic levels in paddy soils varied between 3.1 and 42.5 µg/g in a study reported from Bangladesh (Meharg and Rahman 2003). Alam and Sattar (2000) found that As levels in soils (depth 0-15 cm) ranged from not detectable level to 31.8 µg/g. They found that As content in soils was

Table 1. Concentration of elements in NIST standard reference material 2711 (Montana Soil) by ICPMS after microwave digestion.

Element	n	Certified /non-certified values	Observed values	Percentage of recovery
As (µg/g)	4	105 ± 8	107 ± 7	102
Mg (%)	4	1.05 ± 0.03	0.95 ± 0.06	85.3
Al (%)	4	6.53 ± 0.09	5.05 ± 0.15	77.4
P (%)	4	0.086 ± 0.007	0.080 ± 0.007	91.3
Fe (%)	4	2.89 ± 0.06	2.51 ± 0.04	87.0
Cr (µg/g)	4	47	45.3 ± 4.2	96.5
Mn (µg/g)	4	638 ± 28	529 ± 34	82.9
Ni (µg/g)	4	20.6 ± 1.1	18.2 ± 0.3	88.2
Cu (µg/g)	4	114 ± 2	113 ± 34	99.5
Zn (µg/g)	4	350.4 ± 4.8	331.4 ± 15.7	94.6
Cd (µg/g)	4	41.7 ± 0.25	43.5 ± 0.49	104
Pb (µg/g)	4	1162 ± 31	1153 ± 34	99.2

Table 2. Concentration (µg/g) of arsenic and other heavy metals in soils collected from the agricultural lands (n =20) individually, Bangladesh.

SMPL ID	As)	Mg	Al	P	Fe	Cr	Mn	Ni	Cu	Zn	Cd	Pb
	(---µg/g---)											
B 2	4.7	2912	16238	293	16192	29.3	203	18.6	9.9	72.7	0.07	7.7
B 3	6.6	3427	18546	440	17965	33.6	255	19.4	10.3	155.4	0.07	7.9
B 7	9.4	5099	21055	356	23098	40.8	279	28.1	13.8	65.0	0.08	9.5
B 8	10.6	5174	26421	405	25910	48.1	285	33.3	16.5	63.7	0.11	11.5
B 9	5.3	4709	25508	293	23318	46.3	267	29.9	14.5	56.8	0.07	10.7
B 10	5.9	4685	28560	282	23718	49.1	267	32.8	13.6	100.9	0.07	10.9
B 53	3.9	3102	18945	201	17574	32.8	245	20.4	11.0	142.5	0.06	8.3
B 54	3.9	2611	16973	162	15109	30.0	222	16.6	8.8	32.8	0.06	7.5
B 56	7.1	3100	16565	624	17934	30.6	268	17.4	9.8	78.3	0.08	7.8
B 60	6.2	3316	23248	195	23194	38.5	430	22.7	10.3	35.9	0.04	8.0
B 61	2.3	582	11171	175	6763	21.3	90	10.8	6.1	19.3	0.03	6.2
B 73	7.6	3691	24375	488	19610	41.3	327	21.3	11.2	293.5	0.07	8.1
B 78	9.3	5627	29573	291	28719	52.1	345	35.0	14.3	51.4	0.08	10.7
B 81	9.5	3852	23283	248	19819	39.7	233	23.5	12.1	142.8	0.06	8.2
B 83	11.9	5216	27418	373	24372	47.5	296	31.4	15.6	62.7	0.08	9.9
B 89	5.8	4007	15947	447	18035	32.5	305	19.5	11.2	157.7	0.06	6.1
B 92	8.3	4897	18646	505	22643	37.9	310	27.5	17.8	297.5	0.13	11.0
B 97	7.7	3536	20579	390	21648	36.5	360	23.0	9.8	44.2	0.06	7.9
B 101	4.9	4097	14655	507	22833	31.3	324	21.5	9.9	44.4	0.04	6.2
B 103	7.7	3179	15932	388	18991	30.0	321	18.5	8.6	137.7	0.05	6.5

Table 3. Parametric presentation of As and other metals (µg/g) in 20 soils collected from agricultural lands of Bangladesh.

Parameter	As	Mg	Al	P	Fe	Cr	Mn	Ni	Cu	Zn	Cd	Pb
	(---µg/g---)											
Mean	6.9	3841	20682	353	20372	37.5	282	23.6	11.8	102.8	0.07	8.5
Median	6.8	3771	19762	365	20733	37.2	282	22.1	11.1	68.8	0.07	8.1
Min	2.3	582	11172	162	6763	21.3	90	10.8	6.1	19.3	0.03	6.1
Max	11.9	5627	29573	624	28719	52.1	430	35.0	17.8	297.5	0.13	11.5
SD	2.5	1174	5149	126	4716	8.1	69	6.49	2.9	78.9	0.02	1.7

positively correlated with As content in irrigation water. Roychowdhury *et al.* (2002) reported that the mean As concentration of agricultural lands of West Bengal, India was 10.7 mg/kg, with a range of 3.3-31.6 mg/kg. In this study, As content in examined soils was lower compared to the studies reported from Bangladesh and West Bengal. The agricultural soils have been exposed to groundwater due to irrigation, rainwater and, on occasion, floodwater from rivers or ponds following heavy rain during the wet season (Roychowdhury *et al.* 2002). Arsenic levels in soils may thus vary throughout the year. May be this is one of the probable reasons that As levels in this study were lower compared to the other studies.

The mean concentrations of Cr, Ni and Pb in the examined soils were almost similar compared to the study conducted by Roychowdhury *et al.* (2002). The mean concentrations of Mg, Fe and Zn were much higher and Cd, Cu and Mn were lower in the examined soils compared to the study of Roychowdhury *et al.* (2002). Most of the metals in this study were much lower in the examined soils compared to the study conducted from Faridpur district by Ahsan *et al.* (2009). Figure 1 presents the bar diagram of mean concentrations of As and other metals compared with the data reported from As-affected areas of Bangladesh and West Bengal.

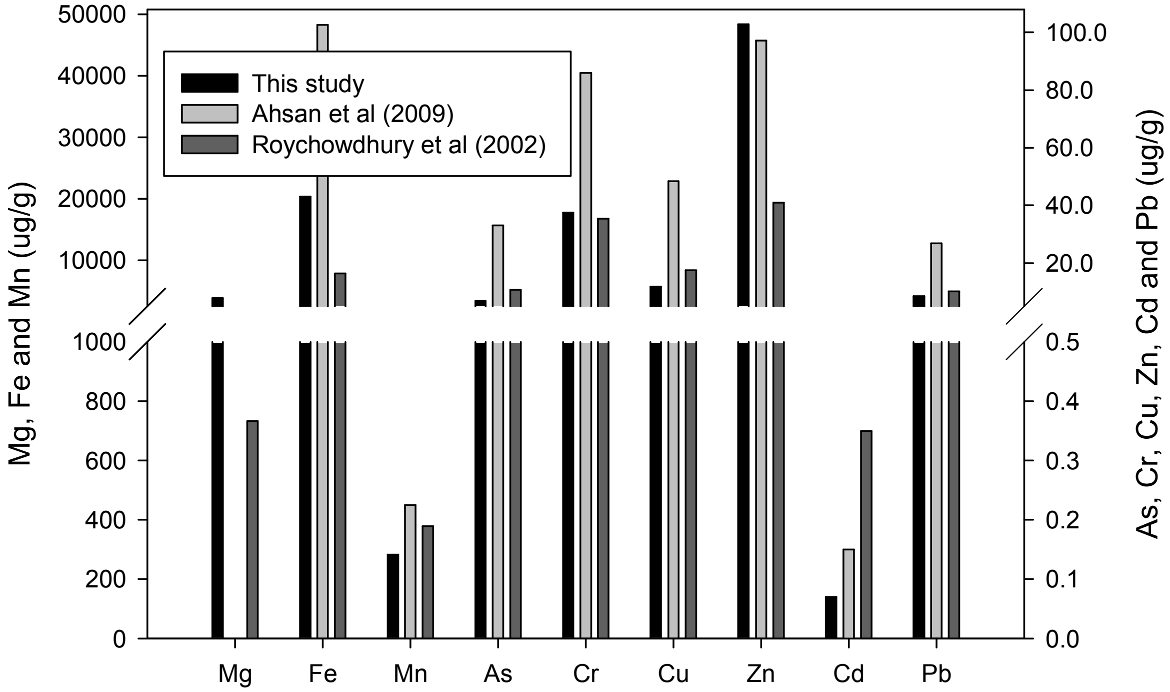

Figure 1. Comparative mean concentrations of As and other metals in agricultural land soils.

Relation between As and other metals in soils

The regression analyses were carried out between As and other metals in soil samples. The study showed positive significant correlation between As and Fe ($r^2 = 0.479$, $p<0.05$), As and Mg ($r^2 = 0.539$, $p<0.05$), As and Cr ($r^2 = 0.451$, $p<0.05$), As and Ni ($r^2 = 0.449$, $p<0.05$) and As and Cu ($r^2 = 0.457$, $p<0.05$). Ahsan *et al.* (2009) also found a positive although very weak correlation between As and Fe in both Faridpur and Dhamrai soils. Roychowdhury *et al.* (2002) found a strongly significant correlations between As and other metals such as Cu, Pb, Ni, Mn, Zn, Mg, Cr, Cd in agricultural soils of As affected area of West Bengal, but did not get any fruitful correlation between As and Fe.

Speciation of As in soils

Ion Chromatography (IC) coupled with ICP-MS was used for the determination of As species [arsenite (AsIII), monomethylarsonic acid (MMA), dimethylarsinic acid (DMA) and arsenate (AsV)] in soils. The soils were extracted using 1M ortho-phosphoric acid. As(V) was detected in all 20 soil samples (mean: 2.3 µg/g and range: 0.25-8.16 µg/g) whereas As(III) was present in 9 soils (mean: 0.38 µg/g and range: 0.21-1.12 µg/g). None of the examined soils contained DMA and MMA. The detail As extraction method and analytical procedures have been discussed elsewhere (Rahman *et al.* 2009).

Conclusion

The study revealed that mean As level in soils in our study was lower compared to the other studies conducted from Bangladesh and West Bengal. Heavy withdrawal of groundwater may be the reason to discharge As and other metals and deposits on agricultural soil. In addition, crops grown in these areas are also contaminated by As and other metals. A detailed study is required to know the contamination status of food crops such as rice and vegetables. Further studies are needed to know the As load in agricultural soils in all contaminated districts of Bangladesh. More investigation is required to determine the accumulation of As and other metals in food crops from contaminated soils.

References

Ahsan DA, DelValls TA, Blasco J (2009) Distribution of arsenic and trace metals in the floodplain agricultural soil of Bangladesh. *Bulletin of Environmental Contamination and Toxicology* **82**, 11-15.

Alam MD, Sattar MA (2000) Assessment of arsenic contamination in soils and waters in some areas of Bangladesh. *Water Science and Technology* **42**, 185-192.

Meharg AA, Rahman MM (2003) Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. *Environmental Science and Technology* **37**, 229-234.

Rahman MM, Chen Z, Naidu R (2009) Extraction of arsenic species in soils using microwave-assisted extraction detected by ion chromatography coupled to inductively coupled plasma mass spectrometry. *Environmental Geochemistry and Health* **31**, 93-102.

Roychowdhury T, Uchino T, Tokunaga H, Ando M (2002) Arsenic and other heavy metals in soils from an arsenic affected area of West Bengal, India. *Chemosphere* **49**, 605-618.

Saha GC, Ali MA (2007) Dynamics of arsenic in agricultural soils irrigated with arsenic contaminated groundwater in Bangladesh. *Science of the Total Environment* **379**, 180-189.

Ullah SM (1998) International conference on arsenic pollution of ground water in Bangladesh: causes, effects and remedies, Dhaka Community Hospital, Dhaka, Bangladesh, p 133.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.