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Effects of organics influencing the arsenic transport in soil-plant systems

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ABSTRACT

A laboratory incubation study was conducted during 2008 to evaluate the levels of arsenic concentration from the soils of contaminated and uncontaminated zone and by treating it with different doses of vermicompost, well decomposed farmyard manure and arsenic. The extractable arsenic was found to be lowered by the applied vermicompost and farmyard manure at different period of incubation. The supporting pot culture experiment with ' IET 1444' rice (*Oryza sativa* L.) by different doses of applied arsenic, vermicompost and farmyard manure demonstrated the lowering of the arsenic uptake by the influence of vermicompost and farmyard manure, irrespective of the different levels of arsenic into the soil. Hence, the incorporated organics seemed to have some moderating effects in releasing arsenic in the soil-plant systems.

Key words: Arsenic, Incubation, Moderating effects, Organics

Most of the districts (9 out of 18) in West Bengal are severely affected by arsenic contaminated water which is used by the rural villagers. The severely affected villages are in the districts of Nadia, Murshidabad, 24-parganas (north and south) and Malda of West Bengal. The average arsenic concentration in water was found to be 0.20–0.25 mg arsenic/ litre which exceed the maximum recommended concentration of 0.05 mg arsenic/litre (WHO 2001). Hence, judicious use of contaminated water is required to reduce the toxicity in drinking water and its subsequent entry into the food chain. Rice (*oryza sativa* L.), the largest water-consuming crop in the agricultural sector (Thakur *et al.* 2009) accumulates arsenic when grown in soils supplied with arsenic contaminated water (ICAR 2001, Abedin *et al*. 2002). Besides, the native organic substances in the form of humic/ fulvic substance also behaved as a good accumulator of arsenic (Mukhopadhyay and Sanyal 2004), following the formation of arsenic-humic complexes with different degrees of stability. Based on the above perspectives, the experiments were conducted with rice to evaluate the levels of arsenic concentration in soils – plant systems in presence of organic sources and also to find out the moderating effect, if any, by the applied organic substances in terms of arsenic retention or release to the soils and its subsequent entry into the plants.

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MATERIALS AND METHODS

An incubation study was conducted with soil samples from the contaminated (Sadipur under Kaliachak block II of Malda District, As>0.01 ppm in drinking water) and subjecting them to two doses of farmyard manure @ 0.5% and 1% by weight of soil (100 g) and two doses of vermicompost @ 1% and 2% by weight of soil (100 g). Simultaneously, soils from uncontaminated site (Uttar Chandipur under Manikchak block of Malda District, As <0.01 ppm in drinking water) were subject to same doses of farmyard manure and vermicompost along with two doses of arsenic @ 5 and 10 ppm by weight of soil (100 g) . The collected soils were processed and important physico-chemical properties were analyzed by the standard methods outlined by Jackson (1973).The soil samples were maintained at a moisture content equivalent to just saturation stage. The incubated soil samples were kept inside an incubator for 7, 14, 21 and 35 days maintaining a constant temperature of 30° C. The soil samples were extracted with 0.5 M $NaHCO_3$ (*p*H 8.5) on expiry of the incubation periods and the extractable arsenic in such extracts were measured by the atomic absorbsion spectrophotometer (Perkin Elmer, AAnalyst–200) coupled with the hydride generator unit.

Pot culture experiment

A supporting pot culture was conducted with the 'IET 1444' rice genotype of the affected area to study the uptake of arsenic by the crop and corresponding release from the soils, both in absence and presence of soil amendments. The

soils were treated with well decomposed farmyard manure [0.5 and 1% by weight of soil (5 kg)], vermicompost [1% and 2% by weight of soil (5 kg)], microbial inoculums (VAM) in a consortium culture of Glomas, Acaulospora and Gigaspora sp.(incorporated in all the treatments but control), and arsenic @ 5 and 10 ppm. The water level was maintained at saturation and the replication was five. Representative samples of bulk surface (0.15 m) collected from the contaminated zone (Kaliachak block II of Malda District of West Bengal) were used for the pot study. The recommended doses of N, P,K fertilizers were applied to the soils in the pot at the start of the experiment (before seeding). The optimum plant density was maintained in each pot having different treatments. The soils and plant samples were collected at different growth stages and arsenic content was measured by the atomic absorbsion spectrophotometer (Perkin Elmer, AAnalyst 200) coupled with the hydride generator systems. Plant samples collected at panicle initiation, flowering and harvest were oven-dried and digested with tri acid mixture (HNO_3: H_2SO_4: $HClO_4$: : 10: 1: 4 by volume) and the arsenic content in the digest was measured by AAS (atomic absorbsion spectrophotometer) coupled with the hydride generator unit.

RESULTS AND DISCUSSION

The important physicochemical properties of the soils are shown in Table 1. The soils were neutral to alkaline in reaction (*p*H 7.2–8.2) with varying amount of clay (10.2–15.5%), amorphous iron(0.22–0.45%), organic carbon(2.9–3.8g/kg),CEC(30.2–31.5 cmol/kg) and extractable (0.5 M $NaHCO_3$) arsenic content(1.5–50 mg/kg).

Incubation study

The effects of farmyard manure and vermicompost and applied arsenic on the 0.5 M $NaHCO_3$ (*p*H 8.5) – extractable arsenic in the soils collected from the uncontaminated site

Table 1 Important physico-chemical properties of soils

Soil	*p*H (soil:water : : 1: 2.5)	ECdS/m (soil:water : : 1: 2.5)	Organic C (g/kg)	CEC/cmol (p+)/kg	Clay (%)	Amorphous Fe (%)	0.5 M $NaHCO_3$ extractable As/mg/kg
Sadipur (As-contaminated)	7.2–7.8	0.14	2.9	30.2	15.5	0.45	10.0–50.0
Uttar Chandipur (As-uncontaminated)	7.8–8.2	0.15	3.8	31.5	10.2	0.22	1.5–2.5

Table 2 Effect of farmyard manure, vermicompost and arsenic on the extractable arsenic content (mg/kg) in soils of un-contaminated area

		7 Days			14 Days			21 Days			35 Days		
		As_0	As_1	As_2	As_0	As_1	As_2	As_0	As_1	As_2	As_0	As_1	As_2
F_0	V_0	1.50	5.06	3.86	1.03	3.43	5.20	3.55	4.09	4.05	2.05	1.91	1.73
	V_1	6.00	7.89	3.19	1.48	0.33	6.15	4.80	4.82	5.36	2.02	2.00	2.02
	V_2	4.06	6.28	2.72	3.70	3.10	4.30	4.14	4.07	4.77	1.84	2.09	2.09
F_1	V_0	2.72	4.72	3.28	1.75	1.50	6.43	4.61	5.18	5.43	1.02	2.14	2.11
	V_1	3.78	6.39	1.83	1.40	1.45	5.95	3.80	3.77	6.80	1.86	1.98	2.07
	V_2	5.72	5.22	2.00	2.50	4.80	4.08	4.98	5.05	4.95	2.02	1.98	2.02
F_2	V_0	5.36	5.06	3.86	0.60	0.68	6.30	3.75	4.20	5.05	2.11	1.84	2.00
	V_1	3.50	6.03	0.64	2.85	2.45	4.63	4.23	4.55	4.16	2.14	0.82	1.77
	V_2	3.44	3.39	1.58	2.90	5.15	4.38	5.14	5.39	3.11	2.05	1.80	1.75
Interaction		CD (*P*=0.05)		CV (%)	CD (*P*=0.05)		CV (%)	CD (*P*=0.05)		CV (%)	CD (*P*=0.05)		CV (%)
As×F		4.297		31.927	0.09818		7.447	1.5615		8.075	0.5402		8.404
V×F		1.397		10.680	1.2636		15.927	0.598		0.339	53.6937		9.929
As×V		2.296		15.969	0.9235		7.536	0.5410		2.923	0.1838		2.812
As		7.236		12.753	0.8824		1.447	3.1765		5.014	1.2995		5.607
V		9.706		15.172	7.2355		19.855	5.2942		7.634	0.4332		1.760
F		22.059		42.882	5.6472		34.043	1.2353		1.905	3.8985		19.636
As×V×F		1.0424		13.028	11.436		90.738	3.7668		33.697	0.4629		12.017

FYM level: F_0, Control; F_1, 0.5% by weight of soil; F_2, 1% by weight of soil; Vermicompost level: Vo, Control; V_1, 1% by weight of soil; V_2, 2% by weight of soil; Arsenic level: Aso, Control; As_1, 5 ppm;As_2, 10 ppm; weight of soil, 100 g

Table 3 Effect of farmyard manure and vermicompost on the extractable arsenic content (mg/kg) in the soils of contaminated area

		7 Days	14 Days	21 Days	35 Days
F_0	V_0	2.68	4.34	1.30	1.92
	V_1	4.32	4.20	1.90	2.10
	V_2	4.45	4.30	1.92	1.86
F_1	V_0	6.18	4.57	2.16	2.06
	V_1	3.23	4.32	1.58	1.64
	V_2	3.91	4.36	1.94	1.94
F_2	V_0	4.27	4.16	1.34	2.18
	V_1	4.57	3.93	1.06	2.16
	V_2	4.45	4.36	1.94	1.88

Interaction	CD (*P*=0.05)	CV (%)	CD (*P*=0.05)	CV (%)	CD (*P*=0.05)	CV (%)	CD (*P*=0.05)	CV (%)
V×F	0.4546	3.536	0.8736	6.766	1.5551	33.093	0.7869	12.945
V	2.1658	3.881	4.4195	8.556	11.9121	47.368	0.3812	1.760
F	2.9109	4.374	0.1354	0.256	0.5294	2.299	3.4307	19.636

FYM level: F_0, Control; F_1, 0.5% by weight of soil; F_2, 1% by weight of soil; Vermicompost level: Vo, Control; V_1, 1% by weight of soil; V_2, 2% by weight of soil; weight of soil, 100 g

(Manikchak block) of the district Malda (West Bengal) is shown in Table 2. It was observed that with the period of incubation, there was a wide variation in the extractable arsenic content irrespective of the different doses of the farmyard manure, vermicompost and applied arsenic. The results showed that with the higher doses of arsenic there was a gradual increase of the extractable arsenic content up to 14 days of incubation over control and thereafter a trend in reduction in arsenic was observed with the progress of time. The treatment containing either the vermicompost or farmyard manure had some role to play in reducing the arsenic content in soils which was pronounced more by the combined application of farmyard manure and vermicompost at 35 days of incubation. The significant reduction in arsenic release into the soil solution by the simultaneous application of farmyard manure and vermicompost tends to serve as binding agents in holding arsenic to the soil matrix.

The effects of farmyard manure and vermicompost on the 0.5 M $NaHCO_3$ (*p*H 8.5) –extractable arsenic in the soils collected from the contaminated site (Table 3) showed that the extractable arsenic increased over the control up to 14 days of incubation, irrespective of the different levels of the applied farmyard manure and vermicompost and thereafter, a decreasing trend in the arsenic content was apparent up to 35 days of incubation. A marginal difference was observed by the individual effect of farmyard manure and vermicompost in the arsenic content that led to significant difference when applied simultaneously in reducing the extractable arsenic in the soil solution. Hence, binding arsenic into the soil matrix was found to be effective by the applied vermicompost and farmyard manure.

Thus, the findings from the present incubation study tend to demonstrate the dependence of arsenic release into the soil solution of the given soils on applied farmyard manure and vermicompost, which were able to bind arsenic in the soil matrix. The latter thereby help moderate the toxicity of arsenic in soil/plant system.

Pot culture experiment

The arsenic uptake (mg/kg) by different plant parts of rice (root plus leaf, straw and grain) at different growth stages (panicle initiation, flowering and harvest) was recorded in the Table 4. The arsenic uptake by the root and leaf at the panicle initiation stage was comparatively higher than the flowering stage. A decreasing trend of arsenic accumulation was observed (root plus leaf>straw>grain) in plant parts at harvest. The treatment with $As_0V_2F_2$ was found to be effective in reducing arsenic uptake at different parts of the crop over different stages. Where there was either incorporation of farmyard manure or vermicompost, the levels of uptake was low, irrespective of the doses of the applied arsenic into the soils and this was found to be more effective by the combined application of farmyard manure and vermicompost into the soils. The findings thus suggested that farmyard manure and vermicompost played an important role in lowering the gradual build-up of arsenic in the rice crop.

The residual arsenic (mg/kg) status in soil (Table 5) at harvest, demonstrated the higher arsenic content in the combination $As_2V_0F_0$ compared to other treatments. The lowest arsenic content (0.72 mg/kg) in soil was recorded in the treatment $As_0V_2F_2$. A reducing effect of arsenic build-up in soil was observed by the application of either or both farmyard manure and vermicompost, may be due to the binding ability by the organics (humic/fulvic acid) and releasing less arsenic in the soil solution. Thus, the applied farmyard manure and vermicompost seem to help reducing the arsenic mobilization to the crop rhizosphere and thus

Table 4 Arsenic content (mg/kg) of rice 'IET 1444' at different growth stages under pot-culture study

Treatment		Panicle initiation (root+leaf)			Flowering (root+leaf)			Harvest: Straw			Harvest: Grain		
		F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
As_0	V_0	5.220	5.175	4.200	4.575	4.575	3.815	3.475	3.050	2.755	0.965	0.930	0.845
	V_1	4.845	4.500	4.160	4.305	3.980	3.110	2.840	2.500	1.835	0.930	0.920	0.825
	V_2	4.475	4.180	3.815	3.725	3.475	2.775	2.500	2.120	1.500	0.865	0.910	0.800
As_1	V_0	10.105	9.170	8.780	9.690	9.725	9.105	4.500	4.155	3.755	2.110	1.845	1.805
	V_1	9.375	8.815	8.430	9.480	8.655	8.110	4.160	3.725	3.325	1.695	1.640	1.500
	V_2	9.180	7.995	7.365	8.305	7.505	7.285	3.835	3.005	2.780	1.625	1.500	1.205
As_2	V_0	15.710	15.380	14.235	11.100	11.055	10.890	6.455	5.955	5.815	3.475	3.055	2.940
	V_1	14.165	12.675	12.740	11.050	10.925	10.075	5.890	5.265	5.105	3.065	2.785	2.480
	V_2	13.155	13.050	10.600	10.615	10.100	9.160	4.925	4.125	3.715	2.750	2.400	2.105

Interaction	CD (P=0.05)	CV (%)	CD (P=0.05)	CV (%)	CD (P=0.05)	CV (%)	CD (P=0.05)	CV (%)
As×F	3.8986	0.585	0.1668	0.514	0.0225	0.144	0.0979	1.275
V×F	0.2215	3.211	0.8259	2.351	0.5083	1.210	0.635	1.815
As×V	0.4255	0.465	0.2496	2.588	0.766	0.863	0.499	2.890
As	0.1698	0.039	0.8123	5.387	0.1291	1.004	0.2095	0.537
V	0.635	0.215	7.1155	2.989	0.6988	1.498	0.1906	0.557
F	0.1271	1.387	1.5247	0.954	0.5082	0.172	0.635	1.690
As×V×F	0.6530	2.705	57.9933	162.333	0.1006	1.096	0.0882	1.911

Table 5 Residual arsenic (mg/kg) in soil at harvest under pot culture study

Treatment		F_0	F_1	F_2
As_0	V_0	1.225	1.080	1.105
	V_1	1.125	0.925	0.815
	V_2	0.985	0.865	0.720
As_1	V_0	2.500	2.400	2.325
	V_1	2.330	2.160	1.800
	V_2	2.145	2.100	1.725
As_2	V_0	4.280	3.875	3.130
	V_1	3.890	3.680	3.610
	V_2	3.625	3.425	3.325
Interaction		CD (P=0.05)		CV (%)
As×F		0.499		0.984
V×F		0.536		1.886
As×V		0.3812		0.562
As		0.2541		0.885
V		0.1906		1.896
F		0.919		1.342
AS×V×F		0.0859		1.332

serving as moderating agents in the soil-plant systems.

The findings from the present study tends to enlighten the interactive effects of vermicompost and farmyard manure, in terms of releasing the extractable arsenic content in the soil solution, where, the applied organics might have some effect in binding the arsenic into soil matrix and thus restricting its entry into the plants.

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REFERENCES

Abedin Md J,Cresser M S, Meharg A A,Feldmann J and Cotter-Howells J.2002. Arsenic accumulation and metabolism in rice (*Oryza sativa* L.). *Environmental Science and Technology* **36**(5): 962–8.

ICAR 2001. *Final Report: Status, Causes and Impacts of Arsenic Contamination in Parts of West Bengal vis-à-vis Management of Agricultural Systems. Ad-hoc* scheme executed (1998–2001) by BCKV (Nodal Centre), NBSS & LUP, Regional Centre, Kolkata; NDRI, Eastern Regional Centre. Kalyani, GSI, Government of India, Kolkata; CSSRI, Regional Research Station, Canning Town; SWID, Government of West Bengal, Kolkata.

Jackson M L.1973.*Soil Chemical Analysis.* Prentice Hall of India Pvt Ltd, New Delhi.

Mukhopadhyay D and Sanyal S K. 2004. Complexation and release isotherm of arsenic in arsenic –humic/fulvic equilibrium study. *Australian Journal of Soil Research* **42**: 815–24.

Thakur A K, Chaudhari S K, Singh R and Kumar A. 2009. Performance of rice varieties at different spacing grown by the system of rice intensification in eastern India. *Indian Journal of Agricultural Sciences* **79**(6): 443–7.

WHO 2001. http: //www. who. int/inf-fs/en/fact210html.