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Sorption and availability of arsenic as influenced by soil properties in soils of Aligarh

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ABSTRACT

The effect of soil organic matter, soil moisture regime, available iron, zinc and ionic strength on arsenic availability in two soils (one of Gangetic alluvial plain and other of bank of Yamuna River) was investigated in the laboratory after 45 d of incubation. The results denote that availability of arsenic increased with organic matter and soil moisture regime (i.e. waterlogging), while it decreases with application of iron and zinc. Availability of arsenic decreased with increase in ionic strength which may be due to more adsorption. From these studies it may be inferred that application of iron fertilizer appeared to be more effective in reducing arsenic availability in soil. Application of high dose of organic manure and soil moisture regime affects adversely.

Key words: soil, arsenic availability, ionic strength, organic manure

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INTRODUCTION

Public concerns over arsenic pollution in both soils and water have substantially increased in recent years [1, 2]. Because As is suspected to be responsible for bladder, kidney, liver, lung and skin cancers, As has been listed by USEP A as a class A human carcinogen[3]. The current maximum permissible limit of arsenic for oral intake and drinking water are set at 0.3 ▯ g $kg^{-1}d^{-1}$ and 50 /lgL-$^{-1}$ respectively [4]. In addition to water contamination, the dietary intake of arsenic through the food chain via uptake from contaminated soils may adversely affect human health [5].

The main source of arsenics in soil is the parent materials from which soil is derived. Also, bio-concentration of arsenic by low land and aquatic organisms such as algae, sea grass and lower invertebrates contributes to elevate arsenic concentration [6]. Recent studies have shown that ground water of entire Ganga basin is contaminated with arsenic [7].

Uptake of arsenic by plant roots depends on the concentration of arsenic in soil solution. Adsorption of metals from liquid phase to the solid phase is one of the most important chemical processes which control the concentration of metal ions and complexes in the soil solution thereby exerting a major influence on their uptake by plant roots. The adsorption and availability of arsenic in soil is influenced by soil organic matter [8]; available iron, zinc [9]; soil moisture [10]; ionic strength; soil salinity etc. So, it was considered useful to study the impact of select soil properties viz. organic matter; available Fe, Zn, soil moisture, ionic strength and soil salinity on plant availability of arsenic in soils of Aligarh district.

EXPERIMENTAL

Two surface soils (0-30 cm) one from Gangetic plain (Ramghat) and other from Bank of Yamuna (Tappal) from Aligarh district were collected and sieved through 100 mesh sieve. Physiochemical properties as determined by usual methods are given in Table 1.

To study the effect of selected soil properties on plant availability of arsenic each soil was incubated under the following five treatments for 45 days at temperature 30±3^{o}C.

(i) Soil organic matter : Four levels of soil organic carbon were maintained by adding calculated amount of well decomposed FYM so that organic carbon level in each could be increased by 0, 25, 50, 80% of original level i.e. 0.82, 1.02, 1.23, 1.48% for soil 1 and 0.56, 0.70, 0.84, 1.01% for soil 2. The final organic carbon levels in soil were assessed by laboratory analyses before the start of the incubation. Five levels of arsenic applied to soil were 0, 5, 10, 30, 60 and 100 mg arsenic kg^{-1} soil. Different As levels in soil were obtained by adding measured amounts of arsenic solution to soil.

(ii) Soil moisture regime : Three soil moisture regimes were maintained using distilled water i.e. 20%, 50% and 100% of water holding capacity and six levels of As (as above) were added.

(iii) Available Fe: Four levels of Fe i.e. 0, 5, 10, 20 mg Fe kg^{-1} soil with six levels of arsenic (as above) were maintained.

(iv) Available Zn: Four leaves of Zn 0, 5, 10, 20 mg Zn kg^{-1} soil with six levels of arsenic (as above) were maintained.

(v) Ionic strength: Four levels of NaCl 0.01, 0.1, 0.5, 1.0 M with six levels of arsenic (as above) were used to evaluate the effect of ionic strength.

Soils were incubated under 50% moisture regime for each treatment except in (ii). Amount of arsenic, iron and zinc were added as $Na_2HASO_4.7H_2O$, $(NH_4)_2SO_4.FeSO_4.6H_2O$ and $ZnSO_4.7H_2O$. The soil samples were incubated for 45 days at 25±2^oC. The moisture regime was maintained by adding distilled water after weighing daily. DTPA extractable available Fe, Zn in soil was estimated using atomic absorption spectrophotometer. Total and Olsen extractable {i.e. 0.5M $NaHCO_3$ (pH 8.5) extractable} arsenic (which constitute the soil arsenic pool amenable to plant uptake) [11] were estimated with the help of AAS using hydride generator.

RESULTS AND DISCUSSION

With increase in arsenic application there was an increase in its available content. The increase in available As content of soil following its application was more in the Tappal soil (Bank of Yamuna) than in Ramghat soil (Gangetic plain). This denote that adsorption and/or fixation of arsenic depends on clay content and organic matter (Ramghat soil has higher concentration of clay than Tappal soil). Other workers have also reported similar findings [8,12].

The application of organic manure (Table 2) caused a considerable increase in the available arsenic content of soil. The increase was more in Bank of Yamuna soil than in Gangetic plain soil. The increase in arsenic content may be due to induced solubilization of fixed soil-As content. These results denote that higher doses of organic manure encouraged more contamination of crop plants with arsenic. Similar results are also reported by Cabrera *et a1* [13], Bandhopadhyay *et al*. [14].

Table 3 denotes that availability of arsenic in soil is also influenced by soil moisture regime. With the increase of moisture regime from 20 to 100% of water holding capacity the mean availability of arsenic increased from 5.78 to 8.44 mg kg^{-1} for soil 1 and 6.61 to 8.34 mg kg^{-1} soil for soil 2. The increase in arsenic content with moisture regime may be due to more release of soil arsenic or less fixation of arsenic in soil under higher moisture regime. The increase in available arsenic from 20 to 50% moisture regime was lesser than from 50 to 100%. Reynolds *et al*.[10] also observed similar effects.

Table 1. Physico-chemical characteristics of soils

Soil properties	Gangetic soil (Soil 1)	Soil of Yamuna Bank (soil 2)
Taxonomic name	Alluvial typic ustochrept	Calicorthents
pH	7.9	8.1

CEC (cmol(P$^+$) kg^{-1})	11.2	9.0
Organic carbon (g kg^{-1})	8.2	5.6
EC (dS m^{-1})	0.72	0.46
Silt %	38.0	27.0
Clay %	17.0	8.6
Major clay minerals	M, Q, I, C	Q, I, K,C
Available arsenic (mg kg^{-1})	0.22	0.31
Available iron (mg kg^{-1})	36.0	23.5
Available zinc (mg kg^{-1})	0.42	0.36

Q = Quartz, I = Illite, M = Montmorillonite, C = Calcite, K = Kaolinite

Table 2. Effect of organic matter application on arsenic (mg kg^{-1} soil) availability in soils after 45 d of incubation

Applied arsenic to soil (mg kg^{-1} soil)	Organic carbon in soil (%)									
	Soil 1					Soil 2				
	0.82	1.02	1.23	1.48	Mean	0.56	0.70	0.84	1.01	Mean
0	0.22	0.28	0.39	0.39	0.32	0.31	0.50	0.64	0.69	0.54
5	1.06	1.24	1.54	1.86	1.43	1.40	1.76	2.18	2.88	2.05
10	2.12	2.42	2.68	2.90	2.53	2.36	2.86	3.14	3.86	3.05
30	5.60	6.06	7.04	7.24	6.48	6.12	7.16	7.84	8.14	7.32
60	11.24	12.64	14.60	15.86	13.58	12.46	14.42	16.34	19.12	15.58
100	16.62	18.14	20.16	22.24	19.29	18.66	20.92	22.14	24.06	21.44
Mean	6.14	6.80	7.73	8.41	7.27	6.88	7.94	8.71	9.79	8.33

CD (P=0.05)	Arsenic	=	0.88
	Arsenic	=	1.20
	Organic matter	=	0.34
	Organic matter	=	0.76

Table 3. Effect of soil moisture regimes on arsenic (mg kg^{-1} soil) availability in soils after 45 d of incubation

Applied arsenic to soil (mg kg^{-1} soil	Soil moisture regime							
	Soil 1				Soil 2			
	20%	50%	100%	Mean	20%	50%	100%	Mean
0	0.20	0.22	0.30	0.24	0.28	0.31	0.38	0.32
5	0.94	1.06	1.26	1.09	1.26	1.40	1.76	1.47
10	2.06	2.12	2.66	2.28	2.18	2.36	3.14	2.56
30	5.04	5.60	6.84	5.83	5.94	6.12	7.42	6.50
60	10.60	11.24	14.66	12.17	12.03	12.46	16.68	13.72
100	15.84	16.62	24.94	19.13	17.94	18.66	20.66	19.09
Mean	5.78	6.14	8.44	6.79	6.61	6.88	8.34	7.28

CD (P=0.05)	Arsenic	=	0.66
	Arsenic	=	1.20
	Moisture regime	=	0.24
	Moisture regime	=	0.76

Table 4. Effect of iron on the arsenic (mg kg^{-1} soil) availability in soils after 45 d of incubation.

Applied arsenic to soil (mg kg^{-1} soil)	Iron applied (mg kg^{-1}) to soil									
	Soil 1					Soil 2				
	0	5	10	20	Mean	0	5	10	20	Mean
0	0.22	0.22	0.20	0.20	0.21	0.31	0.31	0.29	0.27	0.30
5	1.06	0.92	0.80	0.60	0.85	1.40	1.22	1.02	0.90	1.13
10	2.12	1.56	1.22	1.02	1.48	2.36	2.04	1.82	1.54	1.94
30	5.60	5.02	4.50	4.04	4.79	6.12	5.34	4.74	4.02	5.06
60	11.24	10.36	9.74	9.00	10.09	12.46	11.72	10.98	10.34	11.38
100	16.62	15.78	14.80	13.16	15.15	18.66	17.84	16.98	15.84	17.33
Mean	6.14	5.64	5.21	4.67	5.42	6.88	6.41	5.97	5.48	6.19

CD (P=0.05) Arsenic = 0.22 Arsenic = 0.24
Iron = 0.18 Iron = 0.23

Table 5. Effect of zinc on the arsenic (mg kg^{-1} soil) availability in soils after 45 d of incubation.

Applied arsenic to soil (mg kg^{-1} soil)	Zinc applied (mg kg^{-1}) to soil									
	Soil 1					Soil 2				
	0	5	10	20	Mean	0	5	10	20	Mean
0	0.22	0.22	0.20	0.20	0.21	0.31	0.31	0.29	0.29	0.30
5	1.06	1.02	0.92	0.80	0.95	1.40	1.26	1.14	1.10	1.23
10	2.12	1.92	1.76	1.62	1.85	2.36	2.22	2.10	2.00	2.17
30	5.60	5.10	4.84	4.76	5.08	6.12	5.84	5.66	5.50	5.78
60	11.24	10.88	10.46	10.32	10.72	12.46	12.02	11.84	11.66	12.00
100	16.62	16.22	15.84	15.66	16.06	18.66	18.04	17.44	17.02	17.79
Mean	6.14	5.89	5.67	5.56	5.81	6.88	6.61	6.41	6.26	6.54

CD (P=0.05) Arsenic = 0.21 Arsenic = 0.33
Zinc = 0.16 Zinc = 0.22

Table 6. Effect of ionic strength on the arsenic (mg kg^{-1} soil) availability in soils after 45 d of incubation.

Applied arsenic to soil (mg kg^{-1} soil)	Ionic strength									
	Soil 1					Soil 2				
	0.01M	0.1M	0.5 M	1.0M	Mean	0.01M	0.1M	0.5M	1.0M	Mean
0	0.26	0.24	0.22	0.22	0.23	0.33	0.30	0.28	0.28	0.30
5	1.10	1.02	0.96	0.96	1.01	1.62	1.50	1.46	1.42	1.50
10	2.30	2.12	2.00	1.94	2.09	2.58	2.40	2.24	2.18	2.35
30	6.00	5.82	5.60	5.44	5.71	6.74	6.40	6.20	6.10	6.36
60	12.24	12.00	11.66	11.30	11.80	13.40	13.00	12.50	12.34	12.81
100	17.44	16.86	16.32	15.86	16.62	19.14	18.60	18.10	17.88	18.43
Mean	6.56	6.34	6.11	5.94	6.24	7.30	7.03	6.79	6.70	6.45

CD (P=0.05) Arsenic = 0.14
Arsenic = 0.18
Ionic strength = 0.22
Ionic strength = 0.24

A survey of Table 4 and 5 denote that availability of arsenic decreases with the application of iron and zinc. Iron was more effective than zinc in reducing the available arsenic in the soil. The decrease in arsenic availability may be due to formation of unavailable Fe or Zn-arsenate as well as adsorption of soluble arsenic on hydrous ferric oxides[15]. Similar inferences were also inferred by Reynolds et al [10], Craw and Chappel [16].

With increase in ionic strength the amount of available arsenic decreases (Table 6), which may be due to increase of arsenic adsorption by soil. Increase in arsenic adsorption with ionic strength may be due to (a) change in thickness of diffuse layer [17], (b) increased negative charge on the edge surface of soils [18]. Increase in adsorption with ionic strength is also reported elsewhere [19,20].

From these studies it may be concluded that organic matter, soil moisture regime increases the availability of arsenic to crop plants while application of iron, zinc minimize the availability of As in soil and its uptake by crops.

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