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Effect of arsenic contamination on enzyme activities in arsenic contaminated soils of India

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Abstract

A study was conducted to see the effect of arsenic contamination on soil enzyme activities, viz., β-glucosidase, urease, acid and alkaline phosphatase and aryl sulphatase in arsenic contaminated soils of West Bengal, India. A sequential extraction technique was used to measure water soluble, exchangeable, carbonate bound, Fe/Mn oxide bound, organically bound, and residual As fractions. As concentrations in the two most labile fractions (i.e., water soluble and exchangeable fractions) were generally low. The total As concentration at each site seems to be associated with soil amorphous Fe and Al minerals. The studied enzymes were significantly and negatively correlated with water soluble and exchangeable As but did not show any significant correlations with other forms, indicating that water soluble and exchangeable forms exert a strong inhibitory effect on the soil enzyme activities.

1. Introduction

Arsenic pollution in groundwater in India and Bangladesh is considered to be the largest contamination problem in the world. Presently, 5 million people in 978 villages from 8 districts are drinking As contaminated water having As concentration above 0.01 mg As/L. Soil acts as a principal sink of As in the environment, which comes from the contaminated groundwater aquifers through irrigation. The total As concentrations in soil cannot provide a precise index for evaluating their influence on soil enzyme activities. By sequential extraction technique, we can measure metal fractions of different solubilities and mobilities, and which can provide information for predicting metal availability to microorganisms and transformation between different forms of metals in soils. The importance of the enzyme activities study lied in the fact that enzymes control the mineralization of organic matter and availability of plant nutrients, like C, N, P and S and therefore, indicators of soil quality. Soil enzymes are also used to estimate the adverse effects of various pollutants on soil quality. In order to assess the effects of As fractions on enzyme activity, we measured β -glucosidase, urease, phosphatase, and sulphatase activity. By using these properties, it might be possible to determine how the soil ecosystem is being adversely affected

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by various As forms in soils.

2. Method

Forty surface (0-20 cm) soil samples, ten from each site (three from arsenic affected soil and one from a normal soil) were collected and brought to the laboratory in properly labeled and sealed polythene bags. The physico-chemical analyses, total and fractionation of As and enzyme activities were estimated by standard method. Statistical analyses such as factor, correlation, and regression analyses were carried out using SPSS 13.0.

3. Results and Discussion

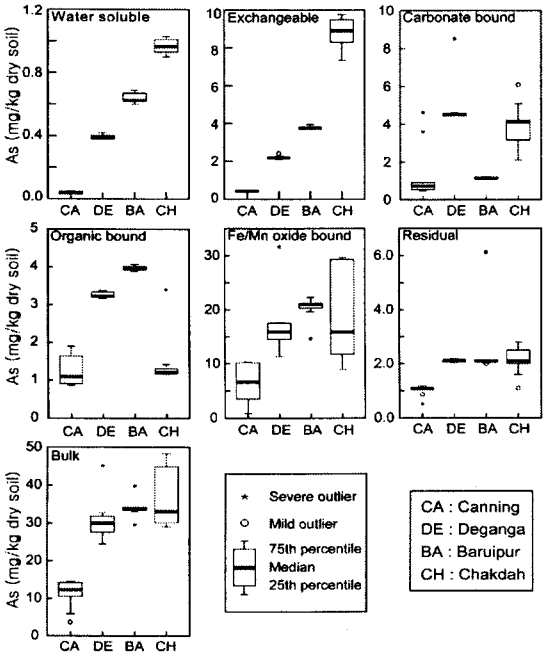

Fig. 1 Concentrations of each As fraction in the studied soils

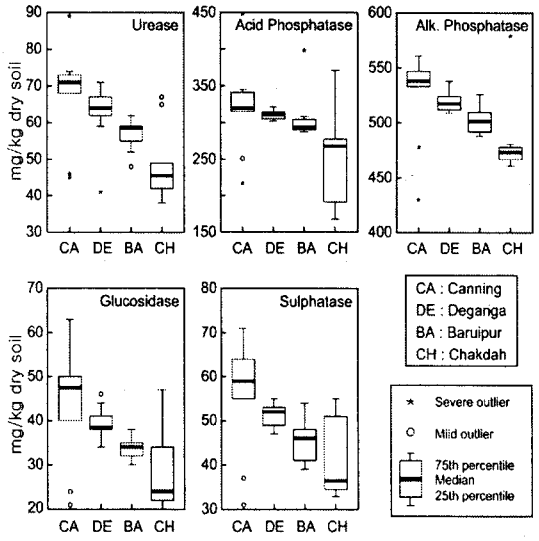

Fig. 2 Enzyme activities in the studied soils

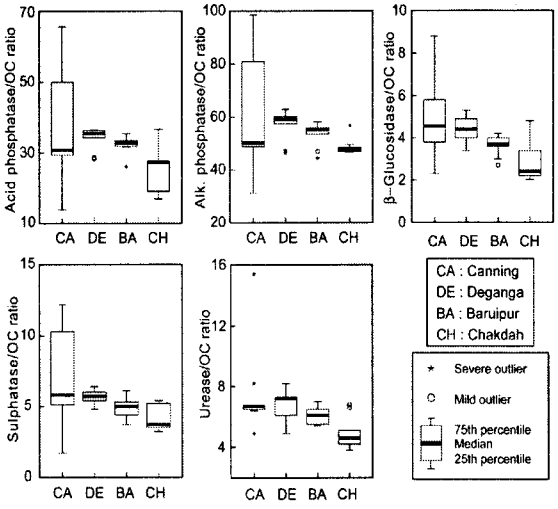

Fig. 3 Ratio of enzyme activity with organic carbon in the studied soils

Table 1. Correlation analysis results between studied parameters

Parameter	OC	WS	EX	CBD	ORG	OXD	Residual	Bulk
WS	-	1	0.95**	0.28	0.13	0.60**	0.44**	0.80**
EX	-	0.95**	1	0.27	-0.13	0.45**	0.3	0.66**
CBD	-	0.28	0.27	1	-0.01	0.15	0.01	0.36*
ORG	-	0.13	-0.13	-0.01	1	0.42**	0.49**	0.43**
OXD	-	0.60**	0.45**	0.15	0.42**	1	0.49**	0.93**
Residual	-	0.44**	0.3	0.01	0.49**	0.49**	1	0.55**
UA	0.38*	-0.63**	-0.63**	-0.21	0.02	-0.23	-0.22	-0.41*
Ap	-0.15	-0.44**	-0.52**	-0.14	0.03	-0.1	-0.17	-0.25
AlP	0.25	-0.52**	-0.51**	-0.2	0.04	-0.12	-0.17	-0.29
Gluco	0.35*	-0.60**	-0.55**	-0.15	-0.01	-0.17	-0.22	-0.34*
Sul	-0.39*	-0.60**	-0.60**	-0.07	-0.13	-0.29	-0.23	-0.42**
UA/OC	-0.54**	-0.53**	-0.53**	0.04	-0.04	-0.3	-0.16	-0.39*
Ap/OC	-0.75**	-0.42**	-0.45**	0.01	-0.06	-0.27	-0.17	-0.33*
Alp/OC	-0.85**	-0.34*	-0.34*	0.05	-0.06	-0.27	-0.11	-0.3
Glu/OC	-0.42**	-0.59**	-0.55**	0.03	-0.02	-0.25	-0.19	-0.36*
Sul/OC	-0.75**	-0.49**	-0.47**	0.01	-0.16	-0.36*	-0.2	-0.42**

*,** correlation is significant at 5% and 1% levels, respectively.
OC-organic carbon content, WS-water soluble, EX-exchangeable, CBD-carbonate bound, ORG-organic bound, OXD-Fe oxide bound, UA-urease, Ap-acid phosphatase, Alp-alkaline phosphatase, Gluco-β glucosidase, Sul-aryl sulphatase

The soils were slightly alkaline in nature (6.9-7.5) and clay loam to clay in texture. Organic carbon and total nitrogen contents ranged from 0.03 to 0.93 g·kg-1. Total As content was highest in Chakdah followed by Baruipur, Deganga, and Canning. The dominant As fractions were those bound to Fe (III) and Mn (IV) oxides. All forms are higher in the As contaminated soils of Deganga, Baruipur, and Chakdah than those in the control soil (Canning). Water soluble (mean 0.97 mg/kg) and exchangeable (mean 8.82 mg/kg) fractions are thehighest in Chakdah soil. Significantvariations in enzyme activities according to the soils were indicated in this study (Fig. 2). The control soils showed the highest activities for all the investigated enzymes but the Chakdah soils generally showed the lowest levels. Expressing enzyme activities on an organic carbon basis can give an improved understanding of metal stress.

The highest and lowest values of enzyme/organic carbon ratios were obtained in Canning and Chakdah soil respectively reflect the direct inhibitory effect of As on soil enzymes(Fig. 3). Correlation analysis showedthat the activities of all enzymes and enzyme activity/OC ratios are significantly and negatively correlated with water soluble and exchangeable As fractions (Table 1). In contrast, carbonate bound, Fe/Mn oxide bound, organic matter bound, and residual fractions do not indicate any significant correlations with enzyme activities.

4. Conclusion

Correlation analysis showed that the water soluble and exchangeable As exerts greater inhibitory effect on enzyme activities compared to other forms. Reducible Fe and Mnoxide bound fractions are important for controlling the bioavailability of As in the submerged rice soil. This signified that with increase in bioavailability, arsenic exerted more inhibitory effect on these microbiological parameters.