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Mineralogical study of some arsenic contaminated soils of West Bengal, India

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Abstract

Five arsenic affected soil profiles, one each from Ghentugachhi and Gotera village of Chakdah block, Gayeshpur, Kalyani block, Nadia district; Ramnagar village of Baruipur block and Sonarpur mouza of Sonarpur block of South 24 Parganas district of West Bengal, India covering the soils of Typic Haplustepts, Typic Endoaquepts, Vertic Haplustepts and Aquic Haplustepts respectively have been studied for their detail mineralogical, chemical composition and also to know the level of arsenic contamination and their probable source. These soils are very deep, developed on Alluvium and are under rice, vegetable and guava cultivation. Sand mineralogy data of these soils are dominated by opaque and limonite, whereas silt is mainly constituted of micas followed by kaolinite and chlorite. The clay mineralogy of the soils indicates that smectite is in higher proportion in Ghentugachhi and Gotera soils followed by mica, kaolinite, chlorite and vermiculite and in the other soils, mica is the dominant clay mineral. In some of these soils, the interstratified mixed layer minerals are also present. The mineralogy class for the soils of Ghentugachhi, Gayeshpur, Baruipur is 'mixed' and for Gotera and Sonarpur it is 'illitic'. Differential thermal analysis (DTA) of clay fraction of surface soil of the profiles displayed the presence of the minerals like magnetite, marcasite, arsenopyrite, illite, montmorillonite and quartz. The source of arsenic in these soils are probably due to the presence of arsenic bearing minerals, marcasite and arsenopyrite, and also it may occur as adsorbtion on iron hydroxide coated sand grains and clay minerals. Arsenic concentration is very high in the surface horizon of pedon 2 (20.2 mg kg^{-1}) and it shows a decreasing trend down the subsurface horizon. The higher concentration of arsenic in the surface horizon may be due to higher abundance of opaque minerals, limonite, and marcasite.

Keywords: Arsenic; Soil; Mineralogy; XRD; DTA

1. Introduction

Arsenic pollution in groundwater in India and Bangladesh is considered to be the largest contamination problem in the world. In the eastern state of West Bengal (India), groundwater resources are quite rich and a major part of the groundwater is used for drinking, agricultural and industrial purposes. With the ever-growing population due to rapid urbanization, industrial and agricultural expansion, groundwater is often being used extensively and erratically, causing a deleterious effect on water quality. In some areas of Bangladesh and West Bengal (India), the concentration of arsenic (As) in groundwater exceeds the guideline concentration set internationally and nationally at 10–50 mg As/l. Presently, in West Bengal 5 million people in 978 villages from eight districts and southern part of Kolkata

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(Ghosh et al., 2004a,b) are drinking As contaminated water, having As concentration above 0.01 mg As/l (WHO, 1996). Such groundwater is also used for irrigation and this makes it possible for As to enter the human food chain through locally grown food crops and vegetables. Adak et al. (2002) showed that the potato contents appreciable amount of As in its tuber, stem and leaf which are grown in the soils having As level of 1.50 mg kg^{-1} and irrigated by arsenic contaminated ground water in Nadia district, West Bengal, India. The similar findings are also reported by Bhattacharyya et al. (2003) in rice growing soils under submerged condition (As content in soil was 2.37 mg kg^{-1}). Ghosh et al. (2004) showed that the low levels of As (3.84–6.15 mg kg^{-1}) decreased the microbial biomass and their activities. There is also a chance of a concomitant biomagnifications of arsenic as it moves up the food chain. Soil is a principal sink of As in the environment and as most of the arsenical residues have low solubility and low volatility, they generally accumulate in the topsoil layers (Woolson et al., 1973).

Mineralogy plays an important role to understand the genesis, physical and chemical properties of the soils. The amount and the nature of clay, silt and sand minerals mainly control As adsorption in soils. The study of primary minerals in sand fractions are important to know the amount and nature of weatherable minerals, nature of inclusion, shape of the grains, nature of parent materials and stages of soil transformations during weathering processes (Bullock et al., 1985; Venugopal, 1992; Lekha et al., 1998; Niranjane et al., 2001). The important minerals that control the arsenic absorption capacity of the soils include Fe and Al oxides (Jacabs et al., 1970; Livesey and Huang, 1981; Fuller et al., 1993). Many workers (Ghosh and De, 1995; Saha et al., 1997; Acharyya et al., 1999, 2000) studied the toxicity in the ground water of West Bengal by taking core sample sediment collected by drilling up to depth of 250 m and analysed the samples for heavy minerals in the sediment particularly belonging to the upper delta plain of Meander belt. These authors indicated that arsenic rich pyrite or other arsenic minerals are rare or absent in the sediments. They also concluded that arsenic appears to occur adsorbed on iron hydroxide coated sand grains and clay minerals and transported in soluble form and coprecipitated with or is scavenged by Fe (III) and Mn (IV) in the sediment.

With this background information, an attempt has been made to report on physical, chemical and mineralogical characteristics of the soils and to know the probable soil components that are responsible for As retention/source in the soils of West Bengal.

2. Materials and methods

2.1. Study area

The study area lies in the Indo-Gangetic alluvial plain covering Gotera village (latitude 23°0′37″ and longitude 88°34′30″), Ghentugachhi village (latitude 23°1′19″ and longitude 88°33′37″) in Chakdah Block, Gayeshpur (latitude 22°56′35″ and longitude 88°29′44″) in Kalyani block, District-Nadia; Ramnagar village (latitude 22°25′15″N and longitude 88°27′30″E) in Baruipur block, District-24 Parganas (S) and in Sonarpur, District-24 Parganas (S).

2.2. Soil surveys

Detailed soil survey of the above stated blocks were carried out on a 1:4000 scale and five soil profiles were studied in details in different arsenic contaminated zones and soil samples were collected horizon wise. Soil samples were air dried and ground in a mortar pestle. The morphological properties of the profiles are described as per standard terminology of the USDA soil survey manual (Soil Survey Staff, 1998). All the important physical and chemical properties were determined according to the methods outlined by Jackson (1979).

2.3. Mineralogical analysis: sand mineralogy

Particle size analyses were carried out following the international pipette method. Sand (2000–50 μm), silt (50–2 μm) and total clay (<2 μm) fractions were separated from the samples after dispersion according to the size segregation procedure of Jackson (1979). Total sand was passed through sieve and different size fractions were separated following the standard procedure (Day, 1965). Fine and very fine sand of the selected horizons were separated and fractionated into heavy and light mineral fractions using bromoform (specific gravity 2.85). These mineral fractions were then mounted on slides with Canada Balsam and mineral species were identified using Laborlux-12 petrographic microscope for qualitative estimation (Cady, 1965). For semi-quantitative estimate nearly 275 grains were counted in all the slides and their percentage abundance was calculated.

2.4. Clay and silt mineralogy

Oriented clay (<2 μm) and silt fractions (50–2 μm) were subjected to X-ray diffraction (XRD) analyses after saturating the samples with Ca and solvated with ethylene glycol, K saturated and heated to 25, 110, 300 and