

Degradation of Agricultural Soils in a Coastal Zone of the Red River Delta, Northern Vietnam

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論 文 名 : Degradation of Agricultural Soils in a Coastal Zone of the Red River Delta,
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(北部ベトナム紅河デルタの海岸地帯における農地土壌の劣化)

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論 文 内 容 の 要 旨

The first study on arsenic and heavy metal contamination in soil and sediment in different land uses in the biggest estuarine area in northern Vietnam was conducted. The study showed current status of As and five heavy metals (Pb, Cr, Cd, Zn, Cu) contents in soils and sediments in this area. The detail information of soil characteristics was revealed. In addition, several biodegradable organic acids were used to investigate the remediation ability for the contaminated soils. The study was divided into six chapters.

In the Chapter 1, general introduction of this study was presented, which including the background of the study. The main subjects and purposes of the study also were showed in this chapter.

In Chapter 2, the information of study area was exhibited. The important methods, which used in present study also were presented .

Chapter 3 showed the results of As and heavy metals analysis in surface soil and sediment samples, which were sampled in Ba-Lat estuary, northern Vietnam. The results in this chapter clarified the contamination levels, supply sources and the effect of land use on the heavy metal concentrations in the estuary. Soil samples were collected from the top soil layer of the estuary, and their arsenic (As), chromium (Cr), cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) concentrations were analyzed along with soil properties. Most soils in the estuary were loam, silt loam and sandy loam soils. The pH was neutral and cation exchange capacity was in the range from 3.8 to 20.2 meq/100 g soil. Manganese and iron concentration were on average 811 $\mu\text{g}\cdot\text{g}^{-1}$ and 1.79 %, respectively. The magnitude of the heavy metal concentrations of the soils were in the order of $\text{Zn} > \text{Pb} > \text{Cr} > \text{Cu} > \text{As} > \text{Cd}$. The concentrations were higher in the river bed and mangrove forest than in the other land use areas. The mean concentrations of the heavy metals were mostly lower than the permissible level in agricultural soils in Vietnam, except for As concentration. The correlation and principal component analyses showed that As, Pb, Zn, Cd and Cu in the soils were of anthropogenic origin, whereas Cr was of non-anthropogenic origin. The spatial distribution of the concentrations with land use indicated that the mangrove forest played an important role in preventing the spread of heavy metals to other land uses and maintaining the estuarine environment.

In Chapter 4 of this study, the first investigation of arsenic (As) contamination in soil cores in Ba-Lat estuary, the biggest estuarine ecosystem in northern Vietnam, was conducted. Concentration of As together with other heavy metals and mineralogy characteristic of soils and sediments in different land uses were analyzed using XRD, EPMA and ICP-MS techniques. Most of the soils contained high proportions of As in

iron, manganese (hydr)oxides, and iron crystalline whereas heavy metals were mainly in fractions that associated with carbonate, iron and manganese oxides and silicate minerals. High concentrations of As (up to 39.3 $\mu\text{g}\cdot\text{g}^{-1}$) and heavy metals were observed in river sediments and top-layers of mangrove forest soil cores. Quantitative analyses using WDS technique on FE-EPMA system found As on the surface of iron (hydr)oxides and framboidal pyrite in the samples, especially in the mangrove forest soils and river sediments. The principal component analysis indicated the enrichment of As and heavy metals in the upper soil layers, suggesting that intensive human activities in upstream of Red river in recent decades were the cause of elevated levels of these toxic elements in the estuarine ecosystem of Ba-Lat estuary.

In Chapter 5, a series of remediation tests were conducted using a washing method with biodegradable organic acids, including oxalic, citric and ascorbic acids. The single oxalic and citric acid solutions showed lower efficiency for arsenic removal than the combination of these acids with ascorbic acid. Approximately 80% of the arsenic in one sample was removed under the effect of the ascorbic and oxalic acid combination, which was roughly twice higher than the effectiveness of the ascorbic and citric acid combination under the same conditions. The close correlation between extracted arsenic and extracted iron/aluminum suggested that arsenic was removed via the dissolution of Fe/Al oxides in soils. The fractionation of arsenic in four contaminated soils was investigated using a modified sequential extraction method. Regarding fractionation, we found that most of the soil contained high concentrations of arsenic (As) in exchangeable fractions with phosphorus, amorphous oxides, and crystalline iron oxides, while a small amount of the arsenic fraction was organic matter bound. After treatment with the degradable organic acids, most of the arsenic content remaining in the soils was in iron crystalline oxides, organic matter and residual fractions. This study indicated that the use of biodegradable organic acid is not only an environmentally friendly method but also a highly effective means for arsenic-contaminated soil remediation.

Finally, the summary conclusions were exhibited in Chapter 6 based on the results in previous chapters.