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Cadmium Status of Some Soils and Sewage Sludge in Red River Delta of Vietnam

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This paper reports the total cadmium content in Fluvisol, Acrisol and in some other soils in traditional rural handicraft production village in Red river delta. The analytical results showed that the average Cd contents were 0.93 and 0.45 mg/kg soil for Fluvisol and Acrisol, respectively. The Cd content in Acrisol was below the critical standard, whereas the Cd content of some Fluvisol samples exceeded the critical level. The difference in Cd content between these two types of soil groups was considered to be due to the difference in the extent of anthropogenic impact on those soils. On the other hand the extent of the Cd contamination of soils was more serious in peri–urban area of Red river delta that have been affected by discharge from traditional rural handicraft production villages. The present research showed that the Cd content of some soils and sediments in the traditional rural handicraft area is approaching the critical level and it has already been exceeded by some soils.

INTRODUCTION

The main part of Red river delta is located in the coastal region of northern Vietnam with the total area of 16,666 km^2. The Red river delta comprises 9 whole provinces (Hanoi, Hatay, Haiduong, Hungyen, Haiphong, Namdinh, Hanam, Ninhbinh, and Thaibinh) and 23 districts of five other provinces (Bacninh, Quangninh, Vinhphuc, and Phutho). The major soils found in the delta are Fluviol and Acrisol according to the classification of FAO. Three districts (Donganh, Gialam, and Thanhtri) are situated to north to south of Hanoi city. The soil in this area is fertile and more than about 50% of the area is being used for production of rice and vegetables. Recently, the agricultural soil in this area has been deteriorated due to contamination by some heavy metal elements as a result of industrial activities and application of a large quantity of agricultural chemicals.

Many factories in this area, most of which were built in 1950s, lack in facilities for waste processing. A large amount of untreated waste water and solid wastes have been discharged directly into environment. With the growth of population in this area, agriculture became more profitable and farmers applied more chemical fertilizers aiming at higher yield. The heavy metal contamination of soils by increased fertilizer application has been recognized by many researchers. Since fertilizers contain not only major elements necessary for plant nutrition but also some trace metal impurities such as cadmium. Thus, both the industrial and agricultural activities caused heavy metal accu-

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mulation in soils.

In addition, traditional handicraft manufactures have prospered after urbanization of this district. It has greatly contributed to increase in income for people in this district but it worsened the environmental quality due to the improper disposal of wastes from poorly equipped manufactories.

Cadmium (Cd) is nowadays of great concern. The toxicity of cadmium has reported by many investigators (Adriano, 1986). There is a lot of evidence for the carcinogenicity of cadmium and cadmium compounds to humans, genotoxic effects of ionic forms on a variety of types of eukaryotic cells. Cd reaches humans mainly via inhalation and ingestion. Intestinal absorption is influenced by dietary factors, and increases with dietary cadmium concentration.

However, heavy metal contamination of soils in Vietnam has not received due interested yet. The Cd accumulation in soils strongly depends on their nature and source of pollutants. Thus, accurate measurement of Cd content should be performed to evaluate the status of Cd contamination, which will provide useful information for decontamination practices. In this research, we collected some soils that are under different land use in Red river delta, analyzed for total Cd content so that administrators can assess its potential hazard, and take some measure to prevent deterioration of soil quality at the early stage of urbanization.

MATERIALS AND METHODS

According to the FAO/UNESCO soil classification system, soils in Red river delta belongs mostly to two soil groups; Fluvisols and Acrisols. Fig. 1 shows the location of sampling sites in Red river delta. Soil samples were obtained in April and July 2002 from Thanhtri, Gialam, and Donganh districts. The sampling sites were selected on the basis of previous investigations about the heavy metals contamination status. Nine soil samples of Fluvisol were taken randomly in agricultural area in Thanhtri and Gialam district. Nine soil samples of Acrisol were from Donganh.

To evaluate the contribution of traditional rural handicraft production to the Cd content of soils, 21 soil samples were colleted from paddy fields and gardens in traditional handicraft village in Vanmon commune in Bacninh. In addition, 17 sewage sludge samples were also collected from the canals and ponds that have been receiving waste water from the surrounding production area.

The collected samples were air–dried, passed through a 2–mm sieve, and stored in plastic bottles before analyses. Total Cd was analyzed basically with the method developed by Asami and Kato (1977) after a preliminary digestion with 7% hydrogen peroxide to remove humic substance. The Cd concentration was determined by atomic absorption spectrometry (AAS).

RESULTS AND DISCUSSION

According to a series of researches by Nguyen and Do (1977), Nguyen and Tran (1978) and Dao (1987), Acrisols in the Red river delta were slightly acidic with pHs from

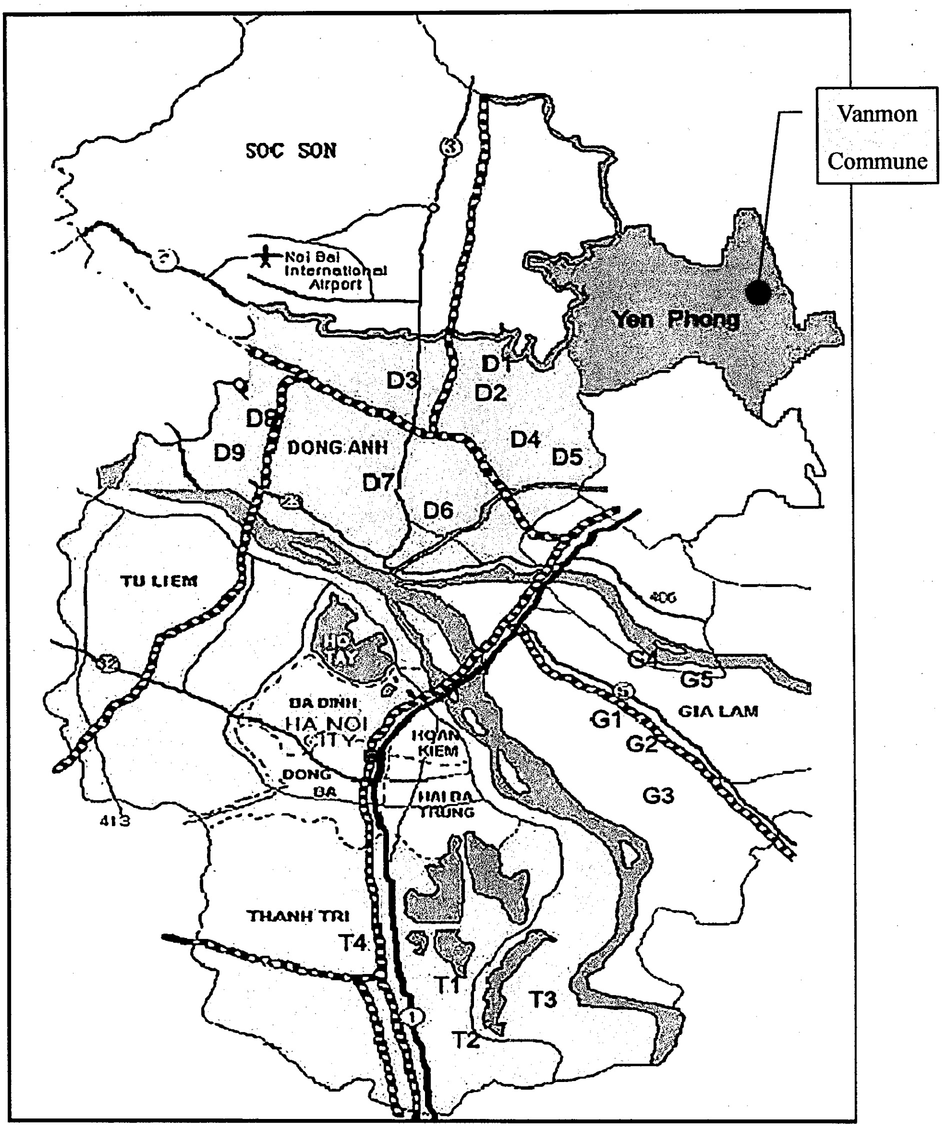

Fig. 1. Location of sampling sites in Thanhtri, Gialam, and Donganh districts. The abbreviations, T, G and D inidicate Thanhtri, Gialam and Donganh, respectively.

5.0 to 6.7, while Fluvisols were basic with pHs from 7.6 to 8.4. The organic matter content ranged from 1.0 to 2.5 % for the both soil groups. Fluvisols had quite high cation exchange capacity (15.6 $cmol_c/kg$), and that of Acrisols was in a range of 7–10 $cmol_c/kg$. There are a few investigations on soil physical properties. Thai and Nguyen (1998) found that the Fluvisols had the texture of silt to clay. The silt/clay weight ratio was more than 0.8 for Fluvisols, whereas Acrisols had coarser texture of sand to loamy sand in the surface horizons. Recently, some investigators reported that soil properties of Fluvisol and Acrisol have been changing during prolonged cultivation.

In this report, we focus on cadmium content of surface soils in Red river delta of Vietnam and discuss the analytical results in terms of soil type. Table 1 lists the total Cd content of 9 Fluvisol samples from Thanhtri and Gialam and 9 Acrisoil samples from Donganh. The Cd content ranged from 0.01 to 1.14 mg/kg. On average, Cd content of Acrisol samples (0.45 mg/kg) was lower than that of Fluvisol samples (0.83 mg/kg). The highest value was 1.14 mg/kg for the T1 sample that was collected in Thanhtri, where many chemical factories including those producing phosphate fertilizers, storage batteries are located. The waste waters from these factories have been discharged into water races and transported through a river to Thanhtri district, where the river water is used for agricultural irrigation and aquaculture. Nguyen (2002) reported the similar results.

The average Cd content of igneous rock is about 0.2 mg/kg and cadmium content of non–polluted soil ranges from 0.001 to 0.7 mg/kg. Cd is used for industrial purposes (plating, metal casting etc.). At high concentrations, it is toxic to living organisms including humans as mentioned in the introduction section (DEFRA and Environment Agency, 2002). This figure and the values listed in Table 1 show that the Cd contents of soils in this region are mostly close to or slightly above the upper bounds for natural non–polluted soils, suggesting some contamination with Cd. However, the highest Cd content of 1.14 mg/kg is much lower than those found in Cd–polluted areas, for example, in Japan. Possible sources of Cd in this region are irrigation water contaminated by inflow of improperly processed waster water, sewage sludge that was incorporated in the agricultural land as an amendment. Actually, there were drainage canals from factories near

Table 1. Cadmium content in some main soils of Vietnam.

Fluvisol	Location of sampling sites	Cd content (mg/kg)	Acrisol	Location of sampling sites	Cd content (mg/kg)
T1	Near phosphate factory	1.14	D1	Near Donganh industrial zone	0.77
T2	Near batteries factory	1.09	D2		0.82
T3	Agricultural land	0.80	D3		0.52
T4		0.90	D4		0.50
G1	Near Saidong Industrial zone	0.67	D5	Agricultural land	0.40
G2		0.78	D6		0.01
G3	Agricultural land	0.78	D7		0.63
G4	Near Ducgiang Chemical factory	0.73	D8		0.40
G5		0.65	D9		0.05
Max		1.14	Max		0.82
Min		0.65	Min		0.01
Average		0.83	Average		0.45

the sampling sites for D1 through D4 and D7 samples, whereas no possible Cd source was noticed around the sites for D5, D6 and D7 samples.

There is a significant difference in the Cd content between Fluvisols and Acrisols, with a higher average for Fluvisols (Table 1). Since the sampling sites of these soil samples were selected randomly, the observed difference may be partly due to the difference in chemical properties of the soils. As mentioned above, Fluvisols in this region have larger cation exchange capacity than Acrisols. In addition, Fluvisols have higher soil pH and it may have significantly contributed the increased Cd accumulation because the Cd retention by oxide minerals and humic substances exponentially increases as soil pH is increased from 5 to 7 (McKenzie, 1985; Schnitzer and Khan, 1972).

The Cd content of the parent material is of course an important factor affecting the Cd content of soils. The parent material of the soils in Red river delta is, however, uniformly mixed old alluvium and it is not probable that the difference in the Cd content between the two types of soils can be explained in terms of difference in the parent material.

Table 2 summarizes the Cd content of the soils and sewage sludge samples from

Table 2. Cadmium content in soil and sewage sludge in Vanmon, Yenphong.

Soil samples			Sewage sludge samples		
Name	Land used	Cd mg/kg	Name	Place	Cd mg/kg
Yp1	Paddy field	0.40	B1	Canal	1.70
Yp 2		1.30	B2	Pond	1.30
Yp 3		0.90	B3		1.50
Yp 4		0.60	B4	Canal	5.00
Yp 5		0.70	B5	Pond	1.30
Yp 6		0.30	B6		1.50
Yp 7		0.60	B7	Canal	1.30
Yp 8		0.50	B8	Pond	60.30
Yp 9		0.80	B9		0.90
Yp 10		0.70	B10		1.00
Yp 11		0.90	B11	Canal	1.40
Yp 12		1.10	B12	River	1.10
Yp 13		1.00	B13	Pond	1.40
Yp 14		1.00	B14	River	1.10
Yp 15	Garden	1.00	B15	Canal	6.40
Yp 16		3.10	B16	River	1.00
Yp 17	Paddy field	1.30	B17	River	1.10
Yp 18		0.90			
Yp 19		1.10			
Yp 20		0.90			
Yp 21	Garden	1.10			
Max		3.10	Max		60.30
Min		0.30	Min		0.90
Average		0.90	Average		5.30

Fig. 2. The waste water receiving canal system in Vanmon commune.

Vanmon in Yenphong district. Vanmon is a suburban commune with the total area of 450 ha. It traditionally produces various handicrafts made of aluminum. There are more than 100 households involved in aluminum casting and they manufacture 2,000 tons of products a year. This greatly boosted the standard of life there but, there is an increasing concern about the decline in the environmental quality particularly the quality of water (Pham, 1996). Fig. 2 illustrates the wastewater receiving canal system in Vanmon commune.

Table 2 shows that the cadmium content of arable soil samples in Vanmon, Yenphong, Bacninh ranged from 0.3 to 3.1 mg/kg with an average of 0.9 mg/kg. These values are significantly higher than those for typical soil samples found in Red river delta (Table 1) and this suggests that the soils of this region are more or less contaminated with Cd from non–agricultural sources. The Cd content of the garden soils was no lower than 1.0 mg/kg and this implies that the contamination is more serious in gardens, but the analysis of much more numbers of garden soil samples is necessary before conclusion.

The cadmium content of sewage sludge samples was much higher than that of soil samples. Particularly samples B8 (sewage sludge in pond) and B15 and B4 (sewage sludge in canal) showed very high Cd content. With the sewage sludge sample (B8) that had extremely Cd content, the average Cd content of the sewage sludge samples was 5.30 mg/kg. Without the B8 sample the average went down to 1.81 mg/kg, but it is still significantly higher than the average for soil samples. A possible source of Cd accumulated in the sewage sludge is improperly treated waste waters from aluminum processing.

The overall analytical results from the present study show that the Cd content of soils in Red river delta is fairly high in view of background Cd content of igneous rocks and natural soils. Since only total cadmium was determined, it is difficult to estimate the availability to crops. However, if we consider the facts that Cd ions incorporated in soils tend to reside on cation exchange sites of layer silicate minerals and that Cd accumulated in rice grains in some paddy field whose Cd content was around 1 mg/kg or below, a apart of soils examined in the present study may produce Cd–contaminated crops. Urgent systematic surveys of the Cd content of soils as well as the Cd level of crops are needed. To prevent the progress of soil contamination, it is important to stop application of sewage to arable land as a soil amendment.

CONCLUSIONS

The Cadmium contents of the Fluvisol and Acrisol samples of Red river delta were in a range from 0.01 mg kg^{-1} to 1.14 mog kg^{-1}. The average total Cd content was 0.93 and 0.45 mg/kg for Fluvisol and Acrisol, respectively. These values suggest that the extent of the Cd contamination of the soils in this region is not critical yet, although there are some signs of pollution in some Fluvisols. On the other hand, soils of peri–urban area in Red river delta that have been receiving sediment from irrigation channels showed higher total Cd content. The analyses of the sediments indicated that they are seriously polluted with Cd probably originated from discharges from traditional rural handicraft production villages and paint and dry cell factories. Control actions including stopping application of sediment to arable land are needed.

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