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Environmental Contamination and Toxicology

Heavy Metal Concentrations in Vegetable Garden Soils from the Suburb of Hangzhou, People's Republic of China

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Contamination of soils with heavy metals is a widespread problem all over the world. Elevated levels of heavy metals in soils are a result of industrial activities, atmospheric deposition, and the land application of sewage sludge and industrial by-products. Heavy metal contents of soils are influenced by several factors including mineralogical and geochemical composition of parent rock, organic metal content, particle size distribution, soil horizonation, age, drainage, vegetation, anthropogenic and aerosol input (Kabata-Pendias, 1993). Anthropogenic soil pollution by trace metals such as As, Cu, Cd, Hg, Ni, Pb and Zn has been recognized in many countries. Heavy metals continue to receive increasing attention due to the better understanding of their toxicological importance in ecosystems, agriculture and human health. Some trace elements, such as Cu and Zn, are necessary in low concentrations for all living organisms while most of them present toxicity hazards at high concentration (Srivastava and Gupta, 1996). The factors controlling the total and bioavailable concentrations of heavy metals in soil are of great importance for human toxicology and agricultural productivity (Alloway, 1995). The study of heavy metal content in soil has a great importance due to the fact that soils effectively act as a reservoir which, after temporary storage of metals, can act as a source under certain conditions. Heavy metal pollution in urban soils related to industrial activities and automobile exhaust have been well studied with the comparison to rural and forest soils (Chen et al., 1997; Govil et al., 2001; Martinez Garcia et al., 2001; Morton-Bermea et al., 2002; Thuy et al., 2000). Levels of heavy metals in paddy soils and forest soils in China have been studied (Chen et al., 1999; Hansen et al., 2001; Wong et al. 2002), but little information exists on heavy metal concentration in vegetable garden soils.

Vegetable garden soils usually located in the suburb of large cities in P. R. China, which are easily polluted by heavy metals through organic manuring, wastewater irrigation, and sludge amendment, as well as automobile exhaust. In the present study, we report data from a pilot study on heavy metal contents in vegetable

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garden soils. Both total and exchangeable concentrations of heavy metals in the vegetable garden soils from the suburb of Hangzhou, China were determined and the importance of organic material addition to heavy metal pollution was also discussed.

MATERIALS AND METHODS

A set of 45 topsoil (1-20cm) samples of the vegetable garden soil was collected in the suburb of Hangzhou, China (latitudes 30°15'-20'N and longitudes 120°6'-10'E), randomly. The soil samples were air-dried, dissagregated and passed though a 0.25mm nylon screen, and than homogenized and stored in polyethylene containers until the analysis was carried out.

For the determinations of the total concentrations of metals, the homogenized sample (0.5g) was digested with aqua regia and diluted to 100 ml with 2% HNO_3. Extractable metals were extracted by 0.005mol/L DTPA with a ratio of soil : extract solution as 1W : 20V. Copper, lead and zinc concentrations in digested and extracted solutions were analyzed using a flaming atomic absorption spectrophotometer (Shimazu AA-6800). Total organic carbon in soils was determined by the chromic acid method (Nelson and Sommers, 1982).

Limit values for heavy metal pollution assessment of soils used this work were as follows: Cu-50, Zn-200, Pb-250mg/kg soil, and the pedogeochemic background of heavy metals were as follows: Cu-35, Zn-100, Pb-35mg/kg soil (Ministry of Environment Protection of P R China, 1995).

RESULTS AND DISCUSSION

The total concentrations of heavy metals Zn, Cu, and Pb in vegetable soils from the suburb of Hangzhou are presented in Table 1. The limit values and the pedogeochemic background of heavy metals in agricultural soils are also shown in Table 1. The analytic results indicated that the concentrations of total zinc, copper and lead in vegetable garden soil range 75.5-302.0mg/kg soil (with an average as 168.1±58.0mg/kg), 4.3-143.5mg/kg soil (with an average as 41.4±28.8mg/kg) and 13.9-98.4mg/kg soil (with an average as 45.9±18.4), respectively. According to the limit levels, 15 soil samples were contaminated with heavy metals, contributing to 33.3% of the total 45 soil samples analyzed. The main soil pollutants were copper (15 occurrences of contamination, OC) and zinc (12 OC). With the comparison to pedogeochemic background, total zinc, copper and lead concentrations in vegetable garden soils are as 1.68, 1.18 and 1.31 times high as the background levels, respectively, which means that vegetable garden soils are contaminated with zinc quite severely and with copper or lead slightly. As shown in Table 2, the concentrations of extractable zinc, copper and lead in vegetable garden soil range 0.8-9.2mg/kg soil (with an average as 3.9±2.0mg/kg), 0.2-6.2mg/kg soil (with an average as 2.7±1.5mg/kg) and 0.2-4.8mg/kg soil (with an average as 1.7±1.1), respectively. And the contents of TOC (total organic carbon) in vegetable garden soils range 4.7-25.3g/kg soil (with an average as 12.8±4.3g/kg).

Table 1. Zinc, copper and lead in vegetable garden soils, with comparison to limit values and to the pedogeochemic background (PGB) of heavy metals.

	Total concentration of heavy metals (mg/kg soil)			Remarks
	Zn	Cu	Pb	
Range	75.5-302.0	4.3-143.5	13.9-98.4	
Average ± SD	168.1±58.0	41.4±28.8	45.9±18.4	
Pedogeochemic background	100	35	35	
Ratio of average content measured to PGB	1.68	1.18	1.31	
Limit value	200	50	250	
Amount of polluted samples	12	15	0	15
% of pollution	26.7	33.3	0	33.3

Table 2. Concentrations of extractable zinc, copper and lead, and total organic carbon (TOC) in vegetable garden soils.

	Concentration of extractable heavy metals (mg/kg soil)			TOC (g/kg soil)
	Zn	Cu	Pb	
Range	0.8-9.2	0.2-6.2	0.2-4.8	4.7-25.3
Average ± SD	3.9±2.0	2.7±1.5	1.7±1.1	12.8±4.3

The results of correlative analysis are shown in Table 3. Total concentrations of heavy metals Zn, Cu, and Pb are significantly correlative to the contents of TOC in the vegetable garden soils with the correlative coefficients 0.706**, 0.775**, and 0.665**, in order, and so are the concentrations of the extractable heavy metals Zn and Cu (except extractable Pb) with the correlative coefficients 0.753** and 0.666**, respectively. It means that organic manure may be one of the main sources of heavy metal pollutants, especially for Zn and Cu. For instance, Application of Cu and Zn rich poultry litter and other soil amendments were found to increase the concentration of these metals to toxic levels in soils (Chen et al., 1999; Kabata-Pendias, 1995; Narwal and Singh 1998; Siamwalla, 1996). In addition, the extractability of heavy metals in vegetable garden soils rise with the contents of TOC, which is effective to increase the toxicity of heavy metals if there is excessive heavy metals accumulated in the soils. From Table 3, it can also be found that there are significant correlation between the total concentrations of Zn, Cu, and Pb with the correlative coefficients of Zn-Cu 0.781**, Zn-Pb 0.791**, and Cu-Pb 0.766**, respectively. This result implies that the complex sources of heavy metals Zn, Cu and Pb may exist. Wong et al (2002) also found that some companion relations existed between various heavy metals in paddy soils supplied with organic manure.

Table 3. Correlative coefficients among total and extractable Zn, Cu, Pb concentrations and TOC contents of vegetable garden soils.

	TOC	T_{Zn}	E_{Zn}	T_{Cu}	E_{Cu}	T_{Pb}	E_{Pb}
TOC	1						
T_{Zn}	0.706 **	1					
E_{Zn}	0.753 **	0.804 **	1				
T_{Cu}	0.775 **	0.781 **	0.819 **	1			
E_{Cu}	0.666 **	0.732 **	0.807 **	0.814 **	1		
T_{Pb}	0.665 **	0.791 **	0.730 **	0.766 **	0.779 **	1	
E_{Pb}	0.245	0.299 *	0.412 **	0.354 *	0.549 **	0.644 **	1

"*" and "**" mean that the coefficients are significant at 0.05 or 0.01 level, respectively.

In summary, the concentrations of heavy metals Zn, Cu and Pb in the vegetable garden soils are higher than the pedogeochemic background. Organic manuring may be one of the main sources of the heavy metal pollution in the vegetable garden soils in the suburb of Hangzhou. As vegetable crops growing in polluted soils can accumulate heavy metals at high concentration, heavy metal pollution in vegetable garden soils may cause a serious risk to human health when vegetable products are consumed. Heavy metal pollution has been occurring in the vegetable garden soils in the suburb of Hangzhou, though it is slight in general. If effective measures are not taken, the situation will worsen.

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