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Characteristics of speciation of heavy metals in municipal sewage sludge of Guangzhou as fertilizer

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Abstract

Application of municipal sewage sludge to agricultural land especially in shallow soils, demands to validate the maximum amount of heavy metal, monitoring its effects on soil and on plants. The use of sewage sludge as a fertilizer and soil amendment has resulted in high concentrations of heavy metals in the soil and food limiting its use. Controlling the pollution of heavy metals is the key factor to realize the safe utilization of sewage sludge. In the present study, the heavy metal stabilizers were added to sludge contained in used plastic containers, through artificially watering or naturally rain falling, the nutrient components flowed out with leaching water and fertilized plants but the heavy metals retained in the sludge within container. The potential toxic risks from heavy metals of sludge depend on their chemical speciation. The contents of heavy metals in different treatments were analyzed and their speciation was determined. The pot experiments with plants *(Zea mays and Laetuca satiuali)* showed that the positive effects of the mixture of the sludge and K_2SO_4 on plant production and reduction of heavy metal contents in plants were significant. The BCR sequential extraction procedure was applied for measurement of heavy metals in the experimental sludge. The results showed that the concentrations of Zn were predominant in acid exchangeable and reducible fractions, and Cu was principally distributed in oxidizable fractions. Metals-bound sludge could be collected easily after treatment to prevent the secondary pollution, provided the heavy metals were fixed within the container and reduced obviously the leaching of heavy metals to soil.

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Keywords: Municipal Sewage Sludge; Heavy Metals; Speciation Characteristics; Red Soils; Fertilizer Effects

1. Introduction

In the past decades, the demand for higher food production and the increase in exploitation of marginal land

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for agricultural food production lead to strong dependence on inorganic fertilizer in the agricultural system in China. However, the uncontrolled use of inorganic fertilizer especially N fertilizer have caused a serious deterioration of the soil and water resources in China, especially for the economic blooming South China. The use of organic fertilizer to partly replace the current practice in uncontrolled use of inorganic fertilizer is the only means to remedy the poor soil quality.

On the other hand, tremendous amounts of sewage sludge are generated daily in China which requires careful handling and disposal to reduce its impact on the environment. Land application is the most popular disposal method but it may entail environmental hazards and decrease plant growth[1,2], which is also the main disposal outlet in industrialized countries[3,4]. In agriculture, crop yield decrease following sewage sludge application has been attributed to high concentration of heavy metals[5] and to phytotoxic substances in the sludge[6]. However, sewage sludge contain very high fractions of organic matters, and organic N and P that represent excellent sources of organic ameliorants for degraded soils [7]. Sludge as Guangdong lateritic red soil crop fertilizer could get the highest fertilizer-use efficiency, and avoid the environmental risk caused by direct agricultural sludge.

2. Materials and methods

2.1 Soils and sewage sludge used

The red soil was sampled in Southern China, and air-dried and screened through a 5 mm sieve. Sewage sludge was an undigested and dewatered sewage sludge obtained from Datansha Wastewater Treatment Plant of Guangzhou. The chemical and physical properties of the soil and sewage sludge are presented in Table 1. According to the Chinese National Standards of Sewage Sludge for Agricultural Application, the main contaminated metals are copper and zinc, other toxic metals were not severely exceeded the standards[8].

Table 1. Physical and chemical characteristics of the soil and sludge.

	Soil	Sludge I	Sludge II	Std for agric. Use*	
				pH< 6.5	pH >6.5
Total Zn, mg/kg	98.8	1362.1	1789.6	500	1000
Total Cu, mg/kg	18.4	287.9	236.5	250	500
Total N, g/kg	1.81	29.7	34.5		
Total P, g/kg	0.64	20.8	26.8		
Total K, g/kg	2.70	18.2	18.9		
Organic matter, g/kg	28.76	313.12	336.0		
Water content, g/kg	25.0	828.6	812.0		
pH (1:2.5 soil:H_2O)	5.65	7.10	7.03		
Germination index, %	60.1	70.0	65.6		
E.coli, MPN/g	/	5.2×10^5	4.9×10^5		

*Chinese national standard (GB4284-1984) of sewage sludge for agriculture use on the soils with soil pH< 6.5 and pH > 6.5 respectively. Sludge I is for Experiment I (the experiment of corn), Sludge II is for Experiment II (the experiment of leaf-used lettuce).

2.2 Experimental design

The following diagram was designed: 15kg of soil was contained in each pot, and fresh sludge (weighted by dry sludge: dry soil=1:100) was filled into each plastic bottle (made by scrap plastic bottle). 10 small holes with diameter of 1 cm were made at 1 cm from the bottom of each bottle. No nutrients were added to the soil in this study. The experiments were undertaken out-door and in 4 replicates.

8 types of treatments were considered as follows: 4 pots, each contained only soils (control 1); 4 pots, each contained soils mixed with sludge (control 2); 4 pots, each contained soils and plastic bottle with fresh sludge;