DERIVATION OF SOIL CRITERIA FOR CADMIUM APPLYING SPECIES SENSITIVITY DISTRIBUTION

Changfeng Ding, X.X. Wang

Institute of Soil Science, Chinese Academy of Sciences, Key Laboratory of Soil Environment and Pollution Remediation, Nanjing, China

cfding@issas.ac.cn

Keywords: Cadmium; Soil criteria; Species sensitivity distribution; Normalization.

Introduction

In many countries across the world, soil criteria of heavy metals used for farmland are estimated from the literature or "imported" from other countries without fully considering the influence of soil properties, and therefore could not completely ensure the production of crops that meet the food quality standard (Recatalá et al., 2010). There is an urgent need to revise and improve the current soil criteria. The generally preferred method to derive soil criteria is to use species sensitivity distribution (SSD) (Posthuma et al., 2002). A significant purpose of SSD modeling is to determine a concentration protective of most species in the ecosystem, usually the 95% protection level, known as the HC5. Currently, the SSD method is mainly used in the toxicity risk assessment and the development of ecological risk criteria for aquatic and terrestrial flora and fauna (Smolders et al., 2009; Gao et al., 2014). However, it is rarely applied in the derivation of soil criteria for heavy metals in view of food safety.

Therefore, with a focus on widely consumed root vegetables, this study aims to derive soil criteria for Cd based on the food quality standard using SSD method, while taking into account the soil properties that would have the greatest influence on Cd phytoavailability.

Methods

A total of twenty-one soils covering a wide variation in soil properties were collected throughout China. Firstly, two typical soils, an acidic Ferrolsols (pH 4.84) and a neutral Cambosols (pH 6.93), were used to test the sensitivity variations of different cultivars for accumulating soil Cd. Three species of root vegetables, radish (*Raphanus sativus* L.), carrot (*Daucus carota* L.), and potato (*Solanum tuberosum* L.) were used in the experiment; four representative cultivars of each species were selected. Then, to minimize the effect of soil properties on the bioaccumulation data, the soil-plant transfer model was developed and used as the normalization relationship from carrot cultivar New Kuroda grown in the twenty-one soils. Uncontaminated soils were spiked with soluble Cd salt ($3CdSO_4 \cdot 8H_2O$) to minimize the effect of varying sources of Cd on phytoavailability. Three treatments were applied, including the control, low-Cd (0.3 mg kg^{-1} for soils pH < 7.5, and 0.6 mg kg^{-1} for soils pH > 7.5), and high-Cd (0.6 mg kg^{-1} for soils pH < 7.5, and 1.2 mg kg^{-1} for soils pH > 7.5). After aging for three months, vegetable plants were cultured under regular farming management style. Three replicates were tested per treatment.

Results

The normalization relationship based on soil added Cd (excluding natural background Cd) was shown as log[BCF_{add}]=1.03−0.20pH−0.31log[OC] with R^2=0.83. The model was subsequently used for normalizing all individual BCF_{add} values of the twelve cultivars cultivated in Ferrolsols and Cambosols to soil conditions with different combinations of soil pH (4.5-9.0) and OC (5-30 g kg^{-1}).

The critical soil concentration for each cultivar under different soil conditions after normalization was back calculated from the corresponding BCF_{add} value and the food quality standard of Cd (0.1 mg kg^{-1}, fresh weight). Then the added hazardous concentrations ($HC5_{add}$) were calculated from the Burr Type III fitted SSD models. The calculation formula for $HC5_{add}$ was provided as the continuous criteria in Table 1. Meanwhile, scenario criteria could also be calculated for different representative soil scenarios (Table 1). The results suggested that the current soil criteria were only valid for soils with limited combinations of soil pH and OC content.

Table 1. The derived soil criteria for Cd (mg kg^{-1})

Approach	Continuous criteria	Scenario criteria [a]								
		pH < 6.5			pH 6.5-7.5			pH > 7.5		
		A	B	C	A	B	C	A	B	C
Added Cd	$HC5_{add}=10^{(0.20pH+0.31logOC-2.30)}$	0.13	0.16	0.18	0.25	0.31	0.35	0.32	0.39	0.44
Total Cd with known C_b [b]	$HC5_{add}+C_b$	Above+C_b								
Total Cd with default C_b	$HC5_{add}$+0.13	0.26	0.29	0.31	0.38	0.44	0.48	0.45	0.52	0.57
Current criteria	Not available	0.30			0.30			0.60		

[a] The rounded criteria at soil pH values of 5.5, 7.0 and 7.5 were used for scenarios of soil pH < 6.5, 6.5-7.5, and > 7.5, respectively; A, B, and C were scenarios with soil OC = 10, 20, 30 g kg^{-1} respectively.
[b] C_b is the background concentration of soil Cd, with a default value of 0.13 mg kg^{-1} (Xia, 1996).

Conclusion

This study adopted the SSD methodology to derive soil criteria for Cd in view of the food quality standard while taking into account the influences of soil properties. The approach proposed here is widely applicable to other crops as well as other heavy metals that have the potential to cause food safety issues.

References

Gao, P.; Li, Z.Y.; Gibson, M.; Gao, H.W. (2014). Ecological risk assessment of nonylphenol in coastal waters of China based on species sensitivity distribution model. *Chemosphere*, *104*, 113-119.

Recatalá, L.; Sánchez, J.; Arbelo, C.; Sacristán, D. (2010). Testing the validity of a Cd soil quality standard in representative Mediterranean agricultural soils under an accumulator crop. *Sci. Total Environ*., *409*, 9-18.

Smolders, E.; Oorts, K.; Van Sprang, P.; Schoeters, I.; Janssen, C.R.; McGrath, S.P.; McLaughlin, M.J. (2009). Toxicity of trace metals in soil as affected by soil type and aging after contamination: using calibrated bioavailability models to set ecological soil standards. *Environ. Toxicol. Chem*., *28*, 1633-1642.

Posthuma, L.; Traas, T.P.; Suter, G.W. (2002). Species Sensitivity Distributions in Ecotoxicology.; *CRC Press*, Boca Raton, Florida, USA.

Xia, J.Q. (1996). Detailed Notes for Soil Environmental Quality Standard.; *China Environmental Science Press*, Beijing, China.