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Health Risk Assessment of Heavy Metals in Arable Soils

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***Abstract*— In order to assess the health risk of heavy metals in urban soils to the people, the health risks of heavy metals assessed based on the model of health risk assessment and a total of 98 soil samples were collected in Pingchang county. Cu, Zn and Mn were analyzed by ICP-MS and ICP-OES respectively. The results indicated that the mean concentrations of Cu and Mn were higher than their mean values in Sichuan province; pH value and organic matter had negative and positive correlation with heavy metals concentration ($p<0.01$); health hazard of individual person of three heavy metals is 1.065×10^{-3} to adult, and 3.107×10^{-3} to child; Mn contributed a lot to the noncarcinogenic risk. It is suggested that the people may experience adverse health effects during his or her lifetime, and soils should be repaired.**

Keywords-Health risk assessment; heavy metals; arable soils

I. INTRODUCTION

With the rapid development in China, heavy mentals pollution in soil have become one of the most serious enviroment problems, because of their non-biodegradable nature and long biological half-live for elimination from the body[1]. Excesive accumulation of heavy mentals in soils may pose serious health to humans and may exert adverse impacts on the ecosystem itself.

Heavy metal pollutants in soils can enter the human body and pose heath risks through two pathways: 1)soil-food-human body (indirect exposure); and 2)soil-human body (direct exposure) [2].

Geostatistical methods provide spatial interpolation and assess uncertainties at unsampled locations, which offer an opportunity to improve the accuracy of estimating spatial distribution of pollutants in a cost-effective manner[3,4].This study set out to determine spatial patterns in the total concentration of Cu, Zn and Mn. Then, their health risks in soils were estimated by the direct exporure method.

II. MATERIALS AND METHODS

A. Sampling site description

Pingchang county has a total 2229 km^2 and located in the northeastern Sichuan province(106º50′～107º34′E, 31º16′～31º52′N), basic properties of agricultural soils in studied area(Table1). The surface soil samples (0-20cm) were collected using a global positioning system (GPS) to identify its locations.

Table1 Basic properties of agricultural soils in studied area

Index	pH	Organic matter /%
Mean	6.73	1.76
Median	6.5	1.7
Maximum	8.4	3.91
Minimum	4.9	0.44
SD	1.03	0.63
Skewness	0.14	0.68
CV(%)	15.3	35.95

B. Laboratory analyses

The moisture soil samples were air-dried and sieved (<0.15mm) to determine the content of heavy metals including Cu, Zn and Mn. Then, soil samples (0.5g) were digested with a mixture of HNO_3(5mL) and H_2O_2(2 mL) at about 180℃ for about 20 min in a closed-Tefon vessel in a microwave oven to avoid losing of some metals via volatilization. The total contents of Cu in the digested solution were measured by inductively coupled plasma-mass spectrometry (ICP-MS). Zn and Mn were analyzed by inductively coupled plasma-optical emission spectrometry (ICP-OES).

III. ASSESSMENT METHODS

A.Health risk assessment method[5]

$$CDI = \frac{c\times IR\times CF\times FI\times EF\times ED}{BW\times AT\times 365}$$

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The potential health risk of individual soil heavy metals is characterized using a hazard quotient (*HQ*), which is the ratio of the chronic daily intake (*CDI*, mg/(kg·d)) to the reference dose (*RfD*, mg/(kg·d)). The *HQ* was calculated using the following equation in the three selected exposure pathways.

Where, *CDI* is the chronic daily intake(mg/(kg·d));*C* is the pollutant concentration of water(mg/L), soil(mg/kg) and atomospher(mg/m^3), *et al*; *IR* is the intake velocity(mg/d);

B. NonCarcinogenic Risk

$$HQ = CDI / RfD$$

Where, *HQ* is the risk index; *CDI* is the chronic daily intake(mg/(kg·d)); *RfD* is the reference dose (mg/(kg·d));

The overall potential risk posed by a mixture of heavymetals is assessed by the summed HQs calculated for each heavy metals, which is expressed as a hazard index (*HI*):

$$HI = HQ_1+HQ_2...+HQ_n$$

There's no chronic non- cancerous risk hapened when *HI*<1; soils should be repaired when *HI*>1 until *HI*<1.

C.Health risk models selecting

Usually, the ways of human touching contaminations by breathing and touching should be considered when assessing the health risk of human who are arouned by the heavy contaminated soil. Refering to previouse studies and the studied area condition, exposure parameters of the health risk assessment models were given in table 2.

Table 2 Exposure parameters of the health risk assessment models

Exposure parameters	Adult	Child	Reference values
BW	70	16	
IR	100	200	
ED	30	10	
EF			300
FI			0.0～1.0
CF			10^{-6}
AT			70

As far as health caused by the non-carcinogenic concered, *RfD* is an important parameter. Accoring to the USEPA's recommendation and assessment, the related *RfD* were listed in the table 3.

Table 3 Model parameters of *RfD* value

Heavy metals	*RfD*/mg·kg·d^{-1}
Cu	0.04
Zn	0.3
Mn	0.14

IV. Results and discussion

A.Heavy metals in soil

The content ranges of Cu, Zn and Mn were 0.25～3.96 mg/kg, 0.17～2.48 mg/kg, 4.98～109.0 mg/kg, respectively. The mean concentrations of Cu and Mn were 2.02 mg/kg, 0.89 mg/kg and 39.43 mg/kg, Cu and Mn were higher than their mean values in Sichuan province, but Zn was lower than that in Sichuan province (Table 4). The mean concentrations of Mn observed in study area exceeded the critical level of secondary environmental quality standards for soil in China.

Table 4 Descriptive statistics of heavy metals in study area

Elements	Cu	Zn	Mn
Mean(mg/kg)	2.02	0.89	39.43
Median(mg/kg)	2.03	0.78	37.35
Maximum(mg/kg)	3.96	2.48	109
Minimum(mg/kg)	0.25	0.17	4.98
SD	0.74	0.41	22.94
Skewness	-0.12	1.12	0.74
CV(%)	36.57	45.98	58.18
Critical value (mg/kg)	2	1.5	3

Estimating the source and spatial distribution of pollutants is crucial to quantifying the level of environmental risks [6]. As shown in Figure 2, the distributional patterns of Cu and Zn were more regular, suggesting that a natural factor plays an important role in controlling their distributions. Mn concentration around Pingchang city is higher than that in other area except for the north part, which maybe caused by human activities. Meanwhile, in the whole study area, the mean concentration and CVs of Mn are high, which suggests a major natural source. Integrating the above model analysis, Mn should be controlled compared with Cu and Zn in studied area.

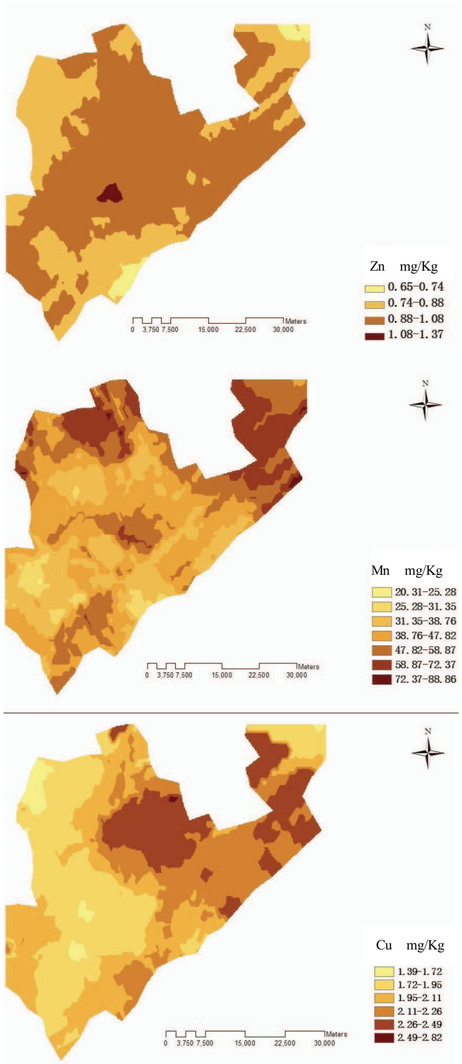

Figure 2 Spatial distribution of soil heavy metals ($mg \cdot kg^{-1}$)

B.Correlation coefficients analysis of soil heavy mentals' content

The results of correlation coefficients between the trace elements content in soil were shown in the table5, there was no significant correlation between the Cu, Zn and Mn ($p>0.05$); meanwhile, correlation coefficients between the content of trace elements and soil characteristics were considered (Table 6), pH value and organic matter had negative and positive correlation with the heavy metals content ($p<0.01$).

Table 5 Correlation coefficients analysis

Elements	Cu	Zn	Mn
Cu	1		
Zn	0.019	1	
Mn	0.022	0.172	1

Table 6 Correlation coefficients between the content of heavy metals and soil characteristics

Indexes	Cu	Zn	Mn
pH	-0.426**	-0.790**	-0.472**
Organic matter	0.758**	0.502**	0.027

* *P*< 0.05, ** *P*< 0.01, the same blow.

C. Human health risk assessment

After understanding the main sources of heavy metals in Pingchang City, we carried out an evaluation of the risk of direct soil heavy metals exposure to adults and children, an *HI* greater than 1.0 suggests that the people may experience adverse health effects during his or her lifetime.

Health hazard of individual person of Zn,Cu and Mn in the soils were assessed by the health risk model, the caculated result was shown in the table7. The results shown that the order of noncarcinogenic caused health risk is Mn>Cu>Zn, meanwhile, children are more sensitive to heavy mentals than adults. Health hazard of individual person of three heavy metals is 1.065×10^{-3} to adult, and 3.107×10^{-3} to child. Mn contributed a lot to the noncarcinogenic risk. It is suggested that the people may experience adverse health effects during his or her lifetime, and soils should be repaired.

Table 7 Health hazard of individual person of Zn, Cu and Mn in the soils (a^{-1})

	Adult	Child
$Cu\times10^{-4}$	0.51	1.48
$Zn\times10^{-4}$	0.22	0.65
$Mn\times10^{-3}$	0.992	2.894
$HI\times10^{-3}$	1.065	3.107

V. Conclusions

A.This work spatially analyzed the potential health risk for people. The mean concentrations of Mn observed in study area exceeded the critical level of secondary environmental quality standards for soil in China.

B.This study indicates that we should attach great importance to the direct soil heavy metal exposure for human's health. Regardless of the *HI* value, more detailed heavy metals investigation would be required when assessing a specific site within the study area.

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