



A Survey of Zn, Pb, Cd, Cr and Cu in Earthworms and Soil from Subsidence Area of Xieyi Coal Mine in Huainan, China†

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Earthworms and soils were collected from subsidence area of Xieyi coal mine and were analyzed for Zn, Pb, Cd, Cr and Cu by ICP-OES. The Zn and Pb could be accumulated much higher in earthworm with bioconcentration factors of Zn (1.39) and Pb (2.17) above 1. In addition, the Cd concentrations in earthworm related with that concentrations in soil ($r = 0.95$, $p < 0.05$) and were best described by a linear equation ($y = ax + b$), which indicating that earthworm could be used as a biological indicator in Cd contaminated soil in the subsidence area.

Key Words: Earthworm, Biological indicator, Subsidence area.

INTRODUCTION

Earthworms are considered to be ecosystem engineers¹ and have been suggested as good indicators of soil contamination^{2,3}. When exposed by direct dermal contact with heavy metals in the soil solution or by ingestion of pore water, polluted food and/or soil particles, earthworms can accumulate high level of heavy metals⁴. However, few reports concerned the heavy metals accumulated in the earthworm from coal mine district, especially in subsidence area. Present study surveys the concentrations of Zn, Pb, Cd, Cr and Cu in earthworms from the subsidence area in Xieyi coal mine in Huainan. The purpose was to determine how the concentrations of these elements were related to the concentrations in soil at subsidence area and to generalize about the value of earthworms as indicators of heavy metal in soil.

EXPERIMENTAL

Soils and earthworms were sampled from subsidence area in Xieyi coal mine in Huainan. Soil samples were air dried, ground and were wet digested with a concentrated "aqua-regia" ($\text{HNO}_3/\text{HCl} = 1:3$)⁵. Earthworms were washed, weighed, dried and were digested with an extract solution of diluted 'aqua regia'⁶.

Concentrations of Zn, Pb, Cd, Cr and Cu in soils and earthworms were determined by ICP-OES. Quality control and standard references were included in the analysis.

RESULTS AND DISCUSSION

Concentrations of Zn, Pb, Cd, Cr and Cu in soils: Concentrations of Zn, Pb, Cd, Cr and Cu in soils vary at different sites (Table-1). As can be seen from Table-1, the range of Zn varied from 30.73-46.6 mg kg⁻¹; Pb, 14.01-10.07 mg kg⁻¹; Cd, 0.06-0.16 mg kg⁻¹; Cr, 17.28-36.22 mg kg⁻¹ and Cu is 15.19 to 22.26 mg kg⁻¹, which were lower than the background value of Huainan soil⁷. The obtained mean value for Cd in soil was

TABLE-1
CONCENTRATIONS OF Zn, Pb, Cd, Cr
AND Cu IN SOILS (mg kg⁻¹)

Sites	Zn	Pb	Cd	Cr	Cu
S1	46.16	14.17	0.16	36.22	20.94
S2	33.34	14.01	0.07	17.28	15.19
S3	30.73	14.17	0.07	22.30	22.26
S4	37.92	18.70	0.07	25.60	17.08
S5	41.64	19.07	0.06	28.49	18.09
Mean	37.96	16.03	0.08	25.98	18.71
SD	6.21	2.61	0.04	7.08	2.87
Huainansoil	80.81	30.47	0.06	64.93	24.16

†Presented to The 5th Korea-China International Conference on Multi-Functional Materials and Application.

TABLE-2
CONCENTRATIONS OF Zn, Pb, Cd, Cr AND Cu IN EARTHWORMS (mg kg⁻¹)

Sites	Zn	Pb	Cd	Cr	Cu
S1	56.52 (1.22)	37.31 (2.63)	0.05 (0.35)	66.56 (1.84)	15.92 (0.76)
S2	34.93 (1.05)	29.10 (2.08)	0.03 (0.46)	13.40 (0.78)	7.75 (0.51)
S3	55.13 (1.79)	37.31 (2.63)	0.03 (0.41)	11.28 (0.51)	7.18 (0.32)
S4	62.45 (1.65)	29.10 (1.56)	0.03 (0.42)	17.61 (0.69)	8.44 (0.49)
S5	51.78 (1.25)	37.31 (1.96)	0.02 (0.29)	19.90 (0.70)	7.91 (0.44)
Mean	52.16 (1.39)	34.02 (2.17)	0.03 (0.39)	25.75 (0.90)	9.44 (0.50)
SD	10.37 (0.31)	4.50 (0.46)	0.01 (0.07)	23.06 (0.53)	3.65 (0.16)

Data in the parenthesis represents BCFs in earthworm

higher than Huainan soil but below the SEPA⁸ limit for soil due to higher Cd concentration in S1 which is 2 times above Huainan soil, which indicating that the majority of subsidence area was unpolluted except some site was occasionally contaminated by Cd. This result was in agreement with the works of Shao⁹ and Yao *et al.*¹⁰.

Concentrations and bioconcentration factors (BCFs) of Zn, Pb, Cd, Cr and Cu in earthworms: The concentrations and bioconcentration factors of Zn, Pb, Cd, Cr and Cu in earthworms are summarized in Table-2. The concentrations of heavy metal in earthworms vary from different sites and were 34.93-73.62 mg kg⁻¹, 29.10-37.31 mg kg⁻¹, 0.03-0.05 mg kg⁻¹, 11.28-66.45 mg kg⁻¹ and 7.18-15.92 mg kg⁻¹ for Zn, Pb, Cd, Cr and Cu, respectively. The bioconcentration factors of heavy metals in earthworm ranked as Pb > Zn > Cr > Cu > Cd and bioconcentration factors of Zn and Pb were higher than 1, which denoting that the earthworm in subsidence area has the ability of enrichment of Zn and Pb and Pb accumulated higher than Zn in the tissue of earthworm.

Bioaccumulation of heavy metals in earthworms in relation to total heavy metals in soils: Based on the Person's correlation test (Table-3), only the Cd in soil positively correlated to Cd ($r = 0.95$, $p < 0.05$), Cr ($r = 0.95$, $p < 0.05$) and Cu ($r = 0.95$, $p < 0.01$) in earthworm. Next, linear regression was used to determine quantities of Cd in soil to that in earthworm and the equation could be calculated as: Earth worm_{Cd} = 0.332Soil_{Cd} + 0.004 ($r^2 = 0.901$, $p < 0.05$). This suggested that the Cd value in earthworm could be used to denote the content of Cd in soil in the subsidence area in coal mine district.

TABLE-3
COEFFICIENTS OF Zn, Pb, Cd, Cr AND Cu CONCENTRATIONS IN EARTHWORMS TO THAT CONCENTRATIONS IN SOILS

Earthworm	Soil				
	Zn	Pb	Cd	Cr	Cu
Zn	0.36	0.44	0.25	0.61	0.54
Pb	0.34	-0.12	0.29	0.58	0.82
Cd	0.47	-0.57	0.95*	0.53	0.27
Cr	0.83	-0.26	0.97*	0.87	0.38
Cu	0.79	-0.31	0.99**	0.83	0.36

* $p < 0.05$; ** $p < 0.01$

Conclusion

When exposed to relatively higher levels of some heavy metals in soil in the subsidence area in coal mine district, earthworm could accumulate Zn and Pb in soil and enrich Pb higher in its tissue than Zn, Cd, Cr and Cu. Based on the analysis correlation and regression analysis of bioaccumulation of heavy metals in earthworms in relation to total heavy metals in soils, the earthworm could be used be as a biological indicator in Cd contaminated soil in subsidence area.

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