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오염된 토양의 중금속 분포와 독성상관 관계 연구

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요 약 문

In this study, the relationship between metals (Cu, Cr, Cd, Zn, Pb, and Fe) 5 fractions and toxicity of soil samples from various contaminated sites in Korea were investigated. Metal toxicity of soils was tested using MetPLATE^{TM} test kit, which is known as metal sensitive and organic insensitive. Significant amount of Fe was found in soils, and metal contents were in the order of Fe>Zn>Pb>Cu>Cr>Cd. Metal levels in organic fraction were rather high for all metals except Fe, and quite high percentages (35 ~ 79%) for residual fraction were observed for all metals.

There were no significant relationships between the content of each metal fraction and toxicity, which showed regression R^2 in the range of 0.0003 ~ 0.414. However, correlation between toxicity and total metal contents showed regression coefficient R^2= 0.72. These results showed that the risk evaluation of metals in contaminated sites should be difficult to assess only by the contents of metal distribution because of the complexity of mixture of various metals.

key word : heavy metal, fraction, toxicity.

1. Introduction

It is well known that metals, reaching excessive levels, can exert serious impacts on humans, animals, and plants. Metal toxicity associated with solids in the environment is of particular concern since they can be released. Nevertheless, their environmental impact is difficult to evaluate qualitatively due to the complex interactions between metals and ecological systems (Kim and Kim, 1999). It is, however, well known that information on the total concentrations of toxic metals in contaminated soils is not sufficient for the understanding of their mobility and availability to the biota (Bunzl et al., 1999). For this reason, various sequential extraction procedures have been proposed to study the partitioning (or fractionation) of metals in soils or sediments (Tessier and Campbell, 1988; Kong and Liu, 1995).

In this study, the relationships between metal fractions and toxicity of collected samples from various contaminated soils in Korea were investigated. Metal toxicity of soils was tested using MetPLATE^{TM} , a test kit based on inhibition of β-galactosidase activity in a mutant strain *E. coli*. This enzyme is selectively sensitive to metals but insensitive to organic toxicants (Bitton et al., 1996).

2. Results and discussion

3.1. Metal contents of soils

Results show that the total concentrations of six metals in each soil were approximately in the range of 14,390 84,326 mg/kg soil. The concentrations of each metal are given in Table 1. Among the detected metals, significant levels of iron were found in soils compared to others, especially soils collected near mining areas. The metal contents were in the following order: Fe >> Zn > Pb > Cu > Cr >> Cd, which is in agreement with the order reported by Gimeno-Garcia *et al* (1995). As reported by other investigators, cadmium displayed the lowest levels while iron occurred at the highest levels (Amrhein et al., 1994)

3.2. Sequential extraction of various metals

The average percentage distribution of each metal fractions obtained from the sequential extraction experiments, is presented in Table 2. Metals were mostly distributed in the organic (min. 8.7%, max. 43.8%) and residual fractions of the soils. In case of the residual fractions, without exception, the average fractions of five metals were ranging from 35 to 79%. Gibbs (1973) reported that most of the Cu and Cr transported in the Amazon and the Yukon rivers was deposited in the crystalline particles of the sediments.

The affinity of the metals for each fraction in investigated soil ecosystem are (based on percentage distribution) following orders : Exchangeable: Cd> Pb> Zn> Cr ≈ Cu> Fe: Precipitated as carbonates: Pb> Cd> Zn ≈ Cr ≈ Cu> Fe ; Associated with amorphous oxides: Zn> Cr ≈ Pb> Fe> Cd> Cu ; Bounded to the organic matter: Cu> Zn ≈ Pb ≈ Cr> Cd> Fe ; Residual: Fe> Cd> Cr> Cu> Pb ≈ Zn

3.3. Correlation between soil toxicity and metal distribution

Six metals were measured. Figs. 1 shows the correlation between the percentage fraction distribution of total metals and toxicity, as measured via MetPLATE^{TM}. As shown in Figs. 1, we did not find any significant relationships between the metal contents of each fraction and toxicity, except for the residual fraction. Residual fractions, which are in the range of 35~ 79 % of total contents, depending on the type of metal, showed regression coefficient R^2 = 0.603, and the rest of R^2 were in the range of 0.0003 (carbonatic) 0.414 (exchangeable). However, correlation between toxicity and total metal contents showed a regression coefficient R^2 = 0.72. Such results may be due to the effects of complexity of the interactions of various metals with soil components. Therefore, metal contaminated environments might be monitored carefully using the relationship between toxicity and total contents, in addition to exchangeable metals.

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4. References

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Table 1. Total metal concentration in each collected samples

Sites		Metal Concentration (mg/kg soil)						
		Cu	Pb	Cr	Zn	Cd	Fe	Total
Industrial areas	#1	32.23	32.22	31.21	171.58	1.62	20,340.7	20,609.57
	#2	85.46	31.22	40.01	256.00	0.99	24,041.9	24,455.62
	#3	41.73	31.62	23.24	147.49	1.19	16,089.9	16,340.23
	#4	34.04	33.62	26.19	145.15	1.26	17,352.0	17,592.32
Waste landfill areas	#5	33.33	39.91	20.99	187.40	2.06	24,978.0	25,253.43
	#6	42.71	25.42	31.05	224.88	0.95	14,064.9	14,389.99
	#7	37.53	40.22	55.01	139.85	1.90	25,747.2	26,021.70
Mine areas	#8	76.12	53.13	26.97	454.10	2.45	27,434.2	28,044.91
	#9	71.73	42.04	34.11	312.02	3.70	21,794.4	22,258.03
	#10	149.31	54.52	35.54	429.91	4.53	34,813.7	35,487.50
	#11	48.70	406.55	32.94	552.91	4.69	35,936.7	36,981.88
	#12	11.16	85.57	14.68	272.10	1.96	17,446.9	17,446.86
	#13	83.98	193.39	10.20	1,266.14	9.68	27,351.6	28,914.95
	#14	74.00	497.66	12.72	218.20	0.85	30,736.2	31,539.66
	#15	89.98	67.63	60.40	109.09	0.75	44,585.0	44,912.84
	#16	390.05	5,001.39	9.25	415.38	0.97	63,855.8	69,672.84
	#17	384.14	395.33	77.67	217.18	0.56	83,251.0	84,325.86

Table 2. Average values of the percentage distribution of heavy metals in each fraction.

Metals	% Distribution of each fraction.				
	Exchange	Carbonates	Fe-Mn oxides	Organic	Residual
Cu	1.86	3.95	6.44	43.77	44.19
Pb	5.82	9.05	16.16	33.67	35.30
Cr	2.00	4.09	17.27	30.32	46.35
Zn	3.72	4.54	22.35	34.45	34.95
Cd	7.41	8.99	8.71	19.78	55.23
Fe	0.42	1.56	10.49	8.71	78.83

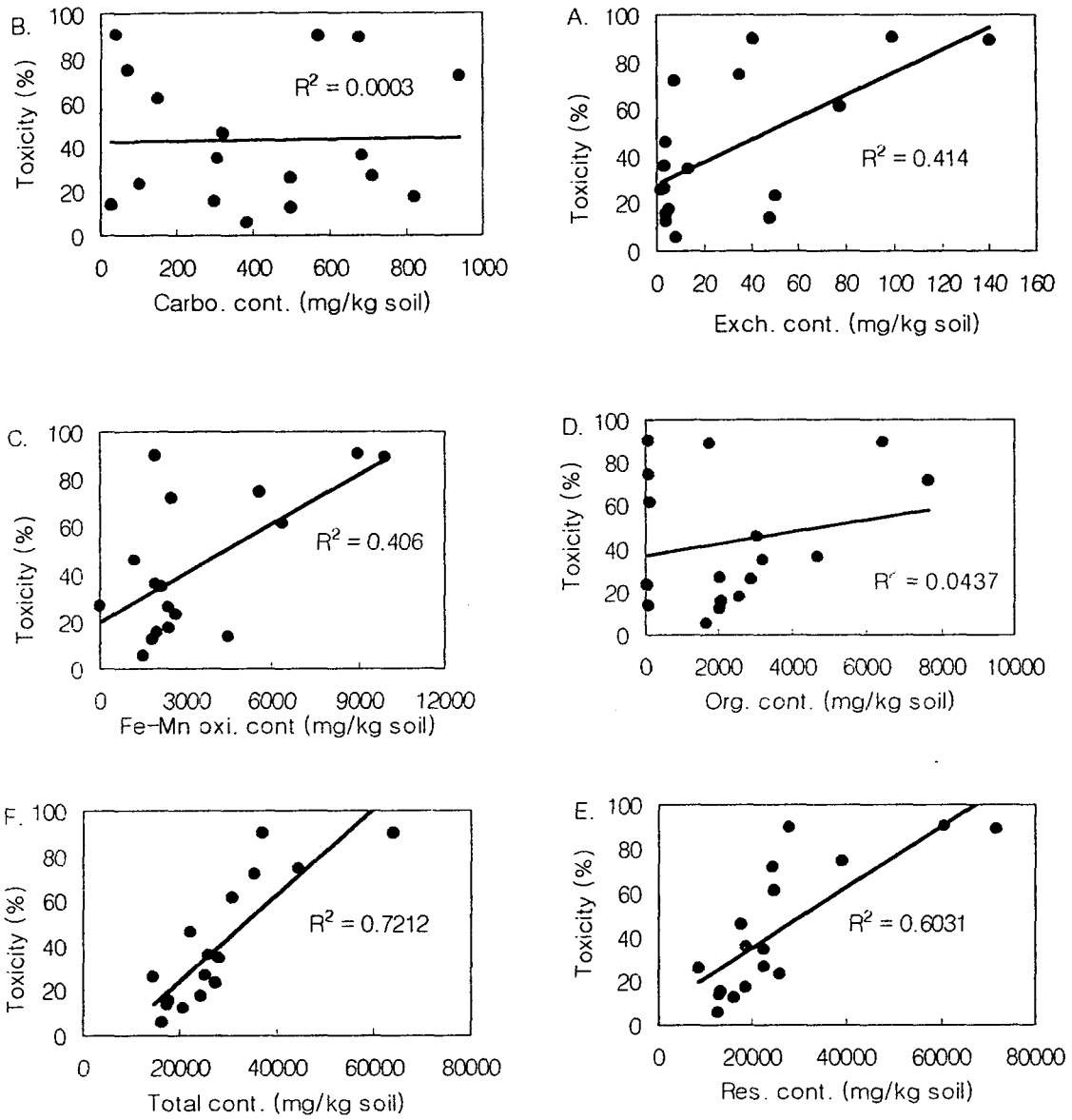

Fig. 1. Correlation of toxicity, as shown by MetPLATETM, and the percentage distribution of fractionated six metals in contaminated soils. A; total exchangeable form, B; total carbonates-bound C; total Fe-Mn oxide-bound, D; total organic-bound, E; residual, F; total metals.