A Correlation Analysis Between Trace Elements Contents of Rice and Soil According to the Soil's Properties

NAQS

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ABSTRACT

This study researched the correlation between the heavy metal content of soil and rice based on the results of heavy metal analysis of soil and the heavy metal analysis of rice in order to investigate the factors causing the production of polluted rice. There was significant correlation between trace element (cadmium, lead) contents of rice and soil. This resulted from the correlation analysis between the cadmium and lead contents of soil and the cadmium and lead contents of soil and the soil's physicochemical properties. However, organic matter content and the pH of soil did not show significant correlation. The transfer rate of cadmium from soil to rice averaged 0.356, whereas that of lead was 0.004, which indicated that lead hardly transfers from soil to rice and that cadmium transfers easily. The transfer rate was high in rice produced from silty clay loam resulting in 17.4% of the rice produced from silty clay loam exceeded rice criteria for Cd. The regression equation utilizing soil's cadmium content, soil texture, and organic matter contents proved to be the most appropriate.

OBJECTIVES

Of various pollution sources in soil, heavy metals do not decompose easily unlike organic matters and nutrients. They bond with organic matters or interact with other inorganic matters to accumulate in soil. By remaining in soil for a long period they impede produce growth by transferring to the produce. They can also cause illnesses in humans and animals ingesting the produce through the food chain (Chung, 2007). These heavy metals can exist naturally in soil through parent material. But they can also be artificially introduced into soil by metal production, fossil fuel combustion, waste incineration, air pollution caused by car exhaust, pesticide and fertilizer usage, sewage sludge, mines and smelting factories (Alloway, 2000).

Recently, cadmium and lead contents detected from produce harvested in the vicinity of abandoned mines, industrial complexes, and landfills exceeded the cadmium and lead standard rate, raising concerns about the severity of heavy metal pollution in produce. Countries have set heavy metal pollution standards for soil to protect human health from soil polluted with heavy metal. However, the heavy metal transfer from soil to plant is reported to vary depending on the soil's heavy metal concentration rate, plant characteristics and the soil's physicochemical properties. It is impossible to prevent the possible heavy metal transfer to produce and its damaging effects on human health with such simple standards. This research investigates the factors affecting heavy metal content of rice by studying the correlation between trace elements (cadmium and lead) contents of rice produced in the abandoned mine areas, heavy metal contents of the areas' soil, and the soil's physicochemical properties for the preparation of measures to prevent the cultivation of produce not suitable for human consumption.

MATERIALS AND METHODS

The Ministry of Environment examined soil pollution in 169 abandoned mine areas throughout Korea from 1992 to 2004. From the research, 44 areas with highest soil pollution level and which were also producing agricultural products were chosen.

Soil, water quality and the heavy metal pollution level of the produce from those 44 abandoned mine areas were investigated in cooperation among the Ministry of Environment, the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF) and Korea Food and Drug Administration from 2005 to 2006. From 2007 to 2009, 374 of 418 abandoned mine areas with severe heavy metal pollution were examined. The 374 areas were the remaining areas excluding the formerly investigated 44 areas. In the 374 areas, the Ministry of Environment carried out the soil and water quality research, and the MIFAFF conducted the produce research. The Ministry of Environment investigated the cadmium, lead, copper, arsenic and mercury contents of soil. MIFAFF examined the cadmium content of rice until 2005 and the cadmium and lead contents of 10 produce with highest daily intake (rice, soy bean, corn, red bean, potato, sweet potato, radish, Chinese cabbage, green onion and spinach) from 2006. Statistical analysis of the results of the areas' soil analysis and the produce analysis employed PASW (former SPSS). Correlation analysis and simple and multiple regression analyses were used as the statistical analysis method.

RESULTS & CONCLUSION

Table 1 shows the unsuitability rate of produce examined annually by NAQS from 2001 to 2008. NAQS analyzed Cd for agricultural products from 2001 to 2005. It analyzed Cd and Pb from 2006.

Table 1. Trace element in agricultural products (NAQS).

Year	01'	02'	03'	04'	05'	06'	07'	08'	Total
No. of samples	158	54	100	69	244	896	4,156	2,660	8,337
No. of unsuitable samples	38	33	12	8	31	105	99	46	372
Trace element			Cd				Cd, Pb		
Unsuitability rate (%)	3.8	61.1	12.0	11.6	12.7	12.0	2.4	1.7	4.5

The correlation between heavy metal contents of rice and heavy metal contents of soil and its chemical properties were examined. This resulted in no significant correlation between the heavy metal content of rice and pH and organic matter content of the soil. However, the heavy metal content of rice was significantly correlated with the heavy metal content of soil from which rice was grown (Cd: 0.327, Pb: 0.141). The content correlation between rice with higher cadmium content (above 0.1 mg/kg) and cadmium content of the soil (Cd: 0.523) was even higher.

Table 2 shows the correlation between correlation between heavy metal contents of rice and heavy metal contents of soil and its chemical properties.

Table 2 . The correlation of between heavy metal contents in rice, heavy metal contents in soil and soil chemical property and heavy metal.

	factor	heavy metal content (mg/kg) Cd	Pb
chemical property of soil	pH	0.049	0.072
	organic matter content	0.064	0.032
heavy metal contents in soil (0.1N HCl)	Cd or Pb	0.327**	0.141**

** : significant value $p=0.01$, $N = 1,961$

The percentage of rice with cadmium content exceeding the permitted level was higher as the cadmium pollution level of the soil increased. The percentage of rice exceeding the permitted level was 1.0% among rice produced from soil with less than 40% of cadmium concern level (1.5 mg/kg), whereas the percentage was 5.4% among rice from soil between 40% of Cd concern level and below the concern level. The percentage reached 75% when the soil exceeded the concern level.

Average transfer rate of lead was 0.004, and that of cadmium was 0.356, indicating that lead hardly transfers to rice, whereas cadmium easily transfers from the soil to rice.

Transfer rate of cadmium and lead in different soil textures were compared. Cadmium transfer rate was very high in silty clay loam at 2.049. Sandy clay loam's rate was 0.458, loam 0.341, sandy loam 0.305, silt loam 0.181, and loamy fine sand 0.122. Due to the variation in transfer rate in different soil textures, the cadmium excess level of rice produced in silty clay loam reached 17.4%. Lead's transfer rate was too low to compare its rates of various soil textures.

Table 3 shows distribution of cadmium concentration in rice in various soil textures.

Table 3. Distribution(%) of cadmium concentration in rice in various soil textures.

soil texture	cadmium concentration in rice(mg/kg) > 0.25	0.15 ~ 0.25	0.05 ~ 0.15	< 0.05
silty clay loam	17.4	15.9	24.6	42.0
silt loam	0.6	1.5	8.7	89.2
sandy loam	1.2	0.5	10.0	88.2
loamy sand	2.9	0.0	0.0	97.1
loam	1.4	2.3	14.1	82.2
Total	1.7	2.0	11.6	84.5

Regression equations utilizing soil's cadmium content, soil texture and organic matter contents proved to be most appropriate as the regression equation for estimating cadmium content of rice. A regression equation of significance for estimating lead content of rice could not be formulated as the lead content in rice was too low. Regression analysis for estimating cadmium content of rice indicated that heavy metal content, soil texture, and organic matters contents have significant effects of cadmium content of rice.

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