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A Survey on Some Heavy Metal Contents of Water and Rice in the Jeon-buk Area of Korea

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Abstract: This study was performed to investigate the levels of cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) in water and rice samples taken from five sites on a stream used for agricultural water in the Jeon-buk area, Korea. The water samples were randomly collected by the recommendations of the World Health Organization, and rice samples were randomly collected from rice paddy. The water and rice samples were analyzed by the recommendations of Food Code of Korea and using inductively coupled plasma spectrometer. Although there was variation between sampling sites, the levels of the metals in rice were on average much higher than those in water. The ratios of metal levels of rice to water were: 8.0~35.4 for Cd; 2.2~7.2 for Cu; 5.9~18.3 for Pb; and 10.6~75.7 for Zn. These results suggest that there were transfer and bioaccumulation of the metals from the water to the rice taken place.

Keywords: heavy metals, water, rice

Introduction

Concerns about high levels of heavy metals in foodstuffs, and chronic health effects associated with consumption of the foodstuffs are growing. Some micronutrient elements for example copper, chromium, fluorine, molybdenum, nickel, selenium or zinc, may be toxic to both animals and humans at high concentrations, although they are essential for plant growth and/or human nutrition in low levels. Other trace elements, such as arsenic, cadmium, mercury and lead, may also inadvertently enter the food chain and may pose health risks to humans and animals. The sources of these elements vary, and the propensity for plants to accumulate and translocate them to edible and harvested parts depends to a large extent on soil and climatic factors, plant genotype and agronomic management (McLaughlin *et al.*, 1999).

Of the elements listed above, the elements that have most frequently raised health concerns about food safety include heavy metals such as cadmium (Cd) and lead (Pb), together with copper (Cu) and zinc (Zn) (McLaughlin *et al.*, 1999). The contamination of these elements in foods, water, and soil has been surveyed by many scientists (Nriagu and Lin, 1995; Tamasi and Cini, 2004; Carlon *et al.*, 2004; Hong and Park, 1984). However, a few reports have studied to find a possible link between the heavy metal contents of rice and water. The objective of this study was to investigate the extent and degree of the four heavy metal contamination of paddy rice and irrigation waters in Jeon-buk area of Korea.

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Materials and Method

Sampling Area

Paddy rice and waters were sampled from five sites along a stream used for agricultural water in Iksan and Wanjoo, Jeon-buk area, Korea (Fig. 1).

Sampling of Water and Rice

The water samples were collected following the World Health Organization (WHO, 1993). Water samples were collected midstream in an acid-cleaned polyethylene bucket. For the trace element analysis, a 200-m*l* sample was immediately filtered through a 0.45-μm membrane filter (Millipore Cor., MA, U.S.A.) and transferred into an acid-cleaned 250-m*l* polypropylene bottle, and then 2 m*l* of high-purity (>35%) hydrochloric acid (Duck-san, Korea)

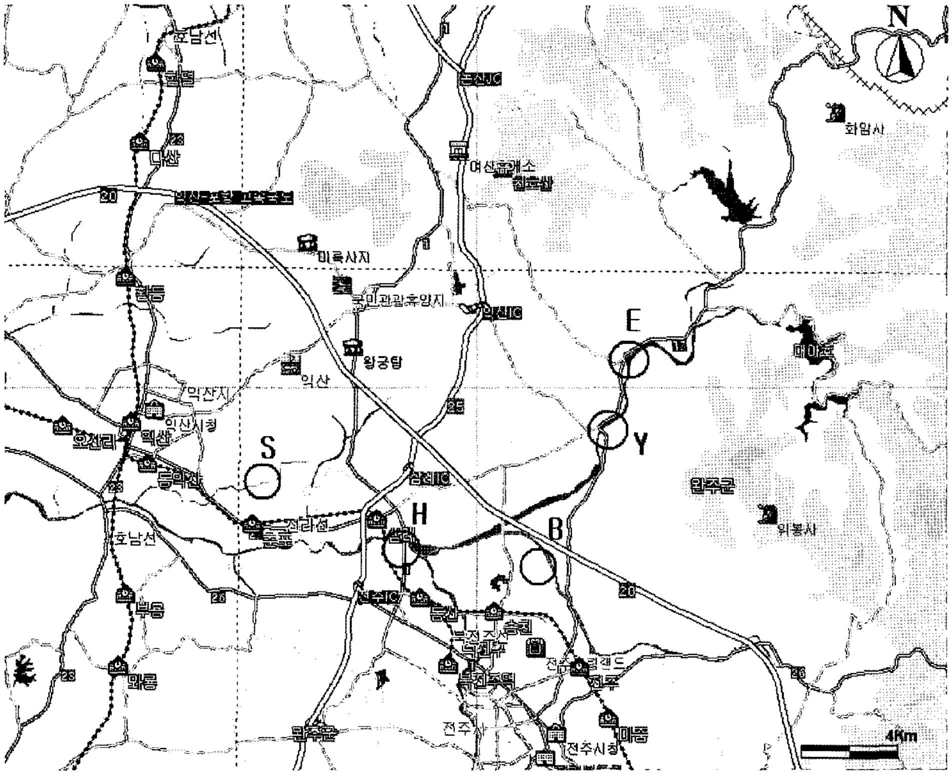

Fig. 1. Map showing five water sample sites in Jeon-buk, Korea.

was added to give a pH of ~1.

Rice plants were harvested from September to October in 2000. Grains were randomly sampled and hulled by hands before the metal analysis. Once the hull was removed the brown rice was then dried in an oven for 48 hours. The dried rice was ground in a high-speed vibrating sampling mill (TI 200, Heiko, Japan) to a fine powder (to pass a no. 100 sieve). The water and ground rice sample were used for the heavy metal assay.

Sample Preparation and Analysis of Heavy Metals

Sample preparation of the water and rice was done according to the Food Code of Korea (Korea Food and Drug Administration, 2000). The analyses of the samples were carried out using inductively coupled plasma spectrometer (JY 70 plus, Jobin Yvon Co., France) for Cd, Cu, Pb and Zn.

Data Analysis

The data from samples were compared by analysis of variance. Significant differences among means were determined by using Duncan's multiple range test.

Results and Discussion

The results showed no significant difference of metal levels of water samples collected from the five sites. However, significant differences of metal levels (Zn, Pb, and Cd) of rice between sampling sites were observed ($p<0.05$), although the study did not find relationships in the metal levels between sampling sites. The average heavy metal levels of water and rice observed was in the order of Cd < Cu < Pb < Zn (Tables 1-4).

In the five sample sites, the average Cd levels of sample means in water and rice were 0.09 mg/*l* (0.04~0.12 mg/*l*), and 1.46 mg/kg (0.50~3.89 mg/kg), respectively. The average Cu levels of sample means in water and rice were 0.69 mg/*l* (0.38~0.83 mg/*l*), and 2.13 mg/kg (1.42~2.58 mg/kg), respectively. The average Pb levels of sample means

Table 1. Levels of zinc in water and rice samples in Jon-buk, Korea

Sampling site	Water (mg/*l*)	Rice (mg/kg)	Ratio of rice/ water
E	1.67 ± 1.30	126.38 ± 30.43[a]	75.7
Y	2.03 ± 0.76	120.29 ± 17.04[a]	59.3
B	2.03 ± 0.81	21.54 ± 12.33[b]	10.6
H	3.28 ± 2.29	80.42 ± 7.97[a]	24.5
S	2.19 ± 1.16	82.27 ± 15.25[a]	37.8
Average	2.24 ± 0.55	86.18 ± 37.4	

All values represent the mean ± S.D., n = 5.
Means with the different lettered superscripts in a column are significantly different each other as determined by ANOVA and Duncan's multiple range test ($p<0.05$).

Table 2. Levels of copper in water and rice samples in Jeon-buk, Korea

Sampling site	Water (mg/*l*)	Rice (mg/kg)	Ratio of rice/ water
E	0.38 ± 0.02	2.75 ± 0.47	7.3
Y	0.61 ± 0.04	1.42 ± 0.37	2.3
B	0.83 ± 0.03	1.79 ± 0.97	2.3
H	0.83 ± 0.04	2.58 ± 0.40	3.1
S	0.82 ± 0.07	2.12 ± 1.76	2.6
Average	0.69 ± 0.18	2.13 ± 0.49	

All values represent the mean ± S.D., n = 5.
Means with the different lettered superscripts in a column are significantly different each other as determined by ANOVA and Duncan's multiple range test ($p<0.05$).

Table 3. Levels of lead in water and rice samples in Jeon-buk, Korea

Sampling site	Water (mg/*l*)	Rice (mg/kg)	Ratio of rice/ water
E	0.49 ± 0.03	5.12 ± 2.29[ab]	10.5
Y	1.97 ± 0.02	10.59 ± 0.25[b]	5.8
B	0.51 ± 0.07	9.35 ± 1.75[a]	18.3
H	1.16 ± 0.57	6.79 ± 0.93[ab]	5.9
S	0.96 ± 0.07	5.79 ± 3.23[ab]	6.0
Average	1.02 ± 0.54	7.53 ± 2.10	

All values represent the mean ± S.D., n = 5.
Means with the different lettered superscripts in a column are significantly different each other as determined by ANOVA and Duncan's multiple range test ($p<0.05$).

in water and rice were 1.02 mg/*l* (0.49~1.97 mg/*l*), and 7.53 mg/kg (5.12~10.59 mg/kg), respectively.

Table 4. Levels of cadmium in water and rice samples in Jeon-buk, Korea

Sampling site	Water (mg/*l*)	Rice (mg/kg)	Ratio of rice/ water
E	0.06 ± 0.01	0.87 ± 0.12[b]	14.5
Y	0.11 ± 0.04	0.88 ± 0.52[b]	8.0
B	0.12 ± 0.01	1.18 ± 0.15[b]	9.8
H	0.04 ± 0.01	0.50 ± 0.06[b]	12.5
S	0.11 ± 0.08	3.89 ± 0.13[a]	35.4
Average	0.09 ± 0.03	1.46 ± 1.22	

All values represent the mean ± S.D., n = 5.
Means with the different lettered superscripts in a column are significantly different each other as determined by ANOVA and Duncan's multiple range test ($p<0.05$).

The average Zn levels of sample means in water and rice were 2.24 mg/*l* (1.67~3.28 mg/*l*), and 86.18 mg/kg (80.42~126.38 mg/kg), respectively. Rice collected from sites E and Y contained higher Zn concentrations than the samples from the other sites. Also, rice obtained from site S contained significantly higher Cd concentration than samples from the other sites ($p<0.05$).

The Cd and Cu contents of rice samples (brown rice) in this study were lower than the levels in rice grain reported in other studies by foreign scientists. Samples of wild rice grains available for sale in Manitoba, Canada contained <0.01~6.2 μg/g of Cd, <0.01~6.7 μg/g of Pb, and 1.6~14.4 μg/g of Cu (Bennett *et al.*, 2000). The Cd concentrations of rice grain in 524 fields, ranged from 0.05 to 7.7 mg/kg in a zinc mineralized area in Thailand (Simmons *et al.*, 2005). However, the results of this study showed much higher levels of the metals in comparison with the results of domestic samples by Lee and You, and Kim and Lee. Kim and Lee (1996) reported that the contents of Pb, Cd, Cu, and Zn of polished rice samples in the vicinity of Ulsan area were 0.426 ppm, 0.014 ppm, 1.111 ppm, and 5.297 ppm, respectively. Lee and You (1992) reported that the Pb and Cd levels of water samples of the Kum river were ND~2.15 μg/*l* and ND~4.29 μg/*l*, and rice samples (brown rice) along the river were 0.145~0.521 mg/kg and 0.025~0.062 mg/kg, respectively. The sampling area of this study is located near the southern, small branch of the Kum river. The findings that the levels of Cd and Pb in water and rice samples along the Kum river in Lee and You's study were about 1/10 of the metal levels in water and rice sampled in this study seem significant. Their results and the results of this study suggest that the environmental pollution around the river has increased during the past years, although water and rice were sampled once. Further research dealing with seasonal water quality variations and monitoring the changes of metal concentrations according to the amount of flowing water should be conducted.

The rice samples collected from five sites in this study contained Cd at concentration exceeding the Codex Committee on Food Additives and Contaminants (CCFAC) draft Maximum Permissible Level for rice grain of 0.2 mg/kg of Cd. Prolonged consumption of rice containing elevated Cd levels is a significant health issue particularly in subsistence communities that are dependent on rice produced on-farm. This poses a significant public health risk to local communities. Although no attempts were made to evaluate the metal concentration of rice after milling in this study, we could expect a lower level in polished rice. However, we have to remember that the residues after polishing are used as feed for domestic animals, which in turn are a source of protein for humans. More detailed epidemiological studies and environmental monitoring are needed in this area.

Conclusion

The results of this study suggest that there might be transfer of the heavy metals from the water to the rice. Also there might be bioaccumulation of these metals in rice samples. There should be a long-term monitoring of the water quality and agricultural products in this area.

Acknowledgement

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