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Cadmium Content in Rice and Rice Field Soil in China, Indonesia and
Japan, with Special Reference to Soil Type and
Daily Intake from Rice

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‡T Introduction

The present study was carried out to: 1)
assess cadmium content in both rice and soil

of China, Indonesia and Japan, 2) determine the relation of cadmium content in rice and

soil to soil type and country, and 3) estimate the average daily cadmium intake from rice from the results of cadmium analysis and rice consumption data of FAO.
Much data on cadmium content in rice and

soil of Japan have been reported (Iimura 1981; Masironi et al., 1977; Morishita 1981; Moritsugu et al., 1964; Nakatsuka et al., 1988; Yanagisawa 1984), but those for Indonesia are limited (Suzuki et al., 1988; Rivai et al., 1990). Moreover, the only data on cadmium content in rice of China have been reported by Rivai et al.(1990), none are available on the cadmium content in soil of China. Rice is a major source of cadmium intake for man in rice eating countries such as China, Indonesia and Japan. Thus, rice may be the best indicator to monitor cadmium exposure. Iimura (1981) reported the mean cadmium content in brown rice and paddy soil of Japan to be 90 and 450 ppb, respectively. Yanagisawa et al. (1984) found this parameter in brown rice and paddy soil from polluted area of Japan to be 0.37 and 1.35 ppm, respectively.
Hutton et al. (1987) found the major sources of cadmium pollution to the agriculture land in England to be sewage disposal, manufac-

ture and phosphate fertilizer. Morishita (1981) and Asami (1981) reported that rice grown in polluted soil contains more cadmium than that of non polluted soil. However, there are no data on relationship between cadmium content in rice and soil to

the soil type. Assessment of the accumulation of cadmium content in rice and soil by soil type may also facilitate environmental monitoring.
Daily cadmium intake from rice may be estimated from cadmium content in rice mul-

tiplied by daily rice consumption. Ohmomo (1981) reported the daily cadmium intake from rice of Japan to be 26 ,ug/person. Though the biological role of cadmium is not known for plants, under certain condi-tions it may accumulate in some plants to levels hazardous for animals and finally for man at the end of the food chain. This

element, after entering into the soil would not be leached out and thus accumulate.

Some of it is absorbed by plants that are a part of the ecological cycle. The hydrochloric acid extraction method can be used to detect the soluble fraction of the element absorbable

from the roots of rice plants (Nihon Dojo Hiryo Gakkai 1986).

‡U Materials and Methods

A total of 178 pairs of rice and soil samples were collected from China, Indonesia and

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Japan. Soil samples were also collected from rice fields where rice plants were growing. All
the rice samples were unpollished. Samples
were taken from East, Northeast and South China. In Indonesia, they were taken from
Java, Sumatra, Kalimantan and Sulawesi, and in Japan, from Hokkaido/Tohoku, Hokuriku, Kanto, Tokai, Chugoku, Shikoku and Kyushu. Sample sites recorded were usually prefecture or city level.

Pre-treatment of a rice sample: 0.1 gram
of a rice sample was put into a test tube and
weighed, dried in an oven at 105•Ž for 48
hours and weighed again to assess water
content. The dried sample was asked on a hot
plate with 1.0 ml of concentrated nitric acid
(metal free) until dry. Then, 2.0 ml of 14%
nitric acid were added, dissolving the residue
at the bottom of the test tube. Two methods
were used for pre-treatment of a soil
sample: 1) Extraction by HCl without
ashing. About one gram of a dried and filtered
soil sample was put into a test tube and
weighed and then 5.0 ml of 0.1 N HCl was
added. The test tube was shaken in a water-

bath of 30•Ž for 1 hour. The upper clear
solution was separated and centrifuged at
3000 rpm for 5 minutes for cadmium analysis,
2) Extraction by ashing with nitric acid.
About one gram of dried and filtered soil
sample was put into a test tube, weighed, and
5.0 ml of concentrated nitric acid (metal free)
were added, followed by ashing on a hot plate.
10.0 ml of pure water were then added and the
clear supernatant was taken for cadmium
analysis.

Cadmium in the solution was assessed by a flameless atomic absorption spectrophoto-meter (Hitachi 180-30), with automatic background correction. Each sample was

analyzed two or three times by an autosam-pler at wave length 229 nm for rice samples and 320 nm for soil samples. Under the same conditions, standard materials provided by the US National Bureau of Standard were

used for reference to confirm accuracy: 0.1 gram of powdered rice (No. 1568) and 0.5 g of orchard leaves (No. 1571) for soil samples. The reliabilities of the cadmium determina-

tion in rice, soil extracts by HCl, and in supernatants of soil ashed by HNO3 were 18.7%, 7.1% and 17.8%, respectively, in terms of the coefficient of variation of 10 repeated analyses of the same sample lot. A recovery test was made by adding 0.002ug of cadmium to each five sample of rice (0.1 g) from the same sample. The recovery rate was 94% on the average, ranging from 74% to 118%. Identification of soil type was based on the "Soil Map of the World"
, Volume VIII (1978)
and Volume IX (1979) by FAO (Food and Agriculture Organization). A few samples on a borderline between two soil types were excluded.

Daily cadmium intake from rice was cal-culated by cadmium content in rice multiplied by daily rice consumption from Food Balance Sheets, 1979-1981 Average, by FAO (1984).

‡V Results

Geometric mean and geometric standard deviation of cadmium content in the 178 pairs of rice and soil samples from China, Indonesia and Japan are shown in Table 1. Geometric mean concentration of cadmium in rice was

11.8, 20.3 and 75.9 ng/g for China, Indonesia and Japan, respectively, and that in soil from China, Indonesia and Japan, 33.1, 20.1 and 81.4 ng/g, respectively, by the hydrochloric acid extraction method, and 99.5, 73.7 and

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Table 1 Geometric means and deviations of cadmium content (ng/g wet wt.) of 178 pairs of rice and soil samples from the three countries.

Note : Cd, cadmium ; N, number of samples ; GM, geometric mean ; GD, geometric deviation ; (a), extracted by hydrochloric acid ; (b), ashed by nitric acid ; ANOVA, F=26.3, 36.6 and 120.5 at p<0.01, for Cd in rice, (a) and (b), respec-tively.

Table 2 Geometric means and deviations of cadmium content of 178 pairs of rice (ng/g wet wt.) and soil (ng/g dry wt.) samples grouped according to soli type.

Abbreviations and marks : See the footnote of Table 1; *, the mixed soil of Andosols, Lithosols, Histosols and Acrisols ; ANOVA, F=6.2, 8.6 and 25.7 at p<0.01, for Cd in rice, (a) and (b), respectively.

445.8 ng/g, respectively, by the nitric acid ashing method. Cadmium content in the rice and soil of Japan was two to several times higher than in the other two countries. The cadmium content in rice of China was lower

than that of Indonesia, though in soil ashed by the nitric acid in China higher than that of Indonesia.
Table 2 shows the difference in cadmium content in the 178 pairs of rice and soil samples broken down by soil type. Seven soil types were identified from the 178 collection sites as: Andosols, Cambisols, Fluvisols, Gleysols, Histosols, Luvisols and Acrisols.,

"Mixed soil" was given to sample sites having

more than one soil type. Cadmium content in rice grown on the soil type of Fluvisols, all from Japan, was highest or 164.0 ng/g, and that of Gleysols lowest or 12.2 ng/g. Twelve samples out of 15 Gleysols, were from China (Tables 2 and 3). Cadmium content in soil by extraction with hydrochloric acid and by ashing with nitric acid showed the data of Cambisols, all samples from Japan, to be the highest or 148.4 and 601.8 ng/g, and that of Histosols, lowest or 12.2 and 36.6 ng/g, respec-tively. Differences in cadmium content in the 178 pairs of rice and soil samples by soil type

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Figure 1 Relationship between cadmium content in rice and soil extracted by hydrochloric acid.

Table 3 Numbers of rice samples collected from China, Indonesia and Japan broken down into
seven soil types.

*

, see foot note of Table 2,

were statisticaly significant at p<0.01.
The number of soil types collected from China, Indonesia and Japan is shown in Table 3 broken down by soil type. Soil types in a country were grouped into only one or two.

Gleysols and Mixed soils were the only soil types found in China. Soil types in Indonesia were comprised of Andosols, Histosols, Luv-isols and acrisols. In Japan, the soil type was mainly of Andosols (73%) the rest being Cambisols, Fluvisols, Gleysols and mixed soil. The mean ratio of cadmium concentration

in rice to that in soil (a) was 0.89 of 178 paired samples, as shown in Table 4. This ratio differed by soil type ranging from 0.26 for Gleysols to 2.32 for Fluvisols. Thus, Fluvisols of Japan showed the highest biological con-centration from soil (b) to rice, though the ratio of cadmium concentration in soil (b) to in soil (c) is low.
Figure 1 shows the relationship between the concentration of cadmium in rice and that

in soil extracted by hidrochloric acid (a) clas-

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Table 4 Geometric mean ratios of cadmium content in rice to soil extracted by hydrochloric acid (a) and soil ashed by nitric acid (b) broken down by soil type.

Abbreviations and marks : GM, geometric mean ; GD, geometric deviation ; *, see foot note of Table 2 ; ANOVA, F=3.65, 3.36 and 4.82 at p<0.01, for rice/a, rice/ b and a/b, respectively.

Table 5 Geometric means and deviations of cadmium content in rice grown on the soil type of Andosols and Gleysols by country (ng/g wet wt.).

Abbreviations : N, number of sample ; GM, geometric mean ; GD, geometric deviation ; p, level of statistical significance.

sif ied by soil type and indicates rice grown in the soil of Fluvisols of Japan to contain the most cadmium, though the cadmium content
in the soil was not high. Gleysols in China contained less cadmium in rice but inter-mediate amounts were present in the soil. The geometric mean and geometric stand-ard deviation of cadmium content of rice

grown on a same soil type but in different country are shown in Table 5. Cadmium content in rice grown on Andosols in Japan was 70.1 ng/g which is higher than that of Indonesia or 17.6 ng/g. Rice grown in Gleysols in Japan was 81.4 ng/g, and had more cad-mium than that in China, 7.4 ng/g.

The coefficient of correlation between the concentrations of rice and soil is shown in

Table 6 in each country. In china and Japan, negative correlation was seen between cad-mium in rice and in soil extracted by the hydrochloric acid, but a positive significant value was found for Indonesia (r=0.32, p<0.05). Relationships of cadmium content in rice to that in the soil ashed by nitric acid from China, Indonesia and Japan were not significant. The correlation coefficients be-tween cadmium content in soil (a) to that in soil (b) were 0.53 and 0.68, these being signifi-cant at p<0.01 for Indonesia and Japan, re-spectively. The correlation coefficient be-

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Table 6 Correlation coefficients between concentration of cadmium in rice and soil samples by country.

Abbreviations and marks : Cd, cadmium ; (a), extracted by hydrochloric acid ; (b), ashed by nitric acid ; * & * *, significant correlation at p<0.05 & p < 0.01, respectively.

Table 7 Estimation of daily cadmium intake from rice by country (microgram/person)',

*

, Average daily rice consumption (g/person) of 1979-1981 from the data of Food Balance Sheets by FAO (1984).

tween cadmium content in rice and soil ex-

tracted by hydrochloric acid (r=0.25) and soil ashed by nitric acid (r=0.39) was positively significant at p<0.01. A positive significant correlation was obtained also for the relation-

ship of cadmium content in soil extracted by hydrochloric acid (a) to soil ashed by nitric acid (b) (r=0.71, p<0.01).
Among the three countries investigated, the daily cadmium intake from rice of Japan was highest or 22.8 ,ug with a 95% confidence

limit from 3.8 to 136.8 ,ug. Mean daily cad-mium intakes from rice in China and in Indonesia were estimated to be 4.1 and 13.3

,ug, respectively (Table 7).

‡W Discussion

Cadmium content in the rice of Japan as reported by several researchers were: 65 ng/g wet wt. (Masironi et al.,1977), 52 ng/g dry wt. (Nakatsuka et al., 1988), 66 ng/g dry wt. (Moritsugu et al., 1964), 90 ng/g dry wt.

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(Yamagata et al., 1978) and 137 ng/g wet wt.
(Yanagisawa et al., 1984). The Cadmium con-
tent in the unpolished rice of Indonesia or 26.3
ng/g wet wt. was somewhat less than the
previous data of cadmium content in unpol-
ished rice of Java in Indonesia by Suzuki et al. (1980) or 39 ng/g dry wt. when corrected to 13% of water content in the samples. Unfor-tunately, data on cadmium content in rice and soil of China were not available. Cadmium content in rice of China was

significantly lower than that of Indonesia, though the soil in China contains more cad-mium than that in Indonesia. Probably, some different conditions between China and

Indonesia influence cadmium absorption from soil by rice plants such as the pH of soil, water (irigation), method of agriculture and variety of rice. Thornton et al. (1980) found the availablity and uptake of cadmium by plants to decrease with increasing soil pH of 6.5 or more. Cadmium content in soil also varies depending on the depth of the soil as reported by Hamilton (1980). Samples taken close to the surface or the soil depth of 0-7.5 cm contains more cadmium than those locat-

ed deeper.
The soil type Fluvisols found only in Japan contained the highest level of cadmium in rice. Possibly, cadmium in this soil type may be absorbed most easily by rice plants com-pared to other soil types. Fluvisols had devel-oped from recent alluvial deposits and uncon-solidated materials (FAO 1978; 1979). Matsuzaka (1982) reported Fluvisols in Japan mainly appear along sea coasts. Hokuriku of Japan has been known as a high cadmium area and is located along the Japan Sea. Fluvisols is equivalents to Entisols according to the U.S. Soil Classification of 1949 System

(Brady 1984), which is the component of mineral soil materials. Large amounts of cadmium in soil (up to 30 ppm) may be present in mineralized areas of England (Thornton et al., 1980).
Half of the soil samples in China was comprised of Gleysols which contains the lowest cadmium in rice. Gleysols develops in plains and deltas where better natural or artificial drainage have resulted in the ripen-ing of materials containing little sulfide or neutralizing components that prevent strong acidification following oxidation of the sul-fides upon drainage (FAO 1978; 1979). Cad-mium content in rice grown in 81 out of 85 soil types of Andosols of Japan was higher than in the same soil type of Indonesia. One sixth of the total area of Japan is reported to be covered by the soil type Andosols (Matsuzaka 1982). Gleysols of Japan also con-tains higher cadmium in rice than in China. Cambisols contained the highest cadmium in soil (a) and (b), and Histosols was lowest. Cadmium may thus possibly accumulate more easily in Cambisols. Cadmium content in the soil of Houston, Texas (Suzuki et al. 1982) which occurs in three different colors showed the geometric mean of cadmium con-tent in black soil (37.7 ng/g) to be significan-tly higher than that of white soils (17.6 ng/g) and grey soils (21.5 ng/g) when extracted by nitric acid. No differences in cadmium con-

tent in black, white and gray solis could be found when extracted by acetic acid. There-fore, the color of the soil may give some information on cadmium content in soil.

Cadmium content in soil ashed by nitric acid (b) was three to five times higher in the three countries compared with that in soil extracted by hydrochloric acid (a). This is in

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agreement with the data of Suzuki et al.
(1982) that nitric acid extracts more cadmium
from rice than acetic acid does. Although the
extraction by the hydrochloric acid method is
reported suitable to detect the soluble or
mobilizable fraction of the element (Nihon Dojo Hiryo Gakkai 1986), the data of this study show that the relationship between cadmium content in rice and in soil ashed by nitric acid (b) have a higher correlation coeffi-cient than in the case of soil extracted by hydrochloric acid (a).
Daily cadmium intake from the rice of Japan or 22.8 microgram/person is highest among the three countries. However, the daily cadmium intake from rice of Japan is somewhat less compared to the data of Ohmomo (1981) or 26 microgram/person. Cadmium content in the rice of Indonesia was

three times less than that of Japan but the daily cadmium intake from rice in Indonesia was less than half that of Japan. Daily cad-mium intake from rice not only depended on cadmium content in rice but also on the daily rice consumption of each country. FAO (1984) reported daily rice consumption of Japan (300.2 g/person) to be lower than that of Indonesia (507.3 g/person).
This study indicates geographical deffer-ence to have greater influence on cadmium content in rice and soil. The difference may largely come from natural origin, and in some localized places man made pollution play a major role.

‡X Summary
Cadmium content was assessed for 178 pairs of rice and soil samples collected from China, Indonesia and Japan from 1986 to 1988. The samples were also divided into

eight groups by soil type. Geometric mean content of cadmium in rice was 11.8, 26.3 and 75.9 ng/g for China, Indonesia and Japan, respectively. Geometric mean cadmium con-tent in soil from China, Indonesia and Japan was 33.1, 20.1 and 81.4 ng/g, respectively, by the hydrochloric acid extraction method, and 99.5, 73.7 and 445.8 ng/g, respectively, by the nitric acid ashing method. Cadmium content in soil ashed by nitric acid was several times higher than that extracted by hydrochloric acid of the same sample. The soil type of Fluvisols was found only in Japan, and 12 out of 15 Gleysols samples were found in China. The highest cadmium level in rice was found in Fluvisols samples and the lowest was in Gleysols. Cambisols contained the highest cadmium level in soil, and Histosols the low-est. Cadmium content in rice and soil and

daily cadmium intake from rice were highest in Japan among the three countries. The relationship of cadmium content in rice to soil was low within a country. The geographical or country factor determined, to a greater extent, cadmium content in rice and soil than soil type.

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〔原著〕
中国,インドネシアおよび日本のコメおよび水田土壤中の
カドミウム濃度,特に土壤型および一日摂取量との関連
イダ ・ ファリダ ・ リファイ小山洋　 鈴木庄亮
　1986～88年に,中国,インドネシアおよび日本
から178対のコメおよび水田土壤が収集され,その
中のカドミウムが定量された.これらのサンプル ・
はまた土壤型によって8群に分けられた1コメの
中のカドミウム濃度の幾何平均値は,中国,イ
ンドネシアおよび日本でそれぞれ,33.1,26.3およ
び75.9ng/gであった.水田土壤の中のそれは,同
じくそれぞれ,塩酸抽出の場合33.1,20.1および
81.4ng/g,硝酸灰化の場合99.5,73.7および445.8
ng/9であった.このように,水田土壤の中のカド
ミウム濃度は硝酸灰化の場合のほうが塩酸抽出よ
りも数倍高かった.土壤型Fluvisolsは,日本にの
み見出され,Gleysolsは15中12試料が中国に見出
された.コメのカドミウム濃度は,Fluvisolsで最
も高く,Gleysolsで最も低かった.水田土壤のそ
れは,Cambisolで最も高く,Gleysolsで最も低
かった.コメおよび水田土壤中のカドミウム濃度
およびコメからの1日摂取量は幾何平均値で,こ
れら3力国の中では日本が最も高かった.コメと
水田土壤のカドミウム濃度間の関係は各国内では
相関が低かったが,地域(国)間では相関が高い.
コメと水田土壤のカドミウム濃度は,土壤型より
も地域(国)によって大きく規定されていること
が認められた.
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