Heavy metal contamination of soils from organic paddy fields in Thailand

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Abstract
The objective of this study was to investigate the heavy metal concentrations (Cd, Cr, Pb, Cu, Ni, Zn) in paddy fields used for production of organic rice in Thailand. The researchers evaluated soil samples from four sites located north and west of Bangkok. From visual assessment and historical study, the locations did not appear to have been affected by industrial waste. Soil samples were collected from the 0–15 cm depth, air dried, and ground to pass a 2 mm sieve. Heavy metals were extracted from soil samples by acid mixture and then determined by atomic absorption spectrophotometry. Heavy metal concentrations as measured across the soil samples ranged from 0 – 0.0727 mg Cd/kg, 0 – 1.92 mg Cr/kg, 0.186 – 1.39 mg Pb/kg, 0.372 – 2.57 mg Ni/kg, 0.698 – 2.90 mg Cu/kg, and 0.987 – 14.4 mg Zn/kg. All of the heavy metal concentrations measured in these soils were much lower than the critical levels of the heavy metals.

Key Words
Heavy metals, contamination, paddy field, critical heavy metal values.

Introduction

The consumption of organic agricultural products is increasing worldwide. To take advantage of this growing market, Thailand, as a world leading rice exporter, has encouraged its farmers to produce rice using organic methods. In addition, the Thai government's policy in organic rice export is also stated.
To cultivate organic rice, Thai farmers have commonly applied cow or pig manure as a low cost fertilizer. However, accumulation of heavy metals from the manures has become a concern of consumers, farmers and researchers. Accumulation of the heavy metals in humans, particularly cadmium (Cd) , chromium (Cr), lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn), can have toxic effects. For example, cadmium, one of the most common and most widely distributed of environmental metal poisons, when consumed in rice causes proximal tubule damage, anaemia and a severe loss of bone minerals resulting in fractures (Reilly 2002). In addition, cases of *itai–itai* disease were identified among people living in cadmium–polluted areas (Yoshioka 1964; Waalkes 2000). An intake of 1–2 g/d of the hexavalent form of chromium causes kidney and liver necrosis (Kaufman *et al.* 1970). Lead, widely distributed in the environment, affects the central nervous system. Zinc salts at intake levels greater than 250 mg/d in adults causes intestinal irritation, nausea, vomiting and abdominal pain (Faila 1999). Although, emissions of heavy metals have declined in most developed countries, exposure still continues in developing countries, especially among the poorer populations where the toxic effects have not been widely known. Since rice is important economically to Thailand and is a major component of the daily diet of its citizens, this research has focused on the contamination of the heavy metals of soils from organic rice production fields.

Methods

Soil samples
Soil samples were collected from four paddy fields used in organic rice production. There were no indications of industrial pollution, from visual assessment and historical study. Two sites, with cow manure applied, were located approximately 100 km north, and two sites, with pig manure applied, were located approximately 120 km west of Bangkok, Thailand (Figure 1). At each site, ten randomly distributed samples were taken from the 0–15 cm depth (Tandon 1995; Soil and Plant Analysis Council Inc,2000). The soil samples were air dried, ground to pass a 2 mm sieve and kept in plastic bags prior to analysis.

Analysis methods
Heavy metal ions in the soil samples were extracted by acid mixture (1N HCl/1N H_2SO_4) according to Perkins (1970). Concentrations of Cd, Cr, Pb, Cu, Ni, and Zn in the extractants were then determined by atomic absorption spectrophotometry (GBC AVANTA).

Figure 1. Sampling sites located in the north and west of Bangkok.

Results

The concentration of heavy metals in forty soil samples from the organic paddy fields varied widely. The ranges of concentration are shown in Table 1.

Table 1. Heavy metal concentrations of Cd, Cr, Pb, Ni, Cu, and Zn in 40 soil samples from Thailand rice paddy fields.

Heavy metal	Concentration (mg/kg)	Mean	Standard deviation
Cd	0.000 – 0.0727	0.034	0.03
Cr	0.00 – 1.92	0.385	0.52
Pb	0.186 – 1.39	0.925	0.49
Ni	0.372 – 2.57	1.38	0.85
Cu	0.698 – 2.90	1.82	0.67
Zn	0.987 – 14.4	5.41	4.45

A survey of heavy metals in soils from the central, east, northeast, north and south of Thailand by Pongsakul and Attajarusit (1999) showed wide ranges but generally higher concentrations of Cd, Cr, Pb, Ni, Cu, and Zn compared to our study (Table 2). All of the soils in our study had heavy metal concentrations much lower than the critical levels for each element (Fergusson 1990; Table 3).

Table 2 Heavy metal concentrations in 40 soil samples compared with Pongsakul and Attajarusit (1999)*.

Heavy metal	Concentration (mg/kg)	Concentration (mg/kg)*
Cd	0.000 – 0.0727	0.001–0.294
Cr	0.00 – 1.92	0.1–114
Pb	0.186 – 1.39	0.2–295
Ni	0.372 – 2.57	0.5–550
Cu	0.698 – 2.90	0.2–350
Zn	0.987 – 14.4	0.1–138

Table 3. Heavy metal concentration in soils from four sites compared with critical levels of heavy metals as determined by Fergusson (1990).

Heavy metal	Concentration (mg/kg)				Critical heavy metal values (mg/kg)
	Site 1[a]	Site 2[a]	Site 3[b]	Site 4[b]	
Cd	0.0033 – 0.0267 (0.011)	0.0033 – 0.0727 (0.054)	0.0066 – 0.0298 (0.021)	0.0000 – 0.0670 (0.049)	3
Cr	0.396 – 1.92 (1.17)	0.036 – 0.245 (0.166)	0.0000	0.190 – 0.223 (0.202)	50–200
Pb	0.303 – 0.186 (0.234)	1.21 – 1.88 (1.38)	1.28 – 1.39 (1.36)	0.661 – 0.800 (0.725)	100
Ni	2.28 – 2.57 (2.41)	1.45 – 2.47 (1.97)	0.372 – 0.871 (0.522)	0.598 – 0.670 (0.633)	50–125
Cu	2.30 – 2.68 (2.49)	1.81 – 2.90 (2.31)	1.27 – 1.74 (1.57)	0.698 – 1.10 (0.892)	50
Zn	11.3 – 14.4 (12.9)	1.26 – 4.02 (3.04)	3.49 – 4.65 (4.21)	0.987 – 1.77 (1.54)	300

[a] cow manure application
[b] pig manure application
( ) mean

Conclusion

This study surveyed the contamination levels of Cd, Cr, Pb, Ni, Cu, and Zn in organic rice paddies at four sites north and west of Bangkok, Thailand. All of the heavy metal concentrations measured were very low and much lower than critical levels. So the researchers recommended that Thai farmers can apply cow or pig manure as an organic fertilizer to their paddy fields.

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