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IDENTIFICATION OF LEAD AND CADMIUM LEVELS IN WHITE CABBAGE (*Brassica rapa* L.), SOIL, AND IRRIGATION WATER OF URBAN AGRICULTURAL SITES IN THE PHILIPPINES

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ABSTRACT

Urban agriculture comprises a variety of farming systems, ranging from subsistence to fully commercialized agriculture. Pollution from automobile exhaust, industrial and commercial activities may affect humans, crops, soil, and water in and around urban agriculture areas. The research aimed to investigate the level and distribution of lead (Pb) and cadmium (Cd) in white cabbage (*Brassica rapa* L.), soil, and irrigation water taken from urban sites. The research was conducted in Las Piñas and Parañaque, Metro Manila, Philippines. The field area was divided into three sections based on its distance from the main road (0, 25, and 50 m). Irrigation water was taken from canal (Las Piñas) and river (Parañaque). Pb and Cd contents of the extract were measured by Atomic Absorption Spectrophotometry. Combined analysis over locations was used. The relationship between distance from the main road and metal contents was measured by Pearson's correlation. Based on combined analyses, highly significant difference over locations was only showed on Cd content in white cabbage. Cd content in white cabbage grown in Parañaque was higher than that cultivated in Las Piñas, while Cd content in the soil between both sites was comparable. The average Pb content (1.09 $\mu g\ g^{-1}$ dry weight) was highest in the white cabbage grown right beside the main road. A similar trend was also observed in the soil, with the highest concentration being recorded at 26 $\mu g\ g^{-1}$ dry weight. There was a negative relationship between distance from the main road and Pb and Cd contents in white cabbage and the soil. Level of Pb in water taken from the canal and river was similar (0.12 mg l^{-1}), whereas levels of Cd were 0.0084 and 0.0095 mg l^{-1}, respectively. In general, the concentrations of Pb and Cd in white cabbage and soil as well as irrigation water were still in the acceptable limits. In terms of environmental hazards and polluted city environment, it seems that big cities in Indonesia especially Jakarta and Surabaya have the same problem with the Philippines. Therefore, it is suggested that the study on heavy metal contamination in several crops, especially those grown along the main road, should be conducted.

[***Keywords***: *Brassica rapa*, cadmium, lead, urban agriculture]

INTRODUCTION

Urban agriculture is practiced in many different places, such as vacant and underutilized land and water surface in the urbanized sphere, space on and around buildings, public lands and parks, and roadsides and traffic circles (Smit 2000; Mougeout 1998; Mougeout 2000). Midmore (1996) reported that between 25% and 85% of vegetable production supplied in major Asian countries such as Singapore, Hong Kong, and China come from urban farming. This means that urban farming is lifting millions of people out of extreme poverty and is also improving the nutrition and food supplies of city dwellers (Robinovitch and Schmetzer 1997; Ali and Porciuncula 2001; Zeeuw *et al*. 2000).

Rapid growth of urbanization as well as transportation and industries are leading to serious environmental hazards (Urban Harvest 2007). Among chemical elements and compounds which are regarded as environmental pollutants, toxic metals such as Pb and Cd are the most widely spread and found around the urban agriculture areas (Zheljazkov *et al*. 1999; Miller *et al*. 2004; Li *et al*. 2005; Mico *et al*. 2006; Fitamo *et al*. 2007). Elevated levels of Pb and Cd in urban areas are mainly attributed to automobile exhaust, particularly from leaded gasoline, motor vehicle tires, and lubricant oils (Tsadilas 2000; Parekh *et al*. 2002; Duzgoren 2007). Recently, it was claimed that Pb in urban areas can be over 1000 ppm, whereas a tolerable intake of ingested Pb for adults is 3 mg per week which is equivalent to an average daily uptake of 430 µg and 130 µg for children (Day *et al*. 1975). For Cd, critical levels for adults, food source, and water are 120, 45, and 13 µg per day, respectively. In addition, FAO/WHO recommended maximum tolerable intake of Cd of 400-500 µg per week or equal to 70 µg per day. Pb and Cd contents in uncontaminated soils vary between 15 and 106 $\mu g\ g^{-1}$ dry weight and 0.001 to 30 $\mu g\ g^{-1}$ dry weight in normal surface soil (0-15 cm), respectively (Tsadilas 2000). Several studies revealed that 60-80% of heavy metal toxins found in human bodies in urban areas were the result of consuming contaminated foods rather than through air pollution (Quijano 2001; Cui *et al*. 2004; Wang *et al*. 2005; Zheng *et al*. 2007).

Pb and Cd accumulation on several crops including horticultural crops as well as in soils and irrigation water in urban areas have been documented (Dunbar *et al*. 2003; He *et al*. 2004; Fitamo *et al*. 2007; Oliveira *et al*. 2007; Peris *et al*. 2007). In uncontaminated areas, mean concentrations of Pb for lettuce, spinach, tomatoes, peanuts, potatoes, soybeans, sweet corn, and wheat were 0.013, 0.045, 0.002, 0.10, 0.09, 0.042, 0.0033, and 0.037 µg g^{-1} wet weight, respectively (Wolnik *et al*. 1985). Moreover, Boon and Soltanpour (1992) analyzed garden vegetables grown in contaminated soil (mine dump materials) and found that tissue concentration of Pb was highest in the leaves, whereas levels in the roots and tubers were between those in the leaves and fruits. Cabbage and broccoli leaves contained Pb of less than 5 mg kg^{-1} while lettuce and spinach leaves contained Pb of 41-45 mg kg^{-1}. The Pb may also settle on the leaves and fruits of crops. If consumed, the crops may cause metal poisoning and intestinal problems for some people.

Caselles (1998) reported that Pb concentration in leaves of citrus decreased up to 40% within a distance of 50 m from the roadside. Nabulo *et al*. (2006) also pointed out that leafy vegetables grown in roadside areas were considered a potential source of toxic metal contamination to consumers. Therefore, it is recommended that leafy vegetables should be grown at least 30 m from roads in high traffic, urban areas. Aside from distance from road, traffic density may also affect Pb accumulation in plants. Exposed plants accumulated only minor amounts of Pb when the traffic density was less than about 5000 motor vehicles per day, but substantially affected when the volume was greater than 35,000 vehicles per day (Davies 1990).

Consuming of Cd contaminated crops causes a serious health concern such as carcinogenic and mutagenic effects. Kuboi *et al*. (1986) observed Cd uptake in 34 plant species of 9 plant families and found that Cd content was low in Leguminosae, moderate in Cucur bitaceae, and high in Cruciferae and Solanaceae. Leafy vegetables are likely to accumulate Cd at higher levels compared to other crops (Wolnik *et al*. 1985). Lune and Zwart (1997) and Ni *et al*. (2002) reported that Cd accumulation in crops decreased linearly with increasing depth of Cd addition to the soils, and for some crops like spinach the decrease was exponential. In relation to plant distance from road, Lagerwerff (1971) reported that aerial contamination accounted for more than 40% of the Cd content of the radish top grown at 200 m from the highway. Cd is readily available to plants from both air and soil sources. The highest concentrations of Cd in polluted areas were always reported for roots and leaves (Yang *et al*. 2004). The objective of this research was to investigate the level and distribution of Pb and Cd in white cabbage (*Brassica rapa* L.), soil, and irrigation water taken from urban sites of Las Piñas and Parañaque, Metro Manila, Philippines.

MATERIALS AND METHODS

The study was conducted in Las Piñas and Parañaque, Metro Manila, Philippines from October 2001 to May 2002. Selection of these sites was based on several criteria such as major crops planted, total number of vehicles passing through the two urban areas, and position of the fields and distance from the main road.

Sampling Sites

Samples of white cabbage, soil, and irrigation water were taken from the two production sites for analyses of the levels of the toxic metals Pb and Cd. Samples were taken at the corner street between Abel Nosle St. and P. Mapa St. in Business Friendly Resort Village (Las Piñas), and between Multinational Avenue St. and Riyad St. in Multinational Village (Parañaque), Metro Manila, Philippines. White cabbage was only vegetable planted in both sites. An average of 6240 and 7680 vehicles per day passes through these major streets in Las Piñas and Parañaque, respectively.

The field area was divided into three sections based on the distance (0, 25, and 50 m) to the main road (Chalbi and Hawker 2000). For each site, samples of white cabbage and soil approximately 2.0 and 1.5 kg per sample, respectively, were taken from each section, and replicated three times. Soil samples were collected within the depth of 0-15 cm from the surface. In Las Piñas, water used for irrigating the crops comes from the canal, while the source of water in Parañaque is a nearby river. Both the canal and river water was pumped to an artificial basin. About 5 l of water sample, in three replicates, were taken from each artificial basin.

Sample Preparation

Plant

Plant samples from the field were brought to the Plantation Crop Division screen house of the Department of Horticulture, University of the Philippines Los Banos (UPLB) for sample preparation. Samples were rinsed with tap water to remove the soil and other visible residues present. The samples (leaf and shoot) were then cut into small pieces and oven dried at 70°C. After 2-3 days, dried samples were ground to pass through a 2-mm sieve. One gram of sample was placed in a digestion test tube with 5 ml HNO_3 and 0.5 ml $HClO_4$. The mixture was kept for 24 hours at room temperature. The treated samples were then heated in a digestion block at 100°C for 1 hour. The temperature was increased gradually to 200°C. About 1.5 ml of the extract was diluted with deionized distilled water to 25 ml (Jones 1999 with modification).

Soil

Soil samples weighing 1.5 kg each were ground prior to air dried. The air-dried soil was then ground into fine powder using pestle and mortar to pass through 2 mm and then 0.5-mm sieve. Well-mixed samples of 1 g each were taken in 250 ml glass beakers and digested with 5 ml of aqua regia on a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 5 ml HNO_3, filtered and then diluted to 50 ml with distilled water (Jones 1999 with modification).

Water

One liter of water sample was evaporated in a 500-ml beaker, and then mixed with 5 ml HNO_3. The sample was slowly evaporated in a hot plate at low temperature until the volume reached 5 ml. After adding 5 ml HNO_3, the solution was filtered using filter paper into a 25-ml volumetric flask (Jones 1999 with modification).

Pb and Cd Analyses

Pb and Cd contents of the samples were measured by Atomic Absorption Spectrophotometry (AAS) using Hitachi Zeeman Polarization (Z-8230). Absorbance reading for Pb and Cd were 283.3 and 288.8 nm, respectively (Jones 1999).

Statistical Analysis

A randomized block design consisted of three treatments with three replications was used in this research. The distance from the main roads (0, 25, and 50 m) was served as a treatment. A combined analysis was used in comparing levels of toxic metals in the two urban areas. Treatment means were compared using a Duncan's Multiple Range Test (DMRT). Pearson's correlation was used to evaluate the metal concentration in plant and soil versus distance from road (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Highly significant difference of metal content in white cabbage and soil between the two urban farm sites was only showed on Cd content in white cabbage (Table 1). Cd content in white cabbage grown in Parañaque was higher than that cultivated in Las Piñas. The average Cd contents in white cabbage from both areas were 0.42 and 0.18 μg g^{-1} dry weight, respectively.

In terms of distance from the main road, there were high correlations between Cd content and distance, these were $r = -0.87$, $p < 0.005$ for Cd content in white cabbage, and $r = -0.95$, $p < 0.005$ for Cd content in the soil. The elevated Cd content in white cabbage grown in Parañaque could be attributed to many factors including particle size and mass, direction of the prevailing winds, moisture level, level of Cd originating from vehicular emissions that was derived from traffic density and source of irrigation water, and sewage effluents (Lokeshwari and Chandrappa 2006).

It was about 7680 vehicles per day passes through the major street in Parañaque as compared to Las Piñas that was only 6240 vehicles per day. In addition, urban area in Parañaque was more open space than that in Las Piñas as resulted in high aerial deposition of Cd. Furthermore, Lagerwerff and Specht (1970) stated that Cd levels in exhaust emissions have been related to the composition of gasoline, motor oil, car

Table 1. Cd contents in the shoots of white cabbage and soil from the two urban farm areas.

Distance from the main road (m)	Cd content (μg g^{-1} dry weight)				
	White cabbage		Soil		
	Las Piñas	Parañaque	Las Piñas	Parañaque	Means
0	0.28a B	0.49a A	0.30a A	0.35a A	0.33a
25	0.18ab B	0.59a A	0.19b A	0.18b A	0.19b
50	0.09b A	0.19b A	0.12b A	0.17b A	0.15b
Means	0.18B	0.42A	0.20	0.23	

Numbers followed by the same letters in each column and row are not significantly different at p = 0.05 (DMRT).

tires, and roadside deposition of the residues of those materials as well as traffic density. In terms of metal contamination in irrigation water, Cd contents in the canal and the river were 0.0084 and 0.0095 mg l^{-1}, respectively. It seems that Cd content in the river (Parañaque) was relatively higher than that in the canal (0.0084 mg l^{-1}). The river was located along the main road of Parañaque, whereas a canal was relatively far from the main road. Moreover, wastes dumped as well as sewage sludge generated by domestic or municipal activities were observed in the river that could also be pointed out as a possible source of Cd. The same findings were also pointed out by Al Enezi *et al*. (2004) and Wang *et al*. (2005). Nevertheless, in terms of health hazard due to Cd content, white cabbage grown in either Las Piñas or Parañaque was relatively safe for human consumption. In general, Cd content in many crops including vegetables is categorized as beyond the limits when more than 1.5 μg g^{-1} dry weight (Lokeshwari and Chandrappa 2006).

Cd content in the soil taken at 0 m from the main road was the highest. The value decreased to about 40% at a distance of 25 m from the main road. Based on these results, the average Cd content in the urban soil still lies within the normal range, because levels of Cd in contaminated soil can reach 3-8 μg g^{-1} dry weight (Boon and Soltanpour 1992).

Regardless of the locations, the average Pb content was highest in white cabbage grown right beside the main road (Table 2). The level decreased to about 50% within a distance of 25 m from the main road. The level of Pb in white cabbage was comparable when sampling was taken at distances of 25 and 50 m away from the main road. Simple correlation analysis revealed correlations between Pb content and a distance, these were $r = -0.88$, $p < 0.005$ for Pb content in white cabbage, and $r = -0.93$, $p < 0.005$ for Pb content in the soil.

Allow (1990) and Ona *et al*. (2006) reported that 90-99% of Pb in the leaf material were due to foliar uptake and primarily to vehicular emission. Pb mainly reaches leaves by aerial deposition. Likewise, the aerosol-deposited Pb particles do not penetrate the cuticle of leaves but tend to adhere to leaf surfaces (Caselles 1998; Intawongse and Dean 2006; Nabulo *et al*. 2006; Kuang *et al*. 2007). Basically, Pb content in crops grown in uncontaminated areas as cited by Umali (1999) and Flynn (1999) ranged from 0.1 to 10 ppm dry weight. In terms of leafy vegetable, Boon and Soltanpour (1992) reported that Pb contents in leafy vegetable tissue grown in mine dump areas in Aspen Garden soils were between < 5.0 and 45 μg g^{-1}, while Harrison *et al*. (1981) pointed out that lettuce and cabbage grown 9 m from the main road with a traffic density of 29,000 cars per day contained 6.5 μg g^{-1}, and for every 1.27 g white cabbage eaten per day the corresponding intake of Pb was about 0.0027 μg. Referring to daily intake, Zheng *et al*. (2007) also reported that daily intakes of Pb for children through the consumption of vegetables around Huludao Zinc Plant, China reached 446.8 μg per day, and this would lead to potential health risk. Hence, in terms of Pb, white cabbage grown in urban areas of Las Piñas and Parañaque, Metro Manila, Philippines is still safe for human consumption.

Accumulation of Pb in the soil was also significantly different among the distances from the main road. Highest concentration of Pb (26.08 μg g^{-1} dry weight) was noted in the soil right beside the main road. Pb content decreased to about 38% from a distance of 25 m from the main road. This value obtained from the

Table 2. Pb contents in white cabbage and soil from the vegetable farms in Las Piñas and Parañaque as a function of distance from the main road.

Distance from the main road (m)	Cd content (μg g^{-1} dry weight)					
	White cabbage shoot			Soil		
	Las Piñas	Parañaque	Means	Las Piñas	Parañaque	Means
0	0.97a A	1.22a A	1.09a	28.56a A	0.33a A	26.08a
25	0.15b A	0.54b A	0.53b	16.91b A	21.79b A	19.35b
50	0.50b A	0.50b A	0.50b	17.77b A	18.42b A	18.10b
Means	0.66	0.75		21.08	24.60	

Number followed by the same letters in each column and row are not significantly different at p = 0.05 (DMRT).

soil sampled at 50 m away from the main road was not significantly different from that at 25 m away from the main road (Table 2). There were negative correlations between Pb content and distance from road, these were $r = -0.88$, $p < 0.005$ for Pb in white cabbage and $r = -0.93$, $p < 0.005$ for Pb in the soil. Pb content in soil was still within the acceptable limits as reported by Tsadilas (2000), where the range of Pb accumulated in uncontaminated soils reached 15-106 $\mu g\ g^{-1}$ dry weight. In polluted soils, Pb content ranges from 100 to 400 $\mu g\ g^{-1}$ dry weight.

Concentrations of Pb in water were similar (0.12 mg l^{-1}). In relation to toxicity level, recommended level of Pb and Cd for irrigation purposes is less than 0.5 and 0.05 mg l^{-1}, respectively (Umali 1999). Clearly, Pb and Cd contents of the water used for irrigating the vegetable crops were still below the toxic level.

CONCLUSION

There were high correlations between metal contents (Pb and Cd) and distance from road; these were $r = -0.87$, $p < 0.005$ for Cd content in white cabbage, $r = -0.95$, $p < 0.005$ for Cd content in the soil, $r = -0.88$, $p < 0.005$ for Pb in white cabbage, and $r = -0.93$, $p < 0.005$ for Pb in the soil. The average Cd contents in white cabbage from Parañaque and Las Piñas areas were 0.42 and 0.18 $\mu g\ g^{-1}$ dry weight, respectively.

Concentration of Pb in water taken from canal (Las Piñas) and river (Parañaque) was similar (0.12 mg l^{-1}), while levels of Cd were 0.0084 and 0.0095 mg l^{-1}, respectively. In general, the levels of Pb and Cd in white cabbage and soil were below the standard limit considered safe for human consumption.

In terms of environmental hazards and polluted city environment, it seems that big cities in Indonesia such as Jakarta and Surabaya have the same problem with the Philippines. Therefore, it is suggested that the study on heavy metal contamination in several crops, especially those grown along the main road, should be conducted.

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