LEAD AND CADMIUM CONTENTS IN ORGANIC, HYGIENIC AND CONVENTIONAL CHINESE KALES

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Thesis
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LEAD AND CADMIUM CONTENTS IN ORGANIC, HYGIENIC AND CONVENTIONAL CHINESE KALES

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ABSTRACT

This study is conducted to determine and compare lead and cadmium contents in Chinese kales grown under three cultivation practices. Chinese kales were collected from a number of farms in different locations and the same location from different seasons. Closed system digestion method and GFAAS, was used as lead and cadmium determination. The study found that the median lead and cadmium levels in the hygienic Chinese kales were significantly higher than in the organic and the conventional Chinese kales ($p<0.05$). However, there was no significant difference in the median lead and cadmium levels found in the organic and the conventional Chinese kales. According to the study, the usage of pesticides may not be critical factor leading to lead and cadmium accumulation in the vegetables. As a consequence, a number of possible factors that lead to lead and cadmium contamination in the Chinese kales were raised. This includes the history of the farms, the environment around farms, organic and bio-extract fertilizers.

The study indicates that the environment around the farm has an important factor on lead and cadmium accumulation in vegetables. The Chinese kales from the farms in the industrial areas contained higher lead and cadmium levels than the Chinese kales from the farms in the agricultural areas. However, the usage of raw materials contaminated with high lead or cadmium in the fertilizers may also provide high lead and cadmium levels in crops from agricultural areas. The use of organic and bio-extract fertilizers also have an impact on cadmium accumulation in vegetables. This study found high cadmium levels occurred in the Chinese kales grown on farms located in the agricultural areas.

In addition, the seasonal factors play a major role in lead accumulation in the Chinese kale samples, whereas there was insignificant impact in cadmium accumulation in the Chinese kale samples. That is, the highest lead level in Chinese kale was found in the rainy season, whereas the lowest level was found in winter.

The study of lead and cadmium intake indicates that the mean weekly intake of lead and cadmium from Chinese kale consumption in the Thai population was lower than the PTWI (Provisional Tolerable Weekly Intake). However vegetarians, who consume large quantities of Chinese kale containing lead and cadmium at 95 percentile, could be getting exposed to lead and cadmium over the PTWI.

KEY WORDS: LEAD/CADMIUM / ORGANIC CHINESE KALE / HYGIENIC CHINESE KALE / CONVENTIONAL CHINESE KALE

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บทคัดย่อ

คะน้าเป็นผักใบชนิดหนึ่งที่คนไทยนิยมบริโภค การศึกษานี้เป็นการหาปริมาณตะกั่ว และแคดเมียมในผักคะน้าที่มีการเพาะปลูก 3 รูปแบบ ได้แก่ ผักคะน้าอินทรีย์, ผักคะน้าปลอดภัยจากสารพิษ และผักคะน้าเคมี จากพื้นที่การเพาะปลูกต่างกัน และพื้นที่การเพาะปลูกเดียวกัน ในแต่ละฤดู เพื่อศึกษาถึงปัจจัยที่มีผลต่อการตกค้างของตะกั่ว และแคดเมียมในผัก และนำข้อมูลการวิเคราะห์ที่ได้ไปประเมินความเสี่ยงของการได้รับตะกั่ว และแคดเมียมจากการบริโภคผักคะน้า การหาปริมาณตะกั่ว และแคดเมียมในผักโดยวิธีย่อยสลายในระบบปิด Closed System Digestion และวิเคราะห์ปริมาณโดยใช้เครื่อง Graphite Furnace Atomic Absorption Spectrometry ผลการศึกษาพบว่า ค่ามัธยฐานของปริมาณตะกั่ว และแคดเมียมในผักปลอดภัยจากสารพิษมีค่าสูงกว่าค่ามัธยฐานของปริมาณตะกั่ว และแคดเมียมในผักอินทรีย์ และผักเคมีอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) อย่างไรก็ตามไม่พบความแตกต่างของค่ามัธยฐานของปริมาณตะกั่ว และแคดเมียมระหว่างผักอินทรีย์ และผักเคมี ผลการศึกษาพบว่าปริมาณการใช้สารเคมีป้องกันกำจัดศัตรูพืชอาจไม่ใช่ปัจจัยสำคัญต่อการตกค้างของตะกั่ว และแคดเมียมในผัก

การศึกษานี้พบว่าสภาวะแวดล้อมรอบแปลงผักเป็นปัจจัยสำคัญที่มีผลต่อการปนเปื้อนของตะกั่วและแคดเมียมในผักคะน้า ผักคะน้าจากพื้นที่เพาะปลูกต่างกันสะสมปริมาณตะกั่ว และแคดเมียมต่างกัน ผักคะน้าจากพื้นที่เพาะปลูกในแหล่งอุตสาหกรรมมีการสะสมตะกั่ว และแคดเมียมสูงกว่าผักคะน้าที่ปลูกในแหล่งเกษตรกรรม อย่างไรก็ตาม จากการศึกษาพบว่าผักคะน้าในแหล่งเกษตรกรรมบางแปลงมีปริมาณตะกั่ว และแคดเมียมสูง ซึ่งเนื่องมาจากการปนเปื้อนในพื้นที่นั้นๆ จากการนำวัสดุที่มีการปนเปื้อนของโลหะหนักมาใช้ในการทำปุ๋ย โดยเฉพาะปุ๋ยน้ำหมักชีวภาพ อาจเป็นสาเหตุหนึ่งของการสะสมตะกั่ว และแคดเมียมในผักจากแหล่งเกษตรกรรม ตัวอย่างผักคะน้าจากแปลงเดียวกันในฤดูต่างกัน มีการสะสมของปริมาณตะกั่วต่างกัน โดยพบปริมาณตะกั่วสูงสุดในฤดูฝน และพบปริมาณตะกั่วต่ำสุดในฤดูหนาว ปัจจัยทางอุตุนิยมวิทยา อาจเป็นสาเหตุหนึ่งของการสะสมตะกั่วในผัก อย่างไรก็ตามจากการศึกษา พบว่าปัจจัยทางอุตุนิยมวิทยาอาจไม่มีผลต่อการสะสมของแคดเมียมในผัก

การประเมินความเสี่ยงของการได้รับตะกั่ว และแคดเมียมจากการบริโภคผักคะน้าเฉลี่ยต่อสัปดาห์ในกลุ่มประชากรทั่วไป พบว่า มีค่าต่ำกว่าค่า PTWI อย่างไรก็ตามพบว่ากลุ่มคนรับประทานมังสวิรัติที่บริโภคผักคะน้าจากแปลงที่มีระดับตะกั่วและแคดเมียมสูง (95 เปอร์เซ็นไทล์) จะมีความเสี่ยงต่อการได้รับตะกั่ว และแคดเมียมสูงกว่าค่า PTWI

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LIST OF ABBREVIATIONS

bw	body weight
kg	kilogram
mg	milligram
ml	milliliter
µg	microgram
ng	nanogram
ADI	Acceptable Daily Intake
TDI	Tolerable Daily Intake
PTWI	Provisional Tolerable Weekly Intake
^{o}C	Celsius degree
wt	weight
hr	hour
min	minute
sec	second
SD	standard deviation
%	percent

CHAPTER 1
INTRODUCTION

Thailand is an agricultural country and certainly a leading food producer. The agricultural products are allocate to both for domestic supply and for export to other countries. The main problem of Thai exporting is poor food safety caused by chemical contaminants. The fact that Thai food often includes chemicals has led to trade conflicts. For examples, the European Union claims that Thai shrimp and chicken are not safe for consumption, The United State of America and China claim that Thai fruits contain chemicals, The United of Kingdom claimed that Thai rice are contaminated with chemicals and Japan claimed that they found chemicals in Thai vegetables.

The Thai government recently launched the campaign called "The food safety year ", starting from year 2004, in which agricultural products will be monitored for safety standard every year from now on (1). The analysis of chemical contaminants in agricultural products is very important. Not only pesticide residues but other chemicals should be detected, including heavy metals. Lead and cadmium are toxic heavy metals, normally used as raw materials in various industries. Due to the expansion of industrialization, these metals contaminate the environment and harm human through the food chain. Moreover, the rapid extension of population and the expansion of the economy are also the major factors that lead to polluted environment. In addition, most farmers have to use large amount of chemicals for cultivations. Some pesticides and fertilizers may contain heavy metals that may cause heavy metals contamination in vegetables.

Nowadays, hygienic and organic farming has expanded, in particular, hygienic and organic vegetables farming have been widly practiced. However, hygienic and organic products are still less than 1% of the total agricultural products (2).

There are three main agricultural processes practiced in Thailand. First, conventional agriculture; the farmers use a large amount of chemical pesticides and fertilizers in order to increase crop products. Second, hygienic agriculture; the farmers can use chemical pesticides and fertilizers if the pesticide residues do not exceed “The Maximum Residue Levels” (MRLs). Third, organic agriculture; the farmers are not allowed to use the chemical pesticides and fertilizers but they can use organic pesticides and fertilizers or bio-extract fertilizers (3).

Lead and cadmium have been widely used in many industries for more than 20 years. People take lead in many products such as battery, pigment, alloy, pesticide, etc. Cadmium is a by-product of zinc and lead mining, it is widely used as electroplating or galvanizing, color pigment, cathode material for nickel-cadmium batteries. Lead and cadmium have been listed as pollutants of concern due to their persistence in the environment, potential to bioaccumulate, and toxify human and the environment. The Ministry of Public Health limit maximum level for lead in food at 1 mg/kg food and the Codex Alimentarius Commission (CODEX) limit Maximum Level for lead in vegetable at 0.1 mg/kg vegetable (4). Cadmium is the heavy metal that has different limitation of Maximum Level in each country. The Maximum Levels are between 0.05-2 mg/kg. Though the Maximum Level for cadmium by CODEX is not terminated, the Proposed Draft Maximum Level for cadmium in leafy vegetable at step 6 of the procedure is 0.2 mg/kg (4). In addition FAO/WHO Expert Committee on Food Additive limits Provisional Tolerable Weekly Intake (PTWI) of lead and cadmium at 25 and 7 μg/kg body weight/week, respectively (5).

Solving this food safety problem should investigate the factors that cause heavy metal contaminations in vegetables. So it is necessary to analysis the heavy metals in vegetables and study the cultivated practices of the farmers that have different fertilizer and pesticide usage including the environment of the field and cultivated seasons. This study is conducted to detect heavy metals contamination in the popular vegetable, Chinese kale (Brassica Oleracea), that is mostly consumed by Thai people. For the propose of database and guideline to produce good quality and safe vegetables for the population and exportation. Beside that, to make Thailand is “The Kitchen of the World”.

CHAPTER 2

OBJECTIVES

2.1 To determine lead and cadmium contents in organic, hygienic and conventional Chinese kales.

2.2 To compare the levels of lead and cadmium in Chinese kale from different cultivation practices.

2.3 To compare the levels of lead and cadmium in Chinese kale grown in different areas.

2.4 To compare the levels of lead and cadmium in Chinese kale grown in different seasons.

2.5 To investigate the determinants that lead to the occurance of lead and cadmium in Chinese kale.

2.6 To estimate average intake of lead and cadmium from Chinese kale consumption.

CHAPTER 3
LITERATURE REVIEW

3.1. Lead

3.1.1. Chemical and physical properties

Lead (atomic number 82; atomic weight 207.19 ; specific gravity 11.34) is a soft, malleable, grey-white metal with a low melting point (327.5°C). It is the most abundant of the natural heavy elements with an atomic greater than 60. It occurs in nature as four stable isotopes in varying relative amounts: ^{204}Pb, 1.2-1.6%; ^{206}Pb, 20-28%; ^{207}Pb, 20-23%; and ^{208}Pb, 50-54%; and fourshort-lived radioactive isotopes: ^{210}Pb, ^{211}Pb, ^{212}Pb, and ^{214}Pb, which are decay products of uranium and thorium.

Metallic lead is readily smelted from its major natural source, the mineral galena, in which it occurs as sulfide PbS. It is also found in cerussite (the carbonate), anglesite (the sulfate), as well as in a number of other metal bearing minerals. The inorganic salts of lead, lead sulfide, and oxides of lead are generally poorly soluble. Lead perchlorate (450 g/100 ml H_2O) and lead acetate (44 g/100 ml H_2O) are the most soluble common forms of lead; the nitrate, chlorate, and to a lesser degree the chloride are less soluble in descending order. Toxicity of inorganic lead salts is attributable to lead per se and the chemical form of the salt is of significance only in that it influences solubility and bioavailability (6).

3.1.2. Organic compounds

Stable organolead compounds, tetraethyl and tetramethyl lead , may be synthesized under particular conditions. Toxicity of these compounds differs from that of inoganic compounds and is only of importance from potential occupational exposure and abusive use of leaded gasoline such as “sniffing” for hallucinogenic effects.

Although biomethylation of lead has been postulated , it had not been possible to methylate lead by bacterial species know to alkylate mercury and other heavy metals (7).

Lead forms complexes with humic and fulvic acids in soils and surface waters but they are not known to have any specific biological signification.

3.1.3. Physiology

Intake, Absorption, and Excretion

Atmospheric lead and in food are the two major routes of exposure for people in the general population. For the contemporary urbanite, the amount of respired lead is about one-half the intake from the diet Atmospheric lead is largely in the form of dust or particles of lead oxide Absorption by the lungs is dependent on size distribution of lead-containing particles and volume of air respired per day.

Gastrotestinal absorption of lead is influenced by a large number of factor, particulary age and nutrition. Adults about 5-15 % of ingested lead and retain less than 5 % of what is absorbed. Children are known to have a greater absorption of lead than adults.

Lead in blood

More than 95 % of lead in blood is associated with red blood. There are at least two compartment for lead in red cells , one associated with the membrane and the other with red cell proteins, particularly hemoglobin. Whole-blood lead has a biological half-life of about 25-28 days and is in equilibrium with plasma lead, in turn, other tissue compartments as well as excretory pathways. Plasma lead is mostly bound to albumin; other plasma ligands are not well defined but may increase with increasing blood lead levels.

Lead in tissues

Total lead in body tissues for a child less than 10 year of age is less than 2 mg but increases with age and may be over 200 mg for persons in the later decades of life.

Whole-blood lead has a biological half-life of 25-28 days, whereas the diffusible or labile plasma pool biological half-life may be as short as 1-3 days. Only the diffusible lead fraction from plasma passes in and out of capillaries, permeates cell membranes, and enters parenchymal cells of the central nervous system, liver, kidney, and other organs.

Renal excretion of lead

Renal excretion of lead is with glomerular filtrate and enhanced or decreased by secretion or resorpting by renal tubular lining cells. Renal excretion is influenced by a number of factors including level of lead exposure age , renal function , and competing cations. Rate of glomerular filtration and tubular resorption must be the major determinants of renal excretion in persons in the general population with exposure to lead limited to minor levels in the ambient environment. With higher blood lead levels, tubular cell secretion by way of trancellular transport blood lead levels, tubular cell secretion by way of transcellular transport from peritubular capillaries must assume a greater role.

Interaction with essential metals

Lead has been shown to interact with essential metals, particularly calcium, iron , and zinc. Diets given to rats that are low in calcium (0.1 %) result in higher tissue concentrations of lead at equivalent levels of lead intake (8). The alterations in lead metabolism induced by dietary calcium are complex and illustrate the metabolic relationships between lead and calcium metabolism. Low dietary calcium (0.1 %) also increases the proportion of body lead found in soft tissues. Rosen and Wexler (9), using bone organ culture, showed that the release of previously incorporated ^{210} Pb from bone explant to the medium increases as calcium concentration in the medium decrease. Calcium deficiency also appears to cause weaning rats to increase their intake of lead-containing solutions. However, no related studies exist for human populations.

3.1.4. Cellular effects

Toxicological effects of lead have their basis in perturbations in cell function of various organ systems. Effects of lead at the cell are multiple and complex as is the diversity of for effects at the carboxyl groups of glutamic and aspartic acids, the sulfhydryl groups of cysteine, and the phenoxy groups of tyrosine whether presents of unknown function such as acidic proteins in inclusion bodies or on cell membranes or enzyme systems.

Calcium interactions

Calcium provides cells with important homeostatic mechanisms and mediates intracellular communication or messenger activities. Pounds (10) in a thorough review of calcium-lead interactions has subdivided lead effects into direct and indirect effect of lead on calcium metabolism result from the displacement of Ca^{2+} by lead ions at functionally significant binding sites. This may result in inhibition of calcium transport or function.

Mitochondrial effects.

The mitochondrion may in fact be the “critical” organelle for lead toxicity in many cell and tissues due to subsequent changes in energy metabolism and ion transport. Whether exposure to lead is in vitro or in vivo, lead has been found to have a strong affinity for mitochondria membranes. Within 72 hr. of a single parental injection of radioactive lead, an equilibrium is established between the lead content of intracellular organelles of liver and kidney.

3.1.5. Clinical manifestations

The clinical signs and symptoms of lead toxicity were documented in considerable detail by the early part of this century by occupational health physicians. Nonspecific symptom and signs include loss of appetite, metallic taste in the mouth, constipation and obstipation, pallor (from anemia), melaise, weakness, insomnia, headache, irritability, muscle and joint pains, fine tremors and colic.

Lead linse (Burton’s lines) or purple-blue discoloration of gingiva is a classical feature of severe lead toxicity in children with lead encephalopathy.

Neurological effects

The central nervous system is probably the most clinically significant in terms of human health and performance (11). Children with lead intoxication who are brought to hospital or emergency room for medical aid invariably manifest some central nervous system abnormality. Symptoms vary from ataxia to stupor, coma, and convulsions. This form of lead intoxication had decreased appreciably in North America over the past 20 years with improved control of major sources of lead poisoning for children, namely, ingestion of lead-containing paint chips. Also, there is now increased awareness of other potential sources of lead although episodes of acute lead toxicity from burning of battery casings still occur.

Hematological effects

Lead has multiple hematological effects. In lead-induced anemia, the red blood cell are microcytic and hypochromic as in iron deficiency and usually there are increased numbers of reticulocytes with basophilic stippling. This morphological characteristic has long been recognized as a feature of lead induced anemia and in the past (pre-World War II), it was employed as a method of monitoring workers in the lead industry.

The test is no longer useful because it is now known to be nonspecific and, most important, it is an uncommon occurrence with blood lead below 80 μg /dl, which is considerably above the present day permissible industrial standard. Basophilic stipping results from the inhibition of the enzyme pyrimidine-5-nucleotidase, an enzyme that cleaves residual nucleotide chains remaining in erythrocytes after extrusion of the nucleus (12).

Renal effects

Toxicological effects of lead on the kidney divide into two major concerns: reversible renal tubular dysfunction that occurs mostly in children with acute exposure to lead, usually associated with overt central nervous system effects, and irreversible chonic interstitial nephropathy characterized by vascular sclerosis, tubular cell atrophy, interstitial fibrosis, and glomerular sclerosis (13). It is most often seen in workmen with years of exposure to lead. In the early stages of excess lead exposure, morphological and functional changes in the kidney are confined to the renal tubules and are most pronounced in proximal tubular cells.

Gout

Gout occurs in about 50% of persons with chronic lead nephropathy. Campbell and coworkers (14) report that among gout patients in Scotland without known lead exposure, blood lead levels are higher than among nongouty controls. Lead does reduce uric acid excretion, so that lead at the least alters susceptibility to gout. Beyond the renal effects, lead can disrupt purine metabolism per se.

Hypertension

The relationship between lead and hypertension has long been suspected but has been tenuous at best, even among workmen with excessive exposure to lead (15). Recently, however, the potential relationship between lead and elevated blood pressure received new attention with the finding of a statistically significant relationship ($p<0.01$) between systolic and diastolic blood pressure and blood lead levels form data obtained from the second National Health and Nutrition Examination Survey. Experimental support for this finding is largely from animals exposed to small increases in lead for long periods of time.

Reproduction

Severe lead toxicity has long been known to cause sterility, abortion, and neonatal mortality and morbidity. In the nineteenth and early twentieth centuries, women in lead occupations recognized lead as abortifacient and male workers employed in lead-related industries had a high incidence of sterile marriages. Lancranjan (16) found that fertility of lead workers with blood lead levels above 40 µg/dl was decreased and this was correlated with an increased frequency of oilgospermia and astherospermia or teratospermia.

Immunological effects

Lead induces suppression of the three major components of the immune system: humoral, cellular, and macrophage-related immunity. These effects have been shown to occur in animal models at dose levels at which there is no apparent evidence of toxicity. The significance of the experimental finding is not clear but experimental animals have increased susceptibility to endotoxins and infectious agents. Whether related or not, it has also been noted that children with asymptomatic increase in blood lead levels appear to have more frequent febrile illness (17).

Carcinogenesis

The possible carcinogenic effects of lead have been receiving increased attention. It is clear that lead can induce cancer in kidney of rodents when fed high doses of lead (18). On the other hand, the evidence that lead is carcinogenic to man is very limited. A study of workmen in England many years ago with occupational exposure to lead did not show an increased incidence of cancer (19). A more recent study of causes of mortality in 7000 lead workers in the United States showed a slight excess of deaths form cancer (20) but the statistical significance of these findings has been debated (21). The most common tumors found were of the respiratory and digestive systems, not the kidney.

3.2. Cadmium

3.2.1 Chemical properties

In crystalline form, cadmium forms a close-packed hexagonal, silver-white metal. The only valency state for cadmium is Ca^{2+}. Major compounds of cadmium include cadmium acetate, cadmium chloride, cadmium nitrate, cadmium oxide, cadmium sulfate, and cadmium sulfide. Specific chemical properties for these compounds are given in **Table 1 (6)**.

Table 1: Physical and chemical properties of cadmium compounds

Cadmium compound	MW	mp (°C)	Solubility in water g/100 g H_2O
Cadmium chloride	183.32	568	128/30 °C
Cadmium nitrate	236.41	350	109/0 °C
Cadmium oxide	128.40	1540	9.6×10^{-4}
Cadmium sulfide	144.46	980	1.3×10^{-4}/18 °C
Cadmium acetate	230.50	250	Very soluble
Cadmium sulfate	208.48	1000	76.6/20 °C

3.2.2. Physiology

Deposition and metabolism

The metabolism and tissue disposition of cadmium has been extensively reported in humans and animals. Animal data are available on cadmium oxide deposition after inhalation exposure and after oral exposure. One paper reports on the oral distribution of cadmium nitrate. There is little or no information on the distribution of cadmium sulfide.

Human data

The main organs for cadmium accumulation in humans are kidneys, liver, lungs and pancrease. The kidney is critical organ in long-term, low-level exposures because of a 30-year biological half-life in this organs. Cadmium is also absorbed following oral and inhalation exposures. After oral ingestion cadmium is transported to the liver where it stimulates synthesis of metallothionein. Cadmium bound to metallothionein released from the liver move via the blood to the kidneys. In the kidneys, metallothionein cadmium accumulates in tubular cell by pinocytosis and is subsequently released at low pH in the lysosomes during proteolysis of the reabsorbed metallothionein. Cadmium stored in the kidneys is excreted via the urine. Cadmium may also be excreted in bile, feces, saliva, skin, and sweat. It is estimated that human absorb 5 % of ingested cadmium is 10-70 µg/day, and intake of cadmium from each cigarette is 0.1-0.2 µg (22, 23).

Animal data

Rats administered on one dose of cadmium by the oral ,inhalation,intravenous,or intraperitoneal route were found to retain 2.3, 41.1, 91.4 or 93.1% of this dose (respectively) 30 days after exposure (24). Whole-body retention studies in other animals (e,g., monkey and mice) show a half-life of cadmium after subcutaneous or intravenous injection of greater than 1 year (25).

3.2.3. Toxicity

Cadmium toxicity may be manifested by a variety of syndromes and effects including renal dysfunction, hypertension, hepatic injury, lung damage after inhalation exposure, reproductive toxicity, teratogenic effects, and bone defects (26, 27, 28)

Respiratory

Acute toxicity of cadmium in the workplace is usually via the respiratory route and is characterized by lung edema, cell proliferation, and fibrosis. Symptoms of respiratory exposure in the workplace include coughing, shortness of breath, irritation of the upper respiratory system, and loss of sense of smell.

Kidney

Symptoms of cadmium toxicity to the kidney include tubular proteinuria, decreased capacity for concentrating urine, glucosuria, calcuria, and micro globulinuria. As noted Above, recent studies have the cadmium/metallothioniein

(CdMT) complex to moderate dose of Cd and plays a major role in Cd^{2+} nephrotoxicity. The (CdMT) comp is rapidly filtered by the glomerulus and is reabsorbed by the proximal tubule cells (PTC) where it undergoes rapid lysosomal degradation with releases of the Cd^{2+} which is subsequently bound by induced renal MT. During this process, high concentrations of Cd^{2+} appear to disrupt the normal formation of secondary (mature) PTC lysosomes from endocytic vesicles and primary lysosomes prior to induction of renal MT.

Bone

Itai-itai (ouch-ouch) disease was first reported in 1955 among the human populartion of to Toyoma, Japan. Symptom include femoral pain and lumbago, painful sites spread all over the body, and a ducklike gait. The condition progresses and bond fractures are common. Pathological changes include osteomalacia and osteoporosis (most prevalent in postmenopausal women) and toxicity in the kidney (tubular atrophu and degeneration). Patients show normochromic anemia, increased granulocyte count, and decreased lymphocyte count. Administration of vitamin D is effective in treating some of the severe cases. Urinary cadmium level were found to be high in affected patients. Studies showed that cadmium content was particularly high in rice, a staple food for this population. The source of cadmium contamination was felt to be via water from the Kamiaha mine upstream from Toyama. It was concluded that oral ingestion of cadmium played the most important role in the development of Itai-Itai disease.

Hypertension

Cadmium was first reported to cause hypertension in the 1960s, and since this time several studies have been conducted to elucidate the effects of cadmium on the cardiovascular system. Recently Kopp et al. (29) reported that the effect of cadmium acetate on the cardiovascular system of the rat was dose dependent. Cadmium acetate was administered in drinking water 0.01-50 ppm for 18 months to Long Evans rats. Average systolic blood increased at exposures to cadmium of 10-20 ug-kg body weight /day (0.5 ppm level) while exposure to higher concentration of cadmium in lowered blood pressure.

Immunological effects

The data show that depending on the dose, cadmium may increase or decrease immunological response to foreign antigens. For example, administration of cadmium chloride to mice in drinking water at 50-200 ppm increases the ability of the animal to form antibody to sheep red blood cells, whereas 300 ppm exposure decreases the antibody response to sheep red blood cells.

Reproductive effects

Cadmium has been shown to affect the reproductive system of male and female rodents. Subcutaneous injection of cadmium chloride in the female golden hamster inhibited ovulation; the effect was reversible with time (30). Jenny et al. (31) showed that cadmium chloride causes pathological changes in the rat uterus and ovary.

Reproductive toxicity in male rodents was first noted in 1965 (32). Subcutaneous injection of cadmium chloride decreased the weight of the testes, seminar vesicles, and epididymis in the Sprague-Dawley rat; sperm concentration and serum testosterone levels were also reduced (33).

Teratogenicity

The teratogenic effects of cadmium were first reported in 1976 by Ferm and Carpenter (34). Intravenous administration of cadmium sulfate was shown to be teratogenic in the hamster causing cleft palate, anophthalmia, exencephaly, limb defects, and rib fusions. A review of the literature shows that cadmium chloride, cadmium acetate, cadmium sulfate, and cadmium administration by subcutaneous, intravenous, or intraperitoneal injection may be teratogenic in the rat, mouse, or hamster causing limb defects, cleft palate, and delayed ossification (35).

Carcinogenicity

Early carcinogenicity studies with cadmium have been summarized by the International Agency for Research on Cancer (36) and the Environmental Protecttion Agenency (37). These studies have shown that injection of cadmium into rodents (cadmium, cadmium oxide, cadmium chloride, cadmium sulfide, cadmium sulfate) caused local tumors (at site of injection) and in some cases tumors distal to the site of injection (interstitial cell tumors [testes]-cadmium, cadmium sulfate, and cadmium chloride)

Recently some cadmium compounds were further studies for carcinogenicity by inhalation, oral, or intratracheal administration cadmium oxide has been shown to cause mammary tumors after intratracheal injection in Fischer 344 rats. No lung tumors were seen (38).

Mutagenicity

The Environmental Protection Agency (37) has also reviewed data on the mutagenicity of cadmium. Most of the mutagenicity test have been done with the soluble cadmium compounds (cadmium chloride, cadmium sulfate, and cadmium nitrate). The EPA conclude that “the results of gene mutation) studies in mammalian cell culture, rec-assays in bacteria, chromosomal nondisjunction studies in cultured mammalian cells and intact mammals, chromosomal aberration studies in plant, and biochemical studies indicative of mutagenic damage, together with the synergistic effect in *Salmonella* and rat embryo cultures, support the conclusion that cadmium is mutagenic”.

3.3. Plant uptake of metals

The soil-plant system is an open system subject to inputs, such as contaminants, fertilizers and pesticides, and to losses, such as the removal of metals in harvested plant material, leaching, erosion and volatilization (39).

The factors affecting the amounts of metal absorbed by a plant are those controlling:

(i) The concentrations and speciation of the metal in the soil solution

(ii) The movement of the metal from the bulk soil to the root surface

(iii) The transport of the metal from the root surface into the root

(iv) Its translocation from the root to the shoot

Absorption of metals by plant roots can be by both passive and active (metabolic) processes. Passive (non-metabolic) uptake involves diffusion of ions in the soil solution into the root endodermis. On the other hand, active uptakes place against a concentration gradient but requires metabolic energy and can therefore be inhibited by toxins. The mechanisms appear to differ between metals; for instance Pb uptake is generally considered to be passive while that of Cu, Mo and Zn, is thought to be either active metabolic uptake, or a combination of both active and passive uptake.

Absorption mechanisms can vary for different metal ions, but ions which are absorbed into the root by the same mechanisms are likely to compete with each other. For example, Zn absorption is inhibited by Cu and H^+, but not by Fe and Mn; Cu absorption is inhibited by Zn, Nn, NH_4^+, Ca and K.

Table 2: Soil-plant transfer coefficients of heavy metals

Element	Soil-plant transfer coefficient
Cd	1-10
Co	0.01-0.1
Cr	0.01-0.1
Cu	0.1-10
Hg	0.01-0.1
Ni	0.1-1
Pb	0.01-0.1
Ti	1-10
Zn	1-10
As	0.01-0.1
Be	0.01-0.1
Se	0.1-10
Sn	0.01-0.1

From Kloke et al. (40)

Relative differences in the uptake of metal ions between plant species and cultivars is genetically controlled and can be due to various factors, including: surface area of the root, root exudates and the rate of evapotranspiration. The latter mechanism affects the mass flow of the soil solution in the vicinity of the root and thus the movement of ions to the root absorbing surface. Kloke et al. gave the general order of the transfer coefficients for most of biologically important heavy metals which are shown in **Table 2**. The transfer coefficient is the metal concentration in plant tissue above ground divided by the total metal concentration in the soil. Although numerous soil and plant factors can affect the order of metals in plants, the values given are intended as guides to the order of magnitude of the transfer coefficients and not precise values. From the values in **Table 2**, it can be seen that Cd, Tl and Zn have the highest transfer coefficients and the most readily taken up and translocated of all the metals considered.

3.4. Sources of heavy metal contaminants in soils

Although heavy are ubiquitous in soil parent materials, the major anthropogenic source of metals to soils and the environment are :

a) Metalliferous mining and smelting
b) Agricultural and horticultural materials
c) Sewage sludges
d) Fossil fuel combustion
e) Metallurgical industries-manufacture, use and disposal of metal commodities
f) Electronics-manufacture, use and disposal of electronic commodities
g) Chemical and other manufacturing industries
h) Waste diposal

3.4.1 Metalliferous mining and smelting

Metals utilized in manufacturing are obtained from either the minning of ore bodies in the earth's or the recycling of recycling of scrap metal. Ores are naturally occurring.

Concentration of minerals with a sufficiently high concentration of metals to render them econnomically worthwhile exploiting. With increasing demand for metals and improvements in mineral extracion technology, ore bodies with progressively lower metal contents are being mined.

3.4.2. Agricultural and horticultural materials

Agricultural practices constitute very important non-point sources of metals which make significant contribution to their total concentrations in soil in mamy parts of the world, especially in regions of intensive farming. The main sources are (41):

- impurities in fertilizers: Cd, Cr, Mo, U, V, Zn
- sewage sludge: especially Cd, Ni, Cu, Pb, Zn (and many other elements)
- manures from intensive animal production, especially pigs and poultry: Cu, As, Zn

- pesticides: Cu, As, Hg, Pb, Mn, Zn
- refuse derived composts (not widely used in agriculture): Cd, Cu, Ni, Pb, Zn
- dessicants: As
- wood preservatives: As, Cu,Cr
- corrosion of metal objects (galvanised metal roofs and wire fences : Zn, Cd)

3.4.3. Sewage sludges

Sewage sludge is the residue produced from the treatment of domestic and industrial waste waters and large amounts are produced worldwide. In the early 1990s The UK produced 1.1 million tonnes dry sludge solids per year (the USA produced 5.4 million tonnes, West Germany 2.5, France 0.7, the Netherlands 0.28 and Switzerland 0.215 million tonnes) and 6.3 million tonnes in the whole of the European Community.

Sewage sludgs are a significant source of plant nutrients and organic matter and some specially treated sludges, such as those containing lime or cement kiln dust, have useful liming properties as well. However, the beneficial properties of sludges are limited by their contents of potentially harmful substances such as the heavy metals and organic micropollutants (PAHs, PCBs and pesticides). Although all sludges contain a wide range of metal and other contaminants in varying concentrations, those from industrial catchments generally have higher metal contents than those from mainly suburban domestic area.

3.4.5. Fossil fuel combustion

In general, fossil fuel combustion results in the dispersion of a wide range of heavy metals which can include: Pb, Cd, Sb, Cr, Zn, As, Sb, Ba, Cu, Mn, U and V over a very large area, although not all these elements are present in significant concentrations in all types of coal and petroleum. The metals accumulate in the coal and petroleum deposits as they formed and are either emitted into the environment as airborne particles during combustion, or accumulate in the ash which may itself be transported and contaminate soils or waters,or,may be leached in situ. The combustion of petrol (gasoline) containing Pb additiver has been the largest source of this metal in the environment and has affected soils over a high proportion of the earth’s terrestrial surface.

3.4.6. Metallurgical industries

Metallurgical industries can contribute to soil pollution in several ways: (i) by the emission of aerosols and dusts which are transported in air and eventually deposited on soils or vegetation; (ii) by liquid effluents which pollute soil at times of flooding; (iii) by the creation of waste dumps in which metals become corroded and leached into the underlying soil. Many heavy metals are used in specialist alloys and steels – V, Mn, Pb, W, Mo, Cr, Co, Ni, Cu, Zn, Sn, Si, Ti, Te, Ir, Ge, Ti, Sb, In, Cd, Be, Bi, Li, As, Ag, Sb, Pr, Os, Nb, Nd, and Gd (41).

3.4.7. Electronics

A large number of heavy metals are in the manufacture of semi-conductors, cables, contacts and other electrical components, these include: Cu, Zn, Au, Ag, Pb, Sn, Y, W, Cr, Se, Sm, Ir, In, Ga, Ge, Re, Sn, Tb, Co, Mo, Hg, Sb, As and Gd (41). Environmental pollution can occur from the manufacture of the components, old electronic equipment may often also include capacitors and tranformers containning polychlorinated biphenyls (PCBs), which are persistent organic pollutants in soils.

3.4.8. Chemical and other industrial sources

Other significant sources of heavy metal pollution of sils and environment can be either the manufacture and/or use and disposal of the following (41):

- Chlorine mannufacture: Hg
- Batteries: Pb, Sb, Zn, Cd, Ni, Hg
- Pigments and paints: Pb, Cr, As, Sb, Se, Mo, Cd, Ba, Zn, Co
- Catalysts: Pt, Sm, Sb, Ru, Co, Rh, Re, Pd, Os, Ni, Mo
- Polymer stabilisers: Cd, Zn, Sn, Pb (pollution from incineration of plastics)
- Printing and graphics: Se, Pb, Cd, Zn, Cr, Ba
- Medical uses: Ag, As, Ba, Cu, Hg, Sb, Se, Sm, Pt, Zn
- Additive in fuels and lubricants: Se, Te, Pb, Mo, Li

3.4.9. Waste disposal

The disposal of household, municipal and industrial waster can lead to soil pollution with heavy metals in various ways. The landfilling of municipal solid waste can lead to several metals including Cd, Cu, Pb, Sn, Zn being dispersed into soil, groundwaters and surface water in leachates if the landfill is not managed properly. Landfill leaches normally have high concentrations of Cl^- and so many of the metals may be present as chloride complexes which are often more mobile and less readily adsorbed than free metal cations. Incineration of wastes can also lead to the emission of metal aerosols (Cd, Pb) if appropriate pollution control equipment is not installed.

3.5 Chinese Kales

3.5.1. The development of Chinese kale

Chinese kales are part of a large family of plants called Brassica Oleracea as other Brassica. Chinese kales were first found in Asia minor and later developed in India and China. Chinese kales play a major role in feed in the population in these areas. They have great economic and commercial value, particularly in Asian countries i.e. Thailand, China, Taiwan, Hong Kong, Malaysia and Singapore (42).

3.5.2. The importance of Chinese kale

- Economic Values:

Chinese kales have become one of the main vegetables in Thailand. One reason is that it can be grown all year long. Chinese kales are extensively used in Thai dishes and popularly consumed by Thai people due to its economical prices and good taste.

- Nutritional Values:

Chinese kales provide a major source of vitamins, carbohydrates, protiens, minerals, calcium and phosphorous.

3.5.3. Chinese kale can be categorized into three types (42):

- Pointed leaf:

It is a popular Chinese kale grown in Thailand. This type is represented by the cultivar P.L.20 (DOA). The plant has a large stem, long internodes and smooth pointed leaves. It is heat and disease tolerant and is widely grown at present. Other well-known cultivars are Long Stalk (Chia tai) and Red Arrow (Eastwest). The crop takes 30-55 days from seeding to harvest.

- Broad leaf:

It is an old type of Chinese kale. This type includes Fang No.1 (DOA) and Large leaf (Chia Tai) cultivars. They are widely adapted cultivars that can be grown under a wide range of conditions. The plant has a large stem and short internodes. The leaves are broad, round, thick and crispy making it popular among consumers.

- Long petiole:

This type is grown for its stem and petiole. The cultivars include Maejo No.1 (DOA) and Super 094 (Chia Tai F1). The plant has a large stem and long internodes. The leaves are narrow, pointed, with a thick-long petiole. It is well suited for inter-regional transport and distribution as it has a better quality.

3.6. Agricultural practices

There are three agricultural practices mentioned in this study; Organic farming, Hygienic farming and Conventional farming.

3.6.1 Organic farming

Organic farming is more than a source of safe and healthy food for consumers. Organic farming is "farming without chemicals", or replacing chemical with a biological input The heart of organic farming encompasses the cultivation without chemical fertilizers, synthetic pesticides, and herbicides. In addition, organic farming promotes the use of renewable resources and management of biological cycles to enhance biological diversity, without the use of synthetic pesticides or chemical fertilizers and genetically modified organisms.

3.6.2. Hygienic farming

Hygienic farming is considered as the method of good agricultural practices (GAP). The farmers are allowed to use pesticides that permitted by the Thai government. It is also important that the pesticide resides in hygienic vegetables must not exceed the maximum residues limits (MRL) of Codex Alimentarious Commission or Food and Drug Administration of Thailand.

3.6.3. Conventional farming

Conventional farming is the method of cultivation that emphasizes on industrialized agricultural system. This includes using synthetic pesticides, herbicides, chemical fertilizers and any kinds of chemicals and hormones that may lead to the increasing and fast production.

3.7. The estimated average of lead and cadmium intake

The establishment of a relationship between the ingested amount of a substance and the manifestation of adverse health effects characterize dose–response assessment. The acceptable daily intake (ADI) is widely used to describe ‘safe’ levels of intake; another term that is used is ‘tolerable intake’ and can be expressed on either a daily basis (TDI or tolerable daily intake) or a weekly basis (TWI or tolerable weekly intake). The weekly designation is particularly used to stress the importance of limiting the intake of a specific substance over a period of time. JECFA uses the term ‘provisional tolerable weekly intake’ (PTWI) for contaminants that may accumulate in the body. The ADI/TDI is usually generated from the lowest no-observed-adverse-effect-level (NOAEL) in the most sensitive species, using a 100-fold safety factor. The estimation of dietary intakes combines data on the levels of the substance in particular foods with data on the quantities of those foods consumed by the population (43).

CHAPTER 4

MATERIALS AND METHODS

4.1 Sample collection

The Chinese kales were collected from three types of plantations; organic, hygienic and conventional in the rainy, the winter and the summer seasons. The vegetables used in the study were collected from four provinces during September 2002 to October 2003**.** The Chinese kales collected are as follows:

1). Organic Chinese kale samples were collected from 3 farms in province A
2 farms in province B, 1 farm in province C and 3 farms in province D.

2). The hygienic Chinese kale samples were collected from 2 farms in province A, 2 farms in province B and 3 farms in province C.

3). The conventional Chinese kale samples were collected from 2 farms in province A, 2 farms in province B and 2 farms in province C.

There are 471 samples of Chinese kales in total and overall. The samples were collected from 22 farms as listed above.

The locations for the collection were selected based upon the availability of the Chinese kales in three different types of plantation. Organic, hygienic and conventional farms can be found in all the provinces as mentioned above, except province D.

Besides collected the Chinese kale samples from 10 shops of one market for comparison of lead and cadmium contents with the samples from farms

The collection of the Chinese kale samples for this study was strictly compliance with "The manual of sample collection and treatment for determination of heavy metals" (44). Ten samples of Chinese kale were collected from each field by systematic sampling and one sample was collected from at least 6-8 plants. Exception, there were only six and five organic Chinese kale samples from farm 1 and farm 2 in province B, respectively. The Chinese kale samples were cut and kept in plastic bags labeled with the codes. They were then kept in the iced box and sent to the Institute of Nutrition on the day of collection in order to be stored in the refrigerator at 4°C before homogenization within 24 hours.

All the agricultural practices information, including the amount of pesticide and fertilizer usage and the environment around the farms, were gathered by conducting the interviews and questionnaires (Appendix A) with the farmers.

4.2 Preparation of samples

Only edible parts of Chinese kale samples were used in the experiment and they were washed to remove the soil with tap water and rinsed with de-ionized water. The Chinese kale samples were then cut into small pieces and weighed. The samples were homogenized with de-ionized water by the ratio of 1:1. The homogenized samples were kept in the acid-washed plastic bottles at -20 °C and lyophilized with lyophilizer. The dried samples were collected in the acid-washed plastic bottles for lead and cadmium analysis.

4.3 Determination of lead and cadmium in samples

The Chinese kale samples were determined for lead and cadmium by wet digestion in closed system method (19). Organic matter was decomposed by concentrated nitric acid in teflon jar. Lead and cadmium from Chinese kale sample were extracted into chloroform layer by complexation with APDC. Lead and cadmium in diluted nitric acid were determined by Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS).

Triplicate analysis was determined in each sample. The detection limit for lead and cadmium were 0.25 ng/g and 0.048 ng/g, respectively.

The performance of analysis was monitored through the recovery studies in each analytical batch and by inclusion of a reference material (Joint UNEP/FAO/WHO for lead, cadmium and mercury analysis; milk powder No. 01). The percentage of lead and cadmium recovery from spiked samples varied from 89 - 114%. **Table 3** shows good agreement with certified levels for lead and cadmium.

Table 3: Accuracy of the analytical method

Elements	Milk powder No. 01		%RSD
	Certified	Observed	
Pb	0.198	0.199	0.51
Cd	0.033	0.036	9.09

4.4 Analytical procedure

Chemical reagents and apparatus

Chemical reagents

1) Nitric acid (65% w/v)
2) Ammonia solution (25%w/v)
3) Chloroform
4) Lead standard solution, prepared by serial dilution with 3% nitric acid
5) Cadmium standard solution, prepared by serial dilution with 3% nitric acid
6) Ammonium Pyrrolidinedithiocarbamate (APDC)
7) Ammonium Hydrogen Citrate
8) Ammonium Dihydrogen Phosphate

Apparatus

1) Analytical balance
2) Blender
3) Lyophilizer
4) Teflon jar
5) Hot air oven
6) pH meter
7) Glassware (cleaned by submerging in 20% nitric acid overnight)
9) Graphite Furnace Atomic Absorption Spectrometer (GFAAS);
   Varian SpectrAA-400

Procedure

1. Organic matter decomposition

The lyophilized sample (0.1 g) was weighed into a teflon digestion vessel and 10 ml concentrated nitric acid was added. The analytical sample was heat at 110°C in hot air oven at least 9 hr and then cooling at room temperature in hood.

2. Chelation and extraction

Added 10 ml of ammonium citrate buffer solution, adjusted pH of solution to 9.5 with concentrated ammonia solution and cooling in the ice water bath. Poured the solution into a 100 ml separatory funnel, 5 ml of 1% APDC was then added and shaked well for 30 sec. Then 20 ml of chloroform was added, shaked vigorously for 1 min. The chloroform phase was seperated and poured into another separatory funnel. Added 10 ml of 3% HNO_3 and then shaked vigorously for 5 min. Then the phase were seperated, removed the chloroform phase and collected the acid phase into a polypropylene tube for lead and cadmium determination.

3. Lead and cadmium determinations by using GFAAS

Lead and cadmium determinations were performed with a Varian SpectroAA-400 Zeeman atomic absorption spectrometer. The standard addition method was used, a known amount of analyte was added to an aliquot of the sample. The absorbance values of the unspiked and spiked samples were calculated or measured and compared to the added analyte.

4.5 Statistical analysis

Lead and cadmium levels in Chinese kale samples were presented as median, mean and standard deviation. Komogolov Smirnov test was employed to examine the distribution of data. For normal distribution, one-way analysis of variance (ANOVA) and Scheffe test were used to examine statistical significance of differences in the mean of concentration of metals between group of cultivation practices, different areas and seasons of vegetables. Kruskal Wallis test and Mann-Whitney-U test were used to examine statistical significance of differences in the median concentration of metals between group of cultivated practices, different areas and seasons of vegetables for non normal distribution. A probability level of $p<0.05$ was considered statistically significant.

4.6 The estimated average of lead and cadmium intake from Chinese kale Consumption

The provisional tolerable weekly intake of lead and cadmium from Chinese kale consumption was calculated by the following equation:

PTWI = Occurrence (µg/kg)×consumption (kg/week) /Body weight (kg)

PTWI = The provisional tolerable weekly intake of lead and cadmium from Chinese kale consumption (µg/kg body weight)

Occurrence = The average concentration of lead and cadmium in Chinese kale (µg/kg wet weight)

Consumption = The average weekly consumption of Chinese kale (kg/week/person)

Body Weight = The average body weight of Thai people (60kg)

The consumption data of Chinese kale are compiled from the food consumption survey of the Department of Health, Thailand. According to the survey, the average intake of Chinese kale was 1.13 g/person/day (46). In the meantime, the consumption data of Chinese kale of vegetarians are obtained from vegetable consumption survey of Nantana S (47) which showed that the average intake of Chinese kale was 80.64 g/person/day.

CHAPTER 5
RESULTS

5.1 Lead and cadmium contents in Chinese kale

5.1.1 Lead content in Chinese kale

The level of lead concentration found in Chinese kale samples is presented in **Table 4**. According to the research on lead and cadmium in Chinese kale from three different agricultural practices, it found that the mean of lead levels in organic, hygienic and conventional Chinese kales were 41.59, 43.87 and 21.21 µg/kg fresh wt, respectively. The median of lead levels in organic, hygienic and conventional Chinese kales were 2.09, 10.38 and 6.79 µg/kg fresh wt., respectively. The study also found that hygienic Chinese kale contained lead significantly higher than organic and conventional Chinese kales ($p<0.05$). In fact, lead levels found in organic and conventional Chinese kales were insignificantly different.

The percentages of organic, hygienic and conventional Chinese kale samples exceeded Codex Maximum Level of lead in vegetable(100 µg/kg) were 9.4%, 11.3% and 5.7% ,respectively. Only 8.94% of the overall Chinese kale samples showed lead contents in excess of the Codex Maximum Level. However, all Chinese kale samples did not exceed the Maximum Level of lead in food that was established by Thai Ministry of Public Health (1000 µg/kg food).

Table 4: Lead content in Chinese kale samples grown with different cultivation practices

Agricultural practice	n	Lead (µg/kg fresh weight)				
		Mean±SD	**Median**	**Min-Max**	**Exceeding Codex Maximum Level % (n)**	**Exceeding Thai Maximum Level % (n)**
Organic	180	41.59±127.35^{a}	2.09^{a}	<LOD-811.95	9.4% (17)	0% (0)
Hygienic	150	43.87±85.80^{b}	10.38^{b}	<LOD -448.39	11.3% (17)	0% (0)
Conventional	140	21.21±50.92^{a}	6.79^{a}	<LOD -407.87	5.7% (8)	0% (0)
Total	470	36.25±96.92	6.28	<LOD -811.95	8.9% (42)	0% (0)

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between cultivation practices at the level of $p<0.05$.

5.1.2 Cadmium content in Chinese kale

The level of cadmium concentration found in the Chinese kale samples is presented in **Table 5**. According to the research on cadmium in Chinese kale from three different agricultural practices, it was found that the mean of cadmium contents in organic, hygienic and conventional Chinese kales were 429.63, 104.58 and 55.74 µg/kg fresh wt., respectively. The median of cadmium contents in organic, hygienic and conventional Chinese kales were 19.32, 52.72 and 20.04 µg/kg fresh wt., respectively. The study also found that the hygienic Chinese kale samples contained cadmium content significantly higher than the organic and the conventional Chinese kale samples ($p<0.05$). There was no significant difference in cadmium content between organic and conventional Chinese kales.

The percentages of organic, hygienic and conventional Chinese kale samples exceeded Codex Draft Maximum Level of cadmium in vegetable (200 µg/kg of vegetable) were 26.7%, 19.3% and 4.3%, respectively. 17.66% of the overall Chinese kale samples showed cadmium contents in excess of the Codex Draft Maximum Level.

Table 5: Cadmium content in Chinese kale samples grown with different cultivation practices

Agricultural practice	n	Cadmium (µg/kg fresh weight)			
		Mean±SD	**Median**	**Min-Max**	**Exceeding Codex Draft Maximum Level % (n)**
Organic	180	429.63±1091.80	19.32^{a}	<LOD -6028.31	26.7% (48)
Hygienic	150	104.58±125.61	52.72^{b}	3.40-900.12	19.3% (29)
Conventional	140	55.74±61.71	20.04^{a}	4.45-247.06	4.3% (6)
Total	470	214.52±700.17	28.80	<LOD -6028.31	17.66% (83)

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between cultivation practices at the level of $p<0.05$.

According to the results as shown in the tables above, lead and cadmium found in organic and conventional Chinese kale samples were insignificantly different, whereas there were the extensive use of pesticides in the conventional farms. According to the interview, all organic farms didn't use any pesticides. From **Table 6-9**, most farmers in hygienic and conventional farms frequently used a large amount of pesticides in the summer and the rainy seasons. Conventional farms used more types and amount of pesticides than hygienic farms. The farmers used a variety of pesticides in the same farm. Some pesticides were classified in Ib class (Highly Hazadous) of WHO toxicity class, including monochrotophos, methamidophos, dichotophos and methomyl. Some pesticides were classified in II class (Moderately Hazadous) of WHO toxicity class that were used, including endosulfan, chlorphenapyr, cypermethrin, paraquat dichloride and paraquat. Some pesticides were classified in III class (Slightly Hazadous) of WHO toxicity class that was used, including alachlor, malathion, quizalofop-P-tefuryl, glyphosate. Some pesticides were classified in U class (unlikely to present acute hazard in normal use) of WHO toxicity, including propineb and spinosad. Finally, some pesticides that are in not listed of WHO toxicity class were also used in the farms, including abamectin and metalaxyl M.

Table 6: The use of pesticides in hygienic farms in province A and province B

Province	Farm	Season	WHO Toxicity class	Chemical family	Common name	Trade name	Dilution (per 100 L of H_2O)	Frequency (time/crop)
Province A	1	rainy	Ib	Organophosphate	Monochrotophos	Biteen	ND	4
		winter*						
		summer	Ib	Organophosphate	Monochrotophos	Biteen	150 ml	2
			-	Macrocyclic lactone glycoside	Abamectin	Nock-Tun	50 ml	2
	2	rainy	III	Triazole	Alachlor		150 ml	2
Province B	1	rainy	-	Phenylamide	Metalaxyl M		150 g	3
			Ib	Organophosphate	Methamidophos		20 ml	2
			III	Organophosphate	Malathion		10 ml	2
		winter	Ib	Organophosphate	Methamidophos		20 ml	2
		summer	-	Phenylamide	Metalaxyl M		200 ml	2
			-	Macrocyclic lactone glycoside	Abamectin	Abacron	200 ml	2
	2	rainy	-	Macrocyclic lactone glycoside	Abamectin	Abacron	10 ml	1
		winter*						
		summer	-	Phenylamide	Metalaxyl M		20 ml	2

* = Not use pesticides in the farm

Table 7: The use of pesticides in conventional farms in province A

Province	Farm	Season	WHO Toxicity class	Chemical family	Common name	Trade name	Dilution (per 100 L of H_2O)	Frequency (time/crop)
Province A	1	rainy	II	Bipyridium	Paraquat dichloride	Grammoxone	500 ml	5
			II	Organochlorines	Endosulfan		150 ml	5
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	125ml	5
			III	Inorganic	Copperoxychloride		100ml	5
			III	Acetanilide	Alachlor		500 ml	5
		winter	II	Organochlorines	Endosulfan		150 ml	5
			III	Triazole	Alachlor		500 ml	5
			II		Quizalofop-P-tefuryl	Cannu	100ml	5
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	125ml	5
		summer	II	Bipyridium	Paraquat	Grammoxone	500 ml	5
						Hydro	150 ml	5
						Caruka	150 ml	5
			-	Macrocyclic lactone glycoside	Abamectin	Nock-Tun	150 ml	5
	2	rainy	Ib	Organophosphate	Monochrotophos	Biteen	150 ml	6
			-	Macrocyclic lactone glycoside	Abamectin	Nock-Tun	100 ml	6
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	125ml	5
			III	Triazole	Alachlor		200 ml	5

Table 8: The use of pesticides in conventional farms in province B

Province	Farm	Season	WHO Toxicity class	Chemical family	Common name	Trade name	Dilution (per 100 L of H_2O)	Frequency (time/crop)
Province B	1	rainy	II	Halogenated pyrroles	Chlorphenapyr	Rampage	20 ml	3
						Di-Care	20 ml	2
			U	Thiocarbamates	Propineb	Antracol	20 ml	2
		winter	II	Halogenated pyrroles	Chlorphenapyr	Rampage	150 ml	2
						Carax	50g	2
			U	Thiocarbamates	Propineb	Antracol	250 g	2
		summer	III	Organophosphates	Glyphosate	Glyphosate	750 ml	2
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	100 ml	2
			-	NC	Metalaxyl M	Metalaxyl	100 ml	3
	2	rainy	II	Halogenated pyrroles	Chlorphenapyr	Rampage	150ml	4
			III	Organophosphate	Malathion	Malathion	100 ml	4
		winter	II	Halogenated pyrroles	Chlorphenapyr	Rampage	150ml	4
						Toxic M	50 g	4
		summer	III	Organophosphates	Glyphosate	Glyphosate	500 ml	4
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	150 ml	4
						Toxic M	50 g	4

Table 9: The use of pesticides in conventional farms in province C

Province	**Farm**	**Season**	**WHO Toxicity class**	**Chemical family**	**Common name**	**Trade name**	**Dilution (per 100 L of H_2O)**	**Frequency (time/crop)**
Province C	1	rainy	II	Pyrethroids	Cypermethrin		100g	6
			Ib	Organophosphate	Dichotophos		100g	6
			Ib	Organophosphate	Metamidophos	Baberon	250g	6
			U	Dithiocarbamate	Mancozeb	Mancozeb	100g	6
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	75g	8
			-	Oxadiazine	Indoxacarb	Ammate	50g	8
			Ib	Carbamate	Methomyl	Cuzero	125g	6
		winter	Ib	Organophosphate	Metamidophos	Baberon	250g	5
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	50g	5
			II	Pyrethroids	Cypermethrin		50g	5
			Ib	Organophosphates	Dichotophos		50g	5
		summer	III	Organophosphates	Glyphosate	Glyphosate	500ml	8
			U	Thiocarbamates	Propineb	Antracol	20 ml	8
			Ib	Organophosphate	Methamidophos		200 ml	8
			U	Macrocyclic lactone glycoside	Spinosad	Success	50 ml	8
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	50 ml	8
			II	Pyrethroid	Cypermetrin	Cypermetrin 25	200 ml	8
			-	Macrocyclic lactone glycoside	Abamectin		200 ml	8
			Ib	Carbamate	Methomyl	Lannate	200 ml	8
Province C	2	rainy	Ib	Organophosphate	Methamidophos	Tamaron	100ml	8
			Ib	Carbamate	Methomyl	Lannate	200 ml	8
			II	Halogenated pyrroles	Chlorphenapyr	Rampage	50 ml	8
			U	Macrocyclic lactone glycoside	Spinosad	Succsess	50 ml	8
			U	Thiocarbamates	Propineb	Antracol	20 ml	8

5.2 Lead and cadmium contents in Chinese kale from three cultivation practices in different locations

5.2.1 Lead contents in organic, hygienic and conventional Chinese kales from each province in the rainy season.

The mean and median levels of lead in Chinese kale grown in different agricultural practices from each province in the rainy season are shown in **Table 10**. The result found that the mean of lead levels in total organic, hygienic and conventional Chinese kales were 78.74, 33.06 and 27.61 μg/kg fresh weight, respectively. The median of lead levels in total organic, hygienic and conventional Chinese kales were 6.92, 12.73 and 9.12 μg/kg fresh weight, respectively. Lead concentration in Chinese kale from three different cultivation practices was not significantly different. In addition, the mean of lead levels in total Chinese kale from province A, province B and province C were 8.51, 149.18 and 23.04 μg/kg fresh weight, respectively. The median of lead levels in total Chinese kale from province A, province B and province C were 7.03, 69.42 and 9.68 μg/kg fresh weight, respectively. There were significant differences between the Chinese kale from each province. However, province D was not included in the comparison of lead content in total Chinese kale in the rainy season, since there was only organic Chinese kale from this province.

According to **Table 10**, the mean of lead levels in organic, hygienic and conventional Chinese kales from province A were 10.70, 6.98 and 6.87 μg/kg fresh weight, respectively. The median of lead levels in organic, hygienic and conventional Chinese kales were 5.98, 5.34 and 7.60 μg/kg fresh weight, respectively. The study showed no significant difference of lead concentration found in Chinese kale from three cultivation practices.

The mean of lead levels in organic, hygienic and conventional Chinese kales from province B were 477.39, 51.23 and 66.62 μg/kg fresh weight, respectively. The median of lead levels in organic, hygienic and conventional Chinese kales were 385.55, 49.07 and 53.64 μg/kg fresh weight, respectively. The organic Chinese kale contained lead significantly higher than the hygienic and conventional Chinese kales

($p<0.05$). In the meantime, lead concentration in hygienic and conventional Chinese kales was no significantly different.

The mean of lead levels in organic, hygienic and conventional Chinese kales from province C were 4.59, 38.33 and 9.34 µg/kg fresh weight, respectively. The median of lead levels in organic, hygienic and conventional Chinese kales were 3.89, 15.15 and 7.81 µg/kg fresh weight, respectively. The highest lead level was found in hygienic Chinese kale. The study showed the significant differences of lead content in Chinese kale from each agricultural practice ($p<0.05$).

In province D, there was only organic Chinese kale. The mean and median of lead levels in organic Chinese kale were 23.04 and <LOD µg/kg fresh weight, respectively.

Table 10: Lead content of organic, hygienic and conventional Chinese kales from each province in the rainy season

Province	n	Organic		n	Hygienic		n	Conventional		n	Total	
		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)
Province A	29	10.70±15.43	5.98^{ax} (<LOD-77.19)	20	6.98±7.21	5.34^{ax} (<LOD-24.92)	20	6.87±4.16	7.60^{ax} (<LOD-16.36)	69	8.51±10.99	7.03^{a} (<LOD-77.19)
Province B	11	477.39±231.56	385.55^{bx} (161.58-811.95)	20	51.23±45.76	49.07^{bcy} (<LOD-138.45)	20	66.62±54.1	53.64^{by} (<LOD-170.53)	51	149.18±207.11	69.42^{b} (<LOD-811.95)
Province C	10	4.59±2.47	3.89^{cx} (1.58-8.76)	30	38.33±65.99	15.15^{cy} (<LOD-273.47)	20	9.34±5.79	7.81^{az} (2.10-26.68)	60	23.04±48.91	9.68^{c} (<LOD-273.47)
Province D	30	23.04±34.25	$<LOD^{b}$ (<LOD-119.28)	0	*	*	0	*	*	30	23.04±34.25	0 (<LOD-119.28)
Total	80	78.74±181.67	6.92^{x} (<LOD-811.95)	70	33.06±52.21	12.73^{x} (<LOD -273.47)	60	27.61±41.64	9.12^{x} (<LOD -170.53)	210	48.90±120.08	9.54 (<LOD -811.95)

* = None of Chinese kale samples n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between provinces in the same cultivation practices at the level of $p<0.05$.

x, y, z: Different superscripts within the same row indicate significant difference between cultivation practices in the same provinces at the level of $p<0.05$.

5.2.2 Cadmium contents of organic, hygienic and conventional Chinese kales from different locations during the rainy season.

The mean and median levels of cadmium in Chinese kale grown in different agricultural practices from each province in the rainy season are shown in **Table 11.** The result found that the mean of cadmium levels in total organic, hygienic and conventional Chinese kales were 265.16, 91.22 and 61.55 µg/kg fresh weight, respectively. The median of cadmium levels in total organic, hygienic and conventional Chinese kales were 74.42, 58.16 and 18.89 µg/kg fresh weight, respectively. There was significant difference in cadmium content between hygienic and conventional Chinese kales. However, there were no significant differences in cadmium content between organic and hygienic Chinese kales, and between organic and conventional Chinese kales. In addition, the mean of cadmium levels in total Chinese kales from province A, province B and province C were 27.47, 285.85 and 54.59 µg/kg fresh weight, respectively. The median of cadmium levels in total Chinese kales from province A, province B and province C were 11.03, 144.51 and 29.74 µg/kg fresh weight, respectively. There were significant differences in cadmium content of Chinese kale between each province. However, the comparison of cadmium content in total Chinese kale from each province in the rainy season did not include province D because there was only organic Chinese kale from this province. From **Table 11**, the comparison of cadmium content between practices in each province showed the results including;

In province A, the mean of cadmium levels in organic, hygienic and conventional Chinese kales were 22.96, 50.10 and 11.38 µg/kg fresh weight, respectively. The median of cadmium levels in organic, hygienic and conventional Chinese kales were 7.77, 42.21 and 11.55 µg/kg fresh weight, respectively. The highest cadmium content was found in hygienic Chinese kale. There were significant differences in cadmium content of Chinese kale between each cultivation practice ($p<0.05$).

In province B, the mean of cadmium levels in organic, hygienic and conventional Chinese kales were 800.39, 143.97 and 144.74 µg/kg fresh weight, respectively. The median of cadmium levels in organic, hygienic and conventional Chinese kales were 486.69, 142.90 and 128.99 µg/kg fresh weight, respectively. Organic Chinese kale accumulated significantly higher cadmium content than the other cultivation practices ($p<0.05$). While, there was no significant difference in cadmium content between hygienic and conventional Chinese kales.

In province C, the mean of cadmium levels in organic, hygienic and conventional Chinese kales were 20.06, 83.48 and 28.53 µg/kg fresh weight, respectively. The median of cadmium levels in organic, hygienic and conventional Chinese kales were 20.75, 39.27 and 15.04 µg/kg fresh weight, respectively. The highest cadmium content was found in hygienic Chinese kale. There were significant differences of cadmium content in each practice ($p<0.05$).

In province D, there was only organic Chinese kale. Mean and median of cadmium levels in organic Chinese kale were 384.72 and 238.13 µg/kg fresh weight, respectively.

Table 11: Cadmium content of organic, hygienic and conventional Chinese kales from each province in the rainy season

Province	n	Organic		n	Hygienic		n	Conventional		n	Total	
		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)		Mean±SD	Median (min-max)
Province A	29	22.96±46.38	7.77^{ax} (<LOD -194.51)	20	50.10±70.88	42.21^{ay} (5.50-334.03)	20	11.38±3.67	11.55^{az} (<LOD -16.36)	69	27.47±50.29	11.03^{a} (<LOD -334.03)
Province B	11	800.39±977.37	486.69^{bx} (128.96-3525.41)	20	143.97±71.63	142.90^{by} (41-292.12)	20	144.74±44.14	128.99^{by} (60.69-216.02)	51	285.85±517.69	144.51^{b} (41-3525.41)
Province C	10	20.06±8.30	20.75^{ax} (3.72-29.31)	30	83.48±79.59	39.27^{ay} (16.98-254.73)	20	28.53±21.40	15.04^{cz} (8.32-65.48)	60	54.59±64.25	29.74^{c} (3.72-254.73)
Province D	30	384.72±181.67	238.13^{b} (64.71-896.05)	0	*	*	0	*	*	30	384.72±181.67	238.13 (64.71-896.05)
Total	80	265.16±479.80	74.42^{xy} (<LOD -3525.41)	70	91.22±82.35	58.16^{x} (5.50-334.03)	60	61.55±65.94	18.89^{y} (4.45-216.02)	210	149.01±314.58	52.72 (<LOD -3525.41)

n = The number of samples, * = None of Chinese kale samples

a, b, c: Different superscripts within the same column indicate significant difference between provinces in the same cultivation practices at the level of $p<0.05$.

x, y, z: Different superscripts within the same row indicate significant difference between cultivation practices in the same provinces at the level of $p<0.05$.

5.3 The comparison of lead and cadmium contents in Chinese kale from different locations

5.3.1 Lead and cadmium contents in organic Chinese kale from each farm in the rainy season

Table 12 shows lead and cadmium contents in organic Chinese kale from each farm in province A, province B, province C and province D during the rainy season.

In province A, the mean of lead levels in organic Chinese kale were 8.50, 10.12 and 13.81 µg/kg fresh weight in farm 1, 2 and 3, respectively. The median of lead levels in organic Chinese kale were 8.29, <LOD and 16.89 µg/kg fresh weight in farm 1, 2 and 3, respectively. There were no significant differences in lead content between Chinese kale from each farm. The mean of cadmium levels in organic Chinese kale were 3.55, 26.42 and 36.98 µg/kg fresh weight in farm 1, 2 and 3, respectively. The median of cadmium levels in organic Chinese kale were 2.68, 9.16 and 10.36 µg/kg fresh weight in farm 1, 2 and 3, respectively. The lowest cadmium content was found in farm 1. There were significant differences in cadmium content between farm1 and farm 2, and between farm1 and farm3, whereas there was no significant difference between farm 2 and farm 3.

In province B, the mean of lead levels in organic Chinese kale were 575.15 and 360.08 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of lead levels in organic Chinese kale were 592.33 and 283.23 µg/kg fresh weight in farm 1 and farm 2, respectively. There was no significant differences in lead content between farm 1 and farm 2. The mean of cadmium levels in organic Chinese kale were 982.07 and 582.37 µg/kg fresh weight in farm 1 and 2, respectively. The median of cadmium levels in organic Chinese kale were 282.79 and 602.02 µg/kg fresh weight in farm 1 and 2, respectively. There was no significant difference in cadmium content between farm 1 and farm 2.

In province C, there was only one organic farm in this province. Mean of lead and cadmium levels were 4.59 and 23.06 µg/kg fresh weight, respectively. Median of lead and cadmium levels were 3.89 and 23.24 µg/kg fresh weight, respectively.

In province D, the mean of lead levels were 5.90, 59.11 and 4.12 µg/kg fresh weight in farm1, 2 and 3, respectively. The median of lead levels were <LOD, 52.24 and <LOD µg/kg fresh weight in farm1, 2 and 3, respectively. The highest lead content was found in farm 2. There were significant differences between farm 1 and 2, and between farm 2 and 3, whereas there was no significant difference between farm 1 and 3. The mean of cadmium levels were 330.80, 734.48 and 88.90 µg/kg fresh weight in farm 1, 2 and 3, respectively. The median of cadmium levels were 238.13, 758.52 and 74.96 µg/kg fresh weight in farm 1, 2 and 3, respectively. The highest cadmium content was found in farm 2. There were significant differences in cadmium content of Chinese kale between each farm ($p<0.05$).

Table 12: Lead and cadmium contents in organic Chinese kale from each farm in the rainy season

Province	Farm	Pb (µg/kg fresh weight)			Cd (µg/kg fresh weight)		
		Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max
Province A	1	8.50 ± 7.37^{a}	8.29^{a}	<LOD-23.84	3.55 ± 3.37^{a}	2.68^{a}	<LOD -9.56
	2	10.12 ± 24.73^{a}	<LOD ^{a}	<LOD -77.19	26.42 ± 46.20^{b}	9.16^{b}	4.28-153.89
	3	13.81 ± 8.17^{a}	16.89^{a}	0.84-26.86	36.98 ± 62.78^{b}	10.36^{b}	4.81-194.51
Average		10.70 ± 15.43	5.98	<LOD -77.19	22.96 ± 46.38	7.77	<LOD -194.51
Province B	1	575.15 ± 169.90^{a}	592.33^{a}	375.83-762.28	982.07 ± 1341.39^{a}	282.79^{a}	128.96-3525.41
	2	360.08 ± 257.73^{a}	283.23^{a}	161.58-811.95	582.37 ± 173.35^{a}	602.02^{a}	361.39-825.00
Average		477.39 ± 231.56	385.55	161.58-811.95	800 ± 977.37	486.69	128.96-3525.41
Province C	1	4.59 ± 2.47	3.89	1.58-8.76	23.06 ± 7.06	23.24	3.72-29.31
Average		4.59 ± 2.47	3.89	1.58-8.76	23.06 ± 7.06	20.75	3.72-29.31
Province D	1	5.90 ± 16.70^{a}	<LOD ^{a}	<LOD -53.15	330.80 ± 210.82^{a}	238.13^{a}	156.79-849.87
	2	59.11 ± 34.92^{b}	52.24^{b}	18.95-119.28	734.48 ± 131.77^{b}	758.52^{b}	556.97-896.05
	3	4.12 ± 10.55^{a}	<LOD ^{a}	<LOD -33.32	88.90 ± 29.10^{c}	74.96^{c}	64.71-153.90
Average		23.04 ± 34.25	<LOD	<LOD -119.28	384.72 ± 181.67	238.13	64.71-896.05

a, b, c: Different superscripts within the same column indicate significant difference between farms in the same province at the level of $p<0.05$.

Lead and cadmium levels in Chinese kale from each organic farm may be affected by several factors. The history of the farms, the environment around the farms, the amount and the raw materials of fertilizers are discussed. **Table 13** shows the history of the farms, the environment around the farms and the source of water used in the farms from province A, province B, province C and province D. The information were gathered from the interview with the farmers. According to the interviews, six farms (66.67%) had the history of the chemicals usage in their farms. All the organic farms, the farmers refrained from cultivation in their farms at least one year before the beginning of organic cultivation practice. There are 3 farms (33.33%), 2 farms (22.22%), 2 farms (22.22%) and 3 farms (33.33%) near the road, the factories, the domestic animals and the conventional farms, respectively. The source of water for organic farms are the irrigated canal (1 farm), the natural canal (2 farms), the stream (3 farms) and the pond (3 farms).

In province A, both farm 1 and farm 3 had the history of chemicals usage in their farms. All farms in province A are far from the road, the factories and the domestic animals. However, farm 1 and farm 2 are near other conventional farms. Every farm uses the water from the stream for cultivation.

In province B, both farms had the history of the chemicals usage in their farms. These farms are located near the road, the factories and the conventional farms. However, only farm 1 is near the domestic animals. Both farms use the water from the canal for their cultivation.

In province C, there was no record of the chemical usage in the farm area. The farm is located near the road, the domestic animals and the factories (animal feeding factory). However, the farm is far from other conventional farm. The farmers use the water from the irrigated canal for cultivation.

In province D, farm 1 and farm 2 had the history of the chemicals usage in their farms (used to be corn farms). All farms in province D are far from the road, the factories and the domestic animals. Farm 1 and farm 2 are close to other conventional farms. All farms use the water from the pond for the cultivation.

Table 13: The history, environment and source of cultivation water of organic farms.

Province	farm	History of farm		Environment around farm				Source of agricultural water				
		Ever used chemicals	Refrain farm before cultivation (<1 yr.)	Road (1 km.)	Factory (1 km.)	Domestic animals (1 km.)	Conventional farms (1 km.)	Irrigated canal	Natural canal	Stream	Pond	ground water
Province A	1	✓	×	×	×	×	✓	×	×	✓	×	×
	2	×	×	×	×	×	✓	×	×	✓	×	×
	3	✓	×	×	×	×	×	×	×	✓	×	×
Province B	1	✓	×	✓	✓(I1)	✓	✓	×	✓	×	×	×
	2	✓	×	✓	✓(I2)	×	✓	×	✓	×	×	×
Province C	1	×	×	✓	✓(A)	✓	×	✓	×	×	×	×
Province D	1	✓	×	×	×	×	✓	×	×	×	✓	×
	2	✓	×	×	×	×	✓	×	×	×	✓	×
	3	×	×	×	×	×	✓	×	×	×	✓	×
Total	9	6 (66.67%)	0 (0%)	3 (33.33%)	2 (22.22%)	2 (22.22%)	3 (33.33%)	1 (11.11%)	2 (22.22%)	3 (33.33%)	3 (33.33%)	0 (0%)

✓: represents yes
× : represents no

I1 = Industrial factory (Lead melting factory)
I2 = Industrial factory (Garage)

A = Agricultural factory (Animal feeding factory)

However, according to the analysis, cadmium levels in the organic Chinese kale samples of province D from farm 1 and farm 2 were relatively higher than farm 3. Besides the history and the environment around the farms, the raw materials and the amount of fertilizers may affect lead and cadmium accumulation in Chinese kale. **Table 14** shows the raw materials and the amount of organic fertilizers (manure, compost and bio-extract fertilizers) used in each organic farm in the rainy season. The information were gathered from the interview with the farmers.

In province A, according to the analysis, the Chinese kale samples from farm 1 showed the lowest lead and cadmium levels. There was only the use of compost in farm 1. Chicken's dung was used as raw material of compost (1,600 kg/rai) in this farm. The farmers used compost and bio-extract fertilizers in farm 2 and farm 3. The raw materials of compost in farm 2 and farm 3 were the mixture of chicken's dung and chaff (800 kg/rai) and the mixture of chicken's dung, chaff and cattle's dung (1,600 kg/rai), respectively. The raw materials of bio-extract fertilizer used in farm 2 and farm 3 were vegetable (12 times/crop) and the mixture of vegetable and fruit (18 times/crop), respectively.

In province B, according to the analysis, lead and cadmium levels in organic Chinese kale from farm 1 was higher than farm 2. However there was no significant difference between farm 1 and farm 2. The farmer used manure and bio-extract fertilizer in farm 1. Pig's dung was used as raw materials of manure (800 kg/rai) and bio-extract fertilizer made from the mixture of food scraps and household waste (6 times/crop) in farm1. The farmer used manure, compost and bio-extract fertilizer in farm 2. The raw materials of manure, compost and bio-extract fertilizer were pig's dung (200 kg/rai), the mixture of pig's dung , chaff and sugar-cane husk (1200 kg/rai), and the mixture of raddish water and fish (3 times/crop), respectively.

In province C, the farmer used compost and plant bio-extract fertilizer in organic farm. The raw materials of compost were the mixture of cattle's dung, chaff and plant bio-extract fertilizer (640 kg/rai). The raw materials of plant bio-extract fertilizer were various types of vegetables (6 times/crop).

In province D, the farmer used manure, compost and bio-extract fertilizer in farm 1. The raw materials of manure, compost and bio-extract fertilizer in farm 1 were pig's dung (3200 kg/rai), the mixture of chicken's dung, pig's dung and cattle's dung (4,200 kg/rai) and the mixture of food scraps and household waste (6 times/crop), respectively. There was only the use of bio-extract fertilizer in farm 2. The raw materials of bio-extract fertilizer were the mixture of food scraps and household waste (6 times/crop). In farm 3, the farmer used compost and bio-extract fertilizer. The raw materials of compost and bio-extract fertilizer were the mixture of chicken’s dung and chaff (1,600 kg/rai), and the mixture of vegetable and fruit (6 times/crop), respectively.

Table 14: The raw materials and amount of organic fertilizers used in organic farms in the rainy season

Province	farm	Manure	Compost	Bio-extract fertilizer; raw material (time/crop)			
		(amount)	(amount)	Plant	Animal	Mixed	Household waste
Province A	1	0	Chicken's dung (1600 kg/rai)	0	0	0	0
	2	0	Chicken's dung+chaff (800kg/rai)	Vegetables (12)	0	0	0
	3	0	Chicken's dung+chaff+cattle's dung (1600kg/rai)	vegetables+fruit (18)	0	0	0
Average	3	800kg/rai	533.3 kg/rai	10	0	2	0
Province B	1	Pig's dung (200 kg/rai)	0	0	0	0	Food scraps + houshold waste (6)
	2	Pig's dung (200 kg/rai)	Pig's dung+chaff+sugar-cane husk (1200 kg/rai)	0	0	radish+fish (3)	0
Average	2	200 kg/rai	600 kg/rai	0	0	1.5	3
Province C	1	0	Cattle's dung+chaff+vegetable bio extract (640kg/rai)	Vegetables (6)	0	0	0
Average	1	640 kg/rai	0	6	0	0	0
Province D	1	Pig's dung (3200kg/rai)	Pig's dung+chicken's dung+cattle's dung (4200kg/rai)	0	0	0	Food scraps + houshold waste (6)
	2	0	0	0	0	0	Food scraps + houshold waste (6)
	3	0	Chicken's dung+chaff (1600 kg/rai)	vegetables+fruit (6)	0	0	0
Average	3	1600kg/rai	533.3 kg/rai	2	0	0	4

5.3.2 Lead and cadmium contents in hygienic Chinese kale from each farm in the rainy season

Table 15 shows lead and cadmium contents in hygienic Chinese kale from each farm in province A, province B and province C during the rainy season.

In province A, the mean of lead levels in hygienic Chinese kale were 3.81 and 9.17 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of lead levels in hygienic Chinese kale were 2.35 and 2.00 µg/kg fresh weight in farm 1 and farm 2, respectively. There was no significant difference in lead content between farm 1 and farm 2 ($p \geq 0.05$). The mean of cadmium levels in hygienic Chinese kale were 54.99 and 45.21 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of cadmium levels in hygienic Chinese kale were 55.04 and 10.86 µg/kg fresh weight in farm 1 and farm 2, respectively. There was significant difference in cadmium content between farm1 and farm 2 ($p < 0.05$).

In province B, the mean of lead levels in hygienic Chinese kale were 77.63 and 24.83 µg/kg fresh weight in farm 1 and 2, respectively. The median of lead levels in hygienic Chinese kale were 66.53 and <LOD µg/kg fresh weight in farm 1 and 2, respectively. There was significant difference in lead content between farm 1 and farm 2 ($p < 0.05$). The mean of cadmium levels in hygienic Chinese kale were 110.44 and 177.49 µg/kg fresh weight in farm 1 and 2, respectively. The median of cadmium levels in hygienic Chinese kale were 92.71 and 162.47 µg/kg fresh weight in farm 1 and farm 2, respectively. There was significant difference in cadmium content between farm 1 and farm 2 ($p < 0.05$).

In province C, the mean of lead levels in hygienic Chinese kale were 10.30, 14.33 and 90.36 µg/kg fresh weight in farm 1, farm 2 and farm 3, respectively. The median of lead levels in hygienic Chinese kale were 11.80, 15.16 and 55.11 µg/kg fresh weight in farm 1, farm 2 and farm 3, respectively. There were significant differences in lead content between farm 1 and farm 3, and between farm 2 and farm 3 ($p < 0.05$). In the meantime, there was no significant difference in lead content between farm 1 and farm 2. The mean of cadmium levels in hygienic Chinese kale were 37.82 , 29.05 and 183.56 µg/kg fresh weight in farm 1, farm 2 and farm 3, respectively. The median of cadmium levels in hygienic Chinese kale were 36.31 , 29.74 and 194.55 µg/kg fresh weight in farm 1, farm 2 and farm 3, respectively. There were significant differences in cadmium content between farm 1 and farm 3, and between farm 2 and farm 3 ($p<0.05$). Whereas, there was no significant difference in cadmium content between farm 1 and farm 2.

Table 15: Lead and cadmium contents in hygienic Chinese kale from each farm in the rainy season

Province	Farm	Pb (µg/kg fresh weight)			Cd (µg/kg fresh weight)		
		Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max
Province A	1	3.81±4.60^{a}	2.35^{a}	<LOD-15.46	54.99±11.67^{a}	55.04^{a}	37.84±78.63
	2	9.17±8.62^{a}	2.00^{a}	<LOD -24.92	45.21±102.06^{b}	10.86^{b}	5.50-334.03
Average		6.98±7.21	5.34	<LOD -24.92	50.10±70.88	44.21	5.50-334.03
Province B	1	77.63±41.27^{a}	66.53^{a}	29.30-138.45	110.44±50.85^{a}	92.71^{a}	68.17-231.61
	2	24.83±34.19^{b}	<LOD^{b}	<LOD -92.70	177.49±75.83^{b}	162.47^{b}	41-292.12
Average		51.23±45.76	49.07	<LOD -138.45	143.97±71.63	142.90	41-292.12
Province C	1	10.30±6.06^{a}	11.80^{a}	<LOD -17.87	37.82±13.59^{a}	36.31^{a}	23.12-59.19
	2	14.33±6.32^{a}	15.16^{a}	2.61-27.26	29.05±6.26^{a}	29.74^{a}	16.98-37.03
	3	90.36±97.12^{b}	55.11^{b}	<LOD -273.47	183.56±58.73^{b}	194.55^{b}	91.67-254.73
Average		38.33±65.99	15.15	<LOD -273.47	83.48±79.59	39.27	16.98-254.73

a, b, c: Different superscripts within the same column indicate significant difference between farms in the same province at the level of $p<0.05$.

Lead and cadmium levels in Chinese kale from each hygienic farm may be affected by several factors. The history of the farms, the environment around the farms, the amount and the raw materials of organic fertilizers used in the farms are discussed. **Table 16** shows the history of the farms, the environment around the farms and the water source used in cultivation in the farms from province A, province B and province C. The information were gathered from the interview with the farmers. According to the interview, five farms (71.43%) had the history of the chemicals usage in their farms and one farm was the old mine (14.29%). Most hygienic farms (85.71%), the farmers refrained from cultivation less than 1 year. There are 3 farms (42.86%), 2 farms (28.57%), 5 farms (71.43%) and 7 farms (100%) near the road, the factories, the domestic animals and the conventional farms, respectively. The source of cultivation water of hygienic farms are from the irrigated canal (1 farm), the natural canal (1 farm), the stream (1 farm), the pond (2 farms) and the ground water (2 farms).

In province A, farm 2 had the history of the chemicals usage in the farm. Both farms in province A are far from the road, the factories and the domestic animals. However, farm 1 and farm 2 are near other conventional farms. Both farms use the water from the pond for cultivation.

In province B, both farms had the history of the usage of the chemicals in their farms. These farms are near the factories, the domestic animals and the conventional farms. However, only farm 1 is near road. Farm 1 used the water from the natural canal in cultivation and farm 2 used the water from the irrigated canal.

In province C, according to the analysis, lead and cadmium levels in Chinese kale from farm 3 were significantly higher than farm 1 and farm 2 ($p<0.05$). Farm 1 and farm 2 had the history of the usage of the chemicals in their farms and farm 3 was the old mine. All farms are far from the factory. Farm 1 is near the domestic animals and the conventional farms. Farm 2 and farm 3 are near the road, the domestic animals and the conventional farms. The source of cultivation water of farm 1 and farm 2 are the ground water and the water used in farm 3 is from the stream.

Table 16 : The history, environment and source of cultivation water of hygienic farms

Province	farm	History of farm		Environment around farm				Source of agricultural water				
		Ever used chemicals/ old mine	Refrain farm before cultivation (<1 yr.)	Road (1 km.)	Factory (1 km.)	Domestic animals (1 km.)	Conventional farms (1 km.)	Irrigated canal	Natural canal	Stream	Pond	ground water
Province A	1	×	✓	×	×	×	✓	×	×	×	✓	×
	2	✓	✓	×	×	×	✓	×	×	×	✓	×
Province B	1	✓	✓	✓	✓	✓(I1)	✓	×	✓	×	×	×
	2	✓	✓	×	✓	✓(I1)	✓	✓	×	×	×	×
Province C	1	✓	✓	×	×	✓	✓	×	×	×	×	✓
	2	✓	✓	✓	×	✓	✓	×	×	×	×	✓
	3	✓*	×	✓	×	✓	✓	×	×	✓	×	×
Total	7	6 (85.71%)	6 (85.71%)	3 (42.86%)	2 (28.57%)	5 (71.43%)	7 (100%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	2 (28.57%)	2 (28.57%)

✓: represents yes

× : represents no

* : This farm used to be an old mine

I1= Industrial factory (Lead melting factory)

Besides the history and the environment around the farms, the raw materials and the amount of fertilizers may also affect lead and cadmium accumulation in Chinese kale. **Table 17** shows the raw materials and the amount of organic fertilizers (manure, compost and bio-extract fertilizer) and the amount of inorganic fertilizers used in each hygienic farm during the rainy season. The information were gathered from the interview with the farmers.

In province A, there was no significant difference in lead content between farm 1 and farm 2, whereas there was significant difference in cadmium content between these farms ($p<0.05$). The farmers used inorganic fertilizer N-P-K formula: 15-15-15 (25 kg/rai) and mixture of 25-7-7 and 26-14-0 (25 kg/rai) in farm 1. In addition, bio-extract fertilizer (6 times/crop) which made from golden apple snail, was also used in this farm. The farmers used inorganic fertilizer N-P-K formula: 15-15-15 (26.6 kg/rai) and 46-0-0 (80 kg/rai) in farm 2. In addition, compost (800 kg/rai) which made from the mixture of chicken's dung and chaff, was also used in this farm.

In province B, according to the analysis, the lead level in Chinese kale from farm 1 was significantly higher than farm 2 ($p<0.05$). Otherwise, cadmium content in Chinese kale from farm 2 was significantly higher than farm 1 ($p<0.05$). The farmers used inorganic fertilizer N-P-K formula: 16-16-16 (180 kg/rai) and bio-extract fertilizer (3 times/crop) in farm 1. The raw materials of bio-extract fertilizer used in this farm were various types of fish. The farmers used inorganic fertilizer N-P-K formula: 16-16-16 (240 kg/rai), compost (60 kg/rai) and bio-extract fertilizer (1 time/crop) in farm 2. The raw materials of compost were chicken's dung and chaff, the raw materials of bio-extract fertilizer were various types of fish.

In province C, The farmer used of inorganic fertilizer N-P-K formula: 25-7-7 (20 kg/rai), manure (500 kg/rai) and bio-extract fertilizer (6 times/crop) in farm 1. Cattle's dung was used as raw material of manure in this farm. The raw materials of bio-extract fertilizer used in farm 1 were vegetable and fish. The farmers used inorganic fertilizer N-P-K formula: 25-7-7 (33.3 kg/rai), compost (400 kg/rai) and bio-extract fertilizer (12 times/crop) in farm 2. The raw materials of compost used in this farm were chicken's dung, chaff and cattle's dung and the raw materials of bio-extract fertilizer were various types of fish. The farmers used inorganic fertilizer N-P-K formula: 46-0-0 (30 kg/rai), manure (200 kg/rai) and bio-extract fertilizer (12 times/crop) in farm 3.

The raw materials of manure used in this farm were chicken’s dung, cattle’s dung and pig’s dung and the raw materials of bio-extract fertilizer were vegetable and golden apple snail.

Table 17: The raw materials and amount of inorganic and organic fertilizers used in hygienic farms in the rainy season

Province	farm	Inorganic fertilizer (amount)	Organic fertilizer					
			Manure	Compost	Bio-extract fertilizer; raw material(time/crop)			
			(amount)	(amount)	Plant	Animal	Mixed	Household waste
Province A	1	15-15-15 (25 kg/rai) 25-7-7+ 26-14-0 (25 kg/rai)	0	0	0	Golden apple snail (6)	0	0
	2	15-15-15 (26.6 kg/rai), 46-0-0 (80 kg/rai)	0	Chicken's dung+chaff (800kg/rai)	0	0	0	0
Average	2	78.3kg/rai	0	400 kg/rai	0	3	0	0
Province B	1	16-16-16 (180 kg/rai)	0	0	0	fish (3)	0	0
	2	16-16-16 (240 kg/rai)	0	Chicken's dung+chaff (60kg/rai)	0	fish (1)	0	0
Average	2	210kg/rai	0	30 kg/rai	0	2	0	0
Province C	1	25-7-7 (20 kg/rai)	Cattle'dung (500 kg/rai)	0	0	0	vegetable+fish (6)	0
	2	25-7-7 (33.3 kg/rai)	0	Chicken's dung+chaff+cattle's dung(400kg/rai)	0	0	fish (12)	0
	3	46-0-0 (30 kg/rai)	Chicken,cattle, pig's dung (200kg/rai)	0	0	0	vegetable+ Golden apple snail (6)	0
Average	3	83.3 kg/rai	700kg/rai	133.3kg/rai	0	0	8	0

5.3.3 Lead and cadmium contents in conventional Chinese kale from each farm in the rainy season

Table 18 shows lead and cadmium contents in conventional Chinese kale from each farm in province A, province B and province C during the rainy season.

In province A, the mean of lead levels in conventional Chinese kale were 9.08 and 4.66 µg/kg fresh weight in farm 1 and farm 2 respectively. The median of lead levels in conventional Chinese kale were 8.34 and 4.63 µg/kg fresh weight in farm 1 and farm 2 respectively. There was significant difference in lead content between farm 1 and farm 2 ($p<0.05$). The mean of cadmium levels in conventional Chinese kale were 8.88 and 13.87 µg/kg fresh weight in farm 1 and farm 2 respectively. The median of cadmium levels in conventional Chinese kale were 8.92 and 14.14 µg/kg fresh weight in farm 1 and farm 2, respectively. There was significant difference in cadmium contents between farm1 and farm 2 ($p<0.05$).

In province B, the mean of lead levels in conventional Chinese kale were 107.28 and 25.96 µg/kg fresh weight in farm 1 and 2, respectively. The median of lead levels in conventional Chinese kale were 112.31 and 20.21 µg/kg fresh weight in farm 1 and farm 2, respectively. There was significant difference in lead content between farm 1 and farm 2 ($p<0.05$). The mean of cadmium levels in conventional Chinese kale were 129.51 and 159.96 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of cadmium levels in conventional Chinese kale were 120.90 and 150.32 µg/kg fresh weight in farm 1 and farm 2, respectively. There was no significant difference in cadmium content between farm 1 and farm 2.

In province C, the mean of lead levels in conventional Chinese kale were 8.31 and 10.38 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of lead levels in conventional Chinese kale were 7.22 and 8.78 µg/kg fresh weight in farm 1 and farm 2, respectively. There was no significant difference in lead content between farm 1 and farm 2. The mean of cadmium levels in conventional Chinese kale were 10.40 and 46.67 µg/kg fresh weight in farm 1 and farm 2, respectively. The median of cadmium levels in conventional Chinese kale were 10.74 and 49.13 µg/kg fresh weight in farm 1 and farm 2, respectively. There was significant difference in cadmium content between farm 1 and farm 2 ($p<0.05$).

Table 18: Lead and cadmium contents in conventional Chinese kale from each farm in the rainy season

Province	Farm	Pb (µg/kg fresh weight)			Cd (µg/kg fresh weight)		
		Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max
Province A	1	9.08±2.81^{a}	8.34 ^{a}	6.49-16.36	8.88±2.52^{a}	8.92 ^{a}	4.45-12.24
	2	4.66±4.21^{b}	4.63 ^{b}	<LOD -10.44	13.87±2.88^{b}	14.14 ^{b}	9.45-20.08
Average		6.87±4.16	7.60	<LOD -16.36	11.38±3.67	11.55	<LOD-16.36
Province B	1	107.28±42.15^{a}	112.31 ^{a}	52.78-170.53	129.51±42.18^{a}	120.90 ^{a}	60.69-209.80
	2	25.96±27.02^{b}	20.21 ^{b}	<LOD -85.90	159.96±42.64^{a}	150.32 ^{a}	116.18-216.02
Average		66.62±54.11	53.64	<LOD -170.53	144.74±44.14	128.99	60.69-216.02
Province C	1	8.31±3.87^{a}	7.22 ^{a}	3.24-15.33	10.40±1.22^{a}	10.74 ^{a}	8.32-12.37
	2	10.38±7.30^{a}	8.78 ^{a}	2.10-26.68	46.67±15.31^{b}	49.13 ^{b}	17.71-65.48
Average		9.34±5.79	7.81	2.10-26.68	28.53±21.40	15.04	8.32-65.48

a, b, c: Different superscripts within the same column indicate significant difference between farms in the same province at the level of $p<0.05$.

Lead and cadmium levels in Chinese kale from each conventional farm from the same province may be affected by several factors. The factors include the history of the farms, the environment around the farms, the amount and the raw materials of organic fertilizers. **Table 19** shows the history of the farms, the environment around the farms and source of water used in the cultivation in each farm from province A, province B and province C. These information were gathered from the interview with the farmers. All conventional farms used the chemicals in their farms and refrained farm before the cultivation less than 1 year. There are 4 farms (66.67%), 2 farms (33.33%), 2 farms (33.33%) and 6 farms (100%) near the roads, the factories, the domestic animals and the conventional farms, respectively. The source of water for the conventional farms are from the irrigated canals (2 farms), the natural canals (2 farms), the pond (1 farm) and the ground water (1 farm).

In province A, both farms had the history of chemicals usage in their farms and refarined the farms less than 1 year. Both farms in province A are far from the roads, the factories and the domestic animals. However, they are near other conventional farms. Farm 1 used the water from the pond and farm 2 used the ground water in the farm.

In province B, farm 1 refrained from cultivation more than 1 year. Both farms are near the roads, the factories, the domestic animals and the conventional farms. All farms used the water from the natural canals.

In province C, farm 1 and farm 2 had the history of chemicals usage in their farms and refrained from cultivation less than 1 year. All farms are near the road and the conventional farms and far from the factories and the domestic animals. The source of cultivation water of these are from the irrigated canals.

Table 19 : The history, environment and source of cultivation water of conventional farms

Province	farm	History of farm		Environment around farm				Source of agricultural water				
		Ever used chemicals/ old mine	Refrain farm before cultivation (<1 yr.)	Road (1 km.)	Factory (1 km.)	Domestic animals (1 km.)	Conventional farms (1 km.)	Irrigated canal	Natural canal	Stream	Pond	ground water
Province A	1	✓	✓	×	×	×	✓	×	×	×	✓	×
	2	✓	✓	×	×	×	✓	×	×	×	×	✓
Province B	1	✓	×	✓	✓(I1)	✓	✓	×	✓	×	×	×
	2	✓	✓	✓	✓(I1)	✓	✓	×	✓	×	×	×
Province C	1	✓	✓	✓	×	×	✓	✓	×	×	×	×
	2	✓	✓	✓	×	×	✓	✓	×	×	×	×
Total	6	6 (100%)	6 (83.33%)	4 (66.67%)	2 (33.33%)	2 (33.33%)	6 (83.33%)	2 (33.33%)	2 (33.33%)	0 (0%)	1 (16.67%)	1 (16.67%)

✓: represents yes

× : represents no

I1: Industrial factory (Lead melting factory)

Besides the history and the environment around the farms, the raw materials and the amount of fertilizers may be the factors that lead to lead and cadmium accumulation in Chinese kale. **Table 20** shows the raw materials and the amount of organic fertilizers (manure, compost and bio-extract fertilizer) and the amount of inorganic fertilizers used in each conventional farm in the rainy season. The information were gathered from the interview with the farmers.

In province A, the farmers used only inorganic fertilizers in their farms. Inorganic fertilizer N-P-K formula: 25-7-7 mixed with 26-14-0 (91.7 kg/rai) and 46-0-0 (8.3 kg/rai) were used in farm 1. Inorganic fertilizer N-P-K formula: 25-7-7 (33.3 kg/rai) and 46-0-0 (16.8 kg/rai) were used in farm 2.

In province B, inorganic fertilizer N-P-K formula: 25-7-7 (121.6 kg/rai) and 46-0-0 (133.3 kg/rai) were used in farm 1. In addition, the farmers also used the bio-extract fertilizer made from fish (1 time/crop) in farm 1. Only inorganic fertilizer N-P-K formula: 25-7-7 (150 kg/rai) and 46-0-0 (150 kg/rai) were used in farm 2.

In province C, inorganic fertilizer N-P-K formula: mixture of 21-0-0, 21-7-14 and 25-7-7 (25 kg/rai) and 46-0-0 (55 kg/rai) were used in farm 1. Inorganic fertilizer N-P-K formula: mixture of 21-0-0, 21-7-14, 25-7-7 and 46-0-0 (33.3 kg/rai) were used in farm 2. In addition, chicken's dung was used as raw material of manure (66 kg/rai) in this farm.

Table 20: The raw materials and amount of inorganic and organic fertilizers used in conventional farms in the rainy season

Province	farm	Inorganic fertilizer (amount)	Organic fertilizer					
			Manure	Compost	Bio-extract fertilizer; raw material(time/crop)			
			(amount)	(amount)	Plant	Animal	Mixed	Household waste
Province A	1	25-7-7+26-14-0 (91.7kg/rai), 46-0-0 (8.3 kg/rai)	0	0	0	0	0	0
	2	25-7-7 (33.33kg/rai), 46-0-0 (16.8kg/rai)	0	0	0	0	0	0
Average	2	75.2kg/rai	0	0	0	0	0	0
Province B	1	25-7-7 (121.6 kg/rai), 46-0-0 (133.3 kg/rai)	0	0	0	fish (1)	0	0
	2	25-7-7 (150 kg/rai), 46-0-0 (150kg/rai)	0	0	0	0	0	0
Average	2	277.45 kg/rai	0	0	0	0.5	0	0
Province C	1	21-0-0+21-7-14+ 25-7-7 (25kg/rai), 46-0-0 (55 kg/rai)	0	0	0	0	0	0
	2	21-0-0+ 21-7-14+ 25-7-7 +46-0-0 (33.33 kg/rai)	Chicken's dung (66.66 kg/rai)	0	0	0	0	0
Average	2	56.67 kg/rai	66.66kg/rai	0	0	0	0	0

5.4 The comparison of lead and cadmium contents in the Chinese kale from the same farm in different seasons

5.4.1 Lead and cadmium contents in organic Chinese kale from the same farm in different seasons

Table 21 shows lead levels in the organic Chinese kale grown during the rainy, the winter and the summer seasons. The mean of lead levels in total organic Chinese kale were 19.33, 12.41 and 11.33 µg/kg fresh weight in the rainy season, winter and summer, respectively. The median of lead levels of total organic Chinese kale were 8.76, < LOD and 3.93 µg/kg fresh weight in the rainy season, winter and summer, respectively. The highest lead level was found in the rainy season and the lowest lead level was found in the winter. There were significant differences in lead content between each season ($p<0.05$).

In province A, the highest lead level was found in the rainy season (median = 5.98 µg/kg fresh weight). The lowest lead level was found in winter (median = < LOD µg/kg fresh weight). There were significant differences in lead levels between the rainy season and winter, and between summer and winter. However, there was no significant difference in lead levels between the rainy season and summer.

In province C, the highest lead level was found in summer (median = 5.64 µg/kg fresh weight). The lowest lead level was found in winter (median = < LOD µg/kg fresh weight). There were significant differences in lead levels between the rainy season and winter, and between summer and winter. However, there was no significant difference between Chinese kales grown in the rainy season and the summer.

In province D, the highest lead level was found in the rainy season (median = 52.24 µg/kg fresh weight). The lowest lead level was found in summer (median = 4.61 µg/kg fresh weight). However, there were no significant differences of lead content in Chinese kale between three seasons.

Table 21: Lead content in organic Chinese kale from the same farm in different seasons

Season	n	Province A		n	Province C		n	Province D		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	29	10.70±15.43^{a} (<LOD-77.19)	5.98^{a}	10	4.59±2.47^{a} (1.58-8.76)	3.89^{a}	10	59.11±34.92^{a} (18.95-119.28)	52.24^{a}	49	19.33±28.08^{a} (<LOD -119.28)	8.76^{a}
Winter	30	1.91±5.69^{b} (<LOD -26.32)	<LOD^{b}	10	0.19±0.61^{b} (<LOD -1.93)	<LOD^{b}	10	56.10±56.67^{a} (<LOD -165.53)	47.42^{a}	50	12.41±33.11^{b} (<LOD -165.53)	<LOD^{b}
Summer	30	5.20±10.11^{a} (<LOD -54.45)	1.02^{a}	10	6.29±4.70^{a} (0.27-15.45)	5.64^{a}	10	34.78±60.73^{a} (<LOD -176.54)	4.61^{a}	50	11.33±29.71^{c} (<LOD -176.54)	3.93^{c}
Total	89	5.88±11.55 (<LOD -77.19)	<LOD	30	3.69±3.96 (<LOD -15.45)	2.69	30	49.99±51.39 (<LOD -176.54)	43.07	149	14.32±30.39 (<LOD -176.54)	2.23

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

Table 22 shows the mean of cadmium levels in the organic Chinese kale grown in the rainy season, winter and summer. The mean of cadmium levels of total organic Chinese kale were 167.58, 220.03 and 902.39 μg/kg fresh weight in the rainy season, winter and summer, respectively. The median of cadmium levels of total organic Chinese kale were 13.16, 15.07 and 18.93 μg/kg fresh weight in the rainy season, winter and summer, respectively. The highest cadmium level was found in the organic Chinese kale grown during summer, whereas the lowest cadmium level was found in organic Chinese kale grown during the rainy season. There were significant differences in cadmium content between the rainy season and summer, and between winter and summer ($p<0.05$). There was no significant difference in cadmium content between the organic Chinese kale grown in the rainy and the winter seasons.

In province A, the highest cadmium level in the organic Chinese kale was found in summer (median = 18.93 μg/kg fresh weight). The lowest cadmium level was found in the rainy season (median = 7.77 μg/kg fresh weight). There were significant differences in cadmium content between each season ($p<0.05$).

In province C, the highest cadmium level was found in the rainy season (median = 20.75 μg/kg fresh weight). The lowest cadmium level was found in summer (median = 12.34 μg/kg fresh weight). There were significant differences in cadmium content between the rainy season and summer, and between winter and summer ($p<0.05$). However there was no significant difference in cadmium content between the rainy season and winter.

In province D, the highest cadmium level was found in summer (median = 4695.18 μg/kg fresh weight). The lowest cadmium level was found in the rainy season (median = 758.52 μg/kg fresh weight). There were significant differences in cadmium content between three seasons ($p<0.05$).

Table 22: Cadmium content in organic Chinese kale from the same farm in different seasons

Season	n	Province A		n	Province C		n	Province D		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	29	22.96±46.38^{a} (<LOD -194.51)	7.77^{a}	10	20.06±8.30^{a} (3.72-29.31)	20.75^{a}	10	734.48±131.77^{a} (556.97-896.05)	758.52^{a}	49	167.58±297.73^{a} (<LOD -896.05)	13.16^{a}
Winter	30	14.19±4.92^{b} (5.33-31.50)	13.68^{b}	10	13.96±7.65^{a} (3.04-25.43)	13.74^{a}	10	1043.64±288.61^{b} (659.28-1605.68)	1074.03^{b}	50	220.03±434.01^{a} (3.04-1605.68)	15.07^{a}
Summer	30	20.90±8.60^{c} (9.12-50.78)	18.93^{c}	10	13.07±2.31^{b} (9.72-17.45)	12.34^{b}	10	4436.17±1261.45^{c} (1429.18-6028.31)	4695.18^{c}	50	902.39±1864.93^{b} (9.12-6028.31)	18.93^{b}
Total	89	19.31±27.04 (<LOD -194.51)	13.45	30	15.70±7.15 (3.04-29.31)	14.47	30	2071.43±1853.10 (556.97-6028.31)	1074.03	149	431.76±1164.34 (<LOD -6028.31)	16.84

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

The difference of lead and cadmium levels in the organic Chinese kale from the same farm in different seasons may be affected by several factors, including the organic fertilizer. **Table 23** shows the application of fertilizers in each organic farm in three seasons.

In province A, the farmers in farm 1 used mixed bio-extract fertilizer (1 time/crop) in winter and compost (1600 kg/rai) in summer. The farmers in farm 2 used compost (800 kg/rai) and plant bio-extract fertilizer (12 times/crop) in the rainy season, compost (800 kg/rai) and plant bio-extract fertilizer (12 times/crop) in winter, and manure (800 kg/rai), compost (1600 kg/rai) and plant bio-extract fertilizer (12 times/crop) in summer. The farmers in farmers in farm 3 used compost (1600 kg/rai) and plant bio-extract fertilizer (18 times/crop) in the rainy season, compost (1200 kg/rai) and plant bio-extract fertilizer (18 times/crop) in winter, and compost (1500 kg/rai) and animal bio-extract fertilizer (18 times/crop) in summer.

In province C, there was only 1 organic farm. The farmers in organic farm from province C used compost (640 kg/rai) and plant bio-extract fertilizer (6 times/crop) in the rainy season, compost (640 kg/rai) in winter and compost (640 kg/rai) in summer.

In province D, there was only 1 organic farm (farm 2) that was able to collect the Chinese kale samples in all seasons. The farmers in organic farm from province D used bio-extract fertilizer made from household waste (6 times/crop) in the rainy season, bio-extract fertilizer made from household waste (6 times/crop) in winter, and compost (1600 kg/rai) and bio-extract fertilizer made from household waste (6 times/crop) in summer.

Table 23: The application of fertilizers used in organic farms in three seasons

Season	Province	Manure (kg/rai)	Compost (kg/rai)	Total (kg/rai)	Bio-extract fertilizer (time/crop)			
					Plant	Animal	Mixed	Household waste
Rainy	Province A, Farm1	0	0	0	0	0	0	0
	Province A, Farm2	0	800	800	12	0	0	0
	Province A, Farm3	0	1600	1600	18	0	0	0
	Province C	0	640	640	6	0	0	0
	Province D	0	0	0	0	0	0	6
	Average	0	608	608	7.2	0	0	1.2
Winter	Province A, Farm1	0	0	0	0	0	1	0
	Province A, Farm2	0	800	800	12	0	0	0
	Province A, Farm3	0	1200	1200	18	0	0	0
	Province C	0	640	640	0	0	0	0
	Province D	0	0	0	0	0	0	6
	Average	0	528	528	6	0	0.2	1.2
Summer	Province A, Farm1	0	1600	1600	0	0	0	0
	Province A, Farm2	800	1600	2400	12	0	0	0
	Province A, Farm3	0	1500	1500	0	18	0	0
	Province C	0	640	640	0	0	0	0
	Province D	0	1600	1600	0	0	0	6
	Average	160	1388	1548	2.4	3.6	0	1.2

5.4.2 Lead and cadmium contents in hygienic Chinese kale from the same farm in different seasons

Table 24 shows the mean of lead levels in the hygienic Chinese kale grown in the rainy season, winter and summer. The mean of lead levels of total hygienic Chinese kale were 30.40, 23.23 and 83.42 µg/kg fresh weight in the rainy season, winter and summer, respectively. The median of lead levels of total hygienic Chinese kale were 15.15, 5.09 and 10.91 µg/kg fresh weight in the rainy season, winter and summer, respectively. The highest lead level was found in the rainy season. The lowest lead level was found in winter. There were no significant differences in lead content between the seasons.

In province A, the highest lead level was found in summer (median = 4.34 µg/kg fresh weight). The lowest lead level was found in winter (median = < LOD µg/kg fresh weight). There were no significant differences in lead content between each season.

In province B, similar to Province A, the highest lead level was found in summer (median = 76.91 µg/kg fresh weight). The lowest lead level was found in winter (median = 18.48 µg/kg fresh weight). However, there were no significant differences in lead content between three seasons.

In province C, the highest lead level was found in the rainy season (median = 15.15 µg/kg fresh weight). The lowest lead level was found in winter (median = 5.74 µg/kg fresh weight). There was significant difference in lead content between the rainy season and winter. However, there were no significant differences in lead content between the rainy season and summer, and between winter and summer.

Table 24: Lead content in hygienic Chinese kale from the same farm in different seasons

Season	n	Province A		n	Province B		n	Province C		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	10	4.79±4.99^{a} (<LOD -15.46)	2.97^{a}	20	51.23±45.76^{a} (<LOD -138.45)	49.07^{a}	10	14.33±6.32^{a} (2.61-27.26)	15.15^{a}	40	30.40±38.63^{a} (<LOD -138.45)	15.15^{a}
Winter	10	2.48±4.27^{a} (<LOD -13.00)	<LOD^{a}	20	42.08±51.03^{a} (<LOD -182.79)	18.48^{a}	10	6.27±3.90^{b} (0.85-15.47)	5.74^{b}	40	23.23±40.53^{a} (<LOD -182.79)	5.09^{a}
Summer	10	5.18±3.61^{a} (0.44-11.17)	4.34^{a}	20	159.29±166.45^{a} (<LOD -448.39)	76.91^{a}	10	9.93±3.26^{ab} (5.50-14.20)	10.91^{ab}	40	83.42±139.32^{a} (<LOD -448.39)	10.91^{a}
Total	30	4.15±4.35 (<LOD -15.46)	2.84	60	84.20±115.40 (<LOD -448.39)	47.97	30	10.18±5.63 (0.85-27.26)	9.5	120	45.68±90.09 (<LOD-448.39)	8.82

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

Table 25 shows the mean of cadmium levels of hygienic Chinese kale grown in the rainy season, winter and summer. The mean of cadmium levels of total hygienic Chinese kale were 92.99, 101.13 and 131.39 µg/kg fresh weight in the rainy season, winter and summer, respectively. The median of cadmium levels of total hygienic Chinese kale were 65.51, 40.64 and 40.72 µg/kg fresh weight in the rainy season, winter and summer, respectively. The highest median of cadmium level was found in the rainy season (65.51 µg/kg fresh weight). The lowest median of cadmium level was found in winter. There were no significant differences in cadmium content between the seasons.

In province A, the highest cadmium level was found in the rainy season (median = 55.03 µg/kg fresh weight). The lowest cadmium level was found in winter (median = 7.76 µg/kg fresh weight). There were significant differences in cadmium content between three seasons.

In province B, the highest cadmium level was found in summer (median = 210.96 µg/kg fresh weight). The lowest cadmium level was found in the rainy season (median = 142.90 µg/kg fresh weight). However there were no significant differences in cadmium content between three seasons.

In province C, the highest cadmium level was found in winter (median = 31.11 µg/kg fresh weight). The lowest cadmium level was found in summer (median = 22.83 µg/kg fresh weight). There were no significant differences in cadmium content between three seasons.

Table 25: Cadmium content in hygienic Chinese kale from the same farm in different seasons

Season	n	Province A		n	Province B		n	Province C		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	10	54.99 ± 11.67^{a} (37.84-78.63)	55.03^{a}	20	143.97 ± 71.63^{a} (41.00-292.12)	142.90^{a}	10	29.05 ± 6.26^{a} (16.98-37.03)	29.74^{a}	40	92.99 ± 72.74^{a} (16.98-292.12)	65.51^{a}
Winter	10	7.77 ± 2.85^{b} (3.40-13.79)	7.76^{b}	20	182.86 ± 119.13^{a} (9.41-473.95)	180.40^{a}	10	31.04 ± 8.94^{a} (15.71-40.68)	31.11^{a}	40	101.13 ± 117.70^{a} (3.40-473.95)	40.64^{a}
Summer	10	11.14 ± 4.79^{c} (5.46-22.95)	9.70^{c}	20	245.49 ± 202.47^{a} (48.70-900.12)	210.96^{a}	10	23.43 ± 6.07^{a} (13.61-32.74)	22.83^{a}	40	131.39 ± 182.64^{a} (5.46-900.12)	40.72^{a}
Total	30	24.63±23.04 (3.40-78.63)	10.6	60	190.77±145.61 (9.41-900.12)	152.34	30	27.84±7.69 (13.61-40.68)	29.13	120	108.50±132.22 (3.40-900.12)	55.44

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

The difference of lead and cadmium levels in the hygienic Chinese kale from the same farm from different seasons may be affected by several factors, including the use of fertilizers. **Table 26** shows the application of fertilizers in each hygienic farm in three seasons.

In province A, there was only 1 hygienic farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The farmers in this farm used inorganic fertilizer (50 kg/rai) in the rainy season, inorganic fertilizer (50 kg/rai) and animal bio-extract fertilizer (1 time/crop) in winter and inorganic fertilizer (83 kg/rai) in summer.

In province B, the farmers in farm 1 used inorganic fertilizer (180 kg/rai) and animal bio-extract fertilizer (3 times/crop) in the rainy season, inorganic fertilizer (200 kg/rai) and animal bio-extract fertilizer (4 times/crop) in winter and inorganic fertilizer (100 kg/rai), manure (250 kg/rai) and animal bio-extract fertilizer (5 times/crop) in summer. The farmers in farm 2 used inorganic fertilizer (240 kg/rai) and animal bio-extract fertilizer (1 times/crop) in the rainy season, inorganic fertilizer (132.8 kg/rai) and animal bio-extract fertilizer (5 times/crop) in winter and inorganic fertilizer (400 kg/rai), manure (33 kg/rai) and animal bio-extract fertilizer (5 times/crop) in summer.

In province C, there was only 1 hygienic farm (farm 2) that was able to collect the Chinese kale samples in all seasons. The farmers in this farm used inorganic fertilizer (20 kg/rai) and animal bio-extract fertilizer (12 times/crop) in the rainy season, inorganic fertilizer (20 kg/rai) and animal bio-extract fertilizer (12 times/crop) in winter and inorganic fertilizer (20 kg/rai), compost (2400 kg/rai) and animal bio-extract fertilizer (12 times/crop) in summer.

Table 26: The application of fertilizers used in hygienic farms in three seasons

Season	Province	Inorganic fertilizer (kg/rai)	Manure (kg/rai)	Compost (kg/rai)	Bio-extract fertilizer (time/crop)			
					Plant	Animal	Mixed	Household waste
Rainy	Province A	50	0	0	0	0	0	0
	Province B, Farm1	180	0	0	0	3	0	0
	Province B, Farm2	240	0	0	0	1	0	0
	Province C	20	0	0	0	12	0	0
	Average	122.5	0	0	0	4	0	0
Winter	Province A	50	0	0	0	1	0	0
	Province B, Farm1	200	0	0	0	4	0	0
	Province B, Farm2	132.8	0	0	0	5	0	0
	Province C	20	0	0	0	12	0	0
	Average	100.7	0	0	0	5.5	0	0
Summer	Province A	83	0	0	0	0	0	0
	Province B, Farm1	100	250	0	0	5	0	0
	Province B, Farm2	400	33	0	0	5	0	0
	Province C	20	0	2400	0	12	0	0
	Average	150.8	70.8	600	0	5.5	0	0

5.4.3 Lead and cadmium contents in conventional Chinese kale from the same farm in different seasons.

Table 27 shows the mean of lead levels in conventional Chinese kale grown in the rainy season, winter and summer. The mean of lead levels in total conventional Chinese kale were 37.66, 2.34 and 30.49 μg/kg fresh weight in the rainy season, winter and summer, respectively. The median of lead levels in total conventional Chinese kale were 10.46, <LOD and 8.19 μg/kg fresh weight in the rainy season, winter and summer, respectively. The highest lead level was found in the rainy season. The lowest lead level was found in winter. There were significant differences in lead content between three season ($p<0.05$).

In province A, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The highest lead level was found in the rainy season (median = 8.34 μg/kg fresh weight). The lowest lead level was found in winter (median = < LOD μg/kg fresh weight). There were significant differences in lead content between three seasons ($p<0.05$).

In province B, similar to province A, the highest lead level was found in the rainy season (median = 53.64 μg/kg fresh weight). The lowest lead level was found in winter (median = <LOD μg/kg fresh weight). There were significant differences in lead content between three seasons.

In province C, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The highest lead level was found in summer (median = 13.27 μg/kg fresh weight). The lowest lead level was found in winter (median = <LOD μg/kg fresh weight). There were significant differences in lead content between the rainy season and summer, and between winter and summer ($p<0.05$). However, there was no significant difference in lead content between the rainy season and winter.

Table 27: Lead content in conventional Chinese kale from the same farm in different seasons

Season	n	Province A		n	Province B		n	Province C		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	10	9.08±2.81^{a} (6.49-16.36)	8.34^{a}	20	66.62±54.11^{a} (<LOD -170.53)	53.64^{a}	10	8.31±3.87^{a} (3.24-15.33)	7.22^{a}	40	37.66±47.88^{a} (<LOD -170.53)	10.46^{a}
Winter	10	0.38±1.19^{b} (<LOD-3.77)	<LOD^{b}	20	3.43±10.97^{b} (<LOD -43.45)	<LOD^{b}	10	2.11±3.47^{a} (<LOD -7.87)	<LOD^{a}	40	2.34±7.96^{b} (<LOD -43.45)	<LOD^{b}
Summer	10	4.65±4.96^{c} (<LOD -13.76)	3.97^{c}	20	50.93±106.91^{c} (<LOD -407.84)	9.21^{c}	10	15.46±9.34^{b} (7.57-37.54)	13.27^{b}	40	30.49±77.70^{c} (<LOD -407.84)	8.19^{c}
Total	30	4.70±4.86 (<LOD -16.36)	4.46	60	40.33±73.46 (<LOD -407.84)	5.27	30	8.63±8.14 (<LOD -37.54)	13.27	120	23.50±54.63 (<LOD -407.84)	6.61

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

Table 28 shows the mean of cadmium levels in conventional Chinese kale grown in the rainy season, winter and summer. The mean of cadmium levels in total conventional Chinese kale were 77.19, 45.27 and 57.48 µg/kg fresh weight in the rainy season, winter and summer, respectively. The median of cadmium levels of total conventional Chinese kale were 36.53, 19.63 and 21.78 µg/kg fresh weight in the rainy season, winter and summer, respectively. The highest cadmium level was found in the rainy season. The lowest cadmium level was found in winter. There were no significant differences in cadmium content between each season.

In province A, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The highest cadmium level was found in summer (median = 16.57 µg/kg fresh weight). The lowest mean cadmium level was found in winter (median = 8.83 µg/kg fresh weight). There were significant differences in cadmium content between the rainy season and summer, and between winter and summer ($p<0.05$). However, there was no significant difference in cadmium content between the rainy season and winter.

In province B, the highest cadmium level was found in the rainy season (median = 128.99 µg/kg fresh weight). The lowest cadmium level was found in winter (mean = 77.34 and median = 38.64 µg/kg fresh weight). There was significant difference in cadmium content between the rainy season and winter. However, there were no significant differences between the rainy season and summer, and between winter and summer.

In province C, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The highest cadmium level was found in winter (median = 16.82 µg/kg fresh weight). The lowest cadmium level was found in summer (median = 10.51 µg/kg fresh weight). There were significant differences in cadmium content between the rainy season and winter, and between winter and summer ($p<0.05$). However, there was no significant difference between the rainy season and summer.

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Table 28: Cadmium content in conventional Chinese kale from the same farm in different seasons.

Season	n	Province A		n	Province B		n	Province C		n	Total	
		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median		Mean±SD (min-max)	Median
Rainy	10	8.88 ± 2.52^{a} (4.45-12.24)	8.92^{a}	20	144.74 ± 44.14^{a} (60.69-216.02)	128.99^{a}	10	10.40 ± 1.22^{a} (8.32-12.37)	10.74^{a}	40	77.19 ± 75.04^{a} (4.45-216.02)	36.53^{a}
Winter	10	9.76 ± 3.72^{a} (4.81-17.18)	8.83^{a}	20	77.34 ± 61.27^{b} (6.79-184.74)	38.64^{b}	10	16.65 ± 5.98^{b} (8.33-26.44)	16.82^{b}	40	45.27 ± 53.86^{a} (4.81-184.74)	19.63^{a}
Summer	10	16.15 ± 4.59^{b} (6.82-22.34)	16.57^{b}	20	101.99 ± 62.15^{ab} (14.21-247.06)	100.83^{ab}	10	9.79 ± 3.17^{a} (5.57-14.55)	10.51^{a}	40	57.48 ± 62.66^{a} (5.57-247.06)	21.78^{a}
Total	30	11.60±4.86 (4.45-22.34)	10.88	60	108.02±62.20 (6.79-247.06)	116.55	30	12.28±4.96 (5.57-26.44)	10.51	120	59.98±65.25 (4.45-247.06)	20.61

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between seasons in the same farm at the level of $p<0.05$.

The difference of lead and cadmium levels in conventional Chinese kale from the same farm in the different season could be affected by several factors. Some details will be discuss from the application of fertilizers. **Table 29** shows the application of fertilizers in each conventional farm in three seasons.

In province A, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The farmers in this farm used inorganic fertilizer (100 kg/rai) in the rainy season, inorganic fertilizer (66.6 kg/rai) in winter and inorganic fertilizer (100 kg/rai) in summer.

In province B, the farmers in farm 1 used inorganic fertilizer (254.9 kg/rai) and animal bio-extract fertilizer (1 time/crop) in the rainy season, inorganic fertilizer (152 kg/rai) and animal bio-extract fertilizer (1 time/crop) in winter and inorganic fertilizer (224 kg/rai), manure (250 kg/rai) and animal bio-extract fertilizer (1 times/crop) in summer. The farmers in farm 2 used inorganic fertilizer (150 kg/rai) in the rainy season, inorganic fertilizer (150 kg/rai) in winter and inorganic fertilizer (150 kg/rai), manure (250 kg/rai) in summer.

In province C, there was only 1 conventional farm (farm 1) that was able to collect the Chinese kale samples in all seasons. The farmers in this farm used inorganic fertilizer (80 kg/rai) in the rainy season, inorganic fertilizer (20 kg/rai) in winter and inorganic fertilizer (132.2 kg/rai), manure (66.7 kg/rai) in summer.

Table 29: The application of fertilizers used in conventional farms in three seasons.

Season	Province	Inorganic fertilizer (kg/rai)	Manure (kg/rai)	Compost (kg/rai)	Bio-extract fertilizer (time/crop)			
					Plant	Animal	Mixed	Household waste
Rainy	Province A	100	0	0	0	0	0	0
	Province B, Farm1	254.9	0	0	0	1	0	0
	Province B, Farm2	150	0	0	0	0	0	0
	Province C	80	0	0	0	0	0	0
	Average	146.5	0	0	0	0.25	0	0
Winter	Province A	66.6	0	0	0	0	0	0
	Province B, Farm1	152	0	0	0	1	0	0
	Province B, Farm2	150	0	0	0	0	0	0
	Province C	20	0	0	0	0	0	0
	Average	97.2	0	0	0	0.25	0	0
Summer	Province A	100	0	0	0	0	0	0
	Province B, Farm1	224	250	0	0	1	0	0
	Province B, Farm2	150	250	0	0	0	0	0
	Province C	132.2	66.7	0	0	0	0	0
	Average	151.6	141.7	0	0	0.25	0	0

5.5 The comparison of lead and cadmium contents in Chinese kale from each province and the market

5.5.1 Lead content in Chinese kale samples from each province and the market

Table 30 shows lead content in Chinese kale samples from province A, province B, province C, province D and the market in the rainy season. The mean of lead levels in Chinese kale from province A, province B, province C, province D and the market were 8.51, 149.18, 23.04, 23.04 and 1312.73 µg/kg fresh weight, respectively. The median of lead levels in Chinese kales from province A, province B, province C, province D and the market were 7.03, 69.42, 9.68, <LOD and 369.90 µg/kg fresh weight, respectively. The highest median of lead level was found in Chinese kale samples from the market and the lowest median lead level was found in Chinese kale from province D. There were significant differences in lead content of Chinese kale across areas, except between province A and province D, and between province C and province D. In addition, Chinese kale collected from the market contained significantly higher lead content than Chinese kale collected from vegetable farms in each province, except province B. The percentage of samples exceeded Codex Maximum Level of lead in province A, province B, province C, province D and the market were 0%, 30%, 0%, 7% and 50%, respectively.

Table 30: Lead content in Chinese kale samples from each province and the market in the rainy season

Province	**n**	**Lead (μg/kg fresh weight)**		**Exceeding Codex Maximum Level* % (n)**
		Mean±SD	**Median (min-max)**	
Province A	69	8.51±10.99^{a}	7.03 (<LOD-77.19)	0% (0)
Province B	51	149.18±207.11^{b}	69.42 (<LOD-811.95)	30% (6)
Province C	60	23.04±48.91^{c}	9.68 (<LOD-273.47)	0% (0)
Province D	30	23.04±34.25^{ac}	<LOD (<LOD-119.28)	7% (2)
market	10	1312.73±1923.62^{b}	369.90 (<LOD-5649.15)	50% (5)
Total	220	106.35±485.23	9.90 (<LOD-5649.15)	6% (13)

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between areas at the level of $p<0.05$.

* : Codex Maximum Level of lead = 100 μg/kg fresh weight.

5.5.2 Cadmium content in Chinese kale samples from each province and the market.

Table 31 shows cadmium content in Chinese kale samples from province A, province B, province C, province D and the market in the rainy season. The mean of cadmium levels in Chinese kale from province A, province B, province C, province D and the market were 27.47, 285.85, 54.59, 384.72 and 718.58 µg/kg fresh weight, respectively. The median of cadmium levels in Chinese kale from province A, province B, province C, province D and market were 11.03, 144.51, 29.74, 238.13and 571.05 µg/kg fresh weight, respectively. The highest cadmium level was found in Chinese kale samples from the market and the lowest cadmium level was found in Chinese kale samples from province A. There were significant differences in cadmium content across areas, except between province B and province D. In addition, Chinese kale collected from the market contained significantly higher cadmium content than Chinese kale collected from vegetable farms in each province. The percentage of samples exceeded Codex Draft Maximum Level of cadmium in province A, province B, province C, province D and the market were 0%, 20%, 0%, 60% and 100%, respectively.

Table 31: Cadmium content in Chinese kale samples from each province and the market in the rainy season

Province	n	Cadmium (μg/kg fresh weight)		Exceeding Codex Draft Maximum Level % (n)
		Mean±SD	Median (min-max)	
Province A	69	27.47±50.29^{a}	11.03 (<LOD-334.03)	0% (0)
Province B	51	285.85±517.69^{b}	144.51 (41-3525.41)	20% (4)
Province C	60	54.59±64.25^{c}	29.74 (3.72-254.73)	0% (0)
Province D	30	384.72±181.67^{b}	238.13 (64.71-896.05)	60% (18)
market	10	718.58±519.38^{d}	571.05 (259.40-2075.52)	100% (10)
Total	220	174.90±345.93	59.82 (<LOD-3525.41)	15% (32)

n = The number of samples

a, b, c: Different superscripts within the same column indicate significant difference between areas at the level of $p<0.05$.

* : Codex Draft Maximum Level of cadmium = 200 μg/kg fresh weight.

5.6 The intake of lead and cadmium from the consumption of Chinese kale

5.6.1 The intake of lead and cadmium from the consumption of Chinese kale by normal Thai population

Table 32 shows lead intake from the consumption of three different types of Chinese kales from province A, province B, province C, province D and the market by normal Thai population in the rainy season. Both mean concentration of lead and 95 percentile concentration of lead were demonstrated. Comparison with PTWI, none of lead intake value exceeded the PTWI in this group of people. The maximum lead intake was only 2.979% of PTWI. This is provided that the consumption of Chinese kale in the mean consumption (1.13 g/person/day) does not pose a risk of lead exposure to public health.

Table 33 shows cadmium intake from the consumption of three different types of Chinese kales from province A, province B, province C, province D and the market by normal Thai population in the rainy season. Both mean concentration of cadmium and 95 percentile concentration of cadmium were demonstrated. Similar to lead intake, none of cadmium intake value exceeded the PTWI. The maximum cadmium intake was only 3.909% of PTWI. This is provided that the consumption of Chinese kale in the mean consumption (1.13 g/person/day) does not pose a risk of cadmium exposure to public health.

Table 32: Lead intake from the consumption of Chinese kale in each province by normal Thai population

Practice	Area	Mean of lead content (µg/kg fresh wt.)	lead intake (µg/kg bw/week)	Percent of PTWI* (%)	95 percentile of lead content (µg/kg fresh wt.)	lead intake (µg/kg bw/week)	Percent of PTWI* (%)
Organic	Province A	10.700	0.001	0.006	52.030	0.007	0.027
	Province B	477.390	0.063	0.252	811.950	0.107	0.428
	Province C	4.590	0.001	0.002	8.760	0.001	0.005
	Province D	23.040	0.003	0.012	112.900	0.015	0.060
	Total	78.740	0.010	0.042	637.450	0.084	0.336
Hygienic	Province A	6.980	0.001	0.004	24.800	0.003	0.013
	Province B	51.230	0.007	0.027	138.410	0.018	0.073
	Province C	38.330	0.005	0.020	252.300	0.033	0.133
	Total	33.060	0.004	0.017	141.900	0.019	0.075
Conventional	Province A	6.870	0.001	0.004	16.080	0.002	0.008
	Province B	66.620	0.009	0.035	170.200	0.022	0.090
	Province C	9.340	0.001	0.005	26.210	0.003	0.014
	Total	27.610	0.004	0.015	130.110	0.017	0.069
NC	market	1312.730	0.173	0.692	5649.150	0.745	2.979

Note: Chinese kale consumption of normal Thai people is 1.13 g./person/day

*: PTWI (Provisional Tolerable Weekly Intake) of lead = 25 µg/kg bw/week.

NC: Not classified

Table 33: Cadmium intake from the consumption of Chinese kale in each province by normal Thai population

Practice	Area	Mean of cadmium content (µg/kg fresh wt.)	Cadmium intake (µg/kg bw/week)	Percent of PTWI* (%)	95 percentile of cadmium content (µg/kg fresh wt.)	Cadmium intake (µg/kg bw/week)	Percent of PTWI* (%)
Organic	Province A	22.960	0.003	0.043	174.200	0.023	0.328
	Province B	800.390	0.106	1.507	3525.410	0.465	6.640
	Province C	20.060	0.003	0.038	29.310	0.004	0.055
	Province D	384.720	0.051	0.725	883.430	0.116	1.664
	Total	265.160	0.035	0.499	871.940	0.115	1.642
Hygienic	Province A	50.100	0.007	0.094	319.480	0.042	0.602
	Province B	143.970	0.019	0.271	290.470	0.038	0.547
	Province C	83.480	0.011	0.157	251.060	0.033	0.473
	Total	91.220	0.012	0.172	256.720	0.034	0.483
Conventional	Province A	11.380	0.002	0.021	19.830	0.003	0.037
	Province B	144.740	0.019	0.273	215.950	0.028	0.407
	Province C	28.530	0.004	0.054	65.440	0.009	0.123
	Total	61.550	0.008	0.116	209.610	0.028	0.395
NC	market	718.580	0.095	1.353	2075.520	0.274	3.909

Note: Chinese kale consumption of normal Thai people is 1.13 g./person/day

* : PTWI (Provisional Tolerable Weekly Intake) of cadmium = 7 µg/kg bw/week.

NC : Not classified

5.6.2 The intake of lead and cadmium from the consumption of Chinese kale by Thai vegetarians

Table 34 shows lead intake from the consumption of three different types of Chinese kales from province A, province B, province C, province D and the market by Thai vegetarians in the rainy season. Both mean concentration of lead and 95 percentile concentration of lead were demonstrated. One value of lead intake in this population exceeded the PTWI. It was lead intake value estimated from the 95 percentile lead concentration in market Chinese kale, the value was 212.59% of PTWI. This is provided that the consumption of Chinese kale from this market pose a risk of lead exposure to vegetarian who consume large amount of Chinese kale (80.64 g/person/day). A risk will occur when consume market Chinese kale containing lead concentration at 95 percentile.

Table 35 shows cadmium intake from the consumption of three different types of Chinese kales from province A, province B, province C, province D and the market by Thai vegetarians in the rainy season. Both mean concentration of cadmium and 95 percentile concentration of cadmium were demonstrated. The cadmium intake values calculated from the mean cadmium concentration and 95 percentile cadmium concentration from the organic Chinese kale in province B exceeding the PTWI in this population (107.57% and 473.82%, respectively). In addition, the cadmium intake value calculated from the 95 percentile cadmium concentration in Chinese kale from the market also exceeded the PTWI (278.95%). This is provided that the consumption of Chinese kale from the organic farms in province B and the market pose a risk of cadmium exposure to vegetarians.

Table 34: Lead intake from the consumption of Chinese kale in each province by Thai vegetarian

Practice	Area	Mean of lead content (µg/kg fresh wt.)	lead intake (µg/kg bw/week)	Percent of PTWI* (%)	95 percentile of lead content (µg/kg fresh wt.)	lead intake (µg/kg bw/week)	Percent of PTWI* (%)
Organic	Province A	10.700	0.101	0.403	52.030	0.489	1.958
	Province B	477.390	4.491	17.965	811.950	7.639	30.555
	Province C	4.590	0.043	0.173	8.760	0.082	0.330
	Province D	23.040	0.217	0.867	112.900	1.062	4.249
	Total	78.740	0.741	2.963	637.450	5.997	23.989
Hygienic	Province A	6.980	0.066	0.263	24.800	0.233	0.933
	Province B	51.230	0.482	1.928	138.410	1.302	5.209
	Province C	38.330	0.361	1.442	252.300	2.374	9.495
	Total	33.060	0.311	1.244	141.900	1.335	5.340
Conventional	Province A	6.870	0.065	0.259	16.080	0.151	0.605
	Province B	66.620	0.627	2.507	170.200	1.601	6.405
	Province C	9.340	0.088	0.351	26.210	0.247	0.986
	Total	27.610	0.260	1.039	130.110	1.224	4.896
NC	market	1312.730	12.350	49.401	5649.150	53.147	212.589

Note: Chinese kale consumption of Thai vegetarians is 80.64 g/person/day

* : PTWI (Provisional Tolerable Weekly Intake) of lead = 25 µg/kg bw/week.

NC : Not classified

Table 35 : Cadmium intake from the consumption of Chinese kale in each province by Thai vegetarian

Practice	Area	Mean of cadmium content (µg/kg fresh wt.)	Cadmium intake (µg/kg bw/week)	Percent of PTWI* (%)	95 percentile of cadmium content (µg/kg fresh wt.)	Cadmium intake (µg/kg bw/week)	Percent of PTWI* (%)
Organic	Province A	22.960	0.216	3.086	174.200	1.639	23.412
	Province B	800.390	7.530	107.572	3525.410	33.167	473.815
	Province C	20.060	0.189	2.696	29.310	0.276	3.939
	Province D	384.720	3.619	51.706	883.430	8.311	118.733
	Total	265.160	2.495	35.638	871.940	8.203	117.189
Hygienic	Province A	50.100	0.471	6.733	319.480	3.006	42.938
	Province B	143.970	1.354	19.350	290.470	2.733	39.039
	Province C	83.480	0.785	11.220	251.060	2.362	33.742
	Total	91.220	0.858	12.260	256.720	2.415	34.503
Conventional	Province A	11.380	0.107	1.529	19.830	0.187	2.665
	Province B	144.740	1.362	19.453	215.950	2.032	29.024
	Province C	28.530	0.268	3.834	65.440	0.616	8.795
	Total	61.550	0.579	8.272	209.610	1.972	28.172
NC	market	718.580	6.760	96.577	2075.520	19.526	278.950

Note: Chinese kale consumption of Thai vegetarian is 80.64 g./person/day

* : PTWI (Provisional Tolerable Weekly Intake) of cadmium = 7 µg/kg bw/week.

NC : Not classified

CHAPTER 6

DISCUSSION

Chinese kale is one of leafy vegetables that is commonly grown in Thailand (as shown in **Table 36**). To investigate the factors that affect lead and cadmium accumulation in Chinese kale, three different types of Chinese kale samples were collected from a number of the farms in various locations and the same location during different seasons. In this study, Chinese kale samples were also collected from the market so as to compare the levels of lead and cadmium between Chinese kales from two different places; the farm and the market.

Table 36: The agricultural record of some leafy vegetables in Thailand (cultivation year 2002-2003)

Type	Cultivation area	Agricultural product/Cultivation area (kg/rai)	Total agricultural product (tons)
Chinese kale	110,978	1,668.91	185,212
Chinese cabbage	48,765	2,801.19	136,600
Gwarng-toong	80,766	1,510.95	122,033
Convovulus	89,772	1,062.89	95,417
Lettuce	21,418	1,395.90	29,897

Source: Modified from the Department of Agricultural Extension, the Ministry of Agriculture and Cooperatives.

6.1. Lead and cadmium contents in Chinese kale from three different agricultural practices

6.1.1. Lead and cadmium contents in all Chinese kale samples from three different agricultural practices

This study shows that the mean and median levels of lead and cadmium in organic, hygienic and conventional Chinese kales were lower the Codex Maximum Levels, except the mean cadmium level of organic Chinese kale. However, 9.4% of organic Chinese kale, 11.3% of hygienic Chinese kale and 5.7% of conventional Chinese kale contained lead content exceeded the Codex Maximum Level. Whereas, none of the Chinese kale samples exceeded the Maximum Level of lead as permitted by Thai Ministry of Public Health (48). In addition, the percentage of organic and conventional Chinese kale samples exceeded Codex Draft Maximum Level of cadmium were 26.7%, 19.3% and 4.3%, respectively. In Thailand, the Maximum Levels of cadmium in food has not been set. This suggest that lead and cadmium concentrations in Chinese kale from some vegetable farms may pose a risk to public health.

According to the research result, hygienic Chinese kale contained the median of lead and cadmium levels significantly higher than organic and conventional Chinese kales. However there were no significant differences in lead and cadmium contents between organic and conventional Chinese kales ($p<0.05$). According to the interview, there was an extensive use of pesticides in the conventional farms and moderate use of pesticides in hygienic farms, whereas none were found in the organic farms. Thus, the conventional Chinese kale should contain pesticide residues more than the organic Chinese kale. It is questionable that the pesticides used in hygienic and conventional farms may contain low level of lead and cadmium. Therefore, the different of pesticides application between the conventional and organic farms may not mainly effect the accumulation of lead and cadmium in the vegetables.

There are a number of factors that has an effect on lead and cadmium accumulation as aforementioned in Chapter 3 (Literature Reviews). Besides the pesticide usage, the history, the environment around the farms and the application of fertilizers are discussed.

6.1.2. Lead and cadmium contents in the Chinese kale samples from three different agricultural practices in the same location (Table 10, 11)

The Chinese kale samples from three different agricultural practices will be investigated in order to identify the factor that lead to lead and cadmium accumulation in Chinese kale.

In province A, there were insignificant differences in lead levels of Chinese kale between three different types of agricultural practices but there were significant differences in cadmium content of the Chinese kale across different agricultural practices. The environment around the farms is quite similar because all farms are located in the same area. Consequently, it is possible that different practices between chemical and non-chemical agricultures may provide low cadmium content in organic Chinese kale. Although hygienic farm used lower amount of chemical agricultural substance, hygienic Chinese kale contained cadmium significantly higher than conventional Chinese kale samples. It may be due to the use of golden apple snail that may contain high cadmium as raw material of bio-extract fertilizer in hygienic farm.

In province B, there were significant differences in lead and cadmium levels of Chinese kale between three different types of agricultural practices. All farms are located in the same area, therefore the environment around the farms are quite similar. However, the organic Chinese kale samples contained lead and cadmium significant higher than the hygienic and the conventional Chinese kale samples. It is possible that the raw material of bio-extract fertilizer used in organic farms such as food scraps and household waste may contain high levels of lead and cadmium.

This suggests that different agricultural practices may affect on lead and cadmium levels in Chinese kale, due perhaps to different fertility practices. Chinese kale grown using bio-extract fertilizer that made from raw materials containing high lead and cadmium contamination may provide high lead and cadmium concentrations.

6.2 Lead and cadmium contents in organic Chinese kale from different locations

6.2.1 Lead content in organic Chinese kale from province A, province B, province C and province D

The study found the significant differences in lead concentration from the organic Chinese kale collected in the same season from different locations. **Figure 1** shows lead content in the organic Chinese kale samples from province A, province B, province C and province D in the rainy season.

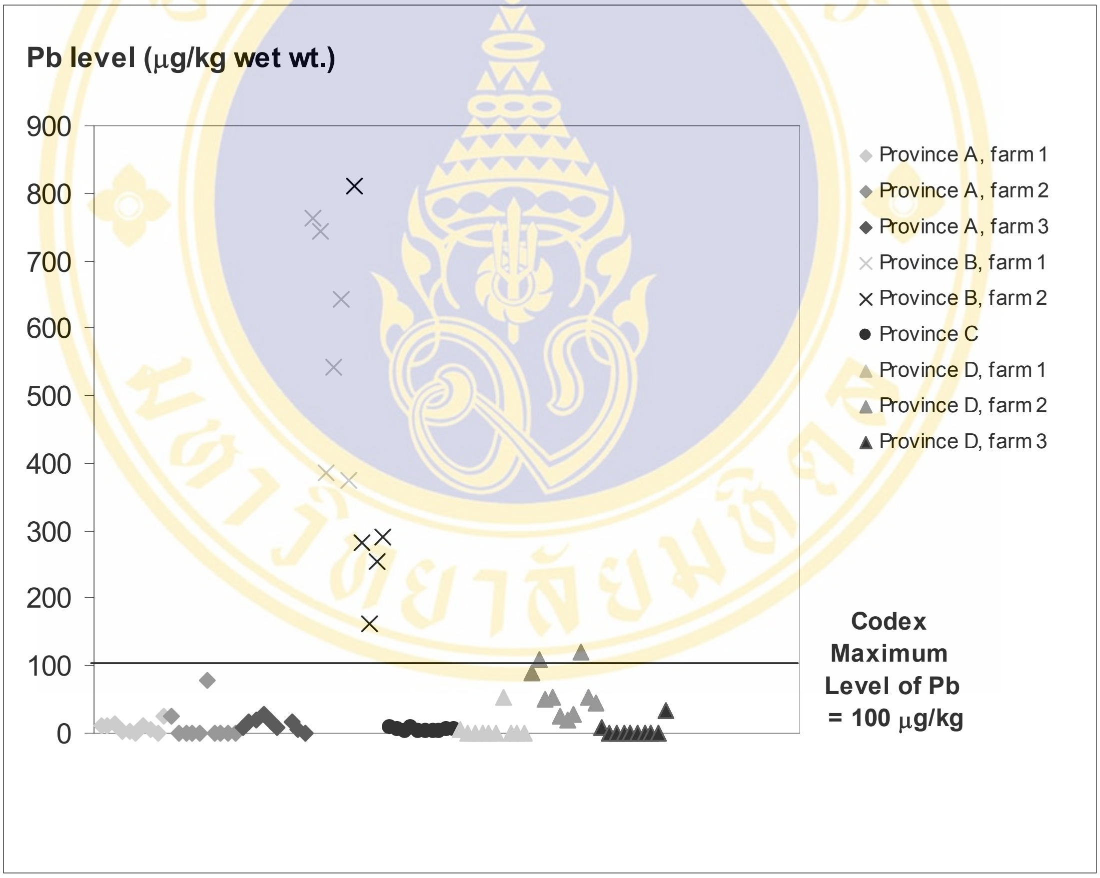

Figure 1: The levels of lead concentration in the organic Chinese kale samples from province A, province B, province C and province D in the rainy season.

Figure 1 shows all that organic Chinese kale samples from province A and province C contained low level of lead concentration (lower the Codex Maximum level). It may be due to the suitable environment around the farms. All farms in province A are far from the road, the factories and the domestic animals. Although the organic farm in province C is near the road, the factory and the domestic animals, the factory near the farm is the animal feeding factory, not the industrial factory. Whereas, all organic Chinese kale samples from province B contained high level of lead concentration (exceeding the Maximum Level of lead). It may be due to the unsuitable environment around the farms. All organic farms in this province are near the road and the factories (farm 1 is near the lead melting factory and farm 2 is near the garage).

This suggests that the environment around the farm may be a major impact on lead concentration in organic Chinese kale. In addition, the level of lead in the organic Chinese kale samples from one farm in province D were relatively high whereas the lead content in the Chinese kale samples from the other organic farms in the same province were low. The environment around the farms is quite similar, as a consequence, there should be other factors that affect lead accumulation in the Chinese kales from this farm. It is possible that the fertilizers used in this farm may be contaminated with lead.

6.2.2 Cadmium Content in the organic Chinese kale from province A, province B, province C and province D

There were significant differences in cadmium concentration in the organic Chinese kale collected in the same season from different locations. **Figure 2** shows cadmium content in the organic Chinese kale samples from province A, province B, province C and province D in the rainy season.

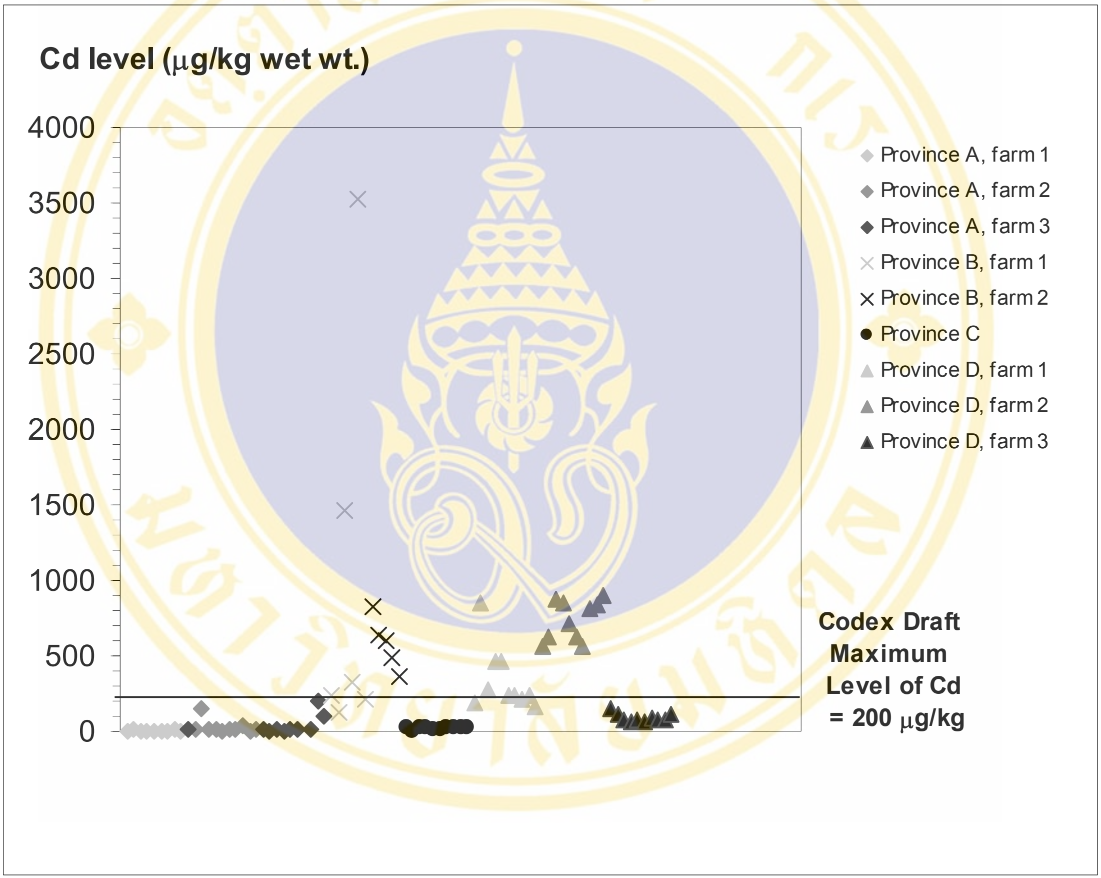

Figure 2: The levels of cadmium concentration in the organic Chinese kale samples from province A, province B, province C and province D in the rainy season.

The study of cadmium accumulation in Chinese kale from different locations has shown the compatible outcomes to the lead accumulation study. **Figure 2** shows that the level of cadmium found in Chinese kale from province A and province C contained low level of cadmium, whereas most organic Chinese kale samples from province B contained relatively high level of cadmium.

This also suggests that the environment around the farm may be a major impact on cadmium contamination in organic Chinese kale. In province B, the median cadmium level in farm 1 was higher than farm 2. It may be due to different types of industries around the farms. In addition, another factor such as fertility practices may also affect on cadmium content in organic Chinese kale. According to the interview, the fertilizers used in farm 1 were manure and bio-extract fertilizers, made from food scraps and household waste, whereas the fertilizers used in farm 2 were manure, compost and bio-extract made from radish and fish.

In province D, the level of cadmium in the organic Chinese kale samples from farm 1 and farm 2 were relatively high, compared with the Chinese kale samples from farm 3. According to the interview, the fertilizers used in farm 1 were manure, compost and bio-extract fertilizer made from food scrap and household waste. However, farm 2 used only bio-extract fertilizer made from food scrap and household waste whereas, farm 3 used both compost and bio-extract fertilizer made from plant. It is assumed that the use of bio-extract fertilizers made from food scraps and household waste or animals may cause lead and cadmium accumulation in crops, aside from the environment around the farms.

In addition, the study of lead and cadmium content in the rainwater of province B during the same year showed that there was high levels of lead and cadmium in rainwater collected from the area that organic farms are located. Thus, high lead and cadmium levels in rainwater from province B may be another factor that provide higher lead and cadmium levels in organic Chinese kale grown in this province. This study found that 100% of organic Chinese kale from province B grown during the rainy season contained lead levels higher than the Codex Maximum Level.

However, this study indicates that most organic Chinese kale contained lead and cadmium levels lower than the Codex Maximum Levels of lead and cadmium in vegetable. According to the analysis and the interview, the organic Chinese kale samples from the organic farms that were certified by the highly recognized organization and not located in the polluted area contained low levels of lead and cadmium.

6.3 Lead and cadmium contents in hygienic Chinese kale from different locations

6.3.1 Lead content in hygienic Chinese kale from province A, province B and province C

The lowest level of lead concentration found in the hygienic Chinese kale from province A. There were significant differences in lead content of hygienic Chinese kale between province A and province B, between province A and province C ($p<0.05$). However, there was insignificant difference between province B and province C. **Figure 3** shows lead content in hygienic Chinese kale samples from province A, province B and province C in the rainy season.

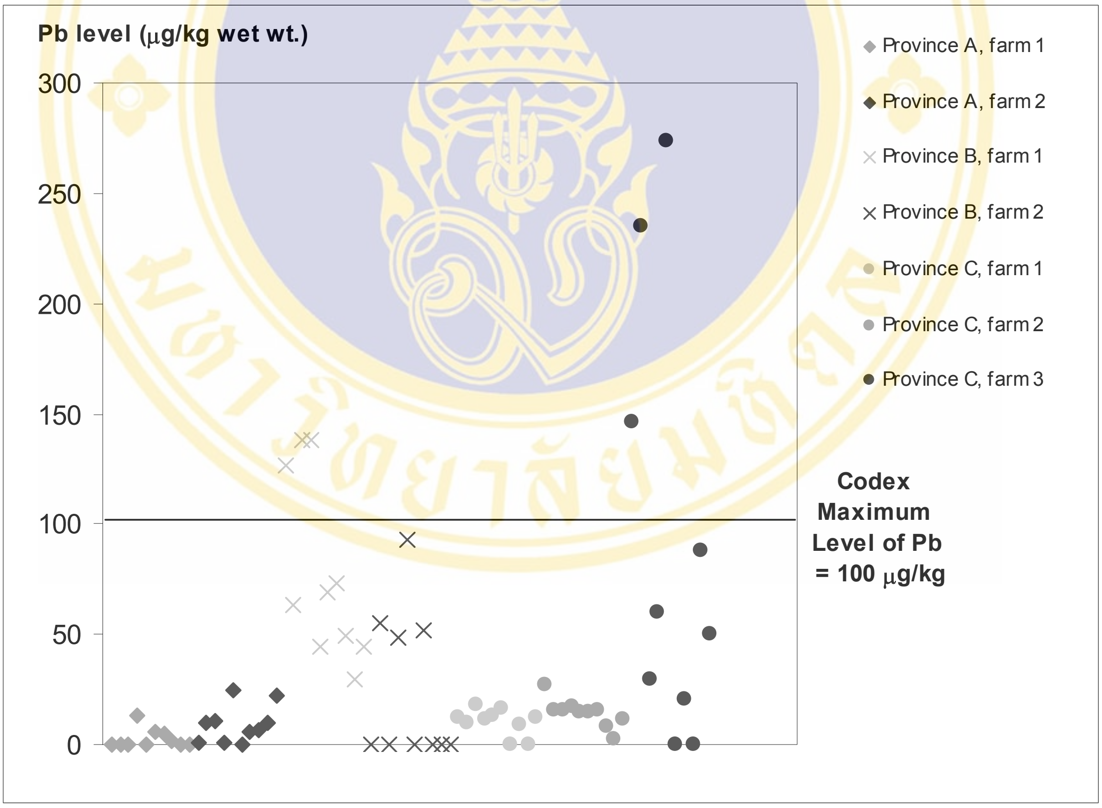

Figure 3: The levels of lead concentration in hygienic Chinese kale samples from province A, province B and province C during the rainy season.

Figure 3 shows that all hygienic Chinese kale samples from province A contained low lead levels. According to the interview, both hygienic farms in province A are distant from the road, the factory and the domestic animals. Thus, suitable environment around the farms may provide lower lead level in hygienic Chinese kale grown in this area. Whereas, hygienic Chinese kale samples from province B contained high lead levels. 15% of Chinese kale samples collected in this area contained lead over the Maximum Level of lead. According to the interview, both hygienic farms in province B had the history of chemicals usage in their farms and they are close to the factory (lead melting factory). It is possible that unsuitable environment around the farms, especially lead melting factory, may lead to high contamination of lead in these hygienic farms.

In province C, the hygienic Chinese kale from farm 1 and farm 2 contained low lead levels, whereas the hygienic Chinese kale from farm 3 contained higher lead level. According to the interview, all hygienic farms in province C are close to the domestic animals and the conventional farms, even though they are distant from the factory. However, farm 3 in province C was once the old mine.

This suggests that besides the environment around the farm, the history of the farm may be the important factor that may affect lead and cadmium accumulation in crops. Many studies in Thailand (49, 50) found that the waste products from the mine caused lead and cadmium contamination in the environment which led to high levels of lead in the animals and crops, and also high level of cadmium in the rice that grown in the contaminative area. Therefore, farming in the old mine may experience high levels of lead and cadmium in crops.

6.3.2 Cadmium content in hygienic Chinese kale from province A, province B and province C

The lowest level of cadmium concentration also found in the hygienic Chinese kale from province A. There were significant differences in cadmium concentration of hygienic Chinese kale between province A and province B, between province B and province C ($p<0.05$). However there was insignificant difference between province A and province C. **Figure 4** shows cadmium content in hygienic Chinese kale samples from province A, province B and province C in the rainy season.

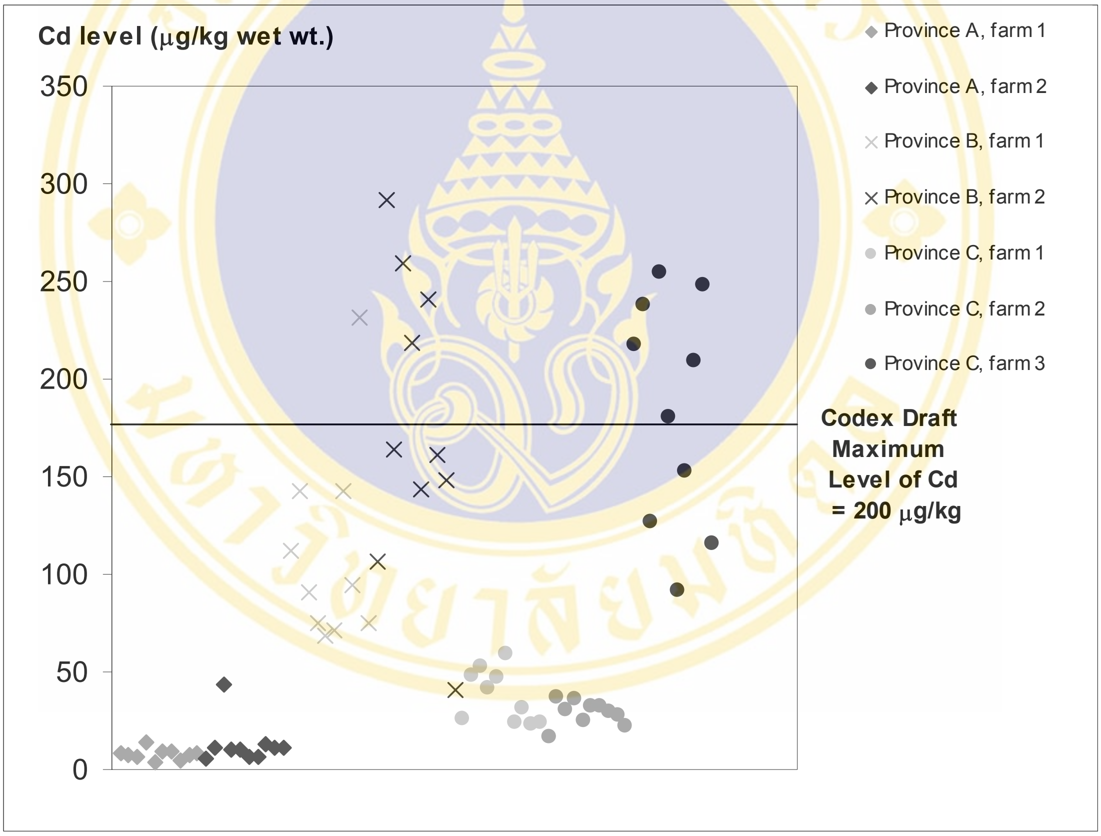

Figure 4: The levels of cadmium concentration in hygienic Chinese kale samples from province A, province B and province C during the rainy season.

Similar to lead, suitable environment around the farms provides low cadmium levels in Chinese kale collected from province A, whereas unsuitable environment around the farms provides high cadmium levels in Chinese kale collected from province B.

In province C, both hygienic Chinese kale samples from farm 1 and farm 2 contained low cadmium level, whereas the samples from farm 3 contained high cadmium level. According to the interview, all farms in this province located in suitable area. But farm 3 in province C was once the old mine. In addition it found that the applications of fertilizers in the farms are relatively similar. Thus the history of the farm (old mine) may be the important factor that impact that impact on cadmium contamination in vegetables.

Previous study in Thailand (50) found that the waste products from the mine caused cadmium contamination in the environment which led to high levels of cadmium in the crops.

6.4 Lead and cadmium contents in conventional Chinese kale from different locations

6.4.1 Lead content in conventional Chinese kale from province A, province B and province C

The lowest level of lead concentration found in the conventional Chinese kale from province A. There were significant differences in lead concentration in conventional Chinese kale between province A and province B, between province B and province C ($p<0.05$). However there was insignificant difference between province A and province C. **Figure 5** shows lead content in conventional Chinese kale samples from province A, province B and province C in the rainy season.

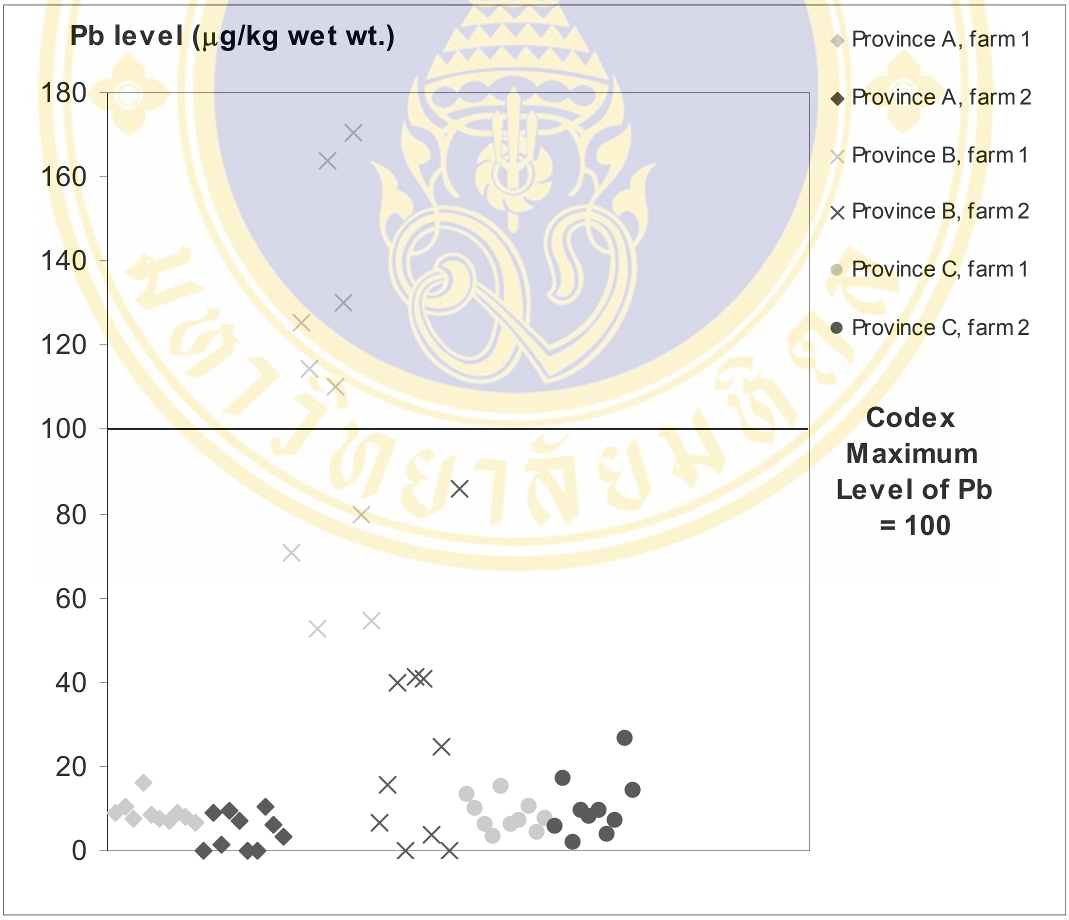

Figure 5: The levels of lead concentration in conventional Chinese kale samples from province A, province B and province C during the rainy season.

According to **Figure 5**, all conventional Chinese kale samples from province A and province C contained low lead levels. From the interview with the farmers, all conventional farms in province A and province C are distant from factory. Whereas, conventional Chinese kale from province B contained higher lead levels than province A and province C. 30% of samples from province B contained lead above the Codex Maximum Level. According to the interview, all conventional farms in province C are close to the factory (lead melting factory). It may be concluded that the environment around the farm is the major factor that caused lead accumulation in crops, especially industrial factories around the cultivation area.

This study found that organic, hygienic and conventional Chinese kales grown in the area near the industrial factories contained higher lead concentration than the other areas that far from the industrial factories. Similar to the study of Napawas B (52) found that lead contamination in some plants grown near industrial area in 3 districts from Samut Prakarn province. The results showed lead content in the plants from industrial area was significantly higher than the plants from agricultural area.

6.4.2 Cadmium content in conventional Chinese kale from province A, province B and province C

The lowest level of cadmium concentration found in the conventional Chinese kale from province A. The highest level of cadmium concentration also found in the conventional Chinese kale from province B. There were significant differences in cadmium concentration in conventional Chinese kale between each location ($p<0.05$). **Figure 6** shows cadmium content in conventional Chinese kale samples from province A, province B and province C in the rainy season.

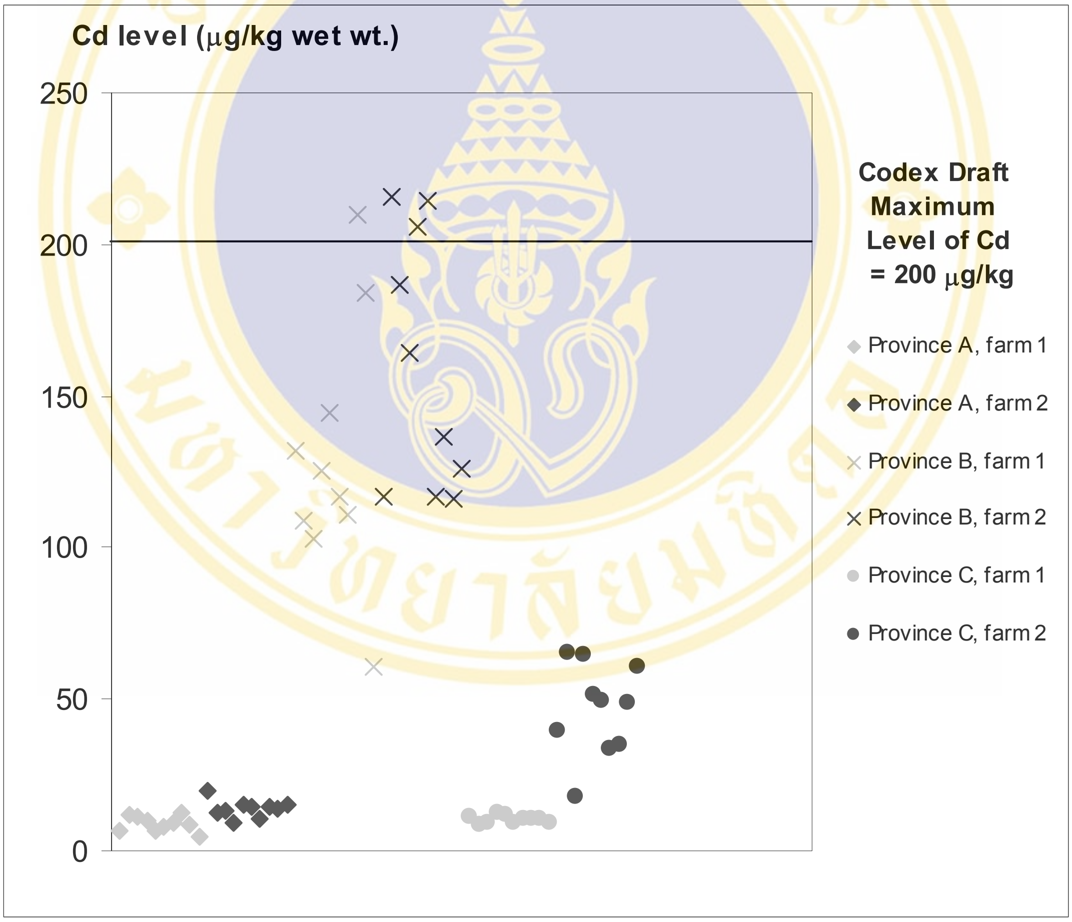

Figure 6: The levels of cadmium concentration in conventional Chinese kale samples from province A, province B and province C during the rainy season.

Figure 6 shows that all conventional Chinese kale samples from province A contained low level of cadmium concentration. It may be due to the suitable environment around the farms and the application of non-contaminated fertilizer. According to the interview with the farmers, only inorganic fertilizers were used in the farms in province A.

In province B, the conventional Chinese kale contained high cadmium level. It may be due to the unsuitable environment around the farms. Whereas, the application of fertilizers in the farms may be non-contaminated with cadmium. The fertilizers used in farm 1 were the inorganic fertilizers and the bio-extract, which were made from fish (only 1 time/crop). The fertilizers used in farm 2 were the inorganic fertilizers.

In province C, the conventional Chinese kale samples from this province contained low cadmium level. However the conventional Chinese kale from farm 2 contained cadmium significantly higher than the samples from farm 1. According to the interview, the fertilizers used in farm 1 were the inorganic fertilizers, whereas the fertilizers used in farm 2 were both inorganic fertilizer and manure. It may be concluded that the application of cadmium contaminated fertilizer in the farm is the factor that caused cadmium contamination in crops.

According to the study, the highest lead and cadmium levels were found in the Chinese kale samples from province B. The information gathered from the farmers indicates that all farms in province B are located in the industrial areas. Which is confirmed by the data from the department of industrial works, Ministry of Industry.

Table 37: The number of factory database in province A, province B, province C and province D grouped by type of industry. (51)

Province	Type 1*	Type2*	Type 3*	Total
Province A	158	195	673	1026
Province B	64	261	2390	2715
Province C	124	264	1317	1705
Province D	4906	356	1557	6819

* Type of the industry:

Type 1 = Power of the machine ≤20 horse power, not bleaching, not dipping or pumping or melting any metals.

Type 2 = Power of the machine ≤50 horse power, not bleaching, not dipping or pumping or melting any metals.

Type 3 = Power of the machine >50 horse power, able to bleach or dip or pump or melt any metals.

In addition, the significant high level of cadmium in organic Chinese kale from farm 1 in province B and farm 1 and farm 2 from province D may come from the usage of bio-extract fertilizer made of food scraps and household waste. It is possible that raw materials from food scraps and household waste may contaminated with lead or cadmium. However there is no scientific evidence to back up the presumption yet.

Table 38 shows the comparison of lead and cadmium levels (μg/kg fresh wt.) in Chinese kale from this study with the levels of lead and cadmium in the plants found in other studies (53, 54, 56, 57). The other studies reported the high level of lead in plant while lead levels in most Chinese kale samples from the farms in this study were relatively low. Exception, the Chinese kale samples from province B. It may be due to the Chinese kale samples in this study were collected from farms that located in the agricultural area. Whereas, the samples from other studies were collected from the polluted areas. In addition, it is believed that the policy to eliminate the use of lead in fuel launched by the Thai government in 1996 significantly leads to the reduction of lead in plants. The levels of cadmium in some organic Chinese kale samples from this study were higher than the cadmium level from the other studies. It may be due to the application of cadmium contaminated fertilizer in some farms. However there is little evidence in Thailand that study about cadmium contamination in vegetables.

Table 38: The comparison of lead and cadmium levels (µg/kg fresh wt.) in Chinese kale from this study with the levels of lead and cadmium in the plants found in other studies

The study of	**Sampling location**	**Type of vegetables**	**Pb level** (dry weight)	**Pb level** (fresh weight)	**Cd level** (dry weight)	**Cd level** (fresh weight)
Theerawut P; 1979 (53)	markets	Leafy vegetables	2.32-8.15	-	-	-
Nuanchawee Y.et al; 1979 (54)	20 m. from Asoke-Dindaeng road	Chinese kales Spinach	16.7 22.2	-	-	-
Worrawit P;1979 (55)	Any provinces of Thailand	Chinese kale (leaf) Chinese kale (stem)	14.8 25.6	- -	0.45 0.95	- -
Thaweesak B.et al; 1988 (56)	Any provinces of Thailand	Chinese kales; mean (min-max)	-	1.18 (0.35-1.58)	-	0.25 (0.21-0.52)
This study (2004)	4 provinces of Thailand	Organic Chinese kales	0.43 (<LOD- 9.23)	0.042 (<LOD-0.81)	4.63 (<LOD-58.89)	0.43 (<LOD-6.03)
	3 provinces of Thailand	Hygienic Chinese kales	0.45 (<LOD-4.06)	0.044 (<LOD-0.45)	1.27 (0.04-6.09)	0.11 ($3.4x10^{-4}$-0.90)
	3 provinces of Thailand	Conventional Chinese kales	0.26 (<LOD-4.48)	0.021 (<LOD-0.41)	0.73 (0.06-3.28)	0.02 ($4.45x10^{-3}$-0.25)
	Market	Chinese kales	11.09 (<LOD-48.70)	1.31 (<LOD-5.65)	6.66 (2.95-17.89)	0.72 (0.26-2.08)

6.5 Lead and cadmium contents in Chinese kale from different seasons

6.5.1 Lead content in Chinese kale from different seasons

In this study, Chinese kale samples were collected from the same farm in various seasons. **Table 39** shows the levels of lead concentration from the same farm in the rainy season, winter and summer. From the result, the highest level of lead in Chinese kales from all agricultural practice were found in the rainy season and the lowest levels of lead in Chinese kales from all agricultural practice were found in winter. There were significant differences in lead levels in Chinese kale from different seasons.

Thus, the seasonal factors may also be have a major impact on lead accumulation in Chinese kale. Theoretical considerations, the atmosphere is an important transport medium for metals from various sources. Leafy crops are most susceptible to contamination from atmospheric deposition of industrial lead (57). Since in the rainy season, air-borne lead particles can wash-out on to the crops, soil, rivers, lakes and the sea. In addition, as the temperature increases, the reaction rates and metabolic activity increase proportionately. Cellular damage at high temperatures may also result from the formation of toxic substances in certain cells exposed to a high localized temperature. The toxic material may subsequently be translocated to other parts of the plant and cause widespread injury (58).

Table 39: Lead content in Chinese kale from the same farm in various seasons

Season	**Practice**					
	Organic		**Hygienic**		**Conventional**	
	Mean±SD	**Median**	**Mean±SD**	**Median**	**Mean±SD**	**Median**
Rainy	19.33±23.08	8.76^{a}	30.40±33.63	15.15^{a}	37.66±47.88	10.46^{a}
Winter	12.41±33.11	<LOD^{b}	23.23±40.53	5.09^{a}	2.34±7.96	<LOD^{b}
Summer	11.33±29.71	3.93^{c}	83.42±139.32	10.91^{a}	30.49±77.70	8.19^{c}
Total	14.32±30.39	2.23	45.68±90.09	8.82	23.50±54.63	6.61

a, b, c: Different superscripts within the same column indicate significant difference between the seasons at the level of $p<0.05$.

6.5.2 Cadmium content in Chinese kales from different seasons

Table 40 shows cadmium content in Chinese kale from the same farm in the rainy season, winter and summer. From the result, there were no significant differences in cadmium content of Chinese kale between each season, except the organic Chinese kale. The organic Chinese kale grown in summer contained cadmium significantly higher than winter and the rainy season.

From **Table 23, 26, 29** show the application of fertilizers in the same farm in various seasons. The organic farms had the extensive use of organic fertilizers include manure, compost and bio-extract fertilizers in summer. While the farmers in the hygienic and conventional farms commonly used the inorganic fertilizers. There were some farms that had the extensive use of organic fertilizers in summer, especially the bio-extract fertilizer. While, the hygienic and conventional farms used the same application of bio-extract fertilizer in various seasons. Thus, the different application of the fertilizers in farms may be the factor that affected on cadmium accumulation in organic Chinese kale.

However, most Chinese kale grown in different seasons contained similarly cadmium level. Thus, the seasonal factor may not a major impact on cadmium accumulation in plants. Theoretical consideration, some species of plants have an ability to concentrate cadmium at the levels that are sometimes much greater than those in the immediate environment. The ratio of cadmium concentration in plants to that in the corresponding soil has been reported to be as high as 10: 1. Some root crops such as carrots and parsnip, and some leafy crops such as spinach and lettuce, tend to contain more cadmium than other plant foods. This indicates that plants tend to take up cadmium from the soil, unlike lead (57).

Table 40: Cadmium content in Chinese kale from the same farm in various seasons

Season	**Practice**					
	Organic		**Hygienic**		**Conventional**	
	Mean ± SD	**Median**	**Mean ± SD**	**Median**	**Mean ± SD**	**Median**
Rainy	167.58±297.73	13.16^{a}	92.99±72.74	65.51^{a}	77.19±75.04	36.53^{a}
Winter	220.03±434.01	15.07^{a}	101.13±117.70	40.64^{a}	45.27±53.86	19.63^{a}
Summer	902.39±1864.93	18.93^{b}	131.39±182.64	40.72^{a}	57.48±62.66	21.78^{a}
Total	431.76±1164.34	16.84	108.50±132.22	55.44	59.98±65.25	20.61

a, b, c: Different superscripts within the same column indicate significant difference between the seasons at the level of $p<0.05$.

6.6 Lead and cadmium contents in Chinese kale samples from the market

Figure 7, 8 show the levels of lead and cadmium concentrations in ten Chinese kale samples from one market. From the result, the levels of lead and cadmium in the Chinese kale samples were high variation. Half of Chinese kale samples contained lead concentration above the Maximum Level of lead (100 µg/kg fresh weight). All Chinese kale samples contained cadmium concentration above the Proposed Draft Maximum Level of cadmium (200 µg/kg fresh weight). However it is hard to interview the seller about the origin of the samples, including the cultivation areas and the agricultural practices. Since it can not explain the factor affected lead and cadmium accumulations in the Chinese kale samples from the market. It is possible that Chinese kale samples sold in this market come from the different areas and the different agricultural practices. Thus, the samples provided high variation of lead and cadmium levels. Most of samples contaminated with high levels of lead and cadmium. It indicates that these Chinese kales may be cultivated with unsuitable agricultural practice or unsuitable agricultural area.

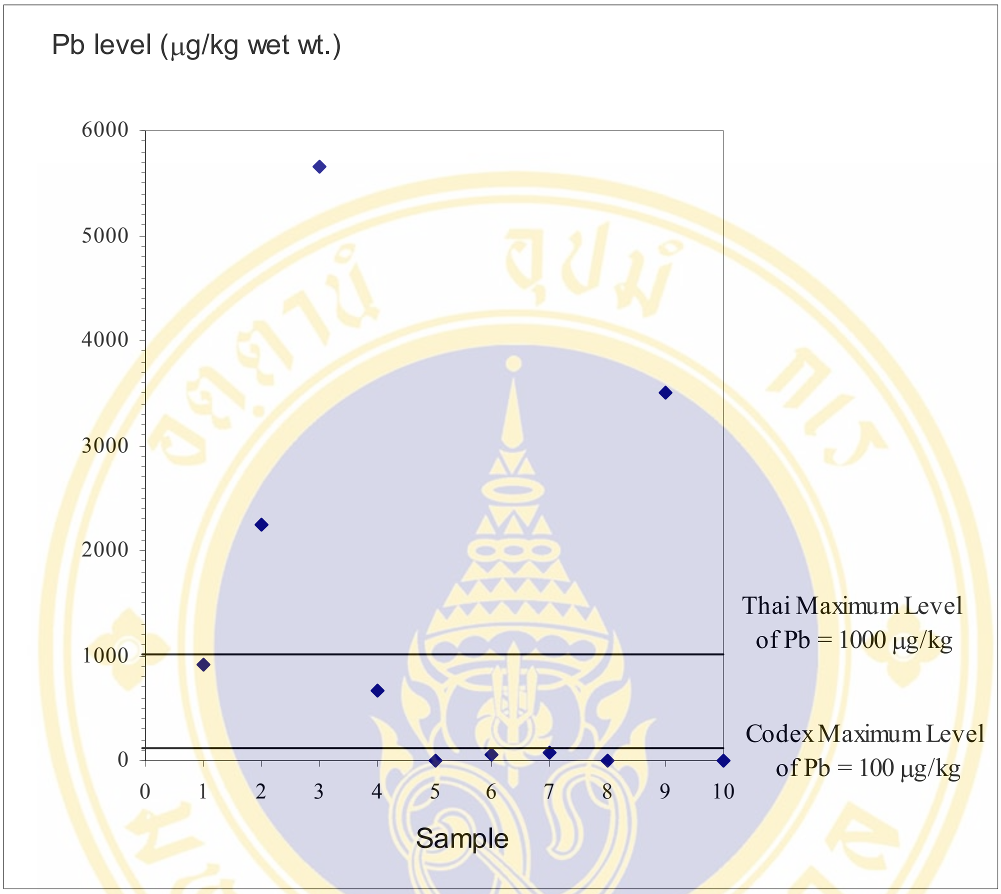

Figure 7: The levels of lead concentration in Chinese kale samples from the market

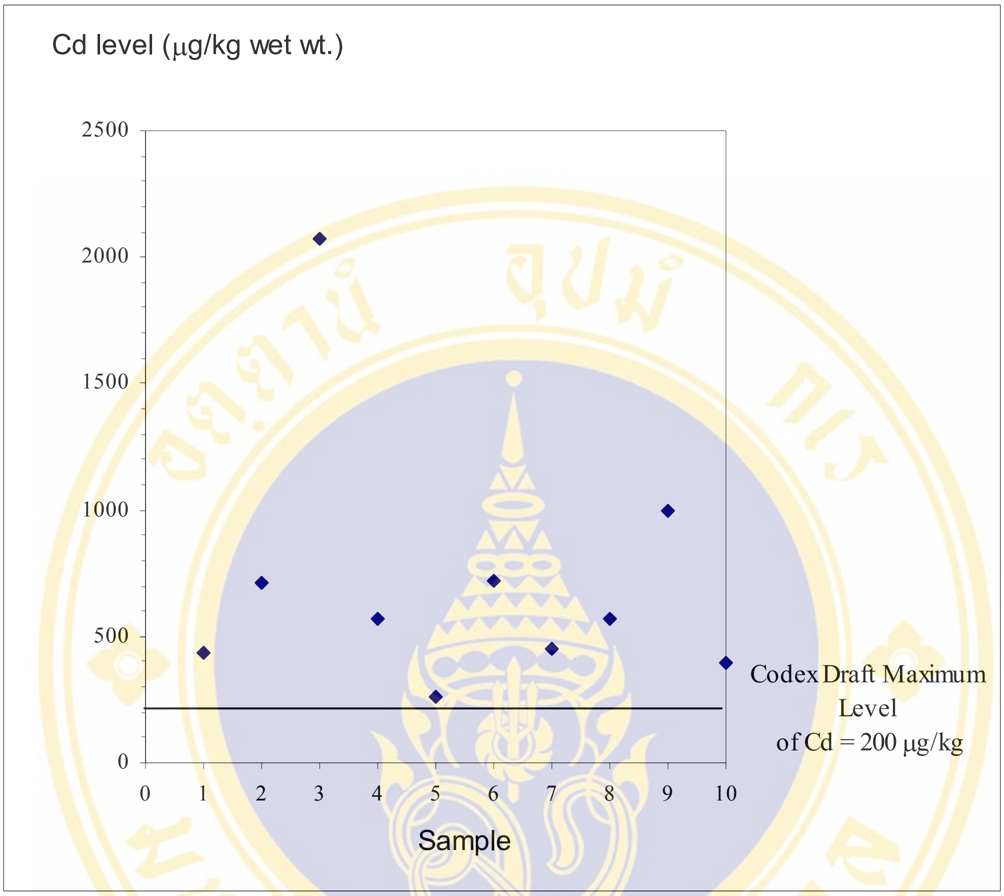

Figure 8: The levels of cadmium concentration in Chinese kale samples from market

6.7 The intake of lead and cadmium from the consumption of Chinese kale

The PTWI for lead and cadmium has been set, by the JECFA, at 25 µg/kg bw/week and 7 µg/kg bw/week, respectively (5). The Chinese kale consumption of Thai population (46) and the vegetarian (47) are 1.13 g/person/day and 80.64 g/person/day. (the average body weight of Thai people = 60 kg). Both of the mean and the 95 percentile of lead and cadmium concentration were calculated.

6.7.1 Lead and cadmium intake from the consumption of Chinese kale by Thai population

In Thai population group, the intake of lead (the mean and the 95 percentile of lead concentrations) from Chinese kale consumption were found to range between 0.001 µg/kg bw/week and 0.745 µg/kg bw/week. The percent PTWI varied between 0.004 and 2.98% **(Table 32).** The intake of cadmium (the mean and the 95 percentile of cadmium concentration) from Chinese kale consumption were found to range between 0.002 and 0.465 µg/kg bw/week. The percent PTWI varied between 0.021 and 6.64 % **(Table 33)**. It indicates that the estimated intake of lead and cadmium from the Chinese kale consumption by Thai population were lower than PTWI. This suggests that lead and cadmium exposure from Chinese kale consumption may not pose a risk to this population.

In the vegetarian group, the intake of lead (the mean and the 95 percentile of lead concentration) from Chinese kale consumption were found to range between 0.043 µg/kg bw/week and 53.147 µg/kg bw/week. The percent PTWI varied between 0.173 and 212.59 % **(Table 34)**. The intake of cadmium (the mean and the 95 percentile of cadmium concentration) from Chinese kale consumption were found to range between 0.107 µg/kg bw/week and 33.167 µg/kg bw/week. The percent PTWI varied between 1.53 and 473.82 % **(Table 35).** The cadmium intake values of mean cadmium concentration and 95 percentile cadmium concentration from organic Chinese kale in province B exceeding the PTWI in this population, there were 107.57 and 473.82% of PTWI, respectively. In addition, the cadmium intake value of 95 percentile cadmium concentration in Chinese kale from the market also exceeding the PTWI in this population (278.95% of PTWI). Since, the estimated cadmium intake through the consumption of these contaminated Chinese kale samples might be of concern to this consumer group.

However, there are many studies about the impact of other nutrients on the bioavailability of heavy metals. Subsequent the experiments examing Pb and Cd exposure through human food confirmed that Ca, Cu, Fe and Zn are antagonists to Pb and Cd retention (59, 60, 61). In addition, Nawirska A (62) studied the binding of heavy metals to pomace fibers. The results showed that the dietary fibers, including cellulose, pectin, lignin and hemicellulose have a remarkable ability to bind heavy metals.

In fact, Chinese kale is the good source of calcium and it contains some dietary fiber (63). Thus, calcium and dietary fiber may be the antagonists to Pb and Cd absorption from the Chinese kale consumption.

Lead is ubiquitous throughout the food chain. **Table 41** is a compilation from a World Health Organization (WHO) document illustrating the typical lead content of various foods.

Table 41: Lead content in foods (μg/g fresh weight) (57)

Food category	Uncanned	Canned
Milk	0.02	0.10-0.13
Eggs	0.17	
Hamburger	0.25	
Salmon	0.39	0.72
Mackerel	0.40	0.99
Tuna		0.45
Oysters	0.17	
Clams	0.21	
Bread (white)	0.08	
Cereals (breakfast)	0.11	
Sugar(refined)	0.03	
Potatoes	0.05	0.12
Cabbage	0.01-0.04	0.08
Lettuce	0.12-0.15	0.39
Beans	0.01-0.04	0.16-0.32
Carrots	0.14	0.13
Onions	0.18	0.32
Cucumbers	0.02	
Citrus	0.01	0.39
Apples	0.02	0.22
Cherries	0.02	0.39

Complied in IMO/FAO/UNESCO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution Report (GESAMP)

As cadmium is ubiquitous in the environment, all food is exposed to and contains cadmium. The Codex Committee of Food Additives and Contaminants (Joint Food and Agriculture Organization World Health Organization Food standards Programme) indicates that the dietary in take of cadmium fluctuates between 10 and 50 µg/person/day for noncontaminated areas. The major sources of cadmium dietary intake are cereals, green leafy vegetables, potatoes, liver and kidney (80% of total cadmium intake). **Table 42** shows the cadmium levels (ng/g) in foods.

Table 42: Cadmium levels (ng/g) in individual food categories

Food category	Cd level
Milk, whole	0.13-0.80
Meat	2-36
Pork, raw	0.46-15.8
Meat organs	85.1-167
Eggs	0.42-5.02
Fresh-water fish, raw	0.54-7.72
Marine fish, raw	1.21-1.87
Shellfish	8.10-38.6
Beans, raw	1.38-3.76
Onions, raw	7.07-44.2
Carrots, raw	17.8-38.9
Celery	3.74-46.2
Corn, raw	1.86-23.6
Cucumber, raw	0.77-3.10
Lettuce	5.63-71.1
Apples	0.17-0.46
Bananas	0.16-0.66
Citrus fruit, raw	0.14-1.91
Grapes	0.22-1.05
Sugar	0.20-0.48

Thai people may expose to lead and cadmium via food. Thaweesak Bunyachotimongkol et al (56) studied the heavy metals in Thai foods. The intake of lead and cadmium from food consumption is shown in **Table 43**.

Table 43: The average of lead and cadmium intake from food consumption

Food group	Food consumption (g/person/day) (46)	Lead			Cadmium		
		Average (mg/kg) (57)	Intake (µg/kg bw/week)	% intake/ PTWI	Average (mg/kg) (57)	Intake (µg/kg bw/week)	% intake/ PTWI
Rice	137.8	0.55	8.84	35.37	0.14	2.25	32.15
Meats	51.9	0.54	3.27	13.08	0.14	0.85	12.11
Aquatic Animals	24.4	0.84	2.39	9.56	1.43	4.07	58.15
Eggs	20.7	0.95	2.29	9.18	0.23	0.56	7.94
Milk	36.6	0.17	0.73	2.90	0.04	0.17	2.44
Beans	0.9	0.73	0.08	0.31	0.15	0.02	0.23
Vegetables	112.8	0.83	10.92	43.69	0.18	2.37	33.84
Fruits	74.1	0.57	4.93	19.71	0.09	0.78	11.12
Oil	12.8	0	0	0	0	0	0
Sugar	13.2	0.26	0.4	1.60	0.08	0.12	1.76
Salt	1.6	0	0	0	0	0	0
Fish sauce	8.2	0.10	0.1	0.38	0.10	0.10	1.37
Total		**6.17**	**33.95**	**135.8**	**2.92**	**11.29**	**161.29**

Source: Modified from the study of Thaweesak Bunyachotimongkol et al (56)

From this table, it found that the food items that are the main sources of lead intake, including vegetables, rice and fruits. The food items that are the main sources of cadmium intake, including aquatic animals, vegetables and rice. Thus, the vegetables are the main source of lead and cadmium exposure to Thai population.

From many studies, found that the plants from the contaminated area or the industrial area contained the high levels of lead and cadmium (52), (64), (65).

Napawas B (52) studied lead contamination in some plants grown near industrial area in 3 district from Samut Prakarn province. The results showed that lead content in plants from industrial area was significantly higher than plants from agricultural area.

The survey of lead levels in vegetables grown at the village that used the waste of battery to fill road researched by Piumsak M. et al. (64) found lead content in water convovulus, water mimosa, sweet basil were 13.2, 20.8, 36.5 mg/kg fresh weight, respectively.

Beavington F, et al. (65) studied lead content in leafy vegetables were grown near mine in New South Wales, Australia (0.5 km from mine) and found that lead content in lettuce was 23 mg/kg dry weight and lead content in other leafy vegetable was 10 mg/kg dry weight.

Agreement with the other studies, the significantly high levels of lead and cadmium were found in the Chinese kale from the industrial areas, including province B. Hence, the zoning of the agricultural and the industrial areas may be the choice for solving the problem. In addition, the significant high level of cadmium in some organic Chinese kale samples may come from the raw materials of the fertilizers. However there is no scientific evidence to back up the presumption yet.

CHAPTER VII

CONCLUSION

This study indicates that the hygienic Chinese kale contained lead and cadmium levels significantly higher than the organic and the conventional Chinese kales. The organic, the hygienic and the conventional Chinese kale samples that exceeded Codex Maximum Level for lead were 9.4%, 11.3% and 5.7%, respectively. However, all Chinese kale samples did not exceed the Maximum Level of Thai Public Health Ministry (1000 µg/kg food). The organic, the hygienic and the conventional Chinese kale samples that exceeded Codex Draft Maximum Level for cadmium were 26.7%, 19.3% and 4.3%, respectively. There was no significant difference in lead and cadmium content between the organic and the conventional Chinese kales. It is questionable that the pesticides used in any farms may contain low level of lead and cadmium. It is possible that the chemical agriculture applied in conventional farms is not the important factor for lead and cadmium contamination in Chinese kale.

The high level of lead and cadmium in the Chinese kale was found in province B due to the fact that the area is full with the industrial factories that released lead and cadmium pollution. Surprisingly, the study also found the high level of cadmium accumulation in the organic Chinese kale samples from two farms in the rural area of province D. Whereas one organic farm in the same area provide low cadmium levels. Different fertility practices was found between high lead contaminative crops and low lead contaminative crops. Two organic farms in province D which used food scraps and the household waste as raw materials of bio-extract fertilizer provide high cadmium content in their crops. In addition, one organic farm in province B which also used food scraps and the household waste as raw materials provide higher lead and cadmium levels in Chinese kale than another farm located in the same area. It is then assumed that the use of bio-extract, made from the food scraps and the household waste, may possibly affect lead and cadmium accumulation in crops. However, there is no scientific evidence to back up the presumption yet. In addition, the hygienic

Chinese kale samples from the farm that was previously the old mine in Province C also contained high level of lead and cadmium. Thus, the environment around the farm, the history of farm and fertility practice may impact on lead and cadmium accumulation in Chinese kale.

This study also indicates that the seasonal factors may affect lead accumulation in the Chinese kale samples. The highest lead levels in the organic, the hygienic and the conventional Chinese kales were found in the rainy season, whereas the lowest lead levels in the Chinese kales were found in winter. Unlike lead accumulation, cadmium accumulation in Chinese kale tends to have the similarity, although the samples were collected from different seasons. However, the level of cadmium concentration in the organic Chinese kale grown in summer was significantly higher than the samples grown in the rainy season and winter. Accordingly, it can be explained that there was an extensive use of bio-extract fertilizers in the organic farms in summer, whereas the hygienic and the conventional farms use the same amount of bio-extract fertilizers in any seasons. It is possible that atmospheric cadmium may not have an impact on cadmium accumulation in the Chinese kale. The Chinese kale tends to take up cadmium from the contaminated soils. Therefore, the usage of high contaminated raw material in fertilizers may be the important factor for cadmium contamination in Chinese kale.

Besides, the environment around the farm (whether located in the industrial or the agricultural areas), the history of the farm (previously the old mine) and the fertility practices, the climatic factor may be another factor that have an impact lead accumulation in Chinese kale.

Lead and cadmium intakes (µg/kg bw/week) were calculated from the analyzed results (the mean and the 95th percentile of lead and cadmium concentrations) and the mean consumption of Chinese kale in the overall Thai population and Thai vegetarian group from other studies. The results show that lead and cadmium intakes of the overall Thai population did not exceed the PTWI. In contrast, lead intake of the market Chinese kale that contain high level of lead (at the 95 percentile of lead concentration) consumed by the vegetarian group exceeded the PTWI (up to 215.59%). And the cadmium intake of the Chinese kale that contain high level of cadmium (at the 95 percentile of cadmium concentration) including Chinese kale from the market, organic Chinese kale from province B and province D consumed by the vegetarian group exceeded the PTWI (278.95, 473.82 and 118.73%, respectively). Thus, extremely intake of lead and cadmium from the Chinese kale consumption may raise health concern for the vegetarian group.

In order to reduce lead and cadmium accumulation in crops, it is suggested that zoning management is implemented (between the agricultural and the industrial areas). Besides contamination from environment, the farmers should concern about the raw materials used in fertilizers, particularly the bio-extract fertilizer. Further study should investigate lead and cadmium contents in soil, water and various organic fertilizers that are commonly used in the farms.

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APPENDIX

APPENDIX A

<u>แบบสอบถามรูปแบบการปลูกพืชผัก</u>

วันที่สัมภาษณ์ ____________________ ชื่อ – นามสกุล (เกษตรกร) ________________________________

บ้านเลขที่_____ หมู่ที่___ หมู่บ้าน________ ตำบล____________อำเภอ____________จังหวัด___________

เป็นการเพาะปลูกแบบใด ☐ เป็นกลุ่มเกษตรกร ☐ เป็นเกษตรกรรายย่อย(เดี่ยว) ☐ เป็นรูปแบบบริษัท

ชนิดผักที่ปลูก ☐ คะน้า พันธุ์: ☐ พันธุ์ยอด ☐ พันธุ์ต้น

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

☐ แตงกวา พันธุ์: ☐ พันธุ์_____

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

☐ อื่นๆ________ พันธุ์ : _________

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

☐ อื่นๆ_______ พันธุ์ : __________

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

☐ อื่นๆ_______ พันธุ์ : __________

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

☐ อื่นๆ_______ พันธุ์ : __________

ช่วงเวลาที่ปลูก (ระบุเดือน) เริ่มปลูกเดือน: ______________ ถึง เก็บเกี่ยวเดือน: ___________

1 ปีปลูกกี่รอบ : รอบการปลูกใน 1 ปี: รอบที่ 1 เดือน __________ ถึง เดือน ___________

รอบที่ 2 เดือน __________ ถึง เดือน ___________

ข้อมูลเฉพาะผักที่เราเก็บตัวอย่าง ตัวอย่างที่เก็บ คือ:______

เริ่มปลูก วันที่ _____________ เก็บเกี่ยว วันที่ ______________

ขั้นตอนการปลูก

1. **ลักษณะการปลูกผัก** ☐ ปลูกแบบใช้สิ่งที่ได้จากธรรมชาติ โดยไม่ใช้สารเคมี เช่น ปุ๋ยเคมี ฮอร์โมน ยาฆ่าแมลง(ผักอินทรีย์)

☐ ปลูกแบบใช้ปุ๋ยเคมี แต่ไม่ใช้สารเคมีฆ่าแมลงหรืออาจใช้ในปริมาณที่ไม่เกิดการตกค้าง(ผักปลอดภัยจากสารพิษ)

☐ ปลูกแบบใช้ปุ๋ยเคมี ฮอร์โมน ยาฆ่าแมลง ยากันเชื้อรา ฯลฯ (ผักทั่วไป)

1.1 กรณีที่เป็นผักอินทรีย์

- ทำไมจึงหันมาปลูกผักอินทรีย์
  ☐ ปลอดภัยต่อสุขภาพเพราะไม่ใช้สารเคมี
  ☐ ผลผลิตขายได้ราคาดี
  ☐ อื่นๆ: ____________________

- การเพาะปลูกผักอินทรีย์ต่างจากผักอื่นอย่างไร
  ☐ ต้องเอาใจใส่มากกว่าการปลูกผักทั่วไป
  ☐ มีขั้นตอนที่ยุ่งยากและต้องอาศัยความชำนาญมากขึ้น
  ☐ เสียเวลาในการเพาะปลูกมากกว่า
  ☐อื่นๆ____________

- (ประวัติ) พื้นที่เพาะปลูกเคยใช้สารเคมีมาเป็นระยะเวลานาน________ปีและใช้สารเคมีอะไร(ชื่อ) : ________

- เลิกใช้สารเคมีมาแล้ว_________ปี

- ปลูกพืชอินทรีย์มาแล้ว________ปี

- พื้นที่นี้เคยปลูกพืชชนิดอื่นมาก่อน ☐ ไม่เคย ☐ เคย ได้แก่: _________________

- หากเคยปลูกพืชชนิดอื่นมาก่อน เลิกปลูกมาเป็นเวลา______________ปี

- มีการทิ้งช่วงการปลูกหรือไม่ ☐ ไม่ ☐ ทิ้งช่วง เป็นเวลา__________ ปี

1.2 กรณีที่เป็นผักปลอดภัยจากสารพิษ

- พื้นที่นี้เคยปลูกพืชชนิดอื่นมาก่อน ☐ ไม่เคย ☐ เคย ได้แก่: _________________

- หากเคยปลูกพืชชนิดอื่นมาก่อน เลิกปลูกมาเป็นเวลา______________ปี

- มีการใช้สารเคมีกำจัดแมลงหรือไม่ ☐ ไม่ใช้ ☐ ใช้ เป็นเวลานาน ________ปี

- มีการใช้สารเคมีกำจัดวัชพืชหรือไม่ ☐ ไม่ใช้ ☐ ใช้ เป็นเวลานาน ________ปี

- มีการทิ้งช่วงการปลูกหรือไม่ ☐ ไม่ ☐ ทิ้งช่วง เป็นเวลา_________ปี

1.3 กรณีที่เป็นผักทั่วไป

- พื้นที่นี้เคยปลูกพืชชนิดอื่นมาก่อน ☐ ไม่เคย ☐ เคย ได้แก่: ________________
- หากเคยปลูกพืชชนิดอื่นมาก่อน เลิกปลูกมาเป็นเวลา_______ปี
- มีการใช้สารเคมีกำจัดแมลงหรือไม่ ☐ ไม่ ☐ ใช้ เป็นเวลานาน _______ปี
- มีการใช้สารเคมีกำจัดวัชพืชหรือไม่ ☐ ไม่ ☐ ใช้ เป็นเวลานาน _______ปี
- มีการทิ้งช่วงการปลูกหรือไม่ ☐ ไม่ ☐ ทิ้งช่วง เป็นเวลา________ปี

2. **การเตรียมแปลง**

- มีการวางแผนป้องกันการปนเปื้อนที่ปะปนมาทาง ☐ ดิน ☐ น้ำ ☐ อากาศ
- มีการบันทึกวิธีการปฏิบัติอย่างต่อเนื่อง ☐ บันทึก ☐ ไม่บันทึก
- มีการปลูกพืชเป็นแนวกันชนเพื่อป้องกันสารพิษ ☐ ไม่มี ☐ มี
- มีระบบการกำจัดของเสีย ☐ ไม่มี ☐ มี
- มีระบบระบายน้ำ ☐ ไม่มี ☐ มี
- มีการให้น้ำท่วมแปลงแล้วสูบออกเพื่อชะล้างดิน ☐ ไม่เคย ☐ เคย ได้แก่__________
- การบำรุงดิน

☐ ใส่หินปูนปรับความเป็นกรด

☐ ปลูกพืชตระกูลถั่วแล้วไถกลับเพื่อเป็นปุ๋ยพืชสด

☐ ปลูกพืชหมุนเวียน ได้แก่ : ____________________________

☐ เมื่อดินขาดโพแทสเซียม ใช้ปุ๋ยมูลค้างคาว เกลือโพแทสเซียม ขี้เถ้าถ่าน

☐ ใส่ปุ๋ย ใช้ปุ๋ยกี่ชนิด_______ ได้แก่ :

○ ปุ๋ยเคมี สูตร: ________________ ☐ ทำเอง ☐ ซื้อ

วิธีการใช้ (และปริมาณ): __________

ความถี่ในการใช้ : ______________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยหมัก ทำจาก: ______________ ☐ ทำเอง ☐ ซื้อ

วิธีการใช้(และปริมาณ) : __________

ความถี่ในการใช้ : ______________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยคอก ทำจาก: _______________ ☐ ทำเอง ☐ ซื้อ

วิธีการใช้ (และปริมาณ): __________

ความถี่ในการใช้ : _______________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยน้ำชีวภาพ ทำจาก(สูตร):_________ ☐ ทำเอง ☐ ซื้อ

วิธีการใช้ (และปริมาณ): ____________

ความถี่ในการใช้ : _______________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ อื่นๆ: _______________________ ☐ ทำเอง ☐ ซื้อ

- มีการเตรียมแปลงเพื่อป้องกันศัตรูพืชหรือไม่ ☐ อบดินด้วยไอน้ำ

☐ คลุกดินด้วยเชื้อรา

☐ ไถพรวนและตากดิน 1-2 สัปดาห์

☐ ใช้พลาสติกคลุมแปลง

☐ ใส่ปูนโคโลไมด์ หรือปูนขาว

☐ ใช้น้ำท่วมแปลง

☐ ใส่เชื้อราปฏิปักษ์ เช่น ไตรโคเดอมา

- ใช้ยาปราบวัชพืชหรือไม่ ☐ ไม่เคย ☐ เคย ได้แก่: _________________

วิธีการใช้: __________

ปริมาณที่ใช้ :________

ความถี่ที่ใช้ : ________

- มีการให้น้ำท่วมแปลงแล้วสูบออกเพื่อชะล้างดิน ☐ ไม่เคย ☐ เคย
- มีการใช้วัสดุคลุมแปลงปลูกหรือไม่ ☐ ไม่มี ☐ มี ได้แก่: __________
    - ☐ ใช้พลาสติกคลุมแปลง
    - ☐ ใช้ฟาง
    - ☐ ใช้แกลบ
    - ☐ อื่นๆ: ___________
- ท่านคิดว่าปุ๋ยที่ท่านใช้อยู่เหมาะสมต่อการปลูกผักของท่านหรือไม่
    - ☐ เหมาะสมดี ได้ผักที่มีคุณภาพตามต้องการ
    - ☐ ยังไม่เหมาะสม แต่ต้องการพัฒนาให้มีคุณภาพที่ดียิ่งขึ้น
    - ☐ ยังไม่เหมาะสม ต้องการเปลี่ยนชนิดปุ๋ยหรือหาสูตรอื่นมาใช้
    - ☐ อื่นๆ : _________

3.การเตรียมเมล็ดพันธุ์ การเพาะกล้า

- มีการคัดแยกสิ่งสกปรกในเมล็ดพันธุ์หรือไม่ ☐ คัด ☐ ไม่คัด
- มีการเตรียมเมล็ดพันธ์ก่อนปลูกหรือไม่ ☐ ไม่มี ☐ มี ได้แก่:
    - ○ แช่เมล็ดในน้ำร้อน
    - ○ นำเมล็ดไปแช่น้ำอุ่น
    - ○ คลุกเมล็ดด้วยเชื้อรา
    - ○ นำเมล็ดไปหมัก
    - ○ ใช้พันธุ์ต้านทานโรค
    - ○ อื่นๆ: __________
- แหล่งของเมล็ดพันธุ์ ☐ ทำเอง / มีอยู่แล้ว ☐ ได้รับจากหน่วยงานราชการ :______________________ ☐ ซื้อจากร้าน ☐ อื่นๆ: ___________________________

4.การปลูกและการดูแลรักษา

4.1 การปลูก

- การใส่ปุ๋ย ใช้ปุ๋ย_____ ชนิด ได้แก่:

○ ปุ๋ยเคมี สูตร: ________________☐ ทำเอง ☐ ซื้อ

จุดประสงค์ในการใช้ : __________

วิธีการใช้ (และปริมาณ): ________

ความถี่ในการใช้ : _____________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยหมัก ทำจาก: _____________ ☐ ทำเอง ☐ ซื้อ

จุดประสงค์ในการใช้ : __________

วิธีการใช้(และปริมาณ) : __________

ความถี่ในการใช้ : __________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยคอก ทำจาก: _____________ ☐ ทำเอง ☐ ซื้อ

จุดประสงค์ในการใช้ : __________

วิธีการใช้(และปริมาณ) : __________

ความถี่ในการใช้ : __________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก ☐ ดี ☐ ไม่ดี

○ ปุ๋ยน้ำชีวภาพ ทำจาก(สูตร):_________ ☐ ทำเอง ☐ ซื้อ

จุดประสงค์ในการใช้ : __________

วิธีการใช้ (และปริมาณ): ____________

ความถี่ในการใช้ : __________

ผลของปุ๋ยต่อการงอกของเมล็ดพันธุ์ผัก

☐ ดี ☐ ไม่ดี

○ อื่นๆ: ___________________ ☐ ทำเอง ☐ ซื้อ

- มีการพรวนดินให้ร่วนซุยหรือไม่ ☐ ไม่เคย ☐ เคยไม่สม่ำเสมอ

☐ เคย สม่ำเสมอ (จำนวน______ครั้ง)

4.2 ระยะที่ผักเจริญเติบโต

- มีการควบคุมโรค ☐ ใช้จุลินทรีย์ได้แก่: _________(รา,แบคทีเรีย ฯลฯ)

☐ ใช้สารที่อนุญาตให้ใช้ ได้แก่: ______________

- การควบคุมแมลง ☐ ใช้สารสกัดจากพืช

☐ ใช้จุลินทรีย์ปฏิปักษ์ เช่น ไวรัส หรือ__________

☐ ใช้อุปกรณ์เช่น กับดักกาวเหนียว ,กับดักแสงไฟ

- การควบคุมวัชพืช ☐ ใช้วิธีทางกายภาพ เช่น ถอน,ขุด,ตัด

○ ใช้น้ำร้อน ,ไอน้ำ

○ ใช้พืชตระกูลถั่ว

○ ใช้สารสกัดจากพืช ได้แก่ : ____________

○ ใช้ชีววิธี เช่น แมลง ,สัตว์, จุลินทรีย์

- มีการฉีดพ่นยาฆ่าแมลงหรือไม่

☐ ไม่

☐ ฉีด ชื่อยา: __________ วัตถุประสงค์(ฆ่าแมลงอะไร): ________________

วิธีการใช้ : __________

ปริมาณ : ___________

ใช้ในอายุผักเท่าไร: _____________

ความถี่ในการใช้ : ______________

- มีการใช้ยาป้องกันโรคพืชหรือไม่

☐ ไม่ใช้

☐ ใช้ ชื่อยา: __________ วัตถุประสงค์(ป้องกันโรคอะไร): ________________

วิธีการใช้ : __________

ปริมาณ : ___________

ใช้ในอายุผักเท่าไร: ______________

ความถี่ในการใช้ : ______________

5.การเก็บเกี่ยว การเก็บรักษาและการขนส่ง

- หากมีพืชผักที่ไม่เป็นอินทรีย์ด้วย จะมีการคัดแยกจากผลิตภัณฑ์อินทรีย์หรือไม่

☐ แยก ☐ ไม่แยก

- มีการป้องกันผลิตภัณฑ์อินทรีย์ จากการสัมผัสและปนเปื้อนจากสารสังเคราะห์ใดๆตลอดการเก็บรักษาและการขนส่งหรือไม่

☐ ไม่ป้องกัน ☐ ป้องกัน โดย____________________

- มีการล้างผลผลิตหลังเก็บเกี่ยวหรือไม่ ☐ ไม่ล้าง ☐ ล้าง

- มีการใช้สารเคมีเพื่อเก็บรักษาผักหรือไม่

☐ ไม่ใช้

☐ ใช้ ได้แก่ : ____________________

ชื่อสารเคมี : ____________________

วิธีการใช้(และปริมาณ): ____________

6. **การตลาด** ☐ ส่งขายเอง ☐ มีพ่อค้าคนกลางมารับไป ☐ อื่นๆ: ____

กรณีขายเอง ผลผลิตขายได้หมดหรือไม่ ☐ หมด ☐ ไม่หมด

- ปัญหาที่เกิดขึ้นในการขายผลิตภัณฑ์ ☐ ความไม่แน่นอนของราคาผัก

☐ถูกกดราคาจากพ่อค้าคนกลาง

☐หาตลาดระบายผลผลิตไม่ได้

☐อื่นๆ: ___________

- ท่านคิดว่ามีทางแก้ไขปัญหาเหล่านี้อย่างไร :

____

- ข้อมูลสิ่งแวดล้อม

1. บริเวณที่ปลูกอยู่ใกล้

- แหล่งปศุสัตว์หรือไม่ ☐ ไม่ใช่ ☐ ใช่ ได้แก่ : ______ระยะห่าง____ ม.
- โรงงานหรือไม่ ☐ ไม่ใช่ ☐ ใช่ ได้แก่ : ______ระยะห่าง____ ม.
- แปลงผักอื่นหรือไม่ ☐ ไม่ใช่ ☐ ใช่ ได้แก่ : ______ระยะห่าง____ ม.
- ติดถนนหรือไม่ ☐ ไม่ใช่ ☐ ใช่ ได้แก่ : ______ระยะห่าง____ ม.
- อื่นๆ: ____________

2. น้ำ

- ความถี่ในการรดน้ำผักต่อวัน ☐ วันละ 1-2 ครั้ง ☐ วันละ 1 ครั้ง ☐ อื่นๆ: ____________________
- น้ำที่ใช้รดผักมาจากแหล่งใด ☐ น้ำปะปา ☐ น้ำคลอง ☐ น้ำบาดาล ☐ อื่นๆ: _________
  - มีน้ำเพียงพอตลอดปีหรือไม่ พอ ไม่พอ
  - มีปัญหาน้ำเน่าเสียหรือไม่ ☐ ไม่มี ☐ มี ถ้ามี สภาพเป็นอย่างไร_________

เกิดขึ้นในช่วงไหน______________

3. แสงสว่าง – บริเวณที่แปลงปลูกผักมีปริมาณแสงสว่างในช่วงกลางวัน ☐ มาก ☐ น้อย ☐ อื่นๆ: _____

4. บริเวณที่ทำแปลงปลูกผักมีสภาพอากาศเป็นอย่างไร ☐ ร้อนชื้น ☐ เย็นสบาย ☐ ค่อนข้างหนาว

5. ฤดูกาลไหนที่ผักได้ผลผลิตดี ☐ ฤดูร้อน ☐ ฤดูฝน ☐ ฤดูหนาว

6. แมลงศัตรูพืชระบาดมาในช่วงฤดูกาลไหน ☐ ฤดูร้อน ☐ ฤดูฝน ☐ ฤดูหนาว

7. มีการใช้ปุ๋ยเคมีมากในช่วงฤดูกาลไหน ☐ ฤดูร้อน ☐ ฤดูฝน ☐ ฤดูหนาว

APPENDIX B

Table 44: Lead content (µg/kg dry weight) in Chinese kale samples from province A

Season	Mean ± SD (Min-Max)						
	Organic			Hygienic		Conventional	
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	76.31±57.10 (<LOD -172.28)	114.52±301.07 (<LOD -954.60)	143.69±88.51 (7.03-248.64)	36.49±43.64 (<LOD -145.36)	82.33±69.94 (<LOD -195.57)	92.31±28.35 (65.31-166.32)	47.77±43.58 (<LOD -108.44)
Winter	28.77±50.01 (<LOD -140.12)	<LOD	21.89±69.21 (<LOD -218.85)	22.39±39.73 (<LOD -123.10)	*	5.73±18.12 (<LOD -57.30)	*
Summer	87.13±178.79 (<LOD -585.75)	40.60±45.92 (<LOD -109.39)	29.08±40.13 (<LOD -248.64)	58.32±37.87 (<LOD -145.36)	*	86.01±89.88 (<LOD -231.65)	*
Average	64.07±111.23 (<LOD -585.75)	51.71±176.38 (<LOD -954.60)	62.17±86.03 (<LOD -248.64)	39.07±41.85 (<LOD -145.36)	82.33±69.94 <LOD -195.57	61.35±66.82 (<LOD -231.65)	47.77±43.58 (<LOD -108.44)

Table 45: Lead content (µg/kg wet weight) in Chinese kale samples from province A

Season	Mean ± SD (Min-Max)						
	Organic			Hygienic		Conventional	
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	8.50±7.37 (<LOD -23.84)	10.12±24.73 (<LOD -77.19)	13.81±8.17 (0.84-26.86)	3.81±4.60 (<LOD -15.46)	9.17±8.62 (<LOD -24.92)	9.08±2.81 (6.49-16.36)	4.66±4.21 (<LOD -10.44)
Winter	3.11±5.37 (<LOD -15.09)	<LOD	2.63±8.32 (<LOD -26.32)	2.48±4.27 (<LOD -13.00)	*	0.38±1.19 (<LOD -3.77)	*
Summer	8.43±16.62 (<LOD -54.45)	3.60±3.85 (<LOD -8.37)	3.56±4.61 (<LOD -12.39)	5.18±3.61 (0.44-11.17)	*	4.65±4.96 (<LOD -13.76)	*
Average	6.68±10.87 (<LOD -54.45)	4.57±14.58 (<LOD -77.19)	6.42±8.59 (<LOD -26.86)	4.15±4.35 (<LOD -15.46)	9.17±8.62 (<LOD -24.92)	4.70±4.86 (<LOD -16.36)	4.66±4.21 (<LOD -10.44)

Table 46: Cadmium content (µg/kg dry weight) in Chinese kale samples from province A

Season	Mean ± SD (Min-Max)						
	Organic			Hygienic		Organic	
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	45.01±45.48 (<LOD-127.46)	314.46±471.78 (64.90-1570.35)	469.02±801.90 (75.69-2493.75)	622.06±92.20 (450.42-741.81)	547.21±1277.98 (76.39-4175.36)	105.44±28.61 (60.19-145.70)	171.03±31.28 (123.70-220.72)
Winter	166.11±29.81 (125.26-222.68)	144.84±62.04 (54.40-242.44)	150.91±13.97 (129.60-173.92)	90.73±35.17 (40.51-164.13)	*	106.79±33.02 (76.13-175.32)	*
Summer	174.73±52.48 (93.49-297.74)	214.17±31.44 (165.73-264.26)	251.31±107.45 (153.38-528.92)	136.73±49.90 (103.29-273.21)	*	272.67±58.58 (170.17-353.57)	*
Average	131.50±72.54 (<LOD-297.74)	224.49±274.94 (54.40-1570.35)	290.41±470.58 (75.69-2493.75)	283.17±252.11 (40.50-741.81)	547.21±1277.98 (76.39-4175.36)	161.63±89.64 (60.19-353.57)	171.03±31.28 (123.70-220.72)

Table 47: Cadmium content (µg/kg wet weight) in Chinese kale samples from province A

Season	Mean ± SD (Min-Max)						
	Organic			Hygienic		Conventional	
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	3.55±3.37 (<LOD-9.56)	26.42±46.20 (4.28-153.89)	36.98±62.78 (4.81-194.51)	54.99±11.67 (37.84-78.63)	45.21±102.06 (5.50-334.03)	8.88±2.52 (4.45-12.24)	13.87±2.88 (9.45-20.08)
Winter	15.45±6.39 (8.52-31.50)	13.77±4.94 (5.33-21.00)	13.34±3.13 (6.48-16.84)	7.77±2.85 (3.40-13.79)	*	9.76±3.72 (4.81-17.18)	*
Summer	16.10±5.50 (9.12-26.20)	18.40±5.77 (12.05-31.12)	28.19±9.13 (17.49-50.78)	11.14±4.79 (5.46-22.95)	*	16.15±4.59 (6.82-22.34)	*
Average	11.98±7.70 (<LOD-31.50)	19.53±26.62 (4.28-153.89)	26.17±36.75 (4.81-194.51)	24.63±23.04 (3.40-78.63)	45.21±102.06 (5.50-334.03)	11.60±4.86 (4.45-22.34)	13.87±2.88 (9.45-20.08)

Table 48: Lead content (µg/kg dry weight) in Chinese kale samples from province B

Season	Mean ± SD (Min-Max)					
	Organic		Hygienic		Conventional	
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	5731.53±1752.09 (3516.24-7542.90)	4034.18±2934.21 (2071.50-9226.70)	1058.81±453.23 (617.55-2011.46)	249.08±332.6 (<LOD-832.26)	1568.60±533.55 (793.90-2364.42)	256.07±278.90 (<LOD-912.78)
Winter	*	*	701.06±521.22 (<LOD-1510.18)	236.95±461.48 (<LOD-1464.48)	24.51±77.52 (<LOD-245.13)	49.13±155.37 (<LOD-491.31)
Summer	*	*	2220.87±1587.87 (<LOD-4060.02)	519.70±490.68 (<LOD-1506.12)	792.68±1514.85 (<LOD-4479.28)	225.66±241.02 (<LOD-728.38)
Average	5731.53±1752.09 (3516.24-7542.90)	4034.18±2934.21 (2071.50-9226.70)	1326.91±1168.74 (<LOD-4060.02)	335.24±439.05 (<LOD-1506.12)	795.26±1101.57 (<LOD-4479.28)	176.95±241.39 (<LOD-912.78)

Table 49: Lead content (µg/kg wet weight) in Chinese kale samples from province B

Season	Mean ± SD (Min-Max)					
	Organic		Hygienic		Conventional	
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	575.15±169.90 (375.83-762.28)	360.08±257.73 (161.58-811.95)	77.628±41.27 (29.30-138.45)	24.83±34.19 (<LOD-92.70)	107.28±42.15 (52.78-170.53)	25.96±27.02 (<LOD-85.90)
Winter	*	*	57.81±40.57 (<LOD-100.83)	26.36±57.47 (<LOD-182.79)	2.52±7.97 (<LOD-25.21)	4.35±13.74 (<LOD-43.45)
Summer	*	*	240.17±176.28 (<LOD-448.39)	78.42±113.49 (<LOD-381.04)	78.94±147.72 (<LOD-407.84)	22.93±23.77 (<LOD-71.97)
Average	575.15±169.90 (375.83-762.28)	360.08±257.73 (161.58-811.95)	125.20±132.62 (<LOD-448.39)	43.20±77.63 (<LOD-381.04)	62.91±96.79 (<LOD-407.84)	17.74±23.56 (<LOD-85.90)

Table 50: Cadmium content (µg/kg dry weight) in Chinese kale samples from province B

Season	Mean ± SD (Min-Max)					
	Organic		Hygienic		Conventional	
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	10773.83±13612.64 (1742.67-35254.05)	6602.50±2152.60 (3928.19-9375.00)	2149.34±1483.29 (1318.50-6094.95)	2413.36±1007.62 (621.25-4173.12)	2346.44±585.80 (1576.44-3278.16)	1815.78±322.88 (1416.78-2288.30)
Winter	*	*	1559.12±1141.03 (156.91-3995.88)	3472.81±657.78 (2544.48-4646.56)	299.78±119.26 (103.73-433.30)	1690.14±225.46 (1342.08-2099.33)
Summer	*	*	1011.92±371.42 (593.92-1679.94)	3622.95±608.27 (2808.33-4484.70)	1305.07±1102.74 (192.02-3250.80)	1011.77±328.28 (302.08-1382.72)
Average	10773.83±13612.64 (1742.67-35254.05)	6602.50±2152.60 (3928.19-9375.00)	1573.46±1163.08 (156.91-6094.95)	3169.71±929.50 (621.25-4646.56)	1317.10±1100.27 (103.73-3278.16)	1505.90±458.90 (302.08-2288.30)

Table 51: Cadmium content (µg/kg wet weight) in Chinese kale samples from province B

Season	Mean ± SD (Min-Max)					
	Organic		Hygienic		Conventional	
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	982.07±1341.39 (128.96-3525.41)	582.37±173.35 (361.39-825.00)	110.44±50.85 (68.17-231.61)	177.49±75.83 (41.00-292.12)	129.51±42.18 (60.69-209.80)	159.96±42.64 (116.18-216.02)
Winter	*	*	105.79±64.36 (9.41-207.79)	259.93±112.34 (71.25-473.95)	24.24±12.05 (6.79-40.73)	130.43±38.93 (36.55-184.74)
Summer	*	*	98.69±38.79 (48.70-164.63)	392.29±192.73 (257.29-900.12)	111.45±83.26 (14.21-247.06)	92.54±31.97 (25.38-130.63)
Average	982.07±1341.39 (128.96-3525.41)	582.37±173.35 (361.39-825.00)	104.97±50.78 (9.41-231.61)	276.57±159.15 (41.00-900.12)	88.40±70.24 (6.79-247.06)	127.64±46.25 (25.38-216.02)

Table 52: Lead content (μg/kg dry weight) in Chinese kale samples from province C

Season	Mean ± SD (Min-Max)					
	Organic	Hygienic			Conventional	
	Farm 1	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2
Rainy	56.36±27.82 (2.81-94.52)	103.95±61.69 (<LOD-190.07)	165.25±74.80 (31.05-316.97)	1118.71±1289.57 (<LOD-3906.77)	95.74±49.46 (35.22-178.23)	133.50±80.98 (56.73-296.46)
Winter	7.41±23.44 (<LOD-74.11)	*	72.55±37.63 (7.56-145.95)	*	23.44±38.17 (<LOD-89.17)	*
Summer	65.63±48.83 (3.12-167.88)	*	118.19±39.92 (59.77-177.44)	*	180.67±93.21 (87.47-391.02)	*
Average	42.30±43.27 (<LOD-167.88)	103.95±61.69 (<LOD-190.07)	118.66±64.43 (7.56-316.97)	1118.71±1289.57 (<LOD-3906.77)	99.95±90.44 (<LOD-391.02)	133.50±80.98 (56.73-296.46)

Table 53: Lead content (µg/kg wet weight) in Chinese kale samples from province C

Season	Mean ± SD (Min-Max)					
	Organic	Hygienic			Conventional	
	Farm 1	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2
Rainy	4.59±2.47 (1.58-8.76)	10.30±6.06 (<LOD-17.87)	14.33±6.32 (2.61-27.26)	90.36±97.12 (<LOD-273.47)	8.31±3.87 (3.24-15.33)	10.38±7.30 (2.10-26. 68)
Winter	0.19±0.61 (<LOD-1.93)	*	6.27±3.90 (0.85-15.47)	*	2.12±3.47 (<LOD-7.87)	*
Summer	6.29±4.70 (0.27-15.45)	*	9.93±3.26 (5.50-14.20)	*	15.46±9.34 (7.57-37.54)	*
Average	3.69±3.96 (<LOD-15.45)	10.30±6.06 (<LOD-17.87)	10.18±5.63 (0.85-27.26)	90.36±97.12 (<LOD-273.47)	8.63±8.14 (<LOD-37.54)	10.38±7.30 (2.10-26. 68)

Table 54: Cadmium content (µg/kg dry weight) in Chinese kale samples from province C

Season	Mean ± SD (Min-Max)					
	Organic	Hygienic			Conventional	
	Farm 1	Farm 1	Farm 2	Farm 1	Farm 1	Farm 2
Rainy	274.61±47.07 (201.95-358.72)	379.22±125.65 (243.69-564.80)	335.14±77.53 (197.44-444.20)	2113.80±483.37 (1238.84-2830.40)	117.38±18.49 (92.47-139.76)	623.01±161.43 (459.11-896.40)
Winter	173.63±59.59 (110.04-279.46)	*	351.88±60.00 (231.43-451.13)	*	203.10±59.04 (95.04-300.43)	*
Summer	136.60±15.22 (116.30-159.96)	*	273.40±57.13 (198.05-380.74)	*	116.32±31.99 (73.30-173.20)	*
Average	194.95±73.35 (110.04-358.72)	379.22±125.65 (243.69-564.80)	320.14±71.93 (197.44-451.13)	2113.80±483.37 (1238.84-2830.40)	145.60±56.71 (73.30-300.43)	623.01±161.43 (459.11-896.40)

Table 55: Cadmium content (µg/kg wet weight) in Chinese kale samples from province C

Season	Mean ± SD (Min-Max)					
	Organic	Hygienic			Conventional	
	Farm 1	Farm 1	Farm 2	Farm 1	Farm 1	Farm 2
Rainy	23.06±7.06 (3.72-29.31)	37.82±13.59 (23.12-59.19)	29.05±6.26 (16.98-37.03)	183.56±58.73 (91.67-254.73)	10.40±1.22 (8.32-12.37)	46.67±15.31 (17.71-65.48)
Winter	13.96±7.65 (3.04-25.43)	*	31.04±8.94 (15.71-40.68)	*	16.65±5.98 (8.33-26.44)	*
Summer	13.035731.53±30.30 (9.72-17.45)	*	23.43±6.07 (13.61-32.74)	*	9.80±3.17 (5.54-14.55)	*
Average	15.70±7.15^{a} (3.04-29.31)	37.82±13.59 (23.12-59.19)	27.84±7.69 (13.61-40.68)	183.56±58.73 (91.67-254.73)	12.28±4.96 (5.57-26.44)	46.67±15.31 (17.71-65.48)

Table 56: Lead and cadmium content (µg/kg dry weight) in Chinese kale samples from province D.

Season	Lead content (µg/kg dry weight)			Cadmium content (µg/kg dry weight)		
	Organic			Organic		
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 3
Rainy	63.08±177.69 (<LOD-565.41)	865.42±531.39 (350.88-1736.73)	52.81±135.30 (<LOD-427.16)	3250.82±1400.26 (1912.09-6169.73)	10747.59±1567.48 (7844.24-13162.19)	1140.09±365.01 (811.40-1973.09)
Winter	*	576.98±618.76 (<LOD-1744.68)	*	*	10194.27±1699.23 (8098.22-14336.38)	*
Summer	*	342.31±590.20 (<LOD-1765.35)	*	*	45699.48±9435.38 (32653.28-58892.54)	*
Average	63.08±177.69 (<LOD-565.41)	594.90±601.58 (<LOD-1765.35)	52.81±135.30 (<LOD-427.16)	3250.82±1400.26 (1912.09-6169.73)	22213.78±17738.08 (7844.24-58892.54)	1140.09±365.01 (811.40-1973.09)

Table 57: Lead and cadmium content (μg/kg wet weight) in Chinese kale samples from province D.

Season	Lead content (μg/kg dry weight)			Cadmium content (μg/kg dry weight)		
	Organic			Organic		
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Rainy	5.90±16.70 (<LOD-53.15)	59.11±34.92 (18.95-119.28)	4.12±10.55 (<LOD-33.32)	330.80±210.82 (156.79-849.87)	734.48±131.77 (556.97-896.05)	88.90±29.10 (64.71-153.90)
Winter	*	56.10±56.67 (<LOD-165.53)	*	*	1043.64±288.61 (659.28-1605.68)	*
Summer	*	34.78±60.73 (<LOD-176.54)	*	*	4436.17±1261.45 (2429.18-6028.31)	*
Average	5.90±16.70 (<LOD-53.15)	49.99±51.39 (<LOD-176.54)	4.12±10.55 (<LOD-33.32)	330.80±210.82 (156.79-849.87)	2071.43±1853.10 (556.97-6028.31)	88.90±29.10 (64.71-153.90)

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