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Pesticide and Heavy Metal Contamination: Potential Health Risks of Some Vegetables and Fruits from a Local Market and Family Farm in Ongkharak District of Nakhon Nayok Province, Thailand

Sirikul Thummajitsakul[1]*, Rawitsara Subsinsungnern[1], Ngamrat Treerassapanich[1], Nutthida Kunsanprasit[1], Leeyaporn Puttirat[1], Patarapong Kroeksakul[2] and Kun Silprasit[2]

[1]*Faculty of Physical Therapy, Srinakharinwirot University, Ongkharak, Nakhon-Nayok, 10110 Bangkok, Thailand*

[2]*Faculty of Environmental Culture and Ecotourism, Srinakharinwirot University, 10110 Bangkok, Thailand*

ABSTRACT

Organophosphate and carbamate pesticides were preliminarily determined in 33 vegetable samples from Ongkharak market (*N* = 13) and family farm (*N* = 20) in Sisa Krabue community at Ongkharak district of Nakhon Nayok province by a GT-test kit. More than 60% of samples contained pesticides, and eight samples had pesticides at harmful level, namely *Alpinia galanga* (Linn.) Swartz., *Coriandrum sativum* Linn., *Citrus aurantifolia* (Christm) Swing., *Ocimum sanctum* Linn., and *Carica papaya* Linn. from the Ongkharak market, and *Pandanus amaryllifolius* Roxb., *Ocimum sanctum* Linn., *Citrus aurantifolia* (Christm) Swing. from the family farm. Then, heavy metals (Cd, Pb, Fe, Cr, Zn, and Cu) were determined in eight samples by an atomic absorption spectroscopy. Our new finding showed that Pb level exceeded permissible limit in *O. sanctum* Linn., *C. aurantifolia* (Christm) Swing., *C. papaya* Linn., purchased from the local market, and *C. aurantifolia* (Christm) Swing. and *O. sanctum* Linn. from the family farm. In addition, all samples had Fe and Cr levels above permissible limits, but Zn and Cu levels were below permissible limits. Moreover, 100.0%, 62.5%, 37.5%, 37.5%, and 25.0% of the analyzed samples had target hazard quotients above 1 for Cr, Pb, Cu, Fe, and Zn, respectively, which

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E-mail addresses:
sirikul.thum@gmail.com (Sirikul Thummajitsakul)
kokdokdak@hotmail.com (Rawitsara Subsinsungnern)
nun.chh@gmail.com (Ngamrat Treerassapanich)
may_abmf@hotmail.com (Nutthida Kunsanprasit)
Leeyapornp@gmail.com (Leeyaporn Puttirat)
patarapong@g.swu.ac.th (Patarapong Kroeksakul)
kun.silprasit@gmail.com (Kun Silprasit)
* Corresponding author

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indicated potential health risks involving unsafe consumption from each heavy metal. Hazard index also indicated the health risks for female and male via consumption of each vegetable contaminated with multiple heavy metals. *O. sanctum* Linn., especially from the local market, had the highest risk.

Keywords: Family farm, health risks, heavy metals, local vegetables, market

INTRODUCTION

High-quality foods are minimally processed foods such as vegetables and fruits that contain essential nutrients (i.e., vitamins and minerals) needed at low concentration for several activities in human body. Although, metals are naturally found in vegetables, exceeding permissible limits of them can be harmful to human health (Guerra, Trevizam, Muraoka, Marcante, & Canniatti-Brazaca, 2012). They can transfer from soils to vegetables due to human activities, and accumulation of several heavy metals in rural and urban soils at excessive level can cause serious health problems of human (Chao, Xiao-Chen, Li-Min, Pei-Fang, & Zhi-Yong, 2007; Szynkowska, Pawlaczyk, Leśniewska, & Paryjczak, 2009). Using pesticides are major factors in contamination of heavy metals in exposed vegetables, such as Hg, Mn, Cu, Pb, or Zn (Hakeem, Sabir, Ozturk, & Mermut, 2015). Heavy metals can affect metabolic functions in human body by accumulation and functional disruption in organs and glands (i.e., kidneys, heart, brain, bone, and liver) including metabolic components (i.e., genetic materials and enzymes; Singh, Gautam, Mishra, & Gupta, 2011). Moreover, human health concerns, affected by heavy metals, can be indicated by target hazard quotients (THQs) and hazard index (HI). These parameters are used to evaluate the potential health risks in consumption of vegetables, exposed with heavy metals in long term (Guerra et al., 2012).

Several reports involving heavy metal contents in vegetables and human health risks have been represented. For examples, heavy metals (Fe, Mn, Zn, Cu, Ni, Cd, and Pb) have been found in common vegetables (parsley, carrot, onion, lettuce, cucumber, and green beans), and THQ of each heavy metal indicates potential health risk from consumption of the exposed vegetables for male and female (Harmanescu, Alda, Bordean, Gogoasa, & Gergen, 2011). In addition, toxic heavy metals (As, Cd, Pb, Cr, Mn, Ni, Cu, and Zn) are found in fruits and vegetables, and THQ indicates health risks of Mn and Cu through consumption of the investigated vegetables (Shaheen et al., 2016).

In Thailand, pesticides are commonly used by farmers that may lead to higher human health effects even though they have benefits in increasing agricultural products. Therefore, it causes a severe health risk in Thai people who consume the exposed vegetables and fruits. This had been reported by Wachirawongsakorn (2016) that more than 80% of vegetables from fresh market in the lower north of Thailand were contaminated with Pb and Cd above the maximum allowable concentration, and THQ indicated potential health risk associated with consumption of the exposed vegetables for local Thai people. However, knowledge of health risks and surveillance of heavy metals in native vegetables is still limited in local areas of Nakon Nayok province, especially in Ongkharak district. Therefore, this novel knowledge is important for health promotion of human in the rural areas of developing country where they are never investigated. Therefore, our major goals were to detect a level of organophosphate and carbamate contamination, and to evaluate heavy metal contents in local vegetable samples, which related to the pesticide contamination at harmful level, from Ongkharak market and family farm in Sisa Krabue community of Ongkharak district, Nakhon Nayok province. In addition, THQs and HI were calculated and used to predict the potential risks of human health from intake of the vegetables contaminated with heavy metals (Cd, Pb, Fe, Cr, Zn, and Cu) in targeted areas.

MATERIALS AND METHODS

Sample Collection

The number of vegetable samples were obtained from Ongkharak market (N = 13) and family farm (N = 20) in Srisakrabue community, Ongkharak district in Nakhon Nayok province since October 2016 until April 2017. Seven vegetables (*Vigna unguiculata* (L.) Walp., *Eryngium foetidum* Linn., *Ocimum sanctum* Linn., *Cymbopogon citratus* (DC.) Stapf., *Alpinia galanga* (Linn.) Swartz., *Carica papaya* Linn., and *Citrus aurantifolia* (Christm) Swing.) were collected in duplicate, and different 19 vegetable types were randomly chosen. Parts of unpeeled vegetables were divided into leaves, roots, rhizomes, fruits, flowers, stem, pods, and seeds, and rinsed with deionized water, then kept at 4°C until used. Name, code, and part of each sample used in this study are shown in Table 1.

Table 1
Types of vegetables used for pesticide detection, parts of vegetables used in our study and levels of the pesticide contamination

Common name	Botanical names	Sample codes	Parts used	Sampling Area	Levels of the pesticide contamination
Yard long bean	*Vigna unguiculata* (L.) Walp.	VIW1	Pods and seeds	Ongkharak market	Not contaminated***
Bird chilli	*Capsicum flutescens* Linn.	CAF	Fruits and seeds	Ongkharak market	Not contaminated***
Culantro	*Eryngium foetidum* Linn.	ERF1	Leaves	Ongkharak market	Safe level**
White holy basil	*Ocimum sanctum* Linn.	OCS1	Leaves	Ongkharak market	Unsafe level*
Lemon grass	*Cymbopogon citratus* (DC.) Stapf.	CYC1	Leaves	Ongkharak market	Safe level**

Table 1 *(continue)*

Common name	**Botanical names**	**Sample codes**	**Parts used**	**Sampling Area**	**Levels of the pesticide contamination**
Cabbage	*Brassica oleracea* L. var. capitata	BRO	Leaves	Ongkharak market	Safe level**
Corainder	*Coriandrum sativum* Linn.	COS	Leaves	Ongkharak market	Unsafe level*
Galangal	*Alpinia galanga* (Linn.) Swartz.	ALG1	Rhizomes	Ongkharak market	Unsafe level*
Black pepper	*Piper nigrum* Linn.	PIN	Seeds	Ongkharak market	Safe level**
Carrot	*Daucus carota* Linn.	DAC	Roots	Ongkharak market	Not contaminated***
Cucumber	*Cucumis sativus* Linn.	CUS	Fruits	Ongkharak market	Safe level**
Papaya	*Carica papaya* Linn.	CAP1	Fruits	Ongkharak market	Unsafe level*
Lime	*Citrus aurantifolia* (Christm) Swing.	CIA1	Fruits	Ongkharak market	Unsafe level*
Leech lime	*Citrus hystrix* DC.	CIH	Fruits	Family farm	Safe level**
Pandan leaves	*Pandanus amaryllifolius* Roxb.	PAA	Leaves	Family farm	Unsafe level*
Wildbetal leafbush	*Piper sarmentosum* Roxb.	PIS	Leaves	Family farm	Safe level**
Tamarind	*Tamarindus indica* Linn.	TAI	Leaves	Family farm	Safe level**
Lime	*Citrus aurantifolia* (Christm) Swing.	CIA2	Fruits	Family farm	Unsafe level*
Cork wood tree	*Sesbania grandiflora* Desv.	SEG	Leaves and flowers	Family farm	Safe level**
Bitter cucumber	*Momordica charantia* Linn.	MOC	Leaves	Family farm	Safe level**
Galangal	*Alpinia galanga* (Linn.) Swartz.	ALG2	Rhizomes	Family farm	Safe level**
Papaya	*Carica papaya* Linn.	CAP2	Fruits	Family farm	Safe level**
Lemon grass	*Cymbopogon citratus* (DC.) Stapf.	CYC2	Leaves	Family farm	Safe level**
Brazilian pepper tree	*Schinus terebinthifolius* Raddi.	SCT	Leaves	Family farm	Safe level**
White holy basil	*Ocimum sanctum* Linn.	OCS2	Leaves	Family farm	Unsafe level*

Table 1 *(continue)*

Common name	Botanical names	Sample codes	Parts used	Sampling Area	Levels of the pesticide contamination
Yard long bean	*Vigna unguiculata (*L.) Walp.	VIW2	Pods and seeds	Family farm	Safe level**
Ivy gourd	*Coccinia grandis* Voigt.	COG	Leaves	Family farm	Safe level**
Tomato	*Lycopersicon esculentum* Mill.	LYE	Fruits	Family farm	Safe level**
Water morning glory	*Ipomoea aquatica* Forsk.	IPA	Leaves and stem	Family farm	Safe level**
Culantro	*Eryngium foetidum* Linn.	ERF2	Leaves	Family farm	Safe level**
Velvet bean	*Mucuna pruriens* (L.) DC. Var. utilis	MUP	Pods and seeds	Family farm	Safe level**
Red holy basil	*Ocimum sanctum* Linn.	OCT	Leaves	Family farm	Safe level**
Asiatic pennywort	*Centella asiatica* (Linn.) Urban.	CEA	Leaves	Family farm	Safe level**

* The pesticide contamination at unsafe level was identified by colour of the sample solution that appeared darker than colour of critical solution.
** The pesticide contamination at safe level was identified by colour of the sample solution appeared lighter than colour of critical solution, but darker than colour of control solution.
*** Sample without pesticide contamination was identified by colour of the sample solution appeared lighter than or like colour of the control solution.

Determination of Organophosphate and Carbamate Pesticides

Organophosphate and carbamate pesticides were preliminarily determined in 33 vegetable samples using GT-pesticide residual test kit (Higher Enterprises Co., LTD., Thailand) according to the method of Thoophom (1998). This method had 92.3% sensitivity, 85.1% specificity, 87.1% accuracy, 70.6% positive predictive value, and 96.6% negative predictive value for residual detection of pesticides in vegetables, and it is an easy, rapid, and low-cost way to detect the organophosphorus and carbamate pesticides in primary step. The parts of vegetables used in this study were shown in Table 1. Each fresh sample (5 g) was cut into small pieces and extracted by 5 mL of solvent No. 1 with mixing for 15 min. Next, each sample extract (1 mL) were added with 1 ml of solvent No. 2, then evaporated in an evaporation basin until all solvent No.1 residues were removed. After that, GT-1 solvent (0.50 mL) was added in each extract and incubated at room temperature for 10 min. Then, 0.25 mL of GT-2 solvent was added, followed by incubation at 37°C for 30 min, and mixing with 1 mL of GT-3 solvent. Finally, GT-4 (0.5 mL) and GT-5 solvent (0.5 mL) were added to each reaction, respectively, then colour indication, ranging from a yellow through a dark brown of each sample solution, was compared to colour levels of control and critical solutions. The colours of sample solution indicated contamination levels of carbamate and organophosphate pesticides that they were classified into three levels according to percentage of cholinesterase inhibition: (1) If a sample solution is lighter than or like colour of the control solution, it will indicate that the pesticides are not detected in the sample; (2) If a colour of sample solution is lighter than colour of critical solution, but darker than colour of control solution, it will indicate that the pesticides are detected in the sample at a safe level for human consumption; and (3) If a colour of sample solution is darker than colour of critical solution, it will indicate that the pesticides are detected in the sample at an unsafe level.

Sample Preparation and Digestion

To determine heavy metals at unsafe level of pesticide contamination, parts of each vegetable or fruit were rinsed with deionized water and cut into small pieces for incubation at 50°C until dried. Then, each sample was grinded with a homogenizer and kept in room temperature until used.

Each powdered sample (0.5 g) was added with 70% HNO_3 for 10 mL, and digested at 100°C on a hot plate within a fume hood approximately for 1 h or until dried. Moreover, each residue was rinsed with 1% HNO_3, followed by sieving through Whatman No 1 paper, and transferring the supernatant into a 50-mL volumetric flask, and adding with 1% HNO_3 up to a 50-mL volume. Each reaction was performed in triplicate. Next, concentrations of heavy metals (Cd, Pb, Fe, Cr, Zn, and Cu) were determined in each digested sample by an atomic absorption spectrometry (Model 200 Series AA, Agilent Technologies, Malaysia). External standard method was done by dilution from standard solution at 1000 µg/mL stock of each heavy metal with 1% HNO_3, and linear standard calibration curves were generated to measure each heavy metal in individual sample. After that, each heavy metal content was compared to permissible limits found in food and vegetables according to Ministry of Public Health (1986) shown in Table 2.

Table 2
The permissible limits of each heavy metal in food and vegetables

Heavy metals	Concentration (mg/kg)
Cadmium (Cd)	3
Lead (Pb)	1
Iron (Fe)	20
Chromium (Cr)	2
Zinc (Zn)	100
Copper (Cu)	20

Target Hazard Quotients (THQ) and Hazard Index (HI)

Health risks of human from consumption of vegetables contaminated with heavy metals were estimated with a THQ and a hazard index (HI) or the sum of the hazard quotients

(Basim & Khoshnood, 2016; Guerra et al., 2012; Javed & Usmani, 2016; Wang, Qiao, Liu, & Zhu, 2012). If a THQ is below 1, it means that the exposed human is unlikely to undergo obvious risk. THQ was calculated using the following formula (1).

$$THQ = \frac{(E_F * E_D * F_{IR} * C) * 10^{-3}}{(RFD * WAB * TA)} \quad (1)$$

Where;

E_F is exposure frequency in consumption of heavy metals-contaminated vegetables (365 days/year)

E_D is exposure duration or the average lifetime of Thai people; 71.8 years for male and 78.6 years for female (Institute for Population and Social Research, 2016)

F_{IR} is food ingestion rate (kg/person/day) of Thai people; 268 g/person/day for male and 283 g/person/day for female (The Health Systems Research Institute, 2006).

C is metal concentration in vegetables or fruits (mg/kg)

R_{FD} is oral reference dose (mg/kg/day) (Cd,0.001 mg/kg/day; Pb, 0.0035 mg/kg/day; Fe, 0.7 mg/kg/day; Cr, 0.003 mg/kg/day; Zn, 0.300 mg/kg/day; Cu: 0.040 mg/kg/day) (Harmanescu et al., 2011; Chang et al., 2014).

W_{AB} is the average body weight for Thai people (68.83 kg for male and 57.40 kg for female) (Pentamwa, Sukton, Wongklom, & Pentamwa, 2013; Well et al., 2011)

T_A is the averaging exposure time for heavy metals (ED × 365 days/year)

Moreover, multiple heavy metals found in each sample can affect the risks of human health. Therefore, HI was used to determine the overall potential health risk effected by more than one heavy metal according to equation (2).

$$HI = THQ_{Cd} + THQ_{Pb} + THQ_{Fe} + THQ_{Cr} + THQ_{Zn} + THQ_{Cu} \quad (2)$$

Statistical Analysis

Number and proportions were used for explaining levels of pesticide contamination in samples. Moreover, one sample *Z* test was used to prove hypothesis that the proportion of vegetables contaminated with pesticides was more than 60% of total samples at significant level, $p < 0.05$. In addition, heavy metal contents, THQ, and HI were expressed with mean and SD. All statistical analyses were performed using PSPP program version 0.10.5 (Pfaff et al., 2013).

RESULTS AND DISCUSSION

Organophosphorus and carbamate compounds are commonly used as pesticides that are toxic to nervous system of human by inhibiting cholinesterase (ChE) enzymes (Meerdink, 1989). Nowadays, the pesticides are increasingly and commonly used in agricultural regions of Thailand to increase agricultural yields and respond to consumer needs (Chowdhury, Banik, Uddin, Moniruzzaman, Karim, & Gan, 2012). However, consumer perception in safe foodstuffs is still restricted in Ongkharak district in Nakon Nayok province. Therefore, it is interesting to monitor organophosphate and carbamate pesticides contaminated in vegetable samples from the local market and the family farm in Srisakrabue community. The results showed 66.6%, 24.2% for pesticide contamination at safe and unsafe levels, and 9.1% for no pesticides, respectively. These results indicated that more than 60% of total samples were contaminated with organophosphorus and carbamate pesticides (Table 3). In addition, most samples from the local market (38.5% of total analyzed samples) were contaminated with the pesticides at harmful level higher than those from family farm (15% of total analyzed samples). Similarly, it has been reported that several vegetables (79.2%), namely yard long beans, chili peppers, cucumbers, and Chinese kale, are contaminated with the pesticides (Ponthas et al., 2014). Moreover, the organophosphate and carbamate compounds in soil, rice, and water samples from rice paddy fields in Nakhon Nayok province have been detected by a GT-test kit that provides percentages of pesticide contamination for 77.78%, 85.18%, and 70% of total samples, respectively (Thummajitsakul, Praditpol, Poolaoi, & Silprasit, 2015).

However, if a small amount of pesticides enters body through often eating or touching vegetables, it can be accumulated in the body and linked to more risks of human chronic diseases (Mostafalou & Abdollahi, 2013), especially people involved in pesticide exposure (i.e., consumers, farmers, and retailers). Corresponding to the report of Ponthas et al. (2014), 60% of fresh vegetable and fruit retailers in Ongkharak market have health risks from touching frequently organophosphate and carbamate pesticides in vegetables placed on sell in the local market.

Therefore, continuous monitoring of pesticides in vegetables is important for human health surveillance and pesticide applications. In our study, pesticides were found at harmful level in eight samples, namely *A. galanga* (Linn.) Swartz., *C. sativum* Linn., *C. aurantifolia* (Christm) Swing., *O. sanctum* Linn., and *C. papaya* Linn. from Ongkharak market, and *P. amaryllifolius* Roxb., *O. sanctum* Linn., and *C. aurantifolia* (Christm) Swing. from family farm (Table 3).

Table 3
Number and proportions of samples that were not contaminated and contaminated with pesticides, and one-sample z analysis for proportions of all samples contaminated with the pesticides by defining null hypothesis (H0) <60% and alternative hypothesis (H1) > 60%

Samples	**Number (%)**	**Test Prop.**	***P-value***
Not contaminated with pesticides	3 (9.1%)		
Contaminated with pesticides but safe to be consumed	22 (66.6%)	0.6	0.000
Contaminated with pesticides but not safe to be consumed	8 (24.2%)		

In previous report of Chiroma, Abdulkarim and Kefas (2007), organophosphorous pesticide, DELVAP 1000EC, could effect to increasing Cu, Cd, and Pb levels in leaves, stem, and roots of spinach, corresponding to the report of Dogheim, Ashraf, Alla, Khorshid and Fahmy (2004). Pesticides and heavy metals levels in Egyptian leafy vegetables and some aromatic medicinal plants. Food additives and contaminants (Dogheimg et al., 2004), leafy vegetables and some aromatic medicinal plants are contaminated with heavy metals (Pb, Cu, and Cd) above the maximum limits. In addition, organophosphorous pesticides (malathion and profenofos) are mostly found for 203 and 131 from 391 samples, respectively (Dogheim et al., 2004). Moreover, heavy metals (Pb, Cd, Cu, and Zn) and insecticides have been found in soil and plant products (Marković, Cupać, Đurović, Milinović, & Kljajić, 2010).

For our study, heavy metals (Cd, Pb, Fe, Cr, Zn, and Cu) in the samples was also evaluated across the unsafe level of the pesticide contamination. Our results revealed that Cd was not found in all samples. However, Pb, Fe, Cr, Zn, and Cu were found in some samples. Pb was found above the permissible limit in *O. sanctum* Linn., *C. aurantifolia* (Christm) Swing. and *C. papaya* Linn. purchased from the local market, and *C. aurantifolia* (Christm) Swing. and *O. sanctum* Linn. from the family farm ranging from 1.22-8.31 mg/kg dry weight. Fe, Cr, and Zn were found in all analyzed samples ranging from 20.53-287.90, 6.87-13.30, and 5.23-64.77 mg/kg dry weight, respectively. These samples had Fe and Cr above permissible limits except for Zn. In addition, Cu was found in *A. galanga* (Linn.) Swartz., *C. sativum* Linn., and *O. sanctum* Linn. from the local market, and *P. amaryllifolius* Roxb. and *O. sanctum* Linn. from the family farm ranging between 7.43 and 15.67 mg/ kg dry weight that were also below the permissible limit (Table 4).

Table 4
Heavy metal contents of eight vegetables contaminated with the pesticides at unsafe level in mg/kg dry weight analyzed by the atomic absorption spectroscopy

Sample codes	**Heavy metal content (Mean ± SD in mg/kg dry weight)**					
	Cd	**Pb**	**Fe**	**Cr**	**Zn**	**Cu**
ALG1	*ND	*ND	41.20 ± 17.60	6.87 ± 2.36	26.43 ± 0.12	1.43 ± 0.38
COS	*ND	*ND	287.90 ± 8.25	12.73 ± 0.71	36.17 ± 4.10	10.30 ± 0.44
CIA1	*ND	6.48 ± 8.50	21.37 ± 2.20	7.80 ± 1.39	5.23 ± 1.55	*ND
OCS1	*ND	8.31 ± 0.40	213.27 ± 115.95	13.30±1.35	64.77 ± 3.50	12.40 ± 0.5
CAP1	*ND	6.11 ± 8.31	31.83 ± 4.43	6.63±0.47	8.27 ± 1.40	*ND
PAA	*ND	*ND	156.70 ± 56.57	8.17±2.40	22.53 ± 10.02	7.43 ± 0.86
OCS2	*ND	1.22 ± 0.06	125.90 ± 49.75	12.97±0.60	63.93 ± 8.70	15.67 ± 3.67
CIA2	*ND	3.04 ± 3.59	20.53 ± 4.13	5.70 ± 2.08	9.23 ± 2.70	*ND

Note: *ND: Below detection limit. Each reaction was done in triplicate.

The content of each heavy metal varies in vegetables depending on several factors such as atmospheric depositions, sampling areas, plant species and parts, metal forms, and transferring the metals from soils to vegetables (Chao et al., 2007; Sharma, Agrawal, & Marshall, 2008; Xian, 1989). In our result, Zn was the most abundant element in each investigated vegetable when compared with other heavy metals. This may involve absorption and translocation of each heavy metal from roots to shoots of vegetables, and it has been reported that Zn shows the strongest ability involving translocation from soils to vegetables (Chao et al., 2007). Moreover, correlation patterns among levels of metals and pesticides in soil have been reported that pesticides may either help to stabilize heavy metal or to degrade pesticides in soil. Acetamiprid is strongly positively associated with Cu, and negatively associated with Cr, and imidacloprid is negatively associated with Ni (Tariq, Shafiq, & Chotana, 2016).

In this study, the exposed sources of heavy metals in the vegetables and fruits were from Ongkharak market, a distribution local source of fresh-vegetables obtained from agricultural areas through Thailand, and family farm in Sisa Krabue community in Ongkharak district of Nakhon Nayok province where it was a cultivated area for consumption in family. Therefore, pesticide usage in the agricultural areas is a major factor involving the metal exposure in the vegetables. Although organic family farms are processed, they can be influenced from nearby agricultural areas where pesticides are used. However, several heavy metals are essential nutrients for plant growth at low concentration, but concentrations exceeding the permissible limits of them become toxic (Rengel, 1999).

Thus, each heavy metal content in samples was conducted to calculate THQ that was a parameter to determine potential risks of human health in long-term exposure to each heavy metal. In present study, THQ value was used to evaluate the potential health risk of each heavy metal found in each vegetable. The result showed individually obvious risk in each heavy metal except for Cd. The 87.5%, 68.8%, 62.5%, 37.5%, and 0% of total samples showed THQ below 1 for Zn, Fe, Cu, Pb, and Cr, respectively (Table 5). It indicated that most vegetables can be consumed safely from Zn, Fe, and Cu except for Pb and Cr that most samples had THQ >1. For male, the THQ values for Pb, Fe, Cr, Zn and Cu ranged from 1.35-9.23, from 0.11-1.19, from 7.40-17.26, from 0.07-0.84 and from 0.14-1.53, respectively. For female, THQ of Pb, Fe, Cr, Zn, and Cu ranged from 1.71-11.70, from 0.14-2.03, from 9.37-21.86, from 0.09-1.06, from 0.18-1.93, respectively. The sequence of THQ for male and female was Cr > Pb > Cu> Fe> Zn, respectively (Table 6).

Although the THQ values of each heavy metal showed the same sequence for both, they were higher for female. This is possible because of the differences between male and female in average lifetime, vegetable ingestion rate, and average body weight. Therefore, THQ should be calculated separately for adult male and female. In

Table 5
Percentages of vegetables that were found below and above the permissible limit of THQ for each heavy metal

	% of vegetables					
	Cd	Pb	Fe	Cr	Zn	Cu
THQ<1	100.0%	37.5%	62.5%	0.0%	75.0%	62.5%
THQ≥1	0.0%	62.5%	37.5%	100.0%	25.0%	37.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6
Target hazard quotients (THQ) and hazard indexes for the eight vegetables with the contamination of heavy metals for male and female adults (ages >15 years)

	Samples	THQ (mean ± SD)						Hazard Index (mean ± SD)
		Cd	Pb	Fe	Cr	Zn	Cu	
Male	ALG1	ND*	ND*	0.22 ± 0.10	8.91 ± 3.07	0.34 ± 0.00	0.14 ± 0.04	10.09 ± 3.34
	COS	ND*	ND*	1.60 ± 0.04	16.53 ± 0.92	0.47 ± 0.05	1.00 ± 0.04	21.58 ± 2.83
	CIA1	ND*	7.21 ± 9.46	0.12 ± 0.01	10.12 ± 1.80	0.07±0.02	ND*	17.53 ± 10.56
	OCS1	ND*	9.23 ± 0.44	1.19 ± 0.64	17.26 ± 1.74	0.84 ± 0.05	1.21 ± 0.05	26.66 ± 6.46
	CAP1	ND*	6.80±9.24	0.18 ± 0.02	8.61 ± 0.61	0.11 ± 0.02	ND*	15.69 ± 9.65
	PAA	ND*	ND*	0.87 ± 0.31	10.60 ± 3.12	0.29± 0.13	0.72 ± 0.08	13.99 ± 1.68
	OCS2	ND*	1.35 ± 0.07	0.70 ± 0.28	16.83 ± 0.78	0.83 ± 0.11	1.53 ± 0.36	20.79 ± 0.46
	CIA2	ND*	3.38±4.00	0.11 ± 0.02	7.40 ± 2.70	0.12 ± 0.04	ND*	9.89 ± 5.22
Female	ALG1	ND*	ND*	0.29 ± 0.12	11.28 ± 3.88	0.43 ± 0.00	0.18±0.05	12.78±4.23
	COS	ND*	ND*	2.03 ± 0.06	20.93 ± 1.17	0.59 ± 0.07	1.27 ± 0.05	27.33 ± 3.59
	CIA1	ND*	9.13 ± 11.98	0.15 ± 0.02	12.82 ± 2.28	0.09 ± 0.03	ND*	22.19 ± 13.37
	OCS1	ND*	11.70 ± 0.57	1.50 ± 0.82	21.86 ± 2.22	1.06 ± 0.06	1.53±0.06	33.75 ± 8.18
	CAP1	ND*	8.61 ± 11.70	0.22 ± 0.03	10.90 ± 0.78	0.14 ± 0.02	ND*	19.87 ± 12.22
	PAA	ND*	ND*	1.10 ± 0.40	13.42 ± 3.95	0.37 ± 0.16	0.92 ± 0.11	17.72 ± 2.13
	OCS2	ND*	1.71 ± 0.09	0.89 ± 0.35	21.31 ± 0.99	1.05 ± 0.14	1.93 ± 0.45	26.32 ± 0.58
	CIA2	ND*	4.28 ± 5.06	0.14 ± 0.03	9.37 ± 3.42	0.15 ± 0.04	ND*	12.52 ± 6.61

addition, if THQ is above 1, it reflects the level of health concern in exposed people (Harmanescu et al., 2011).

However, more than one heavy metals in each vegetable can multiply to potential health risks of exposed people. Therefore, hazard index (HI) values of male and female, the sum of THQ of each heavy metal, were calculated. Similarly to THQ, HI should also not more than 1 (Javed & Usmani, 2016). In our results, HI values for male and female ranged from 9.89-26.66 and 12.52-27.33, respectively (Table 6). Although it indicated that HI was higher for female, human health could be affected via unsafe consumption of individual vegetable contaminated with multiple heavy metals. The sequence of the HI for male and female was *O. sanctum* Linn. (Ongkarak market) > *C. sativum* Linn. (Ongkarak market) > *O. sanctum* Linn.(family farm) > *C. aurantifolia* (Christm) Swing. (Ongkarak market) > *C. papaya* Linn. (Ongkarak market) > *P. amaryllifolius* Roxb. (family farm) > *A. galanga* (Linn.) Swartz. (Ongkarak market) > *C. aurantifolia* (Christm) Swing. (family farm), respectively.

Therefore, our new finding indicated that contamination of the pesticides in investigated vegetables may affect heavy metal contents in exposed vegetables. Furthermore, the new data involving human health risks and metal concentrations in local areas may be useful to promote human health and in decision about consumption of the vegetables in a local market or family farm. Furthermore, the major information can be used to manage environmental surveillance, awareness among farmers to grow safe vegetables for supply local markets, and health impact of human in the developing country.

CONCLUSION

Organophosphate and carbamate pesticides were investigated in 33 vegetable samples. More than 60% of total samples were contaminated with pesticides in organophosphorus and carbamate group. Then, this study monitored heavy metals in eight vegetables found on harmful level of the pesticide contamination, followed by THQ and HI calculation. Fe, Zn, Cr, Cu, and Pb were mostly found in the vegetables at high level, and most samples had heavy metals above the permissible limits. Furthermore, THQ provided information in safe consumption from Cd of all investigated vegetables, but there are still health risks of unsafe vegetable consumption from other heavy metals for both male and female. Moreover, human health risk from consumption of each vegetable contaminated with multiple heavy metals indicated that *O. sanctum* Linn. from the local market was the highest risk.

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