Residue Pesticides (Pyrethroid Group) in Vegetable and Their Health Risk Assessment via Digestion on Consumers in Ha Nam Province, Vietnam

D T V Huong¹, T T H Nga¹ and D T T Ha²

¹ Lecturer, University of Science, Vietnam National University, Hanoi, Vietnam
² Master Student, University of Science, Vietnam National University, Hanoi, Vietnam
E-mail: tranthihuyennga@hus.edu.vn

Abstract. Pyrethroid group are insecticides recommended for protection against insects by governed organization such as World Health Organization (WHO) and the European Union (EU). They are widely used in agriculture, households, forestry, horticulture, medicine and veterinary medicine. In Vietnam, these pesticides were used with huge amount in crops, especially in vegetable. The residues of λ- cyhalothrin, permethrin, cypermethrin, deltamethrin in four vegetable head mustard, leaf mustard, choy sum, bok choy were detected by GC/MS technique. 84 samples of four leafy vegetable in Brassicaceae family were collected from seven places (farms, stores, markets) in Ha Nam Province. The levels of λ- cyhalothrin in three samples, cypermethrin in four samples, deltamethrin in four samples were above the maximum residue limit of Vietnam Government. There were no significant of health risk by these pesticides via digestion vegetable but the risk for kid was higher than for adult. Their health risk on consumers using these vegetable were evaluated.

1. Introduction
Pesticides are compounds that are used to kill pests, including insects, rodents, fungi and unwanted plants [1]. Pesticides can be classified by many issues such as target organism, chemical structure, physical state, etc. Chemically, pesticides are grouped into families including organochlorines, organophosphates, carbamates, neonicotinoids and pyrethroids [2,3,4]. Pyrethroids are synthetic derivatives of natural pyrethrins from the plant Chrysanthemum cinerariaefolium. Pyrethroids become used worldwide because of their selective toxicity, high potency, ability to reduce disease transmission, relative stability in the environment and easy of degradation in vertebrates, and low cost [5], replaced for other groups such as organochlorines, organophosphates, carbamates. Pyrethroids belong to the fourth group of insecticides according to the WHO classification and include forty two substances [6] like allethrin, pyrethrin, permethrin, cypermethrin, cyfluthrin, cyhalothrin, bifenthrin, deltamethrin, fenpropathrin, ethofenprox, etc.
Cyhalothrin belongs to the second groups of of pyrethroids, is used to control a wide range of pests including aphids, beetles and butterfly larvae for protection of cotton, cereals, hops, ornamentals, potatoes, vegetables or others. Lambda cyhalothrin is moderately toxic via the oral route in test animal, nervous system may be affected after acute exposure [7]. Permethrin belongs to the first group of pyrethroids, used to against mosquitoes and fleas, for the protection of fodder crops and food processing plants, in the construction industry, and in residential
areas. Permethrin may enter the body via the skin, gastrointestinal and respiratory. Permethrin may cause a variety of symptoms which include epidermal lesions, sore throat, nausea, vomiting, abdominal pain, gastrointestinal mucosal irritation, salivation, respiratory distress and headaches in human and animals [8].

Cypermethrin belongs to type II pyrethroid, used in growing of cultivated plants, against butterflies and beetles. Cypermethrin poisoning can cause nausea, vomiting, diarrhea, mucosal irritations, salivation, tearing, motor coordination disorder, chorea, inertia, tremors and clonic seizures [9].

Deltamethrin belongs to type II pyrethroids, used in crops to controls aphids, whiteflies, lice, tse-tse flies, fleas, ticks, spiders, ants, bees, bedbugs and cockroaches [10]. It is also effective against vectors of malaria. It can get into the organism through the digestive, respiratory and skin systems, causes tingling, itching, burning and numbness of the skin, accumulate in brain neurons [11].

Because of popular using in household and agricultural, pyrethroids can be contaminated in soil, food, water therefore can enter the human body by ingestion of pyrethroid-containing products especially vegetable. The potential toxic properties of the pyrethroids were shown as effects on immune system, reproductive system, neuronal system, skeletal muscles, inducing oxidative stress, cardiovascular system, etc [12,13].

2. Materials and methods

2.1 Study area

Ha Nam Province is in the middle of Northern Delta of Vietnam, 40km southern of Hanoi. This is an agricultural Province with main occupation being vegetable and fruit culture. Besides the GAP farming (Good Agricultural Practices farming), there are traditional farms using pesticides uncontrollably in this area. Four vegetable from seven places including old farming cooperatives, organic farming cooperatives, grocery store, market were collected for this study in two seasons (April, 2018 off-season and October, 2018 main-season), (Figure 1, Table 1, Table 2).

![Figure 1. Map for sampling in Ha Nam Province](image)

2.2 Sampling

Vegetable samples were collected follow QCVN 9016:2011. Three subsamples of four vegetables were collected from 7 places, on April 2018 and October 2018, Table 1. The first, fourth, fifth places were farming cooperatives with cultured vegetable under GAP; the third and seventh places were traditional market distributing lots of vegetable; the second and sixth places were model mini mart with safety vegetable. Pyrethroids were investigated in 7 places in Ha Nam Province to getting the estimated average concentration. Pesticides were determined by QuEChERS method, using GC/MS 7890B (Agilent). Four pesticides in pyrethroid group were determined including λ-cyhalothrin, permethrin, cypermethrin, deltamethrin.
Vegetable samples were head mustard, leaf mustard, choy sum, bok choy (Table 2). These leafy vegetables are cultivated and consumed with big amount in the Northern Vietnam as well as in Ha Nam Province. According to report of Ministry of Agriculture and rural development 2009, the average pesticide amount for crop in Vietnam is about 0.2-0.24kg/ha/year, but this number for vegetable is higher to 0.4-0.5kg/ha/year [14]. Therefore, the residues of pesticides in crops should be strictly managed and paid more attention.

| No. | Places for sampling | Sample code | Address                                      |
|-----|---------------------|-------------|----------------------------------------------|
| 1   | Ha Vy farming cooperatives | P1          | Ward 5, Ha Vy, Nhan Chinh                    |
|     |                     |             | Commue, Ly Nhan District, Ha Nam Province    |
| 2   | Green Food grocery store | P2          | Le Công Thanh Street, Phu Ly City, Ha Nam Province |
| 3   | Vinh Tru Market     | P3          | Vinh Tru Town, Ly Nhan District, Ha Nam Province |
| 4   | Thanh Son farming cooperatives | P4         | Ward 5, Thanh Son Commue, Kim Bang District, Ha Nam Province |
| 5   | Phu Van organic farming cooperatives | P5      | Ward 4, Phu Van Commue, Phu Ly City, Ha Nam Province |
| 6   | Nguyen Thi Giang grocery store | P6        | Nguyen Viet Xuan Street, Phu Ly City, Ha Nam Province |
| 7   | Bau Market, Phu Ly  | P7          | Luong Khanh Thien Commue, Phu Ly City, Ha Nam Province |

| No | Species | Family | Name                  | n  |
|----|---------|--------|-----------------------|----|
| 1  | Brassica juncea  integri folia var. rugosa | Brassicaceae | Head mustard | 7x3 |
| 2  | Brassica juncea  juncea | Brassicaceae | Leaf mustard | 7x3 |
| 3  | Brassica rapa subsp. parachinensis | Brassicaceae | Choy sum | 7x3 |
| 4  | Brassica rapa subsp. chinensis | Brassicaceae | Bok choy | 7x3 |
2.3 Health risk assessment of pesticides on consumers using vegetable in investigation area

The risks for noncarcinogenic and carcinogenic impacts were assessed separately. Two toxicity risk indices were the reference dose (RfD) for non-cancer risk characterization and the cancer slope factor (CSF) for cancer risk characterization [15]. In investigation case, the risks for noncarcinogenic impacts by four pesticides and carcinogenic risk by permethrin were assessed.

Exposure rate assessment

In order to non-cancer risk assessment of pyrethroid on consumers using vegetable in investigation area, the chronic daily intakes (CDI) of each λ- cyhalothrin, permethrin, cypermethrin, deltamethrin were conducted. The CDI (mg/kg/day) of pyrethroid uptake from vegetable were calculated using Equation

$$CDI_i = \frac{C_i \times IR_i \times EF_i \times ED_i}{BW \times AT}$$  (1)

where CDI was the chronic daily intake (mg/kg/day), C_i presented the concentration of the pesticides in vegetables (mg/L), IR was the ingestion rate of pesticides per unit time (g/day), ED was the exposure duration, EF was the exposure frequency (days/year), BW was body weight, and AT indicated the averaging exposure time (for non-carcinogens, AT= ED ×365days and for carcinogens, AT=70×365days; USEPA [16,17]).

Non-cancer risks

Non-cancer risks of each pesticide in vegetable were determined separately by the non-cancer hazard quotient for each pesticide (HQ_i) using Equation 2,

$$HQ_i = \frac{CDI_i}{RfD}$$  (2)

where CDI was chronic daily intake (mg/kg/day), and RfD presented chronic oral reference dose (mg/kg/day), respectively (USEPA [16]).

The chronic hazard index (HI) which was used to assess potential risk to human health is HI = ∑HQ_i. HI < 1 implies no significant non-cancer risk and HI ≥ 1 indicates significant non-cancer risks.

Carcinogenic risks

Incremental lifetime cancer risk for each pesticides (ILCR_i) was calculated by Equation 3,

$$ILCR_i = CDI_i \times CSF_i$$  (3)

where ILCR was incremental lifetime cancer risk, CDI presented chronic daily intake (mg/kg BW/day), and CSF indicated cancer slope factor (mg/kg/day), risk produced by a lifetime average dose of 1 mg/kg body weight/day of a contaminant.

The total cancer risk (ILRC) was: ILCR = ∑ILCR_i

ILRC < 10^-6 indicates non-carcinogenic risk, ILCR from 10^-6 to 10^-4 is an acceptable or tolerable carcinogenic risk, and ILCR > 10^-4 is considered to unacceptable or toxic [18,19].

3. Results and discussion

3.1 Pyrethroid residues in vegetable

| Code   | April | October | April | October | April | October | April | October |
|--------|-------|---------|-------|---------|-------|---------|-------|---------|
| Head   | Min   | 0.028   | 0.103 | 0.036   | 0.006 | 0.103   | 0.081 | 0.051   | 0.158   |
|        | Max   | 0.517   | 0.431 | 0.609   | 1.250 | 1.445   | 1.350 | 0.514   | 0.661   |
| mustard | Min   | 3       | 9     | 5       | 5     | 4       | 2     | 6       | 3       |
|        | Max   | 0       | 3     | 3       | 9     | 5       | 8     | 7       | 3       |
The residue levels of \( \lambda \)-cyhalothrin, permethrin, cypermethrin, deltamethrin are shown in Table 3. \( \lambda \)-cyhalothrin is highest in head mustard, more than twice than maximum residue limit of Vietnam and nearly twice than maximum residue limit of FAO. There are 3/84 vegetable samples contaminated \( \lambda \)-cyhalothrin above MRL of Vietnam Government, 18/81 samples are no-detected and 63/81 samples containing \( \lambda \)-cyhalothrin below the MRL of Vietnam. There are 22/84 no-detected permethrin vegetable samples and the 62/84 samples containing permethrin under the MRL. Cypermethrin residues in 84 samples are highest among four pesticides, there are 4/84 vegetable contaminated cypermethrin more than 1mg/kg, 16/84 samples are no-detected. There are 27/84 no-detected deltamethrin samples and the 57 samples are all below the MRL by FAO but there are four samples contaminated deltamethrin higher than 0.5mg/kg as MRL of Vietnam Government. In a study by Nghiem P. T., et al. (2012), there are 32/50 crop samples in Quang Binh Province over the MRL of Vietnam [20]. According to Hien N. V., et al. (2010), cypermethrin residues in 24 vegetable samples in Ho Chi Minh City are under MRL while the cypermethrin residue in vegetable samples in five Northern Provinces is higher than in Ho Chi Minh City, but the cypermethrin residue in common bean is higher than 1.7 times [21]. These four pesticides are used popularly in Vietnam and all over the world and widely reported. Elgueta et al. (2017) quantified pesticide residues level in vegetables where by

|          | Mean   |          |          |          |          |          |          |          |
|----------|--------|----------|----------|----------|----------|----------|----------|----------|
|          | Mean   | 0.161    | 0.277    | 0.250    | 0.358    | 0.496    | 0.503    | 0.191    |
|          | SD     | 0.181    | 0.134    | 0.234    | 0.458    | 0.492    | 0.508    | 0.187    |
|          | Min    | 0.016    | 0.023    | 0.027    | 0.045    | 0.203    | 0.132    | 0.036    |
|          | Max    | 0.216    | 0.657    | 0.730    | 1.245    | 1.135    | 1.068    | 0.618    |
|          | Mean   | 0.113    | 0.231    | 0.351    | 0.424    | 0.576    | 0.499    | 0.230    |
|          | SD     | 0.066    | 0.248    | 0.324    | 0.481    | 0.402    | 0.387    | 0.231    |

|          | Mean   | 0.090    | 0.051    | 0.082    | 0.091    | 0.098    | 0.033    | 0.013    |
|          | SD     | 0.092    | 0.015    | 0.082    | 0.091    | 0.098    | 0.033    | 0.013    |

|          | Mean   | 0.242    | 0.111    | 0.658    | 0.574    | 0.513    | 0.374    | 0.194    |
|          | SD     | 0.108    | 0.072    | 0.407    | 0.341    | 0.395    | 0.466    | 0.222    |

|          | Mean   | 0.075    | 0.011    | 0.011    | 0.078    | 0.831    | 0.051    | 0.015    |
|          | SD     | 0.026    | 0.057    | 0.234    | 0.340    | 0.064    | 0.412    | 0.209    |

| MRL(1)   | 0.2     | 5        | 1        | 0.5      |
| MRL(2)   | 0.3     | 5        | 1        | 2        |

(1): QĐ 46/2007/QĐ-BYT, National technical regulation on the allowable limits of pesticides in foods of Vietnam. MRL is maximum residue limit.
(2): Codex alimentarius international food standards for pesticides, FAO/WHO Values higher than allowable limits (QĐ 46/2007/QĐ-BYT) are bold.
lambda-cyhalothrin, cypermethrin and permethrin were in range of 0.029-1mg/kg, 0-1.61mg/kg, and 0-1.45mg/kg, respectively in chard, lettuce, and spinach, lower than MRL of FAO [22]. In a report by N. Pakvilai et al, (2011) six pesticides in 50 vegetable and 43 fruits in Fang District, Chiang Mai, Thailand mostly exceeding the MRLs of FAO, EU or Thailand Agricultural Commodity and Food Standard 2006 [23]. WHO recommends classifying λ-cyhalothrin, permethrin, cypermethrin, deltamethrin by slightly hazardous toxic (class III). The results indicate that these four vegetable were containing slightly hazardous pesticides, exposed to risk the human health of farmers and consumers. The Government should push more attention to manage the level pesticides in foods.

3.2 Health risk assessment
In order to calculate the health risk index via vegetable ingestion, the exposure parameters were assumed as in Table 4. AT was 70 years, BW for adult and child was 53 and 15kg, ED was 30 and 6 years, IR was 0.2 and 0.1kg/day, respectively, EF was 35 days per year, C_i of four pesticides were shown in Table 3, mean values. For non cancer risk, R_fD of λ-cyhalothrin, permethrin, cypermethrin, deltamethrin were shown in Table 5 [20]. The International Agency for Research on Cancer (IARC) classified λ-cyhalothrin, cypermethrin, deltamethrin as, "not classifiable as to its carcinogenicity to humans", so the cancer risk was calculated by only permethrin in vegetable, cancer slope factor was 0.0184 [24].

| Table 4. Exposure parameters |
|----------------------------|
| AT (year) | BW (kg) | EF (day/year) | ED (year) | IR (kg/day) |
| Adult | 70 | 60 | 35 | 30 | 0.2 |
| Kids | 70 | 15 | 35 | 6 | 0.1 |

| Table 5. R_fD and SF of pyrethroids |
|-------------------------------------|
| λ-cyhalothrin | Permethrin | Cypermethrin | Deltamethrin |
| R_fD | 0.005 | 0.05 | 0.01 | 0.01 |
| Cancer SF | - | 0.0184 | - | - |

Adult non-carcinogenic hazard index of pesticides

| Table 6. Hazard quotient (IQ) and hazard index (HI) of λ-cyhalothrin, permethrin, cypermethrin, deltamethrin for adult |
|--------------------------------------------------------------|
| Hazard quotient HQ adult |
| Head mustard | Leaf mustard | Choy sum | Bok choy |
| λ-cyhalothrin | 0.0140 | 0.0110 | 0.0113 | 0.0062 | 0.0426 |
| Permethrin | 0.0019 | 0.0025 | 0.0039 | 0.0023 | 0.0107 |
| Cypermethrin | 0.0160 | 0.0172 | 0.0142 | 0.0210 | 0.0683 |
| Deltamethrin | 0.0160 | 0.0172 | 0.0142 | 0.0210 | 0.0683 |
| Hazard index HI | 0.0479 | 0.0479 | 0.0436 | 0.0506 | 0.1900 |

Kid non-carcinogenic hazard index of pesticides

| Table 7. Hazard quotient (IQ) and hazard index (HI) of λ-cyhalothrin, permethrin, cypermethrin, deltamethrin for kid |
|--------------------------------------------------------------|
| Hazard quotient HQ kid |
| Head mustard | Leaf mustard | Choy sum | Bok choy |
| Hazard index HI | 0.0479 | 0.0479 | 0.0436 | 0.0506 | 0.1900 |
As the result in Table 6 and Table 7, HQ values of four pesticides via four vegetable in the study area are quite low, the combined hazard indexes for adult and kid are less than 1, meaning no significant non-cancer risk (US-EPA). Although the sum HI of four pyrethroids by four vegetable are below one, the estimated indexes show that HI for kid is higher almost twice than adult, the food for kids must being more strictly controlled. More care should be taken since residues could accumulate and expose chronic health hazards. Enforcing the management on using of toxic, educating the GAP farming to farmers should also be encouraged as it has the potential of reducing levels of pesticide residues in food. In a study by Yang [5], the hazard quotients to human due to fenvelerate and permethrin (pyrethroids) were reported in range 10^-8 to 10^-7 lower many times to HQ in this study. In a study in Arusha district, Tazania, 2019 by Kiwango, the risk of cumulative exposures to the organophosphate pesticide residues was above one and risk of cumulative exposures to the pyrethroids was lower than one [25]. Studies in Egypt, 2015 by Gad-alla S reported cumulative hazard indices for organophosphates higher than those of pyrethroids but both of them below one [26].

Incremental lifetime cancer risk ILCR

|                      | Adult     | Kid        |
|----------------------|-----------|------------|
| Head mustard         | 7.67E-07  | 3.07E-07   |
| Leaf mustard         | 9.78E-07  | 3.91E-07   |
| Choy sum             | 1.55E-06  | 6.22E-07   |
| Bok choy             | 9.08E-07  | 3.63E-07   |
| Sum ILCR             | 4.21E-06  | 1.68E-06   |

ILCR values of permethrin for adult and kid are less than 10^-6, mean non-carcinogen risk by these vegetable, except the value in Choy sum, 1.55x10^{-6}. The sum ILCR values by all four vegetable are 4.21x10^{-6} and 4.68x10^{-6} for both adult and kids, in range from 10^{-6} to 10^{-4}, meaning there is an acceptable or tolerable carcinogenic risk from these vegetable for consumers in this study area. (Table 8) Long-term pesticide exposure may lead to DNA damage and oxidative stress and also disrupt the endocrine system, which may lead to cancer. The WHO recognizes that tumours have been induced in rodents which were exposed to pyrethroids during their whole life, however, in 2001 the WHO considered that there were no clear indication of carcinogenicity relevant for human health risk.
assessments. Since these earlier WHO and IARC publications, Permethrin has been shown to be mutagenic in human and hamster cell cultures. So there were not much reports about carcinogen risk of permethrin via food.

4. Conclusion
The residues of λ-cyhalothrin, permethrin, cypermethrin, deltamethrin in four vegetable head mustard, leaf mustard, choy sum, bok choy were detected by GC/MS technique. The levels of these pesticides in some samples were above the maximum residue limit of Vietnam Government and FAO. There were no significant of health risk by these pesticides via digestion vegetable but the risk for kid was higher than for adult. Tolerable carcinogenic risk from these vegetable for consumers was evaluated.

5. References
[1] US EPA, 2018. "Basic Information about Pesticide Ingredients". US Environmental Protection Agency. Apr 2, 2018. Retrieved Dec 1, 2018.
[2] Gilden C, Huffling K and Sattler B 2010 Pesticides and health risks J. Obstet. Gynecol. Neonatal Nurs. 39 103–10
[3] Educational and Informational Strategies to Reduce Pesticide Risks 1997 Prev. Med. 26 191–200 Nasuti C, Carloni M, Fedeli D, Gabbianelli R, Di Stefano A, Serafina C, Silva I, Dominques V, and Ciccocioppo R 2013 Effects of early life permethrin exposure on spatial working memory, and on monoamine levels in different brain areas of pre-senescent rats Toxicology 303 162–168
[4] US EPA, 2017. "Types of Pesticide Ingredients". US Environmental Protection Agency. Jan 3, 2017. Retrieved Dec 1, 2018.
[5] Nriagu J O 2011 Pyrethroids in Encyclopedia of Environmental Health (Elsevier) pp 702-08
[6] WHO, 2016. Pesticide Evaluation Scheme, Vector Ecology and Management; World Health Organization: Geneva, Switzerland, 2016.
[7] US EPA, 1995. Cyhalothrin, Hazardous Substances Data Bank (HSDB). National Library of Medicine "Toxnet" Database, 4/95.
[8] Toynton K, Luukinen B, Buhl K, Stone D, 2009. Permethrin Technical Fact Sheet. National Pesticide Information Center, Oregon State University Extension Services: Baker City, OR, USA.
[9] Costa C, Rapisarda V, Catania S, DiNola C, Ledda C and Feng, C 2013 Cytokine patterns in green house workers occupationally exposed to-cypermethrin: An observational study Environ. Toxicol. Pharmacol 36 796–800
[10] Deltamethrin; Pesticide Tolerance. Fed. Regist. October 27, 2004, 69 (207), pp 62602-62615.
[11] Elwan M A, Richardson J R, Guillot T S, Caudle W M and Miller G W 2006 Pyrethroid pesticide-induced alterations in dopamine transporter function Toxicol. Appl. Pharmacol. 211 188–97
[12] Nasuti C, Carloni M, Fedeli D, Gabbianelli R, Di Stefano A, Serafina C, Silva I, Dominques V, and Ciccocioppo R 2013 Effects of early life permethrin exposure on spatial working memory and on monoamine levels in different brain areas of pre-senescent rats Toxicology 303 162–168
[13] Nasuti C, Fattoretti P, Carloni M, Fedeli D, Ubaldi M, Ciccocioppo R and Gabbianelli 2014. Neonatal exposure to permethrin pesticide causes lifelong fear and spatial learning deficits and alters hippocampal morphology of synapses J. Neurodev. Dis. 6 7
[14] Hai N T 2011 Thực trạng sử dụng hóa chất bảo vệ thực vật và giải pháp để phát triển bền vững cho sản xuất rau ở Việt Nam. Ký ức hồi nghĩ khoa học Môi trường và Công nghệ sinh học năm 2011, Trường Đại học Kỹ thuật Công nghệ TP.HCM, Khoa môi trường và công nghệ sinh học
[15] WHO/FAO, 2018. General standard for contaminants and toxins in food and feed CXS 193-1995.
[16] US EPA, 2010. Integrated Risk Information System (IRIS), United States Environmental Protection.
[17] US. EPA's Risk Assessment Forum published the Guidelines for the Health Risk Assessment of Chemical Mixtures in 1986 (U.S. EPA, 1986a).
[18] Yang F, Pauzi A, Nusrat B, Wan M, Wan M K 2016 Pesticides residues in agricultural soils and its health assessment for humans in Cameron Highlands, Maylaysia MJAS. 20 1346 – 58
[19] US. EPA, 1986. Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986b).
[20] Nghiem P T, 2012. Nghiên cứu, phân tích và đánh giá dư lượng thuốc bảo vệ thực vật trong sản phẩm rau, củ, quả trên địa bàn tỉnh Quảng Bình. Báo cáo nhiệm thu để tài cấp Tỉnh Quảng Bình.
[21] Hien N V, Vinh D T and Hung D X 2010 Điều tra, đánh giá hiện trạng sản xuất và mức độ ảnh hưởng trên sản xuất rau tại các vùng rau chủ lực cung cấp cho thành phố Hà Nội và thành phố Hồ Chí Minh Tạp chí Nông nghiệp và phát triển nông thôn 222-30
[22] Elgueta S, Moyano S, Sepúlveda P and Quiroz C, 2017. Pesticide residues in leafy vegetables and human health risk assessment in North Central agricultural areas of Chile. Food Additives and Contaminants: Part B. 10(2), pp 105 - 12.
[23] Pakvilai N, Prapamontol T, Phavornyutikarn T, Mangklabruks A, Chantara S and Santasup C 2011 Residues of synthetic pyrethroid pesticides in vegetables, fruit, sediment and water from an intensive agricultural area (Fang district, Chiang Mai, Thailand) WIT Trans. Ecol. Environ. 167 201-10
[24] Daniel A V 2003 Engineering the risks of hazardous wastes (Burlington: Butterworth-Heinemann) pp 299-306
[25] Kwango P A 2019 Risk assessment for dietary exposure of pesticides among vegetables consumers in Arusha, Tanzania. PhD Theses and Dissertation of Life science and Bio-engineering of Nelson Mandela African Institution of Science and Technology
[26] Gad-alla S A, Loutfy N M, Shendy A H and Ahmed M T 2015. Hazard index, a tool for a long term risk assessment of pesticide residues in some commodities, a pilot study Regul. Toxicol. Pharmacol. 73 985 - 91

Acknowledgments
Authors wishing to acknowledge assistance from colleagues of Center of Natural Resources and Environmetal Monitoring of Ha Nam Province.