

# Pesticide use and environmental contamination a study in Khao Koh District, Phetchabun Province, Thailand

Pesticide  
use and  
environmental  
contamination

173

Piraya Aungudornpukdee  
*Department of Environmental Health, Faculty of Public Health,  
Naresuan University, Phitsanulok, Thailand*

Received 17 December 2018  
Revised 18 December 2018  
Accepted 19 December 2018

## Abstract

**Purpose** – The purpose of this paper is to explore environmental contamination from pesticide use in a Khao Kho Sub-district, Khao Kho District in Phetchabun Province, Thailand.

**Design/methodology/approach** – The study area was made up of four villages: Kanok Ngam, Lao Lue, Lao Neng and Phet Dam, all mostly highland areas whose inhabitants are mainly from the hill tribes. The 548 participants were recruited with inclusion criteria being that they must be living in the area over one year and are agriculturists or relevant who use pesticides. The data collection was divided into two parts: first, population data using a questionnaire; and second, samples of environmental media including agricultural products gathered to analyze the contamination of pesticides. The data were analyzed using descriptive statistics.

**Findings** – The most planted crop was rice (53.52 percent). Regarding agricultural chemical uses, the study found that the majority of participants used herbicides (76.83 percent). In terms of herbicide uses, Glyphosate is the most used (39.59 percent). Furthermore, insecticide consumption uses were higher in Phet Dam village than the other villages. The most common uses were Carbaryl (20.66 percent), followed by  $\beta$ -Betoefluthrin (15.49 percent).

**Originality/value** – There were glyphosate and derivatives of glyphosate (Aminomethyl Phosphonic Acid) in soil and sediment samples, while herbicides and insecticides were not found in water and agricultural samples. Because these environmental contaminants are a major cause for health problems amongst producers and consumers alike, agriculturists should be supported by relevant organizations to increase organic crop cultivation methods and organic farming networks.

**Keywords** Pesticide residues, Pesticide use, Glyphosate

**Paper type** Research paper

## Introduction

At present, chemical usage in agriculture is widespread, especially among European and Asian countries including Thailand. The Office of Agricultural Economics[1] reported that Thailand imported 198,317 tons of hazardous agricultural chemicals which estimatedly cost 27,922 million Baht in the year 2017. Among these, the top three imported pesticides from the year 2011–2017 were revealed to be herbicides, insecticides and fungicides, respectively. In 2017, the top-five imported herbicides were glyphosate isopropylammonium, Paraquat dichloride, 2,4-D-dimethylammonium, Atrazine and Ametryn. Also, the top-five imported insecticides were recorded to be Chlorpyrifos, Cypermethrin, Carbaryl, Carbosulfan and Cartap hydrochloride[2]. In 2016, there were 8,689 patients suffering from pesticide-related health effects with a morbidity rate of 14.47 per 100,000. In total, 70.81 percent of them were in the 15–59 age group. From 2010 to 2015, the morbidity rate (caused by pesticides) increased from



© Piraya Aungudornpukdee. Published in *Journal of Health Research*. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at <http://creativecommons.org/licenses/by/4.0/legalcode>

Journal of Health Research  
Vol. 33 No. 2, 2019  
pp. 173-182  
Emerald Publishing Limited  
2586-940X  
DOI 10.1108/JHR-12-2018-0174

2.47 to 8.95 per 100,000[3]. Moreover, Phetchabun Province was ranked third amongst the number of patients affected by pesticide-related medical conditions.

Phetchabun Province is located in the lower northern region of Thailand which geographically slopes from the north toward the south. 45.78 percent of the land is covered in forests. Phetchabun has 11 districts: Mueang Phetchabun, Lom Sak, Chon Daen, Nong Phai, Bueng Sam Phan, Wichian Buri, Si Thep, Wang Pong, Nam Nao and Khao Kho. Khao Kho is a district located in the north of Phetchabun and is in the high land region[4]. Khao Kho sub-district is located in the west of Phetchabun Province. The area is about 1,333 square kilometers or about 833,125 Rai of which 73,608 Rai is agricultural land[5]. Some of this land is very steep at 500–1,400 meters height above sea level.

The population residing in Khao Kho sub-district consists of the hill tribes, namely, the Hmong, Yao and Lisu. They mostly earn a living by cultivation and use agricultural chemicals currently used widely such as chemical fertilizers, plant hormones, herbicides and insecticides to speed up the growth of plants, increase agricultural productivity and to kill pests. These chemicals not only deteriorate natural resources and environments in agricultural areas but also leave residues and contamination in crops[5]. The sub-district health promotional hospitals in Khao Kho district reported that more than 40 percent of people, made up mostly of hill tribe people, were at increased dangerous risk of illness from exposure to chemicals. Half of them possessed test results showing unsafe levels[6]. The aim of this research paper was to conduct a study about environmental problems caused by pesticide usage of people living in the highlands at Khao Kho Sub-district, Khao Kho District, Phetchabun Province in Thailand.

## Methodology

### *Research design*

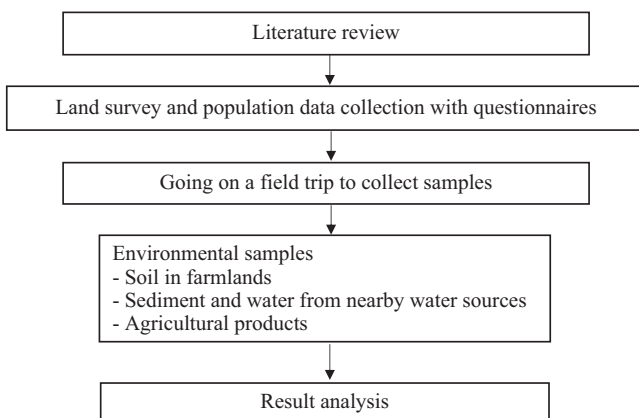
This cross-sectional study aimed to explore environmental contamination from pesticide use in the Khao Kho sub-district of Khao Kho District, Phetchabun Province. The study area was comprised of four villages: Kanok Ngam, Lao Lue, Lao Neng and Phet Dam which are highland areas comprising people belonging to the hill tribes (Hmong, Yao, Lisu). A total of 548 agriculturists were recruited as participants through random sampling with inclusion criteria being that participants had to have lived in the area over one year and had to be agriculturists or working in relevant fields involving pesticide usage.

The data collection was divided into two parts: first, population data were collected using a questionnaire which contained general data of villages such as personal data, socioeconomic data, kinds of cultivated plants, duration of growing plants (land preparation until harvest), and chemical usage in terms of types and quantity. The validity of the research tool was 0.67 – 1. Second, the 27 samples of environmental media including soil, water, sediment and agricultural products were gathered to analyze the contamination of pesticides.

Steps taken in conducting a study shown as Figure 1.

### *Sample groups*

*Soil samples from farmlands.* The size of farmland was used to determine the number of soil sampling using simple random sampling techniques. According to the criteria of the National Environment Board, Pollution Control Department, BE 2547[7] it was determined that ten sampling points should be surveyed in every 3.953 Acres (10 Rais) using simple random sampling. In each sampling point, the soil samples were collected in the same quantity and gathered into one sample for that area. A depth for collecting soil layer samples was about 15 centimeters or 6 inches by digging a V shape. Soil samples from the random sampling in each unit area were then collected in a container. The soil samples were spread on a canvas to get rid of moisture and then divided into 4 parts, known as a quartering procedure. Two parts of soil which were opposite to each other (about 500 grams – 1 kg) were collected into a



**Figure 1.**  
Methodology process

wide-mouthed amber colored glass bottle to prevent sunlight as the best representative soil and sent to a laboratory.

*Water samples.* The water samples were collected from water resources in nearby agricultural areas which are reservoirs for consumption and agricultural activity. The sampling point was chosen from two points using the grab sampling technique[8]. First, the upstream point was used as a reference sample because there was no agricultural activity in this area. Second, the downstream point was used to indicate agricultural chemical distribution including samples from water sources which were used for tap water. The water samples were kept in borosilicate glass at temperatures below 4°C and sent to a laboratory.

*Sediment samples.* The composite sampling technique was used for collecting sediment samples with a depth between 0 and 6 inches from water resources near agricultural areas. The sediment samples were kept in a black container. The sediment samples were dried using a freeze dryer and sent to a laboratory.

*Agricultural product samples.* The sample of agricultural products; rice, maize, ginger, and radish, were collected in edible parts using the random subsample technique. The sampling period was the harvest season. The agricultural product samples were kept in black containers at temperatures below 4°C to prevent sunlight and sent to a laboratory for residue agricultural chemicals analysis.

## Results

### *Demographic characteristics*

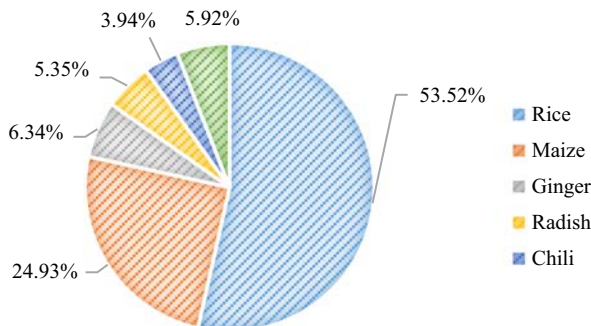
The study found that the majority of workers were male (69.7 percent), whose average age was 46.12 years (SD = 12.257) with participant ages ranging from 21 to 87 years. Almost all of them were married (85.6 percent). The average number of family members was 5.83 (SD = 3.213) and ranged between 1 and 21 members. In total, 88.0 percent of the participants had not had chronic disease by diagnosis and 88.5 percent of the participants did not take medicine regularly. Also, 82.3 percent of participants never had any illness until they stopped working in the past 12 months. Regarding occupational issues, the top-three problems included the price of agricultural chemicals (fertilizers/insecticides/herbicides/fungicide), pest/pestilence and soil deterioration which was 76.4, 74.3 and 68.6 percent, respectively, as shown in Table I.

### *Agricultural chemicals use*

The study found that the most popular crop was rice (53.52 percent). The others were maize, ginger, radish and chilli at 24.93, 6.34, 5.35 and 3.94 percent, respectively, as shown in Figure 2.

Variables	Number	Percentage
<i>Gender (548)</i>		
Male	382	69.7
Female	166	30.3
<i>Age (years) (520)</i>		
21–30	60	11.5
31–40	112	21.5
41–50	175	33.7
51–60	109	21.0
61–70	48	9.2
71–80	13	2.5
81–90	3	0.6
Mean = 46.12, SD = 12.257, Max. = 87, Min. = 21		
<i>Marital status (533)</i>		
Single	23	4.3
Married	456	85.6
Separated/Divorced/Widowed	54	10.1
<i>Number of family member (505)</i>		
Mean = 5.83, SD = 3.213, Max. = 21, Min. = 1		
<i>Having chronic disease by diagnosis (532)</i>		
No	468	88.0
Yes	64	12.0
<i>Taking medicines for treating chronic disease (529)</i>		
No	468	88.5
Yes	61	11.5
<i>Could not work because of illness within a year (531)</i>		
Never	437	82.3
Ever	94	17.7
<i>Occupation related problems (440)</i>		
Expensive agricultural chemicals (Fertilizer/Insecticide/Herbicide and Fungicide)	336	76.4
Pest infestation	327	74.3
Soil degeneration	302	68.6
Low yield	270	61.4
Lack of knowledge of chemicals used	164	37.3
Lack of water	64	14.5

**Table I.**  
Number and  
percentage of  
research populations



**Figure 2.**  
Percentage of the top  
five crops in the  
study area

It also found that radish was popularly planted in the Phet Dam village. This plant used insecticides more than other plants. Therefore, insecticide consumption was used more in the Phet Dam village than the others (Figure 2).

In terms of agricultural chemical use, the study found that the majority of participants used herbicides (76.83 percent), followed by insecticides and fungicide at 15.42 and 7.75 percent, respectively (Figure 3).

Regarding herbicide use, the study found that Glyphosate was the most used (39.59 percent), followed by Metsulfuron-methyl, Paraquat, and mixed Chlorimuron-ethyl + Metsulfuron-methyl, and Atrazine at 26.11, 14.33, 10.46 and 6.31 percent, respectively.

In terms of insecticide use, the study found that insecticide consumption was used more frequently in the Phet Dam village than others. The most common uses were Carbaryl (20.66 percent), followed by  $\beta$ -Betoefluthrin, Carbofuran and Abamectin at 15.49, 7.51 and 6.57 percent, respectively.

### Environmental contamination

#### Soil samples

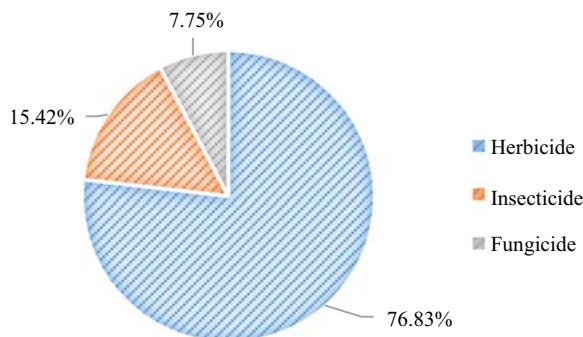
Six samples; S001, S002, S003, S004, S005 and S006, were collected from farmland. Most of the soil samples had pH 4.12–4.71 with the range of cation exchange capacity being 5.09–7.90 cmolc/kg and organic matter being 2.36–2.79 g/100 g (%w/w). These indicated that soil fertility was at a moderate level[9]. The results showed that glyphosate residues were found to be higher in sample numbers S001, S003 and S005 than Aminomethyl Phosphonic Acid (AMPA) which are derivatives of glyphosate. On the other hand, AMPA levels were found to be higher in sample numbers S002, S004 and S006 (Figure 4). However, the Paraquat, Abamectin and Carbamate groups were not detected with the limit of detection (LOD) being 0.05 mg/kg, 0.01 mg/kg, and 0.01 mg/kg, respectively.

#### Water samples

Ten water samples were collected and results found that both herbicides and insecticides were not detected. The LOD of Abamectin, Paraquat, Glyphosate and Carbamate group were 0.005 mg/L, 0.01 mg/L, 0.005 mg/L and 0.0001 mg/L, respectively.

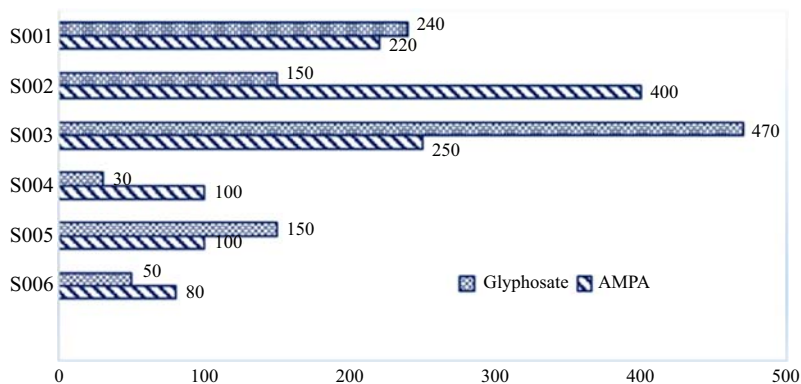
#### Sediment samples

The study showed that Glyphosate residues and AMPA residues were found in the four sediment samples. All samples contained glyphosate residues ranging from 40 to 420  $\mu\text{g}/\text{kg}$  and AMPA residues ranged from 20 to 270  $\mu\text{g}/\text{kg}$  as shown in Figure 5. Moreover, the highest residue levels of both glyphosate and AMPA were found in sample SD003 which was collected from the water source for supplying the village with water.

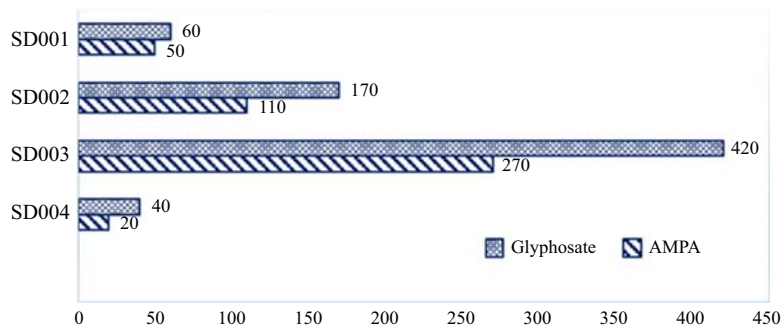


**Figure 3.**  
Percentage of  
agricultural  
chemicals use

**Figure 4.**  
Residues of  
glyphosate and  
AMPA in soil  
samples (mg./kg.)



**Figure 5.**  
Residues of  
glyphosate and  
AMPA in the  
sediment samples  
( $\mu\text{g./kg.}$ )



#### *Agricultural product samples*

The study found that both the residual insecticide and herbicide levels were not detected in all samples. The LOD of glyphosate, paraquat, abamectin and carbamate groups were 0.01 mg/kg, 0.01 mg/kg, 0.01 mg/kg and 0.005 mg/kg, respectively.

## **Discussion**

### *Soil samples*

The results showed that glyphosate and AMPA were detected in soil samples, which might be because hill tribe agriculturists most commonly use glyphosate which can be biodegraded by microorganisms attributed to derivatives of glyphosate (AMPA). These findings are consistent with Battaglin *et al.*[10] who found that microorganisms mainly contribute glyphosate to AMPA. The half-life of AMPA is 60–240 days and can be decomposed to inorganic phosphate, ammonium ions and carbon dioxide eventually.

According to the World Health Organization statement in 1994[11], glyphosate accumulation in the soil will be increased and the numbers of earthworms tend to decrease if agriculturists used glyphosate continuously and/or in increasing amounts. A few studies found that glyphosate residue in the soil affects cucumber seedling growth with the highest toxicity found in mixed glyphosate soil. Furthermore, there is no difference of level of toxicity between 0 and 60 days[12, 13]. In addition, if the amount of glyphosate is over 500 mg/kg, it can affect or be toxic to earthworms and microorganisms.

### *Water samples*

Glyphosate was not detected in water samples, which might be because the glyphosate moved to bind with suspended particles in water and dropped into the water that turned to sediment which is consistent with Kirkwood[14] where it was found that glyphosate could disappear from treated water by dilution or adsorption to bottom sediments. With reference to the Joint FAO/WHO Meeting on Pesticide Residues in 1998[15], the working party recommended an acceptable daily intake of glyphosate or AMPA at 0.3 mg/kg body weight and for drinking water standards must not exceed 0.9 mg/L whereas the default assumption for adult body weight is 60 kg per 2 liters of drinking water.

### *Sediment samples*

Glyphosate is the agricultural chemical most often used to prepare the soil for cultivation. There was a chance that the chemicals will be eroded into the river as well as the soil that has anionic properties that can be bound with Glyphosate which can have a half-life in the soil for 3–130 days[13, 16]. Also, it is consistent with Watts[17] where it is stated that glyphosate was detected in sediment in the sea in New Zealand possibly caused by spraying glyphosate to kill grass on the street. Moreover, derivatives of glyphosate can be found regularly as glyphosate can be degraded by microorganisms[18].

### *Agricultural product samples*

According to the study of Glass[19], glyphosate can be bound with soil particles. This affects plants and cannot be absorbed into the stem while it can be absorbed through the leaves. However, the agricultural product samples were collected in a single-period. Therefore, the results showed that the residue of pesticides were not detected and cannot be used to confirm the residue of pesticides in agricultural production.

### *Health impacts*

The use of glyphosate and its slow rate of decomposition that causes the breakdown product AMPA in the soil, water, and sediment as well as the accumulation of glyphosate in the environment affects our health. The International Agency for Research on Cancer[20] reclassified glyphosate as category 2A: probably carcinogenic to humans. Additionally, various studies have documented the negative impacts of exposure to glyphosate on human health. According to the study of Fortes *et al.*[21], frequent use of pesticides (once a month or more vs less than once a month) was associated with an increased risk of melanoma, although this is not statistically significant. However, the use of pesticides for ten years or more was associated with a seven times increased risk of melanoma (OR 7.40). Exposure to at least two types of pesticides was associated with four times the increased risk of melanoma (OR 4.04). After controlling for all possible confounders, an increased risk for melanoma was associated with the use of herbicides (OR 3.08). While, a panel study of Adriana Camacho and Daniel Mejia[22] indicated that exposure to the glyphosate in aerial spraying campaigns increases the number of medical consultations related to dermatological and respiratory illnesses, as well as the number of miscarriages.

Fluegge and Fluegge[23] found that a 1 kg increase in glyphosate use in one year positively predicts state-level all-listed attention-deficit hyperactivity disorder (ADHD) discharge diagnoses the following year (coefficient = 5.54E-08,  $p < 0.01$ ) and the effects of urbanization on the relationship between glyphosate use and ADHD indicates that the relationship is marginally significantly positive in urban US cities ( $p < 0.025$ ). Also, correlations have been found between increased glyphosate use and a wide variety of human diseases, including various forms of cancer, kidney damage and mental conditions such as ADHD, autism, Alzheimer's and Parkinson's disease[24].

Furthermore, glyphosate may contribute to gut dysfunction and the development of celiac disease by inhibiting the breakdown of proteins such as gluten. There was evidence to suggest that the herbicide compromises commensal gut flora and, through various mechanisms, contributes to microvilli damage and nutrient malabsorption including impaired neurotransmitter production[25, 26]. Several studies found an increased risk for non-Hodgkin's lymphoma in individuals who were occupationally exposed to pesticides or herbicides, including glyphosate, in the USA, Canada and Sweden; testing for glyphosate, which was conducted through blood and urine, detected glyphosate at high levels in agricultural workers and showed a dose-dependent response. In addition, one study also found an increase in micronuclei, a blood marker for genotoxicity, chromosomal damage and cellular oxidative stress in residents of communities where glyphosate was sprayed[20]. Moreover, glyphosate has been shown to also affect other functions of the body such as defective insulin receptor functions[27].

While human trials examining glyphosate toxicity and cancer are still limited, we should still take into consideration glyphosate's effects on rats and mice and the possibility that some of these effects could be relevant for humans as well. Several studies have found renal tubule carcinoma, haemangiosarcoma, skin tumors and pancreatic islet-cell adenoma in animals experimentally exposed to glyphosate[20]. Some studies found livestock to become ill due to animal feed containing high concentrations of glyphosate. Also, it discovered glyphosate in meat and has postulated that glyphosate can pass the placental barrier to reach the embryos, as well as accumulate in fat tissue[28]. A study in dairy cows found that glyphosate affected the liver and muscle cells including high urea level in urine that could be due to nephrotoxicity of glyphosate[29].

### Conclusion

This study demonstrated that the application of pesticides was observed to be widely applied in the agricultural sectors of Khao Koh district, Phetchabun Province. The results showed that there were glyphosate and derivatives of glyphosate (AMPA) in soil and sediment samples, while herbicides and insecticides were not found in water and agricultural samples. This environmental contamination is the major cause of health impacts for producers and consumers alike. Therefore, agriculturists should be supported by related organizations to increase organic cultivation including enhancing systems to increase organic farming networks.

### References

1. Office of Agricultural Economics, Department of Agriculture, Thailand. Imported volume and value of agricultural hazardous chemicals 2011-2017, 2018. [cited 2018 Aug 3]. Available from: <http://oldweb.oae.go.th/economicdata/pesticides.html>
2. Bureau of Agricultural and Agricultural Materials Control, Department of Agriculture, Thailand. Statistics of imported hazardous chemicals, 2017. [cited 2018 Aug 3]. Available from: [www.doa.go.th/ard/FileUpload/hazzard/Import%20DATA/Top%2010%20Import%20of%20Hazardous%20\(B.E.%20202560\).pdf](http://www.doa.go.th/ard/FileUpload/hazzard/Import%20DATA/Top%2010%20Import%20of%20Hazardous%20(B.E.%20202560).pdf)
3. Bureau of Occupational and Environmental Disease, Thailand. Situation of occupational disease and environment in Thailand, 2017. [cited 2018 Aug 3]. Available from: <http://envocc.ddc.moph.go.th/uploads/Occupational%20Health/MOH%20SEM%201-4/1/1.4%20situation.pdf>
4. Phetchabun Provincial Office, Thailand. General information Phetchabun Province, 2012. [cited 2018 Aug 3]. Available from: [www.phetchabun.go.th/data\\_detail.php?content\\_id=3](http://www.phetchabun.go.th/data_detail.php?content_id=3)
5. Khao Kho Agriculture Office, Thailand. Documentation for the second round of fiscal year 2013. Khao Kho: Khao Kho Agriculture Office; 2013.
6. Pan Sukhum Sub-district Health Promoting Hospital, Thailand. Hill tribe's health information. Phetchabun: Pan Sukhum Sub-district Health Promoting Hospital; 2012.

7. Ministry of Natural Resources and Environment, Thailand. Pollution control department. announcement of the national environment board B.E.2547: soil quality standard. [cited 2018 Aug 3]. Available from: [http://infofile.pcd.go.th/law/9\\_1\\_soil.pdf?CFID=2328567&CFTOKEN=87836067](http://infofile.pcd.go.th/law/9_1_soil.pdf?CFID=2328567&CFTOKEN=87836067)
8. Ministry of Natural Resources and Environment, Thailand. Pollution control department: water collection manual. [cited 2018 Aug 3]. Available from: [http://infofile.pcd.go.th/water/Water\\_CollNat\\_Manual.pdf](http://infofile.pcd.go.th/water/Water_CollNat_Manual.pdf).
9. Ministry of Agriculture and Cooperatives, Thailand. Land development department. Soil analysis manual. Bangkok: Ministry Agriculture and Cooperatives; 2010. [cited 2018 Aug 3]. Available from: [www.ldd.go.th/PMQA/2553/Manual/OSD-03.pdf](http://www.ldd.go.th/PMQA/2553/Manual/OSD-03.pdf)
10. Battaglin WA, Meyer MT, Kuivila KM, Dietze JE. Glyphosate and its degradation product AMPA occur frequently and widely in U.S. soils, surface water, groundwater and precipitation. *J Am Water Resour Assoc.* 2014; 50(2): 275-90.
11. World Health Organization [WHO]. Environmental health criteria 159: Glyphosate. Geneva: WHO; 1994.
12. Chuichai W, Thummatun N, Somtrakul K. Toxicity of glyphosate contamination in soil and plant residues on cucumber seedling growth. *J of Agricultural Res and Extension.* 2013; 30(1): 25-32
13. Cornell University, UK. Glyphosate. extension toxicology network, pesticide information profiles. [cited 2018 Aug 3]. Available from: <http://extoxnet.orst.edu/pips/glyphosa.htm>
14. Kirkwood RC. *Advance in pesticide science.* Oxford: Pergamon Press; 1979; 420-9
15. Food and Agricultural Organization [FAO], World Health Organization [WHO]. *Pesticide residues in food 1997, evaluations: part II, Toxicological and environmental.* Geneva: WHO; 1998.
16. Morillo E, Undabeytia T, Maqueda C, Ramos A. Glyphosate adsorption on soils of different characteristics: influence of copper addition. *Chemosphere.* 2000 Jan; 40(1): 103-7.
17. Watts M. Glyphosate; 2012 PANAP (PDF). [cited 2018 Aug 3]. Available from: <https://d3n8a8pro7vhnmx.cloudfront.net/yesmaam/pages/680/attachments/original/1467028803/pesticides-factsheet-specialrelease-glyphosate.pdf?1467028803>
18. Schuette J. Environmental fate of glyphosate, 1998. [cited 2018 Aug 3]. Available from: [www.cdpr.ca.gov/docs/emon/pubs/fatememo/glyphos.pdf](http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/glyphos.pdf)
19. Glass RL. Adsorption of glyphosate by soil and clay minerals. *J Agric Food Chem.* 1987; 35(4): 495-500.
20. Guyton KZ, Loomis D, Grosse Y, El Ghissassi F, Benbrahim-Tallaa L, Guha N, *et al.* Carcinogenicity of tetrachlorvinphos, parathion, malathion, diazinon, and glyphosate. *Lancet Oncol.* 2015 May; 16(5): 490-1. doi: 10.1016/S1470-2045(15)70134-8. Epub 2015 Mar 20.
21. Fortes C, Mastroeni S, Segatto MM, Hohmann C, Miligi L, Bakos L, *et al.* Occupational exposure to pesticides with occupational sun exposure increases the risk for cutaneous melanoma. *J Occup Environ Med.* 2016 Apr; 58(4): 370-5. doi: 10.1097/JOM.0000000000000665
22. Camacho A, Mejía D. The health consequences of aerial spraying illicit crops: the case of Colombia. *J Health Econ.* 2017; 54(Jul): 147-60. doi: 10.1016/j.jhealeco.2017.04.005. Epub 2017 May 13.
23. Fluegge KR, Fluegge KR. Glyphosate use predicts healthcare utilization for ADHD in the Healthcare Cost and Utilization Project net (HCUPnet): a two-way fixed-effects analysis. *PLoS One.* 2015 Aug 19; 10(8): 1489-503. doi: 10.1371/journal.pone.0133525. eCollection 2015.
24. Van Bruggen AHC, He MM, Shin K, Mai V, Jeong KC, Finckh MR, *et al.* Environmental and health effects of the herbicide glyphosate. *Sci Total Environ.* 2018; 616-617(Mar): 255-68. doi: 10.1016/j.scitotenv.2017.10.309. Epub 2017 Nov 5.
25. Samsel A, Seneff S. Glyphosate, pathways to modern diseases II: Celiac sprue and gluten intolerance. *Interdiscip Toxicol.* 2013 Dec; 6(4): 159-84. doi: 10.2478/intox-2013-0026
26. Samsel A, Seneff S. Glyphosate's suppression of cytochrome P450 Enzymes and Amino Acid biosynthesis by the gut microbiome: pathways to modern diseases. *Entropy.* 2013; 15(4): 1416-63. doi: 10.3390/el5041416

27. Samsel A, Seneff S. Glyphosate pathways to modern diseases V: amino acid analogue of glycine in diverse proteins. *J Biological Physics and Chemistry*. 2016;16(Jun): 9-46. doi: 10.4024/03SA16A.jbpc.16.01
28. Wasley A. Deformities, sickness and livestock deaths: the real cost of glyphosate and GM animal feed? *The Ecologist*, Nov 28 2013. [cited 2018 Sep 20]. Available from: <https://theecologist.org/2013/nov/28/deformities-sickness-livestock-deaths-real-cost-glyphosate-gm-animal-feed>
29. Krüger M, Schrödl W, Neuhaus J, Shehata AA. Field investigations of glyphosate in the urine of Danish dairy cows. *J Environ Anal Toxicol*. 2013; 3(5): 1-7. doi: 10.4172/2161-0525.1000186

**Corresponding author**

Piraya Aungdornpukdee can be contacted at: [pirayaa@nu.ac.th](mailto:pirayaa@nu.ac.th)

---

For instructions on how to order reprints of this article, please visit our website:

[www.emeraldgroupublishing.com/licensing/reprints.htm](http://www.emeraldgroupublishing.com/licensing/reprints.htm)

Or contact us for further details: [permissions@emeraldinsight.com](mailto:permissions@emeraldinsight.com)