

# Health Risk Assessment on the Glyphosate Exposure of Knapsack Sprayers

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## Abstract

**Context:** Herbicide poisoning has been increasing among agriculturists in the northeast of Thailand. The aim of this cross-sectional study was to assess the health risk of glyphosate exposure among knapsack sprayers. A health risk assessment matrix was applied to 243 sprayers by considering the extent of glyphosate exposure per year according to the actual amount of glyphosate (48 %w/v) dispensed and frequency of exposure. In addition, use of personal protective equipment (PPE) was taken into account. The second component of the risk matrix was the severity of the recorded adverse effects in the same group. The results revealed that 76.95% of sprayers were slightly exposed (100 to 499 milliliters of glyphosate used per year) and 57.20% wore at least four types of protection, comprised from any of the following types: gloves, mask, boots, trousers, long-sleeved shirt, and others. A majority had a slight likelihood of glyphosate exposure (69.14%) and a minority experienced a mild level of adverse symptoms (17.28%), including rash, dizziness and headache. Some sprayers (36.20%) had a health risk of glyphosate exposure higher than an acceptable level, which might explain the adverse health effects of long-term exposure. This health risk assessment tool combined with PPE usage of a herbicide applicator would be useful for the health surveillance program.

**Keywords:** *Glyphosate, Health risk assessment, PPE, Sprayer*

## Introduction

Health effects from the application of herbicide is a current problem among Thailand's farmers. From 2011-2017, herbicide was the most imported of all pesticides used for agriculture; the highest quantity and value of herbicide was reported in 2017 by the Office of Agricultural Data. Glyphosate is widely known and is a herbicide intensively used by farmers to control weeds and to increase production. The highest amount of glyphosate-isopropylammonium was imported in 2018 and its use is likely to increase further<sup>1,2</sup>.

Generally, glyphosate is considered to be a non-selective herbicide. The commercial formulations of glyphosate contain surfactants that vary in nature and concentrations that increase pure glyphosate toxicity, and are known by a variety of names<sup>3</sup>. Glyphosate toxicity inhibits cytochrome P450 (CYP) enzymes in mammals, and could be a factor in the following diseases: obesity, depression, autism, Alzheimer's disease, Parkinson's disease, multiple sclerosis, cancer, cachexia, infertility and malformation development<sup>4</sup>.

Hence, the International Agency for Research on Cancer (IARC) determined that glyphosate was probably carcinogenic to humans (group 2A), and the case control studies of occupational exposure in the USA, Canada and Sweden showed an increased risk of non-Hodgkin's lymphoma<sup>5</sup>. Occupational exposure to glyphosate was associated with a high risk of cutaneous melanoma<sup>6</sup>.

Although pure glyphosate probably has low toxicity, it is increased by the volume of surfactants in

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formulations marketed for domestic use. Consequently, farmers are occasionally exposed to glyphosate formulations more than in other careers while working on mixing and loading applications, and other processes. In France, detected glyphosate reached a peak of 9.5 µg/L in the urine samples of farmers who sprayed glyphosate<sup>7</sup>. The highest concentration of atmospheric glyphosate (42.96 µg/m<sup>3</sup>) was measured in the air of the operator's breathing zone<sup>8</sup>. Therefore, workers exposed to glyphosate through the inhalation route excreted glyphosate in the urine. Reported cases of the toxic effects of pesticides from 2007-2013 were found predominantly in the northeastern region of Thailand<sup>9</sup>.

Thailand's farmers' attitudes toward pesticide knowledge, behaviors using pesticides, and use of personal protective equipment (PPE) have been unsafe with regard to occupational practices of pesticide use<sup>10</sup>. Health risk behaviors regarding agrochemical use have been a lack of attention to safety precautions and the use of inappropriate protective equipment<sup>11</sup>. Currently, there are no glyphosate regulations or standards in occupational health and safety, which is concerning with regard to the health effects on farmers exposed to glyphosate. Hence, the aim of this study was to apply a health risk assessment matrix by considering the likelihood of glyphosate exposure combined with personal protective equipment (PPE) use behavior and adverse effects to predict farmers' risk and create guidelines for health surveillance.

## Material and Method

**Data Collection:** The study was designed as a cross-sectional study and carried out from November to December 2019; the sample was chosen from 487 farmers who performed pesticide application and whose information was in the Nampong district office of Public Health record. From these farmers, 243 farmers were eventually chosen to be included in the study; this number was calculated under the known number of population in a small size<sup>12</sup>, and by using a previous finding of proportion of glyphosate detection in urine of 0.60<sup>13</sup>. Data was collected by using a questionnaire on personal data, health effects, application information and personal protection equipment. The second tool was an applied risk matrix for health risk assessment, which consisted of two parts: likelihood of glyphosate exposure and severity of subsequent symptoms from exposure to glyphosate. The section on PPE use was an additional component used to assess any decrease in the likelihood

of exposure<sup>14</sup>.

**Health Risk Assessment Tool:** In the present study, the likelihood of glyphosate exposure (amount of pure glyphosate multiplied by spraying frequency per year) was divided into four levels of scoring according to the quantity of glyphosate applied per year: score of 1: below 100 milliliters; score of 2: 100-499 liters; score of 3: 500-1000 milliliters; and a score of 4: above 1000 milliliters. PPE use behavior was classified as one of four scores: score of 0: wearing at least four types of PPE comprised from rubber gloves, N95 /carbon mask, boots, trousers, long-sleeved shirt or others; score of 1: wearing at least four types of PPE comprised from any type of gloves, mask, boots, trousers, long-sleeved shirt or others; score of 2: at least three types of PPE comprised from any type of gloves, mask, boots, trousers, long-sleeved shirt or others; and score of 3: at least two types of PPE comprised from any type of gloves, mask or others. Therefore, four levels of likelihood of glyphosate exposure according to quantity of glyphosate applied and use of PPE were calculated by using a behaviour score combination as follows: level 1 is a low likelihood of exposure (score: 1-2), level 2 is a slight likelihood of exposure (score: 3-4), level 3 is a moderate likelihood of exposure (score: 5-6) and level 4 is a high likelihood of exposure (score: 7).

Severity of glyphosate toxicity experienced six months after application was assessed by using a symptom questionnaire which looked at the adverse health effects according to four criteria: level 1 is no symptoms expressed, level 2 is mild symptoms (headache, dizziness, rash, cough, numbness, stuffy nose, sore throat, hand irritation, itchy skin, drowsiness, fatigue and xerostomia), level 3 is moderate symptoms (nausea, vomiting, chest pain, oliguria, skin burning, burning-stinging-itchy eyes, eczema, blurred vision, exfoliation and diarrhea) and level 4 is severe symptoms (wheezing, hematemesis, kidney failure, pneumonia, shock and syncope). Finally, the likelihood and severity of glyphosate exposure scores were applied in the health risk assessment matrix<sup>14</sup>, in which four resulting risk levels were calculated: level 1 is acceptable risk (score: 1-2), level 2 is low risk (score: 3-4), level 3 is medium risk (score: 6-9) and level 4 is high risk (score: 12-16).

## Results

The results revealed that a majority of the 243 farmers (88.07%) were male. The participants' ages

ranged from 50 to 69 years old, with an average age of 53.0±9.19 years. A majority of farmers (73.25%) had completed primary school and 45.68% of participants had an average income of about 50,855 baht per year. The farmers' glyphosate spraying experience was divided into periods of 5 to 10 years (43.62%), 11 to 20 years (25.93%), less than 5 years (18.11%) and more than 20 years (12.35%). The percentage of farmers who sprayed glyphosate as non-employees was 69.14%, while 28.40% sprayed as both non-employees and employees and 12.35% sprayed only as employees. Approximately 60.49% of farmers had a frequency of exposure which was below five times per year, with an average frequency of 9.64 times per year.

**Glyphosate exposure according to application amount and PPE use:** The majority of farmers who participated in this study (76.95%) had an applied glyphosate (48%w/v) amount per year resulting in a score of 2, while a minority had an applied amount resulting in a score of 3 and a score of 1, respectively, as shown in Table 1.

**Table 1: Glyphosate amount exposed to from application (quantity per year)**

Score	Glyphosate exposure (milliliters)	Number (%)
1	< 100	19(7.82)
2	100-499	187(76.95)
3	500-1000	30(12.35)
4	>1000	7(2.88)

The PPE that was most widely worn was a combination of four types of PPE, from any type of gloves, mask, boots, trousers, long-sleeved shirt or others, worn by 57.20% of farmers, while overall, the best combination tended to be one comprised from rubber gloves, N95 /carbon mask, boots, trousers, long-sleeved shirt and others, worn by 5.76% of farmers, as shown in Table 2.

**Table 2: Personal protective equipment usage behavior**

Score	PPE usage	Number(%)
0	at least four types of PPE comprised of rubber gloves, N95 / carbon mask, and two other types	14(5.76)
1	at least four types of PPE comprised of any type of gloves and three other types	139(57.20)
2	at least three types of PPE comprised of any type of gloves and two other types	42(17.28)
3	at least two types of PPE comprised of any type of gloves, mask or others	48(19.75)

**Health risk Assessment:** The participants were assessed with regards to the likelihood of glyphosate exposure according to quantity of glyphosate applied combined with PPE use. Accordingly, the likelihood of glyphosate exposure was found to be slight in 69.14% of cases, moderate in 20.99% of cases, and low in 9.05% of cases, as shown in Table 3.

**Table 3: Likelihood of exposure according to quantity of glyphosate used and PPE**

Likelihood	Number(%)
Low	22(9.05)
Slight	168(69.14)
Moderate	51(20.99)
High	2(0.82)

The severity of health adverse effects with regard to symptoms associated with glyphosate usage was assessed by using a questionnaire, and it was found that 186 (76.54%) of the farmers had a history of glyphosate exposure but no signs or symptoms of poisoning. The other 42 (17.28%) farmers had mild symptoms, of which the three main symptoms expressed were rash (9.47%), dizziness (8.23%) and headache (7.82%), while the most reported moderate symptom was burning-stinging-itchy eyes (4.12%), as shown in Table 4.

**Table 4: Severity of adverse symptoms among sprayers**

Mild symptom	Number(%)	Moderate symptom	Number(%)
Headache	19(7.82)	Nausea	2(0.82)
Dizziness	20(8.23)	Vomiting	3(1.23)
Rash	23(9.47)	Oliguria	1(0.41)
Cough	7(2.88)	Skin burning	3(1.23)

Mild symptom	Number(%)	Moderate symptom	Number(%)
Numbness	2(0.82)	Burning-stinging-itchy eyes	10(4.12)
Stuffy nose	14(5.76)	Eczema	3(1.23)
Sore throat	1(0.41)	Exfoliation	1(0.41)
Hand irritation	1(0.41)	Diarrhea	2(0.82)
Itchy skin	1(0.41)		
Drowsiness	1(0.41)		
Fatigue	1(0.41)		
Xerostomia	1(0.41)		

Therefore, 155 (63.79%) of the participating farmers had an acceptable level of risk, 25.51% had a low level of risk, 10.70% had a medium level of risk and no farmers were found to have a high level of risk in the present study, according to the matrix in which health risk assessment was combined with personal protective equipment usage (PPE), as shown in Table 5.

**Table 5: Matrix of health risk assessment combined with PPE usage among sprayers**

Severity of symptoms	Likelihood of exposure; number(%)				Risk		
	Low(1)	Slight(2)	Moderate(3)	High(4)	Score	Risk	Level
Severe(4)	0	0	0	0	12-16	High	4
Moderate(3)	1(0.41)	8(3.29)	6(2.47)	0	6-9	Medium	3
Mild(2)	4(1.65)	26(10.69)	12(4.94)	0	3-4	Low	2
None(1)	17(6.99)	134(55.15)	33(13.58)	2(0.82)	1-2	Acceptable	1

## Discussion

Farmers mix amounts of pure glyphosate (48% w/v) which are quite low in knapsack containers. Most farmers use backpack sprayers with a volume capacity of 10 to 20 liters<sup>15</sup>. More than half of the farmers in the present study had a spraying frequency of less than five times per year, probably resulting in a low level of annual exposure among the participants. More than half of the farmers exhibited good behavior with regard to PPE usage, which agreed with a study in eastern Thailand which reported that 80% of farmers had a high level of self-protection by wearing mask, glasses, rubber gloves, trousers, long-sleeved shirt, boots and hat while spraying<sup>16</sup>. In northern Thailand, farmers who applied herbicide did not use PPE such as gloves, mask and goggles all the time, while some farmers also used them improperly and lacked attention with regard to protective equipment<sup>17,18</sup>. In one Thai study, it was found that less than half of the Thai farmers knew that they should use PPE while spraying<sup>19</sup>, while the study also reported that almost half of the farmers exhibited unsafe behavior in the use of PPE<sup>20</sup>. While spraying, workers either did not have access to a filter mask or did not want to wear it in hot weather conditions, indicating

use was unbearable<sup>21</sup>. In our study, about one fifth of the farmers exhibited improper usage of PPE, which led to an increased likelihood of glyphosate exposure.

In northern Thailand, another study found that the highest percentage of farmers with health effects were those who exhibited mild symptoms of headache, dizziness and rash or roseola symptoms after pesticide application<sup>22</sup>. This study found that farmers expressed burning-stinging-itchy eyes and skin burning as per previous reports<sup>23</sup>.

In this study, the fact that severe symptoms were not found may be since pure glyphosate has very low toxicity to humans in short-term exposure. However, acute effects caused by glyphosate have been reported, such as drowsiness, vomiting, sore throat and an alert mental state which may result in suicide attempts and accidents<sup>24</sup>.

In the present study, a health risk assessment combined with PPE usage showed that some sprayers were at risk of long-term adverse health effects. The sprayers had a low to medium level of health risk according to actual amounts of glyphosate dispensed,

frequency of exposure, and behavior in the use of PPE. Therefore, primary health care centers should be able to assess the health risks of herbicide application among farmers through health surveillance programs.

### Conclusion

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**Ethical Clearance:** The study received ethical approval from the Khon Kaen University ethics committee in human research, Khon Kaen University (HE 612297).

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