# RISK ASSESSMENT FOR DERMAL EXPOSURE OF ORGANOPHOSPHATE PESTICIDES IN RICE-GROWING FARMERS AT RANGSIT AGRICULTURAL AREA, PATHUMTHANI PROVINCE, CENTRAL THAILAND

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**ABSTRACT:** This cross-sectional descriptive study investigated the dermal exposure of organophosphate (Ops) pesticides and assessed the health risk due to Chlorpyrifos and Profenofos among rice farmers in the Rangsit Agricultural Area, Pathumthani Province, central Thailand. Interviews were conducted with 29 subjects to understand the characteristics of the rice farmers in the community. Neurological signs and symptoms that could be related to organophosphate pesticides existed among the community. The respondents generally could not identify the names of the pesticides which could cause their symptoms. The most common pesticides used were Chlorpyrifos, Dicroptophos and Abamectin. Neighbor influence was an important factor in pesticide purchasing. The surveyed farmers used at least one type of hazardous pesticide; often mixed more pesticides than recommended in each spray and even more if the previous application was ineffective, which shows that the sampled farmers are of particular concern since they were experiencing extensive potential exposure to harmful pesticides. In the risk assessment portion, hand-wipe samples were collected from 14 subjects who sprayed organophosphate pesticides, specifically Chlorpyrifos and Profenofos. The residues of Chlopyrifos and Profenofos contaminated on the hands of the rice farmers were quantified. The median concentration of Chlorpyrifos was 1.955 mg/Kg, and concentrations ranged from 0.29 to 105.62 mg/Kg. The median concentration of Profenofos was 2.62 mg/Kg, and concentrations ranged from 0.51 to 22.86 mg/Kg. The results indicated that the occupational exposure pathway through dermal (hands) were significantly higher than the reference doses (RfDs) according to US EPA in Chlorpyrifos for one subject ($HQ_{Chlorpyrifos}$ >1) , whereas all 14 subjects were at risk of Profenofos ($HQ_{Profenofos}$>1), and the mixture of both Chlorpyrifos and Profenofos via hand contamination($HI_{Chlorpyrifos, Profenofos}$ >1). Long term dermal exposure of these two organophosphate pesticides in these rice farmers may result in chronic adverse health effects. Risk was found to be highly variable with exposure all in terms of years of exposure, weeks and hours of work, as well as the farmers' job classes. To improve risk evaluation, standardization of environmental laboratory performance, as well as further researches to close many gaps in exposure measures in existing databases are desired.

**Keywords:** organophosphate pesticides, pesticide dermal exposure, human Health risk assessment, pesticide applicators, hand-wipe sampling

**INTRODUCTION:** Thailand leads the world in producing and exporting agricultural products. To minimize crop damage and increase productivity, pesticide use becomes an essential practice. Since the ban of organochlorine pesticides in Thailand, Organophosphates (Ops) become the most widely used imported pesticide. The most insecticide-intensive crops in Thailand are rice, tropical fruit, cassava, cotton, soybean, sugarcane, vegetable, and chili[1)] Ops are potent nerve agents. These compounds can exert adverse effects primarily cholinergic toxicity in non-target species including

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humans. They inhibit the action of acetylcholinesterase at the neuromuscular junctions. Signs and symptoms of acute Ops toxicity include bronchospasm, bradycardia, muscle weakness, hypertension, central nervous depression, or even coma[2]. In chronic toxicity, nausea, headache, dizziness, blurred vision, vomiting, chest tightness are the common signs reported. According to the study in the Pan American Journal of Public Health[3], In occupational exposure, Ops exposure is highest for agricultural workers mainly from mixing, loading, spraying, or transporting the chemicals.

Many chemicals can cross the unbroken skin. The importance of dermal exposure has been recently highlighted by a special edition of the journal *Annals of Occupational Hygiene*[4] and an international conference on occupational and environmental exposure of skin to chemicals was held by the US National Institute of Occupational Safety and Health[5]. There is a lack of knowledge about dermal uptake because dermal absorption was thought unlikely to be the dominant route of exposure in the workplace and in the general environment. Therefore, data from the dermal pathway of exposure are required to highlight the need for accurate estimates of exposure over a wide range of circumstances or scenarios to improve methods for analyzing pesticides and more precise ways of extrapolating the data are necessary.

The Rangsit Agrucultural Area is a large pesticide intensive paddy field area in Klong 7 village, Khlong Luang district, Pathumthani Province, Central Thailand. The Rangsit Agricultural Area has its own irrigation system. It has the capacity of farming 5 crops of rice/ 2 years. This study aimed to assess the dermal exposure risk of Ops, and to understand the demographic background, health information, pesticide use, exposure data, and work practices on pesticides of the rice farmers in the community.

**MATERIALS AND METHODS:** This study was approved by the Ethical Review Committee for Research Involving Human Subjects at Chulalongkorn University, Thailand under protocol number 014.1/53. Informed consents were obtained from the rice farmers prior to participation.

This study was a cross-sectional descriptive study with a laboratory component, supplemented by interviews. Data collections were carried out on two separate days. Qualitative information on pesticide exposure was obtained from 29 respondents through interviews. The subjects were selected by stratified randomization from different Moos as best as the village headman could find. However, due to the farmer's spraying schedule and their choice of pesticides, only 14 farmers sprayed Chlorpyrifos and Profenofos. On this account, while the qualitative results from the total 29 respondents' interviews are reported in order to understand the general characteristics of the respondents in the community, only the risk characterization of Chlorpyrifos and Profenofos dermal exposure on the 14 farmers among the 29 participants who sprayed these two organophosphate pesticides was examined.

*Hand-wipe sampling.* Exposure to Ops was quantified by measuring the residues Ops on the skin of the farmers' hands by hand-wipes followed the study from Geno[6]. A two-step wiping procedure was performed to ascertain that the entirety of each hand of the farmer was sampled. For each step, two moistened sterile cellulose gauze pads with 10ml of 2-propanol are used to wipe each hand of the farmer sequentially by the investigator, being careful to thoroughly wipe each dorsum, palm, digits, and inter-digital surfaces. Immediately following sampling, the gauze pads were carefully enveloped with aluminum foil, labeled, and transferred to zip-lock plastic bags and put in sealed box packed with dry ice for transport to the laboratory as soon as possible.

*Chlorpyrifos and Profenofos extraction, separation, and detection.* Sample analysis was carried out at the Central Laboratory (Thailand) Co.,Ltd, recognized and certified by the Department of Fisheries (DOF) and the Department of Agriculture (DOA) of the Ministry of Agriculture and Cooperatives and the National Bureau of Agricultural Commodities and Food Standards (ACFS) of Thailand. The extraction of Chlorpyrifos and Profenofos from the gauze samples was carried out according to a modified QuEChERs (Quick, easy, cheap, effective, rugged, and safe) method. Gas chromatography coupled with Flame Photometric Detector was used to separate and detect the concentration of the two organophosphate pesticides. The reported limits of detection of Chlorpyrifos and Profenofos were both 0.05 mg/Kg, and limits of quantitation were both reported as 0.10 mg/Kg. The percent recoveries of Chlorpyrifos and Profenofos were in the range between 84.7 to 97.01 were reported.

*Dermal Exposure Assessment. Hand* Dermal exposure was calculated by the following algorithm[7,8]:

$$ADD = (DA_{event}*EV*ED*EF*HSA)/(BW*AT)$$

Where ADD is average daily dermal contact Dose (mg/Kg/day), $DA_{event}$ is absorbed dermal dose per event (mg/cm$^2$-event), EV is event frequency (events/day), ED is exposure duration (years), EF is exposure frequency (days/year), HSA is hand surface area (cm$^2$). HSA was determined by the calculated total surface area obtained from the information of the respondents' body weights and heights, then multiply the total surface area values by the proportion of the mean total surface area to the mean of the hand surface area of default values from Caucasians in order to obtain the surface areas of the hands of the respondents who are Thais. BW is body weight (Kg), and AT is averaging time (ED* 365 days/year for non-carcinogen).

$DA_{event}$ is determined by:

$$(C_s) * \frac{\text{weight (Kg)}}{\text{2 gauze}} * \frac{\text{(2 gauze)}}{\text{(HAS, cm}^2\text{)-event}} * ABS$$

Where $C_s$ is the concentration of pesticides in the gauze (mg/Kg), ABS is the dermal absorption fraction (unitless). ABS is 0.03 for Chlorpyrifos[9], and 0.5 for Profenofos[10].

*Risk Characterization.* Once $ADD_s$ were established, their acceptability was determined by comparing to the reference dose ($RfD_s$), represented by the ratio which are called Hazard Quotients ($HQ_s$):

$$HQ = ADD/RfD$$

RfD is the dermal reference dose (mg/Kg-day). *HQ >1 indicates at risk.* The RfDs according to the EPA Integrated Risk Information System for Chlorpyrifos is 0.0015, and for Profenofos is 0.00005 mg/Kg-day[11].

For chemical mixture of similar chemical group, the $HQ_s$ are combined to form a HI, assuming that the effects of the different compounds and effects are additive.

$$HI = \sum HQ_{\text{Chlorpyrifos , Profenofos}}$$

Where HI is the Hazard Index

*Statistical Analysis.* Data was analyzed by using SPSS 16.0. Descriptive statistics were used to analyze and summarize the data.

**RESULTS AND DISSCUSSION:** Twenty- nine participants (N = 29) gave consent to complete the face to face interviews. The majority of the participants were male, there were only six female participants. The age ranged from 25-62 years old. Among the respondents, there were 4 subjects younger than 30 years of age ; 5 subjects between 31-40 years ; 7 subjects were between 41-50 years; 9 subjects were between 51 to 60 years ; and 3 subjects were older than 60. The average age of the participants was 46.1 years old, with a standard deviation of 11.3 years, and the median was 46 years. The majority of the respondents were in the age ranges of 51-60 and 41-50. All had received some formal education, but none of them had gone to school beyond the secondary school. On the other hand, more than half of them had education level of primary school (58.6%). None of them were employees in the paddy fields of the studied community. Among these 29 subjects, there were 22 respondents grew rice by themselves, 4 subjects hired others to grow rice, and 3 subjects were doing both.

**Table 1:** Socio-demographic characteristics (N=29, 1 missing data on age)

| Characteristics | Frequency | % |
|---|---|---|
| Male | 23 | 79.3 |
| Female | 6 | 20.7 |
| **Age (years)** | | |
| ≤ 30 | 4 | 13.8 |
| 31 – 40 | 5 | 17.2 |
| 41-50 | 7 | 24.1 |
| 51-60 | 9 | 31.0 |
| ≥ 60 | 3 | 10.3 |
| Range Min. – Max.) | 25 -62 | |
| **Educational Level** | | |
| Primary school grade 4 | 9 | 31.1 |
| Primary school grade 5/6 | 17 | 58.6 |
| Secondary school 1-3 | 2 | 6.9 |
| Secondary school 4-6 | 1 | 3.4 |
| **Working Characteristics** | | |
| Grow rice by themselves | 22 | 75.9 |
| Hire other person(s) | 4 | 13.8 |
| Both | 3 | 10.3 |

The rice farming practices and pesticide exposure of the respondents were explored. The average working years with pesticide application was 19.2, with a standard deviation of 14.9. The working time with pesticide application ranged from 1 to 50 years. The frequency they used pesticides in a day was found to be 1.52 times/day as the average value. The frequency of pesticide use in a day ranged from 0.03 to 3.5 times/day.

**Table 2:** Rice farming practices (N = 29)

| Variables | Mean (SD) | Range |
|---|---|---|
| Apply pesticides (years) | 19.2 (14.9) | 1-50 |
| Pesticide use (time(s)/day) | 1.52 (0.71) | 0.03-3.5 |
| Working (hours/day) | 3.29 (1.88) | 1-8 |
| Working (day(s)/week) | 4.45 (1.95) | 1-7 |
| Number of farmers in family(including respondent) | 2.48 (1.55) | 1-7 |
| Rais of land planted in previous year | 37.11(21.44) | 10-90 |

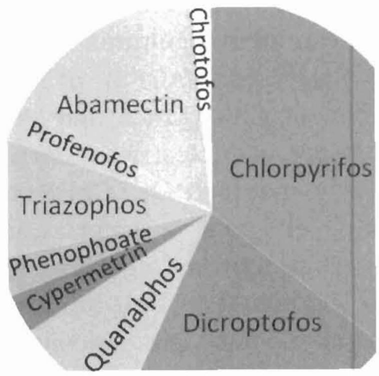


**Figure 1: Common pesticides used by the respondents.** Note: Usage of pesticides is not mutually exclusive.

Since organophosphate pesticides are known neurotoxic agents, the presence of neurological signs and symptoms after exposure to organophosphate pesticides was explored. From the interviews while and /or after applying pesticides during the last 12 months, it was found that some have only one single symptom and some had more than one symptom. The most frequent signs and symptoms from these subjects were dizziness (11 persons), blurred vision (10 persons), and weakness in arms or legs (10 persons), either during application, or within 24 hours of application of pesticides. There was one subject who reported experiencing dizziness both during and shortly after (within 24 hours of) pesticide application. Other common signs and symptoms were nausea/vomiting (8 persons), tearing (8 persons); difficulty of breathing (7 persons); abdominal cramp (6 persons); numbness or pins and needles in hands or feet (6 persons); and chest pain (5 persons), respectively. The least sign and symptom reported was involuntary twitches or jerks in arms or legs (2 persons). Those who reported having chest pain also reported a history of hypertension. Even though the reporting of signs and symptoms is subjective and subject to recall bias, and, even though we do not have knowledge of any underlying diseases (such as cardiovascular, respiratory diseases, and eye diseases) and the symptoms could also be smoking related, it is still important to show that neurological symptoms that could be related to organophosphate or other neurological agents exist among the community.

Among the 29 subjects being interviewed, 8 respondents were smokers, and 3 respondents were ex-smokers. When they were asked if they knew the cause(s) of the signs and symptoms they experienced, the majority (20 subjects) responded with no as the answer, but for those with yes as the answer, no known cause(s) was/were specified. Furthermore, 19 out of 29 subjects reported that their symptoms got worse after smelling odors from pesticides, paints, perfumes, or exhaust.

Peer influence or peer norm happened to be an important factor for farmers in making decisions concerning the purchase of pesticides. Interestingly, none reported follow suggestions from neighbors in the mixing of pesticides. Water was the most common solvent in pesticide mixing, and additives of fertilizer, fungicide, growth hormone, and other pesticides were applied often.

The respondents' behavior and activities related to pesticide exposure were examined. Backpack and mist guns were the common spraying instruments. When they sprayed, they usually sprayed banded instead of furrow, which implied more pesticides were consumed. After they finished pesticide spraying, washing themselves at the end of the day was the most common practice. When the previous pesticide application was ineffective, they opted to change to new pesticides, and/or mixed higher doses of pesticides.

Additionally, the most common 'protective equipment' was cloth protecting face and head. One subject reported wearing socks, for protection; one subject reported not using any protective equipment. However, according to observation, on the days of data collection, no one wore gloves, and one female farmer wore a pair of rubber boots. Apart from their "protective equipment", all farmers wore long-sleeved shirts and long pants. However, most had bare feet.

**Risk Assessment of Rice-Farmers Who Sprayed Chlorpyrifos and Profenofos:** Among the 14 respondents who sprayed Chlorpyrofos and Profenofos, 11 were males (78.6%), and 3 were females (21.4%). The median age was 47, with age ranged from 29 to 62 years old. The median pesticides exposure was 10 years, which ranged from 1 to 50 years. They worked 2 to 7 days a week, with median of 5 working days/week. Their median working hours were 2.5/day, which ranged from 1 to 6 hours/day. Since There are 5 crops/2 year, with 3-4 months/ crop in the area, 40 working weeks /year was assumed to obtain working days/year which resulted in a median 200 working days/year, with a range from 80 to 280 working days/year. 57.1% of the 14 subjects had 1 pesticide use/day, while 42.9% had 2 pesticides uses/day. There were 5 farmers (35.7%) who did not mix pesticides. Among the 14 participants, 4 (28.6%) were smokers, 8 (57.1%) were non-smokers, and 2 (14.3%) were ex-smokers.

The HQ Chlorpyrifos >1 occurred in only one case, while HQs Profenofos >1 for all cases among these 14 respondents. As a result, farmer 13 is at risk of long term adverse health effecs from dermal contamination with Chlorpyrifos application. However, HQ Profenofos > 1 occurred in all 14 subjects, indicating that all 14 respondents are at risk of long term adverse health effects from dermal contact with Profenofos application.

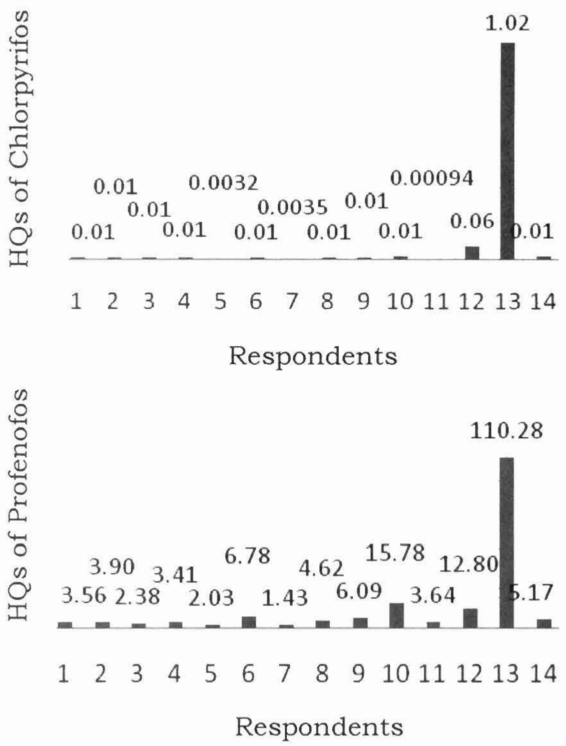


**Figure 2: & 3 HQs of Chlorpyrifos and Profenofos of the 14 subjects.**

For chemical mixture, since all HQs for Profenofos are all > 1, HIs (the sum of HQ of the two Ops) are all >1. All 14 respondents are at risk from long term dermal exposure in chronic adverse health effects from the application of Chlorpyrifos and Profenofos. Owing to the very small sample size, the hazard indices with repect to the farmers' pesticide exposure years and working patterns are qualitatively discussed:

From the interviews, farmer 13 ( female, 61 years old) had the longest exposure duration of 50 years, and she worked 5 days a week, 5 hours a day. Since all hand-wipe samplings were done by the principal researcher, the wiping performance variation was considered minimal. In addition, on the day of hand-wipe sampling, none of the farmers wore gloves. Moreover, none of them were observed of having "pesticide soaked" or particularly "dirty" hands. The practice of pesticide handling of farmer 13 should be investigated further. Farmer 12 had 40 years of pesticide, but his HI is less than farmer 10 (female, 57 years old)who had 15 years of exposure duration. They both worked 7 days a week, but farmer 10 worked 3 hours a day, while farmer 12 only worked 2 hours a day. Moreover, farmer number 2 had the shortest duration of only 1 year of pesticide exposure, but his HI was higher than several other farmers. Strikingly, farmer number 2 tied with farmer number 1 who had 6 years of pesticide exposure. However, farmer 1 worked 5 days a week, and 2 hours a day, while farmer 2 worked 2 days a week, but 6 hours a day. Farmer 7 had the lowest HI; he had 5 exposure years, 5 working days a week, and only worked 1 hour a day. In fact, farmer 7 did not mix pesticides. As a matter of fact, 5 farmers (number 5, 6, 7, 9, and 11) responded that they did not mix pesticides, but not all of them had lower HIs compared to those who mixed pesticides. Since there is no loading, it means the 5 farmers only sprayed pesticides, and the rest of the 9 farmers either only mixed or worked by both mixing and spraying. More detailed interviews should have been done to identify farmers who mixed and farmers who both mixed and sprayed pesticides. In brief, risk was found to be highly variable with exposure all in terms of years, weeks and hours, as well as the farmers' job classes. From the data of the two female farmers, female farmers would be more susceptible to risk of Chlorpyrifos and Profenofos but not conclusive. Smoking status and individual's well being would also be important factors.

This study provided a small scale investigation of the characterization of farmers in their intensive usage of pesticides, as well as a risk assessment of two common organophosphate pesticide skin exposures through the hands among some of the rice farmers in Rangsit Agricultural Area. This information can be added to the existing literature. Thus it is useful for risk management and communication in the community. The results obtained from this study could be discussed at both community and individual (particularly farmer 13) levels and used to provide information on occupational health indicators and recommendations such as methods to reduce exposure. The findings could be used in formulating strategies concerning pesticide use, including promoting Integrated Pest Management approach in agriculture. These finding could also be used to design behavioral intervention programs to assist farmers in protecting themselves from unwanted health effects. This study also provides baseline information for researchers who wish to pursue further epidemiological studies on effects of pesticides on women farmers.

Several limitations in the study should be noted. In this study, due to budget and time constraints, availability of farmers, farmers' spraying schedules and schedules of interviewers, a small sample size of only 29 subjects was recruited for interviews, and only 14 hand-wipe samples from subjects who sprayed Chlorpyrifos and Profenofos were studied for risk assessment calculations. A large enough sample of applicators was not available for analysis resulting in statistical power restriction. As a consequence, the findings from this study might not be generalized to other communities. In addition, a small sample size renders binary regression and association studies of risk and independent variables impossible; links cannot be established with the limited data set. Notably, this study only looks at hands, which is a very small percentage of dermal exposure.

**Recommendation and future Studies**

Reducing pesticide exposure in farm workers remains a significant challenge to occupational health. Use of long-sleeve shirts, long pants, and shoes plus socks are assumed for all applicators and are not counted as separate gear items. The approaches necessary to minimize hazardous exposures should include more targeted community level public health initiatives which include education and training. Since peer norm is common in the community in dealing with unfamiliar information, A respected farmer from the area, identified through nomination would be asked to speak to the group on how he/she had incorporated safe handling into his pesticide application routines to endorse the desired behavioral change would exercise peer influence directly to encourage behavioral change among the peer group. Having said that, one argument of this study is that they are at risk possibly not because they are not aware of adverse health effects of pesticides or they are careless, but are constrained not only by their access to accurate knowledge, but also and more importantly by other conditions such as social, cultural and economic conditions that sometimes beyond their control. Policies and education programs which do not consider these factors would fail to assist farmers in protecting themselves from harmful effects of pesticides. Specifically, policies that only focus on regulating overuse of pesticides without paying due attention to farmers in improving their economic conditions, either through improving rice productivity or other means, would fail. Without addressing the underlying conditions, the farmers would resort to pesticides—the only mean available to them, despite their awareness of its unwanted effects—to achieve what are more important to them than their own health. Of major interest, environmental researches often appeal to authority like United States Environmental Protection Agency (USEPA) reference guidelines. Recognizing the need for controlling the quality of environmental data being generated, in the late 1990, USEPA formed a committee known as the National Environmental Laboratory Accreditation Conference (NELAC) to promote mutually acceptable performance standards for the operation of environmental laboratories[12]. With the potential of developing an excellent scientific program in Thailand, improvement and standardization in environmental analysis is recommended in this direction.

In future studies, a larger sample size of rice farmers should be recruited in order to expand our understanding in the multi-independent variables relationship of the risk. Also, the outcomes of the behavioral intervention program could be another opportunity for future study. In addition, cost effective analysis on the rice farmers in the community would also be a very interesting research to approach and help the respondents. Furthermore, current research studies focus mainly in male farmers, more research data on women pesticide applicators at both national and regional levels are yet to be collected to raise community awareness, and on further epidemiological studies on reproductive health effects of pesticide exposure. Above all, method and researches are absolutely required to close many gaps in exposure measures to provide a reliable and unified database for the purpose of meaningful risk evaluation and policy making.

**ACKNOWLEDGEMENT:** Financial support from the Thai Fogarty ITREOH Center Grant Number: D43TW007849 NIH FIC is gratefully acknowledged. Many thanks go to Dr. Robert S. Chapman, Dr. Somsiri Jaipieam, and Dr. Sathirakorn Pongpanich for their useful comments. Also thanks Dr. Kanchana Rungsihirunrat for reading the manuscript.

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