

Occupational Paraquat Exposure Cases Reported to the Ramathibodi Poison Center

Sahaphume Srisuma^{1,2}, Achara Tongpoo¹, Juthathip Pathumarak¹, Panee Rittilert¹,
Manutsanun Mayurapong¹ and Chathaya Wongrathanandha³

¹Ramathibodi Poison Center, ²Department of Medicine, ³Department of Community Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Correspondence:

Achara Tongpoo, MSc,
Ramathibodi Poison Center
218/11, 3rd floor, Sukho place
building, Sukhothai Rd. Dusit,
Bangkok 10300. E-mail: achara-
tongpoo@gmail.com

Received: March 14, 2023;

Revised: June 5 2023;

Accepted: Aug 10, 2023

ABSTRACT

OBJECTIVE Paraquat (PQ) is a widely used non-specific herbicide. Paraquat poisoning both from intentional and unintentional exposure has been reported. The main objective of this study is to report on the characteristics, clinical effects, and outcomes of occupational PQ exposure reported to a poison control center in Thailand. The secondary objective is to determine factors associated with systemic toxicity from occupational PQ exposure.

METHODS This is a retrospective study of cases of occupational PQ exposure reported to the Ramathibodi Poison Center between January 2018 and December 2021.

RESULTS There were 124 PQ exposure cases during the study period, including 102 males and 22 females. Median age was 46 years (interquartile range 35.5–55.5 years). Routes of exposure included dermal (54.8%), inhalational (37.1%), and ocular (13.7%). Commonly used personal protective equipment (PPE) included trousers (18.5%), long-sleeve shirts (16.9%), and balaclavas (10.4%). Of the 68 dermal exposures, 23 (33.8%) reported having attempted skin decontamination prior to visiting the hospital. Systemic effects were reported in 22 cases (17.7%), including kidney injury (17.7%), hepatic injury (4.8%), and pulmonary injury (8.1%). All cases with systemic effects involved dermal exposures. Factors associated with systemic effects include mixing process, dermal exposure, lack of early skin decontamination, longer period between exposure and hospital visit, presence of wounds, body surface area involved and the grade of wounds.

CONCLUSIONS Occupational dermal PQ exposure can result in systemic effects. Individuals who handle PQ should be trained in and encouraged to practice safe PQ use, e.g., wearing personal protective equipment and using appropriate first aid measures if PQ exposure occurs.

KEYWORDS Paraquat, occupational exposure, poison control center, paraquat toxicity

© The Author(s) 2023. Open Access



This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made.

INTRODUCTION

Paraquat (PQ) is a non-specific herbicide in the bipyridyl family. In plant chloroplasts, PQ

reacts with electrons from plastocyanin–ferredoxin oxidoreductase and oxygen (photosystem 1), resulting in superoxide radicals and cell

death (1). PQ is absorbed in the soil and degraded by microorganisms and photocatalytic degradation (2). PQ has been widely used for weed control due to its efficacy and relative environmental safety.

Toxicities in humans, due to both intentional and unintentional PQ exposures have been reported. Effects of PQ poisoning include irritation of exposed skin and mucous membranes, multiorgan dysfunction, pneumonitis, pulmonary fibrosis, and death (3,4). There is no effective specific antidote for PQ poisoning. To prevent PQ poisoning, PQ has been banned in some countries (5,6). In the United States, Australia, and New Zealand PQ applicators must be trained and certified (7,8).

In Thailand, paraquat has been banned since 1 June 2020 (9). PQ has been used in oil palm and rubber tree plantations as well as on corn, cassava, and sugar cane farms which are planted early in the Thai rainy season (10). PQ effectively controls weeds even when it rains within 15 to 30 minutes of spraying, which may explain the use of PQ in the rainy season (11). There have been training sessions for farmers on the use of pesticides both before and after the ban. Prior to the ban, farmers were required to be trained and certified by the Department of Agriculture to be allowed to purchase, possess, or use PQ (12). According to the Department of Agriculture, PQ users must wear personal protective equipment (PPE) including gloves, goggles, boots, respirators, long sleeve shirts, and trousers and must be covered with either a chemical resistant coverall suit, raincoat, or apron (13). There were 4,223 cases of PQ poisoning, including 1,950 deaths, reported to the Ramathibodi Poison Center (RPC) in the period 2010–2016. The majority of the PQ exposure cases reported to RPC were from intentional oral ingestion (14,15). When a hospital had a PQ exposure case, the primary care team could voluntarily consult the poison center for guidance on management.

Characteristics, clinical effects, treatment, and outcomes of occupational PQ exposure in Thailand have not been described. The main objective of this study is to report on the characteristics, clinical effects, and outcomes of occupational PQ exposure reported to a poison con-

trol center in Thailand. The secondary objective is to determine factors associated with systemic toxicity from occupational PQ exposure.

METHODS

Study setting

This retrospective observational study includes PQ exposures reported to RPC from January 2018 through December 2021. This study was approved by the Human Research Ethics Committee, Faculty of Medicine, Ramathibodi Hospital, Mahidol University. RPC has provided a 24-hour hotline for nationwide toxicological consultation since 1996 (4). The consultation service is free of charge. Calls are received by specialists in poison information (SPIs), nurses or pharmacists with additional training in poison information service. Diagnoses of PQ exposure are based on history. There are medical toxicologist consultants available for complicated cases. Follow-up calls are made until recovery or a definitive outcome is reported. Calls are recorded in electronic database and the cases are reviewed and verified in daily staff meetings. Systemic treatment includes cyclophosphamide, dexamethasone, vitamin C, and vitamin E which are recommended in cases with systemic effects, and in cases with positive urine PQ screening by dithionite test. The final decision on management is made by the primary team taking care of the patient.

Definitions

Systemic effects were defined as the presence of at least one toxicity, including nephrotoxicity, hepatotoxicity, or pulmonary toxicity. The definition of nephrotoxicity was based on the RIFLE classification system for acute kidney injury (16). Hepatotoxicity was defined as an increase in aspartate aminotransferase or alanine aminotransferase levels greater than twice the normal upper limit. Pulmonary toxicity was defined as hypoxia or new pulmonary infiltration (17). Early decontamination was defined as decontamination within 1 hour following exposure.

Data collection

Case records were electronically abstracted using the active ingredient name coded as

“paraquat” and the manner of exposure as “occupational exposure”. All records were reviewed and verified by discussion among medical toxicologists and SPIs. Characteristics of patients, including age, sex, work activity related to exposure, route of exposure, contact area, wearing of PPE, clinical effects, treatment, and outcome of exposure were recorded. Characteristics were compared between cases with systemic effects and cases without systemic effects. If the primary team reported causes other than PQ for any of the clinical effects, those clinical effects were coded as “unrelated effects” and excluded from analysis.

Statistical analysis

Categorical data are presented as frequency and percentage. Continuous data is presented as median and interquartile range (IQR). Univariate analysis was used to determine the differences between cases with systemic effects and cases without systemic effects using the Wilcoxon rank-sum test for continuous variables and the chi-squared or Fisher’s exact test

for categorical variables. A p-value of less than 0.05 was defined as statistically significant.

RESULTS

During the study period there were 124 occupational PQ exposure cases reported to RPC, 102 males and 22 females (Table 1). Median age was 46 years (IQR 35.5–55.5 years). Systemic effects were reported in 22 cases (17.7%). The number of cases were highest in May and June, which is the early part of the rainy season (Figure 1). There was no difference in the number of cases among the reported years ($p = 0.235$ by Kruskal–Wallis test). The region with the highest number of cases was central region (46 cases, 37.1%).

Routes of exposures included dermal (54.8%), inhalational (37.1%), and ocular exposures (13.7%). All cases with systemic effects involved dermal exposures. One case with systemic effects involved both dermal and inhalational exposures. Spraying was the most common work activity related with exposure (108 cases, 86.4%). There was a higher proportion of expo-

Table 1. Characteristics occupational paraquat exposure cases reported to Ramathibodi Poison Center during 2018 to 2021

Characteristics	Number of cases (%)			p-value
	Total (124 cases)	Cases with systemic effect (22 cases)	Cases without systemic effect (102 cases)	
Male sex	102 (82.3)	21 (95.5)	81 (80.4)	0.120
Median age (years) (IQR)	46 (35.5–55.5)	47 (38–57)	46 (35–55)	0.552
Region				0.285
Central region	46 (37.1)	11 (50.0)	35 (34.3)	
Northern region	6 (4.8)	0	6 (5.9)	
North-eastern region	22 (17.7)	5 (22.7)	17 (16.7)	
Eastern region	16 (12.9)	2 (9.1)	14 (13.7)	
Western region	22 (17.7)	1 (4.55)	21 (20.6)	
Southern region	12 (9.7)	3 (13.6)	9 (8.8)	
Route of exposure*				
Dermal exposure	68 (54.8)	22 (100.0)	46 (45.1)	<0.001
Inhalational exposure	46 (37.1)	1 (4.6)	45 (44.1)	<0.001
Ocular exposure	17 (13.7)	0	17 (16.7)	0.041
Work process				0.043
Spraying	108 (87.1)	16 (72.7)	92 (90.2)	
Mixing	5 (4.0)	3 (13.6)	2 (2.0)	
Walking through sprayed area	4 (3.2)	1 (4.6)	3 (2.9)	
Not specified process	7 (5.7)	2 (9.1)	5 (4.9)	
Median duration between exposure to hospital visit (IQR)	1 d (4.5 hrs to 3 ds)	3 ds (2 ds to 5 ds)	1 d (4 hrs to 3 ds)	<0.001

*There were cases exposed to paraquat more than one route of exposure
IQR, interquartile range

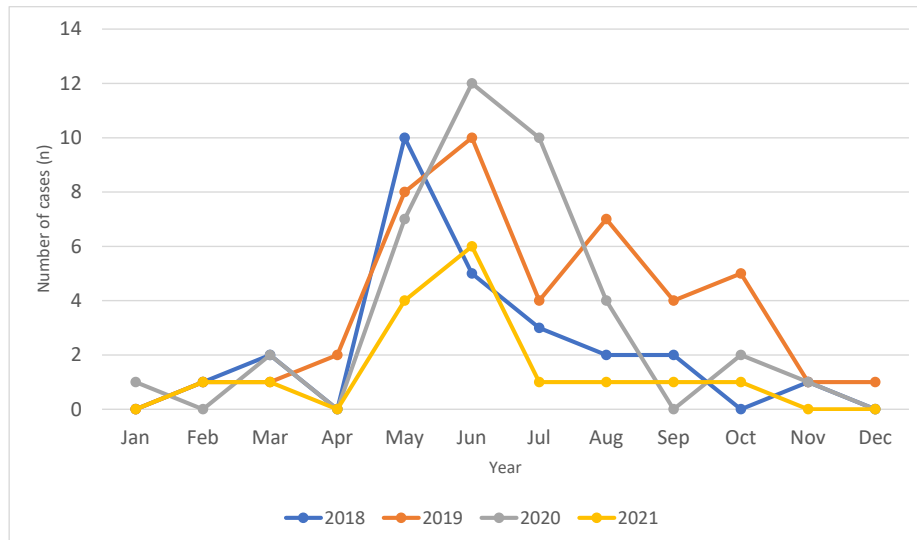


Figure 1. Number of Occupational paraquat exposure cases reported to Ramathibodi Poison Center during 2018 to 2021

Table 2. Personal protective equipment reported used in occupational paraquat exposure cases at Ramathibodi Poison Center from 2018 through 2021

Personal protective equipment reported used	Number of cases (%)			p-value
	Total (124 cases)	Cases with systemic effects (22 cases)	Cases without systemic effects (102 cases)	
Long sleeve shirt	21 (16.9)	2 (9.1)	19 (18.6)	0.362
Trousers	23 (18.6)	2 (9.1)	21 (20.6)	0.363
Balaclava	13 (10.5)	0	13 (12.8)	0.122
Cloth mask	6 (4.8)	1 (4.6)	5 (4.9)	1.000
Goggle	4 (3.2)	0	4 (3.9)	1.000
Gloves	12 (9.7)	2 (9.1)	10 (9.8)	1.000
Boots	10 (8.1)	2 (9.1)	8 (7.8)	1.000

sure during PQ mixing processes in cases with systemic effects (13.6% in cases with systemic effects, and 2.0% in cases without systemic effects). The median time from exposure to hospital visit was 1 day (IQR 4.5 hours to 3 days). Both dermal exposure and longer duration between exposure and hospital visit were associated with systemic effects ($p < 0.001$ for both factors). Commonly used PPE included trousers (18.5%), a long-sleeve shirt (16.9%), and balaclava (10.4%) (Table 2). No cases reported wearing a respirator, apron, raincoat, or coverall suit.

In dermal exposure cases, common contact areas included the perineum, legs, and back (38.3%, 13.3%, and 11.8% of the 68 dermal exposure cases, respectively) (Table 3). Twenty-three cases reported skin decontamination prior to hospital visits (33.8% of 68 cases). No instances of early skin decontamination were

associated with systemic effects ($p = 0.003$). Six cases reported eye decontamination prior to hospital visits (35.3% of 17 ocular exposures).

Wounds were the most common reported clinical effect (56 cases, 45.2%) (Table 4). Median area involved was 1% of the body surface area (IQR 1–2%, range 1–9%). Wound severity was reported as first degree burn in 24 cases, and second degree burn in 32 cases. Presence of wounds, involved body surface area, and grade of wounds were associated with systemic effects ($p < 0.001$ for all three factors). Systemic effects included kidney injury (22 cases, 17.7%), hepatic injury (6 cases, 4.8%), and pulmonary injury (10 cases, 8.1%) (Table 5).

Thirty-eight cases (30.6%) were admitted to hospital (Table 6). The median length of stay was 4 days (IQR 2–7 days, range 1–24 days). Cases with systemic effects had a higher admission rate and longer length of stay (both

Table 3. Dermal contact area and early skin decontamination of occupational paraquat exposure cases reported to Ramathibodi Poison Center from 2018 through 2021

Skin contact area	Number of cases (%)			p-value
	Total dermal exposure cases (68 cases)	Cases with systemic effects (22 cases)	Cases without systemic effects (46 cases)	
Face	3 (4.4)	0	3 (6.5)	1.000
Chest	3 (4.4)	0	3 (6.5)	1.000
Abdomen	2 (2.9)	0	2 (4.4)	1.000
Back	8 (11.8)	2 (9.1)	6 (13.0)	0.631
Arm	3 (4.4)	0	3 (6.5)	1.000
Hand	7 (10.3)	2 (9.1)	5 (10.9)	0.606
Perineum	26 (38.3)	8 (36.6)	18 (39.3)	0.079
Buttock	6 (8.8)	2 (9.1)	4 (3.9)	0.288
Thigh	1 (1.5)	1 (4.6)	0	0.177
Leg	9 (13.3)	4 (18.2)	5 (10.9)	0.052
Foot	5 (7.4)	2 (9.1)	3 (6.5)	0.215
Early skin decontamination*	23 (33.8)	2 (9.1)	21 (45.7)	0.003

*Includes removing of contaminated clothes (if any) and washing the contaminated skin within 1 hour after exposure

Table 4. Clinical effects of occupational paraquat exposure in cases reported to Ramathibodi Poison Center from 2018 through 2021

Clinical effects	Number of cases (%)			p-value
	Total (124 cases)	Cases with systemic effects (22 cases)	Cases without systemic effects (102 cases)	
Wound	57 (46.0)	20 (90.9)	37 (36.3)	<0.001
Wound grading				< 0.001
First degree burn	25 (20.2)	2 (9.1)	23 (22.6)	
Second degree burn	32 (25.8)	18 (81.8)	14 (13.7)	
Wound area				< 0.001
1% of body surface area (BSA)	33 (26.6)	9 (40.9)	24 (23.5)	
2% BSA	12 (9.7)	4 (18.2)	8 (7.8)	
3% BSA	9 (7.3)	4 (18.2)	5 (4.9)	
More than 3% BSA	3 (2.4)	3 (13.6)	0	
Nausea	22 (17.7)	1 (4.6)	21 (20.6)	0.120
Dizziness	22 (17.7)	0	22 (21.6)	0.013
Eye irritation	17 (13.7)	0	17 (16.7)	0.041
Vomiting	14 (11.3)	1 (4.6)	13 (12.8)	0.460
Fatigue	11 (8.9)	0	11 (10.8)	0.210

Table 5. Systemic effects of occupational paraquat exposure cases reported to Ramathibodi Poison Center from 2018 through 2021

Systemic effects	Number of cases (%)	
	Total (124 cases)	Cases with systemic effects (22 cases)
Nephrotoxicity	22 (17.7)	22 (100.0)
Hepatotoxicity	6 (4.8)	6 (27.3)
Pulmonary toxicity	10 (8.1)	10 (45.5)

$p < 0.001$). Local treatment included wound dressing, dermal irrigation, and eye irrigation. Common specific treatment included IV dexamethasone (16.1%), IV vitamin C (15.3%), oral vitamin E (14.5%), and IV cyclophosphamide (12.9%). There were 8 deaths, all of which involved dermal exposure, lack of early skin decontamination, delayed hospital visit (range 2–8 days after exposure), and systemic effects.

Urine PQ screening by dithionite test was performed in 22 cases. Of those, four cases had

Table 6. Clinical effects of occupational paraquat exposure in cases reported to Ramathibodi Poison Center from 2018 through 2021

Treatment	Number of cases (%)			p-value
	Total (124 cases)	Cases with systemic effects (22 cases)	Cases without systemic effects (102 cases)	
Hospital admission	38 (30.7)	22 (100.0)	16 (15.7)	< 0.001
length of stay (days) (IQR)	4 (2-7)	6.5 (4-12)	2.5 (2-3)	0.001
Eye irrigation	16 (12.9)	0	16 (15.7)	0.073
Skin irrigation	14 (11.3)	3 (13.6)	11 (10.8)	0.713
Wound dressing	55 (44.4)	20 (90.9)	35 (34.3)	< 0.001
Endotracheal intubation and ventilation support	4 (3.23)	4 (18.2)	0	0.001
Oxygen supplement	6 (4.8)	6 (27.3)	0	< 0.001
Intravenous fluid	41 (33.1)	20 (90.9)	21 (20.6)	< 0.001
Antibiotic	36 (29.3)	16 (76.2)	20 (19.6)	< 0.001
Antihistamine	17 (13.7)	3 (13.6)	14 (13.7)	1.000
Antiemetic	9 (7.3)	1 (4.6)	8 (7.8)	1.000
Cyclophosphamide	16 (12.9)	15 (68.2)	1 (0.1)	< 0.001
Dexamethasone	20 (16.1)	17 (77.3)	3 (2.9)	< 0.001
Vitamin C	19 (15.3)	17 (77.3)	2 (2.0)	< 0.001
Vitamin E	18 (14.5)	16 (72.7)	2 (2.0)	< 0.001
N-acetylcysteine	4 (3.23)	3 (13.6)	1 (1.0)	0.018

IQR, interquartile range

positive urine PQ screening results. Screening was performed at 1 day (1 case), 2 days (2 cases) and 3 days (3 cases) after exposure. All four were cases of dermal PQ exposure. Three cases with a positive urine PQ screening had systemic effects. One case with a positive urine PQ screening who received systemic treatment for 4 days had no systemic effects. There were 18 cases with negative urine PQ screening, including 5 cases with systemic effects and 13 cases without systemic effects. In the cases with systemic effects with negative urine PQ screening results, the urine PQ screening tests had been performed 1-3 days after exposure. In cases without systemic effects who had negative urine PQ screening, urine PQ screening tests were performed at between 3 hours and 4 days after exposure.

DISCUSSION

This article describes occupational PQ cases reported to a poison control center (RPC) in Thailand. Most cases were reported early in the rainy season. The majority of cases were males of working age, which is consistent with previous studies on occupational pesticide exposure (10,18). Despite PQ being banned since 1 June

2020, no difference was found in the number of occupational PQ exposure cases between years before and after the ban. One possible reason is that there may have been quantities of PQ remaining in the country after the ban. Previous studies in Korea, Taiwan, and Sri Lanka found a decrease in suicide using pesticides including paraquat after banning (6,19,20). The total number of cases of occupational PQ poisoning and pesticide-related suicide in Thailand should be monitored to determine the effect of the ban.

In this study, reported PPE use rates were found to be quite low, consistent with a previous study of occupation carbamate poisoning in Thailand (18). The PPE use rates in our study are lower than those in a voluntarily survey of healthy farmers (21); that difference may be explained by a difference in the study populations. That there was no association between PPE use and systemic effects in our study may be explained by 1) a low rate of PPE use, 2) no reports of wearing a chemical protective coverall suit, raincoat, or apron which can largely prevent PQ absorption to inner-layer clothing and skin. A study of urine and dermal PQ concentrations in PQ sprayers reported that using PPE was associated with lower dermal PQ exposures (22).

Individuals applying dangerous herbicides and pesticides should be trained and encouraged to use PPE and their PPE use should be monitored. Thai farmers should wear PPE as suggested by Department of Agriculture (13).

In our study, systemic effects were reported in cases with dermal exposure. Dermal PQ exposures have been reported to cause systemic effects (23,24). PQ absorption is higher in damaged skin and with prolonged contact (25). PQ can cause irritation and burns on contacted skin, which can enhance absorption (25). We found that early skin decontamination (within 1 hour) helps prevent systemic effects. A previous study reported that early skin decontamination can decrease dermal penetration of toxic chemicals (26). The grade and area of a wound and the length of time between exposure and health care are related to PQ systemic effects. Inflamed or broken skin is also associated with higher PQ absorption. Wound severity may reflect contact time, PQ concentration, and area of exposure. Early decontamination and evaluation by a healthcare provider should be emphasized in training of PQ handlers. Clean water should be available in the workplace for prompt dermal and ocular decontamination.

In this study, systemic effects were not reported in any cases with no dermal exposure. Inhalation exposure and ocular exposure did not result in systemic effects. PQ is less likely to evaporate at room temperature due to its low vapor pressure (0.0000001 mmHg) (25,27). More than 98% of sprayed PQ has a droplet size larger than 7 micrometers, which can be retained in the upper airway, preventing alveolar deposition and absorption (28). Sprayed PQ also has a lower concentration than PQ prior to mixing or diluting, which may explain the lower proportion of systemic effects in cases of spraying (25). PQ concentration during contact may also explain the higher proportion of cases with systemic effects occurring during the mixing process. Eye irritation from PQ and dizziness resulting from the strong odor may cause a farmer to stop working and thus reduce further PQ exposure. This may explain why most reports of eye irritation and dizziness are in cases without systemic effects.

Currently there is no effective antidote for PQ toxicity. Common systemic treatments include a combination of steroids, anti-inflammatory drugs, and antioxidants (3,4). Due to rapid distribution of PQ into tissues, significant quantities of serum PQ can be removed by early hemodialysis and hemoperfusion, i.e., within the first few hours after ingestion (3). Delayed enhance elimination does not change the prognosis of PQ poisoning. In this study, there were no cases that underwent hemodialysis or hemoperfusion. Most of the cases in our study, especially those with systemic effects, presented at the healthcare facility more than 4 hours after exposure. Further study of the kinetics and role of enhanced elimination of dermal PQ exposure is needed to evaluate the role and limitations of enhanced elimination in cases of dermal PQ exposure.

In our study, there were 5 cases with systemic effects that had had a negative urine PQ screening test. In each of those cases, the screening test had been done later than 24 hours after exposure. After ingestion, 90% of the absorbed PQ is excreted in urine within 12–24 hours (29). Urine PQ screening using the sodium dithionite test can predict PQ toxicity if performed within 12 hours following ingestion (4,29). To the best of our knowledge, there have been no studies to evaluate the efficacy of using the urine dithionite test to determine the risk of PQ toxicity resulting from dermal exposure. Further study is needed to evaluate the role of the urine sodium dithionite test in cases of dermal PQ exposure. PQ handlers should be advised to visit a healthcare facility for evaluation as soon as possible after dermal PQ exposure.

As a retrospective study of voluntarily reported data, this study has some limitations. The study was affected by selective bias. The majority of RPC calls were from healthcare providers, which tend to be more severe than cases in survey studies. For the same reason, the cases in this study may not reflect all the occupational PQ exposures in Thailand. The extent of PPE use in this study includes only cases exposed to PQ, so it may be lower than the average of PPE use by all farmers. This study is based on the Thai setting. Studies in other countries may have different findings due to

differences in regulations, product availability, and health systems.

CONCLUSIONS

Based on data from one poison control center, occupational dermal PQ exposure can result in both local and systemic effects. There were no systemic effects reported from occupational inhalational or ocular PQ exposure in this study. There is a low rate of PPE use in PQ exposure cases. Factors associated with systemic effects include exposure during the PQ mixing process, dermal exposure, lack of early skin decontamination after exposure, a longer duration between exposure and hospital visit, the presence and grade of wounds and the body surface area involved. PQ handlers should be trained on and encouraged to practice safe use of PQ, to wear personal protective equipment, and to seek first aid after PQ exposure.

ACKNOWLEDGMENTS

None

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTERESTS

The authors have no conflicts of interest to report.

REFERENCES

- Qian H, Chen W, Sun L, Jin Y, Liu W, Fu Z. Inhibitory effects of paraquat on photosynthesis and the response to oxidative stress in *Chlorella vulgaris*. *Ecotoxicology*. 2009;18:537-43.
- Huang Y, Zhan H, Bhatt P, Chen S. Paraquat degradation from contaminated environments: current achievements and perspectives. *Front Microbiol*. 2019;10:1754.
- Gawarammana IB, Buckley NA. Medical management of paraquat ingestion. *Br J Clin Pharmacol*. 2011;72:745-57.
- Pradoo A, Supthaveethanakij A, Wongvisavakorn S, Rittilert P, Tongpoo A, Sriapha C, et al. Urine sodium dithionite test for determining prognosis and outcome of paraquat poisoning. *J Med Assoc Thai*. 2021;104:24-31.
- Regulation. Paraquat Information Center. Syngenta Crop Protection AG (Internet). 2023 [cited 2023 February 1]. Available from: <https://www.paraquat.com/en/safety/regulation>
- Chang SS, Lin CY, Lee MB, Shen LJ, Gunnell D, Eddleston M. The early impact of paraquat ban on suicide in Taiwan. *Clin Toxicol (Phila)*. 2022;60:131-5.
- Paraquat Dichloride Training for Certified Applicators. United States Environmental Protection Agency (US EPA) (Internet). Washington, DC (last updated 2022 June 8. [cited 2023 February 1]. Available from: <https://www.epa.gov/pesticide-worker-safety/paraquat-dichloride-training-certified-applicators>
- Thompson M, Chauhan BS. History and perspective of herbicide use in Australia and New Zealand. *Adv Weed Sci*. 2022;40(Spec1):e20210075.
- Thailand: Thailand Moves Forward with Ban on Paraquat and Chlorpyrifos on 1 June 2020 [Internet]. Foreign Agriculture Service. U.S. Department of Agriculture. Washington, DC (last updated 2020 May 5 [cited 2023 February 1]. Available from: <https://www.fas.usda.gov/data/thailand-thailand-moves-forward-ban-paraquat-and-chlorpyrifos-1-june-2020>
- Sapbamrer R. Pesticide use, poisoning, and knowledge and unsafe occupational practices in Thailand. *New Solut*. 2018;28:283-302.
- Bovey RW, Diaz-Colon JD. Effect of simulated rainfall on herbicide performance. *Weed Science*. 1969;17:154-7.
- Education Service Center for Agriculture Extension [Internet]. Department of Agriculture Extension. Bangkok, Thailand. 2019 [cited 2023 May 31]. Available from: <https://esc.doe.go.th/การใช้สารเคมี3สาร/> [in Thai].
- Topic 7: Correct and appropriate use of personal protective equipment for using paraquat, glyphosate, and chlorpyrifos [Internet]. Department of Agriculture Extension E-learning. Bangkok, Thailand (last updated 2019 June 19 [cited 2023 May 31]. Available from: <https://youtu.be/8vmYMWzEe2M> [in Thai].
- Fact about paraquat, the poison without antidote [Internet]. Way Magazine. Bangkok, Thailand (last updated 2018 May 18 [cited 2023 May 31]. Available from: <https://waymagazine.org/paraquat/> [in Thai].
- Summary of the ad hoc sub-committee Most agree 'limit' the use of 'paraquat' [Internet]. Isranews Agency. Bangkok, Thailand (last updated 2018 May 23 [cited 2023 May 31]. Available from: <https://www.isranews.org/content-page/item/66215-paraquat-66215.html> [in Thai].
- Lopes JA, Jorge S. The RIFLE and AKIN classifications for acute kidney injury: a critical and comprehensive review. *Clin Kidney J*. 2013;6:8-14.
- Seok S, Kim YH, Gil HW, Song HY, Hong SY. The time between paraquat ingestion and a negative dithionite urine test in an independent risk factor for death and organ failure in acute paraquat intoxication. *J Korean Med Sci*. 2012;27:993-8.

18. Tongpoo A, Sriapha C, Wongvisawakorn S, Rittilert P, Trakulsrichai S, Wananukul W. Occupational carbamate poisoning in Thailand. *Southeast Asian J Trop Med Public Health*. 2015;46:798–804.
19. Knipe DW, Chang SS, Dawson A, Eddleston M, Konradsen F, Metcalfe C, et al. Suicide prevention through means restriction: Impact of the 2008–2011 pesticide restrictions on suicide in Sri Lanka. *PLoS One*. 2017;12:e0172893.
20. Cha ES, Chang SS, Gunnell D, Eddleston M, Khang YH, Lee WJ. Impact of paraquat regulation on suicide in South Korea. *Int J Epidemiol*. 2016;45:470–9.
21. Plianbangchang P, Jetiyanon K, Wittaya-Areekul S. Pesticide use patterns among small-scale farmers: a case study from Phitsanulok, Thailand. *Southeast Asian J Trop Med Public Health*. 2009;40:401–10.
22. Konthonbut P, Kongtip P, Nankongnab N, Tipayamongkholgul M, Yoosook W, Woskie S. Paraquat exposure of backpack sprayers in agricultural area in Thailand. *Hum Ecol Risk Assess*. 2020;26:2798–811.
23. Soloukides A, Moutzouris DA, Kassimatis T, Metaxatos G, Hadjiconstantinou V. A fatal case of paraquat poisoning following minimal dermal exposure. *Ren Fail*. 2007;29:375–7.
24. Wang JW, Yang X, Ning BY, Yang ZY, Luo LH, Xiao H, Ning Z. The successful treatment of systemic toxic induced paraquat poisoning by skin absorption: case reports and a literature review. *Int J Clin Exp Pathol*. 2019;12:3662–70.
25. Dinis-Oliveira RJ, Duarte JA, Sánchez-Navarro A, Remião F, Bastos ML, Carvalho F. Paraquat poisonings: mechanisms of lung toxicity, clinical features, and treatment. *Crit Rev Toxicol*. 2008;38:13–71.
26. Forsberg E, Öberg L, Artursson E, Wigenstam E, Bucht A, Thors L. Decontamination efficacy of soapy water and water washing following exposure of toxic chemicals on human skin. *Cutan Ocul Toxicol*. 2020;39:134–42.
27. Paraquat (Compound) [Internet]. Pubchem. National Library of Medicine, National Center for Biotechnology Information. Bethesda, MD [cited 2023 June 1]. Available from: <https://pubchem.ncbi.nlm.nih.gov/compound/Paraquat>
28. Chester G, Ward RJ. Occupational exposure and drift hazard during aerial application of paraquat to cotton. *Arch Environ Contam Toxicol*. 1984 Sep; 13:551–63.
29. Liu X, Ma T, Liu Z. Prognostic significance of urine paraquat concentrations of patients with acute paraquat poisoning on admission at the emergency department. *Hong Kong Journal of Emergency Medicine*. 2018;25:3–11.