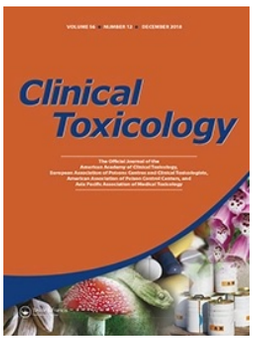
The early impact of paraquat ban on suicide in Taiwan



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SHORT COMMUNICATION

The early impact of paraquat ban on suicide in Taiwan

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ABSTRACT

Introduction: Pesticide ingestion is a leading method for suicide worldwide. Paraquat is a highly lethal herbicide when ingested. We assessed the impact of the first-stage ban on the import and production of paraquat (from February 2018) on suicides by pesticide poisoning in Taiwan.

Methods: Suicide data by method (pesticide vs. non-pesticide), pesticide (paraquat vs. non-paraquat), and area/sex/age were extracted from the national cause-of-death data files (2011–2019). Negative binomial regression was used to estimate changes in suicide rates in 2019, compared to the expected rates based on pre-ban linear trends (2011–2017).

Results: The paraquat ban was followed by an estimated 37% (rate ratio [RR] = 0.63, 95% confidence interval [CI] 0.54–0.74) reduction in pesticide suicide rate (190 [95% CI 116–277] fewer suicides) in 2019, mainly due to a 58% (RR = 0.42, 95% CI 0.33–0.54) reduction in paraquat suicides (145 [95% CI 92–213] fewer suicides). Larger absolute reductions in pesticide suicides were found in rural areas, males, and the elderly (aged 65+ years) than their counterparts. Except for a 10% (95% CI 3–18%) reduction in overall suicide rates in the elderly, there was no statistical evidence for a change in non-pesticide and overall (all-method) suicides.

Conclusion: The ban on the import and production of paraquat was followed by a fall in whole-population pesticide and paraquat suicides and elderly suicides in Taiwan.

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Pesticide ban; pesticide suicide; suicide prevention; paraquat

Introduction

Pesticide ingestion is a leading method for suicide worldwide. Approximately 14–20% of global suicides, or 110,000–168,000 deaths a year, are from pesticide self-poisoning [1]. The prevention of pesticide suicides is a priority area of global suicide prevention strategies [2].

Paraquat, a commonly used herbicide, is amongst the pesticides most frequently involved in suicides. Paraquat is highly lethal when ingested [3], with an estimated case fatality of 55% in Taiwan [4]. Restricting access to paraquat may effectively prevent suicide from paraquat poisoning and reduce pesticide suicide rates [5], as few pesticides are as toxic as paraquat [3] and therefore even a shift to other pesticides in acts of self-poisoning is unlikely to result in higher case fatality. In Taiwan, a nationwide (first-stage) ban on the import and production of paraquat was implemented from February 2018, followed by a complete (second-stage) ban on its sale and use from February 2020. However, some have argued for a reversal of the policy and lifting the ban, citing the possibility of a shift to use other pesticides or methods for suicide that could lead to no effect of the ban on suicide [6]. Therefore, there is an urgent need to evaluate the ban's early effect on reducing deaths. We assessed the impact of the first-stage paraquat ban (i.e., ban on import and production) on suicide in Taiwan. We hypothesised that the impact on pesticide suicides would be most marked in rural areas, males, and the elderly (aged 65+ years), which were previously shown to have the largest burden of pesticide suicides in Taiwan [7,8].

Materials and methods

Suicide data (2011–2019) for people aged 15 years or above in Taiwan were extracted from national cause-of-death data

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Supplemental data for this article is available online at here.

files, coded using the International Classification of Diseases, 10th Revision (ICD-10). A recent time trend analysis showed that Taiwan's suicide rates changed from a downward trend to a stable trend in 2011 [9]. Possible suicide deaths were identified using the following ICD-10 codes: X60-X84 (suicide), Y10-Y34 (undetermined intent), W75-W76, W83-W84 (accidental suffocation) and X48 (accidental pesticide poisoning), as a previous study from Taiwan indicated that many deaths classified as undetermined intent, accidental suffocation, or accidental pesticide poisoning were likely to be misclassified suicides [10]. Pesticide suicides were identified using ICD-10X68 (suicide), Y18 (undetermined intent) and X48 (accident); all other suicides were classified as 'non-pesticide suicides'. Amongst pesticide suicides, suicides by paraquat poisoning were identified by searching 'paraquat' in the 'cause of death' field on the death certificate; all other pesticide suicides were classified as 'non-paraquat pesticide suicides'. Certified suicides accounted for the majority of all possible suicides; the percentage of certified suicides in all possible suicides (i.e., certified suicides and potential misclassified suicides combined) was 87.4%, 90.8%, and 88.8% for overall (all-method), pesticide, and paraquat suicides, respectively, during 2011–2019 (Supplementary Appendix Table 1). To assess the impact of including potential misclassified suicides on our findings, we conducted sensitivity analyses based on deaths certified as suicides only. We used the term 'suicide' when referring to all possible suicides throughout the paper for simplicity.

Mid-year population data by sex, age group, and city/county were extracted from the Demographic Fact Books (2011–2019) published by the Ministry of the Interior. The 23 cities/counties were categorised into urban ($n = 11$) and rural areas ($n = 12$) based on whether their proportions of agricultural workers were below or above the median (5.4%), respectively. Sources for agricultural crop yield data are summarised in the Supplementary Appendix.

We calculated annual age-standardised suicide rates (2011–2019), overall and by method (pesticide vs non-pesticide) and pesticide (paraquat vs. non-paraquat), for people aged 15 years or above, according to the 2000 World Health Organization World Standard Population. We calculated the percentage of pesticide suicides in all suicides, overall and by area/sex/age group, in 2011–2017 to investigate the contributions of pesticide suicide to the burden of suicide prior to the 2018 paraquat ban. Negative binomial regression models were used to estimate rate ratios (RRs), and their 95% confidence intervals (CIs) in 2018 and 2019, compared with the expected suicide rates based on the pre-ban linear suicide trends (2011–2017). We included year, sex, and age group (in 5-year bands) in the models to adjust for time trends as well as changes in population structure. The effect of the paraquat ban was investigated by including two dummy variables, one for 2018 and one for 2019. We focused on the results for 2019 (from 1 January to 31 December 2019) as it is the first complete year after the paraquat ban. Furthermore, official statistics showed that paraquat sale started to drop markedly from mid-2018 and became nearly zero in 2019 [11], enabling an assessment of the effect of no paraquat sale on suicide in that year. Differences between areas (urban vs rural), sexes, and age groups (15–24, 25–44, 45–64 and 65+ years) were examined by including appropriate interaction terms (e.g., area * the dummy variable for year 2019) in the models. The reduced numbers and rates of suicide in 2019 were calculated based on the RR estimates, observed number of suicides, and population. Changes in rates of suicide were presented as rate differences (RDs), i.e., observed rates minus expected rates. The details of regression analyses and the calculation of changes in numbers and rates of suicide were provided in the Supplementary Appendix. All regression analyses were performed using Stata 15.0 (StataCorp, College Station, TX, USA).

The study was approved by National Taiwan University Hospital Research Ethics Committee (201606036RINB).

Results

Figure 1 shows trends in suicide in Taiwan in 2011–2019. Figure 2 shows the forest plots of RRs (Figure 2(A)) and RDs (2B), overall and by subgroup. A marked reduction in pesticide suicide rates was found after the 2018 paraquat ban, compared with expected suicide rates based on pre-ban linear trends (2011–2017) – the pesticide suicide rate decreased by 37% (RR = 0.63, 95% CI 0.54–0.74) in 2019 (Figure 2(A) and Supplementary Appendix Table 2). The corresponding estimated reduced number and rate of pesticide suicides was 190 (95% CI 116–277) and 0.93 (95% CI 0.57–1.35) per 100,000, respectively. The fall in pesticide suicide rate was mainly attributable to the reduction in paraquat suicides (RR = 0.42, 95% CI 0.33–0.54; 145 fewer suicides [95% CI 92–213]; a 0.71 [95% CI 0.45–1.04] per 100,000 reduction in rate). By contrast, non-paraquat pesticide suicides showed a small reduction (RR = 0.82, 95% CI 0.67–1.00; RD= −0.23, 95% CI −0.51 to 0.01 per 100,000). The age-standardised rates of non-pesticide and overall suicide were relatively stable over the study period (Figure 1(B)); there was no statistical evidence for a change in their rates in 2019 after the paraquat ban, although there is a suggestion of a small rise for non-pesticide suicides (RR = 1.05, 95% CI 0.99–1.10; RD = 0.89, 95% CI −0.17 to 1.89) (Supplementary Appendix Table 2). The sensitivity analysis using certified suicides alone showed similar results; there was an estimated 40% (RR = 0.60, 95% CI 0.51–0.70) reduction in certified pesticide suicides in 2019 after the paraquat ban (Supplementary Appendix Figure 1 and Supplementary Appendix Table 3).

In 2011–2017, prior to the paraquat ban, pesticide poisoning accounted for 12.1% of all suicides in Taiwan; the proportion was higher in rural than urban areas (21.8% vs. 5.7%), in males than females (13.1% vs. 10.2%), and highest in the elderly group (21.4%) (Supplementary Appendix Table 2). Based on RRs, the falls in pesticide suicide rates, proportionally, were similar in urban and rural areas, and in males and females (p for interaction = 0.95 and 0.72, respectively) in 2019, whilst they appeared to be most marked in individuals aged 25–44 years and 45–64 years (p for age interaction <0.001) (Figure 2(A) and Supplementary Appendix Table 2).

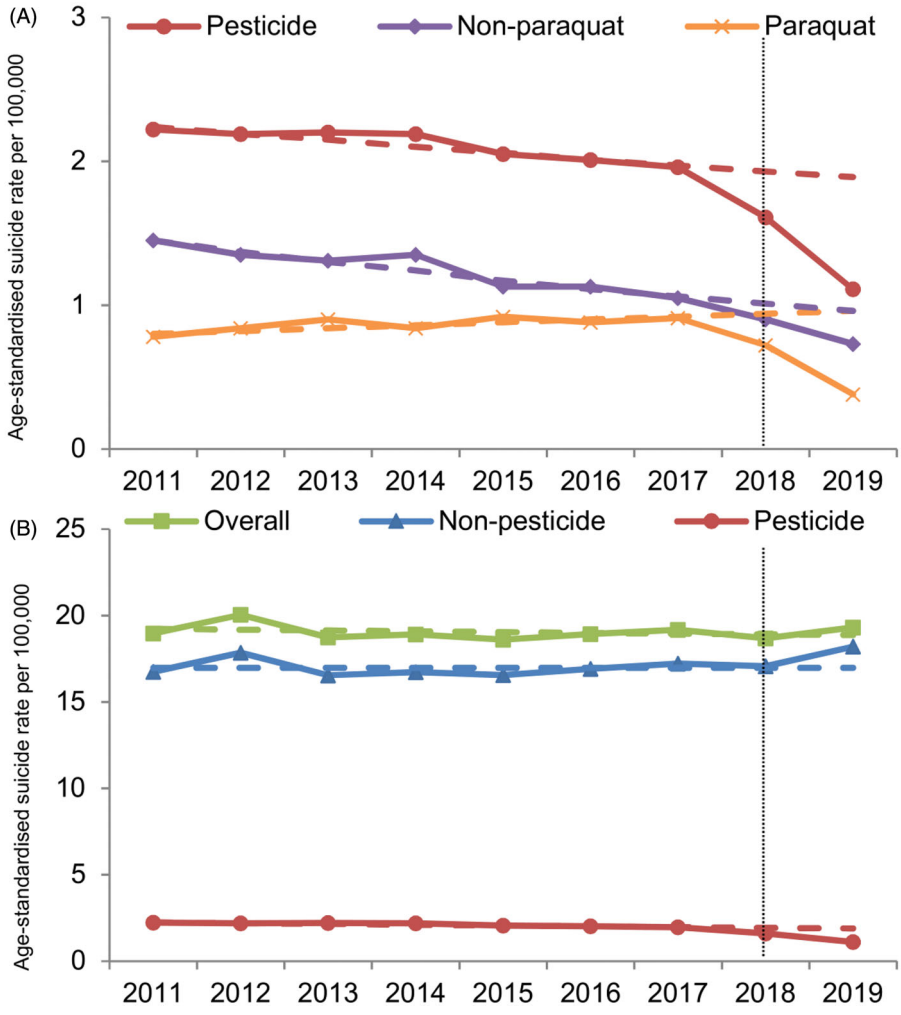

Figure 1. Trends in age-standardised rates (per 100,000) of (A) pesticide, non-paraquat, and paraquat suicide and (B) overall, non-pesticide, and pesticide suicide[a] (the dashed lines indicate the estimated suicide rates based on trend in 2011–2017) in Taiwan, 2011–2019. The vertical line indicates the year when the import and production of paraquat was banned (2018, or 1st February 2018 to be exact). [a]Including certified suicides and possible suicides (deaths certified as undetermined intent, accidental suffocation, or accidental pesticide poisoning).

By contrast, the largest absolute reduction in pesticide suicide rates was found in older people aged 65+ years (1.17 and 1.58 per 100,000 for paraquat and pesticide suicides, respectively), which was also the only age group showing a decrease in all-method suicide rates (RR = 0.90, 95% CI 0.82–0.97; RD= −3.70, 95% CI −6.82 to −0.83 per 100,000) (Figure 2B and Supplementary Appendix Table 2). A larger absolute reduction in pesticide suicide rates was also found in rural (vs. urban) areas and males (vs. females).

No obvious change in the four major crop yields was found after the paraquat ban (Supplementary Appendix Figure 2).

Discussion

Taiwan's ban on the import and production of paraquat from February 2018 was followed by a 37% reduction in pesticide suicides (190 fewer suicides) in 2019, mainly due to the 58% reduction in paraquat suicides (145 fewer suicides). No changes in non-pesticide and all-method suicides were found. In keeping with our hypothesis, larger absolute reductions were found in rural areas, males, and the elderly population, with a 10% fall in all-method suicide rate in the elderly population, amongst whom pesticide poisoning accounted for 21.4% of all suicides before the paraquat ban. The paraquat ban was associated with no obvious changes in crop yields.

There are some limitations of the study. First, this is an ecological analysis and the observed reduction in pesticide suicides could be due to other factors, e.g., national suicide prevention programmes including gatekeeper training and the surveillance and aftercare projects for suicide attempters. However, these programmes were not specific to pesticide self-poisonings, and thus the specific effect that we observed on pesticide suicides makes this unlikely. Furthermore, our data showed that the reduction in pesticide suicides was mainly attributable to the decrease in paraquat suicides, suggesting a causal effect of the paraquat ban on reducing pesticide suicides. Second, this study examined only the short-term effect on suicide of the first-stage paraquat ban starting from February 2018. It was still legal to sell and use paraquat in 2019 before its complete ban from February 2020. Future research is needed to assess the longer-term effect of the complete paraquat ban. Finally, we included

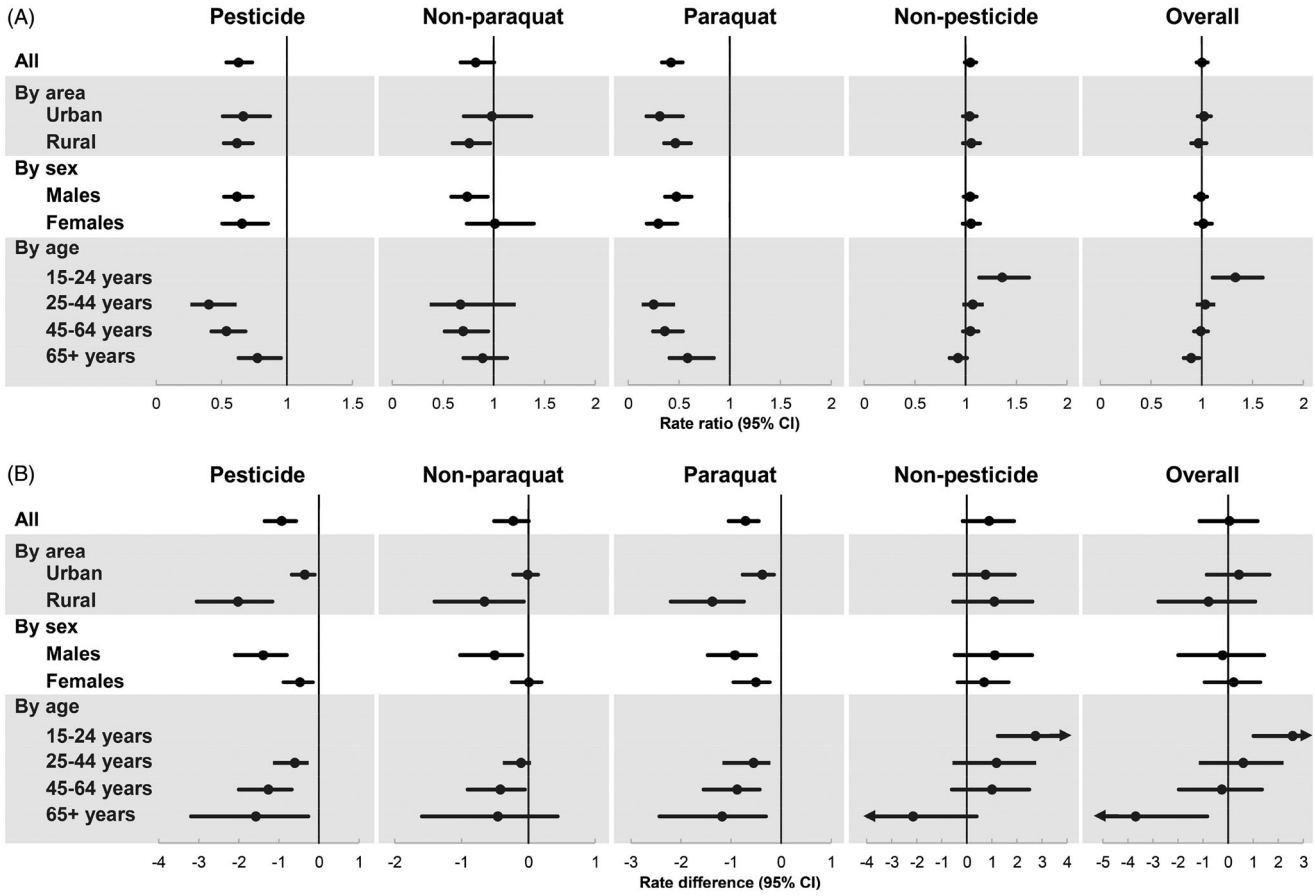

Figure 2. (A) Rate ratios (RRs) and (B) corresponding rate differences (RDs) per 100,000 based on RRs, and their 95% confidence intervals (CIs) of suicide by method (pesticide vs. non-pesticide) and pesticide (paraquat vs. non-paraquat) in 2019 after the paraquat ban in Taiwan. RRs are between the observed rates and the expected rates based on suicide trends 2011–2017 estimated using negative binomial regression models. The import and production of paraquat was banned from 1 February 2018. *Note*: Rate ratios for pesticide (non-paraquat and paraquat) suicides could not be estimated in people aged 15–24 years due to no cases. [a]Including certified suicides and possible suicides (deaths certified as undetermined intent, accidental suffocation, or accidental pesticide poisoning).

both certified and possible suicides (including accidental pesticide poisoning) in the analysis to address possible under-reporting of suicide, whilst possible suicides may not all be actual suicides. However, sensitivity analyses including certified suicides alone showed almost the same findings. Furthermore, accidental pesticide poisoning deaths may also be prevented by the paraquat ban.

Our finding is consistent with that found in South Korea, which observed a 37% fall in pesticide suicides in 2013 after the 2011–2012 ban on the sale of paraquat [5]. In Sri Lanka, a ban on three highly hazardous pesticides including dimethoate, fenthion, and paraquat in 2008–2011 was followed by a 50 and 21% drop in pesticide and overall suicides in 2011–2015, respectively [12]. Individuals who consider ingesting pesticides to kill themselves may impulsively choose the most readily available products. Therefore, banning highly hazardous pesticides may contribute to reductions in suicide rates if lower lethality products are ingested instead [13,14].

We found no change in whole-population overall suicide rate after the paraquat ban. By contrast, a reduction in overall suicides was found in South Korea [5] and Sri Lanka [12] after the bans that involved paraquat. One reason for the difference in findings is the high proportions of pesticide suicides in all suicides in South Korea (21%) [15] and Sri Lanka (50%) [13] before the ban. By contrast, paraquat and pesticide ingestion accounted for only 5 and 12% of all suicides, respectively, in Taiwan before the paraquat ban [11], and thus the expected effect of the regulations on overall suicide rates is limited. By contrast, pesticide poisoning accounted for 21.4% of all elderly suicides in Taiwan (Supplementary Appendix Table 2), in keeping with our finding of a reduction in both pesticide suicides and all-method suicides in the elderly population following the paraquat ban. Another factor that may have contributed to the lack of any impact of the paraquat ban on Taiwan's whole-population suicide rate is the increase in suicide rates in the younger (15–24 years) and middle-aged (45–64 years) groups in Taiwan in recent years [9].

We found limited evidence for method substitution, i.e., a shift from paraquat ingestion to fatal self-poisoning using other pesticides or other suicide methods after the paraquat ban. There was no change or a small decrease in non-paraquat pesticide suicides in the whole population and across age groups. With the exception of the elderly, there was a suggestion of an increase in non-pesticide suicides in the period after the ban (RR = 1.05, 95% CI 0.99–1.10). Nevertheless, in those aged 65+ years, i.e., the age group

with the highest burden of pesticide and paraquat suicides in Taiwan, there was no evidence of method substitution. Follow-up studies are needed to investigate the longer-term impact of paraquat ban and any method substitution.

In contrast to the concerns about the potential harmful effect on agricultural outputs due to pesticide bans, our results showed no obvious change in crop yields after the paraquat ban, in keeping with findings from South Korea [5], Sri Lanka [12,16], Bangladesh [17], and India [18].

In conclusion, the 2018 ban on the import and production of paraquat was associated with a reduction in pesticide suicide rates in Taiwan in 2019, with a fall in all-method suicide rates in older people, who had the greatest burden of pesticide suicides across all age groups. National and international policies restricting access to highly hazardous pesticides may prevent many pesticide suicides.

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Disclosure statement

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