



Common Pesticides Used in Suicide Attempts Following the 2012 Paraquat Ban in Korea

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To determine the change in pesticides used during suicide attempts after the 2012 paraquat (PQ) ban, we evaluated the annual number of suicide attempts by pesticide ingestion between 2011 and 2014. We extracted demographic, clinical outcome, and pesticide class data from the medical records of 1,331 patients that attempted suicide by pesticide ingestion. Pesticides were sorted into 5 groups: herbicides, insecticides, fungicides, other pesticides, and combined pesticides. Each group was subdivided into various classes based on publications by the respective Resistance Action Committees. The chi-square test for trends was used to compare the annual incidence of categorical variables. The total number of suicide attempts decreased each year, from 399 in 2011 to 245 in 2014. Simultaneously, PQ ingestion decreased from 253 patients in 2011 to 60 in 2014. The proportion of PQ to pesticides also decreased from 63.4% in 2011 to 24.5% in 2014. Furthermore, the rate of decrease in the proportion of PQ to all herbicide categories increased by calendar year. In conclusion, there is a significant trend in increased annual number of suicides and proportion of suicides using glyphosates and glufosinates versus total herbicides. However, the number of suicide attempts using glyphosate and glufosinate is lower than that using PQ. The ratio of persons completing suicide to those attempting suicide after pesticide ingestion has decreased every year after the PQ ban.

Keywords: Paraquat; Paraquat Ban, Suicide Attempted; Suicide Completion; Pesticides

INTRODUCTION

The use of pesticides is important in agriculture, and the availability of cheap and effective pesticides has been advantageous for farmers worldwide. However, while pesticides allow for increased food production, they may have adverse effects on the environment. Additionally, pesticide ingestion is a common method of suicide, particularly in Asian countries (1, 2).

In general, people attempting suicide via pesticide ingestion are committing suicide on impulse (3, 4), and may seek help. Patients in this category undergo intensive treatment and the clinical outcomes are good when physicians can treat them with an appropriate remedy, based on accurate toxicological information.

The pesticides commonly used by people attempting suicide vary because pesticides are constantly being launched or removed from the market. Pesticides include a variety of agricultural products, including herbicides, insecticides, and fungicides. In Korea, paraquat (PQ, bipyridylium) was the most commonly ingested pesticide during suicide attempts (5, 6). Thousands of suicides by PQ ingestion were attempted every year, resulting in numerous deaths. The distribution and use of PQ was stopped in 2012 by Korean health authorities. Given that the number of

suicide attempts has not changed, it would be useful to know which pesticides are being used by people attempting suicide. This study was designed to evaluate the trend of change in pesticides commonly used for suicide attempts after the 2012 PQ ban in Korea.

MATERIALS AND METHODS

Between January 2011 and December 2014, 1,331 people that attempted suicide by pesticide ingestion (males: 836, females: 465, mean age: 57.5 ± 16.1 yr) were admitted to the Institute of Pesticide Poisoning at Soonchunhyang University Cheonan Hospital, a tertiary referral center for toxicology patients located in a rural area of Korea. We identified the ingested chemicals and clinical outcomes (patient survival) from medical records. The amount of liquid chemical ingested was calculated by the number of mouthfuls (1 mouthful = 20 mL), as stated by the patient and/or calculated from the remaining amount in the chemical bottle.

Pesticides were sorted into 5 groups: herbicides, insecticides, fungicides, other pesticides, and combined pesticides. Each group was subdivided into various classes based on those published by the respective Resistance Action Committees (Special-

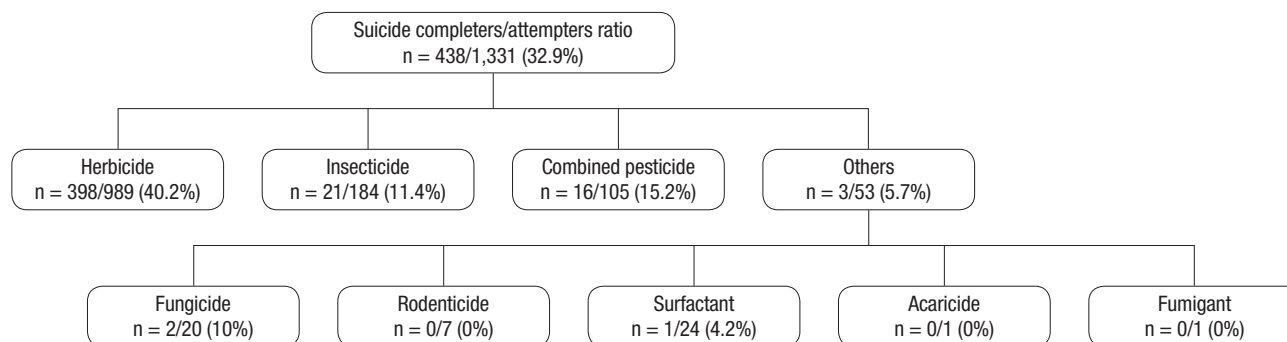


Fig. 1. Pesticide classes and the ratio of suicide completion to suicide attempts (%) in each category, between 2011 and 2014. Combined pesticides*: two active ingredients in a pesticide formulation, or two or three active ingredients in more than two different pesticides. In general, pesticide formulations include various kinds of surfactants as an emulsifier. However, in some instances, the surfactant** is sold separately. For details, please see the "Discussion".

ist Technical Groups of CropLife International: HRAC for herbicides, IRAC for insecticides, FRAC for fungicides, and RRAC for rodenticides (7). The common name of the pesticide was used, as determined by the Technical Committee 81 of the International Organization for Standardization (ISO/TC81).

Statistics

All demographic data were presented as the mean \pm SD, unless otherwise noted. The amount ingested and time between ingestion and arrival at the hospital had a wide distribution. Therefore, the values were presented as the median, range, skewness, and kurtosis. To clearly show the distribution (or phenomenon) of our data, herbicide classes were reclassified into four comparable classes: bipyridyliums, glycine derivatives, phosphinic acids, and other herbicides. Similarly, the insecticide classes were reclassified into four groups: organophosphates, pyrethroids, carbamates, and other insecticides. The "other pesticide" group was reclassified into three classes: surfactants, warfarin, and other. The numbers in the "combined pesticide" and fungicide group were too small to apply statistical tests, with one or two pesticides in many individual classes. The chi-square test for trends was used to compare the annual incidence of categorical variables between 2011 and 2014, and the significance threshold was set at 0.05. SPSS version 17.0 for Windows was used for all analyses.

Ethics statement

The study was approved by the institutional review board of Soonchunhyang Cheonan Hospital (IRB No. 201502002). The board waived informed consent.

RESULTS

Demographic data

The average amount of undiluted liquid pesticide ingested was 125 ± 113 mL (median: 100 mL, range: 3-500 mL). The time between ingestion and arrival at the hospital was 8.3 ± 16.9 hr (me-

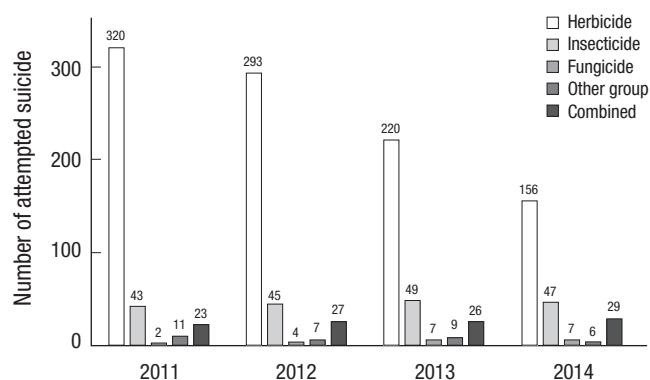


Fig. 2. Change in the annual number of suicide attempts in each pesticide category after the PQ ban in 2012. Note that the annual attempt numbers decreased dramatically after the 2012 PQ ban in the herbicide category, where no significant change was observed in the other pesticide categories. The "other group" comprised of surfactant, warfarin (rodenticide), mite growth inhibitor (acaricide), and aluminum phosphide (fumigant). For the "combined" category, note the "Results" section in the manuscript.

dian: 4 hr, range: 1-192 hr). The average APACH score was 10.2 ± 6.4 (median: 9, range: 1-39). The average admission day was 7.9 ± 7.5 (range 1-60 days).

A schematic of the pesticide classes and completed/attempted suicide ratio (%) in each category is shown in Fig. 1. Among 1,331 attempted suicides between 2011 and 2014, the majority (96%) of patients ingested one herbicide (74.3%), one insecticide (13.8%), or a combination of pesticides (7.9%). The remainder fell within the "other pesticide" category. The herbicide group included thirteen herbicide classes: bipyridylum, glycine derivatives, phosphinic acid, chloroacetamide, benzoic acid, dinitroaniline, phenoxycarboxylic acid, pyridinecarboxylic acid, aryloxyphenoxypropionate, oxadiazole, benzothiadiazinone, benzonitril, cyclodiene, and organochlorine.

Fig. 2 shows the change in the number of suicides attempted within the various pesticide categories between 2011 and 2014. The total number of suicide attempts decreased from 399 in 2011 to 245 in 2014 ($P < 0.001$). Herbicides were the leading pesticide used throughout the observation period, and a similar trend was

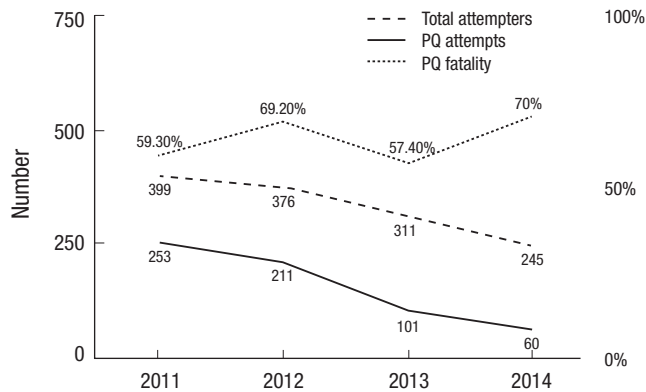


Fig. 3. Change in the annual number of total suicide, suicide attempts with PQ, and PQ fatality. PQ attempts = suicide attempts using PQ ingestion. PQ fatality (%) = suicide completion using PQ versus attempts using PQ. Note a marked decrease in the annual number of both people attempting suicide with total herbicides and with PQ, ($P < 0.001$). The annual PQ fatality was between around 60%-70%.

observed, from 320 in 2011 to 156 in 2014 ($P < 0.001$). Among herbicides, the majority (40.2%) of patients ingested PQ. Glyphosate and glufosinate were the second and third primary classes.

Fig. 3 shows the annual number of suicide attempts and the proportion using PQ, obtained by determining the ratio of suicide attempts using PQ to attempts using all kinds of pesticides. There was a marked decrease in both the annual number of suicides and the proportion using PQ: 79.0% (253 of 320) for 2011, 72.0% (211 of 293) for 2012, 45.9% (101 of 220) for 2013, 38.5% (60 of 156) for 2014 ($P < 0.001$). Furthermore, the proportion of PQ to all pesticides decreased every year: 80.2% (253 of 399) in 2011, 56.1% (211 of 376) in 2012, 32.5% (101 of 311) in 2013, and 24.5% (60 of 245, $P < 0.001$).

The rate of decrease in the proportion of herbicide to all pesticides increased by calendar year. This value decreased 8.4% from 2011 to 2012, 24.9% from 2012 to 2013, and 29.1% from 2013 to 2014. Similarly, the rate of decrease in the proportion of PQ to all herbicide increased by year. This value decreased 16.6% from 2011 to 2012, 52.1% from 2012 to 2013, and 40.6% from 2013 to 2014 ($P < 0.001$, Fig. 3).

There was a significant increasing trend in the annual number of suicides and the proportion of glyphosates and glufosinates used to total herbicides: 32 (10.0%) → 41 (14.0%) → 60 (27.3%) → 46 (29.5%) for glyphosate, and 16 (5.0%) → 23 (7.9%) → 35 (15.9%) → 30 (19.2%) for glufosinate, between 2011 and 2014 ($P < 0.001$, Fig. 4). No significant change in the annual number of suicide attempts and the proportion in other pesticide categories was observed.

The insecticide group included eleven insecticide classes: organophosphates, pyrethroids, carbamates, neonicotinoids, cyclodiene organochlorines, benzoylureas, avermectins, oxadiazines, chloroacetamides, pyridalyls, and sulfuramides. Organophosphates, pyrethroids, and carbamates represented the three major classes. No significant change in the annual number of

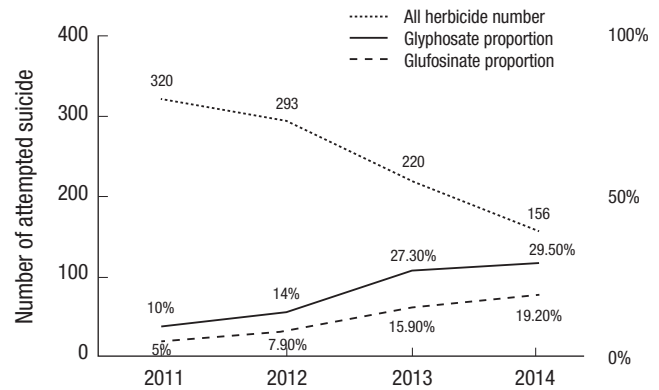


Fig. 4. Change in the annual number of suicide attempters who ingested herbicide and the proportion of glyphosate and glufosinate. Note that the proportion of both glyphosate and glufosinate increased considerably, between 2011 and 2014 ($P < 0.001$).

suicide attempts by insecticide ingestion was observed ($P = 0.759$).

Twenty patients attempted suicide using fourteen different classes of fungicides. The number of patients attempting suicide by fungicide ingestion was too small for statistical analysis.

Thirty-three patients were classified into the “other pesticide” group, ingesting four classes of pesticides: surfactant, wafarin (rodenticide), mite growth inhibitors (acaricide), and aluminum phosphide (fumigant). Surfactants and wafarin (rodenticide) were the primary classes. No significant change in the annual number was observed ($P = 0.134$).

Forty-five pesticide combinations were used by 105 patients. Among these, organophosphate and pyrethroid combination was most common. No significant difference in annual number was observed among patients using combined pesticide ingestion ($P = 0.274$).

DISCUSSION

PQ is banned in more than 32 countries, including the 27 countries in the European Union. The cause of the PQ ban differs between nations. In 2007, the European Court of First Instance ruled that a 2003 directive authorizing the use of PQ failed to satisfy the requirement of protection of human health, particularly relating to operator exposure. It also failed to assess the risk of Parkinson’s disease and to properly assess risk to animals.

In many Asian countries, the rising number of deaths due to PQ suicide attempts is considered a grave social issue (8-11). In Japan, PQ poisoning was a social issue, as these poisonings arose from both suicide and homicide attempts (12). Thus, sale of 24% PQ products was suspended, and products were replaced with 5% PQ in 1986. In spite of this effort, the Japanese Association of Rural Medicine reported in 2013 that the mortality rate for PQ suicide attempts was around 80%, even with the 5% product. Thus, they concluded that attempts to decrease mortality with low concentration of PQ were not effective (12).

In Korea, PQ regulations were introduced in two steps. The first was the cancellation of re-registration in October 2011, which prohibited the manufacture or import of PQ. The second was the complete ban in November 2012, which prohibited distribution, sale, and use of PQ. Until the 2012 ban in Korea, PQ was the most commonly used pesticide for suicide attempts, with an estimated 2,000 toxic ingestions annually and 60%-70% mortality. We cannot explain why PQ was frequently used to commit suicide. In our 2009 study (13), we classified suicide attempts involving PQ use into two groups, intentional and non-intentional, to determine whether the patients had specific information about PQ, such as the lack of an effective therapy and high mortality rate. The intentional selection group accounted for 38.4% of cases. The reason they choose PQ was that they believed PQ had extremely high mortality rates, even after ingesting a few drops. Others (62%; non-intentional selection groups) bought an herbicide from a shop, without seeking a specific trade name, and it simply happened to be PQ. In other situations, farmers selected a pesticide to commit suicide from a pesticide storehouse, which was PQ. This is due to the wide use of PQ in farming areas, as it is cheap and effective.

The annual number of suicide attempts using herbicides is greater than other insecticides, even after the PQ ban. This may be because the general population believes herbicides are more toxic than other pesticides. PQ was the leading pesticide used in suicide attempts in 2014, even 3 yr after its complete ban in 2012. This indicates that some PQ sold before 2012 remains available in farming areas, despite efforts to remove it. However, the proportion of PQ among all pesticides has decreased, from 63.4% in 2011 to 24.5% in 2014. This finding suggests that PQ will not be commonly used for suicide in the future.

Insecticides were the second most common pesticide used, with 186 attempted suicides and 21 deaths. Organophosphate, pyrethroid, and carbamate were the three major insecticides used, and almost all deaths (20 of 21) were associated with these insecticides. There was no significant change in the annual number of insecticide-associated suicides between 2011 and 2014. Fungicides had a lower fatality rate than herbicides and insecticides. Only two patients died of triazole class fungicide intoxication.

In general, pesticide formulations include various surfactants as emulsifiers (14, 15). However, in some instances, surfactants such as polyoxyethylene alkylaryl ether are sold separately as wetting agents for other pesticides. In other instances, PQ (gramoxon inteon) herbicides are sold in pairs of two bottles, with a main bottle containing the active ingredient and an accessory bottle containing the surfactant, which must be mixed before spraying. No significant difference in the annual number of suicide attempts was observed with either fungicide and surfactant class between 2011 and 2014. Among all cases, 105 patients attempted suicide using combined pesticides. The annu-

al number of suicide attempts using combined pesticides was not significantly different during the observation period (Fig. 3).

The current study had some limitations. First, the annual number of suicide attempts in the current study may differ from that in national statistics. As a tertiary referral center for toxicology patients, most critical toxicology patients, such as patients with PQ intoxication, are transferred from other hospitals. However, not all patients who ingested pesticides were referred to our toxicology unit, particularly those with low-grade toxicities. Therefore, the annual number of suicide described does not represent the national number. Despite these limitations, our study shows that the number of suicide attempts and the proportion of PQ to pesticides decreased significantly after the PQ ban. Furthermore, the decreasing proportion of PQ to all herbicide categories increased annually. There was a significant increase in the annual number of suicides and the proportion using glyphosate and glufosinate. However, the number of suicide attempts using glyphosate and glufosinate is not as high as PQ.

DISCLOSURE

The authors declare no conflicts of interest, and the authors alone are responsible for the content and writing of the article.

AUTHOR CONTRIBUTION

Study concept & design: Gil HW, Hong SY. Acquisition of data: Lee JW, Hwang IW, Kim JW, Moon HJ, Kim KH. Data analysis and interpretation: Park S. Drafting and revision: Hong SY. Final approval: all authors.

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