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Pesticide Poisoning Deaths Detected at the National Forensic Service Headquarters in Seoul of Korea: A Five-Year Survey (2005-2009)

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ABSTRACT

Objectives : The records of 447 pesticide poisoning deaths from the National Forensic Service (NFS) headquarters located in Seoul of Korea from 2005 to 2009 were retrospectively reviewed.
Methods : The data of each case were analyzed by using the SPSS program.
Results : The mean age was 57.8 ± 14.8 years and the range was 16-92 years. The numbers of deaths of males and females were 301 and 134, respectively. The largest number of cases occurred in people aged 50-59 years (n=92, 20.6%) followed by the age groups 40-49 years (n=91, 20.4%), 60-69 years (n=88, 19.7%), and 70-79 years (n=75, 16.8%). The total number of deaths among other age groups (10-19, 20-29, 30-39, 80-89, and 90-99 years) was 73, representing only 16.3%. Of all pesticide poisoning deaths, 96.2% were due to suicide, and 28.4% of the total number who died received medical treatment. The mostfrequent site of ingestion was the person's own residence (n=279, 62.4%). The most common classes of pesticide were bipyridylium herbicide (paraquat, 31.1%), organophosphate insecticide (21.7%), and carbamate insecticide (15.4%). The major pesticides having a high proportion of fatalities were paraquat (31.1%), methomyl (11.4%), glyphosate (9.1%), dichlorvos (5.6%), phosphamidon (4.6%), and methidathion (4.0%).
Conclusions : This study showed that poisoning deaths due to pesticides are one of the major public health problems in Korea. Enforcement of regulations and safety education to prevent pesticide poisoning should be carried out by the government.

Key words : Death, Herbicide, Insecticide, Pesticide, Poisoning

INTRODUCTION

According to the Agricultural Chemicals Regulation Law, the term "agricultural chemicals" means fungicides, insecticides, herbicides, and other substances used to control fungi, insects, mites, nematodes, viruses, weeds, and other plants and animals (hereinafter generically called "diseases and insect pests") that may damage crops (including trees and agricultural and forestry products, hereinafter called "crops, etc."), and also refers to other substances (including those, specified by government ordinances, that are used as raw materials or materials to control the diseases and insects pests) [1]. A pesticide is a substance which is inevitably used for the quantitative increase and qualitative improvement of the crops, and it has contributed much to farming productivity due to the increase in the population. Pesticides are toxic to humans or animals, but are easy to purchase, the rules for handl-

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ing pesticides are indefinite, and the regulations are not strictly abided by; therefore, their use occurs with high frequency in suicide, homicide, and other accidents. The World Health Organization (WHO) assumed that there had been 873,000 cases of suicide among the world population in the year 2002 [2]. Jayaratnam reported that, among the world population, there were 220,000 cases of deaths related to pesticides, most of which were suicides, in the year 1984 [3]. Several researches reported on the cases of deaths by pesticides in China, Malaysia, Sri Lanka, and Trinidad-Tobago, and estimated that 330,000 people died by intentional intake of pesticides [4-7]. Normally, people from industrialized countries take surpluses of analgesics, sedatives, or anti-depressants, which are relatively less toxic medicines compared to pesticides [8], and one report stated that the estimated fatality rate by excess intake of those medicines was 0.5% [9]. However, the circumstances are different in undeveloped countries, where there have been many cases of pesticide poisoning leading to deaths, constituting more than 60% of all deaths by toxic materials [4,10-12]. In Korea, deaths by insecticides and herbicides form the majority of the cases of toxic material intoxication [13]. According to the reports of the Korea National Statistical Office, the number of pesticide poisoning deaths and proportion of pesticide poisoning deaths from total toxic material deaths increased every year from the year 2000 (47.0%) to the year 2005 (68.5%) [14]. Despite the recent industrialization, the main cause of death, like in undeveloped countries, is pesticides. Likewise, there is a yearly increase in the number of deaths by pesticides, but the reality is that only basic investigation is happening [15,16]. This study organized and analyzed the results from the requested data related to deaths by pesticide poisoning in the Metropolitan area from the National Forensics Service for the period 2005 to 2009. This study aims to provide baseline data for establishing countermeasures to prevent further pesticide poisoning and for the establishment of a database for the government-initiated poison control center.

MATERIALS AND METHODS

1. Collecting data of deaths caused by pesticide poisoning

This research collected data of 447 people who died due to pesticides. The data, which were collected from January 2005 to December 2009, were provided by the National Forensic Service. The National Forensics Service headquarters covers Seoul Metropolitan area, Gyeonggi province (except for Pyeongtaek and Anseong), Gangwon province, and Jeju province. However, the zone had changed due to the foundation of the eastern branch in Wonju, Gangwon province on November 22, 2005. Gangwon province and some areas of Gyeonggi province, such as Yangpyeong, Gapyeong, Yeoju, and Icheon regions, were examined by the eastern branch of National Forensic Service; therefore, this study only includes the data collected until November, 2005. The sources for examining the toxic materials, after autopsy, were biological samples such as blood, gastric contents, urine, and tissues. In cases without autopsy, the sources were empty bottles that contained pesticides, a cup that was used for ingestion, or vomit, all of which were articles left by the deceased.

2. Methods for testing pesticides from the samples

This study used biological samples or articles left on the scene and pretreatments were done through liquid-liquid extraction, solid phase extraction, and solid phase microextraction. During these processes thin-layer chromatography (TLC), gas chromatography (GC), GC/MSD, high performance liquid chromatography (HPLC), and LC/MS/MS were used. Using these tests, unknown materials were identified and quantified.

3. Data analysis on pesticides poisoning deaths

The data of each case were analyzed according to the age groups and sex, type of death, whether or not

medical treatment took place, route of administration, the original site where the poison was taken, number of deaths according to month and year, and the kinds of ingested pesticides. Statistical analysis was carried out using the SPSS version 10.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

1. Characteristics of deaths by pesticide poisoning

During the study period, from January 2005 to December 2009, the results of information on the cadavers were as follows: out of 447 people, excluding 28 people who were anonymous, the mean age was 57.8±14.8 and the age range was 16 to 92 years (Table 1).

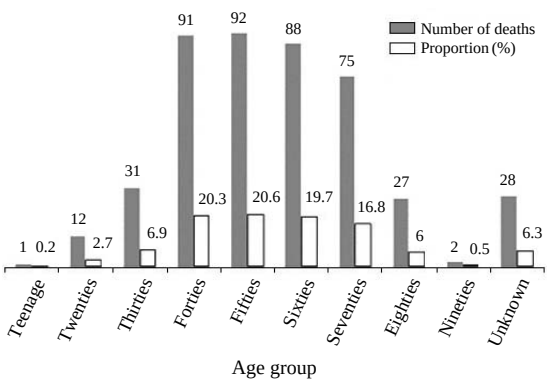

Fig. 1. Number of deaths with acute pesticide poisoning according to age (n=447).

Table 1. Characteristics of 447 deaths with acute pesticide poisoning

Characteristics	
Age (mean±SD, years)	57.8±14.8 (range 16-92, unknown 28)
Gender (male : female)	301 : 134 (unknown 12)
Number of attempted suicides (%)	430 (96.2%, unknown 1)
Number of treated deaths (%)	127 (28.4%, unknown 3)
Route of administration (%)	Oral (100%)

As seen in Fig. 1, the frequency or incidence according to age was teenage (n=1, 0.2%), 20s (n=12, 2.7%), 30s (n=31, 6.9%), 40s (n=91, 20.3%), 50s (n=92, 20.6%), 60s (n=88, 19.7%), 70s (n=75, 16.8%), 80s (n=27, 6.0%), 90s (n=2, 0.5%), and 28 anonymous people (6.3%). The male to female ratio was 301 : 134 and the number of deaths of males was twice that of females. The causes of deaths were as follows: suicide comprised 96.2%, eleven people ingested pesticide by mistake, and five were homicide cases. Out of all people who died, 127 people who ingested pesticide died while receiving medical treatment. It was generally considered, unless specified, that people who died ingested the pesticide through oral administration, which was found to be 100% true in all cases.

2. Original place where the pesticide was ingested

The places where the people ingested pesticide were as follows: individual's residence (62.4%), hill (11.4%), accommodation such as a motel (6.7%), public space such as a park (4.3%), inside the car (3.8%), workplace (2.2%), riverside (2.0%), others (3.4%), and unmentioned (2.5%) (Table 2).

3. The monthly and yearly changes in the number of deaths by pesticide poisoning

Table 3 shows the comparative results of total autopsy cases versus autopsy cases related to pesticide poisoning. From 2005 to 2009 there were between 2,200

Table 2. Site of pesticide ingestion

Site	Number of deaths (%)
Residence	
Own	279 (62.4)
Others	6 (1.3)
Hill	51 (11.4)
Accommodation (Inn/Motel/Hotel)	30 (6.7)
Public area	19 (4.3)
In car	17 (3.8)
Workplace	10 (2.2)
Riverside	9 (2.0)
Others	15 (3.4)
Unknown	11 (2.5)

Table 3. Total number of autopsy cases and number of autopsy cases related to pesticide poisoning during 2005-2009 conducted in National Forensic Service headquarters

Year	Total number of autopsy cases	Number of autopsy cases related to pesticide poisoning	Proportion of pesticide poisoning deaths among total autopsy cases (%)
2005	2851	47	1.65
2006	2516	35	1.39
2007	2196	33	1.50
2008	2403	26	1.08
2009	2627	35	1.33
Total	12593	176	1.40

Table 4. Number of deaths according to the class of pesticides during 2005-2009 tested in National Forensic Service headquarters

Year	Insecticides					Herbicides		Rodenticide	≥2*	Total
	OPs	Carbamate	OC	Synthetic pyrethroids	Others	Paraquat	Others			
2005	32	20	8	9	0	37	13	0	7	126
2006	18	19	3	2	1	31	11	1	4	90
2007	18	6	4	3	0	24	7	0	9	71
2008	12	10	4	1	2	22	14	0	7	72
2009	17	14	2	4	3	25	12	0	11	88
Total (%)	97 (21.7)	69 (15.4)	21 (4.7)	19 (4.3)	6 (1.3)	139 (31.1)	57 (12.8)	1 (0.2)	38 (8.5)	447
	212 (47.4)					196 (43.9)				

OPs: organophosphate, OC: organochlorine.
*≥2 means victims ingested more than two components.

and 2,850 autopsy cases each year. Out of those cases, 26 to 47 cases each year were related to pesticide poisoning and the total was 176 cases, consisting of 1.40% of total autopsy cases over five years.

The yearly changes in the number of deaths by pesticides were as follows: 2005 (n=126), 2006 (n=90), 2007 (n=71), 2008 (n=72), and 2009 (n=88) (Tables 4 and 5). The monthly count ranged from 24 to 56 people and was as follows: March (n=43), May (n=45), June (n=49), July (n=56), and August (n=40) (Fig. 2).

4. The frequency of deaths by pesticide poisoning according to region

The order according to region in which the deaths by pesticide poisoning occurred is as follows: Gyeonggi province (n=198), Seoul (n=121), Incheon (n=64), Jejudo (n=26), Gangwon province (n=23), southern Chungnam province (n=7), Daegu/Gyeongbuk province (n=5), and Gyeongnam province (n=3).

5. The classification of pesticides according to the components

When examining pesticides that people ingested, out of all cases of deaths by pesticides, insecticides accounted for 47.4% and herbicides 43.9%, and people who ingested either insecticides or herbicides accounted for more than 90%. It was found that only the person died by rodenticide, representing 0.2%. Thirty-eight people took more than two components of pesticides, accounting for 8.5% of the total (Tables 4 and 5).

Among pesticides that were detected, insecticides accounted for 47.4% (n=212) of total deaths, organophosphorous 21.7%, carbamates 15.4%, organochlor-

Table 5. Name and number of deaths according to the pesticide during 2005-2009 tested in National Forensic Service headquarters

Uses	Class	Name	Year					
			2005	2006	2007	2008	2009	Total (%)
Insecticide	Organophosphate	Dichlorvos	9	5	6	3	2	25 (5.6)
		Phosphamidon	9	3	–	3	6	21 (4.6)
		Methidathion	4	4	4	2	4	18 (4.0)
		Parathion	3	1	1	3	–	8 (1.8)
		Diazinon	3	–	–	1	–	4 (0.9)
		Demeton-s-methyl	1	–	2	–	–	3 (0.7)
		Monocrotophos	–	1	2	–	1	4 (0.9)
		Chlorpyrifos	–	1	2	–	–	3 (0.7)
		Phenthoate	1	1	–	–	1	3 (0.7)
		Chlorpyrifos-methyl	1	–	–	–	–	1 (0.2)
		Fenitrothion	1	–	–	–	1	2 (0.5)
		Phorate	–	1	–	–	–	1 (0.2)
		Fenthion	–	1	–	–	–	1 (0.2)
		EPN	–	–	1	–	1	2 (0.5)
		Edifenphos	–	–	–	–	1	1 (0.2)
	Carbamate	Methomyl	14	10	6	8	13	51 (11.4)
		Carbofuran	4	4	–	1	–	9 (2.0)
		Benfuracarb	1	2	–	1	–	4 (0.9)
		Furathiocarb	1	2	–	–	1	4 (0.9)
		BPMC	–	1	–	–	–	1 (0.2)
	Organochlorine	Endosulfan	8	3	4	4	2	21 (4.7)
	Synthetic pyrethroid	Deltamethrin	3	1	2	–	2	8 (1.8)
		Cypermethrin	2	–	1	–	1	4 (0.9)
		lambda-Cyhalothrin	1	1	–	1	–	3 (0.7)
		Etofenprox	1	–	–	–	–	1 (0.2)
		Fenvalerate	1	–	–	–	1	2 (0.5)
		Bifenthrin	1	–	–	–	–	1 (0.2)
	Others	Flufenoxuron	–	1	–	–	–	1 (0.2)
		Imidacloprid	–	–	–	1	1	2 (0.5)
		Benzoximate	–	–	–	1	–	1 (0.2)
		Clothianidin	–	–	–	–	1	1 (0.2)
		Chlorfenapyr	–	–	–	–	1	1 (0.2)
Herbicide	Bipyridylium	Paraquat	37	31	24	22	25	139 (31.1)
	Others	Glyphosate	10	6	6	10	9	41 (9.1)
		Sulfosate	1	1	1	–	–	3 (0.7)
		Glufosinate	–	–	–	2	–	2 (0.5)
		Dicamba	–	2	–	–	1	3 (0.7)
		Triclopyr	1	1	–	–	1	3 (0.7)
		Imazaquin	–	–	–	1	–	1 (0.2)
		Mecoprop	1	–	–	–	–	1 (0.2)
		Alachlor	–	1	–	1	1	3 (0.7)
Rodenticide		β-fluoroethylacetate	–	1	–	–	–	1 (0.2)
≥Two			7	4	9	7	11	38 (8.5)
Total			126	90	71	72	88	447

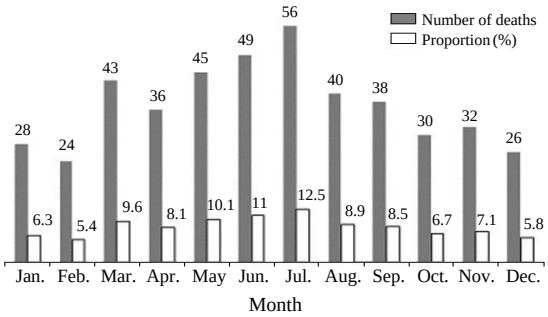

Fig. 2. Number of deaths with acute pesticide poisoning according to the month (n=447).

ines 4.7%, synthetic pyrethroids 4.3%, and others 1.3%. Among organophosphorous insecticides, the order of frequency was dichlorvos (n=25, 5.6%), phosphamidon (n=21, 4.6%), methidathion (n=18, 4.0%), and parathion (n=8, 1.8%). Among carbamate insecticides, methomyl accounted for 11.4% (n=51), and methomyl was more frequently found than other pesticides such as carbofuran and benfuracarb. Among synthetic pyrethroids, deltamethrin was detected most frequently (n=8, 1.8%). The herbicides accounted for 43.9% (n=196) of total cases. Death by paraquat accounted for 31.1% (n=139), and paraquat had the highest proportion as a single component, followed by glyphosate (n=41, 9.1%). There was only one case of rodenticide poisoning. The 54-year-old female who was not in a healthy condition ingested β-fluoroethylacetate. There were 38 cases of deaths of people who ingested more than two kinds of pesticides, representing 8.5% of total cases. The order of components from the highest to the lowest is as follows: paraquat, methomyl, glyphosate, dichlorvos, phosphamidon, and methidathion.

DISCUSSION

Pesticide, with its strong toxicity, easy handling, and indefinite regulation, is used frequently for suicide or homicide in Korea and elsewhere. It is reported that in China, Malaysia, Sri Lanka, and Trinidad-Tobago, 300,000 people die every year of intended pesticide poisoning [4-7]. In industrialized countries, people take analgesics, sedatives, and anti-depressants, all of which possess low toxicity. However, in undeveloped countries, deaths by pesticide poisoning are frequent and account for more than 60% of the total toxic materials poisoning deaths [4,10-12]. Even in Korea, death by toxic materials happens constantly, and the rate of death by pesticides increased from 47.0% in the year 2000 to 68.5% in the year 2005, and had risen continuously every year [14]. Despite the recent high degree of industrialization, just as in cases of the undeveloped countries, deaths by pesticides form the majority of causes of deaths. In order to observe the characteristics of deaths caused by pesticides, the authors analyzed the results gathered by the National Forensic Service within the last five years in regions such as the Metropolitan area, Gyeonggi and Jeju province.

According to reports that analyzed the pesticide poisoning patients who were hospitalized in 38 emergency rooms nationwide from August 2005 to July 2006, 2,064 people were hospitalized, of whom 238 were patients who ingested a pure form of organophosphorous pesticide and 23 were dead or discharged from hospital without the possibility of being cured, and the death rate was 19.1% [16]. Sixty-eight patients ingested carbamate pesticide, 13 people died while receiving medical treatment, and the mortality rate was 19.1% [15]. The mean age of 238 people who were hospitalized due to ingestion of organophosphorous insecticide was 55.3±17.3 years, and the 23 people who died had a mean age of 66.9±18.1 years. Among people who ingested carbamate insecticide, the mean age of the 68 hospitalized patients was 51.9 ±18.0 years, and that of people who died was 63.5 ±15.9 years. In this research, there were many cases of death by pesticides among people aged from their 40s to their 70s, and the results were similar to previous research findings. This research showed that there were more than twice as many deaths among males than females, and only 27.2% of the total number of people who died received medical treatment from the hospital. This research also showed that 96.2% of deaths were suicides. Eleven cases happened by acci-

dent, where people who saw brown bottles filled with pesticides in refrigerators mistook them for soft drinks bottles. From June 2004 to May 2005, out of 30 nationwide emergency room patients, the causes of hospitalization were medication (41.9%) and pesticides (33.3%). However, the death rate was higher among the patients who ingested pesticides [17]. Pesticides are much more toxic than the average medication and there are many cases of deaths; therefore, in order to prevent the misuse of pesticide, there should be thorough safety education and strict restrictions on its purchase.

There are similarities among the researches regarding pesticide poisoning. Research carried out in Daejeon found that the place where a person ingested the toxic material was his or her residence in 84.0% of cases [18]. Another research showed that the place where organophosphorous pesticide was ingested was the person's residence in 85.7% of cases [16]. Likewise, the present research produced similar results and the ratio was 62.4%. However, the reason why the percentage found by this research was lower than in previous researches is because the previous research was done among hospitalized patients, whereas only 28.4% were hospitalized in the present research. This research showed a high death rate in accommodation or hills and this reflects the tendency for people to kill themselves in isolated places.

From the year 2005 to 2009, there were a total of 19,945 autopsy cases reported by the National Forensic Service headquarters and four branches (the southern branch in Busan, western branch in Jangseong of Jeonnam province, central branches of Daejeon, and eastern branch of Wonju of Gangwon province). Out of 19,945 autopsy cases, 12,593 were conducted from the headquarters and accounted for 63.1% of total autopsy cases. Out of 12,593 cases, 176 were pesticides poisoning deaths and accounted for 1.4% of total autopsy cases. During the research period, out of 447 people who died of pesticide poisoning, except for 176 autopsy cases, the results for 271 people were based on articles left by the deceased or their vomit.

From the research, the yearly changes in the number of deaths by pesticide poisoning were as follows: 2005 (n=126), 2006 (n=90), 2007 (n=71), 2008 (n=72), and 2009 (n=88). The number of deaths has shown a tendency to decrease since the year 2006 due to the foundation of the eastern branch at the end of November, 2005, which reduced the coverage area of the National Forensic Service headquarters in Gangwon and some regions of Gyeonggi province and led to lower numbers of requests for autopsy and articles left by the deceased. It was also found that more deaths occurred in March, May, June, July, and August than in other months. One can assume that this happens because the month of March is the month when farming starts. May, June, July, and August are the busy farming season; thus pesticides are more frequently purchased and suicide by pesticide poisoning is more likely to happen. In Asian countries such as Nepal and Sri Lanka, the characteristics of organophosphorous pesticides poisoning patients were as follows; the ratio of male to female deaths was nearly the same, people between the age between their 20s and 40s died in large numbers, and more deaths happened in June, July, and August [19-21]. Compared to the study done in Asia, this study showed that the death rate of males was much higher than that of females and the proportion of deaths of people aged between their 40s and their 70s was more than 77%, but the months were similar. According to Shin *et al.*'s report, suicide happens more in summer and less in winter [13]. Shin *et al.* assumed that this is a difference compared with other poisonings that happen by accident and that are not affected by the season, and this research showed a similar result.

According to the region, Gyeonggi province, Seoul, and Incheon showed higher proportions of deaths by pesticide poisoning than Gangwon province. This is caused by the lower population of Gangwon province, and because requests for the National Forensic Service decreased due to the foundation of the eastern branch. Deaths by pesticide poisoning occurred a lot in large cities such as Seoul and Incheon, which shows that ordinary people need to be educated in toxicity or correct usage of pesticides. Gwangju, Goyang, Namyangju, Yangju, Yongin, Hwaseong city in Gyeonggi

province and western Incheon, Yeonsu of Incheon city, and Seogwipo city of Jeju province had more than 10 people who died of pesticide poisoning.

Based on this research, one compound called paraquat was responsible for 31.1% of total pesticide poisoning deaths, and this is because its toxicity to human beings is very high, (1-2 g is fatal to a human) and because there is no antidote for this compound [22]. Shin *et al.* reported that among Korean people who died due to poisoning by toxic materials between 1991 and 2001, insecticide and herbicide poisonings accounted for 30.21% and 17.10%, respectively [13], and even this study showed that among people who died of pesticide poisoning 90% or more died due to the use of either insecticide or herbicide. Lee *et al.* [16] reported on patients in 38 emergency rooms nationwide for one year who ingested organophosphorous pesticide and found that the order of pesticides ingested by those hospitalized was dichlorvos, methidathion, phosphamidon, EPN, parathion, monocrotophos, and chlorpyrifos. In this study, the order of organophosphorous pesticides ingested by those people who died was similar: dichlorvos, phosphamidon, methidathion, parathion, diazinon, and monocrotophos.

Pesticides are highly toxic and their use is not strictly forbidden, so there are many cases of deaths by suicide or homicide every year. However, unlike in industrialized countries, the poisoning control system in Korea has just begun. Thus, the results of this study might not reflect all possible cases of deaths by poisonous pesticides but the researchers hope that this research will be used for establishing health policy to prevent pesticide poisoning and to provide an accurate database for a government-initiated poisoning control center in the near future.

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