



Cyanide Poisoning Deaths Detected at the National Forensic Service Headquarters in Seoul of Korea: A Six Year Survey (2005~2010)

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The records of 255 cyanide poisoning deaths obtained from National Forensic Service (NFS) headquarters, located in Seoul of Korea, from 2005 to 2010 were retrospectively reviewed. The mean age was 41.88 ± 13.09 and range was 6~80 years (unknown in seven cases). The number of deaths of males and females were 200 and 53, respectively (unknown in two cases). The largest number of cases occurred in people aged 40~49 years (81 cases, 31.8%), followed by the age groups 30~39 years (51 cases, 20%), 50~59 years (44 cases, 17.2%) and 20~29 years (43 cases, 16.9%). The total number of deaths among other age groups (below 10, 10~19, 60~69, 70~79, over 80 years and unknown) were 36, representing only 14.1%. Of all cyanide poisoning deaths, 97.3% were due to suicide, and 14.5% of the total number who died received medical treatment. The most frequent site for ingestion was the person's own residence (120 cases, 47.1%) and the route of administration was mainly oral (252, 98.8%). From the total of 255 cyanide poisoning cases, white powders were submitted for analysis in 92 cases. Potassium cyanide and sodium cyanide occupied 51 and 41 cases, respectively. This study showed that poisoning deaths due to cyanide are one of the continuously reported public health problems in Korea. Enforcement of regulations and safety education to prevent cyanide poisoning should be carried out by the government.

Key words: Cyanide, Poisoning, Suicide

INTRODUCTION

Cyanide is used in a number of industries, such as electroplating, metal refinery, organic syntheses and various chemical processes. But this compound is extremely toxic to humans - a lethal dose for humans is 0.05 g/person for hydrogen cyanide or 0.15~0.3 g/person for potassium cyanide, and it acts rapidly. Cyanide is one of the most important materials in forensic toxicology studies in Korea because the compound has been used for suicide or homicide purposes. Cyanide exerts its toxic effects by reacting with the trivalent iron of cytochrome oxidase, thus inhibiting electron transport and preventing the cells from using oxygen (hypoxia), which results in a rapid impairment of vital functions (ATSDR, 2006). The World Health Organization (WHO) assumed that there had been 873,000 cases of suicide among the world population in the year 2002 (WHO, 2004). Normally, people from industrialized countries take an overdose of analgesics, sedatives or anti-depressants, which are rela-

tively less toxic than pesticides (Michel *et al.*, 2000), and one report stated that the estimated fatality rate by excess intake of those medicines was 0.5% (Gunnell *et al.*, 2004). In Korea, deaths by insecticides and herbicides form the majority of cases of toxic material intoxication, and death by cyanide occupies 0.51% of all poisoning cases (Shin *et al.*, 2004). Despite recent industrialization the main cause of death, as in undeveloped countries, is pesticides, and poisoning cases by extremely toxic chemicals, such as cyanide salts, happen continuously. And while the number of deaths by toxic substances continues to increase yearly, the reality is that only basic investigation is happening (Park *et al.*, 2004; Oh *et al.*, 2006). This study organized and analyzed the results from the requested data related to deaths by cyanide poisoning in the Metropolitan area from the National Forensic Service for the period 2005 to 2010. This study aims to provide baseline data for establishing countermeasures to prevent further cyanide poisoning and for the establishment of a database for the government initiates poison control program.

MATERIALS AND METHODS

Collecting data of deaths caused by cyanide poisoning. This research collected data about 255 people who

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died due to cyanide. The data, which were collected from January 2005 to December 2010, were provided by the National Forensic Service. The National Forensic 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 Nov. 22, 2005. Gangwon province and some areas of Gyeonggi province, such as Yangpyeong, Gapyeong, Yeosu and Icheon regions, were examined by the eastern branch of National Forensic Service; therefore, this study only includes the data collected there until November 2005. The sources for examining the toxic materials after autopsy were biological samples such as blood and gastric contents. In cases without autopsy, the sources were empty bottles that contained cyanide, a cup that was used for ingestion, or vomit, all of which were articles left by the deceased.

Methods for testing cyanide from the samples. This study used biological samples or articles left on the scene. Spectrometric techniques after microdiffusion (Kim *et al.*, 2005), solid phase microextraction/gas chromatography (Rhee *et al.*, 2008) or headspace gas chromatography (Lee *et al.*, 2009) were used for identification and quantitation of cyanide.

Data analysis on cyanide poisoning deaths. The data of each case were analyzed according to 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, kinds of cyanide salts and the concentrations of cyanide in heart blood and peripheral blood (femoral vein). Statistical analysis was carried out using the SPSS version 10.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Characteristics of deaths by cyanide poisoning.

During the study period, from January 2005 to December 2010, the results of information on the cadavers were as fol-

Table 1. Characteristics of 255 deaths with acute cyanide poisoning

Characteristics	
Age (Mean \pm SD, Years)	41.88 \pm 13.09 (range 6~80, Unknown 7)
Gender (Male : Female)	200 : 53 (Unknown 2)
Number of attempted suicide (%)	248 (97.3%, Unknown 1)
Number of treated deaths (%)	37 (14.5%)
Route of administration (%)	Oral (252, 98.8%) Inhalation (3, 1.2%)

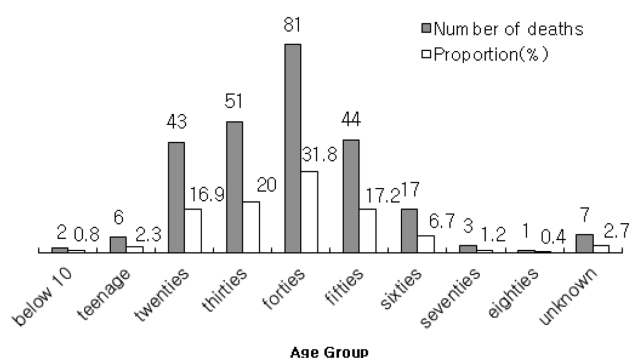


Fig. 1. Number of deaths with acute cyanide poisoning according to the ages (n = 255).

lows: out of 255 people, excluding seven people who were anonymous, the mean age was 41.88 ± 13.09 and the age range was 6 to 80 years (Table 1). As seen in Fig. 1, the frequency or incidence according to age was, below 10 years (2 cases, 0.8%), teenage (6, 2.3%), 20s (43, 16.9%), 30s (51, 20.0%), 40s (81, 31.8%), 50s (44, 17.2%), 60s (17, 6.7%), 70s (3, 1.2%), 80s (1, 0.4%), and seven anonymous people (2.7%). The male to female ratio was 200:53. The causes of death were as follows: suicide comprised 97.3%, four people ingested cyanide by mistake, and two were homicide cases. Of all those who died, 37 people who ingested cyanide died while receiving medical treatment. It was generally considered, unless otherwise specified, that people who died ingested the cyanide through oral administration, which was found to be 98.8%, and three people died from inhalation.

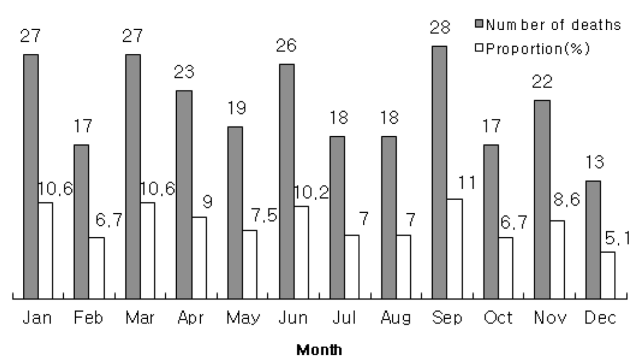
Original place where the cyanide was ingested. The locations where the people ingested cyanide were as follows: individual's residence (47.1%), accommodation such as a motel (16.1%), public space such as a park (8.6%), workplace (8.2%), inside a car (7.8%), hill (3.9%), riverside (1.2%), others (1.6%), and unmentioned (3.1%) (Table 2).

Table 2. Site of cyanide ingestion

Site	Number of deaths (%)
Residence	
Own	120 (47.1)
Others	6 (2.4)
Hill	10 (3.9)
Accommodation (Inn/Motel/Hotel)	41 (16.1)
Public area	22 (8.6)
In car	20 (7.8)
Riverside	3 (1.2)
Workplace	21 (8.2)
Others	4 (1.6)
Unknown	8 (3.1)

Table 3. Total number of autopsy cases and number of autopsy cases related to cyanide poisoning during 2005~2010 conducted in National Forensic Service headquarters

Year	Total number of autopsy cases	Number of autopsy cases related to cyanide poisoning	Proportion of cyanide poisoning deaths from total autopsy (%)
2005	2,851	36	1.26
2006	2,516	34	1.35
2007	2,196	24	1.09
2008	2,403	23	0.96
2009	2,627	29	1.10
2010	2,080	14	0.67
Total	14,673	160	1.09

**Fig. 2.** Number of deaths with acute cyanide poisoning according to the month (n = 255).

The monthly and yearly changes in the number of deaths by cyanide poisoning. Table 3 shows the comparative results of total autopsy cases versus autopsy cases related to cyanide poisoning. From 2005 to 2010 there were between 2,080 and 2,851 autopsy cases each year. Of those cases, 14 to 36 cases each year were related to cyanide poisoning and the total was 160 cases, or 1.09% of total autopsy cases over six years. The yearly totals for the number of deaths by cyanide were as follows: 2005 (55 cases), 2006 (62), 2007 (35), 2008 (39), 2009 (40) and 2010 (24). The monthly count ranged from 13 to 28 people and was as follows: September (28), January (27), March (27), June (26), April (23), and November (22) (Fig. 2). The results show that there was no seasonal peculiarity in cyanide poisoning.

The frequency of deaths by cyanide poisoning according to region. The order according to region in which the deaths by cyanide poisoning occurred is as follows: Gyeonggi province (97 cases), Seoul (95), Incheon (52), Daegu/Gyeongbuk province (5), and Jeju (3). Deaths by cyanide poisoning had a high occurrence in Incheon city where industrial complex is located.

The classification of cyanide salt. Out of 255 cyanide poisoning death cases, white powders were found in 92

cases at the crime scenes, of which 51 cases were confirmed as potassium cyanide and 41 cases were sodium cyanide. Cyanide was identified and confirmed in biological samples from autopsies and articles left by the deceased in other 163 cases.

Concentrations of cyanide in heart blood and peripheral blood. The concentrations of cyanide were determined in biological samples, such as heart blood and peripheral blood (femoral vein). The concentrations of cyanide determined only in heart blood were 63 cases, only in peripheral blood, 27 cases, and both in heart blood and peripheral blood, 70 cases. The cyanide concentrations in heart blood (133 cases) ranged from 0.3~248.6 mg/l, and mean value was 23.1 ± 36.8 mg/l. The cyanide concentrations in peripheral blood (97 cases) ranged 0.4~212.4 mg/l, and mean value was 18.4 ± 37.2 mg/l. The mean cyanide concentrations determined both in heart blood and peripheral blood (70 cases) were 33.34 mg/l in heart blood and 18.19 mg/l in peripheral blood, and the C/P ratios (cardiac blood/peripheral blood) ranged from 0.23~32.50 (average 3.35).

DISCUSSION

Cyanide is extremely toxic to humans, and there is a high frequency of use of this compound for suicide, homicide or accidental death because of its wide use in industry and carelessness of control. Cyanide is found in low levels in the tissues of healthy subjects as a result of normal metabolism, eating of cyanogenic foods and cigarette smoking. Plasma cyanide concentrations in healthy subjects were found to average 0.004 mg/l in nonsmokers and 0.006 mg/l in smokers (Wilson and Matthews, 1966). Most of the cyanide is contained in erythrocytes bound to methemoglobin. Whole blood cyanide concentration in 10 smokers was found to average 0.016 mg/l, whereas in 14 nonsmokers the mean level was 0.041 mg/l. Blood stored at 4°C was generally quite stable, while room temperature storage caused a significant diminution of cyanide content, to the extent of 70% loss after 15 weeks (Ballantyne, 1977).

Cyanide is a potent and rapidly acting poison, and the minimal adult lethal dose has been estimated as 100 mg/person for hydrocyanic acid and 200 mg/person for potassium cyanide (Baselt, 2008).

In industrialized countries, people take overdoses of analgesics, sedatives and anti-depressants, all of which possess low toxicity (Michel *et al.*, 2000). However, in undeveloped countries, deaths by pesticide poisoning are frequent and account for more than 60% of the total toxic materials poisoning deaths (Gunnell and Eddleston, 2003; Maniam, 1988; Somasundaram and Rajadura, 1995; Phillips *et al.*, 2002). Even in Korea, death by toxic materials happens continually, with death by pesticides occupying the highest

ratio (Jung *et al.*, 2008), and death by cyanide also occurring frequently (Shin *et al.*, 2004). Despite the recent high degree of industrialization in Korea, pesticides and cyanide remain a major cause of death, just as in undeveloped countries. In order to observe the characteristics of deaths caused by cyanide, the authors analyzed the results gathered by the National Forensic Service within the last six years (2005~2010) in regions such as the Metropolitan area, Gyeonggi and Jeju province.

According to reports that analyzed the 419 pesticide poisoning deaths tested in National Forensic Service headquarters for five years, from 2005 to 2009, the mean age was 57.8 ± 14.8 years and range was 16~92 years. The frequency or incidence according to age was high from 40s to 70s, and the number of deaths of males was twice that of females. Suicide comprised 96.2% of all pesticide intoxicated people, and 28.4% died while receiving medical treatment. Oral administration was found to be 100% true in all cases (Lee *et al.*, 2010). Compared to the previous study of pesticide poisoning deaths, this study showed that the mean age was about 16 years lower than pesticide poisoning deaths; the frequency or incidence according to age was high from 20s to 50s. The death rates of gender and suicide were similar with pesticide poisoning deaths.

Cyanide is extremely toxic compared to the average medication, and there are many cases of death; therefore, in order to prevent poisoning by cyanide, there should be thorough safety education and strict restrictions on its purchase.

There are similarities found throughout the research regarding toxic material poisoning. Research carried out in Daejeon found that the place where a person ingested the toxic material was at his or her residence in 84% of cases (Park *et al.*, 2004). Another research showed that the place where toxic material was ingested was the person's residence in 73% of cases (Oh *et al.*, 2006). The present research produced similar results, and the ratio was 47.1%. However, the reason the percentage found by this research was lower than in previous researches is because the previous research was done among hospitalized patients, whereas only 14.5% were hospitalized in the present research. This research showed a high death rate in accommodation or workplace, which reflects the tendency for people to kill themselves in isolated places.

From 2005 to 2010, there were total of 23,488 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 branch in Daejeon, and eastern branch in Wonju of Gangwon province). Out of the 23,488 autopsy cases, 14,673 were conducted at the headquarters and accounted for 62.5% of total autopsy cases. Out of those 14,673 cases, 160 were cyanide poisoning deaths, which accounted for 1.09% of total autopsy cases. During the research period, of the 255 people who died of cyanide poisoning, in addition

to the 160 autopsy cases, the results for 95 people were based on articles left by the deceased or their vomit.

From the research, the yearly changes in the number of deaths by cyanide poisoning were as follows: 2005 (55 cases), 2006 (62), 2007 (35), 2008 (39), 2009 (40), and 2010 (24). The number of deaths has shown a tendency to decrease since the year 2007 due to the formation 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 there were no seasonal differences among death numbers. One could assume that because cyanide is widely used in industry, there were no seasonal changes in amount of production and consumption. Shin *et al.* assumed poisonings that are happened by accident are not affected by the season, and this research showed a similar result (Shin *et al.*, 2004).

As for regional differences, Gyeonggi province, Seoul, and Incheon showed higher proportions of deaths by cyanide poisoning than Gangwon province. This is attributed to the lower population of Gangwon province, and because requests for the National Forensic Service decreased due to the formation of the eastern branch. Deaths by cyanide poisoning were prevalent in Incheon, an industrial complex, which shows that factory workers need to be educated about the toxicity and correct usage of cyanide.

Among Korean people who died due to poisoning by cyanide, white powders were found in 92 cases (51 cases of potassium cyanide, 41 cases of sodium cyanide). According to previous reports, a compilation of 32 fatal cases due to apparent ingestion of cyanide has shown a blood cyanide concentration range of 0.4~230 mg/l, with an average of 37 mg/l (Rehling, 1967), and a more recent similar compilation of 17 cases showed a postmortem blood cyanide concentration range of 0.6~185 mg/l, with an average of 38 mg/l (Gil *et al.*, 2004). In this present research, a postmortem heart blood cyanide concentration range was 0.3~249 mg/l, with an average of 23.1 ± 36.8 mg/l in 133 cases, and femoral vein blood cyanide concentration range was 0.4~212 mg/l, with an average of 18.4 ± 37.2 mg/l in 97 cases. In results of present research, blood cyanide concentration ranges in heart or femoral vein were similar to previous reports, but the averages were lower. Dalpe-Scott *et al.* reported that cyanide may exhibit postmortem redistribution in a series of nine deaths, heart/femoral blood concentration ratios averaged 1.3 (range 0.4~2.4) (Dalpe-Scott *et al.*, 1995). In this research, heart/femoral blood concentration ratios in 70 deaths averaged 3.35 (range 0.23~32.5), and these values were higher than those of previous reports.

Cyanide is extremely toxic and acts rapidly, so there are many cases of death by suicide or homicide every year. However, unlike in industrialized countries, the poison control system in Korea has just begun. So even though the

results of this study might not reflect all possible cases of death by cyanide poisoning, the authors hope this research will be used to establish health policy to prevent cyanide poisoning and to provide an accurate database for a government-initiated poison control center in the near future.

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