

Survey of awareness about hazardous chemicals of residents living near chemical plants in South Korea

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Received July 14, 2017 and accepted February 2, 2018

Published online in J-STAGE February 10, 2018

Abstract: With economic growth, the use of chemicals has continually increased, resulting in an increase of chemical accidents. Chemical accidents pose a life threat and can lead to many health problems among the residents living in close proximity to chemical plants. This study aimed to investigate the awareness of the residents living near chemical plants about hazardous chemicals, as well as to survey the awareness of workers who do not directly handle chemicals at chemical plants (WNHCs). To this end, a questionnaire survey was conducted among a total of 600 residents and 160 WNHCs. The questionnaire was composed of three items: awareness of chemical risk, awareness of countermeasures in chemical accidents, and imperious necessity of PPE (personal protective equipment). Statistical analysis of the data was performed with the Statistical Package for Social Sciences (SPSS) version 18.0. The results show that the government needs to complement the notification system of chemical risk for residents who live close to chemical plants. The highest priority of PPE which residents want to prepare for chemical accidents was respiratory protective equipment (RPE). They responded that, if necessary to purchase PPE, they could bear a portion of the expenses (up to US \$30). This study provides basic data for the development of programs and policies on chemical safety relevant for the residents living in close proximity to chemical plants in South Korea.

Key words: Residents' awareness, Chemical accidents, Chemical plants, Personal Protective Equipment (PPE)

Introduction

The amount and variety of chemicals used in the workplace have continually increased, leading to an increase of chemical accidents. The chemical accidents include fires, explosions or leakages, which can cause illness, injury, disability or death of people. In South Korea, as reported by the Ministry of Environment between 2010 and 2014, the total number of chemical accidents has dramatically increased from 15 cases to 104 cases¹. Chemical accidents affect the environment and disrupt societies and economic

burden^{2–4}. In many countries, the hazardous chemicals are controlled and managed by relevant laws and regulations for preventing chemical accidents^{5, 6}. In the U.S., the community right-to-know provisions help increase the public's knowledge and access to information on chemicals at individual facilities, their uses, and releases into the environment. States and communities working with facilities can use the information to improve chemical safety and protect public health and the environment⁵. To review the overall situation of Chemicals Control Act and that of Occupational Safety and Health Act in South Korea, these laws have focused on protecting workers from exposure to hazardous chemicals^{7, 11}. Although these laws also aim to protect the citizens from exposure to hazardous chemicals, these laws are generally perceived to be insufficient to

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Table 1. Age distribution at each sample area of study participants

Age	Residents no.		WNHCs* no.	
20s	109 (18.2%)	a*. 24 (22.0%)	28 (17.5%)	a*. 11 (39.3%)
		b*. 26 (23.9%)		b*. 8 (28.6%)
		c*. 29 (26.6%)		c*. 3 (10.7%)
		d*. 30 (27.5%)		d*. 6 (21.4%)
30s	113 (18.8%)	a*. 26 (23.0%)	65 (40.6%)	a*. 10 (15.4%)
		b*. 27 (23.9%)		b*. 15 (23.1%)
		c*. 31 (27.4%)		c*. 21 (32.3%)
		d*. 29 (25.7%)		d*. 19 (29.2%)
40s	132 (22.0%)	a*. 37 (28.0%)	36 (22.5%)	a*. 5 (13.9%)
		b*. 29 (22.0%)		b*. 11 (30.6%)
		c*. 29 (22.0%)		c*. 12 (33.3%)
		d*. 37 (28.0%)		d*. 8 (22.2%)
50s	147 (24.5%)	a*. 38 (25.9%)	25 (15.6%)	a*. 12 (48.0%)
		b*. 37 (25.2%)		b*. 6 (24.0%)
		c*. 39 (26.5%)		c*. 4 (16.0%)
		d*. 33 (22.4%)		d*. 3 (12.0%)
60+	99 (16.5%)	a*. 25 (25.3%)	6 (3.8%)	a*. 2 (33.3%)
		b*. 31 (31.3%)		b*. 0 (0.0%)
		c*. 22 (22.2%)		c*. 0 (0.0%)
		d*. 21 (21.2%)		d*. 4 (66.7%)
Total	600 (100%)		160 (100%)	

*Workers who do not directly handle chemicals in chemical plants (WNHCs), such as office workers, drivers, and security staff

a*: Ulsan city, b*: Yeosu city, c*: Gumi city, d*: Namyangju city

protect the health and safety of citizens from exposure to hazardous chemicals. Specifically, citizens do not get accurate information and countermeasures when a chemical accident occurs; obviously, this can breed social unrest. Moreover, in order to protect the health and safety of workers in the workplace, employers have duties concerning the provision and use of personal protective equipment (PPE) at work. One such equipment is PPE^{8,9}. In order to protect the health and safety of citizens from chemical accidents, the government or local government may need to provide PPE if citizens want to have it. This study aims to investigate residents' awareness about hazardous chemicals near chemical plants; in addition, we also survey the awareness of workers who do not handle chemicals directly in chemical plants (WNHCs), such as office workers, drivers, and security persons. These issues are explored with the use of a questionnaire composed of three items: awareness of chemical risk, awareness of countermeasures in chemical accidents, and imperious necessity of PPE.

Research Method

To investigate residents' awareness and WNHCs, the

questionnaire was composed of three items, namely, awareness of chemical risk, awareness of countermeasures in chemical accidents, and imperious necessity of PPE. The survey constructed on the basis of previous research and data collection was performed through one-on-one interviews³⁻⁹. The same number of participants at each sample area was determined: 150 each at 4 sample areas, total number of 600 residents, and 40 each at 4 sample areas, total number of 160 WNHCs, were selected to interview. A total number of 760 subjects were finally based on residential addresses and probability sampling methods. Table 1 summarizes the age distribution of the participants. In the case of residents 324 (54%) males and 276 (46%) females responded to questionnaires. 185 (30.8%) of residents have lived in their sampling areas for less than 5 yr, 134 (22.3%) for 5 to 10 yr, 133 (22.2%) for 11 to 20 yr, and 148 (24.7%) for more than 20 yr. 25 (15.6%) of WNHCs' have worked for less than 1 yr, 81 (50.7%) for 2 to 5 yr, 22 (13.7%) for 6 to 9 yr, and 32 (20.0%) for more than 10 yr.

All participants in four sample areas (Yeosu city, Ulsan city, Gumi city, Namyangju city in South Korea) lived within 1 km from each chemical plant. To determine the

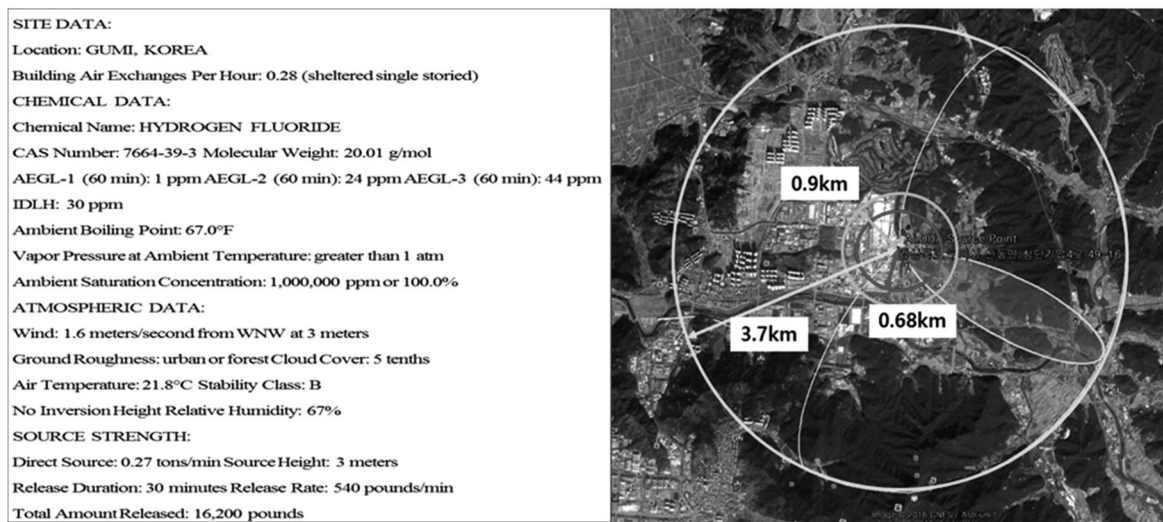


Fig. 1. The sample of the ALOHA Model (Gumi chemical accident 2012).

Table 2. Respondents' awareness about chemical hazards

Questions	Answers	Number of responses (%)
Do you think that there are any chemical hazards in your daily life?	Yes	436/600 (73%)
	No	103/600 (17%)
	Do not know	61/600 (10%)
Have you ever been trained or educated about countermeasures against chemical accidents?	Yes	60/600 (10%)
	No	516/600 (86%)
	Do not know	24/600 (4%)
Do you think the governmental authority or the employer has taken a proper action against chemical accidents in the past?	Yes	177/600 (30%)
	No	325/600 (54%)
	Do not know	98/600 (16%)

extent of expected chemical effects in 4 sample areas, the expectations of chemical accidents were estimated using ALOHA (Areal Location of Hazardous Atmospheres) Model¹⁰. The extent of chemical effects of three chemical substances (hydrogen fluoride, ammonia, and hydrogen chloride) were calculated using the ALOHA Model. Figure 1 shows the extent of chemical effects from Gumi chemical accident in 2012 using ALOHA Model and data set. The result is that, although the extent of chemical effects depends on the each chemical substance, the extent of sample area is set within 1 km, which results in a low probability of adverse health effects in the event of a chemical accident. Also, these areas had chemical accidents in the past and, therefore, we asked the subjects how to cope with chemical accidents. Statistical analysis of the data was performed with the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). The χ^2 test, $p < 0.05$ was accepted as the minimum threshold of statistical significance.

Results

Residents' awareness about chemical hazards

To examine the participants' awareness about hazardous chemicals, 600 residents living near chemical plants were asked to answer the questionnaire. Table 2 shows the corresponding results.

With regard to the answers to the question "Do you think that there are any chemical hazards in your daily life?", 73% of the respondents responded "yes", while 17% percent answered "no". Furthermore, 86% of the respondents reported that they had never been trained or educated about countermeasures on chemical accidents; therefore, only *ca.* 10% had received appropriate training. This distribution suggests that the residents' lack of adequate training can lead to numerous health problems after chemical accidents.

Furthermore, 54% of the participants answered that

Table 3. Participants' awareness about PPE

Questions	Answers	Number of responses (%)
Do you need preparedness of PPE for chemical accidents?	Yes	525/600 (88%)
	No	57/600 (9%)
	Do not know	18/600 (3%)
Who should pay for PPE, if it has to be purchased?	Private cost	111/600 (18%)
	Private cost + Government grant	372/600 (62%)
	Government grant only	117/600 (20%)
How much are you willing to pay for PPE?	≤US \$20	99/600 (16%)
	≤US \$30	322/600 (54%)
	≤US \$50	106/600 (18%)
	>US \$50	30/600 (5%)
	Others	43/600 (7%)
What types of PPE are needed against chemical accidents? (duplicate responses possible)	Respiratory protection	572/600 (95%)
	Hand and arm protection	275/600 (46%)
	Protective clothing	250/600 (42%)
	Foot protection	183/600 (31%)

the governmental authority had not taken a proper action against chemical accidents, while only 30% reasoned otherwise. Even though the Articles 42 (notice of hazard control program to local community) or 43 (countermeasures for chemical accidents) of Chemicals Control Act in South Korea say that the governmental authority or the employer shall inform the residents of chemical hazards and take emergency measures after chemical accidents, it was found that the law was insufficient to satisfy the residents' needs in reality¹¹). To compensate for the law, a stronger law enforcement should be needed or the local government should ensure that the residents receive relevant information, such as schedule of training about chemical hazards, etc.

Table 3 shows the residents' awareness of personal protective equipment (PPE) against chemical accidents. Overall, 88% of the residents indicated that they needed a preparedness of PPE for chemical accidents, while only a small part of the respondents (9%) answered otherwise, which implies PPE should be absolutely necessary for chemical accidents.

If PPE should be purchased, 62% percent of the respondents wanted to pay for it on their own plus the government grant; by contrast, only 20% of the respondents said they were hoping that these expenses would be fully covered by the government. In addition, we asked the residents the following question: "If you purchase PPE, how much are you willing to pay for it?" The results show that 54% of the respondents were willing to pay up to US \$30 to purchase PPE. Almost all respondents (95%) wanted to have respiratory protective equipment (RPE) as the first

priority PPE. This finding can have been underpinned by the fact that, if the residents must get quickly evacuated from the contaminated area after a chemical accident, they should need respiratory protection first.

WNHCs' awareness about chemical hazards

To examine WNHCs' awareness about chemical hazards, we used a questionnaire survey method. A total of 160 workers who do not directly handle chemicals in chemical plants, for example, drivers, office workers, security staff, and so on, were interviewed. Table 4 shows the results of WNHCs' awareness about chemical hazards obtained for each question. A large proportion of the respondents (75%) stated that chemical accidents could occur at plants, while a very small proportion (7%) answered otherwise, suggesting that the majority of WNHCs recognized the possibility of chemical accidents.

When the chemical accident(s) occurred in the past, the methods of coping with those accident(s) were, in the descending order of frequency of mention, 'indoor evacuation without PPE' (52%), 'stay in the office without PPE' (22%), and 'outdoor evacuation with PPE' (15%), followed by 'stay in the office with PPE' (11%). The fact that 74% respondents reported they had coped with the chemical accident(s) without PPE was consequently the improper countermeasure as a result of which many WNHCs may have been exposed to chemical hazards. A possible reason for these responses may be that the safety and health education system for WNHCs was not working properly. Therefore, an efficient education and countermeasure system for WNHCs against chemical ac-

Table 4. WNHCs' awareness about chemical hazards and PPE

Questions	Answers	Number of responses (%)
Do you think there is a possibility of chemical accidents occurring at the plants?	Yes	120/160 (75%)
	No	11/160 (7%)
	Do not know	29/160 (18%)
How did you cope with chemical accident(s) that occurred at your company in the past?	Indoor evacuation without PPE	14/27 (52%)
	Stay in the office without PPE	6/27 (22%)
	Outdoor evacuation with PPE	4/27 (15%)
	Stay in the office with PPE	3/27 (11%)
What do you think about the difference in quality between PPE for WNHCs and PPE for chemical handling workers?	Even if different, it's alright.	38/160 (24%)
	Should be the same	113/160 (71%)
	Do not know	9/160 (5%)

Table 5. Awareness about chemical accidents between residents of petrochemical complex and general industry areas

Questions	Petrochemical complex		General industry areas		$\chi^2(p\text{-value})$
	Yes	No	Yes	No	
Do you think that there are any chemical risks in your area?	162/300 (54%)	63/300 (21%)	177/300 (59%)	75/300 (25%)	0.179 ($p=0.672$)
Do you think there is a possibility of chemical accidents in your area?	165/300 (55%)	42/300 (14%)	165/300 (55%)	66/300 (22%)	4.030* ($p=0.045$)
Do you need training for countermeasures against chemical accidents?	273/300 (91%)	9/300 (3%)	198/300 (66%)	15/300 (5%)	3.900* ($p=0.048$)

* $p<0.05$.

cidents should be established on the governmental level. In particular, contents related to PPE should be necessarily included in these systems.

A large part of the respondents (71%) agreed that PPE for WNHCs should be the same as that for chemical handling workers in quality. The remaining respondents (24%) stated that PPE for WNHCs may be alright even through it was relatively poor quality as compared with PPE for chemical handling workers. In other words, most WNHCs wanted to receive PPE of the same quality, regardless of job types.

Comparison of awareness between petrochemical complex and industrial areas

Another part of the survey included a question about the difference of chemical hazard awareness of the residents in the petrochemical complex and in the general industry areas. The survey was conducted in two groups: 300 residents of the petrochemical complex area (Yeosu city, Ulsan city) and 300 residents in the general industry areas (Gumi city, Namyangju city). This questionnaire focused on the three questions, namely, awareness of chemical risks, possibility of chemical accident occurrence, and the need of training for countermeasures against chemical ac-

cidents. Table 5 summarizes the results on the responses to each question. In the question of 'chemical risk', no significant difference was observed between the residents of two areas. However, the question of 'possibility of chemical accident occurrence', significant difference was observed between the residents of two areas ($p<0.05$). Moreover, almost all residents in the petrochemical complex area (91%) reported the need of training for countermeasures against chemical accidents, which significantly differed from 66% percent of the residents of the industry area who said the same ($p<0.05$). This result indicates that residents in the petrochemical complex area are more worried about chemical accident occurrences than residents of general industrial areas.

Discussion

Since this article seems to be the first study in South Korea to survey residents' awareness of chemical hazards and PPE around petrochemical complex or general industrial areas, our results provide useful information related to preparedness for chemical accidents. While there are many regulations related to PPE for workers handling chemicals in many countries, including South Korea, there is hardly

any regulation for PPE for the residents or WNHCs¹¹). Consequently, the results of this survey provide meaningful implications for the establishment of appropriate regulations.

A large number of respondents (73%) recognized chemical hazards in their lives, but only a small number of them (10%) have ever been trained or educated about countermeasures against chemical accidents (Table 2).

This suggests that the government authorities should provide opportunities for residents living near chemical complex areas to be educated about chemical hazards or countermeasures against chemical accidents. Since, in the past, when chemical accident (s) had occurred, only 30% percent of the residents answered that the governmental authority or the employer had taken a proper action, systematization of preparing against chemical accidents should be provided.

It is not surprising that nearly all residents wanted to take PPE for chemical accidents, in particular, respirators (Table 3). The results clearly demonstrate that at least respirators must be provided to residents. Since many respondents (54%) stated that they could spend their own money (up to US \$30) to purchase PPE, the government authorities, as well as PPE manufacturers, should consider this point that US 30\$ would be the most suitable for purchasing PPE when developing PPE purchasing program.

A large percentage of the WNHCs (75%) felt concerned about possible chemical accidents at their plants in the future. Surprisingly, 74% of the respondents had not received PPE during chemical accidents in the past (Table 4). Since 71% percent of the WNHCs wanted to take the same quality PPE as that for chemical handling workers, PPE for WNHCs should not be manufactured in a different way.

Meanwhile, the residents in the petrochemical complex area wanted to receive the training of countermeasures more than the participants living in the general industrial areas ($p<0.05$) (Table 5). We assume that the reason behind this finding is that the residents living near petrochemical complex areas are more afraid of chemical accidents than those residing near general industry areas. Therefore, this result implies that the national or local government should preferentially provide the residents living near petrochemical complex areas with training for countermeasures against chemical accidents and notification system for the prevention of chemical hazards.

The results of this survey suggest that programs for providing PPE for the residents and WNHCs living near chemicals plant complex areas should be established by the law. As the program works, the reasonable prices for

PPE would be US \$30 at this moment in time. Even if this law is not established in the near future, the government authority should first strengthen preparedness training or education in case of chemical accidents.

Conclusion

This survey study investigated the awareness about hazardous chemicals among the residents and WNHCs living near or working at chemical plants complex and general industry areas. To summarize, our conclusions are as follows. First, while the respondents were concerned about chemical hazards in their daily lives, there was a lack of relevant training or education programs for countermeasures against chemical accidents and the participants complained about the improper action against chemical accidents by the government or the employer in the past. A large number of the residents (88%) wanted to prepare PPE for chemical accidents, in particular, respiratory protective equipment (95%). They reported being willing to invest up to US \$30 to purchase PPE. Many WNHCs were also afraid of chemical accidents and wanted to take the same PPE as that for chemical handling workers. In almost the same proportion as the residents living near general industry areas, the residents living near the petrochemical complex area felt anxiety about chemical accidents, but also reported a stronger need of training for countermeasures against chemical accidents ($p<0.05$). These findings provide basic data on future development of legal programs and policies on chemical safety that would effectively communicate and cooperate with the residents living near chemical plants in South Korea.

Funding

This work was supported by a grant from Korea Environmental Industry & Technology Institute (KEITI), 2016.

Conflict of Interest

We report no potential conflict of interest relevant to this article.

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