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Status of Health and Safety Management in Occupational Hygiene Laboratories in Korea

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Ⅰ. Introduction

A chemical laboratory is a facility where scientific experimentation or research is performed. It is a workplace where a wide variety of hazardous chemicals and gases are usually stored and used in small quantities on a non-production basis (Lieckfield & Farrar, 1991; OSHA, 1996; Wawzyniecki & Thompson, 1997).

Occupational hygiene is an area of activities that involve anticipation, assessment, and surveillance of health hazards in the working environment with the objective of protecting worker health

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and well-being, as well as safeguarding the community at large (IOHA, 2007). As part of this activity, an occupational hygiene laboratory generally analyzes samples collected from the field to assess exposures or potential exposures of workers to dusts, fibers, fumes, mist, gases, and vapors in their workplaces.

According to the results of researchers' observations on the conditions of occupational health and safety for laboratory workers, it was found that most Korean occupational hygiene organizations have limited spaces for laboratories due to the small size of institutions, and that laboratory space is often shared with chemical and gas cylinder storage rooms, analytical laboratories, and work offices (Yoo et al., 2000). Most hazardous chemicals are stored in fume hoods and drawers without appropriate ventilation systems. Gas cylinders are stored beside instruments or at corners of the laboratory. Therefore, even though only small quantities of chemicals and gases are stored and used in the occupational hygiene laboratory, the laboratory workers could be exposed to unknown or highly toxic substances and highly corrosive or reactive liquids, resulting in serious consequences such as uncontrolled release of heat or fire and explosion hazards in some cases.

The Korean Quality Control Program (KQCP) is designed to ensure accuracy and precision of analytical data in the occupational hygiene survey institutions, on a biannual basis. This is undertaken by the Korea Occupational Safety and Health Agency (KOSHA) and the Korean Society of Occupational and Environmental Hygiene (KSOEH) in accordance with the Industrial Safety and Health Act (No. 42), Enforcement Regulation (No. 97-2), and Notification of Ministry of Labor (No. 99-38) (KOSHA, 2001 a, b). The KQCP has been improving the quality of laboratory analysis, as well as providing accurate analytical data for the occupational hygiene survey.

The quality assurance provision focuses on the quality of analytical data and includes data on the status of employment of analysts and instruments of participating institutions. Moreover, the KOSHA laboratory guideline does not give much detail about the health and safety of occupational hygiene laboratories. Therefore, occupational hygiene laboratories are not only faced with poor working conditions, but are also being inappropriately managed under the current system of occupational health and safety provision.

This research is aimed to identify and assess the conditions of health and safety related to the operation of Korean occupational hygiene laboratories. The research has also been conducted to identify inadequacies in management of risks in occupational hygiene laboratories, so that suitable provisions can be developed to better manage those risks.

Ⅱ. Methods & Analysis

A questionnaire on health and safety performance was designed to identify occupational hygiene laboratory status. The occupational hygiene laboratory in this study signified the institutions to participate in the KQCP (which was undertaken by the KOSHA and KSOEH in 2001) and generally analyzed samples collected from the field to assess exposures or potential exposures of workers.

119 institutions have been invited to participate in the KQCP. This study included all participating institutions for KQCP.

The survey questionnaire consisted of 12 sections: general health and safety, chemical storage and containers, flammable/combustible liquids, gas cylinders, hazard communications, first aid and emergency equipment, housekeeping, fire safety, electrical safety, personal protective equipment (PPE), fume hoods and general ventilation, and a case study on carbon disulfide.

A questionnaire on health and safety performance was designed to identify occupational hygiene laboratory status and was mailed to each institution of the participating KQCP in August 2002. 63.0% (75 institutions) of questionnaires were returned completed, 3.0% of questionnaires were returned uncompleted, 3.0% of questionnaires were returned to the sender unopened, and 30.0% of questionnaires were not returned at all.

Health and safety performance was evaluated for each institution by scoring 67 items in the questionnaire (Table 1). To quantitatively assess whether the institutions that possessed the health and safety manual, training program, and KOSHA laboratory guideline had managed better than those that did not, one point was assigned to each item marking if the applicable institution was suitable or appropriate for the purpose of the questionnaire item. The score of health and safety performance has been converted to a 100.0% scale.

In order to identify any associations between the score of health and safety performance and the use of a health and safety manual, the existence of a training program, and the use of the KOSHA laboratory guideline, respectively, a two-tailed t-test was undertaken using the Microsoft-Excel 2000 program for Windows.

Ⅲ. Results

Among the 75 responding institutions, a total of 138 chemical

Table 1. Contents and details of health and safety performance questionnaire

Categories of health and safety	No. of questions	Details of questionnaire items
General Health and Safety	4	Regular general health examinations Health and safety manual Training program for safe work KOSHA laboratory guide
Chemical Storage and Containers	4	Chemical storeroom Adequate air-conditioning and/or dehumidifier systems in the chemical storeroom Exposed to direct sunlight or localized heat Accessible only to authorized personnel
Flammable/combustible liquids	3	Flammable liquid storage cabinet “No Smiking” signs Flammable liquid cintainers kept away from fire hazards
Gas cylinders	3	Gas cylinder storage room All gas cylinders stored in Empty gas cylinders stored separately Valve-cap securely in place of gas cylinders
Hazard communications	5	Emergency procedures Emergency evacuation plans Evacuation practices Material safety data sheets Laboratory chemical inventory
First aid & emergency equipment	5	First aid supplies Emergency telephone numbers Emergency personal protective equipment Self-contained breathing apparatus Emergency equipment
Housekeeping	9	Walkways and exits marked Walkways and exits free Eat or drink in laboratory Separate eating area Specific labelled containers (Chemical waste, Sharps, General waste, Recyclable solvents) Chemical waste management guideline
Fire safety	6	Adequate fire extinguishers Periodically inspected and maintained Fire alarm system Fire exits marked “No Smiking” signs posted Automatic fire extinguishing
Electrical safety	4	Electrical equipment properly grounded Extension cords Electrical boxes and panels Electrical cords suspended
Personal protective equipment	2	Wearing of appropriate PPE compulsory Wear open-toed footwear
Fume hoods	5	Fume hood(s) Electical services within the fume hood Checked and recorded periodically Storage of chemicals Canopy type hoods provided over equipment
Carbon disulfide as a case study	17	Health serveillance Monitored for urinary-TTCA Standard operating procedure Written procedures for cleaning up spills Spills of carbon disulfide Formal educational program Reporting system related incidents (spills, Skin/eye splash, lnhalation, lrritation, Symptoms of exposure) Air sampling for carbon disulfide Ventilation system performance Material safety data sheet Smoking prohibited Fire extinguishers PPE required
Total	67	

analysts were employed, and each institution had an average of 1.8 (range 1-8) analysts. Universities, university institutions, and companies' in-house laboratories had more than 2 analysts, while the other institution groups employed less than 2 analysts in their laboratories (Table 2).

According to the findings, in total, 54.7% of the institutions provided a health and safety manual in their laboratories and kept a laboratory health and safety manual (Table 3). The mean score of the institutions for health and safety that provided a health and safety manual was 42.98±13.36 (range 21-76). In comparison, the institutions that did not provide a health and safety manual scored 31.04±10.78 (13-64). The mean score of the institutions that provided the manual was statistically significantly higher than that of those that did not ($p<0.001$).

Only 13.3% of the institutions had a training program for safety in the laboratories (Table 3), meaning most institutions did not provide a safety training program for their laboratory workers. The same analytical methods were applied to training programs for safety in the laboratories. The mean score of the institutions that had a training program in their laboratories was 50.75±14.12 (range 28-75). On the other hand, the institutions that did not have training programs scored 35.52±12.28 (13-71). A statistically significant difference was identified in the mean score of health and safety performance between the institutions that provided the training program and that of those that did not ($p<0.01$).

The KOSHA laboratory safety guideline has been recently published to provide information about laboratory health and safety and also to recommend maintaining its guideline at all laboratories. However, only 36.0% of the institutions had the KOSHA guidelines in their laboratories (Table 3). The mean score (43.58±11.92, range 28-76) of the organizations that had the KOSHA laboratory guideline was higher than that of those that did not (34.48±13.48, 13-71). The analytical data indicated a statistically significant difference between institutions that maintained the KOSHA

Table 2. Number of laboratory analysts employed by each institutional laboratory grup

No. of lab. analysts	University laboratories	KIHA* laboratories	University hospital laboratories	Private & public hospital laboratories	Company in-house laboratories	Total
1	0	7	8	13	3	31
2	2	4	10	11	8	70
3	3	0	1	0	1	15
4	1	0	0	0	0	4
5	0	0	0	0	2	10
8	0	1	0	0	0	8
Total	17	23	31	35	32	138

* Korea Industrial health Assocoation

Table 3. Distribution of health and safety performance score with respect to possession of the health and safety manual, training program, and KOSHA laboratory guideline

Possession	No. of institutions	Mean score*±SD†		P−value
		Yes	No	
Health and safety manual	41	42.98±13.36	31.04±10.78	<0.001
Safety training program	10	50.75±14.12	35.52±12.28	<0.01
KOSHA laboratory guideline	27	43.58±11.92	34.48±13.48	<0.01

Mean score was calculated as percentage score that 67 questions assigned one point by each item, if yes
*SD : Standard deviation

guideline and those that did not ($p<0.01$).

As a result, it is concluded that the institutions that provided a health and safety manual, a training program, and the KOSHA laboratory guideline managed their laboratories' health and safety facilities better than the institutions that did not provide these services.

A total of 60.0% of the institutions had a chemical storage room. Among them, 64.8% of the institutions alphabetically stored chemicals in store areas and 7.4% of the institutions stored chemicals by random placement. Only 27.8% of the responding institutions stored chemicals by class; for example, oxidizers with oxidizers and flammables with non-flammables (Table 4).

Gases such as acetylene were used as an ignition source to operate analytical instruments. Other compressed gases used in occupational hygiene laboratories were compressed air, nitrogen, hydrogen, helium, and argon. 62.7% of the institutions confirmed the use of gas cylinders in the laboratories. An average of 55.1% of gas cylinders were secured by brackets or chains to prevent them from falling or being knocked over (Figure 1).

A total of 54.7% of the institutions had Material Safety Data Sheets (MSDSs) readily available in their laboratories. However, 42.7% of the remaining institutions did not store MSDSs and the last 2.7% of them replied that they did not know whether they had MSDSs or not.

Multiple responses were made that only 8.0% of the institutions (6 institutions; 2-multiple responses) supplied eyewash fountains (2), safety showers (3), and eyewash bottles (3) and all of them were accessible less than 10 meters from the hazardous area. However, 92.0% of the remaining institutions did not have all of the eyewash fountains, safety showers, and eyewash bottles.

In total, 70.7% of the institutions provided fire extinguishers suited to the fire hazards in their laboratories. Of these, 54.7% of the institutions periodically inspected and maintained their fire extinguishers.

Table 4. Laboratory healty and safety features

Categories	No. of institutions	Details of questionnaire items	No	%
Chemical storage room*	45†	Stored chemicals by alphabetically	35	64.8
		Stored chemicals by class	15	27.8
		Stored chemicals by random	4	7.4
Gas cylinders in laboratories	47§	secured by brackets, etc.	–	55.1§
MSDSs availability	75	Yes	41	54.7
		No	32	42.7
		Do not know	2	2.7
Emergency facilities*	75	Yes	6	8.0
Fire extinguishers	75	Yes	53	70.7
		No	15	20.0
		Do not know	7	9.3
Periodical inspection of fire Extinguishers	53¶	Yes	29	54.7
		No	10	18.9
		Do not know	14	26.4
Personal protective equipment*	75	Laboratory coat	65	86.7
		Gloves	47	62.7
		Respiratory protection	38	50.7
		Eye protection	32	42.7
		Face shield	16	21.3
		Footwear	7	9.3
		Apron	7	9.3

*Multiple responses, §Average percentage of secured by brackets, etc.
†A total of 45 institutions possessed chemical storage room(s) in their lab among 75 institutions
‡A total of 47 institutions used gas cylinder(s) in their lab among 75 institutions
¶ A total of 53 institutions had fire extinguisher(s) to the fire hazards in their lab among 75 institutions

Among the 75 respondents, considering compound responses, lab coats (86.7%), gloves (62.7%), and respiratory protection equipment (50.7%) were usually provided to the laboratory workers. However, only 42.7% of the institutions supplied eye protectors, 21.3% supplied face protectors, and 9.3% supplied footwear and aprons. Only 14.7% of the institutions had strict rules about wearing PPE at all times in the laboratories. A total of 66.7% of the institutions permitted the wearing of open-toed footwear during experimentation in the laboratory.

Of the 75 respondents, only 12.3% of the institutions made periodical checks and maintained records of fume hood performance. The average minimum acceptable face velocity of the fume hoods was 0.55m/s (range: 0.21-0.70) as a performance standard of their fume hood(s), which was checked and recorded by laboratory workers.

The storage of chemicals in fume hoods is usually acceptable in most institutions in Korea. A total of 89.0% of the institutions stored their chemicals in the fume hoods (Table 5; Figure 2).

Figure 1. Unsecured acetylene and compressed gas cylinders in use

Figure 2. Storage of chemicals in fume hood

Table 5. Characteristics fume hood and general ventilation in laboratories

Categories	No. of institutions	Details of questionnaire items	No	%
Fume hood(s)	75	Yes	73	97.3
		No	2	2.7
Fume hood(s) checks and records preiodically	73*	Yes	9	12.3
		No	59	80.8
		Do not know	5	6.9
Storage of chemicals prohibited	73*	Yes	8	11.0
		No	65	89.0
General ventilation systems	75	Air conditoning system	46	61.3
		Natural dilution ventilation	15	20.0
		Fan forced dilution ventilation	50	66.7
Concerns of air quality†	75	Temperature	36	48.0
		Humidity	15	20.0
		Air velocity	3	4.0
		Specific contaminants	16	21.3
		General air quality	18	24.0

* A total of 73 institutions had fume hood(s) in their lab among 75 institutions

† Multiple responses

Considering multiple responses, 66.7% of the institutions provided mechanical general ventilation systems, 61.3% of the institutions supplied air conditioning, and 20.0% of the institutions maintained natural general ventilation systems. In relation to the maintenance of air quality in the laboratory, 48.0% of the institutions considered temperature as a more relevant factor in creating comfortable conditions in the laboratory environment, rather than being concerned with general air quality, humidity, specific contaminants, and air velocity.

Ⅳ. Discussion

In general, a wide variety of hazardous chemicals and gases were used in occupational hygiene laboratories even though very small amounts of substances were employed to analyze individual samples. Because of this, among other factors, hazard controls in laboratories are difficult to administrate, and it is not easy to manage these hazardous substances in the laboratory.

A health and safety manual was part of the program for providing safety information to laboratory workers. The manual contained adequate occupational health and safety information as necessary, and also ensured that users of the hazardous chemical substances would receive effective education and/or training before handling or using hazardous materials (Dux & Stalzer, 1988). Approximately half of the institutions had a health and safety manual and these institutions had significantly higher health and safety scores as a result.

A training and education program is one of most important preventive measures that can be taken to ensure health and safety in laboratories (Lieckfield & Farrar, 1991), because an adequate training program can prevent or minimize accidents/incidents on an initial stage, and also maintain good working environment. Therefore, all levels of staff should attend appropriate training programs containing information on organizational policies, emergency procedures, first aid, accident reporting, location or use of MSDSs, and chemical hygiene plans (Lieckfield & Farrar, 1991; OSHA, 1996; Wawzyniecki & Thompson, 1997). Only few organizations had a training program for safety in the laboratory. This is a reflection of poor laboratory health and safety management. And this is part of the reason why laboratory workers do not have a chance to become aware or improve their knowledge of health and safety issues and may not recognize the importance of health and safety rules in the laboratory.

The KOSHA laboratory safety guideline is proposed to all laboratories and is designed to be incorporated into the practices of workplaces where laboratories are located. Thus, the KOSHA (1999) recommends that all laboratories should keep the guideline in their laboratories. However, only a few had the KOSHA guideline in their laboratories. Most institutions still did not seem to recognize the necessity of keeping and using the guideline in their laboratories.

Incompatible chemicals must be kept segregated from one another or should be separated by fire insulators or space (Standards Australia 2243.10, 1993). Among the 45 respondents, multiple responses were made that most institutions stored their chemicals alphabetically or by random placement. As a result, most organizations inadequately managed their chemicals in the storage area. It is clear that incompatible chemicals should be stored by physical properties or characteristics of chemicals by class (Dux & Stalzer, 1988; Man & Gold, 1993).

In regards to gas cylinder usage, organizations without a gas cylinder room stored gas cylinders beside instruments or in spare corners of the laboratory. For the prevention of cases such as falling or knocking over, all cylinders should be fastened on safe material such as walls or heavy experimental desks, etc (Furr, 1990; Haski et al., 1992; RSC, 1992). However, approximately half of the institutions did not secure their gas cylinders.

Material safety data sheets are essential to recognize the risks associated with hazardous chemicals and gases in the laboratory and to manage adequate procedures for new substances. The Korean Ministry of Labor adopted a MSDS system which is provided through the KOSHA web to improve workplace health and safety. Institutions dealing with hazardous materials and substances should be prepared at all times and keep the MSDSs in readily accessible places and train workers in their laboratories (KOSHA, 1997). Furr (1990), Fullick et al. (1996) and Standards Australian (2243.2, 1997) also described that MSDSs should be readily accessible to laboratory personnel and safety officers in the appropriate work area for cases including various types of hazards, control of risks, treatment required for spills, burns, and other injuries, proper storage procedures, safe handling, and correct labeling. Half of the institutions had MSDSs readily available in their laboratories.

Emergency facilities such as an eyewash fountain, safety shower, and eyewash bottles are essential to minimize injuries of laboratory workers by accidental contacts, splashes, and spills of chemicals on the body. In particular, emergency safety showers and eyewashes are vital safety equipment in chemical laboratories. However, the availability of emergency facilities was too limited to minimize the risk of eye/skin injury from harmful chemical splashes and spills in the provision of effective laboratory emergency operations. Lieckfield and Farrar (1991) and Standards Australian (2982.1 & 2243.1, 1997) recommended that each laboratory should be equipped with at least one shower and eyewash station in a hands-free mode, which should be not more than a 10 meter travel distance or within 30 steps walking distance to such devices from any point in the laboratory in an easily accessible location. It is also said to provide large quantities of water for at least 15 minutes of flushing period with tempered water. On the other hand, the KOSHA guideline (1999) states that safety showers and eyewashes shall be installed within 15 meters or in a 15 to 30 second travel distance. In comparison, the KOSHA guideline requires a reasonable travel distance from the farthest point in the laboratory but the recommended distances do not correspond to any specific type of emergency facility.

A fire involving chemicals and gases in laboratories has potential to become extensive due to its wide usage of highly flammable solvents and gases. Dux and Stalzer (1988) and Standards Australian (2243.1, 1997) recommended that each laboratory should be equipped with more than one type of fire protection equipment or at least one fire extinguisher, together with periodic inspection and maintenance of the equipment to be used at any time. However, many Korean occupational hygiene laboratories did not fulfill such minimum requirements, and not so many institutions periodically inspected and maintained their fire extinguishers. The fire extinguisher inspections were carried out an average of 3 to 4 times per year.

Personal protective equipment is frequently required to protect parts of the human body from various hazards or challenging chemicals. The wearing of appropriate PPE is especially essential for laboratory workers because various hazardous substances such as corrosive and reactive liquids, irritants, and organic toxic vapors exist in laboratories. As a result, half or more institutions preferred providing lab coats, gloves, and respirators whereas eye protection, face shields, footwear, and apron were less often provided. Moreover, the majority of institutions did not have strict rules about wearing PPE at all times and permitted the wearing of open-toed footwear in the laboratory.

The purpose of a fume hood is to eliminate toxic and harmful fumes, gases, and vapors from the laboratory environment by exhausting air. Even though most institutions had installed a fume hood in their laboratories, most of them were not aware of its performance, such as face velocity or cross-draughts. In order to improve these instances of inadequate management of fume hood performance, laboratory institutions established a guideline of checks and records of fume hood performance on a 6 month basis. Nonetheless, most of the institutions did not follow these guidelines and permitted storage of chemicals in the fume hood, not an acceptable practice. This may increase the potential possibility for fire or explosion and may interfere with proper fume hood operation (Dux and Stalzer, 1988). Hence, ‘chemicals should never be stored in a fume hood’ (Standards Australia 2243.2, 1997; 2243.8, 2001).

General ventilation in the laboratory is needed to eliminate odors, vapors, fumes, and gases from the air which might have an adverse effect on the health of the employees, as well as to provide tempered air for comfort (Furr, 1990; Lieckfield & Farrar, 1991). As a result, many institutions provided air conditioning and/or fan-forced dilution ventilation systems as a general ventilation system. Most laboratory workers were concerned with temperature in their laboratories rather than general air quality, humidity, and specific contaminants produced in the laboratory.

There are some limitations to this study. First, some of the responses about chemical storeroom were false or lacked details; for example, some replied that their institutions had a chemical storeroom when in fact they did not have an adequate chemical storeroom separated, or stored chemicals in general cabinets, drawers, or on shelves without a proper ventilation system. Secondly, the definition of a gas cylinder was not included in the questionnaire, so most institutions seemed to assume that gas cylinders were dissimilar to compressed gas cylinders. Therefore, many institutions did not reply in the gas cylinder section. In addition, the gas cylinder section failed to include questions about the gas system supply, when some institutions had a piped gas system in their laboratories. Accordingly, the results of these two sections in particular may be affected regardless of the researcher’s intentions.

Ⅴ. Conclusion

This study was intended to identify and assess the status of health and safety in Korean occupational hygiene laboratories with a designated questionnaire which consisted of 12 sections. This study was conducted from July 01 to August 30, 2002.

The results were as follows:

1. As a result of the health and safety performance index for 67

items (one point per item) related to the operation of the occupational hygiene laboratory, the mean scores of the institutions with the health and safety manual, training program, or KOSHA guideline were 42.98±13.36(p<0.001), 50.75±14.12(p<0.01), and 43.58±11.92(p<0.01), respectively.

2. Among 45 respondents in possession of a chemical storage room, 64.8% of the institutions alphabetically stored chemicals in storage areas, 27.8% by class, and 7.4% by random placement.

3. Only 8.0% of the institutions (6 institutions; 2 institutions gave multiple responses) supplied eyewash fountains (2), safety showers (3), and eyewash bottles (3) in their laboratories.

4. A total of 89.0% of the institutions stored their chemicals in the fume hoods.

5. The management of written documents such as MSDSs, fume hood performance records, emergency procedures, and the compliance with KOSHA laboratory guideline was poorly managed and recorded.

6. Overall, most institutions lacked laboratory safety facilities such as emergency equipment, a chemical or gas cylinder storage room, chemical storage cabinets, PPE, fume hoods, and good management practices such as housekeeping.

It is recommended that laboratory workers should wear appropriate personal protective equipment, be trained and educated in using emergency equipment, and take responsibility for maintaining adequate laboratory operations. The laboratory employer should provide a written document system and adequate PPE to be worn by all laboratory personnel, install emergency equipment, develop relevant provisions for the laboratory, and carry out training and education programs. To comply with the above mentioned recommendations, the KOSHA should regularly assess laboratory health and safety in accordance with the KQCP. Korean laboratories should employ and follow these results to ensure general health and safety in their laboratory institutions.

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