

Selecting High-Risk Micro-Scale Enterprises using a Qualitative Risk Assessment Method

Hyunwook KIM^{1*} and Dong-Uk PARK²

¹Department of Preventive Medicine, College of Medicine, The Catholic University of Korea, 505 Banpo-Dong, Seocho-Gu, Seoul 137–701, Republic of Korea

²Department of Environmental Health, Korea National Open University, Dongsung-Dong, Jongro-Gu, Seoul 110–791, Republic of Korea

Received August 31, 2005 and accepted November 25, 2005

Abstract: Micro-scale enterprises (MSEs) with less than 5 employees are subject to be covered by the scheme of the regular workplace environmental inspection and medical health examination from 2002 in Korea. Due to limited resources as well as vast number of enterprises to be covered, there is an urgent need to focus these efforts to only those high-risk MSEs. To identify them, a qualitative risk assessment methodology was developed combining the hazardous nature of chemicals and exposure potentials as modeled by the HSE and the risk categorization technique by the AIHA. Risk Index (RI) was determined by combining characteristics specific to chemicals and scale of use of the chemicals. The method was applied to 514 MSEs that were selected from a random sample of 4000 MSEs. A total of 170 out of 514 MSEs studied were included in the final analysis. Current status and characteristics of MSEs were identified and RI was assigned to chemicals in each industry. Based on the distribution of RIs, the high-risk MSEs were selected. These include: wood and products of wood, chemicals and chemical products, basic metals, other machinery and equipment, motor vehicles, trailer and semi-trailer manufacturing, and furniture manufacturing. Since these MSEs are high-risk ones, more attentions should be focused on them. This method can be applied to other workplaces with no previous history of quantitative workplace inspections.

Key words: MSEs, Hazard band, High Risk, Qualitative risk assessment, Risk index

Introduction

Management of occupational health matters within a company in Korea has been regulated differently based on the number of workers employed within the company¹⁾. For large enterprises with over 300 employees (total number of enterprises 2,400), at least a full-time occupational health specialist must be employed. For medium scale enterprises with 50–300 workers (total number of enterprises 24,000), they can either hire a full-time occupational health specialist or obtain professional services from the group occupational health service providers. For small-scale enterprises (SSEs) with 5–50 employees (total number of enterprises 363,000), a special technical and financial support program, called “CLEAN 3D program” created by the government can be

obtained²⁾. Micro-scale enterprises (MSEs) with less than 5 employees, which comprise vast majority of enterprises in terms of the number of 2.54 million nationwide, however, have been exempt from the coverage of the occupational health regulations.

It has been reported that 64.4% of all occupational accidents were from the SSEs, particularly those enterprises with less than 10 workers³⁾. The Korean government, taking these findings into considerations, launched a financial and technical assistant program for SSEs in 1993. At the beginning of the program, no detailed information regarding the SSEs was available. Therefore, the program was initially designed to provide the following services: workplace environmental monitoring, specific worker health evaluation, group occupational health services, providing matching funds for engineering controls, and direct financial aids⁴⁾.

In Korea, there are 2.54 million MSEs comprising 87% of total number of enterprises, with 4.5 million workers (35%

*To whom correspondence should be addressed.

of total number of employees). Among these MSEs, 880,000 (1.65 million workers) workplaces excluding self-employed, agriculture, fishery, and forest workers, are to be covered by the workers' compensation system as of July, 2000, and subject to regular workplace environmental evaluations and employee health examinations⁵). Therefore, a systematic way of supporting MSEs was needed by the Government.

Recent studies on the characteristics of MSEs have reported that they are scattered around nationwide, are frequently established and gone out of business, and established mostly in the rented facilities. Most of employees are not covered by the health insurance or the workers' compensation. And they have no occupational safety and health systems in place and have limited funds for workplace improvement. Both employers and employees have limited knowledge in occupational safety and health, are not interested in health issues, and have no means of workplace control. Equipments in the MSEs are mostly outdated and accident rates are very high. The results of workplace evaluations showed that many of them are out of compliance and have high incident rates of occupational low back pain and musculoskeletal disorders⁶⁻¹⁰).

The current support system for SSEs would not be suitable for MSEs because of unique characteristics of MSEs, vast number to be served, and limited resources available. Therefore, there is an urgent need to focus these efforts on only those high-risk MSEs. A quick and easily applicable, but still reliable method for selecting high-risk MSEs was urgently needed. The purpose of this study was to develop a risk assessment method for selecting high-risk MSEs using a qualitative approach.

Method

Subject

A total of 514 MSEs employing less than 5 workers selected from 17 industry classification codes were investigated. These MSEs have been exempt from the

occupational health and safety obligations. Trained industrial hygienists visited the MSEs and collected the following data: manufacturing processes, chemicals used in the process, scale of chemical use, chemical hazards, and airborne potential in the workplace, etc. A total of 107 chemical agents, both gaseous and particulate substances, were included for the assessment. No actual quantitative environmental evaluation of these substances was conducted.

Development of risk assessment model: factors considered and procedures used

The risk assessment method developed in the study was based on the UK Health and Safety Executive (HSE) scheme to control health risk from chemicals to help small firms¹¹⁻¹³, the risk assessment concept by Tait¹⁴, and the exposure rating scheme used by the Exposure Assessment Strategies Committees of the American Industrial Hygiene Association¹⁵.

Figure 1 depicts the flow chart of the qualitative risk assessment for chemical agents developed for the study, which combined chemical hazard and exposure potential of the chemical.

1) Hazard bands

Five hazard bands, determined by combining the hazard criteria used by the AIHA and the control band used by the HSE, were constructed in order to qualitatively assess the MSEs, as shown in Table 1. Toxicity and hazard of chemicals were determined by the 2002 TLVs, published by the American Conference of Governmental Industrial Hygienists (ACGIH)¹⁸.

(1) Acute toxic chemicals

For those chemicals with acute effects, fast actors like irritants were classified in the hazard band "B" while corrosive chemicals that can impair permanent damage to skin such as strong acids were classified to the band "C".

(2) Chronic toxic chemicals

Chemicals of chronic toxicants, carcinogens, and

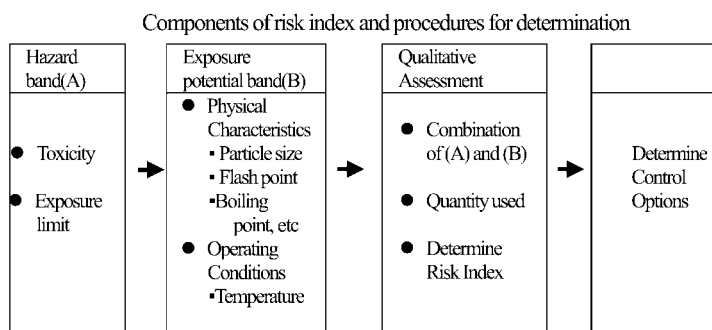


Fig. 1. Overview of approach used to develop a qualitative risk assessment method for selecting high-risk MSEs.

Table 1. Determination of hazard bands by occupational exposure limits and toxicity of chemical agents

Hazard Band	Exposure limit		Classification Scheme	Example chemicals
	Particulates (mg/m ³)	Gas/vapor (ppm)		
A	>1–10	>50–500	No known health effect or reversible and minimal health effects	Dust from paper, fabric, food, etc
B	>0.1–1	>5–50	Reversible health effects	Toluene, trichloroethylene
C	>0.01–0.1	>0.5–5	Reversible but severe health effects	HCl, H ₂ S
D	<0.01	<0.5	Animal carcinogen, Irreversible health effects	TDI, HCHO
E	No exposure limits		Confirmed human carcinogen, Dangerous to life and health	Hexavalent Chrome, Wood dust, MWF, Benzene

teratogens, were assigned in band “E” if they were classified as either suspect or confirmed carcinogens by ACGIH TLVs, NIOSH (National Institute for Occupational Safety and Health), NTP (National Toxicology Program)¹⁶⁾ or IARC (International Agency for Research on Cancer)¹⁷⁾. For substances that have been confirmed as carcinogenic by animal experiment were categorized in “D”.

2) Exposure potential bands

For simplicity, only inhalation hazard was considered while assessing the exposure potential of a chemical. Two factors, physical characteristics and scale of use of the chemical, were combined to create four qualitative bands and one of them was assigned to the chemical.

(1) solid substances

Airborne potential of a solid substance was predicted using the qualitative method for estimating airborne potential based on the physical characteristics of the substance. It was classified as “high dustiness”, “medium dustiness”, or “low dustiness” based on the following criteria.

① high dustiness

Easily dispersed into air while handling and remain airborne for long period of time. For example, dusts from cement, titanium dioxide, and printer toner, etc.

② medium dustiness

Dusts from these materials relatively quickly settle down while airborne. These include granules, grains, and powders.

③ low dustiness

Raw material is in the form of small solid pellet which is not easily dispersed into the air. For example, wax, and PVC pellet, etc. can be classified into this category.

(2) liquids

The vaporization potential of a liquid substance was predicted utilizing information from the process operation conditions and the boiling point of the substance.

① By the operating temperature during the process and the boiling point of a substance.

Exposure potential of a liquid substance was predicted by combining the operating temperature during the process

and the boiling point of the substance and was classified as “high”, “medium”, or “low”. The boundary line between “medium” and “low” was calculated with the following equation: boiling point = 5 × operating temperature + 50. The boundary line between “medium” and “high” was obtained with the equation boiling point = 2 × operating temperature + 10. Liquid chemical substances with boiling points less than 50°C can be classified as “high”, while substances with BPs between 50°C–150°C can be classified as “medium” evaporation potential. Detailed description of these procedures was printed in elsewhere¹²⁾. In case of mixed substances, it is determined by the substance having the lowest boiling point among them.

② Use of vapor pressure

Where no information on the conditions of operating process was available, exposure potential of the substance was predicted using the vapor pressure of the substance. For instance, Exposure potential was “high” if the vapor pressure of the substance was over 25 kPa, “medium” with 25–0.5 kPa, and “low” with 0.5 kPa.

3) scale of use

Exposure potential of a solid and/or liquid substance can be influenced by many operational conditions. Therefore, it is impossible to consider all of them. However, the most significant one is the scale of use in the process.

Tables 2 lists four possible bands of exposure potential for solid and liquid chemicals to respiratory inhalation, which were derived by combining two factors of the substance, airborne potential and scale of use.

4) Risk Index (RI)

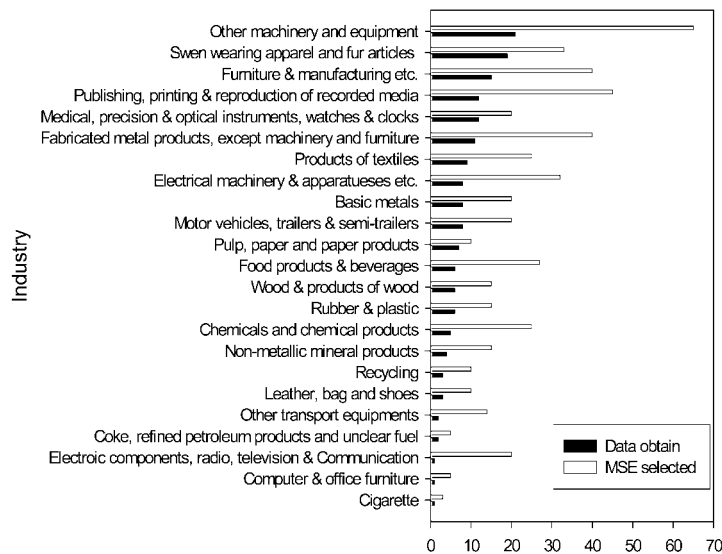
By combining hazard and exposure potential bands of the substance with scale of use in the enterprise in question, as described in the previous paragraphs 1) and 2), qualitative categories of risk indexes, as shown in Table 3, were finally determined and assigned as suggested by the exposure rating scheme used by the Exposure Assessment Strategies Committee of the AIHA¹⁵⁾. For those substances classified as RI I should be handled first and specific engineering controls be considered.

Table 2. Definition of exposure potential bands

(a) Solid chemicals		(b) Liquid chemicals	
Exposure potential band	Description	Exposure potential band	Description
EPS 1	High dustiness Handling limited amount (grams)	EPL1	Low volatility, Handling limited amount (milliliters)
EPS 2	Low dustiness, handling kilograms	EPL2	Low volatility & handling liters or High volatility & handling milliliters
EPS 3	Medium dustiness, handling kilograms	EPL3	Medium volatility & handling m ³ or High volatility & handling liters
EPS 4	High dustiness, handling tons	EPL4	High volatility & handling m ³

Table 3. Determination of Risk Index (RI) from hazard and exposure potential bands

(a) Solid chemicals					(b) Liquid chemicals				
Hazard Band	Exposure potential band				Hazard Band	Exposure potential band			
	EPS 1	EPS 2	EPS 3	EPS 4		EPL 1	EPL 2	EPL 3	EPL 4
A	III	IV	IV	IV	A	III	IV	IV	IV
B	II	III	IV	IV	B	III	III	IV	IV
C	I	II	III	IV	C	II	II	III	IV
D	I	I	II	III	D	I	I	II	III
E	I	I	I	I	E	I	I	I	I

**Fig. 2. Distribution of MSEs surveyed in this study.**

Results and Discussions

Figure 2 shows the distribution of 170 MSEs where data were collected out of 514 MSEs surveyed. A total of 107 chemical substances were identified for risk assessment. Among them, 64 substances (59.8%) were particulates and

43 (40.2%) were gases and vapors. In cases where mixed chemicals were found, i.e., thinner, welding fume, and particulates with several metal components, they were considered as a single substance and a hazard band was determined based on the most toxic chemical in the mixture.

Table 4. Distribution of hazard bands by chemical and industry

Industry	Aerosols					Gases					Total
	A	B	C	D	E	A	B	C	D	E	
Food products & beverages	1										1
Apparel and fur articles	8				1	2					11
Wood & products of wood (except furniture)					3	1	1				5
Pulp, paper, and paper products						1	3				4
Publishing, printing & reproduction of recorded media			1			2	4			1	8
Coke, refined petroleum products and unclear fuel				1							1
Chemicals and chemical products					1					1	2
Non-metallic mineral products		4						3		1	8
Basic metals		2	3	1							6
Fabricated metal products, except machinery				3	1	3	1			1	9
Other machinery and equipment		4	8			3				1	16
Electrical machinery and apparatus	1	3	1		1	1					8
Electronic components, radio, TV and communication equip.						1	1				2
Medical, precision & optical instruments	6	1				1	1	1			10
Motor vehicles, trailer & semi-trailer				2		1					3
Furniture manufacturing		3	1	2					6		12
Recycling		1									1
Total	16	18	14	9	7	6	2	6	7	4	107

1) Comparison of hazard bands by industry

Distribution of hazard bands by chemical and industry is shown in Table 4. After further analysis of the distribution of hazard bands of solid chemicals, we found that the most frequent hazard band was “B” with 18 cases (28.1%) followed by “C” with 14 cases (21.8%). Solid chemicals in these categories are known to have reversible health effects which include: welding fume (band C), metal fume (band C), mist (band C), dusts from clothes and garments (band B), etc. A total of 9 (14.1%) substances were classified in the hazard band “D”, which were either animal carcinogens or having irreversible health effects. In this category, particulates such as metal dusts from steel fabrication, metal working fluids from motor vehicle parts manufacturing, crystalline silica dust from foundry, etc. were included. In addition, formaldehyde from the furniture manufacturing industry was classified to “D”. MWF was also designated into “D” since it is a known carcinogen to several human organs and is listed in the Notice of Intended Change as a suspect human carcinogen A2 by the ACGIH⁽⁸⁾.

A total of 7 particulates (10.9%) were classified to the hazard band “E”, which were all confirmed as human carcinogens. Types of chemicals and industries include:

- chrome VI in the leather apparel and fur articles
- hard wood dusts from wood and products of wood
- acrylonitrile from chemicals chemical products
- chrome VI, insoluble nickel from electroplating

In this investigation, such confirmed human carcinogens designated as A1 by the ACGIH, including asbestos,

beryllium, coal tar pitch volatile, and coke oven emission, etc. were not found.

Hazard band “A” was assigned to those substances with lowest health hazards with exposure limits in the range of 1–10 mg/m³. Particulates in this category were generated from the industries of food products and beverages, clothes and apparel, chemicals and chemical products, etc.

Of 43 gases and vapors, 20 substances (46.5%) were in the hazard band “B”, 6 (14.0%) in the “C”, 7 (16.3%) in the “D”, 6 in the “A”, and 4 in the “E”, respectively. The substances in the “C” band were mostly solvents. For a mixture, a hazard band was assigned according to the substance having the lowest limit in the mixture. If the solvent contains a known carcinogen, it is classified as “E”. Otherwise, they were classified either “B” which is known to have reversible health effects with exposure limits in the range of 5–50 ppm or “C” for those substances with significant health effects. In the hazard band “C”, we found the following:

- hydrogen chloride and fluoride in the fabricated metal products
- hydrogen chloride in the medical equipment manufacturing
- ethanolamine and hydrogen sulfide from the use of metal working fluid in the fabricated metal products and basic metals

Gases and vapors in the hazard band “D” were toluene-2,4-diisocyanate (TDI) and formaldehyde, and were all found in the furniture manufacturing industry.

Table 5. Distribution of exposure potential bands by chemical and industry

Industry	Aerosols (EPS)				Gases (EPL)				Total
	1	2	3	4	1	2	3	4	
Food products & beverages		1							1
Apparel and fur articles	8	1			1	1			11
Wood & products of wood (except furniture)			3				2		5
Pulp, paper, and paper products							4		4
Publishing, printing & reproduction of recorded media			1				7		8
Coke, refined petroleum products and unclear fuel	1								1
Chemicals and chemical products	1							1	2
Non-metallic mineral products			4				4		8
Basic metals	3	3							6
Fabricated metal products, except machinery			4			2	3		9
Other machinery and equipment	2	10					4		16
Electrical machinery and apparatus	5	1					2		8
Electronic components, radio, TV and communication equip.						1	1		2
Medical, precision & optical instruments	5	2				1	2		10
Motor vehicles, trailer & semi-trailer	1	1					1		3
Furniture manufacturing			6				6		12
Recycling	1								1
Total	0	28	36	0	0	5	37	1	107

Those substances in the hazard band “E” were all confirmed as carcinogens. Solvents containing benzene in the publishing, printing, and painting of metal products industries were classified as “E”. No industry was found to use vinyl chloride and bis-ether. Vinyl chloride, a monomer that is a basic material for producing PVC resin, was found at the chemical and chemical products manufacturing industries. Although it is very possible that residual vinyl chloride can be found in the MSEs where PVC resins were extruded, residual amount was reported to be either very minor¹⁹⁾ or occasionally encountered. Therefore, risk assessment for vinyl chloride in the chemical mixture and the chemical products manufacturing was not performed.

2) Distribution of exposure potential by industry

Table 5 shows the distribution of exposure potential bands by chemical and industry. Exposure potential bands for particulates were as follows: 28 cases (43.8%) in the exposure potential band solid (EPS) 2, and 36 cases (56.3%) in the EPS 3. Since no industry was found to use chemicals below grams or over tons in quantity, none were found in EPS 1 and EPS 4. EPS 2, assigned to particulate matters with “medium dustiness” and handled in “kg” range, were as follows:

- dusts from textile and garment manufacturing (8 cases)
- resin and dust from additives in the other chemical products manufacturing (1 case)
- mists from lubricant or surfactants in the compounds and chemical products manufacturing (1 case)

- metal dust from cutting and grinding in the basic metals (3 cases)
- dusts from machining and waxing in the medical equipment manufacturing (5 cases)
- dusts from sanding in the other electric equipment and transformer manufacturing, fume from soldering, metalworking fluids (5 cases)

Particulates in the EPS 3 band include welding fumes and mists from surfactant, lubricant, and metal working fluids. EPS 3 was designated to particulates having the characteristics of “high dustiness” and handled in “kg”. These substances were found in the following industries:

- welding fume from fabricated metal products, metal mists from electroplating and metal working fluids (4 cases). Particularly mist from electroplating process was easily dispersed into the air since the process was not automated. Mists from metal working fluids also airborne due to high speed rotation of machining process.
- welding fume from other machinery and equipment manufacturing and other electric machinery and apparatus, lead dust from battery and primary cell manufacturing (11 cases).
- wood dust from furniture and other product manufacturing (6 cases). Wood dusts were mainly generated from cutting, grinding, sanding, and buffing processes of woods. Controlling wood dust from these processes was difficult and airborne potential was high.
- welding fume from welding, and fume from melting metals. Welding fume was generated in such processes

Table 6. Distribution of risk index by industry

Industry	Risk Index				Total
	I	II	III	IV	
Food products & beverages	0	0	0	1	1
Apparel and fur articles	1	0	1	9	11
Wood & products of wood (except furniture)	3	1	1	0	5
Pulp, paper, and paper products	0	0	3	1	4
Publishing, printing & reproduction of recorded media	1	1	4	2	8
Coke, refined petroleum products and unclear fuel	0	1	0	0	1
Chemicals and chemical products	2	0	0	0	2
Non-metallic mineral products	1	3	4	0	8
Basic metals	1	3	2	0	6
Fabricated metal products, except machinery	5	0	2	2	9
Other machinery and equipment	1	10	3	2	16
Electrical machinery and apparatus	1	0	2	5	8
Electronic components, radio, TV and communication equip.	0	0	1	1	2
Medical, precision & optical instruments	0	1	2	7	10
Motor vehicles, trailer & semi-trailer	1	1	1	0	3
Furniture manufacturing	8	1	3	0	12
Recycling	0	0	0	1	1
Total	25	22	29	31	107

as the steel making, metal foundry, cutting metal products, and fusion welding.

Exposure potential bands for liquid substances (EPL) were assigned by combining vapor pressure and the amount of use if no information was available for process operating temperature. Maidment¹²⁾ reported that no significant difference was found between operating temperature and vapor pressure when determining the exposure potential for liquid substances. The most frequent band found for gases and vapors was EPL 3 with 37 cases (86.4%). Substances in this band include various solvents, acrylonitrile, and methanol.

3) Risk Index (RI) by industry

Risk indexes, as shown in Table 6, were determined by combining chemical specific characteristics and scale of use for the substances. RIs were evenly distributed among industries studied. Twenty-five (25) cases were in RI I (23.4%), 22 in RI II (20.6%), 29 in RI III (27.1%), and 31 in RI IV(29.0%), respectively.

- By analyzing the distribution of RIs, high-risk industries were identified. For example, if an MSE has higher proportion of chemicals assigned in the RI I/RI II than in RI III/RI IV, it is considered as a high-risk MSE. These high-risk MSEs include:
- Wood and products of wood, chemicals and chemical products, basic metals, other machinery and equipment manufacturing, motor vehicle and trailer manufacturing, and furniture manufacturing.

Conclusion

A qualitative risk assessment method was developed to assess environmental conditions of MSEs. A total of 514 MSEs with less than 5 employees in 17 industries were surveyed. Trained industrial hygienists visited the selected MSEs and obtained information on chemicals used and characteristics of processes which could affect airborne potentials of the hazardous substances. The bands of hazard and exposure potential along with the amount of chemical use were combined to create risk index by industry.

The RIs identified a number of high-risk industries having higher proportions of chemicals in RI I and RI II. These industries include: wood and wood products, chemicals and chemical products, basic metals, other machinery and equipment manufacturing, motor vehicle and trailer manufacturing, and furniture manufacturing.

Since risks would be higher in these MSEs, they ought to be given higher priority in management. Because the Ministry of Labor plans to impose health and safety obligations on MSEs, the governmental efforts should be focused on these high-risk MSEs first. The model introduced in this study can be applicable to larger enterprises as well.

Acknowledgement

The work described in this paper was funded by the Ministry of Labor, Korea in 2001.

References

- 1) Ministry of Labor (2003) Industrial safety and health laws, No. 6847. Ministry of Labor, Seoul.
- 2) Ministry of Labor (2000) The 1st 5-year plan on the prevention of industrial accidents. Ministry of Labor, Seoul.
- 3) Ministry of Labor (1996) Analysis of Industrial Accident in 1995. Ministry of Labor, Seoul.
- 4) Korea Industrial Health Association (1994) Proceeding of international symposium on occupational health services for small industries. Korea Industrial Health Association, Seoul.
- 5) Kim SK (2001) Occupational health services suitable for small scale enterprises with less than 5 employees. Presented at the Workshop for the Prevention of Industrial Accidents in Small Scale Enterprises with Less than 5 Employees, 9-23, Ministry of Labor, Seoul.
- 6) Kang KS (2000) Report on the current status of occupational safety and health of small scale enterprises with less than 5 workers. Final report to the Korea Occupational Safety and Health Agency. KOSHA, Seoul.
- 7) Yoon JD (2000) Management of occupational health matters in the small scale industry. Presented at the symposium: Issues of Managing Occupational Health. Korea Occupational Health Nurse Association, Seoul.
- 8) Paek DM (1997) Appraisal of the government-funded subsidiary occupational health program for small scale industries. Final report on the prevention of occupational disease in 97. KOSHA, Seoul.
- 9) Kwon OS, Chung CK (2001) The awareness, knowledge, and attitude regarding occupational health of the employers and employees among under 5 industry workers. Thesis, Graduate School of Occupational Health, The Catholic University of Korea, Seoul.
- 10) Kim DS, Roh Y, Kim H, Jeong CH, You KH (2001) The Current status and recommendation of work environment management in small scale industry with less than 5 workers. *Korean Ind Hyg Assoc J* **11**, 179-89.
- 11) Brooke IM (1998) A UK scheme to help small firms control health risks from chemicals: toxicological considerations. *Ann Occup Hyg* **42**, 377-90.
- 12) Maidment SC (1998) Occupational hygiene considerations in the development of a structured approach to select chemical control strategies. *Ann Occup Hyg* **42**, 391-400.
- 13) Russell RM, Maidment SC, Brooke I, Topping MD (1998) An introduction to a UK scheme to help small firms control health risks from chemicals. *Ann Occup Hyg* **42**, 367-76.
- 14) Tait K (1992) The workplace exposure assessment expert system (worksper). *Am Ind Hyg Assoc J* **53**, 84-98
- 15) Munhausen JR, Damiano J (1998) A strategy for assessing and managing occupational exposures, 2nd ed., American Industrial Hygiene Association Press, Fairfax, Virginia.
- 16) National Toxicology Program (NTP) (2002). Report on carcinogens, 10th ed. U.S. Department of Health and Human Services, Public Health Service. Available at <http://ehp.niehs.nih.gov/roc/toc10.html> (accessed May, 2002).
- 17) International Agency for Research on Cancer (IARC) (2002). Lists of IARC Evaluations. Available at <http://monographs.iarc.fr/monoeval/grlist.html> (accessed May, 2002).
- 18) American Conference of Governmental Industrial Hygienists (ACGIH) (2002) TLVs & BEIs, threshold limit values for chemical substances and physical agents and biological exposure indices. ACGIH, Cincinnati.
- 19) Park DW, Shin YC, Lee NR, Lee KY, Oh SM, Chung HK (1994) A study on the control and exposure assessment to vinyl chloride on the factory processing and producing PVC resin. *Korean Ind Hyg Assoc J* **4**, 33-42.