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Extensive changes to occupational exposure limits in Korea

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ABSTRACT

Occupational exposure limits (OELs) are used as an important tool to protect workers from adverse chemical exposures and its detrimental effects on their health. The Ministry of Labor (MOL) can establish and publish OELs based on the Industrial Safety and Health Act in Korea. The first set of OELs was announced by the MOL in 1986. At that time, it was identical to the Threshold Limit Values of the American Conference of Governmental Industrial Hygienists. Until 2006, none the first OELs except for those of three chemicals (asbestos, benzene, and 2-bromopropane) were updated during the last twenty years. The Hazardous Agents Review Committee established under the MOL selected 126 chemicals from 698 chemicals covered by OELs using several criteria. From 2005 to 2006, the MOL provided research funds for academic institutions and toxicological laboratories to gather the evidence documenting the need to revise the outdated OELs. Finally, the MOL notified the revised OELs for 126 chemicals from 2007 to 2008. The revised OELs of 58 substances from among these chemicals were lowered to equal or less than half the value of the original OELs. This is the most substantial change in the history of OEL revisions in Korea.

1. Introduction

As in other developed countries, occupational exposure limits (OELs) in Korea have played an important role in protecting worker health in occupational environments. The Ministry of Labor (MOL) establishes and publishes OELs based on the Industrial Safety and Health Act (ISHA). The first set of OELs in 1986 was identical to the Threshold Limit Values (TLVs) for the American Conference of Governmental Industrial Hygienists (ACGIH) at that time. Until 2006, the OELs of only three chemicals (2-bromopropane, asbestos, and benzene) had been revised (Paek and Park, 2006) and questions were being raised by both labor organizations and academic societies about the validity of these outdated figures. It was argued that the outdated OELs could not be fully representative of the new toxicological data and occupational environmental context in Korea.

From 2005 to 2006, the MOL provided larger research funds to toxicological laboratories and academic institutions to gather and review data that would guide the revision of the outdated OELs. The Hazardous Agents Review Committee (HARC) established under the MOL by the ISHA reviewed these research results and the MOL notified the revised OELs for 126 chemicals from 2007 to 2008. This was a great step forward in establishing socially and economically acceptable OELs in Korea.

In this paper, we describe the overall procedure for amending OELs and explain the OEL setting process for metalworking fluids (MWFs) in detail as an example.

2. The procedure of OEL amending

To prioritize the revision of the outdated OELs, the HARC reviewed the OELs set according to the following criteria (Chung, 2007).

First, the chemical had to be a substance for which the current OEL equivalent in developed countries (the ACGIH TLVs, the Maximum Allowable Concentration (MAK) in Germany, the Workplace Exposure Limits (WELs) in the United Kingdom, or similar), was stricter than the Korean OEL at that time. The chemical classification under the 2003 regulatory framework included a list of OELs for 698 chemicals, 14 of which were permission-required substances, 168 of which were substances for which periodic measurement was required, and 516 of which were OEL-listed substances associated with no regulatory requirements. Any employer handling of the "permission-required" substances had to be approved in advance by the MOL. If using permission-required substances or substances requiring mandatory periodic measurement, employers were required to monitor the exposure levels of their workers and improve the workplace environment by the monitoring the results once every 6 months, once every 3 months

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if the monitoring results exceeded the OEL by 200% or more (100% for carcinogens), or every 12 months if the whole workplace showed no excess exposure to any OEL-listed substance (except for carcinogens). The OELs of the 516 chemicals with no regulatory requirements are recommended limits and do not impose legal obligation on employers with regard to measurement.

The second criterion was that substance in question had to cause occupational diseases or significant health risks in Korea.

Thirdly, the HARC examined the number of workers exposed to OEL-listed chemicals and also reconsidered the quantity of the chemical used, produced, imported, and exported based on the National Survey of Work Environment Status. This survey was conducted over a five-year period by the ISHA.

Based on the review results, the HARC selected 126 chemicals, 14 of which require permission (12 of these have no OELs), 103 with stricter OELs in developed countries than in Korea, seven without an OEL in Korea despite their having such limits in developed countries, and 2(n-hexane and trichloroethylene) that had led to occupational diseases in Korea (Lee et al., 2008).

The Korea Occupational Safety and Health Agency (KOSHA) under the MOL allocated research funds to openly soliciting proposals for gathering and reviewing evidence as required to amend the OELs of these 126 chemicals from toxicological laboratories and academic institutions from 2006 to 2007. Each research result had to be submitted to the KOSHA in a standardized document form with the following information:

- Chemical and physical properties, including information on molecular weight, CAS number, form, color, freezing, melting and boiling point, vapor pressure, and solubility of the chemicals in water and other solvents.
- Toxicological and epidemiological data providing information on carcinogenic, mutagenic, and teratogenic properties, dose–response/effect data from animal and human studies, and cases of occupational disease caused by chemical exposure.
- Production and use in the workplace, with an emphasis on the specific working conditions that entailed significant exposure, main exposure routes, sources and operation types.
- Exposure monitoring data from companies selected using the stratified random sampling method and statistical analysis data from the monitoring results reported to the MOL (employers must report their monitoring results for the substances that have measurement requirements to the MOL).
- Regulatory impact analysis including information on the necessity of amendments to OELs, the technical feasibility of new OELs in the workplace, checking for the presence of any other alternative methods instead of amending OEL and a cost-benefit analyzes.
- The suggestion of new chemical OELs based on the presented evidence, and information regarding technical and socioeconomic considerations that would affect the adaptation to a new OEL.

After the new OELs had been developed from the information indicated in the above lists and the HARC had reviewed the research results, the proposals for the new OELs were communicated to the labor and employer representatives so that they could be converted into legal OELs. Finally, the MOL announced the new OELs for 126 chemicals from 2007 to 2008. The flow of the overall process of amending the OELs was presented in Fig. 1.

3. The level of the amended exposure limits

The level of the change to the OELs was summarized in Table 1 using the ratios between the new OELs and the old OELs. In some cases, there are considerable differences between the ratios depending on whether the OELs are measured in ppm or mg/m^3. In such cases, preference is given to ppm values (Schenk et al., 2008). However, there was no option of using mg/m^3 values for the OELs of the substances with no molecular weight, such as cotton dust. Of the 126 OELs, 96 (76%) were lowered, 19 (15%) had new OELs, and 11 (9%) did not change. The revised OELs for 58 substances (46.0%) were lowered to values equal to or less than half of the original OELs. The chemical with the biggest change was vinyl cyclohexene dioxide from 10 to 0.1 ppm.

To create a comparison between the new OELs and the old OELs, the geometric mean method was used in this study (Hasson, 1998). The geometric mean was calculated from the ratios between the new OELs and the old OELs to represent the overall difference. The geometric means of the ratios of the new OELs from 2008 to the old OELs from 1983 were 0.297 for the 100 substances with ppm values and 0.454 for the seven substances with mg/m^3 values. In Schenk et al. (2008), the geometric mean range of the ratios of 2005 OELs established by 18 organizations to the combined values of ACGIH TLVs from 1946 and the European Union (EU) OELs was from 0.228 to 0.608. The highest geometric means were those of the EU and the US Occupational Safety and Health Administration (OSHA), at 0.584 and 0.608, respectively. The lowest geometric means were those of Poland, the Japan Society for Occupational Health (JSOH), and Sweden, at 0.228, 0.282, and 0.286, respectively.

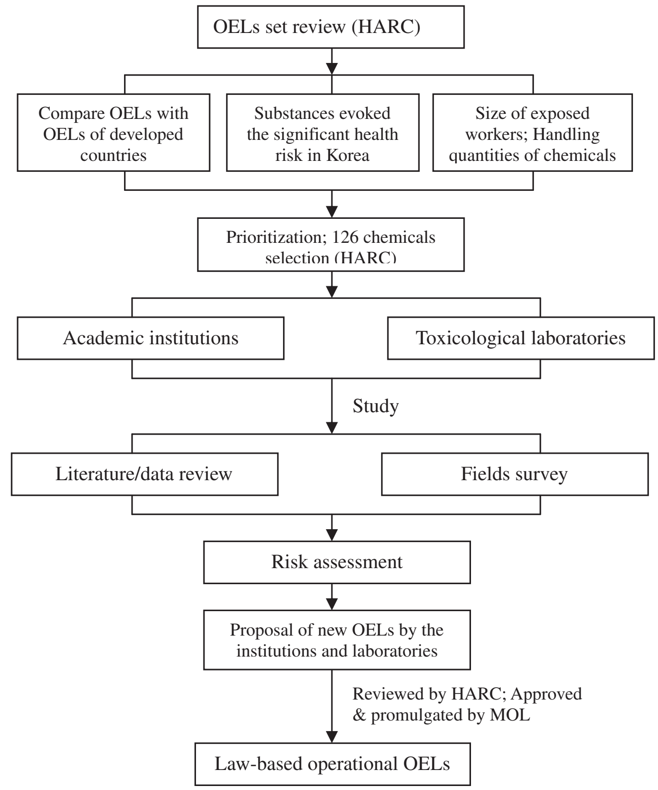

Fig. 1. The flow of overall processes in amending OELs. HARC, Hazardous Agents Review Committee; MOL, Ministry of Labor.

4. The enforcement and communication of new OELs

The ISHA has established detailed workplace monitoring programs, including monitoring periods, reporting requirements, and workplace improvement plans to be implemented when the OEL is exceeded. Paek and Park (2006) report on about 110 technical

Table 1
Distribution and geometric mean of ratios of the new OELs to the old OELs.

	Range and mean of ratios	No. of substances	Chemicals involved
Distribution	$X < 0.1$	7	Arsenic, 1,1-dimethylhydrazine, 2,3-epoxy-1-propanol, ethyl bromide, hydrogen fluoride, methyl hydrazine, vinyl cyclohexene dioxide
	$0.1 \leqslant X < 0.5$	51	Acrylic acid, allyl glycidyl ether, allyl propyl disulfide, arsine, aryll alcohol, asphalt, beryllium, 1,3-butadiene, chlorobenzene, 1-chloro-2,3-epoxy propane, cobalt, cyclonite, diazinone, dichlorobos, diethanol amine, 2-diethylaminoethanol, dimethyl aminobenzene, dinitrotoluene, 2,6-di-tert-butyl-p-cresol, EPN, 1,2-epoxy propane, ethylene glycol, glutaraldehyde, hexavalent chromium, hydrogen chloride, isopropylacetate, kaoline, lead chromate, malathion, maleic anhydride, manganese, methyl acrylate, methylbromide, monochrotofos, n-butyl acrylate, n-butyl glycidyl ether, nitromethane, o-dichlorobenzene, p-dichlorobenzene, phenyl mercaptan, pyridine, sec-amyl acetate, styrene, sulfuric acid, tetrahydrofurane, thiram, triethyl amine, 2,4,6-trinitro toluene, turpentine, vinyl bromide, zinc oxide
	$0.5 \leqslant X < 1$	38	Acetaldehyde, acetone, acetonitrile, 2-butoxy ethanol, cadmium, carbon monoxide, chlorine, chlorpyrifos, coal dust, cyclohexane, 1,1-dichloroethane, diethyl amine, dimethyl amine, dioxane, ethyl amine, formaldehyde, glass fiber, graphite, hydrazine, hydrogen bromide, hydrogen cyanide, isoamylacetate, isopropyl alcohol, mercury, methyl amine, 4,4′-methylenebis(2-chloroaniline), methyl metacrylate, molybdenum, n-amyl acetate, nickel(insolube), ozone, parathion, perchloroethylene, phenyl glycidyl ether, silica dioxide, sodium cyanide, toluene, trimethyl amine
	$X = 1$	11	Acrolein, benzene, bromine, copper, cotton dust, cyclohexanone, p-tert-butyltoluene, phorate, tricholoethylene, vinyl acetate, wood dust
	NA[a]	19	Alpha-naphthylamine, benzotrichloride, benzoyl chloride, 1-bromopropane, 2-butoxyethylacetate, dianisidine, dichloroacetic acid, 1,1-dicholoro-1-fluoroethane, flour dust, grain dust, hexamethylene diisocyanate, kerosene, methyl tert-butyl ether, mica, metalworkingfluids, n-vinyl-2-pyrrolidone, refractory ceramic fibers, strontium chromate, toluene-2,6-diisocyanate
	Total	126	
Geometric mean	0.297[b]	100	
	0.454[c]	7	

[a] Not applicable because those did not originally have OELs.
[b] Geometric mean calculated using the ppm value.
[c] Geometric mean calculated using the mg/m^3 value.

service agencies in Korea that provided measurement services to employers, indicating that only 182 of 698 chemicals measured have measurement requirements. The 516 OEL-listed chemicals that do not have legal measurement requirements have been measured voluntarily by employers.

Although the OEL is designed to control exposure to hazardous substances and provide a safe environment for workers, OELs in Korea are a recommendation rather than requirement because worker exposure above the OEL is not directly linked to an employer penalty. The MOL only imposes penalties on employers that do not carry out their measurement and reporting duties, or that fail to establish workplace improvement plans when the OEL is exceeded.

Questions have been raised about the effectiveness of OELs and particularly on the workplace monitoring programs. The variation in the exposure level during the non-monitoring period has not been well characterized, the measurement results have not been directly linked with improvements to the work environment, and acute poisoning episodes due to chemical exposure have still occurred (Lee et al., 2008).

In 2009, the MOL introduced mandatory Permissible Limits (PLs) to the ISHA for 13 of the 126 amended OELs, meaning that an employee's exposure to any substance in Table 2 shall not exceed the PL. The Act defines the PL as the maximum time-weighted average (TWA) concentration for a conventional 8-h workday, or the short-term exposure concentration for any 15-min period during a workday. In selecting the substances with PLs, many aspects have been considered, including carcinogenicity, the severity of health risks, the number of workers exposed, and the substances causing domestic occupational diseases.

An employer who exceeds the PL provision without a reasonable excuse may be assessed a maximum fine of approximately US 45,000 dollars.

Although the implementation and enforcement of occupational exposure standards such as PLs and stricter OELs are necessary to protect the health of workers, such standards do not guarantee that workers' level of exposure to hazardous chemicals in workplaces will be well controlled and thus do not ensure that their health will be protected. The MOL has adopted comprehensive risk assessment programs for hazardous chemicals in workplaces in addition to the workplace monitoring programs, and related research has been conducted to develop effective implementation tools. A special committee will be set up to review the results.

Table 2
The list of PLs[a] established by the Ministry of Labor in Korea (Unit: mg/m^3).

Substance	Korea PL (2009)	
	TWA	STEL
Asbestos	0.1 f/cc	
Benzene	3	
2-Bromopropane	5	
Cadmium and its compounds as Cd	0.03	
Carbon disulfide	30	
Dimethylformamide	30	
Formaldehyde	0.75	
n-Hexane	180	
Hexavalent chromium compound as Cr		
Insoluble	0.01	
Soluble	0.05	
Lead and its inorganic compounds as Pb	0.05	
Nickel (insoluble inorganic compound) as Ni	0.5	
Toluene-2,4-diisocyanate	0.04	0.15
Trichloroethylene	270	1080

[a] Permissible limit.

5. Example of OEL amending for metalworking fluids (MWFs)

According to the National Survey of Work Environment Status in the manufacturing sector conducted by the MOL during 2004, the number of companies and workers that directly handled MWFs was 31,523 and 111,634, respectively (MOL, 2005). Approximately 32% of all companies in the manufacturing sector produced or used MWFs in Korea. Several skin diseases (irritant or allergic contact dermatitis) and adverse respiratory effects (asthma and breathing

Table 3
Summary of the exposure level of extractable mass for MWFs.

Variable	Measurement year		
	2003	2004	2006
No. of samples	822	3309	33
Geometric mean (mg/m^3)	0.30	0.20	0.12
75th percentile (mg/m^3)	0.64	0.50	0.24
90th percentile (mg/m^3)	1.11	0.77	0.33
95th percentile (mg/m^3)	1.51	1.08	0.46

problems) resulting from exposure to MWFs have often been reported in Korea (Chun et al., 1996; Jin et al., 1997; Lee et al., 1991; Park, 2007).

The OELs for MWFs were lowered from 5 mg/m^3 of mineral oil mist and 10 mg/m^3 of vegetable oil mist as total particulate mass to 0.8 mg/m^3 as extractable mass in 2008.

During the revision process, we considered three key factors: (1) that the new OEL should better protect workers from diverse respiratory problems, (2) that it needed to be applicable to all kinds of MWFs because we could not collect discriminately the airborne mists released from various kinds of MWFs used, and (3) that it would be technologically feasible to comply with the limit in most metal working operations.

First, we reviewed the OELs established by seven different countries or organizations, the US OSHA Permissible Exposure Limits, the ACGIH TLVs, the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs), the JSOH OELs, the Japan Control Limits, the Germany MAKs, and the UK WELs. The strictest standard for MWFs was set by the NIOSH at 0.4 mg/m^3 of thoracic particulate mass, corresponding to approximately 0.5 mg/m^3 for total particulate mass (NIOSH, 1998). This standard was intended to prevent the diverse respiratory disorders associated with MWF exposure in the workplace. In addition, it was applicable to all kinds of MWFs.

To evaluate the technical feasibility of implementing the standard, we surveyed the current exposure levels of the MWFs at five companies using NIOSH method 5524 for all categories of MWFs (NIOSH, 2003) in 2006 and also reviewed the past workplace measurement records from 2003 and 2004. All of the past measurement records for MWFs during those intervals were attained using the gravimetric method as total particulates. The extractable mass in the total particulate mass was estimated using the conversion factor of 0.508 (extractable mass = 0.508 $\times$ total particulate mass) based on the relationship between each pair of the total particulate mass and the extractable mass as measured in the field survey. The exposure level for the MWFs is summarized in Table 3.

The geometric mean concentrations of extractable mass for MWFs were 0.30 mg/m^3 (2003), 0.20 mg/m^3 (2004), and 0.12 mg/m^3 (2006), respectively. In 2003, 25% of the estimated extractable mass exposures exceeded 0.64 mg/m^3, and 10% exceeded 1.11 mg/m^3. One year later, 25% of the figures exceeded 0.50 mg/m^3, and 10% exceeded 0.77 mg/m^3. Only 3.0% of extractable mass concentrations from the field survey in 2006 exceeded 0.5 mg/m^3. Based on the MWFs exposure level trends, 0.8 mg/m^3 as extractable mass concentration was considered to constitute the limit of technical feasibility. The proposed OEL (0.8 mg/m^3) of the MWFs was higher than the NIOSH REL (0.5 mg/m^3) of the MWFs, but it was much stricter than the existing OELs for mineral oil mist (5 mg/m^3) and vegetable oil mist (10 mg/m^3). After the proposed OEL was reviewed by the HARC, the employer and employee representatives were notified. The MOL finally announced the proposed level as the OEL of the MWFs instead of invalidating the OELs for mineral oil mist and vegetable oil mist in 2008.

6. Conclusion

Since the first setting of OELs based on ACGIH TLVs in 1986, OEL is a still useful guide for evaluation and control of workplace environment in Korea. However there was no systematic process for setting or updating OELs until 2003.

The HARC established by the MOL in 2003 under the authority of the ISHA reviewed the outdated OELs and selected 126 chemicals for review according to several critical criteria described in the procedure for OEL amendments in 2004. By providing research funds for toxicological laboratories and academic institutions from 2005 to 2006, the MOL had gathered and reviewed evidence that could be used to revise the chemicals with outdated OELs. Besides toxicological and epidemiological information, technical and socioeconomic feasibility was considered in detail.

Finally, of the 126 OELs, 96 (76%) were lowered, 19 (15%) had new OELs, and 11 (9%) did not change. The geometric means of the ratios of the new OELs from 2008 to the old OELs were 0.297 for the 100 substances with ppm values and 0.454 for the seven substances with mg/m^3 values. Additionally, the MOL introduced mandatory PLs for 13 of the 126 amended OELs into the ISHA to prevent the incomplete enforcement of the OELs in 2009.

It is meaningful in that accumulating experiences to make OEL setting framework actually work as well as the most substantial change in the history of OEL amendment in Korea.

Conflict of interest and funding sources statement

All authors do not have any conflicts of interest, and this paper does not have any involvement of study sponsors.

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