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1991년부터 2016년까지 미국 산업위생 전문가협의회의 화학물질 직업적 노출기준 (ACGIH-TLV)의 변화에 관한 연구

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위 논문을 공학 석사학위 논문으로 제출함

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1991년부터 2016년까지 미국 산업위생전문가협의회의 화학물질 직업적 노출기준(ACGIH-TLV)의 변화에 관한 연구

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본 연구는 1991년부터 2016년까지 ACGIH-TLV의 화학물질에 대하여 TLV값의 변화(상향 또는 하향조정) 및 삭제나 추가 그리고 STEL 및 C의 추가나 변경 등의 변경사항을 파악하고 분석하였다.

ACGIH에서 발간한 TLV 소책자에 수록된 화학물질 종류는 1991년에는 659종이었고, 2016년도에는 694종인 것으로 나타났다. 1991년도부터 2016년 현재까지 TLV 기준에 전혀 변화가 없는 화학물질은 384종이었다. 지난 25년간 TLV값이 하향 조정된 물질은 151종이었다. 반면 상향 조정된 화학물질은 4종이었다. 1991년부터 2016년 사이에 TLV 소책자에서 삭제된 화학물질은 95종이었고, 새롭게 추가된 화학물질은 130종이었다.

1991년 이후 2016년까지 TLV값이 하향 조정된 정도(감소율)가 20%이하인 경우는 5종, 20~30%인 경우가 3종, 30~40%는 3종, 40~50%는 30종, 50~60%가 12종, 60~70%가 5종, 70~80%가 37종, 80~90%가 34종, 90% 이상 감소한 화학물질은 20종인 것으로 나타났다.

TLV값이 상향조정된 화학물질은 Butane, Nickel Elemental, Pentane 및 Tributyl phosphate 등 4개였다. 1991년부터 2016년까지 25년간 TLV 소책

자에 새롭게 나타난 화학물질은 130개였다. 새롭게 TLV가 추가된 화학물질 중 일부는 1991년 및 그 이전에는 각각 별개의 노출기준을 가지고 있던 화학물질을 묶어서 크게 하나의 화합물(compound) 군으로 표현한 것들이 있다. 그 외에 여러 연구를 통해 새롭게 건강장해가 밝혀진 것들은 신규로 TLV를 추가한 것이다. 1991년부터 2016년까지 25년간 TLV 소책자에서 삭제된 화학물질은 95종이었다. 삭제된 이유는 각각 TLV가 설정되어 있던 개별 화학물질을 보다 넓은 범위 또는 유사한 것을 하나의 화합물 군으로 합치면서 개별 화학물질은 삭제된 것이 있고, 일부는 자료 불충분으로 삭제했으며, 일부 단순 질식제는 Minimal Oxygen Content로 대체하면서 삭제하였다.

【주요어】 노출기준 변화, 화학물질 노출기준, TLV, OEL, ACGIH-TLV

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제 1 장 서 론

미국정부산업위생전문가협의회(American Conference of Governmental Industrial Hygienists, ACGIH; 이하 'ACGIH'라 함)는 작업장의 유해요인으로부터 근로자를 보호하기 위한 직업적 노출기준에 가장 권위 있는 기관이다. 전 세계 에서 가장 널리 인용되는 작업장의 유해요인에 대한 산업보건기준은 ACGIH에서 정한 Threshold Limit Values(이하 'TLV'라 함)이다. ACGIH의 화학물질 TLV 위원회(Threshold Limit Values for Chemical Substances (TLV®-CS) Committee)는 1941년도에 설립되었다. 이 위원회는 매년 TLV를 검토하고 관련 조사와 개정에 관한 추천을 받는 등 재검토에 대하여 책임지고 있다. 1944년부터는 상임위원회로 되었다. 1956년도에 처음으로 TLV를 설정하였다.

현재 TLVs의 목록에는 700개가 넘는 화학물질 및 물리적 인자가 있다. TLVs는 1일 중 노출되는 시간범위에 따라 8시간-시간가중 평균노출기준 (8 hr-Time Weighted Average; 이하 'TWA'라 함), 최고노출 기준 (Ceiling; 이하 'C'라 함), 단시간 노출기준(Short Term Exposure Limit; 이하 'STEL'라 함)를 설정하고 있다.

ACGIH에서는 매년 새로운 독성자료나 사업장의 역학조사 및 작업환경 조사자료 등을 바탕으로 TLV를 개정해 오고 있다. ACGIH-TLV는 물론 가장 널리 인용되는 권위 있는 기준이지만 절대적으로 안전한 값이 아니다. 또한 ACGIH-TLV는 수많은 직업적 노출기준 가운데 하나이다.

많은 나라에서는 처음 직업적 노출기준을 설정할 때 ACGIH-TLV를 거의 대부분 그대로 인용한다. 하지만 그 이후에 ACGIH-TLV는 매년 일부 화학물질에 대한 개정이 이루어지지만 많은 나라에서는 한번 설정한 기준을 잘 바꾸지 않는다. 일단 기준이 한번 정해지고 난 이후 개정을 하려면 여러 이해당사자가 반발하는 등, 개정이 쉽지 않기 때문이다.

한편 ACGIH-TLV 기준은 독성과 같은 건강정보, 경제적 여건, 기술적 가능성(현실성) 등을 고려하여 설정한다. 따라서 경제적 여건이나 기술적 여건이 미국의 현재 수준에 미치지 못하는 국가나 소규모 사업장에는

ACGIH-TLV가 지나치게 엄격한 값일 수도 있다.

본 연구는 이러한 점에 착안하여 지난 1991년부터 2016년까지 ACGIH-TLV가 설정되어 있는 화학물질에 관하여 물질별로 지난 25년간 ACGIH-TLV 기준이 어떻게 변화되었는지를 파악하고 분석하였다. 이러한 분석을 통해 다른 나라 또는 규모가 다른 사업장 등에서 최소한 기준 또는 적정한 기준 등을 설정하는데 참고가 될 것이며, 사업장에서는 물질별로 어떤 수준으로 관리해야 하는지 그 수준을 파악할 수 있을 것으로 기대된다.

제 2 장 연 구 방 법

제 1 절 연구의 범위와 내용

1991년부터 2016년까지의 미국 ACGIH-TLV 소책자에 수록된 화학물질 전체의 TWA, C, STEL 기준에 대하여 어떠한 변화가 있었는지 분석하였다. 지난 25년간 노출기준이 감소하거나 증가한 화학물질, 삭제되었거나 신규 추가된 화학물질, 변화 없는 화학물질 등으로 분류하고 기준이 바뀐 경우 그 근거를 파악하였다.

제 2 절 연구방법

1) 자료수집

1991년도부터 2016년도까지의 ACGIH TLV 소책자에 수록된 화학물질의 TLV값을 취합하였다.

2) 연구방법

지난 25년간 ACGIH-TLV를 엑셀에 입력하여 DB로 만든 다음, 연도별로 TLV 값에 차이가 있는 것을 연도별로 순차적으로 분류하였다. 기준이 변화된 경우 그 근거를 파악하고 정리하였다.

제 3 장 연 구 결 과

제 1 절 노출기준의 전반적 변화

1) 1991-2016 사이 ACGIH-TLV 기준의 변화

1991년도부터 2016년도까지 TLV 값이 바뀐 화학물질 수를 정리한 것은 〈표 1〉과 같다. 1991년도부터 2016년 현재까지 노출기준에 변화가 없는 화학물질이 384종이다. 1991년보다 TLV 값이 낮아진 화학물질은 총 151종이다. 반면 TLV 값이 높아진 화학물질은 4종이다. 지난 25년간 총 130종의 화학물질이 새로 TLV 값이 설정되었고, 95종은 삭제되었다.

지난 25년간 TLV 값이 두 번 이상 바뀐 물질도 많다. 예를 들어 Acetone은 1991년도에 TWA-750 ppm, STEL-1000 ppm이었으나 1997년도에 TWA-500 ppm, STEL-750 ppm으로 변경됐다. 이후 다시 2015년도에 TWA-250 ppm, STEL-500 ppm으로 낮아졌다.

노출기준이 높아졌거나 낮아졌을 뿐만 아니라 TWA값이 삭제되었거나 STEL값, C값 등이 신규 추가 되는 등 다양한 변화가 있었다. 총 21종의 화학물질은 TLV 수치 변경이 아니라 다른 변화가 있었다. 예를 들어 Ethylene은 TLV 소책자에 Ethylene이 들어 있었지만 노출기준은 설정되지 않고 단순 질식사 유발요인이라고만 기술해 놓았었다가, 2005년도에 Ethylene의 TLV로 TWA -200 ppm을 설정했다.

〈표 1〉 1991-2016 화학물질에 대한 ACGIH-TLV 변화 요약

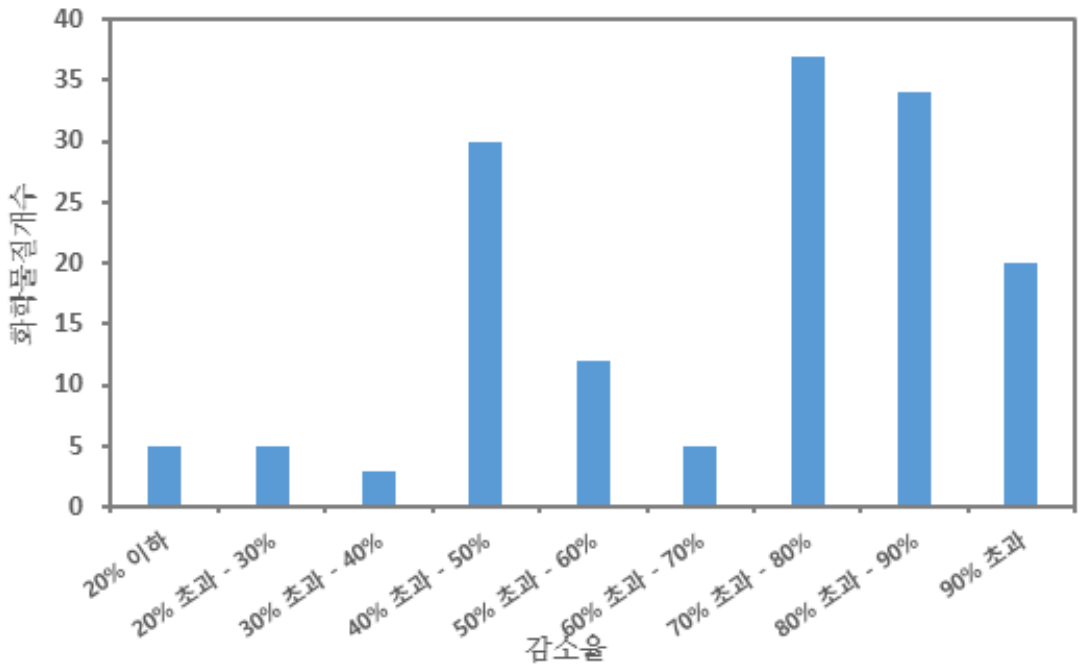
구분	연도 (5년 단위)					
	(1991-2016)	(1991-1995)	(1996-2000)	(2001-2005)	(2006-2010)	(2011-2016)
화학물질 개수	659 (1991)					694 (2016)
변화없음	384	-	-	-	-	-
낮아짐	151	37	25	32	43	23
높아짐	4	-	1	1	-	4
신규	130	28	30	37	19	14
삭제	95	17	11	19	29	19
기타	25	-	-	-	-	-

TLV에는 1991년에 총 659종의 화학물질이 있었고, 2016년도에는 총 694종의 화학물질이 있다. 〈표 1〉에 5년씩 화학물질 노출기준의 변화를 보여주고 있다. 25년간 TLV에 변화가 있었던 화학물질은 모두 180종이었다. 이 중에서 노출기준이 낮아진 물질이 151종에 이른다. 이로부터 TLV 값은 지속적으로 감소해 왔다는 추세를 알 수 있다.

제 2 절 1991-2016년 동안 TLV가 하향 조정된 화학물질

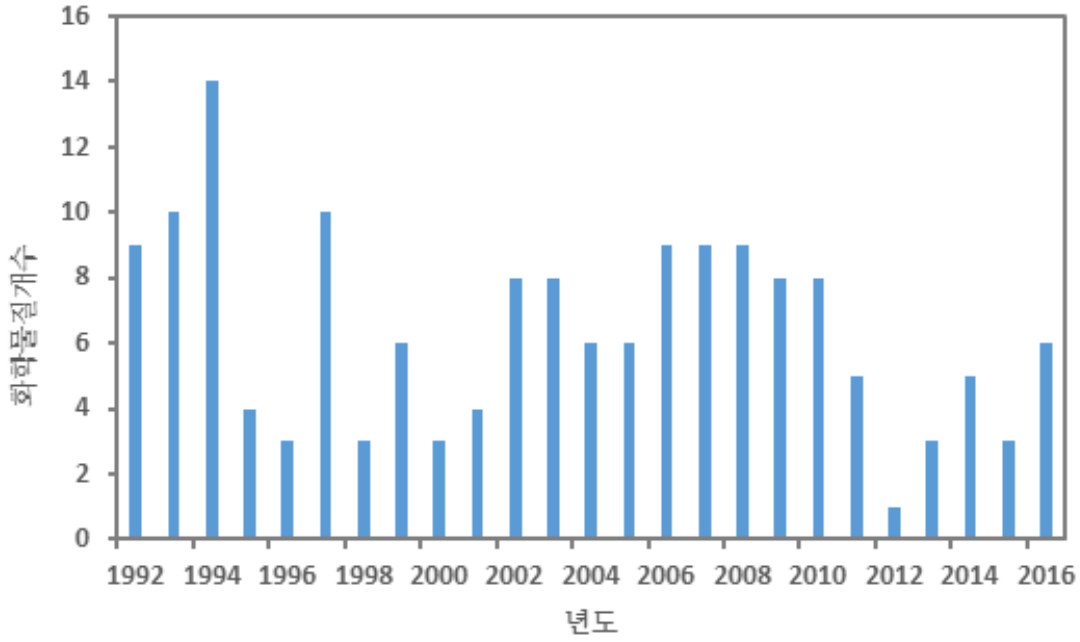
1) 연도별 TLV가 하향 조정된 화학물질의 개수

1991년도의 노출기준과 2016년도의 노출기준을 비교하였을 때 낮아진 정도별 따른 화학물질 수는 [그림 1]과 같다.



[그림 1] 1991-2016년 사이 TLV값 하향된 감소율별 화학물질 수.

1991년 대비 2016년 TLV를 비교한 결과, 하향 조정된 정도(감소율)가 20%이하인 경우는 5종, 20~30%인 경우가 3종, 30~40%는 3종, 40~50%는 30종, 50~60%가 12종, 60~70%가 5종, 70~80%가 37종, 80~90%가 34종, 90% 이상 감소한 화학물질은 20종인 것으로 나타났다. 이와 같이 감소한 화학물질은 총 151종이었고 50% 이상 크게 감소한 물질은 108종이었다. 이와 같이 ACGIH-TLV는 지난 25년간 상당히 낮아져 왔다.



[그림 2] 연도별 TLV가 하향 조정된 화학물질의 개수.

1991년부터 2016년까지 연도별로 TLV가 하향 조정된 화학물질의 수는 [그림 2]와 같다. 1991년 이후 ACGIH는 거의 매년 1~14개의 화학물질에 대한 TLV를 낮추는 방향으로 개정해 왔다.

2) 90% 이상 하향 조정된 화학물질

1991년 이후 2016년까지 TLV값이 낮아진 화학물질은 총 151종이었다. 1991년 이후 2016년까지 TLV의 감소치가 90% 이상 크게 낮아진 화학물질은 19종이다. 낮아진 연도와 낮아진 주요 이유는 〈표 2〉와 같다.

1991년 이후 2016년까지 TLV값이 크게 낮아진 대표적인 예로는 Benezene과 Tetranitromethane이 있다. Benzene은 1991년 8 시간가중평균(8 hr-time weighted average, 8h-TWA) TLV는 10 ppm이었다. 1997년에 STEL 2.5 ppm을 새롭게 추가하였고, 8h-TWA는 0.15 ppm으로 낮췄다. 벤젠이 백혈병을 일으키는 것으로 밝혀지자 Benzene TLV-TWA를 95%나 낮춘 것이다.

Tetranitromethane 경우에는 1991년 TWA가 1 ppm이었는데 1993년는 0.005 ppm으로 99.5%나 낮췄다. 여러 연구에서 Tetranitromethane의 직업적 노출이 노동자의 안구 및 호흡기도 자극을 일으키고 호흡기 발암가능성이 있는 것으로 밝혀졌기 때문이다.

〈표 2〉 1991년이후 2016년까지 TLV값이 90% 이상 낮아진 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Arsenic [7440-38-2] and solube compounds, as As	(1991-1992) TWA-0.2 mg/m^3 (1993-2016) TWA-0.01 mg/m^3	95	The quantitative air monitoring data indicate a significant excess of lung cancer risk for workers exposed to mean level of 0.2 mg/m^3 of arsenic. This is based on standard reference materials (SRM) of 213, where there 47 observed lung cancer deaths. It is the lowest level at which an excess risk of cancer in human has been found. To allow some measures of safety, TWA of 0.01 mg/m^3 is recommended
2	Benzene [71-43-2]	(1991-1996) TWA-10 ppm (1997-2016) TWA-0.5 ppm, STEL-2.5 ppm	95	The results from studies of the Pliofilm cohort which use a ppm-years dose metric suggest that, at a TWA of 0.5 ppm, the odds of death from leukemia due to occupational benzene exposure would be indistinguishable from the odds of death from leukemia for a worker who is not exposed to benzene. It is these analyses and interpretation of the Pliofilm cohort of benzene exposure and deaths from leukemia that provide the basis for a TLV-TWA of 0.5 ppm benzene. A TLV-STEL of 2.5 ppm is recommended to protect against excess risk of leukemia due to the dose-rate-dependent hematopoietic toxicity of benzene
3	Beryllium [7440-41-7] and compounds, as Be	(1991-1996) TWA-0.002 mg/m^3 (1997-2008) TWA-0.002 mg/m^3 STEL-0.01 mg/m^3 (2009-2016) TWA-0.00005 mg/m^3	97.5	A growing number of studies are providing information regarding workplace exposure levels that are associated with the development of BES and subclinical or clinical CBD. Reports showed that 3 cases of beryllium-sensitized individuals in beryllium machining plant had mean total Lifetime weighted (LTW) exposure between 0.05 and 0.1 microgram Be/m^3. There for of TWA-0.05 μg/m^3 is expected to be protective of the beryllium-sensitive population because available data indicate very low or no incidences of beryllium sensitization or disease at this level
4	Diethanolamine [111-42-2]	(1991-1993) TWA-3 ppm	92.3	A TLV-TWA of 1 mg/m^3 (0.2 ppm) for Diethanolamine (DEA) should be sufficient to protect against its irritative and systemic effects. There are no quantitative data available

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		(1994-2008) TWA-2 mg/m^3 (2009-2016) TWA-1 mg/m^3		from man or the human experience upon which to base a TLV, thus the recommended value derives from animal experiments. In the study where 2 mg/kg was a no-effect level, the next dose tested, 4 mg/kg, produced liver and kidney damage along with mortality suggesting a steep dose response. The 2 mg/kg dose, assuming 100% absorption, would be equivalent to an inhalation dose of 14 mg/m^3 or 3.2 ppm. Integrating this calculated dose with the no-effect inhalation exposure demonstrated in multi-species suggests that an exposure of 0.2 ppm (1 mg/m^3) should be sufficient to protect nearly all workers from the unwanted effects of DEA
5	1,1-Dimethylhydrazine [57-14-7]	(1991-1994) TWA-0.5 ppm (1995-2016) TWA-0.01 ppm	98.0	A TLV-TWA of 0.01 ppm (0.025 mg/m^3) is recommended for occupational exposure to 1,1- dimethylhydrazine (UDMH) in part by analogy to the TLV for methylhydrazine. This value is intended to minimize the potential for respiratory tract irritation and possible cancer, reported only in animals
6	Ethyl bromide [74-96-4]	(1991-1991) TWA-200 ppm, STEL-250 ppm (1992-2016) TWA-5 ppm	97.5	A TLV-TWA of 5 ppm (22 mg/m^3) is recommended for occupational exposure to ethyl bromide. This value is intended to minimize the potential for adverse liver, kidney, and cardiac effects and possible cancer reported in animals. Animal and human data indicate the potential for dermal absorption of ethyl bromide and contribution to systemic toxicity
7	Glycidol [556-52-5]	(1991-1995) TWA-25 ppm (1996-2016) TWA-2 ppm	92.0	A TLV -TWA of 2 ppm (6.1 mg/m^3) is recommended for occupation exposure to glycidol to minimize the potential risk of cancer and genotoxicity, reported only in experimental animals and in vitro studies of human W138 cells. This value also should provide a wide margin of protection from ocular, upper respiratory, and skin irritation
8	Maleic anhydride [108-31-6]	(1991-1999) TWA-0.25 ppm (2000-2010) TWA-0.1 ppm	99	A TLV-TWA of 0.01 mg/m^3 (0.0025 ppm), inhalable fraction and vapor is recommended for occupational exposure to maleic anhydride (MA). This value is intended to minimize the potential for respiratory sensitization. At lower exposures (less

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		(2011-2016) TWA-0.01 mg/m^3		than 10 μg/m^3), negative findings are noted. In the analysis, which included all workers and all three acid anhydrides, there was some evidence "that those employed in jobs with mean full-shift exposure ≥ 10 μg/m^3 were more at risk of sensitization than those employed in jobs where the mean full-shift exposure was 〈10 μg/m^3
9	Methomyl [16752-77-5]	(1991-2013) TWA-2.5 mg/m^3 (2014-2016) TWA-0.2 mg/m^3	92	A TLV-TWA of 2.5 mg/m^3 is recommended for occupational exposure to the carbamate insecticide methomyl. This value is intended to minimize the potential for symptoms of toxicity characteristic of cholinesterase-inhibiting chemicals. Cholinergic symptoms may include nausea or vomiting, salivation, muscle weakness, fatigue, blurred vision and contracted pupils, and at high levels of exposure, tremors
10	2-Methoxyethanol [109-86-4]	(1991-2005) TWA-5 ppm (2006-2016) TWA-0.1 ppm	98	A TLV-TWA of 0.1 ppm is recommended for occupational exposure to the glycol ether, 2-methoxy- ethanol (EGME), primarily to protect against hematologic and reproductive toxicity. This value also should minimize the potential for other adverse effects, including effects on the immune system organs and depression of central nervous system
11	2-Methoxyethyl acetate [110-49-6]	(1991-2005) TWA-5 ppm (2006-2016) TWA-0.1 ppm	98	A TLV-TWA of 0.1 ppm is recommended for occupational exposure to the glycol ether, 2-methoxyethyl acetate (EGMEA), primarily to protect against hematologic and reproductive toxicity. This value also should minimize the potential for other adverse effects, including those on the immune system organs and depression of central nervous system. This substance is rapidly metabolized to 2-methoxyethanol (ethylene glycol monomethyl ether, EGME, and effects tend to parallel those from exposure to that substance
12	Molybdenum [7439-98-7], as Mo Soluble compounds	(1991-2000) TWA-5 mg/m^3 (2001-2016) TWA-0.5 mg/m^3	95	The National Toxicology Program (NTP) study also showed exposure-related increases in chronic inflammatory changes of the respiratory tract in mice and rats of both sexes. Based on the no-observed-effect-level of 10 mg/m^3 for lung inflammation in rats, a TLV- TWA of 0.5 mg/m^3 (respirable particulate mass) was derived for workplace exposures

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
13	Naled [300-76-5]	(1991-2001) TWA-3 mg/m^3 (2002-2016) TWA-0.1 mg/m^3	96.67	The TLV-TWA of 0.1 mg/m^3, inhalable aerosol and vapor, should be sufficient to protect against cholinergic and other adverse effects. This reflects current understanding regarding the relationship between Red Blood Cell (RBC) cholinesterase inhibition and adverse effects for this compound
14	Nitrogen dioxide [10102-44-0]	(1991-2011) TWA-3 ppm, STEL-5 ppm (2012-2016) TWA-0.2 ppm	93.33	Based on respiratory system irritant effects during controlled human exposure studies to nitrogen dioxide, a TLV-TWA of 0.2 ppm (0.38 mg/m^3) is recommended. This value should protect both non-asthmatic and asthmatic workers from respiratory system effects. Asthmatic workers require a lower TLV-TWA than would be needed by non-asthmatic workers
15	Sulfur dioxide [7446-09-5]	(1991-2008) TWA-2 ppm, STEL-5 ppm (2009-2016) STEL-0.25 ppm	95	The TLV-STEL is based on experimental studies showing acute lung (respiratory tract) effects in experimentally exposed human subjects under controlled conditions. These studies show acute symptoms and bronchoconstrictor effects with exposure and exercise at 0.5 ppm (1.3 mg/m^3) and 0.4 ppm in subjects with asthma but not at 0.25 ppm. These effects were seen at 0.75 ppm (1.97 mg/m^3) in some healthy adult subjects; however, no effects were seen in healthy adults at 0.4 ppm. The TLV-STEL is placed at 0.25 ppm to prevent inducing these effects in most asthmatic individuals including during exercise
16	Tetranitromethane [509-14-8]	(1991-1992) TWA-1 ppm (1993-2016) TWA-0.005 ppm	99.5	A TLV-TWA of 0.005 ppm (0.004 mg/m^3) is recommended for occupational exposure to Tetranitromethane (TNM). This value is intended to minimize the potential for ocular and respiratory tract irritation and potential respiratory carcinomas reported in rats and mice at the lowest tested exposures. Lifetime inhalation bioassays in rats and mice demonstrated that TNM is capable of inducing hyperplasia and squamous metaplasia of the respiratory epithelium and alveolar and bronchiolar carcinomas at relatively low exposure concentrations
17	Thiram[137-26-8]	(1991-2007) TWA-1 mg/m^3	95	Thiram has demonstrated genotoxicity in a wide variety of genetic toxicity screening tests. It does not produce an increase in tumors in long-term feeding studies in rodents.

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		(2008-2016) TWA-0.05 mg/m^3		Reproductive endpoints are not generally altered and the fetal animal does not appear to be more sensitive. Irritation has been described in worker populations but there is no reliable data to link effects with known thiram exposures. Thus, the TLV derives from repeated dose studies in animals. A TLV-TWA of 0.05 mg/m^3 (inhalable fraction and vapor) should be sufficient to protect against all adverse effects
18	1,2,3-Trichloropropane [96-18-4]	(1991-2014) TWA-10 ppm, STEL-200 ppm (2015-2016) TWA-0.005 ppm	99.95	A TLV-TWA of 10 ppm (60 mg/m^3) is recommended for occupational exposure to 1,2,3-Trichloropropane. This value is intended to minimize the potential for eye and upper respiratory tract irritation reported in workers, and liver and kidney toxicity, reported in rats. Equivocal, data have reporting reported possible liver, lung and kidney injury among rodents exposed to 1,2,3-Trichloropropane at concentrations as low as 0.007 ppm
19	Trimelitic anhydry [552-30-7]	(1991-1992) TWA-0.005 ppm (1993-2007) C0.04 mg/m^3 (2008-2016) TWA-0.0005 mg/m^3, STEL-0.002 mg/m^3	98.72	A TLV-TWA of 0.0005 mg/m^3 (0.5 μg/m^3) and a TLV-STEL of 0.002 mg/m^3 (2 μg/m^3), inhalable fraction and vapor, are recommended for TMAN. Because the estimated saturated vapor concentration may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate may occur during sampling, both the particulate mass and vapor phase concentrations should be considered and summed to determine total airborne concentration
20	Vinyl cyclohexene dioxide [106-87-6]	(1991-1995) TWA-10 ppm (1996-2016) TWA-0.1 ppm	99	A TLV-TWA of 0.1 ppm (0.57 mg/m^3) is recommended for occupational exposure to vinyl cyclohexene dioxide (VCD), in part by analogy with the TLV for 4-vinyl cyclohexene. This value is intended to minimize the potential for adverse

3) 80%-90% 하향 조정된 화학물질

1991년 이후 2016년까지 TLV의 감소치가 80%-90% 정도 하향조정된 화학물질은 19종이다. 하향 조정된 연도와 하향 조정된 주요 이유는 〈표 3〉과 같다.

Arsine은 1991년도에 TWA가 0.05 ppm이었지만 2007년도에 0.005 ppm으로 낮아져 약 90% 감소되었다. Arsine은 0.005 ppm이하가 되어야 호흡기계 기관지에 만성적인 변화가능성을 최소할 수 있고 만성 노출로 인한 용혈을 방지할 수 있다고 보았기 때문이다.

4) 80% 미만 하향 조정된 화학물질 노출기준

1991년 이후 2016년까지 TLV의 감소치가 노출기준이 80%미만 하향 조정된 화학물질이 다음 〈표 4〉, 〈표 5〉, 〈표 6〉, 〈표 7〉, 〈표 8〉, 〈표 9〉 및 〈표 10〉과 같다.

〈표 3〉 1991년이후 2016년까지 TLV값이 80%-90% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
1	Ammonium perfluorooctanoate [3825-26-1]	(1991-1993) TWA-0.1 mg/m^3 (1994-2016) TWA-0.01 mg/m^3	90	TWA of 0.01 ppm is based on the data from the human studies and the extended half-life in the blood system. Organic fluoride concentrations were found in the blood of workers exposed to Ammonium perfluorooctanoate in an industrial environment. These levels were higher in industrial workers than individuals who had no industrial exposure
2	Arsine [7784-42-1]	(1991-2006) TWA-0.05 ppm (2007-2016) TWA-0.005 ppm	90	Since arsine can enter the systemic circulation, probably partially as the trioxide, exposure to arsine can represent a systemic exposure to organic arsenic. Thus, although its short pulmonary retention time compared to insoluble arsenic compounds reduces its pulmonary carcinogenicity, its metabolites may present a systemic arsenic risk to other organ systems. The peripheral nervous system, vascular system, and the kidneys and liver all have been affected in worker chronically exposed to low levels of inorganic arsenic. ACGIH believes a TWA of 0.005 ppm will keep urinary values below those found to be associated with chronic organ system changes due to systemic arsenic absorption. ACGIH also believes that TWA will protect most chronically exposed worker from hemolysis
3	Benomyl[17804-35-2]	(1991-2007) TWA-0.84 ppm (2008-2016) TWA-1 mg/m^3	90	a TWA of 1 mg/m^3 is recommended for benomyl o protect against potential upper respiratory tract, genotoxic and reproductive toxicity o protect against potential upper respiratory tract, genotoxic and reproductive toxicity. the most significant animal studies included a 60-days inhalation study at doses ranging from 1 to 200 mg/m^3 with reported no-observed-adverse-effect-levels (NOELs) of 10 mg/m^3 in males and 50 mg/m^3 in females. adverse effects observed was degeneration of olfactory epithelium and decreased gains of body weight (A 60-day inhalation toxicity study with benomyl in rat-1989). The rat-feeding study showed decreases in testicular weights with a lower fertility index at the dose level of 1 ppm, 6 ppm (1.9 mg/m^3) and 203 ppm. benomyl was genotoxic in the variety of studies at various concentrations of Benomyl. In Human

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
				Benomyl causes eye irritation and contact dermatitis
4	n-Butyl Glycidyl ether (BGE) [2426-08-6]	(1991-2004) TWA-25 ppm (2005-2016) TWA-3 ppm	88	TLV-TWA of 3 ppm is recommended for occupational exposure to BGE to minimize the risk of male reproductive effect (testicular atrophy). This is based on no-observed-adverse-effect-level (NOAEL) of 38 ppm in male rats. The adverse impact of BGE on male germ cells in the dominant lethal test provides corroborating evidence that BGE is a male reproductive toxicant. In addition, there is evidence both in vitro and vivo that BGE is mutagen
5	p-tert-Butyltoluene [98-51-1]	(1991-1992) TWA-10 ppm, STEL-20 ppm (1993-2016) TWA-1 ppm	90	TLV-TWA of 1 ppm is recommended for occupational exposure to p-TBT. This value is intended to minimize the potential for ocular irritation and provides a margin of protection for nausea and cardiovascular and hematologic disturbance
6	Carbaryl [63-25-2]	(1991-2007) TWA-5 mg/m^3 (2008-2016) TWA-0.5 mg/m^3	90	The recommended 0.5 mg/m^3 TLV-TWA should be sufficiently low to protect against the cholinesterase effects of carbaryl in man and should be low enough to prevent the effects produced at higher dosages in animals
7	Carbon disulfide [75-15-0]	(1991-2005) TWA-10 ppm (2006-2016) TWA-1 ppm	90	A TLV-TWA of 1 ppm is recommended for carbon disulfide to protect workers from adverse effects on the nervous system and all other organ systems. In assessing an occupational exposure limit for carbon disulfide, a large body of literature was reviewed with particular attention to central nervous system (CNS) effects in workers. Quantitatively relating these effects to workplace exposures is not always feasible; therefore, author estimations were relied upon for exposure assessment. Some study provides the most convincing evidence of reduced motor conduction velocities attributable to occupational carbon disulfide exposure through clearly defined exposures and appropriate study design. Those studies appear to be best suited for quantitatively and qualitatively assessing of potential effects in the workplace

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
8	p-Dichlorobenzene [106-46-7]	(1991-1992) TWA-75 ppm, STEL-110 ppm (1993-2016) TWA-10 ppm	86.7%	A TLV-TWA of 10 ppm for p-DCB is recommended to protect against eye irritation reported in humans as low as 17 ppm and renal toxicity observed in rats at 150 mg/m^3 (25 ppm)
9	Dinitrotoluene [25321-14-6]	(1991-1991) TWA-1.5 mg/m^3 (1992-1996) TWA-0.15 mg/m^3 (1997-2016) TWA-0.2 mg/m^3	86.7%	A TLV-TWA of 0.2 mg/m^3 (0.03 ppm) is recommended for occupational exposure to dinitrotoluene (DNT). This value is intended to minimize the potential for heart disease and possible reproductive effects. It also should provide a wide margin of protection against methemoglobinemia.
10	Ethion₩ [563-12-2]	(1991-2002) TWA-0.4 mg/m^3 (2003-2016) TWA-0.05 mg/m^3	87.5%	A TLV-TWA of 0.05 mg/m^3 (inhalable aerosol and vapor) is recommended for occupational exposure to ethion. This exposure limit is intended to prevent the occurrence of cholinergic symptoms and other adverse biologic effects in workers. It is derived from a no-observed-adverse-effect level (NOAEL) obtained in humans and in animals and corresponds to a dose that is not expected to result in any reductions in Red Blood Cell (RBC) acetylcholinesterase activity in a group of workers
11	Ethyl chloride [75-00-3]	(1991-1994) TWA-1000 ppm (1995-2016) TWA-100 ppm	90	A TLV-TWA of 100 ppm (264 mg/m^3) is recommended. ACGIH considers that this concentration will minimize the potential risk for the effects cited above, although it is not possible to evaluate the quantitative aspects of the cancer response in female mice
12	Ethyleneimine [151-56-4]	(1991-2008) TWA-0.5 ppm (2009-2016) TWA-0.05 ppm, STEL-0.1 ppm	90	Based on the extreme respiratory difficulty experienced by rats and guinea pigs at concentrations above 10 ppm ethyleneimine, and bronchitis experienced by rats inhaling 5 ppm for 1.5 months, a TLV- TWA of 0.05 ppm is recommended
13	Heptachlor [76-44-8] and	(1991-1993) TWA-0.5 mg/m^3 (1994-2016)	90	A TLV-TWA of 0.05 mg/m^3 is recommended for occupational exposure to heptachlor and heptachlor epoxide to minimize the potential for liver damage,

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
	Heptachlor epoxide [1024-57-3]	TWA-0.05 mg/m^3		reported in animal studies. This value is also intended to minimize the potential for blood dyscrasias and possible cancer reported only in experimental animals
14	Hydrazine [302-01-2]	(1991-1994) TWA-0.1 ppm (1995-2016) TWA-0.01 ppm	90	A TLV-TWA of 0.01 ppm (0.013 mg/m^3) is recommended for occupational exposure to hydrazine, in part, by analogy to the TLV for methyl hydrazine. This value is intended to minimize the potential for nasal tumors, observed in rats exposed at 0.05 ppm, and adverse effects on the liver. Chemical burns and corrosion may result from skin exposure
15	Hydrogen flouride [7664-39-3] as F	(1991-2004) TWA-3 ppm (2005-2016) TWA-0.5 ppm, C2 ppm	83.3	A TLV-TWA of 0.5 ppm, measured as fluoride (F), is recommended for occupational exposure to the primary irritant hydrogen fluoride. This value is intended to minimize the potential for adverse effects in the respiratory tract, dermal or skeletal fluorosis, and irritation of the eyes and skin. Similar to hydro- gen chloride and hydrogen bromide, there is concern regarding the corrosive nature of hydrogen fluoride vapors, and therefore, a ceiling of 2 ppm is also recommended
16	Hydrogen Sulfide [7783-06-4]	(1991-2009) TWA-10 ppm, STEL-15 ppm (2010-2016) TWA-1 ppm, STEL-5 ppm	90	A TLV-TWA of 1 ppm (1.4 mg/m^3) and a TLV-STEL of 5 ppm (7 mg/m^3) are recommended for occupational exposure to hydrogen sulfide. These values are derived from animal and human data that showed similar qualitative and quantitative responses following single and repeated exposures
17	Iodine [7553-56-2]	(1991-2007) TWA-0.1 ppm (2008-2016) TWA-0.01 ppm, STEL-0.1 ppm	90	The primary health effect associated with exposure to excess dietary iodine is hypothyroidism. The Food and Nutrition Board of the Institute of Medicine (Institute of Medicine, 2000) has set an upper limit for iodine intake of 1.1 mg/day, based on decreased thyroid function above this level. The recommended daily intake of iodine is 150g/day, leaving about 1 mg/day as a margin of safety. Based on an estimated volume of 10 m^3 daily inhalation volume in adults, and acknowledging that inhaled and orally administered iodine undergoes almost complete systemic absorption, a TLV-TWA of 0.01 ppm (0.1 mg/m^3) is

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
				recommended for Iodine
18	Malathion [121-75-5]	(1991-2002) TWA-10 mg/m^3 (2003-2016) TWA-1 mg/m^3	90	A TLV-TWA of 1 mg/m^3 (inhalable aerosol and vapor) is recommended for occupational exposure to malathion. This exposure limit is intended to prevent the occurrence of cholinergic symptoms and other adverse biologic effects in workers. It is derived from a no-observed-adverse-effect level (NOAEL) obtained in humans and in animals and corresponds to a dose that is not expected to result in any reductions in RBC acetylcholinesterase activity in a group of workers. This approach is consistent with the use of the Biological Exposure Index, which is used to ensure that significant Red Blood Cell (RBC) acetylcholinesterase inhibition does not occur in a single user
19	Methyl 2-cyanoacrylate [137-05-3]	(1991-1997) TWA-2 ppm, STEL-4 ppm (1998-2016) TWA-0.2 ppm	90	A TLV-TWA of 0.2 ppm (1.0 mg/m^3) is recommended for occupational exposure to methyl 2-cyanoacrylate (MCA), a principal ingredient in the high-bond-strength, fast-acting household "superglues." This value is intended to minimize the potential for irritation of the eyes and the nasal and pharyngeal mucosae, and for suspected dermal sensitization
20	Methyl demeton [8022-00-2] skin	(1991-2006) TWA-0.5 mg/m^3 (2007-2016) TWA-0.05 mg/m^3	90	A TLV-TWA of 0.05 mg/m^3 (inhalable fraction and vapor) is recommended for occupational exposure to the organophosphate insecticide methyl demeton. This value is established by analogy to the more acutely toxic compound demeton. The TLV for demeton is based on its ability to inhibit red blood cell cholinesterase. Doses of 0.09 mg/kg to humans showed no effects, as did repeat oral doses of 0.05 mg/kg in rats and 0.025 mg/kg in dogs. These oral doses are equivalent to an exposure of approximately 0.2 mg/m^3 inhaled. Based on this potency, a TLV-TWA of 0.05 mg/m^3 should be sufficient to protect against all unwanted effects, including cholinesterase inhibition
21	Methyl isopropyl ketone [563-80-4]	(1991-2010) TWA-200 ppm (2011-2016)	90	A TLV-TWA of 20 ppm (70 mg/m^3) is recommended for occupational exposure to methyl iso-propyl ketone (MIPK) in order to protect against developmental toxicity because of the severity of the outcome. This is based on

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
		TWA-20 ppm, STEL-20 ppm		a no-observed-adverse-effect level (NOAEL) of 284 ppm for maternal, fetal and neonatal effects in Sprague-Dawley rats
22	Phenyl glycidyl ether (PGE) [122-60-1]	(1991-1993) TWA-1 ppm (1994-2016) TWA-0.1 ppm	90	A TLV-TWA of 0.1 ppm (0.6 mg/m^3) is recommended for occupational exposure to phenyl glycidyl ether (PGE). Testicular toxicity, nasal cancer, and sensitization have been demonstrated in animal studies, and the TLV-TWA will reduce the risk of these possible effects
23	Portland cement [65997-15-1]	(1991-2009) TWA-10 mg/m^3 (2010-2016) TWA-1 mg/m^3	90	A TLV-TWA of 1 mg/m^3 respirable particulate matter is recommended to prevent respiratory symptoms, losses in lung function, and asthma. This level is less than that associated with an increase in asthma prevalence rate, and is below the levels associated with changes in lung function and increased respiratory symptoms. Confining exposures to a TLV-TWA of 1 mg/m^3 respirable particulate matter will likely protect the substantial majority of exposed individuals from asthma, respiratory symptoms, and lung function effects
24	Propylene dichloride [78-87-5]	(1991-2005) TWA-75 ppm, STEL-110 ppm (2006-2016) TWA-10 ppm	86.7	A TLV-TWA of 10 ppm (47 mg/m^3) is recommended for occupational exposure to propylene dichloride. The 10-ppm TLV-TWA is recommended on the basis of body weight and nasal pathology observed in rats following 13 weeks of inhalation exposure at 50 ppm and 150 ppm, but not 15 ppm. Additional studies in mice and rabbits indicated rats were more sensitive than these other species, and the critical 13-week rat study was exceptional in demonstrating effects below 150 ppm. A TLV-TWA of 10 ppm should be sufficient to protect against the potential for damage to the respiratory tract and other adverse effects, including the liver, a target in selective, high-dose oral studies in rodents
25	Propyleneimine [75-55-8] skin	(1991-2008) TWA-2 ppm (2009-2016) TWA-0.2 ppm, STEL-0.4 ppm	90	A TLV-TWA of 0.2 ppm (0.5 mg/m^3) with a STEL of 0.4 ppm (1 mg/m^3) should be sufficient to protect against the unwanted effects of PI. Based on the low dermal rabbit LD50, a skin notation is recommended

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
26	Propylene oxide [75-56-9]	(1991-2000) TWA-20 ppm (2001-2016) TWA-2 ppm	90	A TLV-TWA of 2 ppm (0.8 mg/m^3) is recommended for occupational exposure to propylene oxide. This value is intended to minimize the potential for skin sensitization; irritation of the eyes, mucous membranes, and skin; and increased cell proliferation, thus reducing the cancer risk.
27	Sulprofos [35400-43-2]	(1991-2008) TWA-1 mg/m^3 (2009-2016) TWA-0.1 mg/m^3	90	A TLV-TWA of 2 ppm ((4.8 mg/m^3) is recommended for occupational exposure to propylene oxide. This value is intended to minimize the potential for skin sensitization; irritation of the eyes, mucous membranes, and skin; and increased cell proliferation, thus reducing the cancer risk.
28	Temephos [3383-96-8]	(1991-2004) TWA-10 mg/m^3 (2005-2016) TWA-1 mg/m^3	90	The recommended TLV-TWA of 1 mg/m^3 should be sufficient to protect against cholinergic effects and any other untoward biologic effects. Because the estimated saturated vapor concentration may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate may occur during sampling; both the particulate mass and vapor phase concentrations should be considered and summed to determine total airborne concentration
29	1,1,2,2-Tetrachloro-1,2-diflouroethane [76-12-0]	(1991-2007) TWA-500 ppm (2008-2016) TWA-50 ppm	90	A TLV-TWA of 50 ppm is recommended for 1,1,2,2-Tetrachloro-1, 2-diflouroethane (CFC-112), based on its potential hepatic and renal effects. In guinea pigs exposed to CFC-112 for seven hours a day for five days a week over six months, the lowest exposure concentration that produced an effect was 500 ppm. At this concentration, liver changes were seen, including necrosis
30	4,4'-Thiobis(6-tert-butyl-m-cresol) [96-69-5]	(1991-2010) TWA-10 mg/m^3 (2011-2016) TWA-1 mg/m^3	90	A TLV-TWA of 1 mg/m^3, measured as inhalable particulate matter, is recommended for occupational exposure to 4,4'-thiobis(6-tert-butyl-m-cresol) (TBBC). For a 70 kg worker breathing 10 m^3 of air during an eight-hour work day, this level of exposure
31	1,12,2-Tetrabromoet	(1991-2005)	90	A TLV-TWA of 0.1 ppm, inhalable fraction, and vapor, is recommended for

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요원인
	hane [79-27-6]	TWA-1 ppm (2006-2016) TWA-0.1 ppm		tetrabromoethane. Because the estimated saturated vapor concentration may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate may occur during sampling, both the particulate mass and vapor phase concentrations should be considered and summed to determine total airborne concentration. The TLV is based on subchronic inhalation studies of multiple animal species
32	Triethylamine [121-44-8]	(1991-1993) TWA-10 ppm, STEL-15 ppm (1994-2016) TWA-1 ppm, STEL-5 ppm	90	A TLV-TWA of 1 ppm (4.1 mg/m^3) and a TLV-STEL of 3 ppm (12.4 mg/m^3) are recommended for occupational exposure to triethylamine (TEA). The TLV-TWA is intended to minimize the potential for corneal change causing visual disturbances such as hazing, blurring, and halo vision reported among workers at 3 to 4 ppm but not at 1 to 1.25 ppm. The TLV-STEL is recommended to minimize transient visual disturbances observed at higher exposure concentrations of TEA. These values also should minimize the potential for dermal, upper respiratory tract, and ocular irritation
33	Vinyl bromide [593-60-2]	(1991-1998) TWA-5 ppm, STEL-22 ppm (1999-2016) TWA-0.5 ppm	90	A TLV-TWA of 0.5 ppm (2.2 mg/m^3) is recommended for occupational exposure to vinyl bromide, largely by analogy to the TLV-TWA for vinyl chloride. This value is intended to minimize the potential for liver cancer, observed in rodents exposed at 10 ppm and suspected by analogy to vinyl chloride
34	Warfarin [81-81-2]	(1991-2015) TWA-0.1 mg/m^3 (2016-2016) TWA-0.01 mg/m^3	90	-

〈표 4〉 1991년이후 2016년까지 TLV값이 20%이하 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	2-Butoxyethanol (EGBE) [111-76-2]	(1991-1998) TWA-25 ppm (1999-2016) TWA-20 ppm	20	Based on direct human experience, a TLV-TWA of 20 ppm is recommended to minimize the potential irritant effects from occupational exposure to 2-butoxyethanol
2	Carbon black [1333-86-4]	(1991-2010) TWA-3.5 mg/m³ (2011-2016) TWA-3 mg/m³	14.3	A TLV-TWA of 3 mg/m³, measured as inhalable particulate matter, is recommended for occupational exposure to carbon black (CB). Symptoms of bronchitis are the human health effect most sensitive to exposure to CB; therefore, the recommended TLV-TWA is intended to prevent CB-related bronchitis
3	Cyclohexanone [108-94-1]	(1991-2001) TWA-25 ppm (2002-2016) TWA-20 ppm, STEL-50 ppm	20	A TLV-TWA of 20 ppm and a TLV-STEL of 50 ppm are recommended for cyclohexanone to minimize eye, nose, and throat irritation. It was reported that exposure at 50 ppm was irritating to the throat; exposure at 75 ppm for 3 to 5 minutes resulted in pronounced irritation of the eyes, nose, and throat and was judged intolerable for an 8-hour day. In a study where volunteers were exposed to cyclohexanone for 7 minutes, nasal irritation was reported at 70 ppm and eye and throat irritation was reported at 90 ppm. An inhalation exposure of 756 ppm produced a 50% decrease in the mouse respiratory depression (RD) assay. The TLVs have been found to be highly correlated with 0.03xRD50

4	2,2-Dichloropropionic acid [75-99-0]	(1991-1999) TWA-1 ppm (2000-2016) TWA-5 mg/m³	13.8	In a 2-year feeding study in rats, 50 mg/kg/day produced only slight increases in kidney weights; the no-observed-effect level was 15 mg/kg/day of the sodium salt. Assuming 100% absorption and applying an uncertainty factor, it is believed that a 70-kg human breathing 10 m³ per work day could be exposed to approximately 10 mg/m³ without effects. This is consistent with the TLV-TWA of 1 ppm (5.8 mg/m³) for 2,2-dichloropropionic acid (dalapon), which has been recommended since 1978 to minimize the potential for irritation of the eyes and respiratory passages. No additional data justifying a different TLV-TWA have been found in the literature
5	1,4-Dioxane [123-91-1]	(1991-1998) TWA-25 ppm (1999-2016) TWA-20 ppm	20	ACGIH believes that the TLV should be derived from the data on hepatotoxic and nephrotoxic effects which have occurred in workers and have been shown to result in animals from exposures one-tenth those required to produce a significant carcinogenic response. The revision in the TLV-TWA from 25 ppm to 20 ppm was instituted for the purpose of facilitating harmonization with other international occupational health exposure standards. Therefore, a TLV-TWA of 20 ppm for dioxane is recommended

〈표 5〉 1991년이후 2016년까지 TLV값이 20%-30% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Boron tribromide [10294-33-4]	(1991-2015) C1 ppm 2016-C0.7 ppm	30	-
2	Boron triflouride [7637-07-2]	(1991-2015) C1 ppm 2016:TWA-0.1 ppm,C0.7 ppm	30	-
3	Ethylidene norbornene [16219-75-3]	(1991-2013) TWA-5 ppm (2014-2016) TWA-2 ppm, STEL-4 ppm	21.3	There was a study stating that human volunteers exposed to continuous (up to 22 hours/day) aerosolized ethylene glycol experienced irritation of the upper respiratory tract at 140 mg/m^3 (57 ppm); exposure at 188 mg/m^3 (75 ppm) was irritating and could only be tolerated for 15 minutes; exposure at 244 mg/m^3 (98 ppm) could not be tolerated due to respiratory irritation after a minute or two; exposure at 308 mg/m^3 (123 ppm) was intolerable, even for brief periods. Based on urine and blood sampling, absorption of ethylene glycol from aerosol exposure was poor. Accordingly, the above-cited controlled human data are consistent with a TLV-Ceiling of 100 mg/m^3 for aerosolized ethylene glycol to minimize the potential for respiratory and ocular irritation
4	Methyl propyl ketone [107-87-9]	(1991-2006) TWA-200 ppm, STEL-250 ppm (2007-2016) TWA-150 ppm	25	A TLV-STEL of 150 ppm is recommended to protect against the short-term irritant effect of bronchoconstriction found in the only subject tested at 200 ppm and in two of four subjects tested at 400 ppm. This level will also protect against ocular irritation reported at 400 ppm and against decreases in respiratory rate and tidal volume
5	Vinyl acetate [108-05-4]	(1991-1992) TWA-10 ppm, STEL-20 ppm (1993-2016) STEL-15 ppm	25	Vinyl acetate vapors were irritating to human eyes at 21.6 ppm but not at 10 ppm. A TLV-TWA of 10 ppm is recommended to minimize the potential risks of systemic effects of vinyl acetate, including cancer in exposed workers. A TLV-STEL of 15 ppm is recommended to minimize the potential for eye irritation

〈표 6〉 1991년이후 2016년까지 TLV값이 30%-40% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Bromine [7726-95-6]	(1991-1993) TWA-0.1 ppm, STEL-0.3 ppm (1994-2016) STEL-0.2 ppm	33.3	Because of an incident involving the accidental release of a cloud of bromine gas in the city of Geneva that caused upper respiratory irritation and complaints of coughs and headaches at reported emission levels in the range of 0.2 to 0.5 ppm, a TLV-STEL of 0.2 ppm is recommended to reduce the risk of respiratory irritation and injury to the lungs. The present TLV-TWA of 0.1 ppm is reaffirmed
2	Hydrogen bromide [10035-10-6]	(1991-2003) C3 ppm (2004-2016) C2 ppm	33.3	The animal studies found that hydrogen bromide was quantitatively similar to hydrogen chloride, whose TLV is a ceiling limit of 2 ppm. Therefore, a TLV- Ceiling of 2 ppm (reduced from 3 ppm) is recommended for hydrogen bromide, based upon irritation effects. A report on the responses of six human subjects who inhaled hydrogen bromide at concentrations ranging from 2 to 6 ppm formed part of the basis of the previous TLV recommendation, but this report is not available from the agency that supported the study and was, therefore, not considered in the present recommendation. Maintaining workplace air concentrations below the TLV-Ceiling should minimize even transient irritation and complaints. There is no implication that brief, small excursions above the 2-ppm ceiling are life-threatening or have the potential for creating permanent harm
3	1-Methoxy-2-propanol [107-98-2]	(1991-2012) TWA-50 ppm, STEL-150 ppm (2013-2016) TWA-50 ppm, STEL-100 ppm	33.3	A TLV-TWA of 50 ppm (184 mg/m^3) and a TLV-STEL of 100 ppm (369 mg/m^3) are recommended for occupational exposure to 1-methoxy-2-propanol (PGME). This is based on a human volunteer study where, at 100 ppm the odor was initially reported to be intolerably strong by 4 of 6 subjects but after 25 minutes the subjects habituated. However, eye irritation was reported by two subjects after two hours of exposure. In a second experimental study where 12 people were exposed to 150 ppm, the results indicated no significant treatment-related effects for any objective measure but very slight effects on the eyes were reported by the subjects. Transcription of human inflammatory cytokines was observed in vitro at 100 ppm

〈표 7〉 1991년이후 2016년까지 TLV값이 40%-50% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Acetonitrile [75-05-8]	(1991-2001) TWA-40 ppm, STEL-60 ppm (2002-2016) TWA-20 ppm	50	A TLV-TWA of 20 ppm (33 mg/m^3) is recommended for occupational exposure to acetonitrile. This value is intended to minimize the potential for adverse lung involvement. The TLV-TWA is based on the limited human data in which 40 ppm produced no effects in two of three volunteers; the third sensed chemical presence in the lung. No-effect levels of 200 ppm in repeated animal exposure studies also support this level as being appropriate and protective
2	Barium Sulfate [7727-43-7]	(1991-2013) TWA-10 mg/m^3 (2014-2016) TWA-5 mg/m^3	50	-
3	Carbon monoxide [630-08-0]	(1991-1991) TWA-50 ppm, STEL-400 ppm (1992-2016) TWA-25 ppm	50	A TLV-TWA of 25 ppm is recommended for occupational exposure to carbon monoxide to maintain blood COHb levels below 3.5%, to minimize the potential for adverse neurobehavioral changes, and to maintain cardiovascular work and exercise capacities. This recommendation also provides a margin of safety for individuals particularly susceptible to the adverse effects of carbon monoxide exposure, including pregnant workers and those with chronic heart and respiratory disease
4	Chlorpyrifos [2921-88-2]	(1991-2002) TWA-0.2 mg/m^3 (2003-2016) TWA-0.1 mg/m^3	50	The first biologic response to chlorpyrifos involves decreased activity of cholinesterase enzymes. In repeated exposure studies in monkeys, dogs, and rats, 0.1 mg/kg/day produced no changes in red blood cell cholinesterase activity. This dose, when converted to an inhalation exposure, is equivalent to inhaling 0.7 mg/m^3 chlorpyrifos per work shift. Observation of workers showed no effects when inhaling 0.4 mg/m^3. An inhalation study in rats indicated that exposure of approximately 0.3 mg/m^3 for 6 hours/day does not affect red blood cell (RBC)

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				cholinesterase activity. Thus, a TLV－TWA of 0.1 mg/m^3 (inhalable aerosol and vapor) is recommended for occupational exposure to chlorpyrifos
5	Cotton dust, raw, untreated	(1991-2009) TWA-0.2 mg/m^3 (2010-2016) TWA-0.1 mg/m^3	50	A TLV－TWA of 0.1 mg/m^3 for unwashed (raw) cotton dust, thoracic particulate matter, is recommended based on studies of byssinosis and chronic lung function changes in cotton textile workers. and at 0.197 mg/m^3, there was a synergistic effect for cotton dust and cigarette smoke on annual decline in lung function in yarn manufacturing workers
6	Dibutyl phosphate [[107-66-4]	(1991-2008) TWA-1 ppm, STEL-2 ppm (2009-2016) TWA-5 mg/m^3	41.8	The recommended TLV is based on animal data as there is no peer-reviewed literature citing human effects from exposure to DBP. The limited data on DBP was used in conjunction with data on tributyl phosphate, a closely related chemical that is metabolized in part to DBP, to derive the TLV. Systemically, the adverse effect of concern is irritation of the bladder epithelium resulting in hyperplasia and necrosis. The recommended TLV should be sufficient to protect against this potential adverse health effect
7	o-Dichlorobenzene [95-50-1] skin	(1991-1991) TWA-50 ppm (1992-2016) TWA-25 ppm, STEL-50 ppm	50	After reviewing data on the human eye and upper respiratory irritation that result from exposures extent of binding to cellular constituents and the at 100 ppm and considering the liver damage in rats ppm and a TLV－TWA of 25 ppm STEL of 50 ppm are recommended
8	1,1-Dichloroethane [75-34-3]	(1991-1991) TWA-200 ppm, STEL-250 ppm (1992-2016) TWA-100 ppm	50	The lowest NOEL that has been established in a 13-week inhalation study is 500 ppm. Based on the data from the animal studies with repeated inhalations, a TLV－TWA of 100 ppm is recommended. This value should minimize the potential risk for possible hepatic and renal injury and eye and upper respiratory irritation that may occur after acute and chronic exposure to 1,1-dichloroethane

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
9	Diethylamine [109-89-7]	(1991-1992) TWA-10 ppm, STEL-25 ppm (1993-2016) TWA-5 ppm, STEL-15 ppm	50	Acute diethylamine exposure produces severe irritation to the eyes and skin of laboratory animals and of humans. Irritation was seen in humans exposed at 12 and 25 ppm; however, no changes in nasal tissues were detected by rhinometry. Repeated inhalation exposure to diethylamine vapor also produced irritation of the upper respiratory tract of rodents. Although a no-observed-effect level (NOEL) was not determined for the rat, lung changes at 31 ppm were not accompanied by significant toxicity to other organ systems and no adverse effects were seen in mice inhaling 32 ppm for 105 weeks. A TLV-TWA of 5 ppm is recommended to minimize the potential risk of irritation produced by repeated, low-level exposures to diethylamine. A TLV-STEL of 15 ppm is recommended to prevent transient irritation that could be produced at higher concentrations
10	Dimethylamine [124-40-3]	(1991-1991) TWA-10 ppm (1992-2016) TWA-5 ppm, STEL-15 ppm	50	These values are intended to minimize the potential for dermal, ocular, respiratory, and gastrointestinal tract irritation evidenced in animals exposed by inhalation or oral administration of DMA. The recommended TLV-STEL should enhance the minimization of sensory effects. Based on the results of continuous 90-day inhalation exposure of several species of animals and by analogy with methylamine and ethylamine, a TLV-TWA of 10 ppm was previously adopted for DMA. However, in view of the results of the 2-year inhalation study where 10 ppm approximated a NOEL in rats, a TLV-TWA of 5 ppm, with a 15 ppm TLV-STEL, is recommended
11	Dioxathion [78-34-2]	(1991-2000) TWA-0.2 mg/m³ (2001-2016) TWA-0.1 mg/m³	50	A TLV-TWA of 0.1 mg/m^3, inhalable aerosol vapor, is recommended for dioxathion. The first response to dioxathion (organophosphates in general) involves decreased activity of cholinergic enzymes. In humans, oral doses of 0.075 mg/kg for 60 days produced no signs of cholinesterase inhibition, with 0.15 mg/kg inhibiting plasma, but not red blood cell cholinesterase. Assuming total absorption and an air exchange of 10 m^3

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				per 8-hour work shift, 0.15 mg/kg is equivalent to 1.0 mg/m^3 in a 70-kg individual. Repeated dose feeding studies in animals support this level of potency with the lowest-effect level reported (0.07 mg/kg in dogs) affecting plasma cholinesterase activity being equivalent to a daily inhalation exposure of 0.5 mg/m^3. Tests looking at other biological endpoints were consistent with cholinesterase changes being the first sign of adverse response to dioxathion
12	Disulfoton [298-04-4]	(1991-2001) TWA-0.1 mg/m^3 (2002-2016) TWA-0.05 mg/m^3	50	Disulfoton is extremely toxic following acute exposures with an oral LD50 in rats of 2 to 20 mg/kg, a dermal LD50 of 6 to 20 mg/kg, and a 4-hour LC50 in rats of from 15 to 60 mg/m^3. In two 21-day inhalation studies in rats, the lowest concentrations associated with significant red blood cell cholinesterase inhibition ranged from 0.1 to 1.4 mg/m^3. In repeat-dose feeding studies, cholinesterase activity of the red blood cell (RBC) and brain, as well as all other biologically important endpoints, were unaffected at 0.5 mg/kg/day in the mouse, 0.04 mg/kg/day in the rat, and 0.025 mg/kg/day in the dog. Using the lowest-no-effect level for anticholinergic activity in animals of 0.025 mg/kg/day and assuming complete absorption and an air exchange of 10 m^3 per 8-hour work shift, the equivalent inhalation exposure is 0.2 mg/m^3. A collective assessment of the available human and animal data indicates that a TLV-TWA of 0.05 mg/m^3, as an inhalable aerosol and vapor, should be sufficient to protect against cholinergic and other unwanted biological effects
13	Ethylamine [75-4-7]	(1991-1993) TWA-10 ppm (1994-2016) TWA-5 ppm, STEL-15 ppm	50	A TLV-TWA of 5 ppm is recommended to minimize the potential risk of irritation produced by repeated, low-level exposures to ethylamine. A TLV-STEL of 15 ppm is recommended to prevent transient irritation that could be produced at higher concentrations. Repeated inhalation exposures of 50 ppm ethylamine vapor by rabbits produced lung damage and corneal injury. Exposure at 100 ppm also produced kidney change. The

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				upper respiratory tract of the rabbits in this study was not evaluated, but it is likely that changes reflecting irritation were produced. No effects were seen in rats following inhalation of ethylamine for 24 weeks at 100 ppm. Acute exposure to ethylamine produced severe irritation to the eyes and skin of laboratory animals. There are no data reported on the irritation potential of ethylamine in humans. Although the animal toxicity data for other ethyl-amines are similar (diethylamine and triethylamine), the TLV-TWA for triethylamine is 1 ppm. No reports of this manifestation have been reported to date with ethylamine
14	Fenamiphos [22224-92-6]	(1991-2005) TWA-0.1 mg/m³ (2006-2016) TWA-0.05 mg/m³	50	A TLV-TWA of 0.05 mg/m³, inhalable fraction and vapor, is recommended for fenamiphos. The adverse effect of concern for fenamiphos (and for all organophosphates in general) is Red Blood Cell (RBC) acetylcholinesterase inhibition. There were no quantitative data linking exposure of humans to fenamiphos with RBC cholinesterase inhibition. Hence, the TLV is based on animal studies. Studies in dogs demonstrated significant effects on RBC cholinesterase at doses of 0.025 mg/kg and higher. This level would equate to 0.18 mg/m³, assuming a 10 m³ per day air exchange rate by a 70-kg person. Dogs appear to be more sensitive than rats, as cholinesterase effects have been observed in rats. A 3-week inhalation study in rats produced a no-observed-effect-level (NOEL) of 3.5 mg/m3. Thus, the TLV-TWA of 0.05 mg/m³, inhalable fraction and vapor, should be protective of cholinergic and other adverse effects
15	Ferbam [14484-64-1]	(1991-2008) TWA-10 mg/m³ (2009-2016) TWA-5 mg/m³	50	The TLV derives from repeated dose studies in animals. In a two-year oral study, the no-observed-effect-level (NOEL) in rats was 12.5 mg/kg with the next highest dose tested (125 mg/kg) producing mortality, body weight effects, and neurotoxicity. In the dog, the NOEL following oral administration for four weeks or one year was 5 mg/kg. The next highest level tested (25 mg/kg) produced mortality and central nervous system

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				(CNS) effects. The lower NOEL of 5 mg/kg, assuming complete absorption both orally and by inhalation, is equivalent to an inhaled dose of 35 mg/m^3. A TLV-TWA of 5 mg/m^3 inhalable particulate matter should be sufficient to protect against adverse effects
16	Hydroquinone [123-31-9]	(1991-2007) TWA-2 mg/m³ (2008-2016) TWA-1 mg/m³	50	Based on results from hydroquinone human industrial and consumer experience, a TLV-TWA of 1 mg/m^3 is recommended to reduce to a minimum the risk to workers of eye irritation and eye damage associated with occupational exposure to hydroquinone
17	Indene [95-13-16]	(1991-2007) TWA-10 ppm (2008-2016) TWA-5 ppm	50	A TLV-TWA of 5 ppm indene vapor is recommended to minimize the potential for adverse systemic responses from acute exposures that may include liver damage and death seen at 400 ppm in mice, and at 1,100 ppm in rats. Liver, kidney and spleen injuries were observed at 800 ppm in rats. The no- observed-effect-level (NOEL) for rats for acute effects was 400 ppm. A TLV-TWA of 5 ppm should also protect against effects such as dyspnea and irritation as seen in rats at 630 ppm
18	Methylamine [74-89-5]	(1991-1991) TWA-10 ppm (1992-2016) TWA-5 ppm, STEL-15 ppm	50	A TLV-TWA of 5 ppm (6.4 mg/m³) and a TLV-STEL of 15 ppm (19 mg/m³) are recommended for occupational exposure to methylamine. These values are derived from both human and animal information. They are intended to minimize the potential for irritation of the eyes, skin, and upper respiratory tract reported from inhalation studies with experimental animals and from industrial experience with methylamine. Acute exposure to methylamine produces severe irritation to the eyes and skin of laboratory animals and humans
19	4,4'-Methylene bis(2-chloroaniline) (MBOCA) [101-14-4]	(1991-1995) TWA-0.02 ppm (1996-2016) TWA-0.01 ppm	50	A TLV-TWA of 0.01 ppm (0.11 mg/m³) is recommended for occupational exposure to the aromatic amine 4,4'-methylene bis(2-chloroaniline) [MBOCA] to minimize the significant risks of cyanosis, methemoglobinemia, adverse effects in cluding cancer of the kidney, and bladder

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
20	Methyl formate [107-31-3]	(1991-2014) TWA-100 ppm, STEL-150 ppm (2015-2016) TWA-50 ppm, STEL-100 ppm	50	Methyl formate is expected to be an irritant of human eyes and the upper and lower respiratory tract at concentrations greater than 1500 ppm; after exposure at 1600 ppm, it was associated with caused narcosis. Methyl formate was more irritating than methyl or ethyl acetate. The narcotic and lethal effects of this series of esters were associated with their partition coefficients, and their toxicities apparently were the result of actions of the parent compound rather than to those of the corresponding alcohols. For these reasons, a TLV-TWA of 100 ppm for methyl formate is recommended, with a TLV-STEL of 150 ppm
21	Methyl methacrylate [80-62-6]	(1991-1999) TWA-100 ppm (2000-2016) TWA-50 ppm, STEL-100 ppm	50	Based on the rat inhalation subchronic lowest-observed-adverse-effect level (LOAEL) (116 ppm) the rat chronic NOAEL (25 ppm), the reports of impaired human olfactory function, and human pulmonary deficits after repeated exposures at concentrations greater than 50 ppm, a TLV-TWA of 50 ppm is recommended. At this time, a STEL of 100 ppm takes into account the rapid elimination kinetics of this material from the body and is intended to reduce complaints of objectionable ocular and upper respiratory tract irritation reported after exposures in excess of 100 ppm
22	Parathion [56-38-2]	(1991-2002) TWA-0.1 mg/m³ (2003-2016) TWA-0.05 mg/m³	50	A TLV-TWA of 0.05 mg/m^3 (inhalable aerosol and vapor) is recommended for occupational exposure to parathion. This exposure limit is intended to prevent the occurrence of cholinergic symptoms and other adverse biologic effects in workers. It is derived from a no-observed-adverse-effect level (NOAEL) obtained in humans and corresponds to a dose that is not expected to result in any reductions in Red Blood Cell (RBC) acetylcholinesterase activity in a group of workers. This approach is consistent with the use of the Biological Exposure Index
23	n-Propyl alcohol [71-23-8]	(1991-2003) TWA-200 ppm, STEL-250 ppm	50	n-Propyl alcohol is a sensory irritant that causes narcosis in animals at high concentrations. It appears to have many of the same biological effects as 2-propanol. Based upon acute animal studies that show

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		(2004-2006) STEL-400 ppm (2007-2016) TWA-100 ppm		n-Propyl alcohol to be more toxic than 2-propanol and upon RD50 studies described above, a TLV-TWA of 100 ppm is recommended. Given the extremely high percutaneous exposure required to elicit systemic toxicity, there is no skin notation for n-propanol
24	2-Propanol [67-63-0]	(1991-2002) TWA-400 ppm, STEL-500 ppm (2003-2016) TWA-200 ppm, STEL-400 ppm	50	The TLV is set on the basis of avoidance of ocular and upper respiratory tract irritation. Few human studies have been completed and sample sizes were relatively small; available human studies have suggested a lowest-observed-adverse-effect level (LOAEL) of 400 ppm resulting in mild irritation of the eyes, nose, and throat or subtle changes in postural sway, although other authors have concluded that the irritation threshold is above 400 ppm. The lowest chronic NOAEL in rodents is 500 ppm. The lowest applicable subchronic LOAEL in rodents is 500 ppm, based on obvious upper respiratory tract irritation, with a NOAEL of 100 ppm. A TLV-TWA of 200 ppm and a STEL of 400 ppm are recommended for 2-propanol
25	Ronnel [299-84-3]	(1991-2005) TWA-10 mg/m³ (2006-2016) TWA-5 mg/m³	50	The adverse effect of concern for ronnel (and for all organophosphates in general) is inhibition of Red Blood Cell (RBC) acetylcholinesterase. Repeated oral exposure no effect levels for RBC cholinesterase inhibition in dogs and rats have been reported to be 3 and 5 mg/kg/day, respectively. These doses would be received by workers inhaling roughly 21 or 35 mg/m^3 the treatment of creeping eruption was associated with reversible signs of cholinergic toxicity in 5 of 21 subjects (roughly equivalent to inhaling 70 mg/m^3). No other adverse effects have been shown to occur at levels below those associated with cholinesterase inhibition. A TLV-TWA of 5 mg/m^3 should be sufficient to protect workers from cholinergic, as well as any other biologic effects associated with ronnel
26	Silica- crystaline cristobalite [14464-46-1]	(1991-2005) TWA-0.05 mg/m³	50	Based on the human studies, the recommended TLV-TWA for cristobalite is 0.025 mg/m^3 of respirable silica, the same as for α-quartz. Although not reflected in the epidemiological data, the quartz-cristobalite

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		(2006-2016) TWA-0.025 mg/m³		relationship observed in animals gives warning that cristobalite may be more inflammatory and fibrogenic than α-quartz
27	Sulfotepp (TEDP) [3689-24-5]	(1991-2004) TWA-0.2 mg/m³ (2005-2016) TWA-0.1 mg/m³	50	The recommended TLV was derived from animal experiments. Sulfotepp is highly toxic on an acute basis. TLV-TWA of 0.1 mg/m should be sufficient to protect against cholinergic and other adverse effects. This reflects current understanding regarding the relationship between RBC cholinesterase inhibition and adverse effects for this compound
28	Tetrachloroethylene [127-18-4]	(1991-1992) TWA-50 ppm, STEL-200 ppm (1993-2016) TWA-25 ppm, STEL-100 ppm	50	A TLV-TWA of 25 ppm is recommended for tetrachloroethylene to provide a margin of safety in minimizing potential discomfort and subjective complaints (e.g., headache, dizziness, sleepiness, incoordination) that may occur from prolonged exposure at 100 to 200 ppm. A TLV-STEL of 100 ppm is further recommended to minimize the risk of anesthetic-like effects. These recommended values provide a wide margin of safety in preventing possible liver injury
29	Trichloroacetic acid [76-03-9]	(1991-2013) TWA-1 ppm (2014-2016) TWA-0.5 ppm	50	-
30	Trimethylamine [75-50-3]	(1991-1991) TWA-10 ppm, STEL-15 ppm (1992-2016) TWA-5 ppm, STEL-15 ppm	50	A TLV-TWA of 5 ppm is recommended based on results of inhalation tests in animals. The TLV-STEL of 15 ppm was based on analogy to methylamine, where irritation was documented in humans exposed at 20 ppm

〈표 8〉 1991년이후 2016년까지 TLV값이 50%-60% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Atrazine[1912-24-9](andrelatedsymmetrical triazines)	(1991-2013) TWA-5 mg/m³ (2014-2016) TWA-2 mg/m³	60	-
2	Cobalt[7440-48-4] as Co metal dust and fume	(1991-1993) TWA-0.05 mg/m³ (1994-2016) TWA-0.02 mg/m³	60	Transient myocardial changes have been reported at exposure concent rations below 0.06 mg/m³. Accordingly, a TLV-TWA of 0.02 mg/m³, as Co, is recommended to minimize the potential risk of developing asthma, pulmonary function changes, and myocardial effects. The recommended TLV applies to elemental cobalt and inorganic compounds, including cobalt exposure in the cemented tungsten carbide industry
3	Demeton [8065-48-3] Skin	(1991-2001) TWA-0.01 ppm (2002-2016) TWA-0.05 mg/m³	54.6	A TLV-TWA of 0.05 mg/m^3, inhalable aerosol and vapor, is recommended for demeton. The first response to demeton (organophosphates in general) involves decreased activity of cholinergic enzymes. In human volunteers, daily oral doses of up to 0.09 mg demeton/kg produced no cholinesterase inhibition, whereas 0.10 mg/kg showed the beginning of a response. It should be noted that at 0.06 mg/kg, one of five individuals did show a response after 24 days. Animal experiments support this potency with repeated exposure to rats and dogs producing no cholinesterase inhibition at 0.05 and 0.025 mg/kg, respectively. These oral doses were equivalent to approximately 0.2 mg/m^3, assuming complete absorption and an exchange of 10 m^3 air per 8-hour work shift

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
4	Dieldrin [60-57-1]	(1991-2009) TWA-0.25 mg/m³ (2010-2016) TWA-0.1 mg/m³	60	Dieldrin is toxic by ingestion, absorption through the skin, or by inhalation and absorption through the respiratory tract. A TLV-TWA of 0.1 mg/m³ is recommended for occupational exposure to dieldrin. This is based on a study that led to changes in rat liver following up to eight months of feeding at 2.5 ppm (equivalent to 0.2 mg/m³). Likewise, this level should prevent the reproductive effects noted in rats fed 2.5 ppm, and the central nervous system effects associated with human exposure. These include hyperirritability and muscular spasms, followed by convulsive seizures. Assuming 100% absorption in vivo and a respiratory volume of 10 m³ per work shift, this dose is equivalent to an airborne concentration of 1.4 mg/m³. Thus, a 0.1 mg/m³ TLV-TWA should minimize the possibility of effects from dieldrin
5	Ethyl amyl ketone [541-85-5]	(1991-2006) TWA-25 ppm (2007-2016) TWA-10 ppm	60	A TLV-TWA of 10 ppm (52.4 mg/m³) is recommended to minimize potential neurotoxic effects. This is based on the no-observed-adverse-effect level (NOAEL) of 82 mg/kg/day for neuropathy in a rat study. An equivalent airborne concentration to this NOAEL is 574 mg/m³ or 110 ppm for a 70-kg human who inhales 10 m³ in an 8-hour workday
6	Ethylene glycol [107-21-1]	(1991-2004) C50 ppm (2005-2016) C100 mg/m³	60	A TLV-TWA of 5 ppm (27 mg/m³) is recommended for occupational exposure to 2-ethoxyethyl acetate to minimize the potential for reproductive effects, primarily testicular atrophy observed in mice administered 2-ethoxyethyl acetate by gavage for 5 weeks. Although the rabbit dermal LD50 for 2- ethoxyethyl acetate is large, 10.3 g/kg body weight compared to 3.4 g/kg for the parent alcohol (2-ethoxyethanol)

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
7	Hydrogen chloride [7647-01-0]	(1991-2002) C5 ppm (2003-2016) TWA-C2 ppm	60	Based on the reports of respiratory irritation from short-term exposures to hydrogen chloride and a no-observed-adverse-effect level (NOAEL) of 1.8 ppm, a TLV-Ceiling of 2 ppm is recommended to minimize the acute irritation associated with exposure to hydrogen chloride vapor. Occupational exposure to hydrogen chloride occurs primarily via exposure to vapor. In environments in which aerosols of hydrogen chloride are encountered, the TLV should be converted to mg/m^3
8	Hydrogen cyanite [74-90-8]	(1991-1993) C10 ppm (1994-2016) TWA-C4.7 ppm	53	The previous TLV-Ceiling of 10 ppm for Hydrogen cyanite (HCN) was reduced to a TLV-Ceiling of 4.7 ppm (5 mg/m^3), as CN, to provide a greater margin of safety against acute poisoning and to minimize the risk to exposed workers of throat irritation, headache, and symptoms resulting from chronic exposure to cyanide such as thyroid enlargement. A TLV-Ceiling of 5 mg/m^3, as CN, is recommended for NaCN, KCN, and Ca(CN)2 to minimize the potential for irritation and injury to the respiratory tract as well as the acute and chronic effects of cyanide
9	Isopropyl acetate [108-21-4]	(1991-2002) TWA-250 ppm, STEL-310 ppm (2003-2016) TWA-100 ppm, STEL-200 ppm	60	A TLV-TWA of 100 ppm and a TLV-STEL of 200 ppm are recommended for occupational exposure to isopropyl acetate. The values are intended to minimize the potential for eye and upper respiratory system irritation and narcotic effects. These TLVs are based on the range of derivable TLV-TWAs (43-440 ppm) from the mouse RD50 and from the report of eye irritation among the majority of volunteers exposed at 200 ppm
10	Methyl isoamyl ketone [110-12-3]	(1991-2012) TWA-50 ppm	60	A TLV-TWA of 20 ppm (93 mg/m^3) is recommended to protect against nasal irritation, eye irritation, lethargy, and decreased response to noise

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				(NOAEL 200 ppm) identified in rats. In addition, it is expected to protect against behavioral effects in mice. Moreover, since methyl isoamyl ketone (MIAK) is structurally similar to methyl isobutyl ketone (MIBK), whose TLV-TWA is 20 ppm, it is expected that their toxicities would be similar. MIAK (RD50) 1222 ppm) is a respiratory irritant at a lower concentration than MIBK (RD50) 3195 ppm). The TLV-STEL for MIBK is 75 ppm based on human data. Because MIAK is more irritating than MIBK, a TLV-STEL of 50 ppm (233 mg/m^3) is recommended
11	Methyl isobutyl ketone [108-10-1]	(2013-2016) TWA-20 ppm, STEL-50 ppm (1991-2009) TWA-50 ppm, STEL-75 ppm (2010-2016) TWA-20 ppm, STEL-75 ppm	60	A TLV-TWA of 20 ppm (82 mg/m^3) is recommended to protect against human central nervous system (CNS) symptoms as reported on a 17-item questionnaire associated with 90 to 120 minutes exposure at 200 mg/m^3 (49 ppm). A TLV-STEL of 75 ppm (307 mg/m^3) is recommended to protect against irritation of the mucous membranes associated with short-term exposures. Both limits should protect against irritation, central nervous system (CNS), and gastrointestinal symptoms observed in occupational populations
12	Styrene, monomer [100-42-5]	(1991-1996) TWA-50 ppm, STEL-100 ppm (1997-2016) TWA-20 ppm, STEL-40 ppm	60	Based on the results of controlled human inhalation and occupational studies of the influence of styrene exposure on the function of the central and peripheral nervous systems and to minimize the potential of irritation, a TLV-TWA of 20 ppm and a TLV-STEL of 40 ppm are recommended

〈표 9〉 1991년이후 2016년까지 TLV값이 60%-70% 하향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Acetone [67-64-1]	(1991-1996) TWA-750 ppm, STEL-1000 ppm (1997-2014) TWA-500 ppm, STEL-750 ppm (2015-2016) TWA-250 ppm STEL-500 ppm	66.7	TWA of 250 ppm and STEL of 500 ppm is recommended for occupational exposure to minimize the potential for upper respiratory tract and eye irritation as well as centre nervous impairment. TLV has developed to protect both of workers who have developed sensory habituation due to repeated acetone exposure, and workers without habituation, occusionally exposed to acetone
2	Clopidol [2971-90-6]	(1991-2012) TWA-10 mg/m^3 (2013-2016) TWA-3 mg/m^3	70	A TLV-TWA of 3 mg/m^3, inhalable fraction and vapor, should be sufficient to protect against the potential harmful effects of clopidol. The toxicologic database for this chemical is limited but shows the chemical to be low in acute oral toxicity, its irritation properties remain undefined, and repeated oral doses of 5 mg/kg to dogs and 15 mg/kg to rats did not produce either chronic toxicity or an increase in tumors
3	Cyclohexane[110-82-7]	(1991-2001) TWA-300 ppm (2002-2016) TWA-100 ppm	66.7	Recent studies have demonstrated in both mice and rats that the subchronic toxicity of cyclohexane is low. Only mild, reversible liver-weight gain and increases in erythrocyte mass and plasma protein were seen at the high dose of 7000 ppm. Sedation was observed in both studies at 2000 ppm, a lowest-adverse-effect level. The no-adverse-effect level for sedation was 500 ppm; intermediate doses were not tested. An unpublished PBPK model estimated human sedation at a concentration of 3900 ppm (with no effect estimated at a concentration of 1200 ppm), based on comparisons of brain concentration-behavioral effects in the rat. A human inhalation study did not see effects on neurobehavioral testing at a concentration of 250 ppm, although a majority of subjects reported minor symptoms such as headache

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				and dry throat. Given the uncertainties and incompleteness of the above information, a TLV－TWA of 100 ppm is recommended for cyclohexane to minimize the potential for sedation or neurobehavioral effects and systemic toxicity
4	Cyclonite[121-82-4] skin	(1991-1996) TWA-1.5 mg/m³ (1997-2016) TWA-0.5 mg/m³	66.7	A TLV of 0.5 mg/m^3 is recommended to minimize the potential risk of subtle effects observed in the chronic bioassays with rats and mice. The toxic effects observed at low cyclonite exposure levels in chronic studies were histopathological and involved the liver and the hematopoietic and urogenital systems. The potential neurophysiological effects should also be minimized by a 0.5 mg/m^3 TWA. The uncertainty in extrapolation from laboratory animal test results to humans was reduced by the presence of well- designed chronic bioassays in rodents and a 90-day toxicity study with primates
5	Lead [7439-92-1] and inorganic compounds, as Pb	(1991-1994) TWA-0.15 mg/m³ (1995-2016) TWA-0.05 mg/m³	66.7	A TLV－TWA of 0.05 mg/m^3, measured as lead (Pb), is recommended for occupational exposure to elemental lead and its inorganic compounds based on the BEI® for lead. This value is intended to minimize the potential for adverse health effects that may include blood dyscrasias, reduced nerve conduction velocities, peripheral neuropathies, a possible kidney dysfunction, spermatogenesis, impaired intellectual development in children exposed to lead during gestation, and carcinogenicity (as reported from animal studies with soluble lead compounds)

〈표 10〉 1991년이후 2016년까지 TLV값이 70%-80% 하향조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
1	Aldrin [309-00-2]	(1991-2006) TWA-0.25 mg/m³ (2007-2016) TWA-0.05 mg/m³	80	A TLV-TWA of 0.05 mg/m³ (inhalable fraction and vapor) is recommended for occupational exposure to aldrin to minimize its potential for central nervous system (CNS), kidney, and liver effects. This value is based upon data obtained in rats and dogs and is supported by human data
2	Allyl alcohol [107-18-6]	(1991-1998) TWA-2 ppm, STEL-4 ppm (1999-2016) TWA-0.5 ppm	75	Base on the high, acute inhalation toxicity of allyl alchoho and the ralatively RD50, light of the subchronic inhalation no-observed-effect level of 2 ppm in annimal TWA of 0.5 ppm was recommended
3	Allyl glycidyl ether (AGE) [106-92-3]	(1991-1997) TWA-5 ppm, STEL-10 ppm (1998-2016) TWA-1 ppm	80	Based on the results of rodent irritation anf chronic inhalation bioassays, the human ocular and upper respiratory tract inrritation, contact dermatistic, skin irritation, and allergy/ sensitization, TWA of 1 ppm is believed to be sufficiently low to prevent primary irritaiton
4	Allyl propyl disulfide [2179-59-1]	(1991-2003) TWA-2 ppm, STEL-3 ppm (2004-2016) TWA-0.5 ppm	75	TWA of 0.5 ppm is recommended based on the irritation af mucous membranes and lacrimation. This value is based on a study using a small number of volunteers which was conducted in 1940. This value is more experience-based than experimentally derived but it reflect the irritation properly of this chemical.
5	1,3-Butadiene[106-99-0]	(1991-1993) TWA-10 ppm (1994-2016) TWA-2 ppm	80	The reported exposure levels in the industry in the decade of the 1980s, largely 25 ppm and below, represent a low risk as compared with those risks experienced during wartime operations in the 1940s and postwar activities in the 1950s. A TLV-TWA of 2 ppm is intended to provide an adequate margin of safety with respect to the risk of human cancers following occupational exposure to 1,3-butadiene

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
6	‡n-Butyl acrylate [141-32-2]	(1991-1998) TWA-10 ppm (1999-2016) TWA-2 ppm	80	A TLV-TWA of 2 ppm (11 mg/m^3) is recommended for occupational exposure to n-butyl acrylate. Although there were scant, relevant human data upon which to base the TLV, rat inhalation studies established no-observed-adverse-effect levels at 21 ppm for ocular, nasal, and respiratory tract irritation and other indications of systemic toxicity and at 25 ppm for maternal toxicity. Applying an uncertainty factor, the 2 ppm TLV-TWA should minimize the potential for skin, ocular, and respiratory tract irritation
7	Butylated hydroxytoluene (BHT) [128-37-0]	(1991-2000) TWA-10 mg/m³ (2001-2016) TWA-2 mg/m³	80	A TLV-TWA of 2 mg/m^3 is recommended for occupational exposure to butylated hydroxytoluene (BHT). Given that BHT is a nonvolatile solid with at saturated vapor concentration of approximately 120 mg/m^3, the TLV-TWA is based on total inhalable BHT (aerosol and vapor). The finding of reduced respiratory rates in mice exposed to BHT vapor supports the widely accepted opinion that the chemical is irritating to the eyes and upper respiratory tract. Therefore, this value is recommended to minimize the potential risk of sensory irritation in workers
8	Cadmium [7440-43-9]	(1991-1992) TWA-0.05 mg/m³ (1993-2016) TWA-0.01 mg/m³	80	A TLV-TWA of 0.01 mg/m^3, measured as cadmium (Cd), for “total” particulateis recommended for occupational exposure to cadmium and its compounds. The 0.01 mg/m^3 “total” particulate TLV is intended to minimize the potential for development of preclinical kidney dysfunction (urinary â2-microglobulin excretion). The respirable particulate TLV is intended to minimize the potential for lower respiratory tract accumulation of a cadmium burden that could induce lung cancer
9	Chromium Certain water Insoluble Cr VI compounds	(1991-1993) TWA-0.05 mg/m³ (1994-2016) TWA-0.01 mg/m³	80	-

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
10	2-N-Dibutylaminoethanol [102-81-8]	(1991-1993) TWA-2 ppm (1994-2016) TWA-0.5 ppm	75	DBAE is an ocular and nasal irritant and inhibitor of cholinesterase activity, producing tremors, convulsions, and neuromuscular blockage leading to respiratory arrest at effective doses of 50 mg/kg in rats. In view of the no-observed-effect level (NOEL) of 22 ppm in a 6-month inhalation study in rats and considering that DBAE has an approximately tenfold greater toxicity than diethanolamine (DEA), a TLV-TWA for DBAE of 0.5 ppm is recommended (see current TLV Documentation for Diethanolamine). This value is believed to be sufficiently low to minimize the potential for adverse systemic effects. Information is not available to judge whether 0.5 ppm will protect against irritation
11	Dicrotophos [141-66-2]	(1991-2001) TWA-0.25 mg/m³ (2002-2016) TWA-0.05 mg/m³	80	The recommended TLV was derived from animal experiments. Dicrotophos is highly toxic on an acute basis. In rats, the oral LD50 was 16 to 21 mg/kg, the dermal LD50 was 42 mg/kg, and the inhalation 4-hour LC50 was 90 mg/m^3. In 2-year feeding studies, no inhibition of RBC, brain, or plasma cholinesterase was reported in dogs at 0.04 mg/kg or in rats at 0.05 mg/kg Assuming 100% absorption and a breathing volume of 10 m^3 per 8-hour work day, an approximate equivalent inhalation exposure is about 0.3 mg/m^3. No adverse effects have been reported to occur at levels of exposure below those that cause cholinesterase inhibition. Thus, the TLV-TWA of 0.05 mg/m^3 should be sufficient to protect against cholinergic and other adverse effects. This reflects current understanding regarding the relationship between RBC cholinesterase inhibition and adverse effects for this compound
12	2-Diethylaminoethanol [100-37-8]	(1991-1993) TWA-10 ppm (1994-2016) TWA-2 ppm	80	The only study that can be used for an evaluation is the 14-week inhalation study in rats which resulted in a no-observed-effect-level (NOEL) of 10 ppm and in irritation of the nasal mucosa at 25 ppm. By also considering the testicular atrophy seen in rats fed 200 ppm DEAE in their diet (lowest dose tested), a greater degree of safety is applicable. A TLV-TWA of 2 ppm should provide significant protection from acute and chronic effects

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				(irritation, neurotoxicity). Because the toxicological profile of DEAE is not well established, this TLV is seen as preliminary until additional human data are found. By analogy with the other ethanolamines, and by applying the dermal LD50 data reported for rabbits, a Skin notation is recommended
13	3,5-Dinitro-o-toluamide [148-01-6]	(1991-2006) TWA-5 mg/m³ (2007-2016) TWA-1 mg/m³	80	A TLV-TWA of 1 mg/m^3 is recommended for occupational exposure to 3,5-dinitro-o-toluamide to minimize the potential for liver damage and other unwanted effects. The database for this chemical is limited; however, a repeated exposure feeding study in rats has identified the liver as the first target and a dose of 3 mg/kg as a no-observed-adverse-effect level (NOAEL). A study in dogs confirms this level of potency but failed to test high enough levels to demonstrate a target organ/tissue in that species. There is no information regarding genotoxicity in mammalian systems, but tests in bacterial systems have shown 3,5-dinitro-o-toluamide to be mutagenic
14	Epichlorohydrin [106-89-8]	(1991-1996) TWA-2 ppm (1997-2016) TWA-0.5 ppm	75	The recommended TLV-TWA of 0.5 ppm is based on the NOAEL of 5 ppm in a male fertility, 10-week inhalation study with rats and the 9 ppm no-observed-effect level (NOEL) in an 18 to 20-day inhalation study in rabbits and rats. The NOEL of 0.5 ppm in a 98-day Russian inhalation study with rats and an observed effect level at 5.2 ppm in a 6.5 month Russian inhalation study in rats were given minimal weighting by ACGIH in the recommendation of 0.5 ppm as the TLV because of the scanty experimental details in these studies
15	EPN [2104-64-5]	(1991-2002) TWA-0.5 mg/m³ (2003-2016) TWA-0.1 mg/m³	80	The first biologic response to EPN produces decreased activity of cholinesterase enzymes. In rats and dogs following repeated oral exposures, the no-effect levels in red blood cell (RBC) cholinesterase activity ranged from 0.25 to 1.0 mg/kg. Under controlled experimental conditions, an oral dose of 6 mg EPN did not affect RBC cholinesterase activity in humans, but a dose of 9 mg did. The oral dose of 6 mg corresponds to an inhalation exposure of 0.6 mg/m^3, assuming a 70-kg body weight and an exchange of

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				10 m^3 air during the workday. A TLV-TWA of 0.1 mg/m^3 (inhalable particulate mass) is recommended for occupational exposure to EPN. This exposure limit is intended to prevent the occurrence of cholinergic symptoms and other adverse biologic effects in workers. It is derived from a no-observed-adverse-effect level (NOAEL) obtained in humans and in animals and corresponds to a dose that is not expected to result in any reductions in RBC acetylcholinesterase activity in a group of workers
16	Ethyl benzene [100-41-4]	(1991-2010) TWA-100 ppm, STEL-125 ppm (2011-2016) TWA-20 ppm	80	A TLV-TWA of 20 ppm (87 mg/m^3) is recommended to minimize the potential risk of irritation, organ damage and hearing loss (cochlear impairment). Ethyl benzene causes irritation in humans after eight hours of exposure only if 200 ppm was exceeded. Ethyl benzene has acute depressant effects (ataxia) on the central nervous system (CNS) of guinea pigs at 2000 ppm for 6.5 hours. Potential chronic health hazards, as evidenced by rat studies, include damage to the liver and kidneys after chronic oral dosing at 408 mg/kg/day, and hearing loss suggested by rat exposures at 400 ppm for eight hours on five consecutive days and six-hour exposures, six days a week for 13 weeks
17	Fenthion [55-38-9]	(1991-2005) TWA-0.2 mg/m^3 (2006-2016) TWA-0.05 mg/m^3	75	A TLV-TWA of 0.05 mg/m^3, inhalable fraction other organophosphates, the initial sign of response is in the cholinergic system with a decrease in red blood cell cholinesterase activity being an indication of excessive exposure. No signs of cholinesterase inhibition were seen in men exposed for 4 weeks at 0.07 mg/kg. Animal study no effect levels of 1 mg/m^3 inhaled and 0.13 mg/kg given orally converge to suggest that 1 mg/kg is approximately the no observed adverse effect level. A 2-year oral study in the monkey supports that 0.07 mg/kg (equivalent to 0.5 mg/m^3 inhaled) is the threshold for cholinergic effects. The TLV-TWA of 0.05 mg/m^3 should be sufficient to prevent enzyme activity decreases

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
18	Glutaraldehyde [111-30-8], activated or inactivated	(1991-1998) C0.2 ppm (1999-2016) TWA-C0.05 ppm	75	A TLV-Ceiling of 0.05 ppm for glutaraldehyde, activated or unactivated, was adopted in 1976 and revised in 1979 to 0.2 ppm, also as a TLV-Ceiling. The latter value was based on the irritating potential of glutaraldehyde reported in studies of medical workers at concentrations greater than 0.3 ppm. There was been a paucity of occupational hygiene data and glutaraldehyde-induced irritation reported in the literature. However, since 1988, three occupational exposure studies have reported nose, throat, skin, and eye irritation; headaches; and several other symptoms associated with airborne glutaraldehyde exposure concentrations at or below 0.1 ppm. All of these studies were based on short-term (15-minute) personal sample results
19	Kaolin [1332-58-7]	(1991-1991) TWA-10 mg/m³ (1992-2016) TWA-2 mg/m³	80	Because of the uncertainty in determining the contribution of extremely high historical exposures in the respiratory disease of kaolin production workers and the experience of those involved in mining, a kaolin TLV-TWA of 2 mg/m^3, as respirable particulate containing no asbestos and <1% crystalline silica, was adopted in 1992 to minimize the potential for kaolin-induced pneumoconiosis (kaolinosis)
20	Methyl acrylate [96-33-3]	(1991-1996) TWA-10 ppm (1997-2016) TWA-2 ppm	80	It is a moderate skin and mucous membrane irritant, and it is a skin sensitizer in animals. In lifetime inhalation studies, the NOEL in rats was less than 15 ppm (as compared with less than 135 ppm for butyl acetate). The effects seen at 15 ppm included reversible irritation of the nasal mucosa and opacity and neovascularization of the cornea. No published human data are available other than experimental skin testing, which revealed that methyl acrylate is a skin sensitizer and a moderate irritant, and a short-term case-crossover study at levels at or below 2 to 5 ppm TWA, in which some participants reported eye irritation that increased in those with higher exposures and increased bronchial reactivity in a previously unexposed worker after exposure. A TLV-TWA of 2 ppm is recommended, based on the results from the acute human study and the rodent chronic toxicity

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				bioassay, to minimize the potential for acute and chronic irritative effects of methyl acrylate on the cornea, skin, and mucous membranes
21	Methyl bromide [74-83-9]	(1991-1996) TWA-5 ppm (1997-2016) TWA-1 ppm	80	Data suggested that mild irritation of the nasal mucosa may have occurred in a 29-month inhalation study with the rat at an exposure concentration of 3 ppm. Although the results of this study must be viewed as uncertain for reasons discussed in this Documentation, since this exposure concentration was reported as a lowest-observed-adverse-effect level (LOAEL) rather than a no-observed-effect-level (NOEL), a TLV-TWA of 1 ppm (3.89 mg/m^3) appears reasonable. Because all dose-responses of methyl bromide were very steep, its half-life short, and irritation was shown to be reversible in both animals and humans, a TLV-TWA of 1 ppm should minimize the potential for workers from irritation and, hence, also from all other endpoints of methyl bromide toxicity
22	α-Methyl styrene [98-83-9]	(1991-2009) TWA-50 ppm, STEL-100 ppm (2010-2016) TWA-10 ppm	80	A TLV-TWA of 10 ppm (48 mg/m^3) is recommended for α-methyl styrene (AMS) to minimize the potential for irritation of the upper respiratory tract, renal toxicity, and adverse reproductive effects. In a chronic inhalation study in rats, a no-observed- adverse-effect level (NOAEL) of 100 ppm could be derived based on an increased incidence of mineralization of the renal papilla in females at 300 and 1000 ppm. Human experimental data have shown that AMS vapor is acutely irritating to the eyes and upper respiratory tract above 200 ppm
23	Monocrotophos [6923-22-4]	(1991-2001) TWA-0.25 mg/m^3 (2002-2016) TWA-0.05 mg/m^3	80	In humans, repeated oral doses of up to 0.015 mg/kg produced no Red Blood Cell (RBC) cholinesterase inhibition. Assuming total absorption and an air exchange of 10 m^3 per 8-hour work shift, 0.015 mg/kg is equivalent to about 0.1 mg/m^3 in a 70-kg individual. Repeat-dose feeding studies in animals support this level of potency with regard to cholinesterase inhibition. The no-observed-adverse-effect level reported for inhibition of RBC cholinesterase was 0.04 mg/kg in dogs. This dosage was equivalent to a

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				daily inhalation exposure of about 0.3 mg/m^3. Tests examining other biological endpoints were consistent with cholinesterase changes being the first sign of adverse response to monocrotophos. Thus, the TLV-TWA of 0.05 mg/m^3, as an inhalable aerosol and vapor, should be sufficient to protect against cholinergic and other adverse biologic effects
24	Nitromethane [75-52-5]	(1991-1993) TWA-100 ppm (1994-2016) TWA-20 ppm	80	In view of the fact that exposure to nitromethane 7 hours/day, 5 days/week for 6 months at 98 ppm resulted in adverse thyroid effects in rabbits, as evidenced by decreased T4 levels, elevated but not statistically significant thyroid weights, and transient pulmonary hemorrhage and congestion, and the dose-response increases in the weights of the thyroid glands of exposed rats provide additional evidence that the thyroid may be a target organ; and the NTP chronic inhalation bioassay results for non-neoplastic effects (nose) olfactory epithelium-degeneration and metaplasia; respiratory epithelium hyaline degeneration) in mice, the ACGIH recommends a TLV-TWA of 20 ppm for nitromethane
25	Nickel Insolube inorganic compounds (NOS)	(1991-1997) TWA-1 mg/m^3 (1998-2016) TWA-0.2 mg/m^3	80	Animal studies consistently showed pulmonary damage, comprising biochemical and histological changes, when exposed by inhalation in the range of 0.1 to 1.0 mg/m^3 "total" aerosol, for soluble and insoluble forms of nickel. These recommendations were made to minimize the potential for an increased risk of lung and sinus cancer and the production of inflammatory pulmonary changes. ACGIH believes that the TLV-TWA for nickel and its inorganic compounds should be expressed in terms of inhalable nickel particulate as opposed to "total" nickel particulate, because of the association between some forms of nickel and sinus cancer
26	Phenyl mercaptan [108-98-5]	(1991-2003) TWA-0.5 ppm (2004-2016) TWA-0.1 ppm	80	A TLV-TWA of 0.1 ppm (0.45 mg/m^3) is recommended for phenyl mercaptan, based on central nervous system (CNS) (headaches, dizziness), ocular, and dermal effects. Acute lethality was seen in rats and mice exposed at approximately 30 ppm phenyl mercaptan. Reproductive, hepatic, and renal effects were also seen in rats administered phenyl mercaptan by gavage

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
				(equivalent to an inhalation concentration of approximately 10 to 20 ppm over an 8-hour period). Because the TLV of 0.1 ppm exceeds the odor threshold by perhaps a thousandfold, it is doubtful that this concentration can be maintained in a workplace without causing a nuisance
27	Pyridine [110-86-1]	(1991-2003) TWA-5 ppm (2004-2016) TWA-1 ppm	80	A TLV-TWA of 1 ppm should be sufficient to minimize the potential for adverse effects of exposure to pyridine. Human data following inhalation of pyridine is not available; accordingly, the TLV relies on data from animals
28	Sulfuric acid [7664-93-9]	(1991-2003) TWA-1 mg/m³ (2004-2016) TWA-0.2 mg/m³	80	Based upon observed clearance and pulmonary function changes, a TLV-TWA of 0.2 mg/m^3, thoracic particulate mass, is recommended for occupational exposure to sulfuric acid aerosols
29	1,1,1,2-Tetrachloro -2,2-difluoroethane [76-11-9]	(1991-2007) TWA-500 ppm (2008-2016) TWA-100 ppm	80	1,1,1,2-Tetrachloro-2,2-difluoroethane (CFC-112a) is a chemical with relatively low toxicity following either acute or subchronic exposure. Lethality occurred in rats and mice exposed to CFC-112a at concentrations of 15,000 and 20,000 ppm. Low-level narcotic effects, minimal hepatocyte degeneration, and cloudy swelling of the kidneys were reported in rats exposed to 10,000 and 5,000 ppm for seven hours. Repeated inhalation studies in rats exposed to 1,000 ppm showed no effects. On the basis of these data, a TLV-TWA of 100 ppm is recommended. This value should be sufficient to protect the central nervous system, hepatic, and renal effects of CFC-112a
30	Tetrahydrofuran [109-99-9]	(1991-2004) TWA-200 ppm, STEL-250 ppm (2005-2016) TWA-50 ppm, STEL-100 ppm	75	A TLV-TWA of 50 ppm is recommended to reduce the potential for a number of effects that occur or are seen as study no-observed-effect-levels (NOELs) at 100 to 200 ppm in test animals. Animal studies suggest 250 ppm is too high a STEL to prevent acute neurotoxicity effects. A case report of a worker who experienced Immunoglobuliin-A nephropathy was exposed to short-term THF exposures

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
31	Thallium [7440-28-0] solube compounds as TI	(1991-2009) TWA-0.1 mg/m³ (2010-2016) TWA-0.02 mg/m³	80	The recommended TLV-TWA for thallium and its compounds of 0.02 mg/m^3, inhalable particulate matter, measured as Tl, is based on the highest airborne levels measured in a battery plant where no evidence of adverse health outcome related to thallium was observed
32	Thionyl Chloride [7719-09-7]	(1991-2009) C1 ppm (2010-2016) C0.2 ppm	80	The TLV is derived from the TLVs for those irritant gases. Irritating concentrations of 5 ppm and 49 ppm for sulfur dioxide and hydrogen chloride, respectively, have been reported. The reaction of one molecule of thionyl chloride with one molecule of water produces two molecules of hydrogen chloride and one of sulfur dioxide; thus, 1 ppm of thionyl chloride yields a total irritant gas concentration equivalent to 3 ppm. The TLV-Ceiling for hydrogen chloride is 2 ppm and the TLV-STEL for sulfur dioxide is 0.25 ppm. Accordingly, a TLV-Ceiling of 0.2 ppm (1 mg/m^3) is recommended for occupational exposure to thionyl chloride. This value is intended to minimize the potential for irritant effects associated with exposure to the decomposition products of this chemical
33	Toluene [108-88-3]	(1991-2006) TWA-100 ppm, STEL-150 ppm (2007-2016) TWA-20 ppm	80	A TLV-TWA of 20 ppm is recommended to protect from subclinical changes in blue-yellow color vision and the potential for spontaneous abortion in female workers. Color vision changes have been reported in a longitudinal study of a population of rotogravure printers in France where personal air sampling in the breathing zone showed an average of 36 ppm at the time the tests were administered in early 1993. There is no information upon which to assign a SEN notation or recommend a TLV-STEL
34	Toluene-2,4- or 2,6-diisocyanate (or as a mixture) [584-84-9; 91-08-7]	(1991-2015) TWA-0.005 ppm, STEL-0.02 ppm (2016-2016)	80	Studies in animals are of limited value in estabishing a TLV for 2,4-TDI because TDI respiratory sensitization is difficult to produce in animals. The previous TLV-Ceiling of 0.02 ppm was based on the findings of Subsequent studies, however, have shown that a substantial proportion of the working population, ranging from 4.3% to 25%, can be sensitized to TDI at this

번호	화학물질의 명칭	년도에 따른 노출기준	감소율 (%)	주요이유
		TWA-0.001 ppm, STEL-0.005 ppm		concentration
35	Trichloroethylene[79-01-6]	(1991-1992) TWA-50 ppm (1993-2006) STEL-100 ppm (2007-2016) TWA-10 ppm, STEL-25 ppm	80	Human exposure to TCE produced reversible CNS effects such as dizziness and lassitude at concentrations above 100 ppm. Extensive epidemiologic cohort studies of TCE-exposed workers do not indicate significant increases in cancer incidence, but case-control studies suggest that prolonged exposure to high concentrations of TCE (hundreds to thousands of ppm) can increase the incidence of renal cancer. A TLV-TWA of 10 ppm (54 mg/m^3) should protect against the CNS effects of TCE as well as the potential for other effects including renal toxicity and cancer. A TLV-STEL of 25 ppm (135 mg/m^3) is recommended because the CNS effects of TCE appear to be related to peak exposures
36	2,4,6-trinitrotoluene (TNT0 [118-96-7]	(1991-1996) TWA-0.5 mg/m³ (1997-2016) TWA-0.1 mg/m³	80	Skin irritation and percutaneous absorption of sufficient quantities of TNT to induce systemic poisoning have also been reported. Altered liver parameters were seen in workers exposed at 0.3 to 0.8 mg/m^3, and changes in hematologic parameters were seen in workers exposed at 0.05 to 7.5 mg/m^3 for 1 to 2 years. Based on these data, a TLV-TWA of 0.1 mg/m^3
37	Triorthocresyl phosphate [78-30-8]	(1991-2015) TWA-0.1 mg/m3 (2016-2016) TWA-0.02 mg/m3	80	Triorthocresyl phosphate (TOCP) may be absorbed through the skin and may exert frank toxicity upon ingestion. Exposure to TOCP causes central and peripheral neuropathies with paralysis of the distal muscles of the upper and lower extremities. Air concentrations between 1.55 and 1.7 mg/m^3 have been associated with polyneuritis; reduced cholinesterase activity has been related to air concentrations of 0.27 to > 3 mg/m^3. Accordingly, a TLV-TWA of 0.1 mg/m^3, with a Skin notation, is recommended for TOCP

제 3 절 TLV값이 상향 조정된 화학물질

ACGIH TLV값이 낮은 쪽으로 하향조정된 것만은 아니다. 시간이 지남에 따라 오히려 상향조정된 것도 있는데 1991년부터 2016년까지 TLV값이 상향 조정된 화학물질은 Butane, Nickel Elemental, Pentane 그리고 Tributyl phosphate 등 4개였다.

Butane은 1991년 TLV-TWA가 800 ppm이었는데 2011-2012년도에는 Aliphatic Hydrocarbon gases, Alkanes(C1-C4)로 대신했다가 2013년도에는 TWA는 삭제되고, STEL만 1000 ppm으로 제시했다.

Nickel Elemental(니켈원소)는 1991년 TLV-TWA가 1 mg/m^3이었는데 2016년 TWA를 1.5 mg/m^3으로 약 1.5배가 되었다.

Pentane(all isomers)은 1991년도에 TWA가 600 ppm, STEL이 750 ppm 이었는데 1998년도에 STEL기준이 삭제되었으며, 2014년도에 TWA는 1000 ppm으로 1.67배(167%) 상향조정되었다.

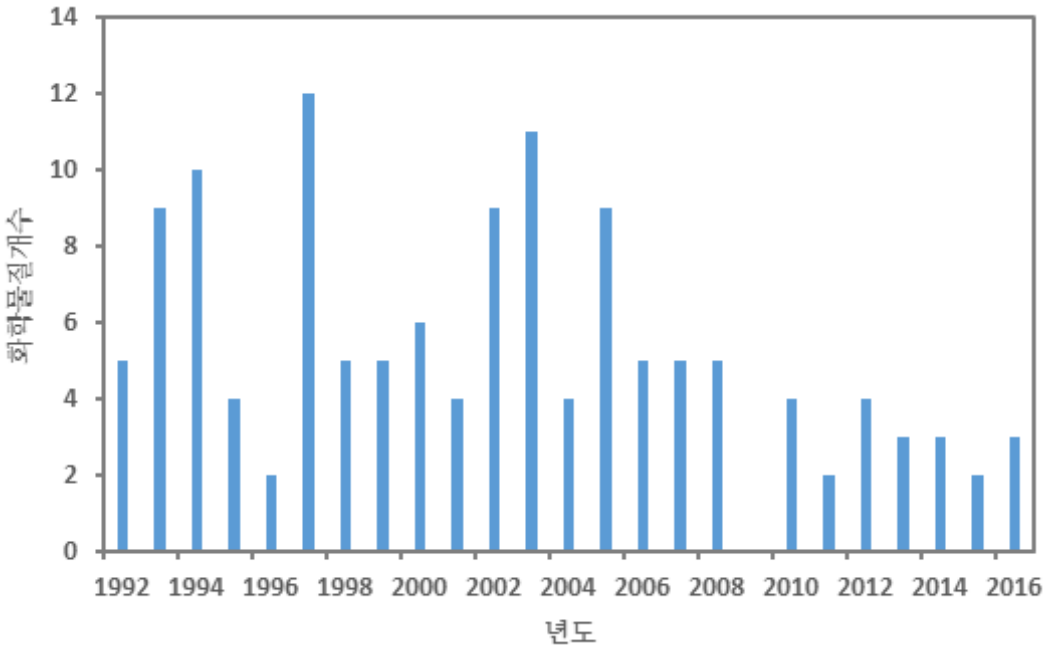
Tributyl phosphate는 1991년도 TWA가 2.2 mg/m^3이었는데 2012년에 방광 자극, 눈 및 상부 호흡기도 자극으로부터 보호하기 위하여 TWA를 5 mg/m^3로 2.27배(227%) 상향시켰다. 노출기준을 상향 조정한 이유는 〈표 11〉와 같다.

〈표 11〉 1991년 이후 2016년까지 TLV값이 상향 조정된 화학물질

번호	화학물질의 명칭	년도에 따른 노출기준	주요 이유
1	Butane, all isomers [75-28-5; 106-97-8]	(1991-2000) TWA-800 ppm (2001-2012) TWA-1000 ppm (2013-2016) STEL신규-1000	Replaced by Aliphatic Hydrocarbon gases, Alkanes [C1-C4], TLV-TWA, 1000 ppm. A TLV-STEL of 1000 ppm (2370 mg/m^3) is recommended for occupational exposure to the two isomers of butane (n-butane and isobutane) to minimize the potential for narcosis
2	Nickel Elemental [7440-02-0]	(1991-2015) TWA-1 mg/m^3 2016 TWA-1.5 mg/m^3	-
3	Pentane, all isomers [78-78-4;109-66-0;463-82-1]	(1991-1997) TWA-600 ppm STEL-750 ppm (1998-2013) TWA-600 ppm (2014-2016) TWA-1000 ppm	Replaced by Aliphatic Hydrocarbon gases, Alkanes [C1-C4], TLV-TWA, 1000 ppm
4	Tributyl phosphate [126-73-8]	(1991-2011) TWA-2.2g/m^3 (2012-2016) TWA-5 mg/m^3	A TLV-TWA of 5 mg/m^3 (0.5 ppm), measured as inhalable fraction and vapor, is recommended for occupational exposure to tributyl phosphate (TBP) to protect against bladder irritation, as well as eye and upper respiratory tract irritation. Exposure at this concentration would result in an absorbed dose of approximately 0.7 mg/kg/day. Because the estimated saturated vapor concentration may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate may occur during sampling, both the particulate mass and vapor phase concentrations should be considered and summed to determine total airborne concentration

제 4 절 1991년 이후 TLV가 설정된 화학물질

1991년부터 2016년까지 25년간 TLV 소책자에 새롭게 나타난 화학물질은 총 130개였다. 연도별 새로 TLV에 추가된 화학물질의 개수가 [그림 3]과 같다.



[그림 3] 연도별 신규 TLV가 설정된 화학물질의 개수.

1991년 이후 TLV 소책자에 새롭게 나타난 화학물질은 〈표 12〉와 같다. 새롭게 TLV가 추가된 화학물질 중 일부는 1991년 및 그 이전에는 각각 별개의 노출기준을 가지고 있던 화학물질을 묶어서 크게 하나의 화합물(compound) 군으로 표현한 것들이 있다. 예를 들어 1991년도에 Borate tetra sodium salts Anhydrous, Borate tetra sodium salts Decahydrate, Borate tetra sodium salts Pentahydrate는 각각 TWA가 1 g/m^3, 5 g/m^3, 1 g/m^{3}으로 설정되어 있었으나 2005년도에 Borate compounds, inorganic이라는 화합물로 통합되어 TWA는 2 g/m^3, STEL은 6 g/m^{3}로 변경하였다. 그 외에 신규 추가된 화학물질 노출기준이 여러 연구를 바탕으로 주로 노동자의 건강을 보호하기 위해 추가된 것이었다. 예를 들어 Adipic acid의 경우, 자율 신경계 및 위장관의 기능 장애와 위 호흡기 기관의 점막 자극으로부터 보호하기 위해 1992년도에 TWA를 5 mg/m^{3}로 설정하였다.

〈표 12〉 1991년이후 2016년까지 TLV가 추가로 설정된 물질

번호	화학물질의 명칭	신규 년도	주요이유
1	Acetone cyanohydrin [75-86-5], as CN (1991)	1994	Because acetone cyanohydrin behaves qualitatively and quantitatively, both in vitro and in vivo, exactly as does its molar equivalent in free cyanide the TLV for acetone cyanohydrin is assigned so as to be identical to that for free hydrogen cyanide, namely a TLV-Ceiling of 4.7 ppm (5 mg/m^3), as CN. Inhalation and skin absorption of acetone cyanohydrin have been responsible for several deaths and numerous instances of acute, nonfatal occupational poisoning
2	Acetophenol [98-86-2]	1993	An eight-hour TLV-TWA of 10 ppm (50 mg/m^3) is recommended to provide an adequate margin of safety against potential systemic and reproductive toxicity of acetophenone and to reduce the likelihood of sensory irritation
3	Adipic acid [124-04-9]	1993	There currently is a paucity of human effects or air concentration data on which to recommend a TLV for adipic acid. The study of suggests that a TLV-TWA of 5 mg/m^3 for worker exposure to adipic acid should minimize the potential for functional disorders of the autonomic nervous system and gastrointestinal tract and for irritation of the mucosa of the upper respiratory tract. The TLV Committee solicits additional information that can be used to support the TLV recommendation of 5 mg/m^3
4	Adiponitrile [111-69-3]	1994	A TLV-TWA of 2 ppm (8.8 mg/ml3) is recommended for occupational exposure to adiponitrile, based on irregular respiration reported in rats exposed to vaporized adiponitrile for 2 weeks at concentrations ranging from 7 to 68 ppm
5	Alachlor [15972-60-8]	2007	The no-observed- adverse-effect level (NOEL) for adverse effects of alachlor in animals was 1 mg/kg/day, based on detectable hemosiderosis in liver, spleen, and kidneys of dogs dosed chronically. This NOEL (1 mg/kg/day) is considered to be a conservative index of adverse reaction, since hemosiderosis has seldom, if ever, been reported for humans exposed to alachlor, and it is not a primary lesion in other species exposed to alachlor. Using the NOEL of 1 mg/kg/day and assuming a typical 70-kg worker breathing 10 m^3/per workday, a TLV-TWA of 1 mg/m^3 (0.1 ppm), inhalable fraction and vapor, is recommended for alachlor

번호	화학물질의 명칭	신규 년도	주요이유
6	Aliphatic hydrocarbon gases Alkanes [C1-C4]	2002	AA TLV-TWA of 1000 ppm is recommended for applies to individual gasses (methane, ethane, propane, butane, isobutane) and mixtures of these gases, to include liquefied petroleum gas and natural gas. This is a complete list of gases to which this TLV applies. The TLV is believed to be protective against potential health effects that include central nervous system (CNS) depression and cardiac sensitization. The TLV is based on the abilities of these gases to produce weak depressant effects on the CNS at high concentration levels approaching the lower flammability limit. It has also been reported that ethane and propane can induce cardiac arrhythmias under certain conditions leading to ventricular fibrillation that can result in death in the presence of high epinephrine levels
7	Allyl bromide [106-95-6]	2012	A TLV-TWA of 0.1 ppm (0.5 mg/m^3) is recommended for occupational exposure to allyl bromide based on the structure-activity relationship with allyl chloride, which appears to be approximately 10 times less active) allyl bromide LD50 = 30 mg/kg in the guinea pig compared with allyl chloride LD50 = 460 mg/kg; and allyl bromide RD50 = 257 ppm in mice compared with allyl chloride RD50 = 2330 ppm
8	Aluminum metal [7429-90-5] and insoluble compounds	2008	A TLV-TWA of 1 mg/m^3, respirable fraction, is recommended for aluminum metal and insoluble aluminum compounds. In general, these forms of aluminum are poorly absorbed and are readily cleared from the lungs by mucociliary and bronchoalveolar clearance (e.g., by alveolar macrophages); however, there is evidence that aluminum accumulates in the body with long-term exposure
9	Asbestos [1332-21-4], all forms (1994)	1994	A TLV-TWA of 0.1 fiber/cc is recommended for occupational exposure to all forms of asbestos. This value is intended to minimize the potential for asbestosis and also to minimize the risk for development of lung cancer. The recommended Threshold Limit Value should also serve to reduce the risk of mesothelioma in asbestos-exposed workers
10	tert-Amylmethylether(TAME)[994-05-8]	2002	There is a lack of human data and established no-observed-effect levels (NOELs) in rodents for tertiary amyl methyl ether (TAME) for chronic effects such as neurologic and reproductive toxicity; existing neurologic and reproductive no-observed-adverse- effect levels (NOAELs) start at 250 ppm. Based on the available data and the existing NOAELs (as well as by analogy to methyl tertiary butyl ether (MTBE) and ethyl tertiary butyl ethyl with their

번호	화학물질의 명칭	신규 년도	주요이유
			much larger databases) and in accord with the so-called "preferred value approach," the recommended TLV- TWA for TAME is 20 ppm
11	Antimony hydride [7803-52-3]	2000	A TLV-TWA of 0.1 ppm is recommended for occupational exposure to antimony hydride. This value is intended to minimize the potential risk of hemolysis, pulmonary irritation, and kidney damage. Antimony hydride, like arsine, is a hemolytic agent and the recommended TLV is based, in part, on analogy with arsine and its biological effects in exposed animals and humans
12	Benz[a]anthracene [56-55-3]	1993	A numerical TLV is not recommended for occupational exposure to benz[a]anthracene (B[a]A). An A2, Suspected Human Carcinogen, notation is assigned based on the skin tumors observed in exposed animals that resulted from exposure conditions (topical) which were relevant to worker exposures. B[a]A should be dealt with in a manner similar to benzo[a]pyrene. Environments containing B[a]A should be evaluated using the TLV for Coal Tar Pitch Volatiles, i.e., a TWA of 0.2 mg/m^3, as benzene solubles
13	Benzo[b]fluoranthene [205-99-2]	1992	A numerical TLV is not recommended for occupational exposure to benzo[b]fluoranthene (B[b]F). Studies with rats and mice have clearly demonstrated the oncogenic potential of B[b]F following subcutaneous injections, lung implants, and skin painting, as well as the potential for at least 11 metabolites of B[b]F to initiate tumors. These studies also indicate that B[b]F may be carcinogenic to humans. Accordingly, an A2, Suspected Human Carcinogen, notation is designated and should be dealt with in a manner similar to benzo[a]pyrene (B[a]P)
14	Benzotrichloride [98-07-7]	1997	A TLV-Ceiling of 0.1 ppm (0.8 mg/m^3) is recommended for occupational exposure to benzotrichloride. This value is intended to minimize the potential for ocular, skin, and respiratory tract irritation. A Skin notation is assigned, based on the mouse skin-painting bioassay in which skin, lung, and thymic tumors were produced. These data, plus the 12-month mouse inhalation exposure study in which tumors were produced at multiple sites, warrant a designation as an A2, Suspected Human Carcinogen

번호	화학물질의 명칭	신규 년도	주요이유
15	Benzoyl chloride [98-88-4]	1995	A TLV-Ceiling of 0.5 ppm (2.8 mg/m^3) is recommended for occupational exposure to benzoyl chloride. This value is intended to minimize the potential for marked ocular, mucous membrane, and respiratory tract irritation. Benzoyl chloride is a strong lachrymator. Oncogenic studies with mice produced a tumorigenic response in the lungs and skin. Although the tumor incidences were not statistically significant, benzoyl chloride is considered a weak carcinogen; thus, an A4, Not Classifiable as a Human Carcinogen, notation is warranted
16	Benzyl acetate [140-11-4]	1995	A TLV-TWA of 10 ppm (61 mg/m^3) is recommended for occupational exposure to benzyl acetate to minimize the potential for nasal and upper respiratory tract irritation. Data from a 2-year carcinogenesis bioassay with rats and mice were associated with an increase in acinar-cell adenomas in the male rat pancreas and benign liver tumors in treated mice. Therefore, an A4, Not Classifiable as a Human Carcinogen, notation is assigned for benzyl acetate
17	Borate compounds, inorganic [1303-96-4; 1330-43-4;10043-35 -3;12179-04-3]	2005	Thereisnoindicationthatanyparticular sodium borate is more potent than another sodium borate, and similar health effects are noted for boric acid. A TLV-TWA of 2 mg/m^3 and a TLV-STEL of 6 mg/m^3, inhalable particulate mass, are therefore recommended for all forms of sodium borate and boric acid. These values are intended to minimize the potential for acute irritant effects of borates when in contact with mucous membranes of the eyes, nose, and other sites in the respiratory tract and skin as well as any potential reproductive and developmental effects following systemic absorption
18	Bron trichloride [10294-34-5]	1997	A TLV-Ceiling of 0.1 ppm (0.8 mg/m^3) is recommended for occupational exposure to benzotrichloride. This value is intended to minimize the potential for ocular, skin, and respiratory tract irritation. A Skin notation is assigned, based on the mouse skin-painting bioassay in which skin, lung, and thymic tumors were produced. These data, plus the 12-month mouse inhalation exposure study in which tumors were produced at multiple sites, warrant a designation as an A2, Suspected Human Carcinogen
19	1-Bromopropane [106-94-5]	2004	A TLV-TWA of 10 ppm (50 mg/m^3) should provide protection against the potential for workers. 1-Bromopropane (1-BP) is a potential substitute for solvents used in cleaning, adhesive, and aerosol propellant applications

번호	화학물질의 명칭	신규 년도	주요이유
20	Butenes, all isomers [106-98-9; 107-01-7;590-18-1;624-64-6;25167-67-3] isobutene [115-11-7]	2008	For butenes, a TLV-TWA 250 ppm (574 mg/m$^{3)}$ is recommended, based on lack of weight gain in female mice exposed to 2,000 ppm of isobutene in a two-year inhalation study and on low body weight in rats exposed to 5,000 ppm n-butene in a subchronic inhalation study. Exposure to 500 ppm or more of isobutene by inhalation in the two-year study caused irritation of the upper respiratory tract, evidenced by increased rates and severity of hyaline degeneration of the respiratory tract in mice exposed to isobutene
21	Butane, all isomers [75-28-5; 106-97-8]	2013	A TLV-STEL of 1000 ppm (2370 mg/m^3) is recommended for occupational exposure to the two isomers of butane (n-butane and isobutane) to minimize the potential for narcosis
22	Isobutene [115-11-7]	2008	-
23	Iron oxide (Fe2O3) [1309-37-1]	2006	A TLV-TWA of 5 mg/m^3, respirable particulate mass, is recommended for occupational exposure to iron oxide. This value is intended to minimize the potential for nonspecific inflammatory responses and development of X-ray changes in the lung following long-term exposure
24	2-Butoxyethyl acetate (EGBEA) [112-07-2]	2003	A TLV-TWA of 20 ppm (131 mg/m^3) is recommended for occupational exposure to 2-butoxyethyl acetate. This value should minimize the potential for hemolytic effects, and also by comparison to the more comprehensively studied 2-butoxyethanol, to which this compound is extensively metabolized following systemic absorption. Although the TLV-TWA for the analogous 2-butoxyethanol is based on a report of eye and nose irritation in naïve volunteers, 2-butoxyethyl acetate is not anticipated to be a potent respiratory irritant, based on findings from inhalation animal studies
25	Butyl acetate, all isomer [105-46-4;110-19-0; 123-86-4;540-88-5]	2016	-
26	Butylated hydroxytoluene (BHT) [128-37-0]	2001	A TLV-TWA of 2 mg/m^3 is recommended for occupational exposure to butylated hydroxytoluene (BHT). Given that BHT is a nonvolatile solid with at saturated vapor concentration of approximately 120 mg/m^3, the TLV-TWA is based on total inhalable BHT

번호	화학물질의 명칭	신규 년도	주요이유
			(aerosol and vapor). The finding of reduced respiratory rates in mice exposed to BHT vapor supports the widely accepted opinion that the chemical is irritating to the eyes and upper respiratory tract. Therefore, this value is recommended to minimize the potential risk of sensory irritation in workers
27	Cadmiumcompounds,asCd	1993	A TLV-TWA of 0.01 mg/m^3, measured as cadmium (Cd), for "total" particulate, and 0.002 mg/m^3, as Cd, for the respirable particulate fraction are recommended for occupational exposure to cadmium and its compounds. The 0.01 mg/m^3 "total" particulate TLV is intended to minimize the potential for development of preclinical kidney dysfunction. The respirable particulate TLV is intended to minimize the potential for lower respiratory tract accumulation of a cadmium burden that could induce lung cancer. The TLVs should also significantly reduce the potential for metal fume fever in cadmium-exposed workers
28	Calcium sulfate [7778-19-8;10034-76-1;10101-41-4;13397-24-5]	2006	A TLV-TWA of 10 mg/m^3, inhalable particulate mass, is recommended to protect against long-term respiratory health effects. The very limited data available for calcium sulfate suggest that it is a relatively non-toxic substance. No toxic effects were measured in rat lungs at concentrations ranging from 15 to 60 mg/m^3. In short-term human exposures at 10, 20, and 40 mg/m^3 during exercise, elevated chemesthetic effects were found on the nose and throat at 40 mg/m^3. Eye irritation, nasal secretion and resistance, and mucociliary transport were not affected at any of the exposure levels
29	Calcium silicate, natrually accurring as Wollastonite [1344-95-2]	2016	A TLV-TWA of 10 mg/m^3, total dust containing no asbestos and <1% crystalline silica, is recommended for occupational exposure to synthetic calcium silicate. This value is intended to minimize the potential for respiratory tract irritation. Limited data are available on adverse effects of exposure to calcium silicate. What is available indicates a substance of minimal, if any, toxicity at concentrations in the range of 10 to 20 mg/m^3
30	Caprolactam [105-60-2]	2003	Caprolactam is used as a monomer for synthetic well as a cross-linking agent for polyurethanes. In larges doses, it is a respiratory stimulant and a mild circulatory depressant. Irritation of the nose, throat, and eyes has been noted as vapor levels of 7 ppm (32 mg/m^3) or greater. This irritation was dose-related, decreasing with decreasing concentration.

번호	화학물질의 명칭	신규 년도	주요이유
			Therefore, a TLV-TWA of 5 mg/m^3 (1.08 ppm), inhalable aerosol and vapor, should be sufficient to protect against mucous membrane, respiratory tract, and dermal irritation. There are no specific data on which to base a TLV-STEL
31	Carbonyl sulfide [463-58-1]	2012	A TLV-TWA of 5 ppm (12 mg/m^3) is recommended for occupational exposure to carbonyl sulfide to minimize the potential for all adverse effects including central nervous system (CNS) effects. The TLV-TWA recommendation is based on the no-observed-effect level (NOEL) of 51 ppm for CNS effects in Sprague-Dawley rats receiving 11 six-hour whole-body exposures over a two-week
32	1-Chloro-2-propanol[127-00-4]and2-Chlor o-1-propanol[78-89-7]	2002	A TLV-TWA of 1 ppm is recommended for pure and technical grade 1-chloro-2-propanol, with a skin notation, based on acute dermal toxicity. The chlorohydrin isomer, 2-chloro-1-propanol, is also present in technical grade 1-chloro-2-propanol at 25%. Since the acute toxicities of the two cyanohydrin isomers are equivalent, a TLV-TWA of 1 ppm is also appropriate for 2-chloro-1-propanol
33	Chromium [7440-47-3] Metal and Cr III compounds	1994	Because the effects of soluble Cr III salts were not shown to cause changes of pathophysiological significance at exposures below 0.5 mg/m^3 and there were no observed associations between Cr III salts and cancer, the TLV-TWA of 0.5 mg/m^3, as Cr, has been retained, with an A4 carcinogenicity notation
34	o-Chlorinated diphenyl oxide [31242-93-0] (	1994	A TLV-TWA of 0.5 mg/m^3 is recommended for occupational exposure to chlorinated diphenyl oxide to minimize the potential for hepatotoxicity, and acneiform dermatitis. The liver injury reported for treated rabbits and rats was characterized by congestion and fatty degeneration
35	Citral [5392-40-5]	2010	A TLV-TWA of 5 ppm (32 mg/m^3) inhalable fraction and vapor is recommended for citral. This limit is to protect against multiple effects observed in an inhalation study on rats. This study was designed, however, to investigate the developmental toxicology of citral
36	Coal dust (1995)Anthracite	1998	Separated fromCoel dust 1987

번호	화학물질의 명칭	신규 년도	주요이유
37	Coal dust (1995)Bituminous or Lignite	1998	Separated fromCoel dust 1987
38	Coumaphos [56-72-4]	2006	Since there is no quantitative information on human exposure, this TLV-TWA is based on animal studies and should be sufficient to protect against the potential adverse health effects. In a one-year feeding study of beagle dogs, coumaphos at concentrations of 30 and 90 ppm resulted in depressed plasma and RBC cholinesterase activity levels compared to controls
39	Cresol, all isomers [95-48-7; 106-44-5; 108-39-4; 1319-77-3]	2010	A TLV-TWA of 20 mg/m^3, measured as inhalable fraction and vapor, is recommended for occupational exposure to cresol. Because the estimated saturated vapor concentration may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate may occur during sampling, both the particulate mass and vapor phase concentrations should be considered and summed to determine total airborne concentration
40	Cyanogen bromide [506-68-3]	2015	A TLV-Ceiling of 0.3 ppm (0.75 mg/m^3) is recommended for occupational exposure to cyanogen chloride to minimize the potential for eye, skin, and respiratory tract irritation, and the possibility of cellular metabolic interference by the cyanide radical of cyanogen chloride
41	Demeton-S-methyl [919-86-8]	2002	Long-term feeding studies in rodents have established no-observerd-effect levels, based on cholinesterase effects in the red blood cell, of 0.25 mg/kg in mice and 0.05 mg/kg in rats. The lower dose is equivalent to an inhalation exposure of 0.35 mg/m^3. Tests that examined other biological
42	Diacetyl [431-03-8]	2012	A TLV-TWA of 0.01 ppm (0.04 mg/m^3) is recommended for occupational exposure to diacetyl. Several cases of bronchiolitis obliterans-like illness were reported among microwave popcorn workers exposed to diacetyl used as a flavoring agent in 2002. Short-term peak exposures may be potentially important in the genesis of this illness; therefore, a TLV-STEL of 0.02 ppm (0.07 mg/m^3) is assigned
43	Dichloroacetic acid [79-43-6]	2005	Based on a collective assessment of all available human and animal data, and extrapolation to a dose that is unlikely to cause adverse effects in workers, a TLV-TWA of 0.5 ppm (2.6 mg/m^3) for DCA is recommended

번호	화학물질의 명칭	신규 년도	주요이유
44	1,4-Dichloro-2-butene [764-41-0]	1993	From the animal studies, the excess lifetime cancer risk to workers exposed at 0.005 ppm was estimated to be 8x10^-3. The only epidemiological study conducted was inconclusive. In light of the above findings and in order to minimize the potential risk of adverse effects for exposed workers, ACGIH recommends a TLV-TWA of 0.005 ppm for 1,4-DCB with an A2, Suspected Human Carcinogen
45	Diesel fuel [68334-30-5; 68476-30-2; 68476-31-3;68476-34-6; 77650-28-3], as total hydrocarbons (2007)	2002	A TLV of 100 mg/m^3 total hydrocarbons, vapor and aerosol is recommended for diesel and closely related hydrocarbons to protect from central nervous system (CNS) impairment and liver damage which have been identified in laboratory animals. This TLV will also protect from lung effects shown in laboratory animal studies with inhalation exposures to high concentrations of aerosol
46	N,N-Diethylhydroxylamin [3710847]	2013	A TLV-TWA of 2 ppm (7.3 mg/m^3) should be sufficient to protect against the unwanted effects of diethylhydroxylamine (DEHA). There is no information on the human response so the recommendation derives from animal studies. Rats showed no adverse effects when inhaling 15 ppm DEHA 6 hours/day, 5 days/week for 4 weeks, while concentrations of either 150 or 1500 ppm produced irritation to the upper respiratory tract
47	bis(2-Dimethylaminoethyl) ether [3033-62-3]	2000	A TLV-TWA of 0.05 ppm should be sufficient to protect against the irritation from DMAEE. There is no specific information on which to establish a TLV-STEL, but the effects produced strongly support that one is needed. The repeated exposure data in rats where 1.22 ppm produced irritation in a 14-week study suggest that human irritation to shorter-term concentrations not to exceed 0.15 ppm. Therefore, a TLV-STEL of 0.15 ppm should suffice
48	Dimethyl Dissulfide [624-92-0]	2007	A TLV-TWA of 0.5 ppm (2.0 mg/m^3) is recommended for DMDS based upon its ability to irritate mucous membranes and its ability to produce CNS effects. This value is derived from 90-day rat inhalation data. The lowest concentration tested in the Elf Atochem rat studies (10 ppm) produced reversible damage to the nasal and olfactory epithelium, while systemic

번호	화학물질의 명칭	신규 년도	주요이유
			effects were produced at exposure concentrations of 50 ppm and higher
49	Dimethylethoxysilane [14857-34-2]	1996	Based on human experience of headache and eye irritation occurring at 1.5 to 6.7 ppm, a TLV-TWA of 1.5 ppm is recommended. This recommendation is based on limited human data. A TLV-STEL of 1.5 ppm is also recommended based upon the irritant effects identified with human exposure
50	1,3 Dioxolane [646-06-0]	2002	The available information for 1,3-dioxolane indicates the compound is of low genotoxic potential and of relatively low acute toxicity in animals. Because the primary route of dioxolane absorption is nasal and because rats are obligate nasal breathers with a larger nasal surface area-to-weight ratio than humans, rat inhalation toxicity data are likely to be conservative relative to humans. For this reason, the TLV was derived by applying a single uncertainty factor of 10 applied to the 13-week rat no-observed-adverse-effect-level (NOAEL) of 300 ppm for reduced white blood cell count. The resulting 30 ppm value is conservatively reduced to a TLV- TWA of 20 ppm for consistency with the preferred numbers designation
51	Diquat [85-00-7; 2764-72-9; 6385-62-2]	1993	A TLV-TWA of 0.5 mg/m^3 mg, for inhalable particulate, as the cation, and 0.1 mg/m^3, respirable particulate, as the cation, are recommended for occupational exposure to diquat. These values are intended to minimize the potential for lung irritation, and the formation of cataracts from prolonged exposure
52	Diquat [85-00-7; 2764-72-9; 6385-62-2]	1993	-
52	Dodecyl mercaptan [112-55-0]	2004	A TLV-TWA of 0.1 ppm (0.8 mg/m^3) is recommended for dodecyl mercaptan, based on irritation effects seen in animal studies. Rats, mice, and dogs showed no adverse effects following repeated inhalation exposures of approximately 1 ppm with higher (7-8 ppm) concentrations producing irritation and systemic toxicity
53	Ethyl tert-butyl ether [637-92-3]	2000	A TLV-TWA of 25 ppm (105 mg/m^3) is recommended for occupational exposure to ethyl tert-butyl ether (ETBE) to protect against respiratory tract irritation and central nervous

번호	화학물질의 명칭	신규 년도	주요이유
			system (CNS) impairment exposed 8 healthy male volunteers to ETBE at 25 and 50 ppm for 2 hours during light exercise and reported a statistically significant increase in complaints of discomfort in the throat and airways at 50 ppm but not 25 ppm
54	Ethyl cyanoacrylate [7085-85-0]	1998	A TLV-TWA of 0.2 ppm (1 mg/m^3) is recommended for occupational exposure to ethyl cyanoacrylate to minimize the potential for eye, skin, and upper respiratory tract irritation, dermatitis, and possible respiratory sensitization or asthma
55	2-Ethylhexanoic acid [149-57-5]	2002	The recommended TLV-TWA is 5 mg/m^3, inhalable fraction and vapor (IFV), as it may be present in both the particle and vapor phases with each contributing a significant portion of the dose at the TLV-TWA. Because the vapor may significantly contribute to the exposure at the TLV-TWA and evaporative losses of collected particulate matter may occur during sampling, both particle and vapor phase concentrations should be considered and summed to determine total airborne concentration
56	Ethylisocynate [109-90-0]	2014	-
57	Flour dust	2000	ACGIH recommends a TLV-TWA of 1.5 mg/m^3 for occupational exposure to inhalable flour dust to protect against both sensitization (in both atopic and nonatopic workers) and the symptoms resulting from both sensitization and irritation
58	Gallium arsenide [1303-00-0]	2005	In the absence of quantifiable human data and in the absence of an animal no-observed-adverse-effect level (NOAEL) at the 0.01 mg/m^3 level and in light of the severity of the pulmonary effects in test animals, a TLV-TWA of 0.3 g/m^3 (0.0003 mg GaAs/m^3), respirable particulate mass, is recommended for occupational exposure to gallium arsenide to protect against pulmonary inflammation. This recommendation also reflects concern for the potential for adverse reproductive effects and lung cancer
59	Glyoxan [107-22-2]	2014	-
60	Hard metl containing cobalt [7400-48-4] and Tungsten carbide	2016	-

번호	화학물질의 명칭	신규 년도	주요이유
	[12070-12-1]		
61	Hexachlorobenzene [118-74-1]	1994	A TLV-TWA of 0.002 mg/m^3 is recommended for occupational exposure to hexachlorobenzene (HCB). This value is intended to minimize the potential for increased formation and excretion of porphyrins (porphyrogenicity) leading to dermal lesions and ulcerations, neurotoxicity, and possible liver cancer reported only in animals
62	Hexaflouropropylene [116-15-4]	2007	A TLV-TWA of 0.1 ppm is recommended for hexafluoropropylene (HFP), based on the subchronic inhalation data in both rats and mice that showed no-observed-adverse-effect levels (NOAELs) of 10 ppm
63	Hexahydrophthalic anhydry, all isomers [85-42-7;13149-00-3;14166-21-3;14166-21-3]	2004	A TLV-Ceiling of 0.005 mg/m^3 (5g/m^3) is recommended for HHPA. A sensitization notation (SEN) is proposed based on human and animal studies as discussed above. The TLV is based on the avoidance of IgE- and IgG-mediated disease, including sensitization, asthma, allergic rhinitis, asthma, hemorrhagic rhinitis, hypersensitivity pneumonitis, and ocular and upper respiratory tract irritation
64	1,6-Hexanediamine [124-09-4]	1992	A TLV-TWA of 0.5 ppm (2.3 mg/m^3) is recommended for occupational exposure to 1,6-hexanediamine (HMDA) to minimize the potential for upper respiratory tract and dermal irritation. Conflicting data have been reported from experimental studies with rats regarding reproductive and develop mental toxicity as a result of exposure to HMDA
65	1-Hexane [592-41-6]	1998	1-Hexene is used in fuels and in the manufacture of chemicals. The principal health effect in humans is reported central nervous system (CNS) depression. A TLV-TWA of 50 ppm is recommended, based on the no-observed-adverse-effect level (NOAEL) for decreased body weight seen in a 13-week inhalation study with Fischer 344 rats and the human CNS effect
66	Cyanite Salt [143-33-9;151-50-8;592-01-8]	1994	Derived from Cyanides
67	Iodides	2008	Derived from Iodine

번호	화학물질의 명칭	신규 년도	주요이유
68	Isobutyl nitrite [542-56-3]	2003	A TLV-Ceiling Limit of 1 ppm (4.2 mg/m^3), inhalable aerosol and vapor, is recommended for IBN. This ceiling limit is intended to minimize the potential for vascular and hematological effects in workers exposed to IBN
69	Kerosene [8008-20-6; 64742-81-0]/Jet fuels,as total hydrocarbon vapor	2003	It is the judgment of ACGIH that under work-place conditions kerosene and jet fuel exposures may be aerosol or vapor, but the hydrocarbons will be absorbed predominantly from the vapor state. Therefore, the TLV for kerosene/jet fuels applies to exposures in which the vapor phase predominates and that sampling systems collect only vapor
70	Manganese [7439-96-5], elemental	1995	Derived from Manganese
71	Manganese Inorganic compounds as Mn	1995	Derived from Manganese
72	Mercury [7439-97-6] all form except Akyl as Hg Aryl compounds	1993	Derived from Mercury
73	Mercury Elemental and inogarnic forms	1994	Derived from Mercury
74	Methyl tert-butyl ether (MTBE) [1634-04-4]	1994	Noting no symptoms noted in a chamber study of ten human subjects up to 50 ppm, a no-observed-adverse-effect level (NOAEL) for repeated was a low prevalence of cigarette smoking and no inhalation exposure of rats at 800 ppm, the NOAEL of 400 ppm in rats from a two-generation study, with renal toxicity noted in rats (both the dams and offspring) after inhalation of 300 and 3400 ppm, and taking into account the preferred value approach, a TLV-TWA of 50 ppm is recommended
75	1-Methylnaphthalene[90-12-0]and2-Methyl	2007	AA TLV-TWA of 0.5 ppm (3 mg/m^3) is recommended for both 1-methylnaphthalene (1-MN) and 2-methylnaphthalene (2-MN) to minimize the potential for upper respiratory

번호	화학물질의 명칭	신규 년도	주요이유
	naphthalene[91-57-6]		irritancy based on studies in mice. Other effects of exposure to these chemicals include alveolar proteinosis, which is probably secondary to damage to metabolically active cells in the respiratory epithelium, found in chronic studies in mice
76	Methyl vinyl ketone [78-94-4]	1999	A TLV-Ceiling of 0.2 ppm (0.6 mg/m^3) is recommended for occupational exposure to methyl vinyl ketone to minimize the potential for irritation of the skin, eyes, and respiratory tract and the risk of dermal sensitization or allergic type reactions. Because systemic toxicity as a result of skin absorption has been reported following dermal contact with methyl vinyl ketone, the Skin notation is assigned
77	Mineral oil, excluding metal working fluids Pure, highly and severely refined	2010	Derived from Oil mist, Mineral
78	Mineral oil, excluding metal working fluids Poorly and mildly refined	2010	Derived from Oil mist, Mineral
79	MolybdenumMetalandInsolubecompounds	2001	Derived from Molybdenum
80	MolybdenumMetalandInsolubecompounds	2001	Derived from Molybdenum
81	Monochloroacetic acid [79-11-8]	2006	-
82	Naturegas[8006-14-2] seeAppendix	2006	-
83	Nature ruber latex	2013	Animal experiments and human observational studies consistently demonstrate an excess risk

번호	화학물질의 명칭	신규 년도	주요이유
	[9006-04-6] as Inhalable allergenic proteins		of a sensitization or allergic reaction following repeated exposure to natural rubber latex (NRL). In humans, the most common adverse effect of latex exposure is irritant dermatitis of the hand. Skin exposure is an important risk factor and may be more important than respiratory exposure in predicting latex dermatitis and sensitization. This combined information indicates that a TLV-TWA of 0.0001 mg/m^3, measured as inhalable allergenic proteins, should be protective for unsensitized workers exposed primarily by inhalation
84	Nickel subsufide [12035-72-2] as Ni	1998	ACGIH believes that the TLV-TWA for nickel and its inorganic compounds should be expressed in terms of inhalable nickel particulate as opposed to "total" nickel particulate, because of the association between some forms of nickel and sinus cancer
85	3,5-Nitro-o-toluidine [99-55-8]	2007	The LOAEL in rats of 2.5 mg/kg body weight would be equivalent to an inhalation exposure of 17.5 mg/m^3. Thus, a TLV-TWA of 1 mg/m^3 should be protective
86	p,p'-Oxybis(bezenesulfonyl hydrazide) [80-51-3]	2000	Based on related chemicals, the reactive component of OBSH could be the hydrazide portion of the molecule; hydrazine, with a TLV-TWA of 0.01 ppm, is highly irritating to the skin, eye, and respiratory tract and is a positive carcinogen. Other compounds structurally related to OBSH, benzenesulfonyl hydrazine and 4-chloro-3-(N-sulfonylhydrazine) benzoic acid, are reported as marginally carcinogenic to the liver and lung of exposed animals
87	Ozone [10028-15-6] Heavy work	1997	Derived from Ozone
88	Ozone [10028-15-6] Moderate work	1997	Derived from Ozone
89	Ozone [10028-15-6] Light work	1997	Derived from Ozone
90	Ozone [10028-15-6] Heavy, moderate, or light workloads (< 2 hours)	1999	Derived from Ozone

번호	화학물질의 명칭	신규 년도	주요이유
91	2,4-Pentanedione [123-54-6]	2011	A TLV-TWA of 25 ppm (102 mg/m^3) is recommended for 2,4-pentanedione (PD) to protect against degenerative changes in the central and possibly the peripheral nervous systems, as well as adverse effects in the thymus
92	Pentyl actate, all isomers [123-92-2;620-11-1;624-41-9;625-16-1;626-38-0;628-63-7]	1999	Derived from n-Amylacetate, sec-Amylacetate, Isoamylacetate
93	Peracetic acid [79-21-0]	2014	-
94	Perflourobutyl ethylene [19430-93-4]	2004	TLV-TWA of 100 ppm is recommended for occupational exposure to PFBE. This value is based on the NOAELs of 500 and 2000 ppm, respectively, found in the 2- and 4-week subchronic inhalation studies in male and female rats, the concomitant with a mild toxicological effect measured at 5000 ppm (increased monocytes), and no histopathological effects observed at 500, 5000, or 50,000 ppm or at 400 or 2000 ppm. This value should be protective for workers exposed to PFBE vapor
95	Perflouroisobutylene [382-21-8]	1992	Based upon very limited, but relatively consistent animal data, a TLV-Ceiling of 0.01 ppm for PFIB is recommended to minimize the potential for acute pulmonary and adverse systemic effects in other organs, as documented in short-term laboratory studies at 0.1 ppm and above
96	Persulfates as persulfate	1996	It was reported that rats inhaling 4 mg/m^3 of ammonium persulfate exhibited symptoms of lung inflammation or edema and loss of body weight; at exposures of 1 mg/m^3, these effects were not statistically significant. Considering the low statistical power of the study and extrapolating information from animal data to humans, a TLV-TWA of 0.1 mg/m^3, as persulfate (S_2O_8) is commended for ammonium persulfate
97	Phenylisocyanate[103-	2015	-

번호	화학물질의 명칭	신규 년도	주요이유
	71-9]		
98	o-Phthalodinitrile [91-15-6]	2011	A TLV-TWA of 1 mg/m^3, measured as inhalable fraction and vapor, is recommended for occupational exposure to o-phthalodinitrile to protect against potential central nervous system toxicity as seen in multiple oral animal studies
99	Piperazineandsalts[110-85-0],aspiperazine	2012	A TLV-TWA of 0.03 ppm (0.1 mg/m^3) inhalable fraction and vaporise recommended for occupational exposure to piperazine and its salts (dihydrochloride, hexahydrate, citrate, phosphate, propionate, adipate, tartrate, quinate, sebacate) that are known to exhibit similar pharmacokinetic behavior
100	Polyvinyl chloride (PVC) [9002-86-2]	2008	Based on the results from studies in experimental animals and the cross-sectional studies in workers exposed to PVC dust, a TLV-TWA of 1 mg/m^3, respirable fraction, is recommended to prevent the occurrence of respiratory symptoms, chest radiographic changes, and decrements in pulmonary function in exposed workers
101	Propionaldehyde [123-38-6]	2002	Propionaldehyde was minimally irritating to the upper respiratory tract of mice; the concentration producing a 50% reduction in respiratory rate (RD50) exceeded 2,000 ppm in two strains of mice. Chemical concentrations that are 0.01 to 0.03xRD50 typically will not produce respiratory irritation in the workplace. Thus, based on a 2000 ppm RD50, a TLV of 20 to 60 ppm (i.e., 0.01 to 0.03 xRD50) is predicted to protect against respiratory irritation in humans
102	Silica, fume [69012-64-2]	1992	-
103	Silicon carbide [409-21-2] NonFibrous	2003	Derived from Silicon
104	Silicon carbide [409-21-2] NonFibrous	2003	Derived from Silicon

번호	화학물질의 명칭	신규 년도	주요이유
105	Silicon carbide [409-21-2] Fibrous including Whiskers	2003	Derived from Silicon
106	Strontium chromate [7789-06-2], as Cr	1992	Based on the study in which strontium chromate was a more potent carcinogen than calcium chromate, a TLV-TWA of 0.0005 mg/m^3, as Cr, one-half that for calcium chromate (0.001 mg/m^3, as Cr), is recommended
107	Sulfometuron methyl [74222-97-2]	1994	The lowest no-observed-adverse-effect level (NOAEL) determined in these feeding studies (50 ppm) is equivalent to approximately 5 mg/kg/day in the rat. Assuming a 70-kg worker inspiring 10 m^3 of air per day and 100% absorption, this would correspond to 35 mg/m^3. A 5 mg/m^3 TLV-TWA is recommended which incorporates a suitable safety factor from the lowest NOAEL
108	Synthetic vitreous fibers Continuous filament glass fibers	1997	Derived from Mineral wool fiber and Fibrous glass dust
109	Synthetic vitreous fibers Continuous filament glass fibers	1997	Derived from Mineral wool fiber and Fibrous glass dust
110	Synthetic vitreous fibers Glass wool fibers	1997	Derived from Mineral wool fiber and Fibrous glass dust
111	Synthetic vitreous fibers Rock wool fibers	1997	Derived from Mineral wool fiber and Fibrous glass dust
112	Synthetic vitreous fibers Slag wool fibers	1997	Derived from Mineral wool fiber and Fibrous glass dust
113	Synthetic vitreous	1997	Derived from Mineral wool fiber and Fibrous glass dust

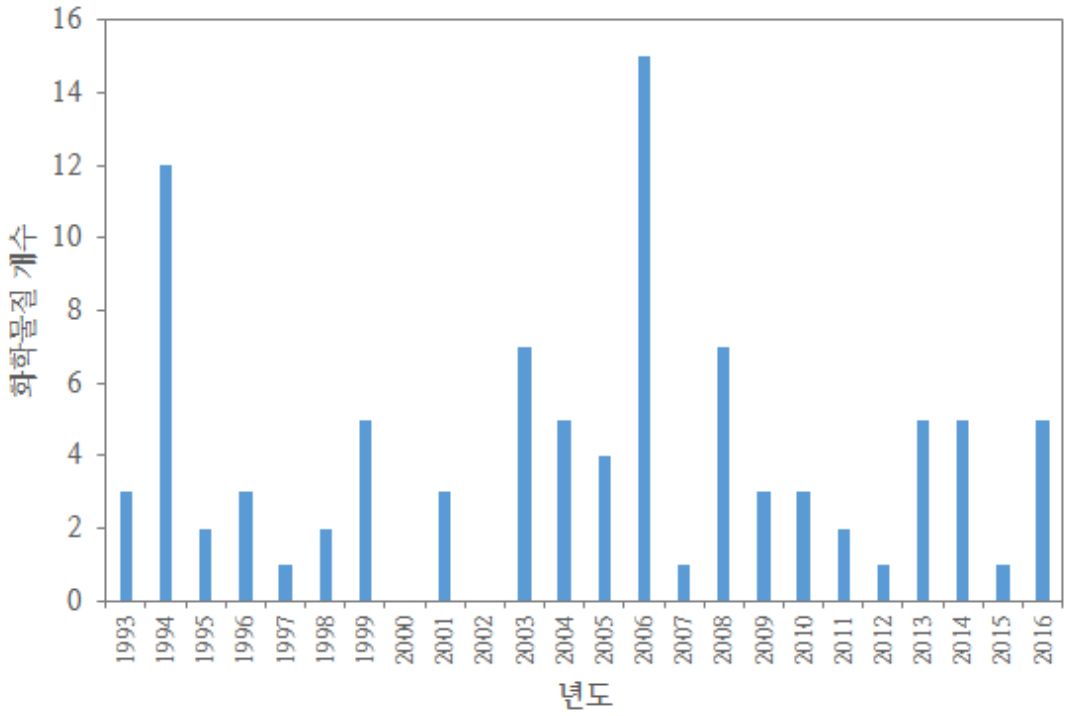
번호	화학물질의 명칭	신규 년도	주요이유
	fibers Special purpose glass fibers		
114	Synthetic vitreous fibers Refractory ceramic fibers	2001	Derived from Mineral wool fiber and Fibrous glass dust
115	Terbufos [13071-79-9]	2002	A TLV-TWA of 0.01 mg/m^3 is recommended for terbufos. The first response to terbufos (and organophosphates in general) involves decreased activity of cholinergic enzymes. No quantitative human data were available; consequently, this recommendation was derived from animal experiments
116	Tetrafluoroethylene [116-14-3]	2000	A TLV-TWA of 2 ppm is recommended for occupational exposure to tetrafluoroethylene. This value is intended to minimize the potential for kidney toxicity and liver and kidney cancers reported in rodents exposed to TFE at concentrations of 156 ppm and above for 6 hours/day, 5 days/week over nearly two years
117	Tetrakis (hydroxymethyl) phosphonium salts Tetrakis (hydroxymethyl) phosphonium chloride [124-64-1]	2005	A TLV of 2 mg/m^3 is recommended for tetrakis (hydroxymethyl) phosphonium salts, both the chloride and the corresponding sulfate. THPC and THPS are used to produce crease-resistant, flame retardant finishes on cotton textiles and cellulosic fabrics. Both compounds are crystalline solids
118	Tetrakis (hydroxymethyl) phosphonium salts Tetrakis (hydroxymethyl) phosphonium sulfate [55566-30-8]	2005	A TLV of 2 mg/m^3 is recommended for tetrakis (hydroxymethyl) phosphonium salts, both the chloride and the corresponding sulfate. THPC and THPS are used to produce crease-resistant, flame retardant finishes on cotton textiles and cellulosic fabrics. Both compounds are crystalline solids

번호	화학물질의 명칭	신규 년도	주요이유
119	Trichlorphon [52-68-6]	2003	Both human and primate studies indicate oral exposure to 0.2 mg/kg/day has marginal effects on Red Blood Cell (RBC) or brain cholinesterase, equivalent to about 1.4 mg/m^3 over an 8-hour day. Thus, a TLV-TWA of 1 mg/m^3 is recommended for occupational exposure to trichlorphon. This exposure limit is intended to prevent the occurrence of cholinergic symptoms and other adverse biologic effects in workers. It is derived from a no-observed-adverse-effect level obtained in humans and in animals, which corresponds to a dose that is not expected to result in any reductions in Red Blood Cell (RBC) acetylcholinesterase activity in a group of workers
120	Triethanolamine [102-71-6]	1993	Evidence for the carcinogenic potential of triethanolamine is inconclusive and genotoxicity studies were negative in bacterial assays and on mammalian cells in culture. A TLV-TWA of 5 mg/m^3 is recommended to minimize the potential for skin and eye irritation and acute and chronic effects, following exposure to triethanolamine
121	1,3,5 Triglycidyl-s-triazinetrione [2451-62-9]	1997	A TLV-TWA of 0.05 mg/m^3 is recommended for occupational exposure to 1,3,5-triglycidyl-s-triazinetrione (TGIC) to minimize the potential for adverse hematopoietic, spermatogonial, and fertility effects and because of unresolved concerns that TGIC may be a sensitizer. This value includes a substantial correction below the mouse no-observed-adverse-effect level (NOAEL) of 2.5 mg/m^3 for spermatogonial cell cytotoxicity because of uncertainties in interpreting and extrapolating the data and because of the concern for hematopoietic effects and possible sensitization
122	Turpentine [8006-64-2] and selected monoterpenes [80-56-8; 127-91-3; 13466-78-9]	2003	Derived from Turpentine
123	Vinyl fluoride [75-02-5]	1999	Under equivalent bioassay conditions in the same species, vinyl bromide was more than twice as potent as vinyl fluoride. The recommended TLV-TWA for vinyl fluoride is therefore 1 ppm, which is twice the current recommended TLV-TWA (0.5 ppm) for vinyl bromide
124	N-Vinyl-2-pyrrolidon	2003	For purposes of setting an airborne occupational exposure value for N-Vinyl-2-pyrrolidone

번호	화학물질의 명칭	신규 년도	주요이유
	e [88-12-0]		(NVP), the series of rat inhalation studies provides the best qualitative and quantitative information. In these studies, lifetime exposures at 5 ppm produced liver toxicity and nasal tissue changes in rats as well as liver, lung, larynx, and nasal tumors. These studies clearly demonstrated that NVP produced dose-related and exposure-related changes, and a no-observed-adverse-effect level was not determined. A TLV-TWA of 0.05 ppm should be sufficient to protect against these effects. Irritation does not appear to be a response in humans
125	Vinylidene fluoride [75-38-7]	1999	Based on the much lower rate of VDF metabolism compared with vinylidene chloride, a TLV-TWA of 500 ppm for VDF is recommended to minimize the potential of hepatic or other systemic toxicity
126	Wood dusts Western red cedar	2005	Derived from Wood dusts
127	All other species (wood dust)	2005	Derived from Wood dusts
128	Wooddusts Birch, mahogany, teak, walnut	2005	Derived from Wood dusts
129	Wooddusts All other wood dusts	2005	Derived from Wood dusts
130	zinc oxide [1314-13-2]	2003	A TLV-TWA of 2 mg/m^3 is recommended for occupational exposure to zinc oxide. This is to reduce the incidence of metal fume fever, which is characterized by chills, muscular pain, nausea, and vomiting. A TLV-STEL of 10 mg/m^3 is also recommended, based on controlled clinical exposures that demonstrated a significant pulmonary response occurs after a brief exposure to high levels of zinc oxide (greater than 10 mg/m^3)

제 5 절 TLV가 삭제된 화학물질

1991년부터 2016년까지 25년간 TLV 소책자에서 삭제된 화학물질은 95종이었다. 연도별 삭제된 화학물질 개수는 [그림 4]와 같다.



[그림 4] 연도별 삭제된 화학물질개수.

화학물질 중에서 TLV가 삭제된 이유 중 하나는 개별로 설정되어 있던 TLV를 보다 넓은 범위의 화합물 군으로 합쳐진 친 것이 일부 있기 때문이다. 그 외의 삭제 이유는 불충분한 자료와 Minimal Oxygen Content 등이 있다.

Minimal Oxygen Content란 단위용적의 혈액에 녹아있는 산소의 총량을 말한다. Acetylene, Argon, Ethane, Helium, Hydrogen, Neon, Nitrogen과 같은 단순질식제의 경우 혈액 내에 최소한의 산소함량만 있으면 별도로 노출기준을 설정할 필요가 없다고 보고 TLV 기준을 삭제하였다. Calcium carbonate, Silicon 등은 데이터가 불충분하다고 판단하여 TLV를 삭제했다.

개별 화학물질의 TLV는 삭제하고 하나의 화합물 군으로 합친 것은 n-Butyl acetat, sec-Butyl acetate, tert-Butyl acetate를 삭제하고 Butyl acetate, all isomers 하나로 합쳤다.

Butane, Methane, Propane은 2004년도에 Aliphatic hydrocarbon gases Alkanes[C1-C4]로 합쳤다가 2013년도에 Minimal Oxygen Content만 설정하면 된다고 판단하여 Aliphatic hydrocarbon gases Alkanes[C1-C4]는 삭제하였다.

〈표 13〉 1991년과 2016년 사이에 TLV 리스트에서 삭제된 화학물질

번호	화학물질의 명칭	삭제년도	이유
1	Acetylene [74-86-2]	2015	Minimal Oxygen Content
2	Aliphatic hydrocarbon gases Alkanes [C1-C4]	2013	Methane, Ethane, Propane, Liquefied petroleum gas (LPG) and Natural Gas-refer to Minimal Oxygen Content.. Butane and Isobutane refer to Butane all isomers
3	Aluminum metal [7429-90-5] Metal dust	2008	Combined into Aluminum metal and insoluble compounds
4	Aluminum metal [7429-90-5] Pyro powder	2008	Combined into Aluminum metal and insoluble compounds
5	Aluminum metal [7429-90-5] Welding Fumes	2004	Combined into Aluminum metal and insoluble compounds
6	Aluminum metal [7429-90-5] Soluble salts	2008	Combined into Aluminum metal and insoluble compounds
7	Aluminum metal [7429-90-5] Alkyls	2008	Combined into Aluminum metal and insoluble compounds
8	Aluminum oxide [1344-28-1]	2008	Combined into Aluminum metal and insoluble compounds
9	n-Amyl Acetate [628-63-7]	1999	CombinedtoPentylactate,allisomers
10	sec-Amyl Acetate [626-38-0]	1999	CombinedtoPentylactate,allisomers
11	Anisidine [29191-52-4] (o-,p-isomers)-Skin	1996	Separated to o-Anisidine; p-Anisidine
12	Antimony trioxide [1309-64-4] Handing and use s Sb	1994	-
13	Argon [7440-37-1]	2014	Mineral Oxygen content
14	Arsenic trioxide production [1327-53-3]	1994	-

번호	화학물질의 명칭	삭제년도	이유
15	Amosite [12172-73-5]	1994	Combined to Asbestos all form
16	Chrysotile [1(2001-29-5]	1994	Combined to Asbestos all form
17	Crocidolite [1(2001-28-4]	1994	Combined to Asbestos all form
18	AsbitosOtherform	1994	Combined to Asbestos all form
19	Borate tetra, sodium salts [1303-96-4] Anhydrous	2005	Combined into Borate Compounds
20	Borate tetra, sodium salts [1303-96-4] Decahydrate	2005	Combined into Borate Compounds
21	Borate tetra, sodium salts [1303-96-4] Pentahydrate	2005	Combined into Borate Compounds
22	Butane [106-97-8]	2004	Presently covered by Aliphatic hydrocarbon gases) Alkane[C1-C4]
23	n-Butyl acatate [123-86-4]	2016	refer to Butyl acetate, all isomers
24	sec-Butyl acetate [105-46-4]	2016	refer to Butyl acetate, all isomers
25	tert-Butyl acetate [540-88-5]	2016	refer to Butyl acetate, all isomers
26	Cadmium oxide [1306-19-0] Fume as Cd	1993	Combined to Cadmium compounds
27	Cadmium oxide [1306-19-0] Production	1993	Combined to Cadmium compounds
28	Calcium carbonate [471-34-1]	2007	Insufficient data
29	Calcium sulfate [13397-24-5]	2006	Represent by Calcium sulfate [7778-18-9; 10034-76-1; 10101-41-4; 13397-24-5]
30	Calcium silicate, synthetic nonfibrous [1344-95-2]	2016	Represent by Calcium silicate, natrually accurring as Wollastonite [1344-95-2]
31	Caprolactam [105-60-2] Dust	2003	Represent by Caprolactam [105-60-2]
32	Caprolactam [105-60-2] Vapor	2003	Represent by Caprolactam [105-60-2]
33	Chlorinate diphenyl oxide [55720-99-5]	1994	o-Chlorinated diphenyl oxide [31242-93-0]

번호	화학물질의 명칭	삭제년도	이유
34	Chromium [7440-47-3] Metal	1994	Combined to Chromium [7440-47-3] Metal and Cr III compounds
35	Chromium II compounds as Cr	1994	Combined to Chromium [7440-47-3] Metal and Cr III compounds
36	Chromium III compounds as Cr	1994	Combined to Chromium [7440-47-3] Metal and Cr III compounds
37	Coel dust 1987	1998	Separated to) Coal dust (1995)Anthracite Coal dust (1995)Bituminous or Lignite
38	Cresol [1319-73-3] all isomer skin (1977)	2010	-
39	Diquat [231-36-7]	1993	TLV-TWA, 0.5 mg/m^3, inhalable particulate, as the cation; 0.1 mg/m^3, respirable particulate, as the cation
40	Emery [1320-74-5]	2008	Combined into Aluminum metal and insolube compounds
41	Ethane [74-84-0] see Appendix F) Mineral Oxigen content	2013	Mineral Oxygen content
42	Fibrousgasdust	1996	-
43	Glycerin mist [56-81-5]	2013	Insufficient data relevant to human occupational exposure
44	Helium [7440-57-7] see Appendix	2014	Refer to Minimal oxygen content
45	Hydrogen [1333-74-0] see Appendix	2014	Refer to Minimal oxygen content
46	Iron oxide Fume (Fe2O3) [1309-37-1]	2006	Combined into Iron Oxide
47	Isoamyl acetate [123-92-2]	1999	-

번호	화학물질의 명칭	삭제년도	이유
48	Isobutyl acetate [110-19-0]	2016	Refer to Butyl acetates, all isomers
49	lead asenate [7784-40-9]	2009	Insufficient data
50	L.P.G [68476-85-7]	2013	Insufficient data
51	manesite [564-93-0]	2006	Insufficient data
52	Manganese Dust	1995	Manganese [7439-96-5], elemental
53	Manganese fume	1995	-
54	Mercury[7439-97-6] all form xcept Akyl,as Hg, Aryl and organic coupound	1994	Represented by Mercury [7439-97-6] all form except Alkyl as Hg Aryl compounds, Elemental and inorganic forms
55	All form except Akyl Vapor	1994	Represented by Mercury [7439-97-6] all form except Alkyl as Hg Aryl compounds, Elemental and inorganic forms
56	Methane [74-82-8]	2004	Presently covered by Aliphatic hydrocarbon gases) Alkane [C1-C4]
57	Mineral wool fiber	1996	-
58	Molybdenum Insolube compounds	2001	-
59	Neon [7440-01-9] see Appendix	2014	Refer to Minimal oxygen content
60	Nickel sulfide roasting fume & dust as Ni	1998	See Nikel Subsulfide
61	Nitrogen [7727-37-9] See Appendix	2014	Refer to Minimal oxygen content
62	oilmist,mineral	2010	Refer to Mineral oil, including metal working fluids
63	Ozone [10028-15-6]	1997	Separated to) Ozone [10028-15-6] Heavy work Ozone [10028-15-6] Moderate work

번호	화학물질의 명칭	삭제년도	이유
			Ozone [10028-15-6] Light work Ozone [10028-15-6] Heavy, moderate, or light workloads (< 2 hours)
64	Perlite [93-763-70-3]	2006	Insufficient data
65	Phosphorus [7723-14-0]	2013	Correct CAS number to 12185-10-3
66	Piperazine dihydrochloride [142-64-3]	2012	Refer to Piperazine and salts
67	Polytetraflouroethylene decomposition product	2004	-
68	Propane [74-98-6] see appedix F	2004	Presently covered by Aliphatic hydrocarbon gases) Alkane[C1-C4]
69	Propylene glycol mono-methyl ether [107-98-2]	2001	Alphabetical listing changed from popylene glycol mono-methyl ether
70	Rouge	2006	Combined into iron oxide
71	Rubbersolvent	2009	-
72	Silica -Amorphous Diatomaceous earth [61790-53-2]	2006	Insufficient data on single-substance exposure, most are co-exposures with crystalline silica
73	Silica, fume [69012-64-2]	2006	Insufficient data
74	Silica -Amorphous Precipitated silica [112926-00-8]	2006	Insufficient data
75	Silica -Amorphous Silica gel [1129926-00-8]	2006	Insufficient data
76	Silica, Crystaline- Quartz [14808-60-7]	2006	Combined into one TLV® and Documentation, i.e., Silica, crystalline
77	Silica, fused [60676-86-0]	2006	Insufficient data
78	Silica, CrystalineTridymite [15468-32-3]	2005	Insufficient data
79	Silica, CrystalineTripoli [1317-95-9]	2006	Insufficient data and unlikely single-substance

번호	화학물질의 명칭	삭제년도	이유
			exposure. Combined into one TLV® and Documentation, i.e., Silica, crystalline
80	Silicon [7440-21-3]	2006	Insufficient data
81	Siliconcarbide [409-21-2]	2003	Separated to NonFibrous and Fibrous including Whiskers
82	Soapstone Respirable dust	2011	Refer to Talc
83	Soapstone Total dust	2011	Refer to Talc
84	Tantalum [7440-25-7] metal and oxide [1314-61-0] dust as Ta	2010	Insufficient data
85	TEPP [107-49-3] skin	1999	-
86	Tetrasodium pyrophosphate [7722-88-5]	2006	Insufficient data
87	Tryphenyl amine [603-34-9]	2008	Insufficient data
88	Turpentine [8006-64-2]	2003	-
89	Vegatable Oil Mist	2006	Insufficient data
90	VM 7 P Naphtha [8032-32-4]	2009	Refer to Appendix H) Reciprocal Calculation Method for Certain Refined Hydrocarbon Solvent Vapor Mixtures
91	Welding fumes (NOC)	1999	-
92	Solf wood	2001	-
93	Zinc oxide [1314-13-2] Fume	2003	Combined to Zinc oxide [1314-13-2]
94	Zinc oxide [1314-13-2] Dust	2003	Combined to Zinc oxide [1314-13-2]
95	Particulates Not Otherwise Classified (PNOC) see Appendix B	2003	Insufficient data

제 6 절 기타 변경사항

TLV 값을 상향 또는 하향 조정하는 것과 신규로 추가하거나 삭제하는 것 이외에도 TLV 기준을 변경한 것들이 있다. 예를 들어 Ethylene의 경우에 1991년도에 구체적 TLV값을 설정하지 않았지만 권고지침에 단순한 질식제로 지정했다. Ethylene은 동물과 사람의 체내에서 발암 물질로 의심되는 ethylene oxide (EtO)로 변환된다. Ethylene은 ethylene oxide (EtO)와 마찬가지로 인간에게 헤모글로빈 부가체도 생성한다. 만성 독성 연구 및 Ethylene과 ethylene oxide (EtO)의 관계를 바탕으로 2005년도에 TWA를 200 ppm으로 추천했다. ACGIH는 현재 지식을 기반으로 Ethylene은 TWA 200 ppm 노출될 경우, 노동자에게 발암 가능성은 거의 없다고 보고 있다.

〈표 14〉 1991년과 2016년 사이에 TLV의_STEL 및 C와 관련된 변경이 있었던 화학물질

번호	화학물질의 명칭	변화년도	주요이유
1	Acetaldehyde[75-07-0]	(1991-1992) STEL-100 ppm (1992-2016) C25 ppm	A TLV-Ceiling of 25 ppm (45 mg/m^3) is recommended for occupational exposure to acetaldehyde to reduce the potential for ocular and upper respiratory tract irritation. Sensitive workers concentrations as low as 25 ppm
2	Acetic anhydride [108-24-7]	(1991-1992) C5 ppm (1992-2010) TWA-5 ppm (2011-2006) TWA-1 ppm, STEL-3 ppm	Clinical and microscopic evidence of respiratory tract irritation was observed in a 13-week inhalation study in rats at concentrations 〉 5 ppm with a no-observed-adverse-effect level (NOAEL) of 1 ppm, i.e., the true threshold for irritation was between 1 and 5 ppm in this study (HLS, 1996). Inhalation of vapor concentrations above 5 ppm produces immediate irritation of the eyes and upper respiratory tract. A TLV-TWA of 1 ppm (4.2 mg/m^3) and a TLV-STEL of 3 ppm (13 mg/m^3) are recommended for occupational exposure to acetic anhydride
3	Acrolein [107-02-8]	(1991-1997) TWA-0.1 ppm, STEL-0.3 ppm (1998-2016) C0.1 ppm	A TLV-Ceiling of 0.1 ppm (0.23 mg/m^3) is recommended for occupational exposure to acrolein. This value is intended to minimize the potential for intense irritation of the eyes, mucous membranes, and respiratory tract and the development of pulmonary edema. An irritation threshold to all mucous membranes within 5 minutes was reported to be 0.25 ppm, and human fatalities were reported from exposure at concentrations as low as 10 ppm
4	n-Butanol [71-36-3]	(1991-2001) C50 ppm (2001-2016) TWA-20 ppm	Several early 1940s reports indicate that ocular irritation is the primary adverse effect consistently reported following occupational exposure to n-butanol. Thus, eye irritation is the endpoint upon which control of occupational exposure to n-butanol can most reliably be based. Observational human studies from the 1940s indicated that exposures below 100 ppm did not result in excessive complaints of irritation. Inhalation chamber studies with naive subjects also indicated that exposures over 50 ppm resulted in ocular irritation. Given these reports,

번호	화학물질의 명칭	변화년도	주요이유
			a TLV-TWA of 20 ppm should be protective of n-butanol ocular irritancy. Importantly, a 20 ppm TLV-TWA will prevent the possibility of attaining n-butanol exposures greater than 100 ppm, the concentration at which the most reliable worker study suggested was the threshold for initiation of eye irritation
5	Carbon tetrachloride [56-23-5]	(1991-1992) TWA-5 ppm (1993-2016)TWA-5 ppm, STEL-10 ppm	The recommended TLV-STEL is based on the prediction from pharmacokinetic modeling that workers exposed to an 8-hour TWA carbon tetrachloride concentration of 5 ppm, provided that a 15-minute concentration at no time exceeds 10 ppm, would not experience hepatocellular toxicity as observed in rats at higher concentrations
6	Crotonaldehyde [4170-30-3]	(1991-1997) TWA-2 ppm (1998-2016) C0.3 ppm	Given that crotonaldehyde is a rapidly acting irritant, producing lacrimation and upper respiratory tract irritation within 30 seconds of exposure at 4.1 ppm, and it is equipotent to formaldehyde in the mouse RD50 assay, a TLV-Ceiling of 0.3 ppm is assigned, by way of analogy with the TLV-Ceiling limit for formaldehyde, for which considerable data on human ocular and upper respiratory tract irritation exist
7	Cyanogen [460-19-5]	(1991-2015) TWA-10 ppm 2016: C5 ppm	-
8	Di(2-ethylhexyl)phthalate(DEHP)[117-81-7]	(1991-1998) TWA-5 mg/m³, STEL-10 mg/m³ (1999-2016) TWA-5 mg/m³	Sufficient data were not available to recommend Skin or SEN notations or a TLV-STEL
9	Diethyl ketone [96-22-0]	(1991-1997) TWA-200 ppm (1998-2016)	TLV-STEL of 300 ppm is recommended in keeping with the homologous series of the ketones

번호	화학물질의 명칭	변화년도	주요이유
		TWA-200 ppm, STEL-300 ppm	
10	Dimethyl carbamoyl chloride [79-44-7]	(1991-2006) A2 (2007-2016) TWA-0.005 ppm	A TLV-TWA of 0.005 ppm (5 ppb) is recommended for dimethyl carbamoyl chloride (DMCC). This value is based on the tumorigenic response of rodents to airborne concentrations as low as 0.3 and 0.5 ppm (300 and 500 ppb). The recommended value should be sufficiently low to protect against all unwanted effects of this chemical
11	Ethanol [64-17-5]		
12	Ethylene [74-85-1]	(1991-2004) None (2005-2016) TWA-200 ppm	A TLV-TWA of 200 ppm is recommended, based on the chronic toxicity study that established a no-observed-adverse-effect level of 3000 ppm and incorporating a suitable uncertainty factor
13	Ethyl formate [109-94-4]	(1991-2011) TWA-100 ppm (2012-2016) STEL-100 ppm	A TLV-STEL of 100 ppm (303 mg/m^3) is recommended for occupational exposure to ethyl formate to minimize upper respiratory and overt central nervous system effects. Ethyl formate is an upper respiratory irritant. In human exposures, ethyl formate was found to be an irritant at concentrations of 330 ppm to 1000 ppm. Animals exposed to 5000 ppm ethyl formate showed eye irritation and salivation. A TLV-STEL of 100 ppm will also be protective of overt central nervous system effects found at much higher levels
14	Formaldehyde [50-00-0]	(1991-1992) TWA-1 ppm, STEL-2 ppm (1993-2016) C0.3 ppm	A TLV-Ceiling of 0.3 ppm (0.37 mg/m^3) is recommended for occupational exposure to formaldehyde. This value is recommended to minimize the potential for sensory irritation, chiefly eye and upper respiratory tract. Although the recommended TLV is intended to protect nearly all workers, ACGIH recognizes that the value may not safeguard that portion of the worker population (10%-20%) reported to be responsive to low ambient concentrations (<0.25 ppm) of the chemical, e.g., workers in schools, offices, laboratories, or other settings, where

번호	화학물질의 명칭	변화년도	주요이유
			formaldehyde or formaldehyde-containing products, such as particle board, insulation, and carpets, are used
15	Lithium hydride [7680-67-8]	(1991-2014) TWA-0.025 mg/m^3 (2015-2016) C0.05 ppm	-
16	Mevinphos [7786-34-7]	(1991-2002) TWA-0.01 ppm, STEL-0.03 ppm (2003-2016) TWA-0.01 ppm	A sensitizer (SEN) notation is not proposed nor is a TLV-STEL because there were inadequate data to evaluate the need for either
17	Methyl n-butyl ketone [591-78-6]	(1991-1997) TWA-5 ppm (1998-2016) TWA-5 ppm, STEL-10 ppm	A TLV-STEL is recommended to control exposure concentrations, which have the potential to induce testicular toxicity. A Skin notation is assigned, based on data reporting absorption of MnBK through the skin of humans that contributed substantially to the total body burden
18	Methyl hydrazine [60-34-4]	(1991-1994) C0.2 ppm (1995-2016) TWA-0.01 ppm	A TLV-TWA of 0.01 ppm (0.019 mg/m^3) is recommended for occupational exposure to methyl hydrazine. This value is intended to minimize the potential for upper respiratory tract and ocular irritation, liver damage, plasmacytosis, and tumorigenicity seen in animals exposed to methyl hydrazine
19	Methyl isocyanate [624-83-9] skin	(1991-2014) TWA-0.02 ppm (2015-2016) TWA-0.02 ppm, STEL-0.06 ppm	-
20	Naphthalene [91-20-3]	(1991-2013) TWA-10 ppm,	-

번호	화학물질의 명칭	변화년도	주요이유
		STEL-15 ppm (2014-2016) TWA-10 ppm	
21	Nickel carbonyl [13463-39-3]	(1991-2012) TWA-0.05 ppm (2013-2016) C0.05 ppm	Sufficient data were not available to recommend Skin, SEN, or carcinogenicity notations or a TLV-STEL
22	Octane [111-65-9]	(1991-1998) TWA-300 ppm, STEL-375 ppm (1999-2016) TWA-300 ppm	Sufficient data were not available to recommend TLV-STEL
23	Propylene [115-07-1]	(1991-2005) None (2006-2016) TWA-500 ppm	A TLV-TWA of 500 ppm is recommended for occupational exposure to propylene. This value is intended to prevent changes in nasal mucosa, based on the chronic animal studies
24	Sodium flouroacetate [62-74-8]	(1991-1993) TWA-0.05 mg/m^3, STEL-0.15 mg/m^3 (1994-2016) TWA-0.05 mg/m^3	Sufficient data were not available to recommend TLV-STEL
25	Vinylidene chloride [75-35-4]	(1991-1998) TWA-5 ppm, STEL-20 ppm (1999-2016) TWA-5 ppm	Sufficient data were not available to recommend TLV-STEL

제 4 장 결 론

본 연구는 1991년부터 2016년까지 ACGIH-TLV의 화학물질에 대하여 TLV값의 변화(상향 또는 하향조정) 및 삭제나 추가 그리고 STEL 및 C의 추가나 변경 등의 변경사항을 파악하고 분석하였다.

ACGIH에서 발간한 TLV 소책자에 수록된 화학물질 종류는 1991년에는 659종이었고, 2016년도에는 694종인 것으로 나타났다.

1991년도부터 2016년 현재까지 TLV 기준에 전혀 변화가 없는 화학물질은 384종이었다. 지난 25년간 TLV값이 하향 조정된 물질은 151종이었다. 반면 상향 조정된 화학물질은 4종이었다. 1991년부터 2016년 사이에 TLV 소책자에서 삭제된 화학물질은 95종이었고, 새롭게 추가된 화학물질은 130종이었다.

1991년 이후 2016년까지 TLV값이 하향 조정된 정도(감소율)가 20%이하인 경우는 5종, 20~30%인 경우가 3종, 30~40%는 3종, 40~50%는 30종, 50~60%가 12종, 60~70%가 5종, 70~80%가 37종, 80~90%가 34종, 90% 이상 감소한 화학물질은 20종인 것으로 나타났다.

TLV값이 상향조정된 화학물질은 Butane, Nickel Elemental, Pentane 및 Tributyl phosphate 등 4개였다.

1991년부터 2016년까지 25년간 TLV 소책자에 새롭게 나타난 화학물질은 총 130개였다. 새롭게 TLV가 추가된 화학물질 중 일부는 1991년 및 그 이전에는 각각 별개의 노출기준을 가지고 있던 화학물질을 묶어서 크게 하나의 화합물(compound) 군으로 표현한 것들이 있다. 그 외에 여러 연구를 통해 새롭게 건강장해가 밝혀진 것들은 신규로 TLV를 추가한 것이다.

1991년부터 2016년까지 25년간 TLV 소책자에서 삭제된 화학물질은 95종이었다. 삭제된 이유는 각각 TLV가 설정되어 있던 개별 화학물질을 보다 넓은 범위 또는 유사한 것을 하나의 화합물 군으로 합치면서 개별 화학물질은 삭제된 것이 있고, 일부는 자료 불충분으로 삭제했으며, 일부 단순 질식제는 Minimal Oxygen Content로 대체하면서 삭제하였다.

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ABSTRACT

A Study on Changes of American Conference of Governmental Industrial Hygiene (ACGIH) Threshold Limit Values (TLVs) for Chemical Substances during 1991-2016

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This study was conducted to analyze the changes of American Conference of Governmental Industrial Hygiene (ACGIH) Threshold Limit Values (TLVs) for Chemicals during 1991-2016. There has been significant changes such as decrease, increase, elimination, addition and changes over last 25 years.

Total number of chemical substances in the 1991 version of TLV booklet was 659 and it has increased to 694 in the 2016 version.

Total 384 chemical substances were no changes between the year of 1991 and 2016. The TLV values were reduced for 151 chemicals and increased for 4 chemicals. Ninety-five chemicals were removed from the list, and 130 chemicals were added in the list.

Among 151 chemicals which TLV values were reduced, Twenty

chemicals' TLV values were reduced more than 90% compared to previous TLVs. Five chemicals's TLV values reduced less than 20%; 3 chemicals 20~30%; 3 chemicals 30~40%; 30 chemicals 40~50%; 12 chemicals 50~60%; 5 chemicals 60~70%; 37 chemicals 70~80%; 34 chemicals 80~90%.

TLV values for Butane, Nickel Elemental, Pentane and Tributyl phosphate were increased. The number of chemicals newly added in the TLV booklet between 1991 and 2016 was 130, and 95 chemicals were removed from the list of the booklet.

【Key words】 TLV changes, ACGIH-TLV, Threshold Limit Values, Occupational Exposure Limit.