Case Report

Reassessment of Occupational Exposure Limits

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Background *Although the Netherlands currently has its own procedure for evaluating chemical compounds and setting occupational exposure limits (OELs), most of these limits were originally adopted in the 1970s from threshold limit values (TLVs) set by the American Conference of Governmental Industrial Hygienists (ACGIH). However, beginning in the late 1980s, criticism about non-scientific considerations being used to set TLV's suggested that TLVs might not offer sufficient health protection to workers. This situation prompted the Dutch Ministry of Social Affairs and Employment to request that the Health Council of the Netherlands reassess the health protection of MAC values that were contained in the 1994 Dutch MAC list.*

Methods *Criteria documents were prepared for 161 compounds. They were evaluated by a committee of the Health Council of the Netherlands consisting of international experts who reassessed the toxicological hazards of these substances and recommended, whenever possible, health-based OELs. The results of the reassessment by the Health Council were compared with the MAC values of the 1994 Dutch MAC list, ACGIH TLVs, and existing German OELs.*

Results *The toxicological database met the committee's criteria for a health-based OEL for only about 40% of the compounds.*

Conclusions *Many older MAC values were either too high or not scientifically supported and therefore not health-based.* Am. J. Ind. Med. 51:407–418, 2008. *© 2008 Wiley-Liss, Inc.*

KEY WORDS: occupational exposure limits; occupational health; TLVs

INTRODUCTION

The threshold limit values (TLVs) published by the American Conference of Governmental Industrial Hygienists (ACGIH) have been adopted as occupational exposure limits (OELs) in countries all over the world, including the Netherlands in the 1970s and Germany in the 1950s. However, beginning in the late 1980s, criticism about non-scientific considerations being used to set TLV's suggested that TLVs might not offer sufficient health protection to workers. The criticism, which voiced internationally [Castleman and Ziem, 1988; Ziem and Castleman, 1989; Roach and Rappaport, 1990; Robinson et al., 1991] and in the Netherlands [Ulenbelt, 1991; Ulenbelt et al., 1991; Bus and Posthuma, 1992], concerned strong corporate influence in developing TLVs and the quality of the justifications underlying TLVs. This prompted the Dutch Ministry of Social Affairs and Employment to request that the Health Council of the Netherlands reassess the health protection of the MAC values listed in the 1994 Dutch MAC list.

This article describes the results of the reassessment by the Health Council.

History of Setting Occupational Standards

The derivation of acceptable air concentrations for chemicals in the workplace started in Germany. At the end of the 19th century, Lehmann was the first to publish maximum

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concentrations for a number of compounds. At the beginning of the 20th century, occupational standard setting began in the United States and Russia. In the United States several organizations were formed, including the American Standards Association which introduced the term ''maximum allowable concentration'' (MAC). However, the most well known and influential organization that dealt with OELs was ACGIH, founded in the 1930s. In 1947, ACGIH published its first list with more than 150 OELs defined as TLVs [Notten, 1979].

In 1955 in the Federal Republic of Germany, the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) set up the Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission). Initially, this commission published lists with the maximale Arbeitsplatzkonzentrationen (MAK), which were largely adopted from the ACGIH lists. The first MAK list appeared in 1958. From 1969 onwards, the MAK Commission developed health-based OELs from its own documentation and evaluations. At present, in most cases the Commission relies exclusively on scientific publications or reports that are fully available to the public. If necessary, unpublished internal company data in the form of complete study reports are also included. These are then identified as such in the reference list of the documentation. The OELs set by the MAK Commission are exclusively based on scientific arguments. Personal communications and aspects such as economic and technical feasibility are excluded [Woitowitz, 1988; Deutsche Forschungsgemeinschaft, 2006]. Next, the Committee on Hazardous Substances (Ausschuss für Gefahrstoffe, AGS), consisting of representatives of industry, trade unions, authoritative bodies, and the scientific community, is responsible for incorporating these values into national regulation [Woitowitz, 1988].

The regulatory basis for OELs in Germany is the Hazardous Substances Ordinance (Gefahrstoffverordnung), which was completely revised and made effective in January 2005. This new ordinance now refers only to health-based OELs (Arbeitsplatzgrenzwerte, AGW) whereas previously, AGS also established technically based OELs. The latter commonly described as exposure concentrations that could be achieved by existing technology. Health-based regulatory OELs are listed in the Technical Rule for Hazardous Substances 900 (Technische Regel für Gefahrstoffe, TRGS 900), which is published by the German Ministry of Labor and Social Affairs in the Gemeinsames Ministerialblatt and also on the homepage (www.baua.de) of the Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA). In most cases, the recommendations for health-based OELs of the MAK Commission or the European Union (indicative occupational exposure limit values, IOELVs) form the basis for inclusion in TRGS 900. These recommendations are examined by Subcommittee III (*Evaluation of Hazardous Substances*) of the AGS. Thereafter the Subcommittee III proposes a health-based OEL to the AGS. In addition, the Subcommittee III derives health-based OELs on its own and proposes them to the AGS as well. After adopting the OELs, the AGS recommends them to the Federal Ministry of Labor and Social Affairs, which includes the OELs in the TRGS 900.

In the Netherlands, the first list of OELs was published in 1978 and consisted mainly of TLVs adopted from the ACGIH list. At the same time, the minister of Social Affairs and Employment decided to become independent from foreign organizations and develop national limit values (MAC values) using its own procedure. One of the reasons was that the Ministry felt the TLVs were poorly documented in many cases. To this end, a three-step procedure was set up [Notten, 1979]. During the first step, the Dutch Expert Committee on Occupational Standards (DECOS) (a standing committee of the Health Council of the Netherlands since 1994) evaluated data on the toxicokinetics and toxicodynamics of a substance from scientific publications and other reports that were fully available to the public and derived a health-based recommended OEL (HBROEL). This step included the release of a draft document for public review and a final ''internal'' review by the Council's Standing Committee on Health and Environment. During the second step, only technical and economic aspects of the feasibility of the recommended health-based value were discussed by the OEL Subcommittee, a committee of the Social and Economic Council. If there were constraints on the applicability, the OEL Subcommittee might recommend another OEL or a time frame for determining the health-based OEL. Based on both recommendations, the State-Secretary of Social Affairs and Employment set a legally binding MAC value that was marked as such in the Dutch MAC list. In case the OEL was different from the HBROEL, this was indicated in the list.

The three-step procedure for setting MAC values in the Netherlands has been replaced by a new system of public and private OELs which became effective on January 1, 2007. The new system implies that, basically, employers and employees are responsible for developing health-based private OELs for most substances. According to Dutch regulations, employers must ensure safe working conditions. The ministry of Social Affairs and Employment sets public OELs for only a selected number of compounds, and adopts the IOELVs of the European Union. For genotoxic carcinogenic compounds, the ministry will continue to request cancer risk calculations by the Health Council and evaluation of the feasibility of these cancer risk values by the subcommittee of the Social Economic Council. As a consequence of the new system, the State Secretary of Social Affairs and Employment published a list of legally binding OELs in December 2006. This list consists of about 125 OELs for non-carcinogenic compounds (part A) and about 45 OELs for genotoxic carcinogenic compounds (part B) [see Ministry of Social Affairs and Employment, 2006].

Background of the Updating Project

Since the health protection of TLVs was questioned and most limit values in the Dutch MAC list were adopted from the TLV list, the Dutch State Secretary of Social Affairs and Employment requested the TNO Nutrition and Food Research Institute[1] (Zeist, the Netherlands) to perform a screening of the degree of health protection of the MAC values in the 1994 MAC list. For this purpose, concise toxicity profiles were prepared on almost 300 substances based on the ACGIH documentation and criteria documents from other European countries (Germany and Nordic countries). TNO concluded that for about 100 substances, the adopted MAC values were not sufficiently protective. For another approximately 100 substances, the MAC values could not be supported with the available toxicological database [Feron et al., 1995].

After consultation of the Social and Economic Council, the State Secretary requested that the Health Council of the Netherlands in April 1997 reassessed the toxicological hazard posed by 196 substances and recommended (when possible) health-based OELs. Given the international character of the TLVs and in view of the European harmonization, the State Secretary asked the President of the Health Council to set up a committee consisting of international experts. Members of the committee were selected from a list of nominees composed after consultation among regulatory organizations of several European countries. From each country, one member was invited to participate in a non-official capacity. A representative of ACGIH was invited as an advisor. All members were acknowledged experts in toxicology, epidemiology, or occupational medicine, as well as experienced in setting OELs. Beside the chairman and 4 Dutch members, the committee included members from Denmark, Finland, Germany, Ireland, Sweden, the United Kingdom, and the United States (NIOSH) (see Appendix A). The President of the Health Council inaugurated the International Committee on Updating of OELs in August 1997.

Procedure of Updating OELs

Under the authority of the Ministry of Social Affairs and Employment, toxicological reviews for 196 substances were prepared at several Dutch research institutes. The International Committee on Updating OELs (hereafter referred to as the Dutch Committee) determined that the reviews were to be based on a full search of the published scientific literature. This committee also set the outline for the contents of the documents.

The Dutch Committee also formulated a minimum database necessary for a health-based OEL. Such a database should include at least data on acute (irritation) and repeated-dose toxicity using multiple doses. Preferably, the key study should provide information about the target organ and critical effect, and a concentration at which there is no observed adverse effect. In addition, in the case of missing data, the Dutch Committee decided not to make use of structure-activity-relationships, because differences in kinetics of structurally related compounds cannot be excluded.

From the available data, the Dutch Committee identified a key study serving as the starting point for deriving a health-based OEL. To apply the human or animal data from the key study to the occupational exposure situation of the worker, the Dutch Committee used an overall assessment factor. The overall factor results from multiplying separate assessment factors covering the following aspects: variation in sensitivity between workers, extrapolation from animals to humans (when starting from an animal study), differences in duration and pattern of exposure between the key study and the exposure of the worker, the type of critical toxic effect, the presence or absence of a dose–effect relationship, and the quality of the total database. Unless the scientific data indicated otherwise, the Dutch Committee chose to use fixed (default) values for each of the assessment factors. These values are based on theoretical considerations and empirical investigations and they compensate for uncertainties inherent to extrapolation of experimental (animal) data to a given human situation and for uncertainties in the toxicological data base. Principally, the overall factor is established by multiplication of the separate factors. The values were adopted from the report *Methods for Establishment of Health-based Recommended Occupational Exposure Limits for Existing Substances*, V96.463, 4 July 1996, by TNO Nutrition and Food Research Institute, Zeist, the Netherlands [Hakkert et al., 1996; see also de Raat et al., 1997; Appendix B]. All available data were discussed and thoroughly evaluated. For each aspect, the appropriateness of applying assessment factors was considered. In case the key study referred to an oral animal experiment, differences in caloric demand between the experimental animal and humans were taken into consideration (allometric scaling). Given the inherent uncertainty in deriving OELs and in view of the European harmonization, that is, aligning with the Scientific Committee for Occupational Exposure Limits to Chemical Agents (SCOEL), the health-based OEL was rounded up or down to a preferred value (e.g., 0.1, 0.2, 0.5, 1, 2, 5 mg/m^3, etc.).[2] The health-based OEL is intended to protect workers

[1] Since 2005: TNO Quality of Life.

[2] This procedure of deriving health-based OELs resembles to a large degree the procedure applied in Germany by the Subcommittee III of the AGS [Anon, 1998; Kalberlah and Schneider, 1998; Kalberlah et al., 1999]. Health-based OEL in Germany (Arbeitsplatzgrenzwert, AGW) shall mean the limit value for the time-weighted mean concentration of a substance in workplace air relative to a defined reference period. This value shall indicate the concentration of a substance that is not expected to induce any acute or chronic deleterious effect on the general state of a worker's health.

and their progeny against adverse effects from exposure to the particular compound during their working life (i.e., 8 hr/day, 5 days/week, for 40 years).

If the toxicological data on a given substance did not meet the minimum requirements necessary for a health-based OEL, the Dutch Committee strived to give ''expert judgment'' on the degree of health protection of the present MAC value. That means that the Dutch Committee indicated whether the present MAC-value might be too high, too low, or about right based on extrapolation from a study that did not meet the criteria, for instance, a study with repeated exposure to only one concentration or dose.

Carcinogenic substances were not considered by the Dutch Committee but were passed on to DECOS to obtain a proposal for their classification. Although the health-based OEL should protect against adverse reproductive effects, for a number of substances information was lacking for determining the risk for causing fertility or developmental effects in humans,

The procedure included the release of a draft document for each substance for public review for a period of 6 weeks. Comments received were taken into account in the final version of the document. Finally, the Health Council's Standing Committee on Health and Environment reviewed each document.

RESULTS

The Dutch Committee succeeded in publishing criteria documents for 161 substances (Health Council of the Netherlands, 2000; the reports can also be downloaded from www.healthcouncil.nl). For the remaining 35 compounds, the Dutch Committee did not give an evaluation for several reasons: suspicion of carcinogenicity or genotoxicity, or still being under review by SCOEL.

For 95 substances, the Dutch Committee believed that the toxicological data available did not meet the minimum requirements (see *Procedure of updating OELs*) for the recommendation of a health-based OEL. For 32 of the 95 compounds, the Dutch Committee was able to estimate whether the current MAC value might be health protective: for 7 substances, the current concentration was deemed to be protective; for 24, probably too high; and for one, probably too low.

For the remaining 66 compounds, the Dutch Committee considered the toxicological database to be suitable for recommending a health-based OEL. The results for individual substances and the corresponding values in Dutch and German OEL lists and in the TLV list of ACGIH are summarized in Table I.

For 58 of the 66 compounds, the proposed limits were lower than the values included in the Dutch MAC list of 1994, the starting point of the reassessment: for 24 compounds, the difference was a factor of 2–5; for 16 compounds, a factor of 6–10; for 11 compounds, a factor 11–20; and for 7 compounds, a factor exceeding 20. For seven compounds, the Dutch Committee recommended health-based OELs that were similar, that is, differing by less than a factor of 2, to those on the 1994 list.[3]

DISCUSSION

Compared with the exposure limits in the Dutch MAC list of 1994, 89% (58/65) of the health-based OELs recommended by the Dutch Committee were lower by a factor of two or more (Table I). Most substances (47/65; 72%) have a 10-fold or less lower health-based OEL. The difference between the 1994 limits and the limits recommended by the Dutch Committee might be the result of new data and, particularly, the use of assessment factors. Contrary to ACGIH, the Dutch Committee applied assessment factors when using an experimental animal study as a basis for deriving a health-based OEL. Generally, an assessment factor of 9 was used in the extrapolation to account for inter- and intraspecies variation.

Almost all of the Dutch Committee's recommendations have been reviewed through the proper three-step procedure in the Netherlands. The OEL Subcommittee of the Social and Economic Council recommended adopting almost all of the OEL proposals of the Dutch Committee. Of the 95 substances for which the Dutch Committee considered the toxicological database too poor to recommend a health-based OEL, only 6%[4] of OELs were still retained in the Dutch MAC list of September 2006. Of the 66 substances for which the Dutch Committee has recommended a health-based OEL, most (79%) were already adopted in the 2006 list (see Table II; column NL-SZW 2006). The current official list with legally binding exposure limits published in December 2006 (see *History of setting occupational exposure standards*) includes only 6 of the 66 health-based OELs recommended by the Dutch Committee and 2 of the 95 compounds (nicotine and oxalic acid)[5] for which no OEL could be proposed. All eight compounds were also on the list of the European Commission but the European Commission OELs were higher for five of the six compounds for which the Dutch Committee recommended a health-based OEL.

Nowadays in the Netherlands, employers and employees are, according to working conditions legislation, responsible for developing OELs for the substances that are no longer on this official list. To this end, they may use the health-based OELs recommended by the Dutch Committee or limits developed within the framework

[3] For the remaining compound, diphenyl oxide, there is no entrance in the Dutch MAC-list.

[4] The Dutch committee deemed five of six of these OELs to be protective and the OEL ubcommittee advised the State-Secretary to retain them.

[5] The Dutch committee deemed the OEL for oxalic acid to be protective against systemic effects and the toxicological data base for nicotine too poor for recommendation of an OEL.

TABLE I. Recommendations of the Committee on Updating of OELs From the Netherlands (Dutch Committee) in Comparison to TLVs of ACGIH, OELs of the German TRGS 900, MAK Values of the German DFG and MAC Values of the Ministry of Social Affairs and Employment (SZW) From the Netherlands From the 1994 list, the Starting Point of the Revaluation, and in Force September 1, 2006 (All OELs Are 8-hr Time-Weighted Average Values Unless Otherwise Indicated; for Explanation of Symbols See End of Table)

		Dutch committee	NL-SZW (1994)	NL-SZW (2006)[a]		ACGIH (2006)		TRGS 900 (01/2006)	DFG (2006)	
No.	Substance [CAS-number]	mg/m³	mg/m³	Since	mg/m³	Since	mg/m³	mg/m³	Since	mg/m³
1.	Acetic acid [64-19-7]	X	25	2005	— (I)	1946	25	— (D)	2002	IIb
2.	Aluminum alkyl compounds [96-10-6; 97-93-8; 100-99-2; 563-43-9]	X	2	2005	— (I)	1977	2	—	—	—
3.	Ammonium chloride (fume) [12125-02-9]	X	10	2005	— (I)	1970	10	—	—	—
4.	Benomyl [17804-35-2]	1 (inhalable dust)	10	2006	1 (inhalable fraction)	1979	10	—	2005	—[b]
5.	Benzenethiol (phenyl mercaptan) [108-98-5]	X (↓)	2	2005	— (I)	1978	0.5	— (I)	—	—
6.	Bornan-2-one (camphor, synthetic) [76-22-2]	X	12	2005	— (I)	1969	12	— (I)	1975	13[c]
7.	Boron oxide [1303-86-2]	1	10	1978/1979	10	1971	10	—	1997	IIb
8.	Boron trifluoride [7637-07-2]	0.2	3 C	2005	0.2	1963	2.8 STEL C	— (D)	1997	IIb
9.	Bromine [7726-95-6]	0.2 (15 min TWA)	0.7	1978/1979	0.7	1961	0.66	— (D)	2004	IIb
10.	Butane [106-97-8]	X (≈)	1430	1978/1979	1430	2004	2400	2400	1966 (1999)	2400
11.	Butanethiol (butyl mercaptan) [109-79-5]	X (↓)	1.5	2006	— (I)	1970	1.8	1.9	1969 (2000)	1.9
12.	Butylamine [109-73-9]	X	15 C	2005	— (I)	1963	15 STEL C	— (D)	2006	6.1
13.	2-sec-Butylphenol [89-72-5]	X	30	2005	— (I)	1980	31	— (I)	—	—
14.	*p*-tert-Butyltoluene [98-51-1]	X (↓)	60	2005	— (I)	1993	6.1	— (I)	1998	IIb
15.	Calcium carbonate [1317-65-3]	X	10	2005	— (I)	1972	10	—	—	—
16.	Calcium cyanamide [156-62-7]	0.2 (inhalable fraction) (as cyanamide)	0.5	2006	0.2 (as cyanamide)	1976	0.5	1 E	1979 (2002)	1 E
17.	Calcium hydroxide [1305-62-0]	X	5	2005	— (I)	1978	5	— (D)	—	—
18.	Calcium sulfate [7778-18-9; 10101-41-4]	X (respirable dust)	10	2004	— (I)	1972	10 E (dust)	6 A	2006	1.5 A 4 E
		0.5 A (fibers)		2004	0.5 A (fibers)	—	—	—	—	—
19.	Carbon tetrabromide [558-13-4]	X	1.4	2005	— (I)	1975	1.4	— (I)	—	—
20.	Cellulose [9004-34-6]	X	10	2005	— (I)	1972	10	—	—	—
21.	Cesium hydroxide [21351-79-1]	X	2	2003	— (I)	1975	2	— (I)	—	—
22.	Chlorine trifluoride [7790-91-2]	X (↓)	0.4 C	2005	— (I)	1963	0.38 STEL C	— (I)	2000	IIb
23.	2-Chloro-6-(trichloromethyl)pyridine (nitrapyrin) [1929-82-4]	X	10	2005	— (I)	1975	10	—	—	—
24.	2-Chloroacetophenone [532-27-4]	0.1 (inhalable fraction)	0.3	2005	0.1 (inhalable fraction)	1968	0.32	— (D)	—	—
25.	2-(Chlorobenzylidene) malonitrile [2698-41-1]	0.02 (inhalable dust)	0.4 C	2005	0.02 (inhalable fraction)	1983	0.39 STEL C	— (D)	—	—
26.	1-Chloro-1-nitropropane [600-25-9]	X	10	2005	— (I)	1981	10	— (I)	1995	IIb
27.	*o*-Chlorostyrene [2039-87-4]	X (↓)	285	2005	— (I)	1975	283	—	—	—
28.	2-Chlorotoluene [95-49-8]	2	250	2005	2	1974	259	—	—	—

(*Continued*)

TABLE I. (*Continued*)

		Dutch committee	NL-SZW (1994)	NL-SZW (2006)[a]		ACGIH (2006)		TRGS 900 (01/2006)	DFG (2006)	
No.	**Substance [CAS-number]**	**mg/m^3**	**mg/m^3**	**Since**	**mg/m^3**	**Since**	**mg/m^3**	**mg/m^3**	**Since**	**mg/m^3**
29.	Chlorpyrifos [2921-88-2]	0.2	0.2	1978/1979 (2005)	0.2	2003	0.1	0.2	—	—
30.	Chlorinated diphenyl oxides [31242-93-0; 55720-99-5]	X (↓)	0.5	2005	– (I)	1956	0.5	– (I)	2002	IIb
31.	Clopidol [2971-90-6]	X	10	2005	– (I)	1975	10	—	—	—
32.	Cyanamide [420-04-2]	0.2 (inhalable fraction)	2	2006	0.2 (inhalable fraction)	1977	2	1 E	1979 (2002)	1 E
33.	Cyanogen chloride [506-77-4]	X	0.6 C	2005	– (I)	1980	0.75 STEL C	– (I)	1973	IIb
34.	Cyclohexene [110-83-8]	X (↓)	1015	2005	– (I)	1967	1010	– (I)	2000	IIb
35.	Cyclohexylamine [108-91-8]	5	40	2004	5	1974	41	– (D)	2003	8.2
36.	Cyclopentane [287-92-3]	X	1720	2003	– (I)	1981	1720	—	—	—
37.	Demeton [8065-48-3]	0.1	0.1	1978/1979 (2005)	0.1	2002/2003	0.05	0.1	1999	IIb
38.	Dibismuth tritelluride [1304-82-1]	X (↓)	10	2005	– (I)	1996	10	—	—	—
39.	Diborane [19287-45-7]	0.01	0.1	1978/1979	0.1	1956	0.1	– (D)	1997	IIb
40.	Dibutyl hydrogen phosphate [107-66-4]	X	5	2005	– (I)	1968	8.6	– (I)	—	—
41.	1,3-Dichloro-5,5-dimethylhydantoin [118-52-5]	X	0.2	2005	– (I)	1966	0.2	– (I)	—	—
42.	1,1-Dichloro-1-nitroethane [594-72-9]	X	10	2005	– (I)	1981	12	– (I)	2000	IIb
43.	Dicrotophos [141-66-2]	0.01	0.25	2005	0.01	2002/2003	0.05	– (D)	—	—
44.	Dicyclopentadienyl iron (ferrocene) [102-54-5]	0.1	10	2004	0.1	1975	10	– (D)	—	—
45.	Diethylene triamine (DETA) [111-40-0]	5	4	1978/1979	4	1972	4.2	—	2000	—[d]
46.	Diisopropylamine [108-18-9]	5	20	2005	5	1968	21	– (D)	—	—
47.	Dimethoxymethane (methylal) [109-87-5]	X	3100	2003	– (I)	1952	3110	3200	1958 (2003)	3200
48.	Dioxathion [78-34-2]	0.2	0.2	1978/1979 (2005)	0.2	2002/2003	0.1	0.2	—	—
49.	Diphenyl ether [101-84-8]	10	—	—	—	1967	7	7.1	1966 (2004)	7.1
50.	Dipropyl ketone [123-19-3]	X	235	2003	– (I)	1981	233	– (I)	—	—
51.	Disulfoton [298-04-4]	0.02	0.1	2005	0.02	2003	0.05	– (D)	—	—
52.	Disulfur dichloride [10025-67-9]	X	6 C	2005	– (I)	1986	5.5 STEL C	– (I)	2000	IIb
53.	Disulfur decafluoride (sulfur pentafluoride) [5714-22-7]	X	0.1	2005	– (I)	1986	0.10 STEL C	– (D)	2005	IIb
54.	2,6-Di-tert-butyl-*p*-cresol [128-37-0]	5 (inhalable dust)	10	2006	5	2001	2	– (D)	2004	20 E
55.	Ethanethiol (ethyl mercaptan) [75-08-1]	X	1	2005	– (I)	1970	1	1.3	1969 (2000)	1.3
56.	Ethyldimethylamine [598-56-1]	X (≈)	30	1996 (2005)	6	—	—	– (D)	2000	6.1
57.	Ethylene glycol dinitrate (EGDN) [628-96-6]	0.05 (15 min TWA)	0.3	1987	0.3	1983	0.31	0.32	1982	0.32
58.	Ethyl formate [109-94-4]	X (≈)	300	2005	– (I)	1948	303	310	1961 (1997)	310
59.	4-Ethylmorpholine [100-74-3]	X	23	2005	– (I)	1982	24	– (I)	1983	IIb

60.	Formic acid [64-18-6]	5 (15 minTWA)	9	1978/1979	9[e]	1967	9.4	9.5	1966 (2000)	9.5
61.	Germanium tetrahydride [7782-65-2]	X	0.6	2003	— (I)	1973	0.6	— (D)	—	—
62.	Glycerol trinitrate (nitroglycerin) [55-63-0]	0.05 (15 minTWA)	0.5	1987	0.5	1983	0.46	— (D)	2005	—[f]
63.	Hexachlorocyclopentadiene [77-47-4]	0.01	0.11	2005	0.01	1974	0.11	0.2	2001	IIb
64.	Hexachloronaphthalene [1335-87-1]	X (↓)	0.2	2003	— (I)	1968	0.2	— (I)	1997	IIb
65.	Hexafluoroacetone [684-16-2]	0.05	0.7	2004	0.05	1973	0.68	— (D)	—	—
66.	sec-Hexyl acetate [108-84-9]	X (↓)	300	2005	— (I)	1963	295	— (I)	2000	IIb
67.	Hydroxypropyl acrylate (all isomers) [25584-83-2; 999-61-1; 2918-23-2; 2761-08-2]	1	3	1981	3	1980	2.8	—	1998	IIb
68.	2,2′-Iminodiethanol [111-42-2]	0.5 (inhalable fraction)	15	1996	2	1994	2	— (D)	2006	1E
69.	Indene [95-13-6]	X	45	2005	— (I)	1970	48	— (I)	—	—
70.	Iron salts, water-soluble [-]	0.1 (respirable particles)	1	2005	0.1	1969	1	—	—	—
71.	Isoamyl alcohol [123-51-3]	100	360	2005	100	1966	361	— (D)	1989	370[c]
72.	Iso-octyl alcohol (mixed isomers) [26952-21-6]	X (↓)	270	2005	— (I)	1982	266	— (I)	—	—
73.	Isopropylamine [75-31-0]	X	12	2005	— (I)	1956	12	12	1958 (2000)	12
74.	N-Isopropylaniline [768-52-5]	0.5	10	2005	0.5	1980	11	— (D)	—	—
75.	Ketene [463-51-4]	X (↓)	0.9	2005	— (I)	1963	0.86	— (I)	1999	IIb
76.	Liquefied petroleum gas (L.P.G.) [68476-85-7]	X (≈)	1800	1978/1979	1800	1966 (2004)	1800	—	—	—
77.	Magnesium carbonate [546-93-0]	X (≈)	10	1978/1979 (2005)	10 (inhalable fraction) 5 (respirable fraction)	2006	—	—	—	—
78.	Magnesium oxide (fume) [1309-48-4]	X (↓)	10	2005	— (I)	1971	10	—	1999	IIb
79.	Methanethiol (methyl mercaptan) [74-93-1]	X (≈)	1	2003	— (I)	1970	0.98	1	1969 (2000)	1
80.	Methyl acetate [79-20-9]	100	610	2005	100	1948	610	610	2005	310
81.	Methylcyclohexane [108-87-2]	200	1600	1978/1979	1600	1976	1610	810	2000 (2006)	810
82.	Methylcyclohexanol [25639-42-3]	50	235	2002	50	1973	234	— (D)	1998	IIb
83.	2-Methylcyclohexanone [583-60-8]	X	230	2005	— (I)	1973	229	— (I)	2002	IIb
84.	Methyl ethyl ketone peroxide [1338-23-4]	X	1.5 C	2005	— (I)	1974	1.5 STEL C	—	1982	—[g]
85.	Methyl isopropyl ketone [563-80-4]	X	705	2003	— (I)	1981	705	— (I)	—	—
86.	4-Methylpent-3-en-2-one [141-79-7]	X (↓)	60	2005	— (I)	1981	60	— (D)	2006	20
87.	Methyl-S-demeton [919-86-8]	0.01	0.5[h]	2005	0.01	2002/2003	0.05	—	—	—
88.	Mica [12001-26-2]	X (↓)	2.5 (respirable fraction) 5 (inhalable fraction)	2003	— (I)	1986	3	—	—	—
89.	Monocrotophos [6923-22-4]	0.02	0.25	2005	0.02	2001	0.05	— (D)	—	—
90.	Naled [300-76-5]	0.02	3	2005	0.02	2001	0.1	— (D)	2006	1E
91.	Nicotine [54-11-5]	X	0.5	1978/1979	0.5	1957	0.5	— (D)	2003	IIb
92.	Nitroethane [79-24-3]	20	310	2006	20	1948	307	310	1958 (2000)	310
93.	Nitrogen trifluoride [7783-54-2]	X (↓)	29	2005	— (I)	1966	29	—	—	—
94.	*m*-Nitrotoluene [99-08-1]	2	11	2006	2	1982	11	— (D)	2006	—[c]

(*Continued*)

TABLE I. (*Continued*)

		Dutch committee	NL-SZW (1994)	NL-SZW (2006)[a]		ACGIH (2006)		TRGS 900 (01/2006)	DFG (2006)	
No.	**Substance [CAS-number]**	**mg/m^3**	**mg/m^3**	**Since**	**mg/m^3**	**Since**	**mg/m^3**	**mg/m^3**	**Since**	**mg/m^3**
95.	Nonane [111-84-2]	500	1050	1978/1979	1050	1976	1050	—	—	—
96.	Octachloronaphthalene [2234-13-1]	X	0.1	2003	– (I)	1968	0.1	– (I)	1997	IIb
97.	Octane [111-65-9]	X	1450	2006	– (I)	1976	1401	2400	1961 (2004)	2400
98.	Osmium tetraoxide [20816-12-0]	X	0.002	2005	– (I)	1963	0.0016	– (I)	2002	IIb
99.	Oxalic acid [144-62-7]	X (≈)	1	1978/1979 (2005)	1	1967	1	– (D)	—	—
100.	Oxalonitrile (cyanogen) [460-19-5]	2	20	2004	2	1969	21	– (D)	2003	11
101.	Oxygen difluoride [7783-41-7]	X (↓)	0.1 C	2005	– (I)	1986	0.11 STEL C	—	—	—
102.	Paraffin wax (fume) [8002-74-2]	X	2	2005	– (I)	1974	2	—	—	—
103.	Pentachloronaphthalene [1321-64-8]	X (↓)	0.5	2005	– (I)	1948	0.5	– (I)	1997	IIb
104.	Pentacarbonyliron [13463-40-6]	0.05 (as Fe)	0.08	2004	0.05 (as Fe)	1982	0.23 (as Fe)	– (D)	1970	0.23[c] (as Fe)
105.	Pentan-2-one (methyl propyl ketone) [107-87-9]	X	700	2006	– (I)	1948	705	– (I)	2000	IIb
106.	Pentan-3-one [96-22-0]	X	705	2005	– (I)	1981	705	– (I)	—	—
107.	Perchloromethyl mercaptan [594-42-3]	0.01	0.8	2004	0.01	1962	0.76	– (D)	1988	IIb
108.	Perchloryl fluoride [7616-94-6]	X (↓)	14	2005	– (I)	1963	13	—	—	—
109.	Perhydro-1,3,5-trinitro-1,3,5-triazine [121-82-4]	0.1 (inhalable dust)	1.5	2006	0.1	1997	0.5	– (D)	—	—
110.	Perlite [8075-36-3; 93763-70-3]	5 (respirable dust) 10 (inhalable dust)	10	1978/1979 (2005)	5 (respirable fraction) 10 (inhalable fraction)	2006	—	—	—	—
111.	Phenothiazine [92-84-2]	2 (inhalable dust)	5	2005	2 (inhalable fraction)	1971	5	—	—	—
112.	Phenylphosphine [638-21-1]	0.05	0.25 C	1978/1979	0.25 C	1973	0.23 STEL C	0.05	—	—
113.	2-Phenylpropene (α-methylstyrene) [98-83-9]	20	240	2005	20	1981	242	250	2004	250
114.	Phorate [298-02-2]	0.02	0.05	2005	0.02	1974	0.05	– (D)	—	—
115.	*m*-Phthalodinitrile [626-17-5]	X	5	2005	– (I)	1977	5	– (I)	—	—
116.	Picric acid (2,4,6-trinitrophenol) [88-89-1]	X	0.1	2005	– (I)	1956	0.1	– (D)	2000	—[f]
117.	Pindone [83-26-1]	X (↓)	0.1	2005	– (I)	1967	0.1	– (I)	—	—
118.	Potassium hydroxide [1310-58-3]	X	2 C	2005	– (I)	1974	2 STEL C	—	—	—
119.	Propane [74-98-6]	X	—	—	—	2004	1800	1800	1966 (2004)	1800
120.	Propargyl alcohol (prop-2-yn-1-ol) [107-19-7]	0.5	2	2006	0.5	1969	2.3	4.7	1969 (1999)	4.7
121.	Propyl nitrate [627-13-4]	X	110	2005	– (I)	1962	107	– (I)	1958	110[c]
122.	Propyne [74-99-7]	X (↓)	1650	2005	– (I)	1956	1640	– (I)	2000	IIb
123.	Propyne-allene mixture (MAPP gas) [59355-75-8]	500	1800	2006	500	1966	1640	—	—	—
124.	Pyrethrum [8003-34-7]	1 (inhalable fraction)	5	2006	1	1962	5	5 E	1964 (1997)	5 E

125. 2-Pyridylamine (2-aminopyridine) [504-29-0]	X	2	2005	— (I)	1967	1.9	— (I)	2000	IIb
126. Resorcinol [108-46-3]	10	45	2006	10	1976	45	— (D)	2002	IIb
127. Saccharose (sucrose) [57-50-1]	X	10	2006	— (I)	1972	10	—	—	—
128. Silane (silicon tetrahydride) [7803-62-5]	X (↑)	0.7	2003	— (I)	1983	6.6	—	—	—
129. Silicon [7440-21-3]	X	10	2005	— (I)	1973	10	—	—	—
130. Slate dust [1344-36-1]	X	10	2005	— (I)	—	—	—	—	—
131. Sodium bisulfite [7631-90-5]	X	5	2006	— (I)	1980	5	—	1998	—[d]
132. Sodium hydroxide [1310-73-2]	X	2 C	2003	— (I)	1975	2 STEL C	— (I)	1998	IIb
133. Starch [9005-84-9]	X	10	2005	— (I)	1972	10	—	—	—
134. Strychnine [57-24-9]	X (↓)	0.15	2005	— (I)	1957	0.15	— (I)	1999	IIb
135. Sulfur tetrafluoride [7783-60-0]	X	0.4 C	2005	— (I)	1986	0.44 STEL C	—	—	—
136. Sulfuryl difluoride [2699-79-8]	10	20	2006	10	1963	21	10	—	—
137. 2,4,5-T [93-76-5]	1	10	2005	1	1963	10	10 E	1995	10 E
138. Tantalum [7440-25-7]	X	5	2005	— (I)	1965	5	3 A 10 E	1999	1.5 A 4 E
139. Tellurium and tellurium compounds [13494-80-9]	X	0.1	2005	— (I)	1948	0.1 (as Te)	— (I)	2003	IIb
140. Tellurium hexafluoride [7783-80-4]	X	0.2	2005	— (I)	1967	0.10 (as Te)	—	—	—
141. Temephos [3383-96-8]	2	10	2005	2	1971	1	—	—	—
142. *o,m,p*-Terphenyl (mixture) [26140-60-3]	0.5	4.5 C	2004	0.5	1980	5 STEL C	— (D)	—	—
143. Tetrachloronaphthalene [1335-88-2]	X (↓)	2	2003	— (I)	1968	2	— (I)	1997	IIb
144. Tetraethyl orthosilicate [78-10-4]	10	85	2006	10	1979	85	— (D)	1998	86
145. Tetramethyl orthosilicate [681-84-5]	2	6	2006	2	1981	6	2	—	—
146. Tetramethyl succinonitrile [3333-52-6]	0.2	3	2004	0.2	1967	2.8	— (D)	2001	IIb
147. Thallium and water soluble thallium compounds [7440-28-0]	0.02	0.1	2004	0.02	1957	0.1	— (D)	2000	IIb
148. 4,4′-Thiobis (6-tert-butyl-*m*-cresol) [96-69-5]	5 (inhalable dust)	10	1978/1979	10	1976	10	—	—	—
149. Thionyl chloride [7719-09-7]	X	5 (ceiling)	2005	— (I)	1986	4.9 STEL C	—	—	—
150. Thiram (tetramethylthiuram disulfide) [137-26-8]	0.2 (inhalable dust)	1	2005	0.2 (inhalable fraction)	1990	1	5 E	2006	1 E
151. Tin oxide (tin(IV) oxide) [18282-10-5]; (tin(II) oxide) [21651-19-4]	X	2	2005	— (I)	1982	2	— (D)	1998	IIb[i]
152. Tributyl phosphate [126-73-8]	2	5	1978/1979	5	1981	2.2	— (D)	2000	11
153. Tricarbonyl(eta-cyclopentadienyl) manganese [12079-65-1]	X	0.1	2005	— (I)	1974	0.1	— (I)	—	—
154. Trichloronaphthalene [1321-65-9]	X (↓)	5	2005	— (I)	1948	5	— (I)	1997	IIb
155. Tungsten and tungsten compounds [7440-33-7]	X	5 (insoluble) 1 (soluble)	2005	— (I)	1969	5 (insoluble) 1 (soluble)	— (I)	2002	IIb
156. Valeraldehyde [110-62-3]	X	175	2005	— (I)	1978	176	— (I)	—	—
157. Warfarin [81-81-2]	0.01 (inhalable dust)	0.1	2006	0.01 (inhalable dust)	1962	0.1	— (D)	1958	0.5 E[c]

(*Continued*)

TABLE I. (*Continued*)

No.	Substance [CAS-number]	Dutch committee	NL-SZW (1994)	NL-SZW (2006)[a]		ACGIH (2006)		TRGS 900 (01/2006)	DFG (2006)	
		mg/m^3	mg/m^3	Since	mg/m^3	Since	mg/m^3	mg/m^3	Since	mg/m^3
158.	*m*-Xylene-α,α'-diamine [1477-55-0]	X	0.1 C	2005	– (I)	1976	0.1 STEL C	– (I)	2005	—[d]
159.	Yttrium and yttrium compounds [7440-65-5]	X	1	2003	– (I)	1966	1	– (I)	1998	IIb
160.	Zinc distearate (stearate) [557-05-1]	X	10	2006	– (I)	1974	10 ("total" dust)	—	—	—
161.	Zirconium and zirconium compounds [7440-67-7]	X	5	2005	– (I)	1956	5	– (D)	1998	1 E

X, the toxicological database is too poor to justify a health-based OEL (Dutch Committee); between brackets, the opinion of the Dutch Committee on the level of the MAC-value: $\approx$, level might be protective; $\uparrow$, level could be higher; $\downarrow$, level should be lower; —, substance not listed; (I), OEL was removed due to incomplete toxicological data base; (D), OEL was removed because detailed examination by the subcommittee III of the AGS is necessary; C, ceiling; STEL, short term exposure limit; E, inhalable; A, respirable; IIb, substances for which no MAK-value can be established at present; year in parentheses, year of reassessment of the substance that confirmed the already existing value.

[a]OELs in force September 1, 2006 [OELs were taken from the data base on the website of the Social and Economic Council (www.ser.nl: database on OELs)]; the current official list in the Netherlands with legally binding OELs published in December 2006 and effective in January 2007, includes only 6 of the 66 OELs recommended by the Dutch Committee.

[b]Germ cell mutagen category 3A.

[c]No MAK-Documentation available.

[d]See Section IV of DFG OEL list (Sensitizing substances).

[e]Since January 1, 2007: 5 mg/m^3 (15 min TWA).

[f]Carcinogenic substance category 3B.

[g]See Section Xa of DFG OEL list (Substances requiring special consideration: Organic peroxides).

[h]OEL for methyldemeton [8022-00-2].

[i]Tin and its inorganic compounds.

TABLE II. Ratios of Current OELs to Health-Based OELs Recommended by the Dutch International Committee on Updating of OELs (66 Substances*)

Factor[a]	ACGIH (2006): number of substances	TRGS 900 (2006): number of substances	NL-SZW (2006[b]): number of substances
≥10	21 (32%)	6 (9%)	3 (4%)
≥5	17 (26%)	4 (6%)	3 (4%)
≥2	17 (26%)	2 (3%)	7 (11%)
Identical OEL	3 (4%)	7 (11%)	52 (79%)
<2	5 (8%)	0	0
Without OEL	3 (4%)	47 (71%)	1 (1%)

*Including four substances for which a STEL not an 8-hr TWA is proposed by the Dutch Committee.

[a]Existing OEL (TLV, TRGS 900 or Dutch MAC-list of September 2006) divided by OEL-recommendation of the Dutch Committee.

[b]OELs in force September 1, 2006; the current official list in the Netherlands with legally binding OELs published in December 2006 includes only 6 of the 66 OELs recommended by the Dutch Committee.

of REACH (registration, evaluation, and authorization of chemicals).

The German TRGS 900 lists only 11% of the compounds for which the Dutch Committee could not derive a health-based OEL. Also Germany considered the results of the Dutch Committee when in 2005, the TRGS 900 was revised to fulfill the requirements of the new Hazardous Substances Ordinance [OELs for about 420 substances were removed either because they were obviously not health-based (about 220 OELs) or because their soundness needed a detailed examination by Subcommittee III of the AGS (about 200 OELs); only about 290 OELs are retained in the present TRGS 900]. Seventy-one percent of the 66 substances for which the Dutch Committee recommends a health-based OEL, are not listed in TRGS 900. Many of these substances (32/47 substances) will be examined by Subcommittee III of the AGS for the derivation of a health-based OEL. Eighteen percent of the OELs listed in the TRGS 900 are higher by a factor of two or more compared with the OELs derived by the Dutch Committee; for 9%, a factor of 10 or more (see Table II). Although many OELs were deleted from the German TRGS 900 as scientifically unsupported, it is still the duty of the employer to ensure safe working conditions.

Most (97%) substances for which the Dutch Committee could not recommend a health-based OEL are still present in the 2006 ACGIH list. For about 83% of the substances (55 of 66 substances), for which a health-based OEL was given, the TLV in the ACGH list of 2006 is higher by a factor of two or more. For 32% of the substances, this factor is 10 or more (see Table II).

CONCLUSIONS

The reassessment project showed that many of the older MAC values in the Netherlands (derived from the ACGIH list in the 1970s) were not health based. The exposure limits were found to be either too high or not scientifically supported. Comparison of recent evaluations by the Dutch Committee with 2006 OEL lists indicates a continued discrepancy in the level of recommended exposure limits and the prerequisites for their derivation. This holds especially true for the 2006 TLVs.

These differences indicate the need to routinely scrutinize newly generated health data and to review methodologies, for example, the use of extrapolation factors, for the derivation of OELs. Without such an examination, the health of workers might be endangered. This holds especially true for countries who must rely on OELs established by others because of limited manpower and knowledge.

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Appendix A

The Committee on Updating OELs consisted of the following members:

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Appendix B

Default Values

Unless the scientific data indicated otherwise, the committee chose to use assessment factors adopted from the report *Methods for establishment of Health-based Recommended Occupational Exposure Limits for Existing Substances*, V96.463, 4 July, 1996, by TNO Nutrition and Food Research Institute[6], Zeist, the Netherlands (Hakkert et al., 1996; see also De Raat et al., 1997; 25: 204–10).

Aspects	Factor
Interspecies differences	3
Intraspecies differences	3
Differences between experimental conditions and exposure pattern of the worker	1–10
Type of critical effect	1
Dose-response curve	1
Confidence of the database	1

[6] Since 2005: TNO Quality of Life