



**Impact assessment for the  
Provisions on Occupational  
Exposure Limit Values and  
Measures against Air Conta-  
minants, AFS 2005:17**

# **Rapport 2006:10**

# **Impact assessment for the Provisions on Occupational Exposure Limit Values and Measures against Air Contaminants, AFS 2005:17**

**Report presenting the supporting documentation for the Work  
Environment Authority's resolution concerning new Provisions on  
Occupational Exposure Limit Values and Measures against Air  
Contaminants**

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# **Impact assessment for the Provisions on Occupational Exposure Limit Values and Measures against Air Contaminants, AFS 2005:17**

## **Introduction**

A preliminary version of new Provisions on Occupational Exposure Limit Values and Measures against Air Contaminants was presented to the Directorate of the Work Environment Authority at a meeting on 17th March 2005. The proposal was adopted by the Directorate, which resolved that the Provisions would enter into force on 1st October 2005, with the exception of chromium (VI) and manganese, the limit values for which enter into force on 1st January 2007.

The impact assessments and proposed limit values for individual substances presented as supporting documentation to the Directorate are presented here.

For comparison, tables are given showing limit values for the substances concerned in a selection of other countries. Data concerning carcinogenic and sensitising properties and risk for percutaneous uptake are also presented. To facilitate comparison between the different countries, the designations H for percutaneous uptake, C for carcinogenic effect, S for sensitising effect and R for effects disturbing reproduction are used in the tables of foreign occupational exposure limit values.

The designation M has been introduced for substances which may be affected by health surveillance under the Provisions on Health Surveillance at Work, AFS 2005:6.

The impact assessments contain only brief descriptions of health hazards. For detailed information concerning the effects of each substance on health, reference is made to the scientific supporting documentation compiled by the Occupational Exposure Limit Values Criterion Group at the National Institute for Working Life. The documents are published in the Institute's Arbete och Hälsa publication series.

## **Background**

The Provisions on Occupational Exposure Limit Values are revised continuously. In the course of revision, previous limit values are reappraised and new ones added if necessary. The provisions themselves and the general recommendations are also updated when necessary.

The social partners have helped to prioritise substances and during the work on limit values have been continuously enabled to communicate viewpoints and to examine individual draft impact assessments.

Substances may come to be considered as a result of new scientific findings concerning health hazards. Where other substances are concerned, their professional use may have increased or changed. The adoption of new limit values within the EU can also lead to the introduction of new limit values in Sweden.

For every substance discussed in this revision, information is provided on health effects, use and occurrence, quantities, numbers of persons exposed, the level of exposure and a concise impact assessment, together with limit values proposed by the Work Environment Authority.

The Work Environment Authority also proposes the abolition of planning limit values as an instrument for special prior warning for limit value reductions. In connection with the phase-out of planning values, different measures are proposed for different substances. It is proposed that the planning limits for manganese be introduced as limit values. The new values of 0.2 mg/m<sup>3</sup> for total dust and 0.1 mg/m<sup>3</sup> for respirable dust represent a 50 per cent reduction compared with the present values.

The planning values for **lead** and **styrene** have remained unaltered for 10 and 13 years respectively. In order for these long-term values to be introduced as limit values, the underlying scientific documentation needs to be updated. The old limit values for lead and styrene are being retained to the next revision.

The planning value for **arsenic** was introduced in 1987. The Work Environment Authority proposes that the planning exposure limit of 0.01 mg/m<sup>3</sup> be introduced as a new threshold limit value. The planning limit value is based on the belief that arsenic and its inorganic compounds are carcinogenic. The lower value is still judged to be relevant, regarding to the cancer risk entailed by exposure. For purposes of comparison with other national limit values, it can be noted that Germany and the UK have 0.1 mg/m<sup>3</sup> while Denmark, Finland, Norway and ACGIH have 0.01 mg/m<sup>3</sup>.

This report contains a special impact assessment for **wood dust**. The change to inhalable dust exposure limit value with 2 mg/m<sup>3</sup> results in practice to a reduction to approximately the level referred to by the planning exposure limit value, namely 1 mg/m<sup>3</sup> total dust.

**Thiourine** has been B-listed since 1978. The scientific justification for this placement has for several years been questioned in a number of quarters. On the strength of supporting scientific documentation from the Criterion Group, the Work Environment Authority proposes that thiourine be deleted from the B list.

**p-Aminodiphenylamine and p-phenylene diamine** have, on account of their sensitising properties, been included in group B since 1996. In Sweden the use of these substances in cosmetic products/hair dyes was prohibited for many years. As a consequence of Sweden's EU membership it came to be permitted again. The stipulation of a permit was designed to prevent increasing use, which would have resulted in a growing number of sensitisation cases. The risks of sensitisation/allergic contact eczema should be manageable without any stipulation

of permits. The products must be marked with a text warning of the risk of allergy. The Work Environment Authority proposes that p-aminodiphenylamine and p-phenylene diamine be removed from the B list.

### **Costs**

The level of the occupational exposure limit value is determined on the basis of a comprehensive, balanced assessment of health hazards and technical and economic conditions. This can mean a reduction of the margin normally aimed for in the limit value. Most of the limit values proposed implies negligible expense or none at all, to the companies concerned. For some substances, process ventilation or greater use of personal protective equipment is stipulated for certain operations.

The proposed new limit values for chromium and manganese can entail expense in connection with welding operations, but the Authority's Provisions on Fusion Welding and Thermal Cutting, AFS 1992:9, require ventilation measures which, if taken, will contain the proposed levels for both chromium and manganese. The introduction of a proposed limit value for manganese was announced in AFS 2000:3 as a planning exposure limit. That advance warning has provided an opportunity for adapting to the new proposal.

The limit value proposed for chromium is expected to cause problems above all in connection with work on large objects at temporary worksites. The impact assessment for chromium contains a flat-rate estimate of the cost of a welding visor fitted with a fan and equipped with filter protection. The estimated total expenditure is MSEK 25, assuming protective equipment of this kind to be needed by about 5,000 welders.

Expense has also been foreseen in connection with the elimination of degradation products resulting from hot work in vehicle repair shops. The exposures concerned are diisocyanates and monoisocyanates (MIC and ICA), for which new limit values have been proposed. MIC and ICA concentrations have been judged to be ventilation determinants, and the estimated costs are therefore discussed in the impact assessment for monoisocyanates.

### **Savings and advantages**

The processing of the provisions form and structure bring simplifications and elucidation which will make it more accessible and intelligible. The update and co-ordination with other rules are another important benefit of the new draft instrument. Co-ordination with the Work Environment Authority's exposure register is a prerequisite for the efficient handling of quantitative data.

Synchronisation of timetables has made it possible for work on the limit values for isocyanates and synthetic inorganic fibres to be co-ordinated with drafting of the Provisions on thermosetting plastic and fibres respectively. Similarly, it has been

possible for the drafting of Provisions on Medical Surveillance at Work to be taken into account.

The proposed new list of occupational exposure limit values contains an increased number of dust values defined as inhalable dust. The aim here is to achieve harmonisation with the European standard Workplace atmospheres - Size fraction definitions for measurement of airborne particles, SS-EN 481. This means that all limit values for total dust are eventually to be transformed into inhalable dust. A transition means that the numeric value of the limit value, defined as inhalable dust, will be appreciably higher than the same stipulation expressed as total dust. The introduction of inhalable values has been based on an individual assessment of each dust exposure limit value. The proposed new list has the effect of raising the number of inhalable exposure limit values from 1 to 8.

The new substances and lower limit values proposed will mean less risk of/greater margins for ill-health and disorders of different kinds. Increased requirements for welding, due to reduction of the limit value for chromium (VI) and the limit value for manganese will lead to a simultaneous elimination of unspecified gases and particles potentially affecting the airways.

The measures needed to eliminate MIC and ICA in connection with hot work will, in addition to containment of the limit value for diisocyanates, also mean the abolition of other particles and gases.

There is increasing testimony to suggest a deterioration of the work environment in recent years, in terms of dust exposure on construction sites. Growing awareness of the hazards of such exposure further underscores the importance of reducing dust exposure at these worksites. Revision of the limit value for inorganic dust is supremely justified, considering that the health hazards of exposure to dust in different size fractions has been greatly revalued in recent years.

### **Summary**

In connection with the revision of the Provisions, the Work Environment Authority has discussed the occupational exposure limit values for 35 substances. Of these, 18 are new to the list (including 4 which are a specification of synthetic inorganic fibres). For two substances - arsenic and manganese - the former long-term exposure limit values are being introduced as new limit values. In addition, three substances on the B list have been discussed and thiourea, p-phenylene diamine and p-aminodiphenylamine will be deleted from it.

Certain expenses are foreseen in connection with the issue of the new Provisions on Occupational Exposure Limit Values and Measures against Air Contaminants, but these are offset by the health advantages and savings which are also anticipated.

## Summary of the proposals

	AFS 2005:17				Remarks	AFS 2000:3				
	LLV		STV/CLV			LLV		STV/CLV		Remarks
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>		ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Asbestos	-	0.1	-	-	fibre/cm <sup>3</sup> C					
Asbestos other than crocidolite						-	0.2	-	-	fibre/ml K
Cyclohexanone	10	41	20	81	H, STV	25	100	50	200	H, STV
Dust, inorg.										
inhalable dust	-	10	-	-		-	-	-	-	
total dust	-	-	-	-		-	10	-	-	
respirable dust	-	5	-	-		-	5	-	-	
2,4 Diaminotoluene	-	-	-	-	B sub- stance	-	-	-	-	B sub- stance
2,6 Diaminotoluene	-	-	-	-		-	-	-	-	
Diesel exhaust fumes										
Ref. nitrogen dioxide	1	2	-	-		1	2	-	-	
Diisocyanates	0.002	-	0.005	-		0.005	-	0.01	-	Isocyan- ate
Hexamethylene 1,6-diisocyanate	0.002	0.02	0.005	0.03	CLV, S	0.005	0.03	0.01	0.07	CLV, S
4,4'-methylenedi-phenyldiisocyanate	0.002	0.03	0.005	0.05	CLV, H, S	0.005	0.05	0.01 0	0.1	CLV, S
Toluene diisocyanate	0.002	0.014	0.005	0.04	CLV, C, S	0.005	0.04	0.01	0.07	CLV, K, S
Dimethyl adipate	5	36	-	-		-	-	-	-	
Dimethyl glutarate	5	33	-	-		-	-	-	-	
Dimethyl succinate	5	30	-	-		-	-	-	-	
Fibres, synthetic inorg. vitreous	-	-	-	-		-	1	-	-	fibre/ml
Refractory ceramic fibres	-	0.2	-	-	fibre/cm <sup>3</sup> C	-	-	-	-	
Special fibres	-	0.2	-	-	fibre/cm <sup>3</sup> , C	-	-	-	-	
Others		1			fibre/cm <sup>3</sup>					
Fibres, synthetic inorg. crystalline	-	0.2	-	-	fibre/cm <sup>3</sup> C	-	-	-	-	
Fluoroethanes										
1,1,2,2,2-Pentafluoroethane	500	2500	750	3735	STV	-	-	-	-	
1,1,1-Trifluoroethane	500	1750	750	2625	STV	-	-	-	-	
Phosphorous pentachloride	-	1	-	2	STV	-	-	-	-	
Phosphorous trichloride	0.2	1.2	0.4	2,4	STV	-	-	-	-	

	AFS 2005:17					AFS 2000:3				
	LLV		STV/CLV		Remarks	LLV		STV/CLV		Remarks
Phosphoryl chloride	0.1	0.6	0.2	1,2	STV	-	-	-	-	
Cadmium and inorg. compounds as Cd										
total dust	-	0.02	-	-	C	-	0.05	-	-	K
respirable dust	-	0.005	-	-	C	-	0.01	-	-	K
Calcium hydroxide	-	3	-	6	Inhal., STV	-	-	-	-	
Calcium oxide	-	1	-	2,5	Inhal., STV	-	2	-	5	total dust
Potassium aluminium tetrafluoride	-	0.4	-	-	Inhal.	-	-	-	-	
Potassium hydroxide	-	1	-	2	Inhal., CLV	-	-	-	-	
Chromium and its (II and III compounds) as Cr total dust	-	0.5	-	-		-	0.5	-	-	
Chromium (VI compounds) as Cr total dust	-	0.005	-	0.015	C, S STV	-	0.02	-	0.06	
4,4' Methylene dianiline	-	-	-	-	B substance	-	-	-	-	B substance
5-methyl-2-hexanone	25	120	50	250	STV	25	120	50	250	
Methylisocyanate	0.01	0.024	0.02	0.047	CLV 5 min	-	-	-	-	
Isocyanic acid	0.01	0.018	0.02	0.036	CLV 5 min	-	-	-	-	
α-methyl styrene	20	98	50	245	STV	-	-	-	-	
Sodium hydroxide	-	1	-	2	inhal.	-	-	-	2	total dust
Wood dust	-	2	-	-	C, inhal.	-	2	-	-	K. total dust
<b>Introduction of planning exposure limit values</b>										
Arsenic and inorg. compounds other than arsenic trihydride total dust	-	0.01	-	-	C	-	0.03	-	-	K
Manganese and inorg. compounds (as Mn)										
total dust	-	0.2	-	-		-	0.4	-	-	
respirable dust	-	0.1	-	-		-	0.2	-	-	
<b>Deleted from B list</b>										
p-Aminodiphenylamine	-	-	-	-		-	-	-	-	B subst.
p-Phenylene diamine	-	-	-	-		-	-	-	-	B subst.
Thiourea	-	-	-	-		-	-	-	-	B subst.

NOTE

The limit values for chromium (VI) and manganese entry into force on 1st January 2007. The limit values as per AFS 2000:3 apply until then.

The impact assessment for manganese is contained in Rapport (Report) 2001:16 from the Work Environment Authority

[http://www.av.se/publikationer/rapporter/2001\\_16.pdf](http://www.av.se/publikationer/rapporter/2001_16.pdf)

## Asbestos

	CAS no.
Actinolite	77536-66-4
Amosite	12172-73-5
Antophyllite	77536-67-5
Crocidolite	12001-28-4
Crysotil	12001-29-5
Tremolite	77536-68-6

## Proposal

Asbestos	LLV		STV		Rem.
	<i>ppm</i>	<i>fibre/cm<sup>3</sup></i>	<i>ppm</i>	<i>fibre/cm<sup>3</sup></i>	
	-	0.1	-	-	C

The fibres taken into consideration in a comparison with the limit value are respirable fibres having a length-width ratio exceeding 3:1, a diameter less than 3 µm and a length exceeding 5 µm. The limit value presupposes fibre count in a phase contrast microscope.

## Present limit value (AFS 2000:3)

Asbestos, other than crocidolite	LLV		STV		Rem.
	<i>ppm</i>	<i>fibre/ml</i>	<i>ppm</i>	<i>fibre/ml</i>	
	-	0.2	-	-	K
Crocidolite	-	-	-	-	A substance

A fibre is here defined as a respirable fibre, i.e. a particle having a length-width ratio of at least 5:1, a minimum length of 5 µm (micrometres) and a diameter not exceeding 3 µm. The limit value presupposes fibre count in a phase contrast microscope.

## Occupational exposure limit values in other countries

Asbestos	LLV		TVG		Rem.
	<i>ppm</i>	<i>fibre/ml</i>	<i>ppm</i>	<i>fibre/ml</i>	
Denmark (2002)not crocidolite	-	0.3	-	-	C
Crocidolite	-	-	-	0.3	C
Erionite	-	0.5	-	-	C
Finland (2002) All work	-	0.3	-	-	C
Blasting work	-	0.5	-	-	
Norway (2003) all forms	-	0.1	-	-	C
Germany (TRGS, 2002) Demolition, clearance and maintenance	-	(detection limit for the method)	-	-	C
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	

USA (ACGIH, 2002) all forms	-	0.1	-	-	C
EU	-	0.1	-	-	C

All countries have the same fibre definition as per the proposal above.

### **Health effects**

The limit value is based on the cancer risk. Mesothelioma – cancer of the pleura – is a specific and serious form of cancer with a very long latency period (30-60 years).

### **Use/occurrence**

First-time use of asbestos is not allowed. Bans on various uses were successively introduced between the mid-1970s and 1982. Asbestos has been very widely used as a building material.

### **No. persons exposed**

Exposure to asbestos can occur in connection with demolition work and repairs to old buildings. Demolition and clearance are undertaken by special clearance enterprises with a total of about 1,000 persons employed on this work. In connection with repairs and maintenance, an indeterminate number of building workers can come into contact with asbestos or materials containing asbestos.

### **Atmospheric concentrations**

Work with asbestos is subject to permission from the Work Environment Authority (AFS 1996:13, Asbestos). In addition to planning and preventive technical measures, personal protective equipment/breathing protection normally has to be used in order to exclude inhalation of airborne fibres.

### **Impact assessment**

Recently the EU Council of Ministers and the European Parliament adopted an amendment (2003/18/EC) the Asbestos Directive (83/477/EEC). The Directive contains binding limit values for chrysotile, 0.6 fibres/ml, and for other types of asbestos, 0.3 fibres/ml. Under 2003/18/EC these values are superseded by 0.1 fibres/ml for all types of asbestos. The new limit value is to be introduced in Sweden as part of the implementation of 2003/18/EC.

This measure is not expected to entail additional expense, because all work with asbestos normally has to be done using effective breathing protection.

## Cyclohexanone

CAS no.: 108-94-1

### Proposal

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
10	41	20	81	H

### Present limit value (AFS 2000:3)

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
25	100	50	200	H

### Occupational exposure limit values in other countries

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	10	40	-	-	H
Finland (2002)	10	41	20	82	H
Norway (2003)	20	80	-	-	H
Germany (TRGS, 2002)	20	80	-	-	H
Germany (MAK, 2002)	-	-	-	-	H
USA (OSHA, 1989)	25	100	-	-	H
USA (ACGIH, 2002)	25	-	-	-	H
EU	10	41	20	82	H

### Health effects

Cyclohexanone is a cyclic ketone which at room temperature is colourless, oil liquid with a smell reminiscent of peppermint and acetone. The substance is said to have an odour threshold of 0.88 ppm.

Animal studies have shown cyclohexanone to be absorbed via the lungs, gastrointestinal tract and skin but the pulmonary uptake is the fastest and most efficient uptake path.

In a study of humans exposed to cyclohexanone vapour for between 3 and 5 minutes, irritation of the eyes, nose and throat was reported at 75 ppm. Exposure to 50 ppm caused irritation of the throat and 25 ppm was perceived as an acceptable level for a notional 8-hour exposure.

Workers in a furniture factory coating wood with a product containing cyclohexanone often reported symptoms such as mood swings, irritability, memory difficulties, sleep disturbances and headache. Irritation of the eyes, upper respiratory tract and skin were also more common among the exposed persons than in the control group. Reduced nervous conductivity velocity was observed in three nerves investigated. The average exposure time was about 14 years and the exposure concentrations were between 40 – 92 ppm.

A number of case reports are described with symptoms such as impaired concentration, impaired verbal memory and quasi-epileptic fits. In all cases the exposure was to several different chemicals, and so it is not clear whether the symptoms were due solely to cyclohexanone.

The substance has low acute toxicity. Rabbits exposed to 190 ppm cyclohexanone vapour presented degenerative changes to liver and kidney.

\*

The critical effect in connection with professional exposure to cyclohexanone is judged to be its effect on the nervous system. Persons professional exposed (40-92 ppm) reported such symptoms as effects on the central nervous system and irritation of the airways. Throat irritation was observed in experimental subjects exposed for a few minutes to 50 ppm.

### **Use/occurrence**

The total use of cyclohexanone is fairly small. Among other things the substance is used as a solvent, and as a dilutant for paints and varnishes, printing inks, solvent-based glues and pesticides.

### **Quantities**

Produktregistret 2003 shows 237 tonnes of cyclohexanone to have been handled in this country. The substance occurs in 287 products, 58 of them consumer products.

### **No. persons exposed**

Cyclohexanone is present in certain industrial paints. It is used in paints handled in screen printing works. Exposure can occur among some 3,000 paint-spraying workers and about 1,000 screen printing workers.

### **Atmospheric concentrations**

The Work Environment Authority knows of seven quantitative studies undertaken in screen printing works. Cyclohexanone concentrations were far below the current exposure limit value of 25 ppm. In these quantitative studies, atmospheric concentrations were also below the 10 ppm limit value now proposed.

**Impact assessment**

The Work Environment Authority proposes a reduction to 10 ppm. This will provide an increased margin to effects on the nervous system and to irritative effects in the respiratory tract. Since dermal uptake can substantially contribute to exposure, the H marking is to be retained in the list.

No additional expense is anticipated.

**Further reading**

Arbete och Hälsa, 1999:25.

## Dust

### Inorganic dust

#### Proposal

	LLV		STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Dust, inorganic					
inhalable	-	10	-	-	
respirable	-	5	-	-	

#### Present occupational exposure limit value (AFS 2000:3)

Dust	LLV		STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
total dust	-	10	-	-	
respirable dust	-	5	-	-	
Dust, cement					
total dust	-	10	-	-	
respirable dust	-	5	-	-	

## Background

Occupational exposure limit values for inorganic dust were introduced in 1974, in the Authority's first list of hygienic limit values (Directions No. 100). The term used at that time was mineral inert dust, total concentration and fine fraction respectively. The purpose of these dust exposure limit values was to deal with air contaminants not having specific occupational exposure limit values of their own. Quartz and asbestos are examples of specific risks of this kind covered by low occupational exposure limit values. The term *inert* indicates that the risk of effects was not considered very great at that time.

The main applications of the limit values for inorganic dust are in the building and civil engineering industries (demolition), and over the years these limit values have been regarded as "slush limit values" for inorganic air contaminants.

The limit value level has not changed since the values were introduced in 1974.

The Work Environment Authority considers a review of the occupational limit values for inorganic dust to be urgently needed.

## Health effects

Attention has recently been drawn to the dusty work environment of construction sites. Dust exposure at these worksites has been singled out as a risk factor behind

chronic obstructive pulmonary disease (CPOD), for example. The known high levels in connection with certain jobs on construction sites represent a load on the airways, resulting in irritation and coughing, but there is a lack of scientific studies to confirm such connections. A study of building insulation workers reveals an elevated incidence of persistent cough. In addition to fibre concentrations, total dust (0.1 – 40 mg/m<sup>3</sup>, Bygghälsan) has also been measured. Exposure to mineral wool has been reported as causing irritative symptoms in the eyes, nose and gullet.

Exposure to mineral wool is generally measured in fibre/cm<sup>3</sup>. The fibre limit value is defined as respirable, i.e. the intention is to prevent pulmonary effects. This form of occupational exposure limit value, consequently, is not relevant to the prevention of effects on the upper respiratory tract.

The occupational exposure limit value for inorganic dust is intended to include mineral wool dust in addition to dust from concrete, cement, stone etc..

### **Atmospheric concentrations**

There have been very few quantitative studies in the past 10 years. During the 70s and 80s the then Bygghälsan carried out a number of measurements, many of which revealed very high values. Approximate levels from 1975 indicate 20-30 mg/m<sup>3</sup> for concrete work, 3-10 mg/m<sup>3</sup> for wood working, about 5 mg/m<sup>3</sup> for plumbing and heating installation work and 3-10 mg/m<sup>3</sup> for electrical work. The measurements from the 1980s (cf. Health effects) appear generally to be somewhat lower. All values are recorded as total dust.

It is commonly testified that dust levels at construction sites are still very high. The abolition of occupational health services in the industry is a partial cause of the poor state of the work environment there.

During 2004 the Work Environment Authority will be carrying out a number of quantitative studies of inorganic dust in the construction industry. Dust specimens are to be collected with sampling equipment for inhalable dust.

### **Impact assessment**

The Work Environment Authority proposes the introduction of two occupational exposure limit values for inorganic dust, namely 10 and 5 mg/m<sup>3</sup> for inhalable and respirable dust respectively.

At the same time the headings Dust, total and respirable, and Cement dust, total and respirable, are to be deleted. The new occupational exposure limit value for inorganic dust is intended to cover the same area as both the old ones together. The same figure will be retained. In practice, however, the transition from total to inhalable dust will roughly halve the requirement compared with the situation previously.

The requirement for respirable dust will be the same as before.

The new occupational exposure limit value of 10 mg/m<sup>3</sup>, inhalable dust, implies a reduction of exposure to dust and a reduction of the risk of disorders of the upper

respiratory tract. The introduction of an inhalable dust exposure limit value is part of the successive transition to the SS-EN 481 standard for measuring airborne particles.

Increased use of breathing protectors is expected to be an immediate consequence of the new occupational exposure limit value. Greater awareness of the risks entailed by exposure to dust ought probably to lead to better planning and greater emphasis on prevention.

During the coming years IVL (the Swedish Environmental Research Institute) will be mapping exposure to dust in the workplace and proposing ways of reducing it. This will include the development and recommendation of tools and methods.

The proposed substitution of a single heading, Inorganic dust, for the two headings Dust and Cement dust will simplify matters, indicating more clearly where the limit value is to be applied.

**2,4-Diaminotoluene**  
**2,6-Diaminotoluene**

CAS no. 95-80-7  
CAS no.: 823-40-5

**Proposal**

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>2,4-Diaminotoluene</b>	-	-	-	-	B sub- stance
<b>2,6-Diaminotoluene</b>	-	-	-	-	

**Present occupational exposure limit value (AFS 2000:3)**

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>2,4-Diaminotoluene</b>	-	-	-	-	B sub- stance
<b>2,6-Diaminotoluene</b>	-	-	-	-	

**Occupational exposure limit values in other countries**

<b>2,4-Diaminotoluene</b>	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	-	
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	C
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2002)	-	-	-	-	
EU	-	-	-	-	

<b>2,6-Diaminotoluene</b>	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	-	
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	

USA (ACGIH, 2002)	-	-	-	-
EU	-	-	-	-

### Health effects

At room temperature 2,4-diaminotoluene (toluene-2,4-diamine, 2,4-TDA) and 2,6-diaminotoluene (toluene-2,6-diamine, 2,6-TDA) take the form of colourless crystals. The substances are soluble in water and in many polar solvents.

2,4-TDA can be absorbed through the gastro-intestinal tract and dermally. In one human study, dermal uptake was found to be 24% of the applied dose after 24 hours. Dermal absorption, however, is found to vary considerably, depending on the solvent used.

There are no published data concerning human health effects in connection with exposure to 2,4-TDA and 2,6-TDA.

In various animal studies, the heaviest concentration was found in kidney and liver. Generally, in different species, only a small portion (0.1 – 3%) of 2,4-TDA is secreted unaltered, the rest being metabolised. Several studies have shown 2,4-TDA to be capable of giving DNA and haemoglobin adducts. 2,4-TDA is rapidly eliminated and the main secretion occurs via urine in the form of metabolites.

2,6-TDA is quickly absorbed via the gastro-intestinal tract, and 85% of the dose is eliminated via the urine in the form of metabolites.

2,4-TDA exposure for 14 days led to liver enzyme changes and increased liver weight in mice.

In rats exposed to 1,000 ppm 2,4-TDA in their diet, reduced body weight was observed, coupled with increased formation of red blood cells and liver changes. The corresponding dose did not induce any tissue changes in mice. In another study where mice were exposed to 100 and 200 ppm in their diet, reduced weight increase was observed and increased tissue growth in the liver.

In male rats exposed to 100 ppm 2,6-TDA in their diet, reduced body weight increase was observed. The same effect was seen in the females when exposed to 1,000 ppm. The corresponding effect on mice was recorded at 300 ppm for males and 1,000 ppm for females.

2,4- and 2,6-TDA have been shown to be equivalently mutagenic in *in vitro* tests. *In vivo* studies in rat for genotoxicity with 2,4-TDA have yielded positive results. Tests for 2,6-TDA are mostly negative.

IARC classifies 2,4-TDA as carcinogenic in class 2B. No significant tumour increase was found in 2,6-TDA when it was tested in a cancer study.

In several animal studies, exposure to 2,4-TDA has affected sperm formation. A reduced testosterone level has also been demonstrated in rat. 2,6-TDA has not been tested for effects adversely affecting reproduction.

Animal experiments have shown cancer to be the critical effect of 2,4-TDA. 2,4-TDA affects sperm formation in male rats. 2,4-TDA and 2,6-TDA are both genotoxic. Data are lacking for establishing the critical effect of 2,6-TDA.

### **Use/occurrence**

In Sweden, 2,4-TDA is used only for analytical purposes while 2,6-TDA does not have any known use at all. In other countries these substances are mainly used as intermediaries for producing diisocyanates, urethane products, paints and corrosion inhibitors, for example. Heating of TDI (toluene diisocyanate) and of TDI-based polyurethane products can result in degradation and the formation of TDA.

### **Quantities**

Ten laboratories have permission to use 2,4-TDA in very small quantities (grams).

### **No. persons exposed**

Some 190 persons are reportedly capable of coming into contact with the substance.

### **Atmospheric concentrations**

In its report *Isocyanater från heta arbeten i skadereparationsverkstäder*, IVL has described exposure measurements in which TDA was measured in connection with various kinds of hot work, such as paint removal, tape removal and plastic work using a hot air heat gun. The duration of measurement equals that of the task itself and can vary between 1 and 5 minutes. The exposure levels vary between 0.012 – 0.120 mg/m<sup>3</sup> (0.0024 – 0.0237 ppm).

### **Impact assessment**

The review of these substances has been prompted by the possibility of exposure in connection with work involving the degradation of TDI and TDI-based polyurethane products to TDA. The TDA isomers are included in the metabolism of toluene diisocyanate. The possibility has been discussed of using TDA to control TDI exposure, but methods and routines for this purpose have yet to be developed.

2,4-TDA is at present B-listed, which makes the use of it subject to permission from the Work Environment Inspectorate. The reason for 2,4-TDA being put on the B list is its carcinogenic effect.

Interest in recent years has come to focus on exposure to TDA via respiration. Low concentrations of the substance can form in connection with hot work above all in contact with polyurethane-based polymer (TDI). It is important to eliminate formation of and exposure to TDA as far as possible in the planning and risk assessment of this kind of work.

The requirement of a permit only applies to the use of 2,4-TDA. Rules for hot work in connection with polyurethane-based polymers are contained in AFS 2005:18, Thermosetting Plastics.

The Work Environment Authority propose that 2,4-diaminotoluene remain B-listed. No action is proposed concerning 2,6-diaminotoluene. The scientific information available gives no cause for adding 2,6-TDA to the B list.

### **Further reading**

Arbete och Hälsa 2001:19.

IVL Rapport B 1389, Isocyanater från heta arbeten i skadereparationsverkstäder.

## Diesel exhaust fumes

Diesel exhaust fumes have several different components in both particle and gaseous form. Markers are used to facilitate the measurement of these fumes. In Sweden, nitrogen dioxide has been used as a biological marker for exposure to diesel fumes. Germany has for some years now been using elementary carbon (EC) as an indicator.

**Nitrogen dioxide (ref. exhaust fumes)**

**CAS no.: 10102-44-0**

### Proposal following external consultation

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Nitrogen dioxide (ref. exhaust fumes)	1	2	-	-	

### Proposal

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Nitrogen dioxide (ref. exhaust fumes)	1	2	-	-	

### Present occupational exposure limit value(AFS 2000:3)

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Nitrogen dioxide (ref. exhaust fumes)	1	2	-	-	

### Occupational exposure limit values in other countries

Diesel exhaust fumes	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	-	
Norway (2001)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Below ground (not coal mines)		0.3			Elementary carbon
Sundry		0.1			
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	

USA (ACGIH, 2003)	-	100	-	-	Total hydro-carbon content
EU	-	-	-	-	

### Health effects

Diesel exhaust fumes are formed in the combustion of diesel oil, which produces a complex mixture of gases and differently sized particles.

The particle fractions most often determined in connection with measurement of particles in the ambient environment are PM<sub>10</sub> and PM<sub>2.5</sub>, i.e. particles with a diameter <10µm and < 2.5µm respectively.

The toxic effects of diesel exhaust fumes impact on lungs and airways, which can lead to both acute and chronic effects, with an elevated risk of serious illnesses. It has yet to be made clear, however, which factor or factors in diesel exhaust fumes produce these toxic effects.

### Human studies

One study has shown symptoms from the eyes and nose and increased airway resistance in connection with exposure to diesel exhaust fumes for one hour at a particle concentration of 0.3 mg/m<sup>3</sup> (PM<sub>10</sub>) and a nitrogen dioxide concentration of 2.9 mg/m<sup>3</sup>.

Healthy and slightly asthmatic persons were exposed to diesel exhaust fumes for 2 hours. Slight effect was reported at a particle content of 0.1 mg/m<sup>3</sup> (PM<sub>10</sub>) and 0.4 mg/m<sup>3</sup> nitrogen dioxide. The effect of the exposure was most noticeable among the asthmatic subjects.

In another study, mucous membrane symptoms appeared in the eyes and airways of healthy persons exposed to diesel exhaust fumes for one hour. The concentration was recorded as 2-3 mg/m<sup>3</sup> nitrogen dioxide.

Variation in the concentration of airborne particles in urban environments affects the morbidity of asthmatic persons, with a heightened occurrence of symptoms. In addition, connections have been found between variations in the concentration of atmospheric pollutants and variations in cardiac mortality. Other studies have shown that air contaminants affect the cardiac rhythm of patients with severe heart disease. Connections have also been shown between exposure to air contaminants and inflammatory markers. Since both particles and nitrogen dioxide can emanate from sources other than diesel exhaust fumes, it is impossible to judge the extent to which these health effects are due to diesel exhaust fumes.

The airways of asthmatic patients can very easily react by contracting following inhalation of irritant substances. The doses needed to trigger this reaction are much lower in asthmatic persons than in healthy subjects. This reaction, termed increased bronchial reactivity, is central to asthmatic disorders. Studies of asthmatics have

shown increased incidence of particular air contaminants in the ambient environment to have led to an aggravation of asthma in persons who are already asthmatic. (Asthma patients serve here as a biological marker of air contamination). Other studies have also shown that exposure to dust and exhaust fumes from traffic in ambient surroundings significantly reinforces the asthmatic reaction following inhalation of allergens.

Several experimental chamber studies of pure NO<sub>2</sub> in concentrations between 1.1 and 9 mg/m<sup>3</sup> have failed to show inflammatory changes in the respiratory tract corresponding to those following exposure to diesel exhaust fumes. Nor do any inflammatory changes in the airways result from many times higher exposure to pure NO<sub>2</sub>.

No inflammatory changes were found when the experimental subjects were subjected to a many times heavier exposure to pure NO<sub>2</sub>.

### *Cancer*

Diesel exhaust fumes contain many known mutagens. Elevated concentrations of DNA adducts have been shown in laboratory animals exposed to diesel fumes. Collations of epidemiological studies in humans confirm the suspicion of a link between exposure to diesel exhaust fumes and elevated risk of lung cancer. The occupational categories which have been studied are lorry drivers, driers of contracting machinery and diesel locomotive, and miners.

Other forms of cancer which have been discussed in connection with diesel exposure are cancer of the bladder, lymphatic tissue and blood-forming organs, and cancer of the prostate, but these connections are not unambiguously supported by the literature.

Different animal experiments have shown differing response in cancer tests using diesel exhaust fumes. Studies on mouse do not show any clear carcinogenic response. Rats exposed to particle concentrations in the region of 2.5 mg/m<sup>3</sup> (particle fraction unknown) presented elevated tumour occurrence. It has been shown that rats exposed to similar concentrations of soot particles or particles consisting of titanium dioxide also had an elevated incidence of lung tumours. Rats exposed to filtered (particle-free) diesel exhaust fumes under corresponding conditions did not present any firm increase in lung tumours. Experimental studies in animals have shown that both "pure" carbon particles and organic substances (mixtures of polyaromatic hydrocarbons) can increase the risk of lung cancer in rat.

A possible connection between individual agents in diesel exhaust fumes and health effects has not been investigated. In Sweden a special occupational exposure limit value for nitrogen dioxide in diesel exhaust fumes has been used as occupational exposure limit value/indicator in connection with exposure to diesel fumes. In Germany in recent years, elementary carbon in the respirable fraction has been used as a specific indicator of exposure to diesel exhaust fumes.

\*

The critical effect of diesel exhaust fumes is irritation and inflammation of the airways. Distinct interactive effects between particles and nitrogen dioxide have been demonstrated where effects on the airways are concerned. The exposure data do not permit any conclusion to be drawn concerning a suitable exposure indicator for the risk of lung cancer.

### **Use/occurrence**

Diesel exhaust fumes are formed in the combustion of diesel oil, which produces a complex mixture of gases and particles. The composition of diesel fumes varies, depending on many factors, such as fuel, type of engine and engine adjustment, the age of the engine, driving conditions, load and any exhaust purification methods used. The gaseous phase includes, among other things, carbon dioxide, carbon monoxide, nitrogen oxides, sulphurous oxides, aldehydes and hydrocarbons (both volatile, such as methane, ethane etc., and heavier particle-borne polycyclic aromatic hydrocarbons, PAHs). To facilitate measurement of diesel exhaust fumes, different studies have used different biological markers, e.g. nitrogen dioxide, particles/elementary carbon.

The composition of diesel exhaust fumes is also affected by the density and volatility of the fuel. Studies have, for example, shown that the sulphur and aromatic hydrocarbon content of the fuel contributes towards the formation of particles in the exhaust fumes.

Diesel exhaust fumes have a particle size  $< 1 \mu\text{m}$ . Measurements of exposure to diesel exhaust fumes, however, have included all particles  $< 10 \mu\text{m}$ , i.e.  $\text{PM}_{10}$ . This type of measurement is common in the outdoor environment. Outdoor sampling of  $\text{PM}_{10}$  includes larger particles which do not emanate from diesel exhaust fumes, as well as small particles from oil combustion. Indoor measurement of diesel particles such as  $\text{PM}_{10}$  can yield quantities comparable to those obtained when sampling particles  $< 1 \mu\text{m}$ , the reason being that the heavier particles are generally absent indoors. Measurement of respirable particles ( $< 4 - 5 \mu\text{m}$ ) is also conceivable in an indoor environment, because then the  $5-10 \mu\text{m}$  fraction is not present.

Nitrogen oxide ( $\text{NO}_x$ ) is formed during the combustion of diesel oil. In the emissions context,  $\text{NO}_x$  is used as a biological marker for diesel exhaust fumes. Nitrogen oxide are often measured in the form of nitrogen dioxide but are emitted as a mixture of nitrogen dioxide and nitrogen monoxide.

### **Quantities**

During 2001 the Swedish refineries produced/sold 3,556,000  $\text{m}^3$  diesel fuels. Practically all of this belongs to environment class 1, which means that it contains little sulphur and no PAH.

### **No. persons exposed**

The main occupational categories exposed are miners, railway workers, vehicle mechanics, truck drivers and bus garage workers. Figures from Statistics Sweden (SCB) give the following breakdown:

Miners:	1 700
Vehicle mechanics:	48,000 (inc. railway worker sand bus garage workers)
Truck drivers:	22,000

Thus upwards of 70,000 persons may be occupationally exposed to diesel exhaust fumes to a greater or lesser degree.

### **Atmospheric concentrations**

The Work Environment Inspectorate recently carried out a number of parallel measurements of elementary carbon and nitrogen dioxide in order to investigate the connection between nitrogen dioxide and elementary carbon (EC) content regarding exposure to diesel exhaust fumes. The findings were to form the basis of deliberations as to whether the occupational exposure limit value for diesel exhaust fumes should be linked to NO<sub>2</sub> content or the quantity of elementary carbon. Most of the measurements were taken in mines.

26 samples of elementary carbon were measured in concentrations of between 0.008 – 0.228 mg/m<sup>3</sup>. These broke down as follows:

20 samples < 0.100 mg/m<sup>3</sup>

5 samples had concentrations of between 0.100 and 0.200 mg/m<sup>3</sup>.

1 sample > 0.200 mg/m<sup>3</sup> (0.228 mg/m<sup>3</sup>).

26 measurements of nitrogen dioxide concentrations in the same environment showed between 0.072 – 3.46 mg/m<sup>3</sup>. These broke down as follows:

10 samples < 0.5 mg/m<sup>3</sup>

9 samples had concentrations of between 0.5 -1.0 mg/m<sup>3</sup>

7 samples > 1 mg/m<sup>3</sup>

Sampling of particles <1µm, analysed with respect to elementary carbon, with normal air flow during one working day, generally yield a too small quantity for analysis, but measurement in mines yields sufficient to be completed in one working day. In other environments it takes at least three days' sampling to collect a large enough sample of elementary carbon analysis. To make these samples comparable with the nitrogen dioxide measurements, NO<sub>2</sub> was also measured for three days, but those measurements are too few in number for a relation between elementary carbon and nitrogen dioxide to be estimated.

Personal measurements of diesel exhaust fumes (NO<sub>2</sub>) during the past five years have mostly been carried out in mines. The majority of measurements fall short of the replet-day occupational exposure limit value, 1 ppm. The proposed new

occupational exposure limit value of 0.5 ppm is also fallen short of, except in the case of one operation, loading, where exposures are in the region of the present-day limit value. A number of measurements have also been taken in connection with tunnelling. These have shown the proposed limit value to be briefly exceeded, but average exposure for a whole working day is well below this value.

### **Impact assessment**

The critical effect for diesel exhaust fumes is irritation and inflammation of the airways. Epidemiological studies indicate a connection between elevated risk of lung cancer and exposure to diesel exhaust fumes. It is not clear which component or components is the cause of acute or chronic effects of diesel exhaust fumes, but elementary carbon (EC), unlike nitrogen dioxide, is a specific indicator of diesel exhaust fumes. The Work Environment Authority has investigated the possibility of basing the occupational exposure limit value for diesel exhaust fumes on EC, but the measuring projects conducted have not yet yielded sufficient parallel data for valuation of the connection between EC and NO<sub>2</sub> to be possible. Methods of EC sampling and analysis are not yet available in Sweden for routine measurements. Methods development is in progress.

In the meantime the Work Environment Authority proposes continuing use of the current occupational exposure limit value for nitrogen dioxide as an indicator for diesel exhaust fumes.

### **Further reading**

Arbete och Hälsa, 2003:15.

## Diisocyanates

2,4-Toluene diisocyanate (2,4-TDI)	CAS no.: 584-84-9
2,6-Toluene diisocyanate (2,6-TDI)	CAS no.: 91-08-7
2,4-TDI / 2,6-TDI (4:1)	CAS no.: 26471-62-5
4,4'-Methylene diphenyl diisocyanate (MDI)	CAS no.: 101-68-8
Hexamethylene-1,6-diisocyanate (HDI)	CAS no.: 822-06-0

## Proposal

	LLV		CLV*		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
TDI	0.002	0.014	0.005	0.04	C, S
MDI	0.002	0.03	0.005	0.05	H, S
HDI	0.002	0.02	0.005	0.03	S
Diisocyanates	0.002	-	0.005	-	S

\*Ref. 5 minutes

## Present limit value (AFS 2000:3)

	LLV		CLV*		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
TDI	0.005	0.04	0.01	0.07	K, S
MDI	0.005	0.05	0.01	0.1	S
HDI	0.005	0.03	0.01	0.07	S
Isocyanates	0.005	-	0.01	-	S

\*Ref. 5 minutes

## Occupational exposure limit values in other countries

TDI	LLV		CLV/STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2003)	0.005	0.035	-	-	C
Finland (2002)	-	-	-	0.035	iso- cyan- ate
Norway (2003)	0.005	0.035	0.01	-	S, C
Germany (TRGS, 2000)	0.01	0.07	-	-	
Germany (MAK, 2002)	-	-	-	-	S
USA (OSHA, 1989)	0.005	0.04	0.02	0.15	
USA (ACGIH, 2003) 2,4-TDI	0.005	-	0.02	-	S
EU	-	-	-	-	

MDI	LLV		CLV/STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Denmark (2003)	0.005	0.05	-	-	
Finland (2002)	-	-	-	0.035	isocyanate
Norway (2003)	0.005	-	0.01	-	S
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	0.05	-	-	S
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	0.005	-	-	-	S
EU	-	-	-	-	

HDI	LLV		CLV/STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Denmark (2003)	0.005	0.035	-	-	
Finland (2002)	-	-	-	0.035	isocyanate
Norway (2003)	0.005	0.035	-	-	S
Germany (TRGS, 2000)	0.005	0.035	-	-	
Germany (MAK, 2002)	0.005	0.035	-	-	S
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	0.005	-	-	-	S
EU	-	-	-	-	

### Health effects

Isocyanates are characteristically highly reactive compounds. The isocyanates described in this document are diisocyanates, which means that there are two functional isocyanate groups per molecule. Diisocyanates polymerise easily.

TDI and HDI are volatile at room temperature, whereas MDI has to be heated in order to vaporise.

Diisocyanates and their metabolites – diamines, for example – can form adducts with DNA. In contact with water, aromatic isocyanates can be converted into aromatic amines.

#### *Effects in the airways*

Exposure to TDI in concentrations exceeding 0.100 ppm can be seen to produce a directly irritant effect on mucous membranes in the eyes and airways. More often than not, concentrations of between 0.030 and 0.100 ppm also cause mucous membrane irritation.

89 workers exposed to TDI (8-hour time-weighted average 0.001-0.025 ppm, median 0.005 ppm) were observed for 2.5 years. Significantly elevated occurrence of

coughing, wheeziness, chest constriction and dyspnoea was found in the exposed subjects compared with non-exposed controls. The exposed group of workers had not worked with isocyanates before the study.

Another study showed that when persons who had developed isocyanate asthma were exposed to low concentrations of TDI, the same reaction occurred as with exposure to higher concentrations of TDI for a shorter time. The total dose was the same in both cases.

\*

Exposure to MDI can cause irritation of the skin, eyes and respiratory tract. The relation between exposure level and symptoms has been insufficiently studied for MDI. In one study irritation of the nasal mucous membranes and the oesophagus were noted in about half of a group of employees who had been transferred to other duties on account of discomfort when exposed to diisocyanates.

\*

Occupational exposure to 0.040 ppm HDI gave irritation of the eyes, nose and oesophagus as well as coughing. There was no observable effect on pulmonary function. In a study of car sprayers who had been exposed to HDI and prepolymerised HDI, a significant correlation was found between reduced pulmonary function over time and the number of peak exposure occasions. Average exposure was 0.0002 ppm but temporary concentration peaks occurred in excess of 0.286 ppm.

\*

In a provocation test, experimental subjects (who had been exposed to isocyanates at work and had work-related dyspnoea) were exposed to 0.005 ppm for 15 minutes, followed by 0.010 ppm for 30 minutes and then 0.020 ppm for 5 minutes. The following table shows the number of persons reacting asthmatically to each dose.

	0.005 ppm	0.010 ppm	0.020 ppm
MDI (n=59)	6	2	8
TDI (n=40)	1	3	8
HDI (n=42)	0	2	1

At the first and lowest dose, 0.005 ppm for 15 minutes, more persons (6 persons, 10.2%) reacted to MDI than to TDI and HDI.

\*

Persons with suspected occupational asthma due to exposure to TDI, MDI or HDI at work were subjected to specific bronchial provocation (in an exposure chamber) at concentrations of between 5 and 20 ppb for up to 2 hours. Positive reactions to TDI were found in 67%, to MDI in 59% and to HDI in 38% of the exposed subjects.

\*

In a study of 48 paint sprayers whose work had exposed them to TDI, MDI and HDI, occupational asthma was found in 6 persons (12.5%). Exposure levels were not reported. In occasional instances, exposure to airborne TDI, MDI and HDI has been found capable of causing alveolitis, which means reduced pulmonary function.

### *Cancer*

Epidemiological studies have not been able to show any elevated cancer risk among persons exposed to isocyanates. No elevated risk of cancer could be shown in a study of 7,023 persons whose work had entailed exposure to TDI (0.0036 – 0.414 ppm) and MDI (< 0.001 ppm).

IARC (International Agency for Research on Cancer) has, however, on the basis of animal experiments, placed TDI in group 2B (possibly carcinogenic to humans).

One possible mechanism for the cancer provoked in animal experiments may be that carcinogenic aromatic amines are formed when TDI metabolises.

### *Skin*

Persons with isocyanate asthma often have runny noses and red eyes, as well as nettle-rash-type dermal reactions.

Several case reports have shown workers developing allergic contact dermatitis of the hands, arms and face because of MDI, TDI and HDI.

Studies of animals have shown dermal uptake of MDI to cause greater reactivity in the bronchi. It has also been shown that guinea pigs develop contact dermatology from TDI and HDI. Capacity for developing contact dermatitis in mice is greatest for HDI, followed by MDI and TDI, in that order.

\*

Development of asthma is the critical effect of exposure to TDI, MDI and HDI.

### **Use/occurrence**

The commonest technical TDI product in working life contains a mixture of 2,4-TDI and 2,6-TDI in a ratio of 4:1.

Diisocyanates are used in the production of polyurethane foam and are an important component in the manufacture of certain other plastic products, such as insulation materials, insecticides, two-component glue, paints and varnishes and hardeners of various kinds.

TDI is used above all in the manufacture of low-viscosity polyurethane foam, while MDI is used for manufacturing more rigid polyurethane products in catalytic converters, refractory materials etc.

TDI and MDI are used to make polyurethane for surface coating material, e.g. for conveyor chutes in the mining industry and agriculture. The shoe industry uses polyurethane for manufacturing soles and the automotive industry uses it for manufacturing shock absorbers. MDI is used in the production of bonding agent for moulds in the foundry industry and as a hardener for plastic and glue. MDI is also used in plastic plaster of Paris for orthopaedic bandage materials. HDI is used mainly as a hardener in paint and varnish.

### **Quantities**

The following data concerning numbers and volumes of products are based on figures from Produktregistret 1998.

2,4-TDI	93 products, of which 17 consumer products. Total 2,866 – 3,635 tonnes.
2,6-TDI	28 products, no consumer products. Total 430 - 1199 tonnes.
2,4-TDI/2,6-TDI	44 products, of which 3 consumer products. Total 49 - 50 tonnes.
MDI	216 products, of which 40 consumer products. Total 2,724 – 2,825 tonnes.
HDI	168 products, of which 13 consumer products. Total 3 - 5 ton.

### **No. persons exposed**

The National Board of Occupational Safety and Health and the Labour Inspectorate carried out a joint nationwide measurement project between 1997 and 1999, aimed at charting diisocyanate exposure in industry and other activities where diisocyanate products are used. An estimated 10,000 persons may be occupationally exposed to diisocyanates. Most of them are exposed to TDI, MDI and/or HDI. Diisocyanates can also be formed in the thermal degradation of polyurethanes (cf. methyl isocyanate and isocyanic acid).

### **Atmospheric concentrations**

In the above mentioned study, 590 personal measurements were carried out. These measurements were adapted to and performed in accordance with the duration of the working operation, which varied between 5 – 28 minutes (HDI) 3 – 27 minutes (TDI) and 5 and 37 minutes (MDI). The length of the sampling time deviates from the reference period for both peak (5 min.) and threshold exposure limit values (8 hours) for isocyanates.

Comparing all measurements with 10 ppb (the peak exposure limit value), the majority, 98.8%, come below this level. Further excesses above the peak limit value may, however, be hidden in measurement data for a sampling period of more than 5 minutes.

The excess values observed broke down as follows:

TDI	0.7% (3 of 421 samples)	Teeming of 100°C solution, hot casting
MDI	2.6% (3 of 117 samples)	Cold casting and manufacture of castings, spray booth
HDI	19% (1 of 52 samples)	Welding of newly painted girder

The measuring periods being very short compared with the reference period of a whole day, comparison with the threshold exposure limit value is less interesting, added to which, the peak limit value is probably more important from a medical viewpoint.

MDI, which is not volatile at room temperature, was measured during cold casting. During casting a product containing MDI is sprayed onto a rotating roller. Workers are then exposed to MDI in aerosol form.

In a report entitled "*Medicinska risker, biologiska mekanismer samt medicinsk och social prognos*", the Department of Occupational and Environmental Medicine, Lund University Hospital, has presented whole-day measurements of TDI at a number of companies occupied with casting and flame lamination. All measurements come below the threshold limit value of 0.005 ppm and all measurements but one come below the proposed new threshold limit value of 0.002 ppm.

### **Impact assessment**

Previously no good methods existed for measuring diisocyanates. Partly for this reason, insufficient data are available for an assessment of dose-effect and dose-response relations.

Diisocyanate measurement is complicated for several reasons. The measurement methodology has to be specific and highly sensitive, due to the low limit values. Methods of diisocyanate measurement have been successively developed since the 1950s. The earliest methods were developed for TDI (vapour form).

Due to the scanty supply of quantitative data, the relations presented in the scientific documentation are for the most part based on effects and exposure levels reported for TDI. The limit value for diisocyanates has therefore been principally based on knowledge concerning TDI. This analogous assessment has been generally accepted, because the effects in the respiratory tract have been connected with the reactive isocyanate groups. Recently, however, more scientific information has been published concerning MDI and HDI, though the information on TDI continues to predominate at "critical level".

The proposed values apply to all diisocyanates; see note 23 in conjunction with the list of occupational exposure limit values.

In hot work where both diisocyanates and MIC and ICA are formed, both technical and organisational improvements are needed in many workplaces in order for the proposed limit values to be contained. Examples of safety precautions and expenses are presented under the impact assessment for MIC and ICA; since concentrations of these substances are generally so high as to be determinative of ventilation.

To go beyond the of limit values is often connected with ignorance of the ability of different operations to generate diisocyanates. This is especially the case with hot work and extrusion. Carefully prepared working routines and greater awareness of the situations in which diisocyanates can be formed will enhance the possibilities of reducing exposure by suitable means.

Asthma-like symptoms have been shown in several studies where measurements of TDI indicate exposure levels down to 0.005 ppm. It has been suggested that high brief exposures are likelier than continuous exposure to low concentrations to lead to asthma. The significance of this has not been fully clarified. Despite the fact that exposure cease, asthma, with both symptoms and increased bronchial reactivity, persist in response to direct stimuli. With early diagnosis and rapid discontinuation of exposure for persons who have developed isocyanate asthma, the symptoms can diminish and sometimes disappear.

The critical effect of exposure to TDI, MDI and HDI is development of asthma.

In order to give the occupational exposure limit value a wider margin to the symptoms and reduce the risk of asthma and other isocyanate-related disorders developing, the Work Environment Authority proposes a reduction of the threshold limit value to 0.002 ppm and the peak limit value (5 min.) to 0.005 ppm.

The proposed reduction (0.002 ppm) of the peak limit value is unlikely, judging from current measurements, to mean the limit value being exceeded more frequently. A reduction of the peak limit value to 0.005 ppm, on the other hand, may entail problems leading to certain expenses.

### **Further reading**

Arbete och Hälsa, 2001:19.

<b>Dimethyl adipate</b>	CAS no.: 627-93-0
<b>Dimethyl glutarate</b>	CAS no.: 1119-40-0
<b>Dimethyl succinate</b>	CAS no.: 106-65-0

### Proposal

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Dimethyl adipate	5	36	-	-	
Dimethyl glutarate	5	33	-	-	
Dimethyl succinate	5	30	-	-	

### Present limit value (AFS 2000:3)

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Dimethyl adipate	-	-	-	-	
Dimethyl glutarate	-	-	-	-	
Dimethyl succinate	-	-	-	-	

### Occupational exposure limit values in other countries

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>Dimethyl adipate, dimethyl glutarate, dimethyl succinate</b>					
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	-	
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	-	-	-	-	
EU	-	-	-	-	

### Health effects

Dimethyl adipate (DMA), dimethyl glutarate (DMG) and dimethyl succinate (DMS) usually occur in a mixture taking the form of a colourless liquid.

Glutaric acid and succinic acid, which are metabolites of DMG and DMS respectively, occur naturally in the human body.

DMA, DMG and DMS hydrolyse to monomethyl esters, dicarboxyl acids and methanol. The hydrolysis is aided by carboxylate enzymes in the airways and in the liver of rat. Deposition in the upper respiratory tract was consistently >97% in a study performed on rat. This applied to all three di-esters. Other studies have shown the rate of hydrolysis to be 2-3 powers of ten slower in humans than in rat. Furthermore, a structure-activity relation has been observed with regard to the hydrolysis reaction, showing DMA to hydrolyse faster than DMG, which hydrolyses faster than DMS.

Transient vision disturbances (blurred vision) in connection with exposure to mixtures of the three esters have been reported in safety data sheets from suppliers/manufacturers. No atmospheric concentrations have been indicated, but the effect is probably linked with relatively high atmospheric concentrations or direct contact with the eyes.

In inhalation studies DMA, DMG and DMS are to a great extent deposited in the upper respiratory tract. In one study of rat in which the animals were exposed for 4 hours to a vapour/aerosol mixture comprising 5,900 mg/m<sup>3</sup> of a mixture of DMA, DMG and DMS, injuries occurred to the mucous membranes in the muzzle. These injuries comprised inflammation, degeneration and necrosis, but to a great extent proved to be reversible within 6 weeks.

In another inhalation study, female and male rats were exposed for 6 hours/day, 5 days/week for 13 weeks to 390, 76 or 20 mg/m<sup>3</sup> mixtures of DMA, DMG and DMS. After 7 weeks at the two highest dosage levels, mild degeneration of muzzle epithelium was observed in the nasal cavities of both sexes. This degeneration was dose-related. After 13 weeks' exposure, degradation of the mucous membranes was observed in the nasal cavities of the females at all dosage levels and in the male animals at the two highest dosage levels. Following a 6-week exposure-free period, signs of repair of damaged tissue were observed. At the highest dosage level, impaired weight development and lower liver weight were reported in female rats. These changes were also reversible.

Rabbits were exposed to a mixture of DMA, DMG and DMS via the respiratory tract (15 or 60 ppm for 4 hours), skin (50 or 200 µl) or eyes (10 µl) and examined for effects on the eyes. In the inhalation experiment a dose-related, increased occurrence of slight conjunctive tissue irritation was observable. At the higher dose moderate irritation of the iris and a slight clouding of the cornea were also observable. Rabbits which had received the mixture in the eye showed signs of somewhat greater irritation.

In several reproduction studies of rat, no effects have been found on the young. In one study, lower body weights were found in the young at a certain exposure, but lower body weights were then exhibited by the mothers as well.

Quantitative dermal uptake data are lacking for all three diesters.

Data are lacking with which to establish critical effect on humans, but the animal studies have shown that irritation of the respiratory tract can be a critical effect.

### **Use/occurrence**

Mixtures of DMA, DMG and DMS are used as solvents in the painting of buildings and in industrial painting. They are also used for cleaning polyurethane foam and unsaturated polyester resins. DMS occurs in the cosmetic and food industries, among other things as a flavouring agent in ice cream, confectionery, pastries and drinks.

### **Quantities**

According to Produktregistret 1999:

Dimethyl adipate:	134 products, inc. 15 consumer products. 390 tonnes approx.
Dimethyl glutarate:	171 products, inc. 18 consumer products. 1,390 tonnes approx.
Dimethyl succinate:	139 products, inc. 17 consumer products. 430 tonnes approx.

All three substances occur in mixtures with each other, and so the number of products is far smaller than the sum total of the three substances, due to their being doubly and triply entered in the Product Register. The total quantity of the three substances is 2,210 tonnes.

### **No. persons exposed**

Due to these esters commonly occurring in paints, varnishes and paint removers, a large number of professionally active persons may risk being exposed to them. There are about 15,000 active building painters in Sweden. Additional persons in the engineering industry and persons employed on graffiti removal may also be exposed to various extents.

### **Atmospheric concentrations**

No occupational-hygienic measurement data are available.

### **Impact assessment**

The occupational exposure limit value proposed by the Work Environment Authority is 5 ppm. The value in mg/m<sup>3</sup> varies, owing to differences in molecular weight. The proposed limit value is expected to prevent effects on olfactory epithelium and irritation of the eyes and respiratory tract. Reversible damage to the olfactory epithelium in animals has been observed down to 20 mg/m<sup>3</sup>, which corresponds to approximately 3 ppm. 5 ppm, however, is judged to afford adequate protection against effects on olfactory epithelium, because the activity of the enzyme which degrades the esters has been given as 2 or 3 powers of ten lower in human nasal tissue.

Considering the relatively low volatility of these substances, there should normally be no difficulty involved in containing the limit value level proposed. Application of diesters by spraying can, however, entail heavy exposure. Workplace experience indicates a risk of vision disturbance in the event of uncontrolled handling. The introduction of the occupational exposure limit value will make clear the necessity of

planning and preventive measures. In the event of simultaneous exposure to any of the substances DMA, DMG and DMS, hygienic effect must be calculated..

The introduction of the occupational exposure limit values for the diesters is not expected to entail any significantly increased expenditure.

**Further reading**

Arbete och Hälsa, 1999:25.

## Fibres, synthetic inorganic

### Vitreous fibres

- Refractory ceramic fibres
- Special purpose fibres
- Other fibres

### Crystalline fibres

Aluminium silicate fibres, a refractory ceramic fibre, have CAS no. 142844-00-6

There are no CAS numbers for the other fibres.

### Proposal

	LLV	Rem.
Refractory ceramic fibres	0.2 fibres/cm <sup>3</sup>	C
Special purpose fibres	0.2 fibres/cm <sup>3</sup>	C
Other fibres*	1 fibres/cm <sup>3</sup>	
Crystalline fibres**	0.2 fibres/cm <sup>3</sup>	C

The fibres included in comparisons with the occupational exposure limit value are respirable fibres having a length-width ratio greater than 3:1, a diameter less than 3 µm and a length exceeding 5 µm. The occupational exposure limit value requires fibre counting in a phase contrast microscope.

\*Other synthetic, inorganic, vitreous fibres include, for example, continuous glass fibres and mineral wool (glass wool, slag wool and stone wool).

\*\*Synthetic inorganic crystalline fibres can be exemplified with silicon carbide fibres and graphite fibres. Silicon carbide fibres are considered carcinogenic.

### Present limit value (AFS 2000:3)

	LLV	Rem.
<b>Synthetic inorganic fibres</b>	1 fibre/ml	

For present purposes, a fibre is an article having a length-width ratio of at least 5:1, a minimum length of 5 µm and a maximum diameter of 3 µm. The occupational exposure limit value requires fibre counting in a phase contrast microscope.

### Occupational exposure limit values in other countries

	LLV	Rem.
Denmark (2002)		
Glass wool fibre	1 fibre/cm <sup>3</sup>	

Ceramic fibre	1 fibre/cm <sup>3</sup>	C
Stone wool fibre	1 fibre/cm <sup>3</sup>	
Finland (2002)	-	
Norway (2003)	-	
Synthetic mineral fibres	1 fibre/cm <sup>3</sup>	C
Silicon carbide fibres	0.1 fibre/cm <sup>3</sup>	C
Germany (TRGS, 2004)		
Inorganic fibre dust (not asbestos)	-	
High temperature glass fibres	500 000 fibres/m <sup>3</sup>	
Ceramic fibres, special glass fibres, polycrystalline ceramic fibres in specified areas of use	500,000 fibres/m <sup>3</sup>	
Module production	500,000 fibres/m <sup>3</sup>	
Sundry	250,000 fibres/m <sup>3</sup>	
Germany (MAK, 2002)	-	
USA (OSHA, 1989)		
Inert or disturbing dust	-	
Respirable fraction	5 mg/m <sup>3</sup>	
Total dust	15 mg/m <sup>3</sup>	
Refractory ceramic fibres	0.5 fibre/cm <sup>3*</sup>	
USA (ACGIH, 2003)		
Continuous glass fibres	1 fibre/ml	
Inhalable dust	5 mg/m <sup>3</sup>	
Glass wool fibres	1 fibre/ml	
Stone wool fibres	1 fibre/ml	
Slag wool fibres	1 fibre/ml	
Special fibres	1 fibre/ml	
Refractory ceramic fibres	0.2 fibre/ml	
Silicon carbide fibres (inc. whiskers)	0.1 fibre/ml	C
EU (2002)	-	

\* Recommendation from an optional occupational safety and health programme jointly compiled by the RCF industry and OSHA, PSP 2002.

### Health effects

Data for establishing critical effect in professional exposure to *special fibres*, i.e. glass fibres for special purposes, are lacking. Special fibres, including what are termed type E glass fibres and type "475" glass fibres are considered carcinogenic

The critical effect of occupational exposure to *refractory ceramic fibres* (RCF) is reduced pulmonary function. In a study of persons working in the production of refractory ceramic fibres, it was found that male smokers, male ex-smokers and non-smoking

women presented a significant reduction of pulmonary function (FVC). Exposure was between 0.01-1.0 fibre/ml. The median exposure time was 8.5 years for men and 4 years for women.

Irritative effects in eyes and airways have been shown at a minimum exposure level of 0.2 - 0.6 fibre/ml. There are indications that prolonged exposure to RCF can cause pleural changes in humans, mainly of the pleural plaque variety. Exposure to RCF has caused pleural fibrosis in laboratory animals.

Biopersistence data and animal experiments indicate a carcinogenic potential, and RCF is considered carcinogenic.

Studies of workers exposed to *silicon carbide fibres* are very hard to interpret, since the same workers have been simultaneously exposed, for example, to crystalline quartz., Increased occurrence of silicosis-like changes has been observed in studies of this kind. Elevated cancer risk has been viewed in connection with an exposure level of 0.1-0.9 fibre/ml for several years. Simultaneous exposure to quartz, for example, may have contributed. Silicon carbide is considered carcinogenic.

In the case of *synthetic inorganic fibres* generally, dermal contact with fibres exceeding 5 µm in thickness can cause itching, skin irritation and eczema, especially among sensitive persons (atopics). In occupational exposure to *mineral wool fibres*, irritation of the upper airways and persistent coughing has been reported. The exposure levels have been indicated as median concentrations of fibres (0.1-0.42 fibre/ml) and total dust (0.98-3.15 mg/m<sup>3</sup>). The fibre occupational exposure limit values are defined as respirable, and the Work Environment Authority considers the dust concentrations to be a more relevant consideration in connection with problems of the upper respiratory tract.

See further the impact assessment for inorganic dust.

### **Use/occurrence**

In Sweden, *synthetic inorganic fibres* are mainly manufactured for the production of insulation wool and textile products. The largest quantity of insulation wool fibre is used as thermal insulation in buildings. Large quantities are also included in products for technical thermal insulation, soundproofing and plumbing insulation/lagging.

*Mineral wool fibres* comprise glass wool, slag wool and stone wool fibres. About 30 per cent of stone wool and about 70 per cent of glass fibres are used for insulating buildings. About 70 per cent of stone wool is used as technical insulation, together with a small portion of glass fibres. In addition, fibres are used as friction materials in brake bands and also in gaskets.

*Continuous glass fibres* are used in the production of glass fibre textiles, e.g. fabric wall covering. They are also used as reinforcing or textile fibres. Continuous glass fibres are used mainly as an intermediate product for producing fibrous plastic composites

and for glass fibre fabric. The fabric is used for thermal and electrical insulation and for reinforcing paper sealing strips, vehicle tyres, yarn and threads.

*Refractory ceramic fibres* are used instead of asbestos for insulating from very intense heat and as frictional material. They represent about 50 per cent of the refractory materials market. Other applications include metal composites for reinforcing engine components, catalytic converters, vehicle heat shields, air bag systems for cars and space heat shields. They are also used in the manufacture of thermal insulation products as well as fire and flame retardants for buildings and ships.

At very high temperatures refractory ceramic fibres can crystallise, which can mean conversion to cristobalite.

*Special fibres* can be micro-glass fibres, used mainly as insulating fibres in the aerospace industry. They are used mainly for battery separators, filtration, and aircraft and space-craft insulation.

Synthetic inorganic *crystalline fibres* can be instanced with graphite fibres and silicon carbide fibres. These are used as reinforcement. Silicon carbide is a refractory abrasive. Varying amounts of silicon carbide whiskers – very fine single-crystal fibres – are formed in the production of silicon carbide.

## **Quantities**

In the absence of CAS numbers for the different fibres, exact numbers are hard to present and no information is obtainable from the product register of the Swedish Chemicals Inspectorate. The commonest refractory ceramic fibres, aluminium silicate fibres, do have CAS numbers, however. There were 120 tonnes registered in 2001 and 206 tonnes in 2002. The bulk of this is used in the steel and metal industries and in paper (products) and pulp manufacturing. The material is included in refractory cement and concrete. All aluminium silicate fibres used in Sweden were imported. There was no production or exportation

The following figures for other fibres are estimates from reports and from the industries concerned.

Total EU production of *mineral wool* is estimated at 1,200,000 tonnes/year.

In Sweden, about 80,000 tonnes *stone wool* and about 70,000 tonnes *glass wool* are used annually.

Total EU output of *refractory ceramic fibres* is approximately 40,000 ton/year. None are produced in Sweden.

There is no real production of *special fibres* in Europe. Most special fibres are imported.

No information is available concerning the amount of silicon carbide fibres used in Sweden.

## **No. persons exposed**

The impact assessment for the Provisions on Synthetic Inorganic Fibres, AFS 2004:1, indicate that some 500 persons are exposed to refractory ceramic fibres, special fibres and crystalline fibres in activities where these fibres or material containing more than five per cent by weight of them are handled.

A relatively large number of persons use high-temperature kilns, e.g. for firing pottery. These kilns can be insulated with refractory ceramic fibres. The risk of exposure to fibres in these activities, however, is judged to be very small.

## **Atmospheric concentrations**

The measurements presented below are personal unless otherwise indicated. The measurement period does not generally exceed four hours.

### *Refractory ceramic fibres:*

Crucible changes in glassworks: measurements in 1993 revealed concentrations of between 0.10 – 0.34 fibre/ml. This applied to cleaning, truck driving, and caulking in connection with crucible replacement. The background was 0.04 fibre/ml (stationary measurement).

Measurement during crucible replacement in the same company in 2003 revealed concentrations between 0.04 – 0.23 fibre/ml. (Measurement with the direct-reading FAM instrument showed concentrations between 0.06-8 fibre/ml. It was above all in connection with cutting that high concentrations were obtained.)

Manufacture of ceramic hob cookers: concentrations of about 0.02 fibre/ml were recorded in the assembly of heating units on ceramic hobs.

Manufacture of hot tops for use in foundries: 0.12 fibre/ml was recorded during sawing. 8.24 fibres/ml were observed during manual batching from bags in a remixer.

Manufacture of fireproofing strips: during rough cutting 0.19 fibre/ml was observed, during taping 0.12, during cutting of taped rolls 0.04 and in parting of rolls 0.12.

Demolition of boiler lagging in a district heating plant: 2.2 – 5 fibres/ml were estimated. Dust concentrations were so high that only one or two filters could be analysed.

*Special fibres:* Concentrations of nearly 1 fibre/ml were noted in the production of air filters for ventilation plants. High concentrations were also noted in the manufacture of ear plugs.

*Crystalline fibres:* only very low concentrations have been observed in the production of machining inserts. The same applies to use (ceramic inserts).

When smelting furnaces are demolished, certain parts of the refractory ceramic fibres in the insulation may have crystallised, in which case crystalline fibres occur intermingled with refractory ceramic fibres. No measurements have been

undertaken, but, just as in the above mentioned demolition of boiler lagging in district heating plants, the dust concentrations are very high

### **Impact assessment**

The critical effect for refractory ceramic fibres is pulmonary function reduction. Data for establishing a critical effect for special fibres are lacking, but refractory ceramic fibres and special fibres, as well as the crystalline fibre silicon carbide, are judged to be possibly carcinogenic to humans. The EU has classified refractory ceramic fibres and special fibres as carcinogenic to humans. It has not been possible to indicate exact levels for the effects which have now been mentioned, but it is clear that the occupational exposure limit value for refractory ceramic fibres, special fibres and crystalline fibres should be lower than the current occupational exposure limit value for synthetic inorganic fibres, 1 fibre/ml.

The introduction of a lower occupational exposure limit value for the three groups of fibres described above will mean less risk of the pulmonary function being affected. The new level will also mean a wider margin for a possible cancer risk.

When counting in a phase contrast microscope, it is hard to distinguish between refractory ceramic fibres, crystalline fibres and special fibres. Since refractory ceramic fibres, for example, can crystallise at high temperatures, these fibres may occur simultaneously. It is therefore an advantage for these fibres to have the same limit value.

According to the measurements which have been undertaken, most activities can contain the proposed occupational exposure limit value of 0.2 fibre/ml. The exception for refractory ceramic fibres applies, for example, to the demolition of melting furnace lagging and the demolition of boiler lagging in district heating plants. These, however, are activities requiring breathing protectors.

In the production of air filters for ventilation plants and for the production of ear plugs, concentrations of special fibres come close to and sometimes exceed the proposed occupational exposure limit value. There are, however, good possibilities of reducing exposure by various ventilation measures.

The alteration of the definition of fibre for analysis of fibres in a phase contrast microscope constitutes a harmonisation with the criteria adopted by the WHO and used in other countries. The change is not judged to entail heavy expenditure.

New Provisions on Handling of Synthetic Inorganic Fibres, AFS 2004:1, were adopted on 22nd January 2004. Changes compared with earlier Provisions comprise the introduction of stipulations concerning periodic measurements of refractory ceramic fibres, crystalline fibres and special fibres and the introduction of prescriptions concerning medical examination.

The cost of introducing a new occupational exposure limit value for refractory ceramic fibres, crystalline fibres and special fibres is judged insignificant. Far heavier

expenditure is entailed by compliance with the stipulations in the new Provisions on Handling of Synthetic Inorganic Fibres, AFS 2004:1.

**Further reading**

Arbete och Hälsa 2004:16

Konsekvensbeskrivning för föreskrifterna om syntetiska oorganiska fibrer (AFS 2004:1).

## Fluoroethanes

<b>1,1,1-Trifluoroethane</b>	CAS no.: 420-46-2
<b>1,1,1,2,2-Pentafluoroethane</b>	CAS no.: 354-33-6

### Proposal

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>1,1,1,-Trifluoroethane</b>	500	1,750	750	2,620	
<b>1,1,1,2,2,-Pentafluoroethane</b>	500	2,500	750	3,735	

### Present limit value (AFS 2000:3)

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>1,1,1,-Trifluoroethane</b>	-	-	-	-	
<b>1,1,1,2,2,-Pentafluoroethane</b>	-	-	-	-	

### Occupational exposure limit values in other countries

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>1,1,1,-Trifluoroethane</b>					
<b>1,1,1,2,2-Pentafluoroethane</b>					
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	-	
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	-	-	-	-	
EU	-	-	-	-	

### Health effects

1,1,1-Trifluoroethane (TFE) at room temperature is a gas ignitable in air at concentrations from about 70,000 ppm. 1,1,1,2,2-Pentafluoroethane (PFE) at room temperature is a colourless, non-ignitable gas with low water solubility.

No data are available concerning health effects on humans in connection with exposure to TFE or PFE.

Acute exposure of rat to 97,000 ppm or 540,000 ppm TFE for 4 hours gave transient weight loss which was dose-dependent. In another study where dog was exposed to

300,000 ppm TFE in the presence of adrenalin, an elevated tendency to cardiac arrhythmia was observable. Rat exposed to 800,000 ppm PFE for 4 hours showed reduced capacity for reacting to sound, unsteady walk and dyspnoea. No treatment-related effects were observable in rats after whole body exposure to 50,000, 15,000 or 5,000 ppm 1,1,2,2,2-pentafluoroethane for 4 or 13 weeks.

### **Use/occurrence**

Both TFE and PFE most commonly used in products used as coolant. PFE can also be included in fire-extinguishing agent.

### **Quantities**

Trifluoroethane occurs in seven products, none of them consumer products, total 92 tonnes. Pentafluoroethane occurs in 21 products, none of them consumer products, total 132 tonnes.

### **No. persons exposed**

According to information received from the Swedish Refrigeration Foundation, KYS, between 5,000 and 7,000 persons can be exposed. Of this group, refrigeration fitters number about 3,000-4,000 and are the category at greatest risk of exposure.

### **Atmospheric concentrations**

The Work Environment Authority does not know of any measurements of 1,1,1-trifluoroethane and 1,1,1,2,2-pentafluoroethane.

### **Impact assessment**

Following the abolition of chlorofluorinated hydrocarbons (CFCs) as refrigerants, they have been replaced by a number of fluorinated hydrocarbons. TFE and PFE are relatively common fluorinated hydrocarbons in present-day refrigerants. In the Work Environment Authority's opinion it is important to introduce occupational exposure limit values for all substances which can be involved in exposure during work on refrigeration equipment.

TFE and PFE have similar properties to 1,1,1,2-tetrafluoroethane (HFC 134a), which has previously been given an occupational exposure limit value of 500 ppm. The Work Environment Authority proposes that TFE and PFE will be given the same limit value.

No additional expense is foreseen.

### **Further reading**

Arbete och hälsa, 1999:25.

<b>Phosphorus pentachloride</b>	CAS no.: 10026-13-8
<b>Phosphorus trichloride</b>	CAS no.: 7719-12-2
<b>Phosphorus oxychloride</b>	CAS no.: 10025-87-3

### Proposal

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>Phosphorus trichloride</b>	0.2	1.2	0.4	2,4	
<b>Phosphorus pentachloride</b>	-	1	-	2	
<b>Phosphorus oxychloride</b>	0.1	0.6	0.2	1.2	

### Present occupational exposure limit value (AFS 2000:3)

	LLV		STV		Rem.
<b>Phosphorus trichloride</b>					
<b>Phosphorus pentachloride</b>	-	-	-	-	
<b>Phosphorus oxychloride</b>	-	-	-	-	

### Occupational exposure limit values in other countries

<b>Phosphorus trichloride</b>	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	0.2	1.2	-	-	
Finland (2002)	-	-	0.5	2.8	
Norway (2003)	0.2	1.5	-	-	
Germany (TRGS, 2000)	0.5	2.8	-	-	
Germany (MAK, 2002)	0.5	2.8	-	-	
USA (OSHA, 1989)	0.2	1.5	0.5	3	
USA (ACGIH, 2003)	0.2	-	0.5	-	
EU	-	-	-	-	

<b>Phosphorus pentachloride</b>	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	1	-	-	
Finland (2002)	-	-	-	1	
Norway (2003)	-	1	-	-	
Germany (TRGS, 2000)	-	1	-	-	inhal.
Germany (MAK, 2002)	-	1	-	-	inhal.
USA (OSHA, 1989)	-	1	-	-	

USA (ACGIH, 2003)	0.1	-	-	-
EU	-	1	-	-

Phosphorus oxychloride	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	0.1	0.6	-	-	
Finland (2002)	-	-	0.5	2.4	
Norway (2003)	0.1	0.6	-	-	
Germany (TRGS, 2000)	0.2	1.3	-	-	
Germany (MAK, 2002)	0.2	1.3	-	-	
USA (OSHA, 1989)	0.1	0.6	-	-	
USA (ACGIH, 2003)	0.1	-	-	-	
EU	-	-	-	-	

### Properties

Phosphorus trichloride at room temperature is a colourless liquid which fumes in moist air. Hydrolysis of the substance generates heat, producing phosphonic acid and hydrochloric acid. Phosphorus pentachloride at room temperature is a solid, smoking, yellowish or white to greenish-white substance. Through hydrolysis phosphorus pentachloride changes in a first step to hydrochloric acid and phosphorus oxychloride. In a second step the phosphorus oxychloride (colourless, smoking liquid) hydrolyses, emitting heat in the process and producing phosphoric acid and more hydrochloric acid. Phosphorus trichloride, phosphorus pentachloride and phosphorus oxychloride are all pungent-smelling substances.

### Health effects

Vapour/dust (hydrolysis products included) of phosphorus trichloride, phosphorus pentachloride and phosphorus oxychloride is irritating/caustic to the eyes and respiratory tract. Phosphorus trichloride and phosphorus pentachloride are reportedly highly irritating to the mucous membranes. Phosphorus oxychloride has been reported as affecting both the upper and lower airways to a great extent and has been claimed to cause delayed effects in the airways to a greater extent than phosphorus trichloride. Dermal irritation has also been shown in connection with exposure to phosphorus trichloride and hydrolysis products.

Other effects reported are nausea, vomiting and headache in connection with acute exposure to phosphorus trichloride and hydrolysis products. A few seconds' inhalation of phosphorus pentachloride in vapour form was followed by dizziness and severe headache in one person. Dizziness, nausea, vomiting or disturbances of cardiac function have been observed in connection with short-term exposure of phosphorus oxychloride vapour.

Exposure levels related to reported effects are generally lacking. In two studies symptoms of eye and airway irritation were observed in connection with exposure to

phosphorus trichloride and phosphorus oxychloride respectively. The atmospheric concentrations in the studies were usually 10-20 mg/m<sup>3</sup> for both substances.

### **Use/occurrence**

In Sweden, phosphorus trichloride is used for chlorinating fatty acids. Phosphorus pentachloride is used as a raw material in pharmaceutical production. Phosphorus oxychloride is used in pharmaceutical production and in the manufacture of modified starch..

### **Quantities**

*Produktregistret, Swedish Chemicals Inspectorate (KemI), 1999:*

phosphorus trichloride: 576 tonnes

phosphorus pentachloride: 36 tonnes

phosphorus oxychloride: 44 tonnes

### **No. persons exposed**

The number of persons exposed to phosphorus trichloride is approximately 20. The exposure time is generally brief. Protective clothing (whole-body) is used for operations involving the open handling of phosphorus trichloride.

The number of persons exposed to phosphorus pentachloride is approximately 40. The exposure time is generally brief. Protective clothing (whole-body) is used for operations involving the open handling of phosphorus pentachloride.

The number of persons exposed to phosphorus oxychloride is approximately 20 to 30. The exposure time is generally brief. Protective clothing (whole-body) is used for operations involving the open handling of phosphorus oxychloride.

### **Atmospheric concentrations**

The Work Environment Authority does not know of any measurements.

### **Impact assessment**

Use of these substances is limited and is for the most part enclosed. Open handling does sometimes occur, however, e.g. when batching the chemical. Working operations are generally of brief duration and personal protective equipment is used.

The introduction of the proposed occupational exposure limit values is unlikely to entail any additional expense

### **Further reading**

Arbete och Hälsa, 1999:25.

**Cadmium** CAS no.: 7440-43-9

**Proposal**

	LLV		CLV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
<b>Cadmium and inorg. compounds (as Cd), total dust</b>	-	0.02	-	-	C
<b>Cadmium and inorg. compounds (as Cd), respirable dust</b>	-	0.005	-	-	C

**Present occupational exposure limit value (AFS 2000:3)**

	LLV	CLV	Rem.	
<b>Cadmium and inorg. compounds (as Cd), total dust</b>				
<b>Cadmium and inorg. compounds (as Cd), respirable dust</b>	-	0.01	-	K

**Occupational exposure limit values in other countries**

	LLV		CLV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
<b>Cadmium and inorg. compounds (as Cd), dust</b>					
Denmark (2002)					
Powder, dust, smoke	-	0.005	-	-	C
Finland (2002)					
Cadmium & its compounds		0.02	-	-	H
Cadmium oxide, smoke	-	0.01	-	-	H
Norway (2003)					
Cadmium & inorg. compounds	-	0.05	-	-	C
Cadmium oxide, smoke	-	-	-	0.02	C
Germany (TRGS, 2000)					
Battery prod., extraction of Zn,Pb,Cu, welding inhal.	-	0.03	-	-	
other inhal.	-	0.015	-	-	
Germany (MAK, 2002)	-	-	-	-	C
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003) Total dust	-	0.01	-	-	C
Respirable	-	0.002	-	-	C
EU	-	-	-	-	

Cadmium is a heavy metal occurring naturally in ores, together with zinc, lead and copper. The cadmium compounds acetate, chloride and sulphate are highly soluble in water, whereas oxide and sulphide are sparingly soluble.

### **Health effects**

Exposure to cadmium in the work environment occurs mainly via the respiratory tract. It should be noted that cigarette smoke is the principal source of cadmium exposure among smokers who are not occupationally exposed, and that some exposure may possibly occur through ambient tobacco smoke.

Cadmium uptake through inhalation is between 10 and 50 per cent, depending mainly on particle size and solubility.

Routine exposure control has long been based on determination of cadmium concentration in the blood and urine (AFS 2000:7, Medicinsk kontroll vid kadmiumarbete). Blood cadmium content mainly reflects current exposure, while urine cadmium content is above all related to the quantity accumulated in the body (body load).

Long-term exposure to cadmium causes kidney damage. This primarily affects the tubular part of the kidney and is characterised by increased secretion of low-molecular proteins (protein urea). Several studies have demonstrated connections between exposure (air), biological concentrations (blood, urine) and tubular kidney damage.

It was already observed in 1950 that, in addition to protein urea, workers exposed to cadmium could also have reduced glomerular filtration rate (GFR). This has subsequently been confirmed by several studies of occupationally exposed workers.

Increased occurrence of kidney stone among occupationally exposed subjects has been demonstrated in several studies. The occurrence of kidney stone was most often associated with tubular protein urea.

Long-term exposure to cadmium can also cause skeletal disease, which was first reported from Japan. Exposure was several times higher than in other contexts, and the victims had severe skeletal injuries. In recent years data have emerged suggesting that even relatively low exposure to cadmium can give rise to skeletal injuries in the form of reduced bone density and fractures.

WHO (IARC) has judged that there is sufficient evidence for cadmium to be considered carcinogenic to both humans and laboratory animals. The studies on which IARC based its assessment have, however, been criticised for deficient exposure data. Lung cancer may possibly have developed as a consequence of combined effect with arsenic. There are several studies, e.g. from Sweden and the UK, which do not indicate any connection between lung cancer and exposure to cadmium.

Foetally harmful effects of cadmium have been observed in laboratory animals, most often following the injection of heavy doses, but no conclusions have been possible from the few studies made in humans.

The critical effect of exposure to cadmium is probably tubular kidney damage. Data from two major European studies, however, indicate that skeletal effects can occur at equally low levels. New data indicate a heightened risk of tubular kidney damage at urine levels in the region of 1 nmol Cd/mmol creatinine. This knowledge will form the basis of a review of the occupational exposure limit values for blood and urine cadmium content in Medicinsk kontroll vid kadmiumarbete, AFS 2000:7. Those studies are principally based on ambient exposure, and no atmospheric concentrations are specified. Calculation of an atmospheric concentration based on the above mentioned U-Cd level is too uncertain to furnish a meaningful value. Uncertainty and the low effect levels noted for cadmium in urine are, however, felt to justify a reduction of the occupational exposure limit values for atmospheric cadmium.

Cadmium has been judged by IARC to be carcinogenic to humans, but this is not supported by more recent data. Experimental data do indicate, however, that certain cadmium compounds can be carcinogenic.

### **Use/occurrence**

Cadmium compounds are used as paint pigments and in the production of batteries. More than 90 per cent of the cadmium used in Sweden is found in rechargeable nickel-cadmium accumulators (1996; Swedish Chemicals Inspectorate). For the year 2000 the Environmental Protection Agency reports an estimated collected quantity of 143 tonnes NiCd batteries. Metallic cadmium was formerly used as corrosion proofing (cadmium plating). Cadmium occurs as a contaminant in phosphorus fertilisers. Soldering metal used for soldering tools and in some goldsmithing shops can contain cadmium.

### **Quantities**

(tonnes, according to SCB: Utrikeshandel 2002)

	Imports	Exports
Cadmium oxide	0	77
Cadmium in unprocessed form; cadmium powder	113	0
Cadmium waste and scrap	10	1
Cadmium goods (other kinds)	27	0
Nickel-cadmium accumulators	380	7,714

### **No. persons exposed**

An estimated 190 persons are exposed to Cd in the production of NiCd batteries. About 150 persons are exposed at glassworks. A few persons are affected in

connection with the painting of china and ceramics. Five persons are involved in soldering work on tools with cadmium included in the silver solder. Some 50 persons are exposed at copper and lead ore smelting plants.

### **Atmospheric concentrations**

Exposure to cadmium in the Swedish work environment mainly occurs in the production of batteries. Handling and reuse of scrap metal containing cadmium can also entail a certain, not easily verifiable, degree of exposure. Atmospheric concentrations in the Swedish work environment are probably below the proposed limit value (0.02 mg/m<sup>3</sup>, total dust) for the most part. No measurements have been found in excess of the respirable limit value proposed (0.005 mg/m<sup>3</sup>).

26 measurements during 2001 in connection with the manufacture of industrial accumulators all come below the limit value level (0.0005-0.007 mg/m<sup>3</sup> (total dust)).

In the glass industry, Cd occurs as pigment powder in glass and in colours used for painting. The measurements which have come to the Work Environment Authority's knowledge are all well below the occupational exposure limit value. At one glassworks in 1998, five measurements were carried out – three in the furnace and two in the paint shop. Atmospheric concentrations came between 0.0002-0.0003 mg/m<sup>3</sup> (though it is unclear whether the reference here is to total dust or respirable dust). In six measurements conducted in 2001 at another glassworks, total dust concentrations came between 0.00001-0.0016 mg/m<sup>3</sup>. In five measurements undertaken in 2002 at two different glassworks, the levels at one glassworks, in the furnace department, were 0.000013 mg/m<sup>3</sup> and 0.000025 mg/m<sup>3</sup> (respirable dust). At the other glassworks, handling of paint powder gave 0.000064 mg/m<sup>3</sup> (total dust) and 0.000024 mg/m<sup>3</sup> (respirable dust). One measurement came below the detection limit.

A couple of measurements at soldering furnaces showed total dust concentrations of 0.00013 and 0.00368 mg/m<sup>3</sup>. Circuit board soldering has presented very low concentrations – of the order of 0.000002 mg/m<sup>3</sup> or less. Soldering of vehicle radiators has generated total dust and respirable dust concentrations of 0.032 mg/m<sup>3</sup> and 0.001 mg/m<sup>3</sup> respectively. Measurements in connection with soldering in goldsmithing shops have revealed low concentrations, mainly because the actual soldering work occupies a very small proportion of the total measuring time. The recorded values (total dust) were between 0.0001-0.0004 mg/m<sup>3</sup>. Some values were below the detection limit.

At one metal smelting plant, 91 measurements were carried out between 1996 and 2003. All the measurements recorded were below the occupational exposure limit value. The three highest were 0.027, 0.01 and 0.006 mg/m<sup>3</sup>. Other values obtained were in the 0.001-0.004 mg/m<sup>3</sup> interval and below the detection limit.

Cd concentrations (respirable) of up to 0.0031 mg/m<sup>3</sup> have been shown in connection with the casting of cuprous materials.

Cd has also been analysed in connection with welding measurements. Three observed values came in the 0.000003-0.000005 mg/m<sup>3</sup> interval.

### **Impact assessment**

Atmospheric concentrations of cadmium where the substance is handled or otherwise occurs are generally below the proposed occupational exposure limit value. The proposals are judged to prevent exposure to cadmium from becoming excessive and are thus expected to prevent kidney damage. The reduction is not judged to entail any additional expense.

### **Further reading**

Arbete och hälsa, 2003:15.

**Calcium hydroxide**  
**Calcium oxide**

CAS no.: 1305-62-0  
CAS no.: 1305-78-8

**Proposal**

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Calcium oxide	-	1	-	2.5	inhal.
Calcium hydroxide	-	3	-	6	inhal.

**Present occupational exposure limit value (AFS 2000:3)**

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Calcium oxide (total dust)	-	2	-	5	
Calcium hydroxide	-	-	-	-	

**Occupational exposure limit values in other countries**

Calcium oxide	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	2	-	-	
Finland (2002)	-	2	-	-	
Norway (2001)	-	-	-	2	CLV
Germany (TRGS, 1999)	-	-	-	5	CLV, inhal.
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	5	-	-	
USA (ACGIH, 2003)	-	2	-	-	
EU	-	-	-	-	

Calcium hydroxide	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	5	-	-	
Finland (2002)	-	5	-	-	
Norway (2001)	-	5	-	-	
Germany (TRGS, 1999)	-	5	-	-	inhal.
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	5	-	-	
USA (ACGIH, 2003)	-	5	-	-	
EU	-	5	-	-	

## Health effects

Calcium oxide and calcium hydroxide have alkaline properties and on coming into contact, for example, with skin or mucous membranes they react by breaking up fats and proteins. Calcium oxide harms mucous membranes and moist skin through intense heat emission and tissue dehydration due to the reaction between small calcium oxide particles and water and to the alkalinity of the calcium hydroxide which is formed.

The effects of the two substances are hard to separate, because calcium oxide forms calcium hydroxide on coming into contact with water

Calcium oxide and calcium hydroxide can cause severe injuries, above all to the cornea, resulting in permanent vision reduction. The concentration of the substance, its pH and the exposure time are crucial to its effect. Calcium hydroxide penetrates the epithelium of the cornea more slowly than other alkalis, which can account for the damage being slighter than that caused by other alkalis.

Slight caustic injuries to the cornea produce a superficial clouding. Prolonged exposure leads to more serious injuries, with penetration and clouding extending still deeper into the corneal tissue. At pH 12 and over, this happens immediately. Severe caustic injuries numb the cornea for many days. Calcium oxide is highly irritating and caustic to the skin and can cause burns. Wet cement containing calcium hydroxide can inflict similar caustic damage.

Calcium oxide is severely irritating and caustic to the airways. An undated report from the Pennsylvania Department of Health stated that strong nasal irritation occurred as a consequence of exposure to a mixture of calcium-oxide-containing dusts at a concentration of approximately 25 mg/m<sup>3</sup>, but that exposure to concentrations of 9 to 10 mg/m<sup>3</sup> produced no observable irritation.

A Swedish study showed reduced nasal clearance among fifteen pulp mill workers exposed to calcium oxide, compared to unexposed controls. The difference compared to the unexposed subjects disappeared after exposure was reduced from 1.2 mg/m<sup>3</sup> to 0.1 mg/m<sup>3</sup>. The temperature was reduced from 42 to 28 at the same time, which may have contributed towards the improvement. Inflammatory changes in the nose tended to be commoner among exposed subjects before the dust concentration was reduced.

In an unpublished report from NIOSH, irritation of the nose and throat was unanimously complained of in an industrial undertaking with calcium oxide concentrations between 0.4 and 5.8 mg/m<sup>3</sup>.

Exposure to calcium hydroxide can cause acute symptoms, such as irritation, coughing, pain and possibly caustic injuries to the mucous membranes. Heavy exposure can be followed by pulmonary oedema and states of shock. No data exist, however, concerning connections between symptoms and exposure levels where calcium hydroxide is concerned.

Reduced nasal clearance was noted among persons exposed to calcium dust, especially calcium oxide, where the geometric average of total dust was 1.2 mg/m<sup>3</sup>. Otherwise the documentation does not permit the establishment of dose-response relations for atmospheric concentrations of either calcium oxide or calcium hydroxide.

Dust of calcium oxide and dust or solution of calcium hydroxide can cause acute caustic injuries on coming into contact above all with the eyes but also with skin and mucous membranes. The critical effect of exposure to calcium oxide and calcium hydroxide is reduced nasal clearance and airway irritation. Calcium oxide is far more of an irritant than calcium hydroxide.

### **Use/occurrence**

Calcium oxide is produced by heating limestone (calcium carbonate) to 950 – 1,000 °C. Most consumption takes place in chemical processing industry. Calcium oxide is used as a slag-forming substance and for production of sodium hydroxide, cement, glass, pulp, paper and sugar. Other applications are purification of drinking water and wastewater, ore concentration and refining and as a soil stabiliser for foundation construction.

Calcium hydroxide is formed when calcium oxide and water are mixed, a process which generates a great deal of heat. Calcium hydroxide is cheap and is widely used for neutralising reactions, e.g. liming of fields and lakes. Sugar refining is another application. Mortar is a semi-solid plastic mass of calcium hydroxide, sand and water. Other applications are in lubricants and pesticides. Calcium hydroxide is widely used as a dental preparation for root canal treatment.

### **Quantities**

The total quantities reported to Produktregistret in 2002 were, for calcium oxide, approximately 590,000 tonnes divided between 261 products, 28 of them consumer products, and for calcium hydroxide approximately 70,000 tonnes divided between 280 products of which 44 are consumer products

### **No. persons exposed**

The number of workers who may be exposed to calcium oxide is estimated at about 300 or 400 in the sulphate pulp industry, about 50 in sugar manufacturing, some hundreds in steelworks and melting plants, between 170-200 at ore-dressing plants, between 10 and 20 in cement production, about 100 in lime burning, about 150 in connection with transport of burned lime and 20 or 30 at waterworks and wastewater processing plants.

The number who may be exposed to calcium hydroxide is estimated at about 150 in the production of mortar and plaster. Some 6,000 bricklayers use mortar and plaster, about 50 may be exposed in connection with sugar manufacturing, about 120 at ore-dressing plants and 150 at waterworks.

### **Atmospheric concentrations**

Most of the calcium oxide measurements known to the Work Environment Authority are more than 15 years old. Three measurements were carried out in 1988 at a steelworks. Concentrations for melting plant workers and filter operators were shown to be well under 1 mg/m<sup>3</sup>. Four measurements were carried out at a dental laboratory in 1997. All the measurements then recorded were between 0.016 - 0.003 mg/m<sup>3</sup>.

The concentration of predominantly calcium oxide dust was measured at a Swedish pulp mill. The geometric average total dust concentration in the stationary measurements was 1.2 mg/m<sup>3</sup> (variation range 0.1-7.7) before a rebuild and 0.1 mg/m<sup>3</sup> (0.1-0.2) after it. The biggest reductions were recorded at the two sampling points nearest the kiln. The personal measurements showed the geometric average total dust concentration to have fallen since the rebuild from 1.2 mg/m<sup>3</sup> (variation range 0.4-5.8) to 0.2 mg/m<sup>3</sup> (0.1-0.6).

All measurements refer to total dust.

The Work Environment Authority does not know of any measurement reports for calcium hydroxide.

### **Impact assessment**

Most of the industrial processes in which calcium oxide and calcium hydroxide are used are closed processes. A limited number of persons, such as operators and maintenance personnel, may be exposed. The reduction of the peak limit value for calcium oxide to 1 mg/m<sup>3</sup>, inhalable, and the introduction of a peak limit value of 3 mg/m<sup>3</sup>, inhalable, for calcium hydroxide is therefore not judged to entail any significant expense.

The new occupational exposure limit values are judged to reduce the risk of irritation in the eyes and airways. Closer control of the inhalation risk should also lead to greater awareness concerning the risk of skin injuries.

### **Litteratur**

Arbete och hälsa, 1999:25.

## Potassium aluminium tetrafluoride

CAS no.: 60304-36-1

### Proposal

LLV		CLV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	0.4	-	-	inhal.

### Present occupational exposure limit value (AFS 2000:3)

LLV		CLV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	-	

### Occupational exposure limit values in other countries

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	-	
Finland (1998)	-	-	-	-	
Norway (2001)	-	-	-	-	
Germany (TRGS, 1998)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2002)	-	-	-	-	
EU	-	-	-	-	

### Health effects

In one company, potassium aluminium tetrafluoride (KAlF<sub>4</sub>) was used for about ten years as a fluxing agent for soldering. During that time 22 exposed workers consulted the regional occupational medicine clinic for respiratory tract disorders. The latency period preceding the appearance of discomfort varied between 1 and 60 months. Nearly all those concerned (21 out of 22) were suffering from coughs or perceived chest constriction. The airway disorder diminished or disappeared after exposure ended.

Sixteen of the 22 persons showed signs/symptoms of bronchial hyperreactivity.

There are no data showing clear dose-response relations

Measurements have been carried out and compared with the occupational exposure limit value for aluminium and/or fluorides. Those limit values however, have proved irrelevant to an assessment of the risks entailed by exposure to KAlF<sub>4</sub>. A special KAlF<sub>4</sub> limit value should therefore be established.

It is impossible to define a level at which people are without symptoms. A level of this kind is generally hard to define by hypersensitivity symptoms. One circumstance impeding the assessment of a connection between exposure and effect is that different substances have been measured and used as exposure indicators in different measurements. See further *Atmospheric concentrations*.

### **Use/occurrence**

Potassium aluminium tetrafluoride (KAlF<sub>4</sub>) is a fluxing agent used by a small number of undertakings for soldering aluminium objects. The fluxing agent is a solid powder at room temperature.

### **Quantities**

The total quantity of potassium aluminium fluoride reported to Produktregistret in 2002 was 58 tonnes divided between 2 products, neither of them a consumer product.

### **No. persons exposed**

The number of persons exposed to KAlF<sub>4</sub> as a fluxing agent in connection with soldering work is about 50.

### **Atmospheric concentrations**

Exposure to KAlF<sub>4</sub> has previously been assessed in relation to the occupational exposure limit value for aluminium and also to the limit value for fluorides. On some occasions both substances have been measured at once, while on others either aluminium or fluoride has been measured. Conversion to KAlF<sub>4</sub> has sometimes yielded varying levels of exposure, depending on whether the point of departure has been Al or F. The method of fluoride analysis has since proved to be unreliable.

Two measurements were carried out at the companies concerned in 2003. Total dust was measured on both occasions.

At one undertaking the operators' exposure to KAlF<sub>4</sub> was measured during spells of 4-6 hours. Concentrations from 0.03 to 1.2 mg/m<sup>3</sup> were reported. Most of the measurements come between 0.1 and 0.2 mg/m<sup>3</sup>. Apart from the peak value of 1.2 mg/m<sup>3</sup>, two operators were exposed to 0.25 and 0.45 mg/m<sup>3</sup> respectively.

At another company, 12 personal measurements were carried out. Five of these took place in the assembly department, where the two highest measurements obtained were 0.65 and 0.67 mg/m<sup>3</sup>. The other three came between 0.05 and 0.15 mg/m<sup>3</sup>. In the wash room 0.38 mg/m<sup>3</sup> was recorded, in the baking building 0.18 mg/m<sup>3</sup> and in the com department 0.08 mg/m<sup>3</sup>. A greatly elevated value was recorded in the com-

fluxing room, namely 3.4 mg/m<sup>3</sup>. Two measurements carried out in the welding room showed < 0.01 and 0.05 mg/m<sup>3</sup>, and one measurement in the grinding room resulted in 2.8 mg/m<sup>3</sup>.

With exposure measurements to estimate concentrations of KAlF<sub>4</sub> it is sometimes insufficient to measure Al content alone, especially if there may be atmospheric Al dust present which derives from a source other than KAlF<sub>4</sub>. In such situations it is appropriate to measure potassium as well, so as to be better able to judge the proportion of observed aluminium deriving from KAlF<sub>4</sub>. The measurement samples in the above mentioned studies were analysed for both Al and K. The conversion from K and Al to KAlF<sub>4</sub> yields concurring results.

### **Impact assessment**

Use of KAlF<sub>4</sub> in Sweden is limited, but a relatively large number of workers have been affected by disorders of the respiratory tract. The companies using KAlF<sub>4</sub> have taken steps in recent years to limit exposure. The achievement of a work environment/level in which airway symptoms do not develop/appear requires effective ventilation and good planning, as well as strict working routines which in certain situations can include the use of personal protective equipment.

A specific occupational exposure limit value for KAlF<sub>4</sub> will be an important tool for checking exposure at the undertakings where the substance is handled. The Work Environment Authority proposes that the occupational exposure limit value be defined as inhalable dust. The value proposed, 0.4 mg/m<sup>3</sup>, roughly corresponds to 0.2 mg/m<sup>3</sup> total dust. Judging by the measurements obtained, the proposed limit value can be exceeded in certain operations.

Recently, however, the undertakings using KAlF<sub>4</sub> have substantially improved their work environment. Even so, the introduction of the occupational exposure limit value for KAlF<sub>4</sub> may necessitate certain supplementary measures. The cost involved, however, is judged to be limited.

Exposure to KAlF<sub>4</sub> has previously been compared with the occupational exposure limit value for aluminium (1 mg/m<sup>3</sup>) and/or fluoride (2 mg/m<sup>3</sup>). These levels correspond to a KAlF<sub>4</sub> content of just over 5 mg/m<sup>3</sup> and just under 4 mg/m<sup>3</sup>, respectively. Compared in this perspective, the proposed occupational exposure limit value for KAlF<sub>4</sub> implies, respectively, a 25-fold and 20-fold reduction.

### **Further reading**

Arbete och hälsa, 1997:24.

## Potassium hydroxide

CAS no.: 1310-58-3

### Proposal

LLV		CLV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	1	-	2	inhal.

### Present occupational exposure limit value (AFS 2000:3)

LLV		CLV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	-	

### Occupational exposure limit values in other countries

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	2	
Finland (2002)	-	2	-	-	
Norway (2003)	-	-	-	2	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	2	
USA (ACGIH, 2003)	-	-	-	2	
EU	-	-	-	-	

### Health effects

Several cases of poisoning are described following intake of domestic products containing about 30% potassium hydroxide solution (potassium/potash lye), These poisonings led to serious oesophageal injuries. Even one second's exposure to very small quantities of lye was sufficient to cause tissue necrosis.

A study has been made of eye injuries caused by alkali in industry. Exposure was through splashing. In almost half of all cases, the eye was struck by the alkali solution under pressure. Most injuries occurred in the construction and chemical industries.

Data are lacking for assessment of dose-effect, dose-response relations in occupational exposure to potassium hydroxide. Eye irritation has been studied in

rabbit. A 5% solution had a caustic effect on the eye while 0.1% potassium hydroxide had no effect. Applied to the skin of rodents, 5% solution was highly caustic.

### **Use/occurrence**

Potassium hydroxide is produced by electrolysis of potassium chloride, which occurs in minerals and is a white, solid, hygroscopic substance, usually occurring in lumps, rods or pellets. In air the substance absorbs water vapour and carbon dioxide and is quickly converted into bicarbonate and carbonate.

Potassium hydroxide is used among other things in the manufacture of liquid soap, manufacture of paint removal and cleaning agents, for galvanisation, in the photographic industry and for production of other potassium compounds. In air potassium hydroxide can occur as dust or aerosol.

### **Quantities**

The total quantity reported to Produktregistret in 1998 was about 6,700 tonnes divided between 848 products, 68 of them consumer products.

### **No. persons exposed**

Some 30 workers may be exposed in connection with potassium hydroxide production. About 120 persons are affected by potassium hydroxide in connection with the manufacture of accumulators.

Two persons may be exposed in connection with the production of binding agent for casting moulds and about 300 persons in the manufacture of the casting moulds themselves. Another type of binding agent production may entail the exposure of about another 25 persons.

In the food industry, it is above all high-pressure cleaning that entails a particularly high risk of exposure. Roughly a hundred persons are estimated to be exposed in different types of industrial cleaning, primarily in the food industry.

About 20 or 30 persons are involved in the handling of photographic chemicals at the large photographic laboratories. Fertiliser production may entail the exposure of a few persons.

About 15 persons may be exposed in the production of liquid soap. Use of cleaning and degreasing agents in major industrial applications may entail the exposure of about a hundred persons. In other manufacturing of products containing potassium hydroxide, e.g. degreasing agents, cleaning agents, paints, tensides, paint removal agents, metal surfacing agents, another hundred or so persons may be exposed.

The manufacture of products including potassium hydroxide is often enclosed and automatic. In reality, therefore, there is little risk of exposure in these processes. Potassium hydroxide is used in the majority of products and applications involving a strong hydroxide. Potassium hydroxide is used in fewer applications where for various reasons the use of potassium hydroxide is unsuitable.

### **Atmospheric concentrations**

The Work Environment Authority knows of only two occasions when potassium hydroxide measurement has been undertaken. Both sets of measurements are old now, dating as they do from 1975 and 1987. The first occasion involved three measurements (respirable) in connection with welding, the second two measurements (one stationary) in connection with washing in water. All the measurements recorded come in the 0.017-0.117 mg/m<sup>3</sup> interval.

### **Impact assessment**

Complete data for establishing the critical effect of occupational exposure to potassium hydroxide are lacking. In view of the strongly basic properties of potassium hydroxide, the critical effect is judged to be irritation of the eyes, skin and mucous membranes.

Potassium and sodium hydroxide have similar properties and impact mechanisms. The Work Environment Authority proposes that the limit values proposed for sodium hydroxide should also be introduced for potassium hydroxide. The threshold limit value, 1 mg/m<sup>3</sup>, and the ceiling limit value, 2 mg/m<sup>3</sup>, defined as inhalable dust, are not judged to entail any additional expense.

### **Further reading**

Arbete och Hälsa, 2000:21.

## Chromium and its organic compounds

CAS no.: 7440-47-3

Examples of chromium (VI) compounds:

	CAS no.
Lead chromate	1758-97-6
Potassium dichromate	7778-50-9
Potassium chromate	7789-00-6
Chromic acid	7738-94-5
Chromium trioxide	1333-82-0
Sodium dichromate	10588-01-9
Sodium chromate	7775-11-3
Strontium chromate	7789-06-2
Zinc chromate	13530-65-9

### Proposal

	LLV		STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
<b>Chromium and its inorg. (II and III) compounds (as Cr), total dust</b>	-	0.5	-	-	
<b>Chromium (VI) compounds (as Cr), total dust</b>	-	0.005	-	0.015	CS

### Present occupational exposure limit value (AFS 2000:3)

	LLV		STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
<b>Chromium and inorg. compounds other than chromic acid and chromates (as Cr), total dust</b>	-	0.5	-	-	
<b>Chromates (as Cr), total dust</b>	-	0.02	-	-	KS
<b>Chromic acid (as Cr), total dust</b>	-	0.02	-	0.06	KS

## Occupational exposure limit values in other countries

Chromium and inorg. compounds other than chromium (VI) compounds (as Cr), total dust	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	0.5	-	-	
Finland (2002)	-	0.5	-	-	
Norway (2001)	-	0.5	-	-	
Germany (TRGS, 1998)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989) the metal	-	1.0	-	-	
Chromium (II and III) compounds	-	0.5	-	-	
USA (ACGIH, 2002)	-	0.5	-	-	
EU	-	-	-	-	
<b>Chromium (VI) compounds (as Cr), total dust</b>					
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	Rem.
Denmark (2002)	-	0.005	-	-	C
Strontium chromate	-	0.0005	-	-	C
Finland (2002)	-	0.05	-	-	CrO <sub>4</sub>
Norway (2001)	-	0.02	-	-	AC
Germany (TRGS,1998)					
Chromium (VI), welding smoke	-	0.1	-	-	inhal.
Chromium (VI), soluble	-	0.1	-	-	inhal.
Chromium (VI), others	-	0.05	-	-	inhal.
Germany (MAK, 2002)	-	-	-	-	C(2)
USA (OSHA, 1989)					CLV
Chromic acid and chromates	-	-	-	0.1	as CrO <sub>3</sub>
USA (ACGIH, 2002) soluble	-	0.05	-	-	C
insoluble	-	0.01	-	-	C
Calcium chromate	-	0.001	-	-	C
Lead chromate	-	0.012	-	-	C
Strontium chromate	-	0.0005	-	-	C
Zinc chromate	-	0.01	-	-	C
EU	-	-	-	-	

## Health effects

The commonest oxidation rates for chromium in connection with occupational exposure are hexavalent and trivalent.

Uptake via the respiratory tract has the most important bearing on risks in connection with occupational exposure to hexavalent chromium. Chromium compounds of high or moderate solubility are more easily absorbed than compounds with low or zero solubility. Particle size also has a bearing on chromium uptake in the body. Small particles of hexavalent chromium, of the kind occurring in welding smoke, penetrate far down into the lungs.

Dermal uptake of hexavalent chromium can be of importance in connection with occupational exposure.

The effects of chromium exposure on health are correlated with the valency, solubility, exposure path, exposure level and particle size of the chromium. The hexavalent chromium compounds are the ones judged most important from a toxicological viewpoint.

### *Respiratory tract*

Inhalation of chromate dust/aerosol can cause nasal irritation, sores and perforation of the septum. Nasal irritation has been shown in surface treatment workers exposed to an atmospheric chromic acid concentration of at least 0.001 mg/m<sup>3</sup>.

Temporarily impaired pulmonary function has been observed among surface treatment workers exposed to chromic acid when they were exposed to an average atmospheric concentration of hexavalent chromium in the 0.002-0.02 mg/m<sup>3</sup> interval.

Increased frequency of respiratory tract disorders has been seen in welders exposed to hexavalent chromium when welding stainless steel and railway rails. Respiratory tract disorders increased when chromium concentrations exceeded 0.02 mg/m<sup>3</sup>.

### *Kidney*

Increased urinary secretion of  $\beta_2$ -microglobulin as a sign of kidney damage has been shown in surface treatment workers exposed to chromic acid at mean atmospheric hexavalent chromium concentrations of 0.004-0.008 mg/m<sup>3</sup>. In another study of welders in stainless steel, slightly elevated levels of  $\beta_2$ -microglobulin were seen in connection with exposure to atmospheric concentrations just over 0.05 mg chromium/m<sup>3</sup>.

### *Skin*

Allergic contact dermatitis from chromium/chromates is common and often chronic. Following the enactment of legislation in 1989 on the addition of ferrous salts to

cement, eczema cases cement workers have practically disappeared. Apart from wet cement, contact allergy to chromium can occur in connection with occupational exposure, for example, due to chromium baths, tanning, production of pigments and paints, printing, dry cleaning and textile dyeing and also the use of chromium-tanned leather.

Trivalent chromium compounds are far less allergenic than hexavalent ones. Metallic chromium is not sensitising.

#### *Adverse effects on reproduction*

Some studies have shown hexavalent chromium to have adverse effects on reproduction in animals.

#### *Cancer*

Both the valency of chromium and its solubility have a bearing on its carcinogenic effect. Hexavalent chromium compounds occurring in the production of chromates and chromate pigments and in chromium plating are considered carcinogenic to humans. Zinc chromate has been judged highly potent, but calcium chromate too is considered carcinogenic. Both zinc chromate and calcium chromate are sparingly hydrosoluble. In connection with welding work there is limited support for welding smoke and welding gases having a carcinogenic effect. Metallic chromium and trivalent chromium are not judged to be carcinogenic.

Hexavalent chromium can entail a heightened risk of cancer in the nose and sinuses. This has been noted among both welders and chromate factory workers.

Increased risk of cancer of the gastro-intestinal tract has been noted in several studies of workers exposed to chromium and could be attributed to inhaled particles of hexavalent chromium being swallowed, exposing the stomach and intestines.

#### *Dose-response/dose-effect relations*

There are manifest difficulties involved in defining firm dose-response relations for hexavalent chromium, owing to the deficiencies of exposure data even in more recent studies. Added to this, other exposure occurring to nickel, asbestos and smoking makes it hard in certain cases to single out the effect of chromium. A risk of airway irritation has been reported at an atmospheric chromic acid concentration of 0.001-0.002 mg/m<sup>3</sup>. Temporarily reduced pulmonary function and chromium nasal sores have been indicated at an atmospheric chromic acid concentration of 0.002-0.02 mg/m<sup>3</sup>. Nasal septum perforation has been reported at atmospheric exposure to hexavalent chromium in a concentration of 0.011 mg/m<sup>3</sup>, with the frequency rising as exposure increases. Kidney effects have been reported at a total chromium level of 0.004-0.006 mg/m<sup>3</sup>. The Dutch Expert Committee on Occupational Standards (DECOS) recently judged that 40 years' exposure to 0.008 mg hexavalent inhalable chromium dust/m<sup>3</sup> with linear extrapolation raises the risk of death from lung cancer by 1.4 cases per 100 persons exposed.

### Conclusions

The critical effect of occupational exposure to hexavalent chromium is irritation effects on the mucous membranes of the upper and lower airways. Hexavalent chromium coming into contact with the skin is caustic and can induce allergic contact dermatitis. Asthma is also described. Hexavalent chromium has been shown, in connection with occupational exposure, to be capable of causing cancer of the lung and nose.

Trivalent chromium can give rise to skin irritation and allergic contact dermatitis. Data for determining a critical effect of occupational exposure to trivalent chromium, metallic chromium and other chromium compounds are lacking.

### Use/occurrence

Chromium is widely used in the production of refractory materials, in chemical industry (as a catalyst) and in the metals industry, especially in such alloys as stainless steel e.g. 18:8 steel) and various special grades of steel (acid proof, for example). Chromium is used in the surface treatment industry, both for chromium plating, which applies metallic chromium to the surface, and for chromating, which results in a surface coating of chromium of varying valency and solubility. Certain chromates are used (together with arsenic and copper) for impregnating wood, for tanning leather and in pyrotechnic industry. Chromium(VI)oxide is used in the manufacture of magnetic tape.

### Quantities

(Tonnes, as per SCB: Utrikeshandel 2002)

	<b>Imports</b>	<b>Exports</b>
Chromium ore	No figure	0
Chromium metal	1,262	16
Chromium trioxide (chromic acid)	265	23
Other oxides and hydroxides	105	1
Chromium sulphates	17	0
Zinc and lead chromate	62	14
Sodium chromate	14	2
Other chromates	314	2

### No. persons exposed

The numbers of persons occupationally exposed in Sweden to chromium(VI) are estimated at 1,000 steelworkers, many thousand welders, about 1,000 surface treatment workers and about 150 persons employed on wood impregnation. Work on surface treatment and welding in stainless steel can cause exposure to hexavalent chromium in aerosol, dust and smoke form.

## Atmospheric concentrations

Table 1. Measurements 1998-June 2003

981029	Surface treatment: chromic acid, electrolytic treatment, hard chromium plating	Cr (VI)	0.001 mg/m <sup>3</sup> 0.006 mg/m <sup>3</sup>
990901	Surface treatment: chromium plating, chromic acid	Cr (VI)	0.00020 mg/m <sup>3</sup> 0.00064 mg/m <sup>3</sup>
010220	Surface treatment: chromating, chromic acid	Cr (VI)	< 0.0024 mg/m <sup>3</sup> < 0.0056 mg/m <sup>3</sup>
010518	Surface treatment: chromium plating, chromic acid	Cr (VI)	0.008 mg/m <sup>3</sup> 0.003 mg/m <sup>3</sup> 0.007 mg/m <sup>3</sup> 0.007 mg/m <sup>3</sup>
010910	Surface treatment	Cr (VI)	0.00071 mg/m <sup>3</sup>
980922	Welding in connection with Mn measurement	Cr (VI)	0.002 mg/m <sup>3</sup> 0.003 mg/m <sup>3</sup> 0.001 mg/m <sup>3</sup>
981104	Welding: method unknown	Cr (VI) (chromates)	0.002 mg/m <sup>3</sup> 0.003 mg/m <sup>3</sup> 0.001 mg/m <sup>3</sup>
990203	Welding (MAG & TIG), grinding, cutting of sheet	Cr (VI)	0.00011 mg/m <sup>3</sup> 0.000115 mg/m <sup>3</sup>
001107	Welding	Cr (tot)	0.0024 mg/m <sup>3</sup> 0.0005 mg/m <sup>3</sup> 0.0035 mg/m <sup>3</sup>
020123	Welding: MMA (20%) and MIG-MAG (80%). Grinding	Cr (III)	0.031 mg/m <sup>3</sup>
030327	Welding, grinding	Cr (tot)	0.00002 mg/m <sup>3</sup> < 0.0002 mg/m <sup>3</sup> 0.02 mg/m <sup>3</sup> 0.0002 mg/m <sup>3</sup>
981123	Grinding	Cr (tot)	0.28 mg/m <sup>3</sup>
000914	Grinding of stainless	Cr (resp.)	< 0.02 mg/m <sup>3</sup> 0.07 mg/m <sup>3</sup> < 0.03 mg/m <sup>3</sup> < 0.03 mg/m <sup>3</sup>
000614	Welding of circuit boards	Cr (tot)	0.115 mg/m <sup>3</sup> 0.078 mg/m <sup>3</sup> 0.079 mg/m <sup>3</sup> 0.068 mg/m <sup>3</sup> 0.083 mg/m <sup>3</sup>
011023	Crushing of concrete demolition rubble	Cr (tot)	< 0.0001 mg/m <sup>3</sup>
011212	Melting, casting, fettling of steel	Cr (tot)	0.020 mg/m <sup>3</sup> 0.015 mg/m <sup>3</sup> 0.07 mg/m <sup>3</sup>
980107	Prosthesis manufacture	Cr (VI) Cr (tot)	< 0.0002 mg/m <sup>3</sup> 0.003 mg/m <sup>3</sup> 0.019 mg/m <sup>3</sup>

The measurements for the period 1998-June 2003 which have come to the Work Environment Authority's knowledge show no instances of the occupational exposure limit value for Cr(VI) (0.02 mg/m<sup>3</sup>) being exceeded; see table 1. Cr(VI) has above all been measured for surface treatment, but a number of measurements have referred to welding and one to the manufacture of artificial limbs. A reduction of Cr(VI) to 0.005 mg/m<sup>3</sup> will mean a couple of measurements coming close to the proposed level. Where total chromium contents are concerned, no instance is recorded of the existing limit value (0.5 mg/m<sup>3</sup>) being exceeded.

The Labour Inspectorate carried out a number of measurements and collected measurement data from measurements conducted in connection with various welding operations. The measurements were taken partly in order to ascertain the extent to which the limit value was exceeded in welding by the MMA method at temporary worksites. The measurements were taken in 1997-98, apart from one recorded in 1988. A concise report has been compiled by the Work Environment Authority. The results are shown in Table 2 and Table 3.

Table 2. Results by welding method used.

Welding method	No. measurements	Cr <sub>tot</sub> mg/m <sup>3</sup>	Cr(VI) mg/m <sup>3</sup>	Cr(VI)/Cr <sub>tot</sub> × 0%
TIG	38	0.032 (0.0009-0.2)	0.0006 (0.0001-0.002)	6.2
MIG	13	0.38 (0.06- <b>1.86</b> )	0.002 (0.0005-0.008)	0.7
MMA (manual metal arc with coated electrodes)	24	0.104 (0.02-0.34)	0.009 (0.0002- <b>0.069</b> )	3.5
MAG	4	<b>0.67</b> (0.15- <b>2.11</b> )	0.0016 (0.0012-0.0024)	0.6
Powder arc welding	3	0.12 (0.07-0.15)	0.003 (0.0009-0.004)	2.3
Plasma welding	2	0.033 (0.021-0.044)	0.0007 (0.0004-0.001)	2.1
TIG+MIG	7	0.050 (0.016-0.065)	0.0007 (0.0005-0.001)	1.5
MMA+TIG	4	0.20 (0.0.04-0.344)	0.016 (0.0007- <b>0.058</b> )	6.3
MMA+MIG	4	0.11 (0.053-0.22)	0.0008 (0.0002-0.012)	1.0
MAG+MIG	2	0.24 (0.19-0.29)	0.003 (0.0029)	0.5
Powder cutting	1	0.3	<b>0.09</b>	30
Plasma cutting	5	0.075 (0.01-0.202)	0.004 (0.001-0.01)	6.4
Laser cutting	2	0.014 (0.007-0.02)	<0.002 (0.0003-<0.001)	14
Gas-shielded arc cutting	1	0.046	0.001	2.2

This summary gives averages and maximum and minimum values for the periods of time covered by the measurements. Instances of the occupational exposure limit values for total chromium and hexavalent chromium, 0.5 mg/m<sup>3</sup> and 0.02 mg/m<sup>3</sup> respectively, being exceeded are shown in bold type.

Altogether in this project there were 11 instances of the occupational exposure limit value being exceeded, 5 for total chromium (probably in the form of trivalent chromium and compared with the limit value for inorganic chromium compounds, not including chromic acid and chromates), 5 for hexavalent chromium (one of which touches on the limit value) and one for powder cutting (using Fe powder). These instances are shown in Table 3. Altogether there are 107 observations for total chromium and 103 for hexavalent chromium, which means that limit values were exceeded in upwards of 5% of the measurements.

Table 3. All measurements exceeding and touching on occupational exposure limit values

Date	Welding method	Cr <sub>tot</sub> mg/m <sup>3</sup>	Cr(VI) mg/m <sup>3</sup>	Cr(VI)/Cr <sub>tot</sub> × 100%	Meas. time Min
971216	MMA+grinding	0.16	<b>0.045</b>	28.1	221
971125	MAG wire powder + much grinding	<b>2.11</b>	0.0024	0.1	412
971125	TIG+MMA+ grinding+ div.	0.344	<b>0.058</b>	16.9	366
971202	MIG + 15 min. grinding	<b>0.613</b>	0.001	0.2	424
980129	MMA	0.162	<b>0.069</b>	42.6	180
980129	MMA	0.338	<b>0.019</b>	5.6	260
971021	MIG	<b>0.703</b>	0.003	0.4	224
880401	MAG + 5 min. grinding	<b>1.14</b>	<b>0.021</b>	2.1	42
880401	MAG	<b>1.86</b>	0.008	0.4	50
971119	powder cutting	0.3	<b>0.09</b>	30.0	256

The limit value for hexavalent chromium, 0.02 mg/m<sup>3</sup>, is exceeded or touched on in all measurements with MMA included, one of the MAG measurements and powder cutting (with Fe powder). Total chromium values are elevated with MMA welding but do not exceed the occupational exposure limit value, 0.5 mg/m<sup>3</sup>, which they do with the MIG and MAG methods.

The occupational exposure limit value proposed for hexavalent chromium compounds (0.005 mg/m<sup>3</sup>) raises the instances of exceeding the limit value to 10%, based on the same observation data.

### **Impact assessment**

Reduction of the occupational exposure limit value for chromium(VI) is expected to reduce the risk of airway irritation and lung cancer.

Measurements show that the occupational exposure limit value proposed is generally fallen short of at permanent worksites. Instances of its being exceeded occur in welding operations. The current limit value (0.02 mg/m<sup>3</sup>) is exceeded by about 5% of observed values in connection with welding, especially welding of stainless steel at temporary worksites. The MMA method is over-represented among instances of exceeding the limit value for chromium (VI). The proposed reduction of the limit value to 0.005 mg/m<sup>3</sup> results in the limit value being exceeded in about 10% of instances, based on the observation data presented above.

Use of personal protective equipment is the measure needed at temporary chromium (VI). A suitable form of protective equipment which can be chosen is a welding visor with a blower unit and dust filters. Assuming first-time procurement of such equipment for an estimated total of 5,000 welders working with stainless steel, the total cost could amount to some MSEK 25 (5,000 times SEK 5,000).

If an efficient breathing protector is used, the other health-endangering components of welding smoke, in gaseous and particle form, will be eliminated from inhaled air at the same time.

### **Further reading**

Arbete och hälsa, 2000:21.

## 4,4'-Methylene dianiline

CAS no.: 101-77-9

### Proposal

LLV		CLV		Rem.
ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
-	-	-	-	B substance

### Present occupational exposure limit value (AFS 2000:3)

LLV		CLV		Rem.
ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
-	-	-	-	B substance

### Occupational exposure limit values in other countries

	LLV		CLV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Denmark (2002)	0.1	0.8	-	-	C
Finland (2002)	-	-	-	-	
Norway (2003)	0.1	0.8	-	-	HCS
Germany (TRGS, 2000)	-	0.1	-	-	C
Germany (MAK, 2002)	-	-	-	-	H
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	0.1	-	-	-	H
EU (2000)	-	-	-	-	

### Health effects

4,4'-Methylene dianiline (MDA) at room temperature is a crystalline powder smelling faintly of amine. Technical grades of MDA occur in liquid form and are contaminated with other isomers. The substance is highly soluble in alcohol, benzene and ether but less soluble in water.

MDA at room temperature occurs in aerosol form and can be absorbed through the respiratory tract, dermally and via the gastro-intestinal tract. Several reports describe dermal uptake as the main exposure path. In an experimental study of five subjects, dermal uptake was found to average 28% after one hour's exposure using a patch test technique.

N-acetyl-MDA has been identified as the principal metabolite in urine from exposed workers. Together with MDA, this metabolite has also been shown to be haemoglobin adduct.

Several incidents of MDA poisoning in the form of jaundice or uptake dermally, via food or by inhalation, have been reported. One case report describes floor-layers developing stomach pains and jaundice after using MDA as a hardener for an epoxy adhesive which they mixed on site. In another incident, all 12 workers kneading a plastic compound with MDA are reported to have contacted jaundice.

Direct contact with MDA makes the skin, nails and hair turn yellowish, and several studies have shown MDA to be a contact allergen. There are several case studies describing positive reactions following patch testing with MDA.

A few cases of cancer have been reported following exposure to MDA. Human studies of persons occupationally exposed are limited by the small number of case and simultaneous exposure to several chemicals. Several other aromatic amines, similar to MDA, may, however, cause cancer of the bladder.

Several different experiments, both *in vivo* and *in vitro*, have shown MDA to be mutagenic and genotoxic.

Rats and mice were given MDA in two different doses in drinking water over a period of two years. According to that study, MDA caused tumours of the liver and thyroid in both species.

Human data for establishing a critical effect for MDA are insufficient. Occupational exposure to MDA, with dermal absorption playing a prominent part, has caused liver injury. On the basis of animal experiments, the critical effect is liver cancer and liver damage. MDA is genotoxic *in vitro* and produces DNA adducts *in vivo*. MDA is carcinogenic in laboratory animals and carcinogenic according to EU Directive 67/548/EEC on the classification, packaging and labelling of dangerous substances.

MDA is easily absorbed dermally through direct contact and can cause allergic contact dermatitis.

\*

On the basis of animal experiments, the critical effect is liver cancer and liver injury.

### **Use/occurrence**

MDA is used in the manufacture of various polymers and plastics. The largest quantity is used for making methylene diphenyl diisocyanate (MDI) and prepolymerised isocyanates. There is no production of isocyanates in Sweden, however. MDA is used as an anti-oxidant in rubber and as a hardener for epoxy products and neoprene. It is also used as a hardener for certain types of paint and plastic. MDA can be generated by various kinds of hot work.

## **Quantities**

According to Produktregistret 2002 there are 25 products, none of them consumer products, and a total of 3 tonnes MDA is handled in Sweden annually.

## **No. persons exposed**

The handling of the substance which occurs takes place in enclosed systems. MDA can also form in certain kinds of hot work, e.g. in vehicle repair shops. Car sprayers, panel beaters and vehicle glaziers are occupational categories which might be exposed.

## **Atmospheric concentrations**

In its report *Isocyanater från heta arbeten i skadereparationsverkstäder*, IVL (the Swedish Environmental Research Institute) has presented exposure measurements in which MDA, among other substances, was measured during various kinds of hot work, such as paint removal, tape removal and plastic work using a hot air heat gun. The concentrations observed varied between 0.0013 and 0.022 ppm (0.011-0.180 mg/m<sup>3</sup>). The measurement period equals the duration of the job and can vary from 1 to 5 minutes.

## **Impact assessment**

Based on animal experiments, the critical effect is liver cancer and liver damage. MDA is readily absorbed dermally via direct contact and can cause allergic contact dermatitis. Today it is B-listed, which means that use of it needs permission from the Work Environment Inspectorate. Its inclusion on the B list is prompted by its carcinogenic effect. The permit requirements for its use are appropriate to substances entailing serious risks and with a risk of substantial dermal uptake. The risk of skin-sensitising effects can also be effectively counteracted within the scope of the permit requirements.

Interest in recent years has come to focus on exposure to MDA via respiration. Small concentrations of the substance are formed in connection with hot work such as welding, grinding and use of a heating fan on paint and plastic, especially if they are polyurethane based (MID). When planning such work and assessing the risks involved, it is important that the formation of MDA and exposure to it should be eliminated as far as possible.

Permit requirements apply solely to the use of MDA. Rules on hot work in connection with polyurethane-based polymers are contained in AFS 2004:18, Thermosetting Plastics.

The Work Environment Authority proposes that MDA be kept on the B list.

**Further reading**

Arbete och Hälsa 2002:18.

IVL Rapport B 1389, Isocyanater från heta arbeten i skadereparationsverkstäder.

## 5-Methyl-2-hexanone

CAS no.: 110-12-3

### Proposal

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
25	120	50	250	

### Present occupational exposure limit value (AFS 2000:3)

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
25	120	50	250	

### Occupational exposure limit values in other countries

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	20	95	-	-	
Finland (2002)	29	95	-	-	
Norway (2003)	25	115	-	-	
Germany (TRGS, 2000)	20	95	-	-	
Germany (MAK, 2002)	10	47	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	50	-	-	-	
EU	20	95	-	-	

### Health effects

5-Methyl-2-hexanone (Methylisooamylketone, MIAK) is a clear, colourless, flammable liquid with a pungent, sweet smell and an olfactory threshold of 0.01 – 0.18 ppm.

The substance has relatively low acute toxicity. In a study of rat subjected to 6 hours' exposure at 800 ppm, no demonstrable effects were observable. After corresponding exposure to 1,600 ppm, an impaired auditory reaction was noted (CNS effect).

Inhalation of 416 – 1515 ppm MIAK for 15 minutes showed the respiration rate (RC<sub>50</sub>) in mouse to decline by 27 – 61%. This was due to irritation of the upper airways.

In an inhalation experiment, rats were exposed to a dose of 970 or 2,090 ppm MIAK 12 times in 16 days (6 hours/day, 5 days/week). The higher exposure dose showed

effects on the central nervous system in the form of slight drowsiness and impaired auditory reaction.

With corresponding exposure to 210, 1,030 and 2,080 ppm MIAK for 96 days, dose-related effects on CNS were observed at both the higher dose levels. Porphyrine-like discoloration round the eyes, muzzle and mouth (signs of mild irritation) were observed at both the highest dose levels, as well as a significantly dose-related increase in liver weight. No effects were observed at 210 ppm.

In one study where undiluted MIAK was applied to rabbit skin, no skin irritation was indicated within 24 hours.

No data concerning mutagenicity, carcinogenicity and effects on reproduction have been found in the literature.

On the basis of animal data, the critical effect of short-term exposure is mucous membrane irritation in the respiratory tract.

### **Use/occurrence**

5-Methyl-2-hexanone is used in anti-fouling paint and in clear varnishes used for car spraying.

### **Quantities**

Excerpts from Produktregistret 2003 show 130 tonnes of 5-methyl-2-hexanone handled in Sweden. The substance occurs in 26 products, one of which is a consumer product.

### **No. persons exposed**

As the substance occurs in just a few types of paint, it is judged that only a small number of paint sprayers and painters can be exposed to it

### **Atmospheric concentrations**

The Work Environment Authority does not know of any measurements.

### **Impact assessment**

MIAK has low volatility, which makes it easier for exposure to be kept to a low level. Retention of the occupational exposure limit value of 25 ppm as proposed by the Work Environment Authority will not involve industry in any additional expenditure.

### **Further reading**

Arbete och Hälsa, 2002:23.

**Methyl isocyanate**  
**Isocyanic acid**

CAS no.: 624-83-9

CAS no.: 75-13-8

**Proposal following external consultation**

	LLV		CLV*		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>Isocyanic acid</b>	0.01	0.018	0.02	0.036	
<b>Methyl isocyanate</b>	0.01	0.024	0.02	0.047	

\*Ref. 5 minutes

**Proposal**

	LLV		CLV*		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>Isocyanic acid</b>	0.01	0.018	0.02	0.036	
<b>Methyl isocyanate</b>	0.01	0.024	0.02	0.047	

\*Ref. 5 minutes

**Present occupational exposure limit value (AFS 2000:3)**

	LLV		CLV*		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
<b>Isocyanates</b>	0.005	-	0.01	-	S

\*Ref. 5 minutes

**Occupational exposure limit values in other countries**

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	0.01	0.03	H
Finland (2002)	-	-	0.02	0.05	
Norway (2003)	0.005	0.015	0.01	0.03	S, H
Germany (TRGS, 2000)	0.01	0.024	-	-	H
Germany (MAK, 2002)	0.01	0.024	-	-	H
USA (OSHA, 1989)	0.02	0.05	-	-	H
USA (ACGIH, 2003)	0.02	-	-	-	H
EU	-	-	-	-	

Isocyanic acid	LLV		CLV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Denmark (2002)	-	-	-	-	
Finland (2002)	-	-	-	0.035	isocyanate
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	-	-	-	-	
EU	-	-	-	-	

### Health effects

Methyl isocyanate (MIC) at room temperature is a clear, colourless liquid which reacts violently to water. The substance has a pungent smell with an olfactory threshold above 2 ppm.

Isocyanic acid (ICA) is a polymerisations-prone liquid at temperatures above 0 °C. The substance dissolves in water by ionising or decomposing to form ammonia and carbon dioxide.

Massive exposure to methyl isocyanate occurred in connection with an accident in Bhopal, India, when 27 tonnes of MIC were dissipated in the surroundings. Acute effects observed were symptoms of the eyes and respiratory tract, as well as pulmonary oedema, in some cases fatal. Smarting of the eyes was the dominant symptom among the survivors, followed by a persistent cough and, thirdly, runny eyes and nausea. Exertion-related dyspnoea was the most persistent of the respiratory tract disorders. Neurological symptoms were also observed, such as muscular debility and memory loss. The concentrations have since been estimated as coming between 0.12-85 ppm.

Four volunteers were exposed briefly (1-5 minutes) to MIC. No effects occurred at an exposure level of 0.4 ppm, while 2 ppm caused irritation of the eyes and lacrimation but no perception of smell. At 4 ppm the symptoms of irritation were more noticeable, and at 21 ppm they were unbearable.

Exposure to MIC and ICA has been shown in foundries. A recently completed study by the Swedish Foundry Association at four Swedish foundries using Hot Box binders has shown widespread exposure there to ICA and MIC. Foundry workers are the occupational group with the highest exposure and concentrations varied between 0.002 – 0.157 ppm for ICA between 0.002 – 0.029 ppm for MIC. The measurements were performed as short-term observations and compared with the peak occupational exposure limit value. Neither changes of pulmonary function nor the occurrence of symptoms could be associated with exposure to these substances. The cases of nose bleed reported are not significantly different from those among the controls and are therefore not dealt with any further in the text.

No studies have indicated asthma or quasi-asthmatic symptoms caused by exposure to MIC.

There are no human data available concerning toxic effects of ICA.

#### *Animals*

Uptake and distribution of methyl isocyanate have been studied in mice after 1-6 hours' inhalation exposure to 0.5, 5, and 15 ppm. Uptake in the bloodstream occurred within a few minutes. Uptake did not show a linear increase with exposure, owing, it was presumed, to the higher exposure levels leading to increasing irritation and mucus formation in the airways, which in turn affected the respiration rate and in doing so impeded inhalation and bloodstream uptake. The most efficient uptake and distribution were observed at exposure to 0.5 ppm. This is presumed to be connected with methyl isocyanate bonding with different tissue and blood cell proteins (red) in the body.

The effect most commonly occurring in all animal experiments has been irritation of the upper and lower airways. In study rate was exposed to 0, 0.15, 0.6 and 3.1 ppm MIC via inhalation for 6 hours/day and 4 + 4 days. The concentration of 3.1 ppm caused damage to the airways. The highest level where no effect was observed (NOAEL) was 0.6 ppm.

No mutagenic effect has been shown for MIC.

Exposure of mice via inhalation to 2, 6, 9 and 15 ppm MIC for three hours on the eighth day of pregnancy led to dose-related resorption of the embryos. Reduced embryo and placenta weight was observed at all doses.

The main effects following short-time exposure to MIC are irritation of mucous membranes and eyes in humans.

Data concerning mutagenic, carcinogenic, teratogenic or other toxic effects of isocyanic acid are lacking in the literature.

The critical effect of methyl isocyanate is irritation of the eyes and in the mucous membranes of the respiratory tract. Data for establishing the critical effect of isocyanic acid are lacking.

Given the reactivity and chemical properties of isocyanic acid, the Work Environment Authority finds it reasonable to suppose that it has a critical effect corresponding to that of methyl isocyanate.

#### **Use/occurrence**

MIC and ICA are not used in Sweden, but they can be formed in the thermal degradation of polyurethane or other products containing nitrogen. Because of its instability, ICA is not commercially available.

MIC has been identified in laboratory conditions in connection with the heating of core sand and mineral wool, due to the disintegration or conversion of the binding

agent carbamide resin (urea resin). Exposure measurements in foundries have shown both MIC and ICA during carbamide resin (Hot Box) casting. MIC and ICA have also been observed in vehicle repair shops in connection with welding, cutting or grinding of sheet metal coated with TDI- and HDI-based polyurethane varnish.

ICA occurs together with MIC in up to ten times higher concentrations. Isocyanic acid also forms when urea is heated to more than 152 °C.

Methyl isocyanate can re-form as a result of photolytic degradation, which can occur in connection with the spreading of pesticides made with MIC. MIC is also present in tobacco smoke, of which 1.5 – 5 µg has been found to be formed per cigarette. A person smoking 10 cigarettes per working day inhales between 0.015 – 0.050 mg MIC. A worker exposed at the proposed occupational exposure limit value of 0.047 mg/m<sup>3</sup> for 8 hours in connection with light work (respiration rate 20 litres/min.) has been exposed to 0.45 mg MIC.

## Quantities

Cf. Use/occurrence

### No. persons exposed

Panel beaters and welders:	3,500 persons. approx.
Vehicle glaziers:	1,500 persons. approx.
Car sprayers:	1,500 persons. approx.
Foundry workers:	1,000 persons. approx.

## Atmospheric concentrations

IVL has carried out measurements, presented in its report *Isocyanater från heta arbeten i skadereparationsverkstäder*. The measurements were taken during hot work on painted automotive sheet. Several different working operations were investigated, both with and without ventilation, to indicate formation of and exposure to MIC and ICA. A total of 107 personal MIC and ICA measurements were carried out, and 60 (56%) of these came below the detection limit. The remaining 47 showed concentrations of ICA only or of ICA and MIC simultaneously. MIC measurement exceeded the peak limit value for isocyanates (0.01 ppm) but 35 out of 107 ICA measurements (32.7%) did so. A hygienic effect was confirmed, with several isocyanates found in the same specimen.

The ICA concentrations exceeding the occupational exposure limit value came between 0.012 and 0.130 ppm. Breathing protectors were used for these hot jobs and the sampler positioned underneath the protector.

Exposure to ICA is often accompanied by exposure to MIC. The effects of the two substances are probably similar, and the hygienic effect must therefore be taken into account in measurement. Hygienic effect is calculated for comparison with the occupational exposure limit value.

## **Impact assessment**

In the absence of specific occupational exposure limit values for MIC and ICA, use has been made of the occupational exposure limit value for isocyanates. The limit value for isocyanates was formulated in 1993, the intention then being to cover diisocyanates and phenyl isocyanate. It was not the intention for the limit values to apply to MIC and ICA. Nothing was known at the time concerning the occurrence of these substances in the work environment.

The critical effect of methyl isocyanate is irritation of the eyes and of the mucous membranes of the respiratory tract. Data for establishing the critical effect of isocyanic acid are lacking.

Short-time exposure of a few experimental subjects causes lacrimation and irritation of the mucous membranes in the upper respiratory tract. No irritation is reported at 0.4 ppm. A number of experiments on various animals with up to 6 hours' exposure produced mucous membrane injuries in the respiratory tract at levels of around 1-3 ppm.

The special occupational exposure limit value proposed by the Work Environment Authority for MIC is 0.01 as threshold limit value and 0.02 as peak limit value (5 min.). These values are expected to prevent and provide a certain margin to irritation effects and epithelium injuries in the respiratory tract.

No data exist for an assessment of ICA, but it is judged to have similar reactive properties to those of MIC. In the exposure situations involved in Sweden, MIC and ICA often occur simultaneously.

The Work Environment Authority proposes that ICA should have the same limit values as MIC and that the hygienic effect should be calculated for simultaneous exposure to both of these substances.

Instances where limit values are exceeded are most often connected with ignorance of the possibility of different operations at work generating both mono- and diisocyanates at once. These apply above all to hot work and paint spraying. Reduction of exposure by suitable means is facilitated above all by properly thought out working routines and better awareness of the situations in which isocyanates can form.

Safety precautions which can be taken include, for example, the installation of local extraction devices and tools with integrated extraction. Efficient, user-friendly breathing protectors should be available for supplementary use. The cost of a single workstation can be between SEK 2,000 and 5,000, depending on the scale and present standard of the operation. Vehicle crash repair shops are typical of the workplaces where hot work occurs. There are about 1,500 such workshops in Sweden as a whole.

Measures to reduce exposure below the proposed occupational exposure limit value for methyl isocyanate and isocyanic acid, concentrations of diisocyanates will at the same time come below the limit value level proposed for them. This applies to hot work in which both types of contaminant are formed simultaneously.

The limit values for MIC and ICA are expected to simplify the risk assessment of isocyanates as a whole.

**Further reading**

Arbete och Hälsa, 2002:18.

Gjuteriföreningens rapport "*Kartläggning av isocyanater i gjuterier - Etapp 4*"

Yrkes- och Miljömedicinska kliniken, Universitetssjukhuset i Lunds rapport:

*Isocyanater – Medicinska risker, biologiska mekanismer samt medicinsk och social prognos*

## $\alpha$ -Methyl styrene

CAS no.: 98-83-9

### Proposal

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
20	98	50	245	

### Present occupational exposure limit value (AFS 2000:3)

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	-	

### Occupational exposure limit values in other countries

	LLV		STV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	50	240	-	-	
Finland (2002)	50	250	100	490	
Norway (2003)	50	240	-	-	
Germany (TRGS, 2000)	100	490	-	-	
Germany (MAK, 2002)	100	490	-	-	
USA (OSHA, 1989)	50	240	100	485	
USA (ACGIH, 2003)	50	-	100	-	
EU	50	246	100	492	

### Health effects

$\alpha$ -Methyl styrene is a colourless polymerisable liquid with a distinctive smell. It is said to have an olfactory threshold of 0.29 ppm.  $\alpha$ -Methyl styrene is fat-soluble and therefore soluble in many ordinary solvents.

The substance metabolises in a manner similar to that of the structural analogue styrene.

In a smell and irritation experiment, subjects (number not stated) were briefly exposed to  $\alpha$ -methyl styrene fumes in a hermetically sealed room. An atmospheric concentration of 600 ppm gave rise to a very strong smell and heavy irritation of the eyes and nose. At 100 ppm a smell was experienced which could be tolerated without any noticeable discomfort. At 50 ppm the substance had a clear smell but was not reported as irritating.

The dermal effect of the substance was tested on rabbits whose shaven skin was coated with concentrated  $\alpha$ -methyl styrene for 2-4 weeks. Moderate to distinct reddening was noted, simultaneously with a certain flaking of skin. The eyes were also tested in rabbit by applying two drops of  $\alpha$ -methyl styrene to the cornea. A slight irritation of the conjunctiva was observed.

With exposure to 600 ppm in the inhaled air for six hours daily over a period of twelve days, 6% mortality was observed in female mice. No male mice died during the experiment. Increased liver weight and reduced spleen weight were seen in both sexes.

Rhesus monkeys of both sexes exposed to 2,900 mg/m<sup>3</sup> (600 ppm) and 970 mg/m<sup>3</sup> (200 ppm)  $\alpha$ -methyl styrene (approximately a hundred 7-hour exposures) showed no effects relating to tissue or organ weight.

The critical effect of exposure to  $\alpha$ -methyl styrene is judged to be irritation of the eyes and mucous membranes.

### **Use/occurrence**

$\alpha$ -Methyl styrene is used as a solvent and in polymer production in the plastics industry. The substance occurs, for example, in waxes, surface coatings and paints. Several of the applications involve  $\alpha$ -methyl styrene in very low concentrations.

### **Quantities**

According to Produktregistret 2001 there are 37 product containing  $\alpha$ -methyl styrene. None of these is a consumer product. 48 tonnes are handled altogether.

### **No. persons exposed**

Handling of  $\alpha$ -methyl styrene takes place in closed systems. Other handling concerns it as a residual product in polyester-type binding agents. The quantities to be found in paint are very small, and the risk entailed by exposure is therefore very small.

### **Atmospheric concentrations**

The Work Environment Authority does not know of any measurements.

### **Impact assessment**

The critical effect of exposure to  $\alpha$ -methyl styrene is judged to be inflammation of the eyes and mucous membranes.

A study of an unknown number of persons showed exposure to 100 ppm to involve a smell which was tolerated without any palpable discomfort. Exposure to 50 ppm still created certain olfactory sensations. This study is the basis of 50 pp, in a number of countries.

The Work Environment Authority proposes 20 ppm, given that the supporting documentation is uncertain and limited. The similarity to styrene (20 ppm) in terms of chemical structure and metabolism paths provides further justification for a 20 ppm occupational exposure limit value.

When  $\alpha$ -methyl styrene is used as a reactive monomer in the production of ester plastic the provisions of Sections 16-17 (AFS 2005:17) concerning periodic control are applicable.

The Work Environment Authority does not expect the introduction of this limit value to involve industry in any increased expenditure.

### **Further reading**

Arbete och Hälsa, 2001:19.

## Sodium hydroxide

CAS no.: 1310-73-2

### Proposal

	LLV		CLV	Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	1	-	2	inhal.

### Present occupational exposure limit value (AFS 2000:3)

	LLV		CLV	Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	2	

### Occupational exposure limit values in other countries

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	2	
Finland (2002)	-	2	-	-	
Norway (2003)	-	-	-	2	
Germany (TRGS, 2000)	-	-	-	2	inhal
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	2	
USA (ACGIH, 2003)	-	-	-	2	
EU	-	-	-	-	

### Health effects

The caustic properties of sodium hydroxide on skin are amply documented. One study reported damage to intact skin already on application of 0.03 M solution (0.12%) under occlusion for one hour.

There are a number of case studies describing eye injuries caused by alkali. Most industrial injuries are due to splashing. Caustic injuries occur mainly in the construction, chemical and manufacturing industries. In one study it was observed that the degree of damage following eye contact with an alkali solution depended on concentration, exposure time and penetration rate.

Sodium hydroxide reacts quickly with carbon dioxide to form carbonate, which renders air analyses/exposure data uncertain. There are a few studies describing airway damage after exposure to aerosols of products containing sodium hydroxide.

A study was made of 291 workers who had been exposed to sodium hydroxide dust for between 1 and 30 years. On the basis of measurements, the time-weighted average concentration was estimated at between 0.5 and 2.0 mg/m<sup>3</sup>, depending on the workplace. In the areas with the highest average exposures, irritation was reported and the observed exposure levels varied between 0 and 6.7 mg/m<sup>3</sup> on 19 occasions.

The eyes may possibly be more sensitive than the lungs to aerosols of sodium hydroxide, because when particles enter the respiratory tract, high air humidity and the presence of carbon dioxide cause sodium hydroxide to be converted to less alkaline carbonate. The eye, however, can be struck by particles which cause high concentrations locally on the eye surface.

In a number of case reports, the development of cancer of the gullet as been viewed in connection with a previous injury caused by sodium hydroxide solution (lye). This is probably due to tissue damage and the formation of sores resulting from exposure to strong alkali, rather than to any carcinogenic potential in sodium hydroxide

Sodium hydroxide is judged to be non-mutagenic.

Data are lacking on which to base an assessment of dose-effect and dose-response relations in occupational exposure to sodium hydroxide.

### **Use/occurrence**

Sodium hydroxide is a white, hygroscopic substance occurring in the form of pellets, flakes, rods, and lumps or at 47-75% aqueous solution. Sodium hydroxide is a strong base. It dissolves in water, generating heat and, possibly, mist.

Sodium hydroxide is a very common industrial chemical, used for producing soap, paper, aluminium, petroleum products, chemicals, paints and cleaning products, e.g. for the food industry, for mass catering establishments and restaurants, but also for cleaning/alkaline degreasing of metals and batteries and in film developing.

### **Quantities**

The total quantity reported to Produktregistret 2002 was approximately 300,000 divided between 1,546 products, 197 of them consumer products.

### **No. persons exposed**

Sodium hydroxide is a very common chemical which is handled in large volumes in a host of different connections. The number of persons who risk exposure is hard to judge but can be estimated at several thousand. The number of persons who risk exposure is hard to tell, but can be estimated at many thousand, e.g. those using cleaning agents containing sodium hydroxide.

### Atmospheric concentrations

The Work Environment Authority knows of five measuring reports published between 1979-2002 and comprising 10 personal measurements (total dust). All measurements fall short of the limit value.

1979	nickel-plating and degreasing	0.3 mg/m <sup>3</sup> 0.4 mg/m <sup>3</sup> 0.4 mg/m <sup>3</sup>
1984	cleaning	0.30 mg/m <sup>3</sup> 0 mg/m <sup>3</sup> 0 mg/m <sup>3</sup> 0.36 mg/m <sup>3</sup>
1986	pickling and degreasing of nets	0.11 mg/m <sup>3</sup>
1986	surface treatment	0.006 mg/m <sup>3</sup>
1987	surface treatment	0.042 mg/m <sup>3</sup>

### Impact assessment

Exposure data linked to critical effect for occupational exposure to sodium hydroxide are lacking. Give the powerfully basic properties of sodium hydroxide, however, the critical effect is judged to be irritation of the eyes, airways and skin.

The Work Environment Authority proposes adding a threshold limit value to the peak limit value. At the same time it is proposed that these values be defined as inhalable dust. The threshold limit value proposed is 1 mg/m<sup>3</sup>. The value 2 mg/m<sup>3</sup> is retained as peak limit value. The transition to sampling implied by inhalable dust, however, implies a reduction to about half compared with the situation previously.

The proposed reduction is not judged to entail any additional expenditure. The new level will mean a wider margin to irritant effects in the eyes and airways.

### Further reading

Arbete och Hälsa, 2000:21.

## Thiourea

CAS no.: 62-56-6

### Proposal

LLV		CLV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	-	

### Present occupational exposure limit value (AFS 1996:2)

LLV		STV		Rem.
<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
-	-	-	-	B-substance

### Occupational limit values in other countries

	LLV		CLV		Rem.
	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	<i>ppm</i>	<i>mg/m<sup>3</sup></i>	
Denmark (2002)	-	-	-	-	
Finland (2002)	-	0.5	-	-	
Norway (2003)	-	-	-	-	
Germany (TRGS, 2000)	-	-	-	-	
Germany (MAK, 2002)	-	-	-	-	
USA (OSHA, 1989)	-	-	-	-	
USA (ACGIH, 2003)	-	-	-	-	
EU	-	-	-	-	

### Health effects

Thiourea (thiocarbamide) is a white, crystalline powder with very low vapour pressure. It functions as an antioxidant and is capable of trapping hydroxyl and peroxide radicals.

The substance is rapidly and completely absorbed from the gastro-intestinal tract. After oral intake of 200 mg thiourea, maximum blood concentration was attained in man after only 30 min. By that time thiourea could also be identified in the urine.

Studies of dermal uptake in rabbit showed 4% uptake if the thiourea was dissolved in water but only 0.1% when it was applied to the skin as solid substance

In a Russian study in 1985 of 45 workers employed on thiourea production, signs of reduced thyroid function were observed in about 40%. The atmospheric concentrations were reported as being between 0.6 – 12 mg/m<sup>3</sup>. The exposure had continued for between eight and ten years.

A number of case reports show that contact with photocopying paper containing thiourea can give rise to allergic contact dermatitis. A case of allergic contact dermatitis following exposure to thiourea in silver polish is also described. The number of contact allergy cases reported is small in relation to use.

Repeated exposure to thiourea inhibits the functioning of the thyroid gland in laboratory animals. This has led to underfunctioning of the thyroid gland, enlargement of the pituitary and diminution of ovaries, womb and prostate. Mice appear to be less sensitive than rats.

Rats fed on thiourea have developed tumours of the thyroid, liver, auditory canal and a gland on the eyelid. The ability of thiourea to form tumours in the thyroid gland is believed to depend on hormonal disturbances, and rat is a sensitive species in this respect. No thyroid tumours were observed in mice exposed to thiourea.

Thiourea has been tested for carcinogenic effect in several studies on animals. Those studies do not generally meet the usual requirements for cancer tests on animals.

According to IARC 2001 vol. 79, thiourea is not classifiable with respect to carcinogenic properties in humans (group 3).

\*

The critical effect for thiourea is inhibition of the thyroid function.

### **Use/occurrence**

Thiourea is used in the refining of metals. It also occurs in certain metal polishes and cleaning agents used by goldsmiths. The substance occurs naturally in the laburnum tree.

### **Quantities**

Thiourea is present in 24 products, 10 of them consumer products. The total quantity handled is 14 tonnes/year.

### **No. persons exposed**

Metal refining is a closed process and thus normally entails no exposure. The use of metal polish can above all entail a risk of dermal exposure/dermal uptake. 38 companies today have permits for handling thiourea. Altogether upwards of 300 persons are estimated to be possibly exposed to this substance. Most of the companies with permits for using thiourea use it in small quantities in research laboratories and for polishing metal.

### **Atmospheric concentrations**

The Work Environment Authority does not know of any measurements.

### **Impact assessment**

The carcinogenic properties of thiourea and its inclusion in the B list have been debated, and an updated scientific evaluation has therefore been requested from the Criteria Group. Since, according to that evaluation, carcinogenic effect is not a critical effect of thiourea, the Work Environment Authority recommends that the substance be deleted from the B list.

The handling of thiourea which occurs does not generally entail any risk of inhalation. Its use as a polish and cleaning agent mainly entails a risk of dermal exposure. Dermal contact with thiourea can give rise to allergic contact dermatitis and photo-contact dermatitis.

The majority of companies with permission to use thiourea use it as a metal cleaner. There is cause to suspect that a large number of users do not have permits. Thiourea is not classified as carcinogenic (R 45) under the EU criteria and the substance may therefore be used in consumer products.

The difficulties of supervision coupled with the ready availability of silver polish containing thiourea from the background to the Work Environment Authority's recommendation that the permit requirement for this substance be abolished.

It is felt that the hazards of use can be dealt with under the general rules on Chemical Hazards in the working Environment, AFS 2000:4.

### **Further reading**

Arbete och Hälsa 1999:25.

## Wood dust

CAS no.: -

### Proposal

LLV		STV		Rem.
ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
-	2	-	-	C, Inhal.

### Present occupational exposure limit value (AFS 2000:3)

LLV		STV		Rem.
ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
-	2	-	-	K, Total dust

### Occupational exposure limit values in other countries

	LLV		STV		Rem.
	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	
Denmark (2002)	-	2	-	-	C, Tot. dust
Finland (2002)	-	5	-	10	Org. dust
Norway (2003)					
Oak, beech, hard exotic woods	-	1	-	-	C,
Nordic woods, not oak and beech	-	2	-	-	C
Germany (TRGS, 2000)	-	2	-	-	C, Inhal.
Germany (MAK, 2002)	-	-	-	-	C, Inhal. Broad- leaf
USA (OSHA, 1989)	-	5	-	10	
USA (ACGIH, 2003)					
Hard woods	-	1	-	-	C,
Soft woods	-	5	-	-	C
EU	-	5	-	-	C, Inhal. Broad- leaf

C=cancer, Inhal.=inhalable dust, Tot.= total dust, Org.= organic dust

## Health effects

Wood consists mainly of cellulose, hemicellulose and lignin. Fats, terpenes and phenolic substances also occur, as well as low concentrations of minerals, proteins, acids, alkaloids and carbohydrates.

Wood particles vary in both size and shape. Particles formed during the machining of the wood material vary in size, depending partly on aqueous content, machining method and the type of wood. The proportion of respirable particles is most often greater in the machining of hard woods than with soft ones.

Exposure to wood dust was formerly measured mainly as total dust. In future, however, the occupational exposure limit value will be defined as inhalable dust and inhalable dust will be the object of sampling/measurement. Inhalable dust is defined in a standard, SS-EN 481. Special samples have been designed to match the criteria of that standard.

The quantity of dust is larger when sampling inhalable dust than for total dust.

A number of measurements have been carried out, based on parallel sampling with total dust filters and IOM samplers for inhalable dust, to estimate the ratio between total dust and inhalable dust during exposure to wood dust. See further under the heading Atmospheric concentrations/methods of measurement.

Exposure to wood dust can entail several effects, above all in the nose and upper respiratory tract. Nasal congestion, overproduction of mucous and reduced ciliary transport are effects which can occur after a certain length of exposure to wood dust. Increased frequency of colds, rhinitis, eye irritation and other hypersensitivity symptoms are also connected with exposure to wood dust.

Symptoms from the lower respiratory tract such as asthma, coughing, chronic bronchitis and changes in pulmonary function parameters have also been reported as a consequence of exposure to wood dust. Dust from certain woods such as western red cedar, eastern red cedar and redwood is known for its sensitising properties. Asthma can be provoked by exposure to low concentrations of dust from these woods.

Cancer (adenocarcinoma) of the sinuses has been shown to be strongly connected with exposure to wood dust from hard woods (broadleaf). Adenocarcinoma of the sinuses, however, is a very rare disease and is believed to be a consequence of exposure to relatively high concentrations of dust from hard woods. Other types of cancer in the respiratory tract have also been discussed in connection with exposure to dust from both hard and soft woods, but the evidence for this is considered deficient.

In a Swedish study of 39 woodwork teachers who had been exposed to a total dust content of between 0.12 and 1.18 mg/m<sup>3</sup> from pine and various other woods, several individuals had symptoms such as rhinitis, nasal congestion and nasal irritation and

itching by the end of the working week. The symptoms improved during time away from school.

In a cross-sectional study, 103 sawmill workers were examined who had been exposed to dust from spruce, pine and Douglas fir. Heavily exposed persons (1.3 – 6.3 mg/m<sup>3</sup> inhalable dust) reported work-related coughing, dyspnoea and chest wheeziness significantly more often, which the authors interpret as suggestive of bronchial hypersensibility/hypersensitivity.

A group of 145 African workers exposed to dust from pine and chipboard (3.82 mg/m<sup>3</sup>, total dust, average of several stationary measurements) showed pulmonary function impairment and symptoms such as coughing and nasal discomfort. The proportion of employees with these symptoms was commensurate with standing.

A Swedish questionnaire survey of 130 handicraft teachers showed them to have more disorders of the skin, eyes, nose, throat and lungs than a control group. The disorders were more pronounced in connection with poor ventilation and dustier activity.

Another large number of studies indicate a substantial increase in symptoms of the upper respiratory tract. The symptoms appear at relatively low concentrations of dust (1 mg/m<sup>3</sup> and upwards). The measurements generally refer to total dust.

### *Skin*

Wood and wood dust can give rise to both irritative and allergic contact dermatitis. Occupational eczema occurs among forestry workers and joiners and other personnel employed in forest industry and on furniture manufacturing and interior fitting.

Many tropical woods contain quinones, which are strongly contact allergenic. Allergic contact dermatitis can also be caused by terpenes and rosin (colophony).

The critical effect in humans following exposure to wood dust is discomfort of the upper respiratory tract. Nasal congestion, overproduction of mucus, impaired ciliar function, runny nose and more frequent colds are some of the effects associated with relatively low levels of exposure to wood dust.

### **Use/occurrence**

Wood dust occurs/forms in most contexts where wood and wood products are worked with. Joinery factories, sawmills and school woodwork rooms are examples of workplaces involving exposure to wood dust.

### **Quantities**

-

## No. persons exposed

SCB in 2003 reported 19,527 persons employed in the furniture industry, 35,341 in the timber goods industry and 3,250 as woodwork teachers.

## Atmospheric concentrations

Comparative studies/parallel measurements with the various samplers, IOM and total dust, have shown the IOM sampler to collect roughly twice as much wood dust as the total dust sampler.

Several total dust measurements were undertaken as part of the project entitled *Exposition för damm i svensk träbearbetande industri 1994/95*.

	Exposure interval (mg/m <sup>3</sup> )
• Carpentry:	0.20 – 4.76
• Interior fittings joinery:	0.10 – 4.90
• Cabinet making:	0.30 – 7.28
• Other woodworking:	0.30 – 2.30

Different working operations give a very wide spread of exposure, with buffing in the furniture industry generating the heaviest concentrations of dust (total dust):

• Buffing:	0.30 – 7.28
• Sawing:	0.20 – 4.07
• Drilling:	0.10 – 1.70
• Milling:	0.15 – 2.50
• Planing:	0.30 – 4.76
• Inspection/assembly:	0.40 – 5.60
• Monitoring:	0.30 – 1.30
• Timber handling:	0.30 – 1.07

In this measuring project, inhalable dust was also measured, parallel to total dust. Comparison of a large number of samples showed the IOM sampler to collect roughly twice as much dust as the total dust sampler.

Reduction of exposure to wood dust was one of the targets of the Work Environment Authority's operational plan for 2000-2003. During that time, measurements were taken at 37 worksites, comprising schools, interior fittings joinery works, sawmills, chipping plants and furniture factories.

The results of the 121 total dust measurements show that:

- 6 exceed the occupational exposure limit value of 2 mg/m<sup>3</sup> (5%)

- 15 come between 1-2 mg/m<sup>3</sup> (12%)
- 100 are under 1 mg/m<sup>3</sup> (83%)

### **Impact assessment**

The critical effect in humans following exposure to wood dust comprises a number and variety of disorders of the upper respiratory tract and eyes. In several different studies, both Swedish and international, these effects are reported at low concentrations. The concentrations can have been measured with different samplers, a matter not always made clear in the statement/report.

The occupational exposure limit value for wood dust will in future be defined in terms of inhalable dust, which means that measurements for comparison with the limit value must be taken with a sampler conforming to the criteria of SS-EN 481 (IOM samplers). A number of parallel measurements show the IOM sampler to collect roughly twice as much dust as a total dust filter.

The occupational exposure limit value for wood dust at present is 2 mg/m<sup>3</sup> measured as total dust. The need for a reduction has been identified in an earlier audit, hence the existence of a long-term value of 1 mg/m<sup>3</sup> for wood dust.

The new occupational exposure limit value proposed for wood dust is 2 mg/m<sup>3</sup>, inhalable dust. This new level is judged on the whole to correspond to the old long-term value.

The exposure measurements conducted in the past few years show 83% of the undertakings investigated as coming below the occupational exposure limit value now proposed.

The new level will reduce the risk of the various effects of wood dust on the upper respiratory tract. Still lower exposure levels may, however, be needed for dust from woods known to contain especially sensitising substances, for the avoidance of asthmatic disorders.

Dust dispersion in connection with woodworking is a contributory cause of plant malfunction. Improved dust trapping, therefore, will also have the effect of solving a problem of production technology.

The following are well-known factors which can be inexpensively remedied:

- Deficiencies in the design of the machine's chip head (procurement deficiency - solutions are available)
- Tool cutting data (insufficient knowledge concerning geometry, insert angle, speed)
- The effect of the tool on dust dispersion (the tool acting like a fan)
- The functioning of the chip removal system (serious deficiencies in installations made)
- Choice of cleaning methods (compressed air must not be used)

Solutions to the problem of dust dispersion in woodworking industry can take many different forms. A number and variety of research and development projects have been mounted in the industry. It is imperative that the knowledge accruing from these projects should be fed into applications and production, because the solutions thus presented have very great prospects of reducing dust dispersion both effectively and economically. The right combination of technical measures and a properly thought-through approach to the task can be crucial to achieving a low level of dust exposure. Choosing the wrong method by force of established routine can in the longer term mean greater expense and may also entail additional problems, such as a higher noise level.

The benefits of reducing dust dispersal can be summarised as follows:

- Healthier personnel/less discomfort
- Shorter cleaning times per machine
- Increased output, with less disruption
- Higher quality

#### **Further reading**

Arbete och Hälsa, 2000:21.

Arbetskyddsstyrelsens Rapport 1997:1, Exposition för damm i svensk träbearbetande industri 1994/95.

Hultengren M. och Rosén G. Nordisk Arbetsmiljö Möte 1997 sid. 191-192.

Training material published by the National Institute for Working Life, "Åtgärder mot dammexponering i tillverkningsindustrin, inriktning mot trädamm".