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Endrin

DESIGNATIONS

CAS No.: 72-20-8
Registry name: Endrin
Chemical name: 1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,7,8,8a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalene
Synonyms, Trade names: Hexadrin, Mendrin, Compound 269
Chemical name (German): Endrin, 1,2,3,4,10,10-Hexachlor-6,7-epoxy-1,4,4a,5,7,8,8a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalin
Chemical name (French): Endrine; 1,2,3,4,10,10-hexachloro-6,7-poxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo,endo-5,8-dimthanonaphtalne
Appearance: colourless crystalline powder (technical product with 92 % endrin brownish-yellow); commercially available products are dissolved in organic solvents

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	$C_{12}H_8Cl_6O$
Rel. molecular mass:	380.93 g
Density:	1.77 g/cm^3 (technical product)

	1.77 g/cm^3 (technical product)
Melting point:	> 200C (decomposition)
Vapour pressure:	2.6 x 10^{-5} Pa
Explosion limits:	1.1-7 % by vol. in air (technical product)
Solvolysis/solubility:	in water: virtually insoluble (0.23 mg/l) soluble in acetone, benzene, ethanol, aromatic hydrocarbons, esters and ketones
Conversion factors:	1 ppm = 15.8 mg/m^3 1 mg/m^3 = 0.06 ppm

ORIGIN AND USE

Usage:
Used as a non-systemic insecticide, acaricide and rodenticide for grain.

Origin/derivation:
Endrin is produced as a side product of hexachlorocyclopentadiene and vinyl chloride with cyclopentadiene. Endrin also forms when isodrin is epoxidised with peracetic acid and perbenzoic acid. The degradation of dieldrin in the environment produces endrin (refer also to 'dieldrin' information sheet).

Toxicity

Mammals:		
Rat:	LD_{50} 7-43 mg/kg, oral	acc. MERCIER, 1981
	LD_{50} 15 mg/kg, dermal	acc. UBA, 1986
Mouse:	LD_{50} 1,370 g/kg, oral	acc. UBA, 1986
	LD_{50} 2,300 g/kg, intravenous	acc. UBA, 1986
	TDLo 11 mg/kg, oral, 7.-17. d of pregnancy	acc. UBA, 1986
Monkey:	LD_{50} 3 mg/kg, oral	acc. MERCIER, 1981
Rabbit:	LD_{50} 60 mg/kg, dermal	acc. UBA, 1986
Guinea pig:	LD_{50} 16 mg/kg, oral	acc. UBA, 1986
Pig:	LD_{50} 5,600 g/kg, oral	acc. UBA, 1986
	LD_{50} 1,500 g/kg, intravenous	acc. UBA, 1986
Aquatic organisms:		
Carp:	TL 0.005 ppm (48h)	acc. UBA, 1986

Fish:	0.013-0.004 mg/l	acc. UBA, 1986
Organisms on which fish feed:	0.1 mg/l	acc. UBA, 1986

Characteristic effects:

Humans/mammals: **As a central spasmodic agent, endrin is highly toxic in humans. Skin resorption is possible. Characteristic symptoms are already encountered following the intake of 1 mg/kg (UBA, 1986). 5 - 50 mg/kg are toxic and more than 6 g are lethal (MERCIER, 1981). Excretion via the kidneys and intestines is very slow (risk of accumulation). There is also damage to the liver, kidneys and central nervous system. Chlorine dioxide poisoning is often encountered due to metabolisation in the body.**

ENVIRONMENTAL BEHAVIOUR

Water:
Endrin is virtually insoluble in water and sinks to the bottom. However, its commercial products mix or disperse in water to form toxic, milky 'broths'. Endrin is also sensitive to strong acids. It therefore has a highly toxic effect particularly on fish and the organisms on which they feed and may harm all types of water. In Germany it is listed in class 3 of the catalogue of substances hazardous to water (highly hazardous).
(Refer also to 'dieldrin')

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:				0.0002 mg/l		Long-time value	acc. SCHROEDER,

	Drinkw	USA	L		MCL		1985
	Drinkw	USA	G	0.0005 mg/l		In State of Illinois	acc. WAITE, 1984
	Waste water	EC	L	5 mg/l		Seawater	acc. LEROY, 1985
	Waste water	EC	L	5 mg/l		Freshwater	acc. LEROY, 1985
Air:	Workp	D	L	0.1 mg/m^3	MAK		DFG, 1989
	Workp	USA	(L)	0.1 mg/m^3	TWA		ACGIH, 1986
Foodstuffs:				0.2 ng/kg/d	ADI		acc. MERCIER, 1981

Note:
There has been a complete ban on the use of endrin in the Federal Republic of Germany since 1988.

Comparison/reference values

(Refer to 'dieldrin')

Assessment/comments

(Refer to 'dieldrin')

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Epichlorohydrin

DESIGNATIONS

CAS No.: 106-89-8
Registry names: Epichlorohydrin
Chemical name: 1-Chloro-2,3-epoxypropane
Synonyms, Trade names: ECH, chloromethyloxirane, 2,3-epoxypropyl chloride, oxirane
Chemical name (German): Epichlorhydrin
Chemical name (French): Epichlorhydrine
Appearance: colourless liquid with chloroform-like odour

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	C_3H_5ClO
Rel. molecular mass:	92.53 g
Density:	1.18 g/cm^3
Relative gas density:	3.2
Boiling point:	116.5C

Melting point:	-48C
Vapour pressure:	1.6 x 10^3 Pa
Flash point:	26C
Ignition temperature:	385C
Explosion limits:	2.3-34.4 vol%
Solvolysis/solubility:	in water: 60 g/l soluble in ethanol and ether
Conversion factors:	1 ppm = 3.83 mg/m^3 1 mg /m^3 = 0.26 ppm

ORIGIN AND USE

Usage:
Epichlorohydrin is used in the rubber industry as a solvent and as an initial material in the manufacture of epoxy and phenoxy resins. Epichlorohydrin is likewise used for various types of organic synthesis.

Origin/derivation:
Epichlorohydrin is not found naturally. It is produced synthetically by way of the conversion of propylene with chlorine gas at 600C and hydrolysis with calcium hydroxide. The technical product always contains certain impurities.

Toxicity

Mammals:		
Rat:	LD_{50} 40 mg/kg, oral	acc. KOCH, 1989
	LCLo 250 ppm, inhalation (4 h)	acc. KOCH, 1989
Mouse:	LD_{50} 178 mg/kg, oral	acc. KOCH, 1989
Aquatic organisms:		
Goldfish:	LC_{50} 23 mg/l (24 h)	acc. KOCH, 1989
Water flea:	LC_{50} 30 mg/l	acc. KOCH, 1989
Algae:	6 mg/l toxic limit concentration	acc. KOCH, 1989

Characteristic effects:

Humans/mammals: **Epichlorohydrin is a toxic and carcinogenic substance with mutagenic effect. If it has been resorbed through the skin, the symptoms do not appear immediately. Acute poisoning causes irritation of the skin and mucous membranes, respiratory paralysis and damage to the kidneys and liver. Epichlorohydrin has an adverse effect on the lungs, the liver and the central nervous system. Chronic damage is indicated by allergenic effects and changes to the eyes and lungs.**

ENVIRONMENTAL BEHAVIOUR

Environmental accumulation is moderate. The toxicity is most pronounced in water because of the water solubility. Epichlorohydrin is a mobile substance which is found both in the hydrosphere and in the atmosphere.

Hydrolysis produces pronounced metabolic degradation. Incomplete combustion gives rise to the formation of phosgene.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:	Drinkw	DDR	(L)	10 g/l			acc. KOCH, 1989
Air:	Emiss.	D	L	5 mg/m^3		mass flow 25 g/h	acc. SCHMEZER et. al., 1987
		DDR	L	0.2 mg/m^3		Short-time value	acc. HORN, 1989
		DDR	L	0.06 mg/m^3		Long-time value	acc. HORN, 1989
	Workp	AUS	(L)	20 mg/m^3		1978	acc. SCHMEZER et. al., 1987
	Workp	B	(L)	20 mg/m^3		1978	acc. SCHMEZER et. al., 1987
			(L)				

	Workp	CH		19 mg/m3		1978	acc. SCHMEZER et. al., 1987
	Workp	D	L	12 mg/m3	TRK		DFG, 1989
	Workp	DDR	(L)	10 mg/m3			acc. HORN, 1989
	Workp	DDR	(L)	5 mg/m3			acc. HORN, 1989
	Workp	NL	(L)	4 mg/m3		1978	acc. SCHMEZER et. al., 1987
	Workp	PL	(L)	1 mg/m3		1976	acc. SCHMEZER et. al., 1987
	Workp	RO	(L)	10 mg/m3		Max. impact	acc. SCHMEZER et. al., 1987
	Workp	S	(L)	2 mg/m3		1978	acc. SCHMEZER et. al., 1987
	Workp	SF	(L)	19 mg/m3		1975	acc. SCHMEZER et. al., 1987
	Workp	SU	(L)	1 mg/m3	PDK		acc. SORBE, 1989
	Workp	USA	(L)	10 mg/m3	TWA	Skin	ACGIH, 1986

Assessment/comments

Epichlorohydrin is extremely toxic in water and has been proven to be carcinogenic and mutagenic. Dumping or incineration should be avoided.

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Formaldehyde

DESIGNATIONS

CAS No.: 50-00-0
Registry names: Formaldehyde
Chemical name: Methanal
Synonyms, Trade names: Formic acid aldehyde, formalin, methyl aldehyde, oxomethane, methyleneoxide, oxymethylene, formyl hydrate, Formol, Fannoform, BFV, Formalith, Ivalon, Lysoform, Morbicid, Superslysoform, Tannosynt, Antverruc, Sandovac, Vobaderin
Chemical name (German): Formaldehyd, Methanal
Chemical name (French): Formaldhyde, Mthanal
Appearance: colourless gas with pungent odour

Note: Commercially available aqueous solutions contain 35-55% formaldehyde. As formaldehyde has a tendency towards polymerisation, these solutions are stabilised with methanol (The addition of methanol increases the flammability).

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	CH_2O

Rel. molecular mass:	30.03 g	
Density:	0.8153 g/cm^3 (liquid at -20C)	
Relative gas density:	1.04	
Boiling point:	-19.2C (pure substance)	
Melting point:	-92.0 to -118.0C	
Flash point:	32-61C	(aqueous solution)
Ignition temperature:	300-430C	(aqueous solution)
Explosion limits:	7-73 % by vol.	
Solvolysis/solubility:	in water: completely soluble readily soluble in ether, alcohol and other polar solvents	
Conversion factors:	1 mg/m^3 = 0.80 ppm 1 ppm = 1.25 mg/m^3	

ORIGIN AND USE

Usage:

The use of formaldehyde is extremely widespread and dependent on the additives (e.g. urea, melanin, phenol, ammonia). It is thus used in differing concentrations in adhesives (e.g. for the production of chipboard), foams, tanning agents, explosives, dyes, preserving agents, solvents, pharmaceuticals, resins and fungicides.

Origin/derivation:

Formaldehyde is produced by oxidising methanol using silver or metal oxide catalyst methods (iron and molybdenum). In addition to the emissions resulting from the production and its usage, formaldehyde is released into the atmosphere due to incomplete combustion and the photochemical degradation of organic trace substances.

Production figures:

The production figures in Germany between 1980 and 1982 were about 500,000 tons (BMFJG, 1984). In 1978, 2.9 million tons were produced in the USA. Japan produced 1.2 million tons of formaldehyde in 1979 (WHO, 1982).

Toxicity

Humans:	LDLo female 36 mg/kg, oral	acc. UBA, 1986
	TCLo 17 mg/m^3 (30 min), inhalation	acc. UBA, 1986
	TCLo 8 ppm, inhalation	acc. UBA, 1986
	LDLo 477 mg/kg (unreported)	acc. UBA, 1986
Mammals:		
Mouse:	LC_{50} 300 mg/m^3, subcutaneous	acc. WHO, 1982
Rat:	LD_{50} 800 mg/kg, oral	acc. WHO, 1982
Rat:		acc. WHO, 1982

Rat:	LC_{50} 590 mg/m^3, inhalation LD_{50} 87 mg/kg, intravenous	acc. WHO, 1982
Rabbit:	LD_{50} 270 mg/kg, dermal	acc. WHO, 1982
Guinea pig:	LD_{50} 260 mg/kg, oral	acc. WHO, 1982
Aquatic organisms:		
Small crustaceans:	LC_0 27 mg/l	acc. UBA, 1986
Small crustaceans:	LC_{50} 52 mg/l	acc. UBA, 1986
Small crustaceans:	LC_{100} 77 mg/l	acc. UBA, 1986
Fish:	LC_{100} 28.4 mg/l	acc. UBA, 1986
Algae:	LC_{50} 0.3-0.5 mg/l	acc. UBA, 1986
Water flea:	LC_{50} 2 mg/l	acc. UBA, 1986

Characteristic effects:

***Humans/mammals:* Formaldehyde causes major irritation of the mucous membranes, the conjunctiva, the skin and the upper part of the respiratory tract both as a gas and as vapour or aerosol. In aqueous solutions, it is a protoplasmic poison with caustic and protein-denaturating effect. Skin contact produces surface coagulation,**

necroses with hardening, tanning and anaesthetisation. Swallowing or inhaling large quantities causes burning of the oesophagus or the trachea, pains in the gastro-intestinal tract, nausea, loss of consciousness and collapse. 60 ml of liquid or 650 ml of vapour per m^3 are potentially lethal after a few minutes. The carcinogenic potential is a case for intense scientific discussion likely to be affirmed. Delayed and cumulative damage has not yet been established.

ENVIRONMENTAL BEHAVIOUR

Water:
Because of its good solubility, some 99% of the formaldehyde which is released into the environment is found in water (BMFJG, 1984).

Air:
Approximately 1% of the formaldehyde emitted into the environment reaches the atmosphere, but it is readily washed out again by precipitation. There is no long-distance transportation due to the relatively short half-life. Pressurised formaldehyde forms a cold mist when depressurised. This mist is denser than air, vaporises easily and forms aggressive and explosive mixtures with air (including over the water surface).

Soil:
The effects of the substance in soil are unknown, however no bioaccumulation has been established to date. Infiltration into the groundwater is of minor concern because of the tendency of formaldehyde to evaporate from soil.

Half-life:
The half-life in air (urban air with sun rays) is between 1 and 2 hours, or 12 hours if hydroxo radicals are present.

Degradation, decomposition products:
Degradation is performed by microorganisms in soil and water. At temperatures above 150C, formaldehyde

decomposes to form methanol and carbon monoxide. There is little stability under atmospheric conditions as a result of the short half-life (BMFJG, 1984). Formaldehyde is subject to spontaneous polymerisation in contact with acids and alkalis. It reacts with water to form polymethylenes. When exposed to HCl, formaldehyde forms the highly carcinogenic bis(chloromethyl)ether and catalyzes secondary amines to form carcinogenic nitrosamines/N-nitroso compounds.

Food chain:
There is only slight accumulation in the food chain. Formaldehyde is rapidly oxidised in the organism to formic acid, which is partly excreted with urine.

Combination effects:
Formaldehyde enters into vigorous condensation reactions with ammonia or amines and is disproportionated with alkalis to form methanol and formic acid.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Air:	**Emiss.**	**D**	**L**	**20 mg/m^3**		**mass flow > 0.1 g/h**	**acc. TA Luft, 1986**
		DDR	(L)	0.012 mg/m^3		Long-time value	acc. HORN, 1989
		DDR	(L)	0.035 mg/m^3		Short-time value	acc. HORN, 1989
		WHO	G	100 g/m^3		24 h	acc. UBA, 1988
			L				

	D D	L	0.03 mg/m^3 0.07 mg/m^3	MIK MIK	Long-time value Short-time value	DFG, 1988 DFG, 1988
Workp	AUS	L	3 mg/m^3			acc. WHO, 1982
Workp	B	G	3 mg/m^3			acc. WHO, 1982
Workp	BG	G	1 mg/m^3		1)	acc. BMFJG, 1984
Workp	CS	G	2 mg/m^3			acc. WHO, 1982
Workp	CS	G	5 mg/m^3		10 min	acc. WHO, 1982
Workp	D	L	0.6 mg/m^3	MAK		DFG, 1989
Workp	D	G	0.123 mg/m^3		2)	acc. WHO, 1982
Workp	DDR	(L)	0.5 mg/m^3		Short-time value	acc. HORN, 1989
Workp	DK	(L)	0.148 mg/m^3		2)	acc. WHO, 1982
Workp	H	(L)	1 mg/m^3			acc. WHO, 1982
Workp	I	(L)	1.2 mg/m^3		Long-time value	acc. WHO, 1982
Workp	I	(L)	0.12 mg/m^3			acc. BMFJG, 1984
Workp	J	(L)	2.5 mg/m^3			acc. WHO, 1982

Workp	NL	L	1.2 mg/m^3			acc. BMFJG, 1984
Workp	NL	G	0.12 mg/m^3		2)	acc. BMFJG, 1984
Workp	PL	G	2 mg/m^3			acc. WHO, 1982
Workp	RO	G	4 mg/m^3		3)	acc. WHO, 1982
Workp	S	(L)	3 mg/m^3		10 min3)	acc. WHO, 1982
Workp	S	(L)	0.6 mg/m^3		4)	acc. BMFJG, 1984
Workp	S	(L)	0.12 - 0.5 mg/m^3			acc. BMFJG, 1984
Workp	S	G	0.123 mg/m^3		2)	acc. WHO, 1982
Workp	SF	(L)	1.2 mg/m^3			acc. BMFJG, 1984
Workp	SF	G	3 mg/m^3			acc. WHO, 1982
Workp	SU	(L)	0.5 mg/m^3	PDK	3)	acc. SORBE, 1988
Workp	USA	(L)	1.5 mg/m^3	TWA		acc. SORBE, 1988
Workp	USA	(L)	3 mg/m^3	STEL	30 min	acc. WHO, 1982
Workp	USA	(L)	0.13 mg/m^3			acc. BMFJG, 1984
		(L)				

	Workp	USA		0.6 mg/m^3		5)	acc. BMFJG, 1984
	Workp	YU	(L)	1 mg/m^3			acc. WHO, 1982

Further legislation:

- The concentration levels in chipboard in the Federal Republic of Germany must not exceed the following (ETB, 1980): Emission class 1 (E1) max. 0.1 ppm; emission class 2 (E2) max. 1 ppm; emission class 3 (E3) max. 2.3 ppm. There are no regulations to date regarding the use of chipboard in furniture and in the Do-it-yourself sector.

- There are similar regulations in Belgium and Japan (chipboard classification).

- The maximum concentration levels in the Federal Republic of Germany for finished products are as follows for cosmetics (Order Governing Cosmetics, 1977): nail hardeners: 5%; preservative agent: 0.2%; mouthwash 0.1%

- The quality requirements imposed on urea-resin in-situ foams used for insulation are regulated in the Federal Republic of Germany by DIN Standard 18159.

- There is a total ban on UF foam insulation in Canada.

- The Japanese likewise control the concentration in wallpapers and adhesives and there is a ban on formaldehyde as an additive in the treatment and packaging of foodstuffs as well as in paints. The substance is limited to 75 ppm in textiles (BMJFG, 1984).

Notes:

1) For stationary systems

2) Indoor air

3) Maximum value

4) For new systems

5) Minnesota

Comparison/reference values

Medium/origin	Country	Value	Source
Air:			
Los Angeles, California (1961-66):	USA	0.005-0.16 mg/m^3	acc. BMJFG, 1984
Road air (1977)	CH	0.0011-0.0012 mg/m^3	acc. BMJFG, 1984
Sea air (1979)	D	0.00012-0.008 mg/m^3	acc. BMJFG, 1984
Automobile emissions		35.7-52.9 mg/m^3	acc. BMJFG, 1984
Interior of house (1975):	DK	0.08-2.24 mg/m^3	acc. BMJFG, 1984
Indoor air (BMJFG, 1984; Tests between 1975 and 1984):			
Chipboard:			
New schools		0.36-1.08 mg/m^3 (little exchange of air)	

Classrooms and homes		0.6-0.72 mg/m^3 (furniture)	
Prefabricated house		0.18-1.08 mg/m^3	
Houses in USA		0.012-3.84 mg/m^3 (636 houses)	
Thermal insulation		0.24-3.48 mg/m^3 (43 properties)	
Disinfection:			
Pathology		< 13.56 mg/m^3 (following removal)	
Bed disinfection		< 6 mg/m^3	
Disinfection by scrubbing		< 13.2 mg/m^3	
Spray disinfection		< 12 mg/m^3	
Incubator air		18-30 mg/m^3	
Rainwater:			
Mainz (1974-1977)	D	0.174 0.085 g/l	acc. BMJFG, 1984
Deuselbach (1974-1976)	D	0.141 0.048 g/l	acc. BMJFG, 1984
Clean-air zone (1977)	IRL	0.111 0.059 g/l	acc. BMJFG, 1984

Foodstuffs and semi-luxury goods:			
Tomatoes		5.7-7.3 g/kg	acc. WHO, 1982
Apples		17.3-22.3 g/kg	acc. WHO, 1982
Spinach		3.3-7.3 g/kg	acc. WHO, 1982
Carrots		6.7-10 g/kg	acc. WHO, 1982
Radish		3.7-4.4 g/kg	acc. WHO, 1982
Cigarette smoke		37.5-44.5 g/cigarette	acc. WHO, 1982

Assessment/comments

Workplace exposure is not the only way by which formaldehyde enters the human body. Its use as an adhesive in the manufacture of chipboard and its mixing with urea for in-situ foams is controlled both in Germany and in several other countries. When the above building materials are used, formaldehyde degases into the air inside residential buildings. The carcinogenic potential of formaldehyde has yet to be reliably established. Isolated animal experiments point to the possibility of a carcinogenic and teratogenic effect.

***Special sources:* BMFJG (1984)**

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Hexachlorobenzene

DESIGNATIONS

CAS No.: **118-74-1**
Registry name: **Hexachlorobenzene**
Chemical name: **Hexachlorobenzene**
Synonyms, Trade names: **HCB**
Chemical name (German): **Hexachlorbenzol**
Chemical name (French): **Hexachlorobenzne**
Appearance: **colourless (technical: yellowish) crystals**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	C_6Cl_6
Rel. molecular mass:	284.79 g
Density:	2.04 g/cm^3 at 20C
Relative gas density:	9.84
Boiling point:	322-326C
Melting point:	229C
Vapour pressure:	1.1 x 10^{-3} Pa
Flash point:	242C

Solvolysis/solubility:	in water 0.005 mg/l in benzene 31.6 g/l, in fat 11.5 g/kg at 37C
Conversion factors:	1 ppm = 11.84 mg/m^3 1 mg/m^3 = 0.08 ppm

ORIGIN AND USE

Usage:
Hexachlorobenzene is a fungicide which has primarily been used as a seed protection agent to prevent bunt and for the treatment of soil. It is still used in many developing countries to fumigate grain. Nowadays, HCB is mainly used for fireproofing and as a plasticiser. It is an important base product in the synthesis of various chlorinated organic compounds. In addition, it is used as an additive in wood preservatives.

Origin/derivation:
There are no natural sources. HCB is produced by chlorinating low chlorinated benzenes. HCB forms the basis for the production of pentachlorophenol (PCP).

HCB may be a by-product of the industrial chlorination of hydrocarbons. It is released into the environment both as a result of the combustion of products containing chlorine (e.g. waste incineration) and due to the use of pesticides contaminated with HCB.

Production figures:
Approx. 10,000 t/a worldwide at the end of the Seventies;
EC (1978) approx. 8,000 t/a; D approx. 4,000 t/a (1974) and 2,600 t/a (1976).

Emission figures:

The values quoted are between 20% and 100% of the amount produced.

Toxicity

Mammals:		
Rat	LD_{50} >10,000 mg/kg, oral	acc. DVGW, 1988
	LD_{50} >6,800 mg/kg, dermal	acc. RIPPEN, 1989
Rabbit	LD_{50} 2,600 mg/kg, oral	acc. DVGW, 1988
Cat	LD_{50} 1,700 mg/kg, oral	acc. DVGW, 1988
Aquatic organisms:		
Fish	LD_{50} >100 mg/kg	acc. RIPPEN, 1989
Water flea (Daphnia magna)	EC_0 0.025 mg/l (24h, ability to float)	acc. DVGW, 1988

Characteristic effects:

***Humans/mammals:* HCB is supposed to have carcinogenic potential. Mutagenic and teratogenic effects have not been established. There have been cases of skin disease in humans and of liver damage and neurotic symptoms in**

rats following chronic exposure. HCB is thoroughly resorbed from foodstuffs in the gastro-intestinal tract and slowly metabolised, accumulating in fatty tissue. As the fat depot is degraded, HCB is remobilised and may then be found in all organs.

ENVIRONMENTAL BEHAVIOUR

Water:
In water, HCB is readily adsorbed on suspended matter and thus accumulates in the sediment.

Soil:
HCB accumulates in soil and sewage sludge.

Degradation, decomposition products, half-life:

- Estimated half-life (abiotic and biotic) > 1 year.
- No degradation in surface water.
- Half-life in soil roughly 2 years. 14% degradation (adsorbed) after 24 h exposure to strong, simulated sunlight.
- Photomineralisation observed at wavelengths > 230 nm (adsorbed).
- Thermal decomposition at 510-530C; mineralisation at 950C.
- Metabolites: 2,3,5-Trichlorophenol, tetrachlorobenzene and pentachlorobenzene

Food chain:
HCB accumulates in the fatty tissue of organisms.

ENVIRONMENTAL STANDARDS

Medium/		Country/					

acceptor	Sector	organ.	Status	Value	Cat.	Remarks	Source
Water:	Drinkw	A	(L)	0.01 g/l			acc. DVGW, 1988
	Drinkw	D	L	0.1 g/l			acc. DVGW, 1988
	Drinkw	EC	G	0.1 g/l			acc. DVGW, 1988
	Drinkw	WHO	G	0.01 g/l			acc. DVGW, 1988
	Surface	IAWR	G	0.1 g/l		Drinking water1)	acc. DVGW, 1988
	Surface	IAWR	G	0.5 g/l		Drinking water2)	acc. DVGW, 1988
Air:	Workp	D	L	15 g/dl	BAT	In plasma/ serum	acc. DVGW, 1988
	Workp	SU	(L)	0.9 mg/m^3		Skin resorption	acc. KETTNER, 1979
Foodstuffs:							
Tea, spices		D	L	0.1 mg/kg			acc. DVGW, 1988
Vegetables, oilseed, coffee		D	L	0.05 mg/kg			acc. DVGW, 1988
Other							

vegetable foodstuffs		D	L	0.01 mg/kg			acc. DVGW, 1988

Notes:

1) Natural treatment methods

2) Chemophysical treatment methods

Usage is banned for example in the Federal Republic of Germany and Japan and restricted in countries such as Argentina (acc. CES, 1985).

Comparison/reference values

Medium/origin	**Country**	**Value**
Water:		
Rhine (Koblenz, 1981)	D	20 ppt (mean value)
Large lakes, Niagara River (1980)	CDN	0.02-17 ppt (mean values: 0.04-0.06 ppt)
Mediterranean (1981)		0.7-3.2 ppt
Soil/sediment:		
Soil	CH	0.15-50 ppb
Sewage sludge	CH	6-125 g/kg
Rhine		50-400 ppb

Large lakes (1980)	CDN	0.02-320 ppb (n=71)
Mediterranean (1981)		<10-210 ppt
Air:		
North Pacific		0.095-0.13 ng/m^3 (mean value: 0.1 ng/m^3)
North Pacific (precipitation)		<0.03 ng/l
Near dump with HCB storage		170 g/m^3
Aquatic animals:		
Oysters (contaminated areas)		0.63 g/kg
Eels (Rhine)		1-2 mg/kg
Trout (large lakes)	CND	8-127 g/kg
Fish (North Sea, 1972)		0.2-97 g/kg
Humans:		
Bone marrow		1.3-3.9 mg/kg
Fatty tissue		0.03-22 mg/kg

Note:
1) All data from RIPPEN, 1989.

Assessment/comments

HCB is one of the substances whose effects on the ecosystem have scarcely been researched. All HCB-emitting processes should therefore be subject to appropriately cautious assessment, both with regard to its use in pest control and in the chemical production of chlorine compounds for which HCB is an intermediate product.

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Hydrogen fluoride

DESIGNATIONS

CAS No.: 7664-39-3
Registry name: Hydrogen fluoride
Chemical name: Hydrogen fluoride
Synonyms, Trade names: Hydrogen fluoride (anhydrous), anhydrous hydrofluoric acid, AHF
as aqueous solutions: hydrofluoric acid, acidum hydrofluorium
Chemical name (German): Fluorwasserstoff (wasserfrei), Flusure (wasserfrei)
Chemical names (French): Fluorure d'hydrogne (anhydre), acide hydrofluorique (anhydre)
Appearance: colourless, highly mobile, caustic liquid with penetrating odour

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	HF (mostly as $(HF)_6$ to $(HF)_x$)
Rel. molecular mass:	20.01 g
Density:	1.015 g/cm^3 at 0C, 0.901 g/cm^3 at boiling point
Relative gas density:	1.77
Boiling point:	19.51C
Melting point:	-83.55C
Vapour pressure:	10^5 Pa at 20C, 1.5 x 10^5 Pa at 30C, 2.8 x 10^5 Pa at 50C
Odour threshold:	0.03 mg/m^3
Solvolysis/solubility:	- HF is extremely hygroscopic and miscible in any ratio with water and numerous organic substances (e.g. with alcohols, ethers, ketones and nitriles).
	- Scarcely miscible with hydrocarbons and their halogen derivates
Conversion factors:	1 ppm = 0.832 mg/m^3
	1 mg/m^3 = 1.20 ppm

ORIGIN AND USE

Usage:
Anhydrous hydrogen fluoride is used mainly to produce aerosol fluorocarbons (propellants, refrigerators) as well as metal fluorides, ammonia hydrogen fluoride and fluorosulphuric acid. It is likewise used to desulphurise gas oils and as a solvent in chemical laboratories.

Origin/derivation:
HF issues from rock magma and is thus encountered above all in volcanically active areas (e.g. approx. 200,000 t/a in the 'Valley of the 10,000 Vapours' covering 72 km^2 in Alaska).

The industrial production of HF involves the heating of fluorides with concentrated sulphuric acid or thermal decomposition of fluorosilicic acid with the formation of silicon tetrafluoride.

Production figures:
In the "Western" world: 1964 approx. 555,000 t; 1970 approx. 960,000 t; 1972 approx. 1,045,000 t; 1980 approx. 1,820,000 t (ULLMANN, 1985), 1982 approx. 860,000 t (ULLMANN, 1988)

Emissions:
In addition to natural sources, emissions are to be expected from all industries using HF such as aluminium foundries and glassworks, brickworks, enamelling companies and phosphate factories.

Toxicity

Humans:	LD_{50} ppm, inhalation (30-60 min)	acc. HOMMEL, 1987
Mammals:		

Rat	LD_{50} 1276 ppm, inhalation (1 h)	acc. ROTH, 1988
Aquatic organisms:		
Fish	LC 60 mg/l	acc. HOMMEL, 1987
Fish	LC_0 0.63 g/l	acc. HOMMEL, 1987
Bacteria	0.63 g/l (inhibited cell reproduction)	acc. HOMMEL, 1987
Plants:		
Crocus	2 g/m^3 (276 h, extremely severe leaf necroses)	acc. VDI, 1987
Spruce	5.4 g/m^3 (270 h, severe necroses)	acc. VDI, 1987
Maize	4.7 g/m^3 (7 d, 7% leaf chloroses)	acc. VDI, 1987
Narcissus	2 g/m^3 (276 h, slight to moderate leaf necroses)	acc. VDI, 1987
Chrysanthemum	25 g/m^3 (114 h, very slight chloroses)	acc. VDI, 1987

Classification of plant species according to their relative fluoride sensitivity (from VDI, 1987):

Highly sensitive

American larch
Apricot
Ash maple
Bilberry
Common pine
Coral tree
Cranberry
Crocus family
Douglas fir
Fan maple
Gladiolus
Lilac
Hornbeam
Iris
Japanese larch
Lily-of-the-valley
Mahonia
Mountain ash
Mountain pine
Onion
Peach
Plum
Silver fir
Sorghum
St. John's wort
Spruce
Tulip
Vine
Weymouth pine
Yellow pine

Sensitive

Acer platanoides
Alpine knotgrass
Amaranth
Ambrosia
Apple
Apricot
Arborvitae family
Common pine
Copperbeech
Cranesbill family
Cultivated strawberries
Cultivated carnation
Dahlia family
Dock
Lucerne
Maize family
Mangel wurzel
Melilotus
Mountain ash
Narcissus family
Prunis padus
Spinach
Spruce
Stellaria media
Sumach
Sunflower
Sweet cherry
Sweet potato

Aspen poplar
Aster family
Beech family
Begonia family
Black pine
Black poplar
Black walnut
Canadian amelanchier
Chenopodium album
Cherry plum
Colorado fir
Douglas fir
Dwarf mountain pine
European larch
Field maple
Giant sequoia
Golden rod family
Green ash
Hybrid poplar
Incarnate clover
Japanese yew
Lilac
Peony family
Peach
Rye
Raspberry
Red mulberry
Rhododendron family
Rhubarb
Seed oats
Seed wheat
Silver maple
Sorghum
Tea-rose
Tomato
Vines
Violet
Walnut
Wild sorghum
Willow family
Winter linden

Less sensitive

Ailanthus glandulosa
Amaranth
American linden
American plane
Arborvitae
Canadian amelanchier
Carrot
Celery
Cherry plum
Chinese elm
Dwarf medlar
Elaeagnus
False cypress
Forsythia
Flowering cherry
Prunis padus
Raspberry
Robinia
Siberian elm
Snowberry

Aubergine
Asparagus family
Berberis
Balsam poplar
Black alder
Black elder
Black nightshade
Blackcurrent
Buckthorn
Burdock family
Cabbage
Camellia
Chinese juniper
Chrysanthemum family
Coffee tree
Columbine family
Cornaceae
Cotton
Cucumber
Cultivated antirrhinum
Cultivated bean
Cultivated pumpkin
Cultivated strawberry
Dock family
Hemlock spruce
Lucerne
Mountain ash
Oak family
Pea
Pear
Petunia
Philadelphus coronarius
Plane
Plantain family
Potato
Privet family
Soja bean
Sugar cane
Sumach
Tobacco
Tomato
Wheat family
White beech
Wild vine
Willow family
Yarrow
Yew

Characteristic effects:

Humans/mammals: **HF is caustic and can severely damage the respiratory tract with pulmonary oedemas. Symptoms of acute poisoning are burning of the eyes, the skin, the nasal mucous membranes and the mucous membranes in the throat. Long-term inhalation of HF can cause fluorosis (= osteosclerosis) even at small**

concentrations. Grazing cattle have been found to produce less milk, to grow less, to suffer paralysis and to have damaged teeth following poisoning. Fluorosis is also possible with cattle. Damage to health can occur as soon as the odour becomes perceptible. Fluorine is found as a trace element in bones and teeth. A lack of fluorine may damage human teeth (e.g. caries).

Plants: **HF is the most phytotoxic gas. However, the compatibility of plants to HF varies significantly among the various species depending e.g. on the age of the leaves and the stage of development. HF influences the enzyme activity and causes necroses. Damage due to HF is similar to arid damage.**

ENVIRONMENTAL BEHAVIOUR

Water:
HF dissolves completely in water with considerable amounts of heat being liberated. Corrosive and toxic mixtures may form over the surface of water. Extremely acidic with little dissociation in aqueous solutions.

Air:
HF develops smoky clouds in humic air. Corrosive mists are formed and remain at ground level because of the relative gas density.

Soil:
Depending on the type of soil, fluorine is found in the form of fluorides as a natural element in concentrations between 10 and 150 ppm. HF causes only little acidification of the soil as it is readily bonded through the effect of lime. Damage to plants as a result of uptake from the soil is only a minor problem.

Conversion, degradation, decomposition products, half-life:
Fluorides may be produced. Most metal fluorides are soluble in water; PbF_2, CuF_2 and certain alkaline-earth fluorides are hardly soluble in water or not at all.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:	Emiss.	D	L	5 mg/m^3		mass flow > 50 g/h[12)]	acc. TA Luft, 1986
		D	G	1	WGK		acc. HOMMEL, 1987
Air:		D	L	1 g/m^3	IW1	11)	acc. TA Luft, 1986
		D	L	3 g/m^3	IW2	11)	acc. TA Luft, 1986
		CDN	(L)	1.5 g/m^3		24 h, Manitoba	acc. UBA, 1981
		CDN	(L)	4.5 g/m^3		24 h, Newfoundland	acc. UBA, 1981
		CDN	(L)	26 g/m^3		24 h, Ontario[1)]	acc. UBA, 1981
		CDN	(L)	7 g/m^3		24 h, Ontario[2)]	acc. UBA, 1981
		CDN	(L)	3 g/m^3		24 h, Saskatch.	acc. UBA, 1981
		DDR	(L)	5 g/m^3		24 h	acc. DORNIER, 1984
		DDR	(L)	20 g/m^3		30 min	acc. DORNIER, 1984
		E	(L)	10 g/m^3		24 h	acc. DORNIER, 1984

	E	(L)	30 g/m^3		30 min	acc. DORNIER, 1984
	H	(L)	20 g/m^3		24 h$^{3)}$	acc. DORNIER, 1984
	H	(L)	1.3 g/m^3		24 h$^{4)}$	acc. DORNIER, 1984
	H	(L)	5 g/m^3		30 min$^{4)}$	acc. DORNIER, 1984
	NL	(L)	10 g/m^3		24 h	acc. DORNIER, 1984
	RO	(L)	5 g/m^3		24 h	acc. DORNIER, 1984
	RO	(L)	20 g/m^3		30 min	acc. DORNIER, 1984
	SU	(L)	10 g/m^3		24 h$^{5)}$	acc. DORNIER, 1984
	SU	(L)	30 g/m^3		30 min$^{5)}$	acc. DORNIER, 1984
	YU	(L)	5 g/m^3		24 h	acc. DORNIER, 1984
	YU	(L)	20 g/m^3		30 min	acc. DORNIER, 1984
Workp	D	L	2 mg/m^3	MAK	8 h mean	DFG, 1989
Workp	D	L	3 ml/m^3	MAK	8 h mean	DFG, 1989
Workp	USA	(L)	2.5 mg/m^3	TLV-C	Ceiling value	ACGIH, 1986

	Workp	USA	(L)	2 ppm	TLV-C	Ceiling value	ACGIH, 1986
	Workp	D	L	4 mg/g (aqu)	BAT	Urine11)	DFG, 1988
		D	G	1 g/m^3		1 d, plants6)	VDI, 1987
		D	G	0.25 g/m^3		1 mon, plants6)	VDI, 1987
		D	G	0.15 g/m^3		7 mon, plants6)	VDI, 1987
		D	G	2 g/m^3		1 d, plants7)	VDI, 1987
		D	G	0.6 g/m^3		1 mon, plants7)	VDI, 1987
		D	G	0.4 g/m^3		7 mon, plants7)	VDI, 1987
		D	G	6 g/m^3		1 d, plants8)	VDI, 1987
		D	G	1.8 g/m^3		1 mon, plants8)	VDI, 1987
		D	G	1.2 g/m^3		7 mon, plants8)	VDI, 1987
		USA	G	2.7 g/m^3		1 d, pesticide	acc. ULLMANN, 1985
		USA	G	0.78 g/m^3		1 mon, pesticide	acc. ULLMANN, 1985
		USA	G	0.5 g/m^3		Vegetat. period	acc. ULLMANN, 1985
Foodstuffs:							

Working animals	Fodder	D	L	30 mg/kg (88% DS)		9)	acc. BAFEF, 1987
	Fodder	D	L	50 mg/kg		10)	acc. BAFEF, 1987
	Fodder	D	L	100 mg/kg		Pigs	acc. BAFEF, 1987
	Fodder	D	L	350 mg/kg		Poultry	acc. BAFEF, 1987
	Fodder	D	L	150 mg/kg		Other animals	acc. BAFEF, 1987

Notes:

1) For industrial and business conurbations

2) For residential and rural areas

3) For protected areas

4) For specially protected areas

5) For residential areas

6) Highly sensitive plants

7) Sensitive plants

8) Less sensitive plants

9) Lactating cattle, sheep, goats

10) Other cattle, sheep, goats

11) HF and ist inorganic gaseous compounds, stated as F

12) F and ist vapourous/gaseous compounds, stated as HF

Assessment/comments

When released into the atmosphere, hydrogen fluoride can prove to be a potent plant killer. Therefore, it should only be released in small quantities. Numerous limit values for differing exposure periods were established by the VDI in 1987.
The addition of fluoride to drinking water is the subject of debate. It has been proven beyond doubt that a lack of fluorine is harmful to the teeth, but the absorption of major quantities of fluorine is harmful to both humans and animals.
The information available to date does not permit conclusive assessment.

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Hydrogen sulphide

DESIGNATIONS

CAS No.: 7783-06-4
Registry name: Hydrogen sulphide
Chemical name: Dihydrogen sulphide
Synonyms, Trade names: Sulphuretted hydrogen, hydrogen sulphide
Chemical name (German): Schwefelwasserstoff, Hydrothionsure
Chemical name (French): Acide sulfhydrique, gaz sulfhydrique, hydrogne sulfur

Appearance: **colourless, sweetish gas with offensive odour**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula: H_2S
Rel. molecular mass: **34.08 g**
Density: **1.54 g/l (gaseous)**
Relative gas density: **1.19**
Boiling point: **-60C**
Melting point: **-86C**
Vapour pressure: **18.1 bar at 20C, 36.5 bar at 50 C**
Flash point: **inflammable**
Ignition temperature: **270C**
Explosion limits: **4.3 - 45.5 Vol%**
Odour threshold: **0.01 ppm**
Solvolysis/solubility: **in water: 4.0 g/l at 20C; 2.5 g/l at 40C (approx.)**
Conversion factors:

$1\ mg/m^3 = 0.706\ ppm$
$1\ ppm = 1.416\ mg/m^3$

ORIGIN AND USE

Usage:

Technical H_2S is usually subjected to further processing to form sulphur or sulphur dioxide which is required in large quantities in the production of sulphuric acid. Further uses are the production of metal sulphides, flotation processes, catalyst activation and poisoning.

Origin/derivation:

Small quantities of H_2S are quite common in the environment, e.g. dissolved in mineral springs, bodies of water, waste water and above all in natural gases. H_2S is produced during the decomposition of sulphurous protein amino acids due to the influence of putrifactive and sulphur bacteria, for example in marshes, standing water and sewage treatment plants. It is encountered in various production processes in industry such as in the manufacture of chemical fibres, or in coking plants and refineries. The hydrogen sulphide resulting from the purification of natural gas is generally processed immediately to form sulphur.

Production figures:

Worldwide (1986) 14 x 10^6 t (as sulphur from H_2S) [ULLMANN, 1989]

Toxicity

Humans:	1.2-2.8 mg/l air (immediately lethal)	acc. Tab. Chemie, 1980
	0.6 mg/l air (0.5-1 h, lethal)	acc. Tab. Chemie, 1980
	0.1-0.15 mg/l air (several hours inhalation, poisonous)	acc. Tab. Chemie, 1980
Mammals:		
Mouse	LD_{50} 53 mg/kg, (sodium sulphide)	acc. DVGW, 1988
Aquatic organisms:		
Fish	0.86 mg/l (toxic)	acc. HOMMEL, 1973

Char	LC 0.86 mg/l (24 h)	acc. DVGW, 1988
Carp	LC 6.3 mg/l (24 h)	acc. DVGW, 1988
Tench	LC 10 mg/l	acc. DVGW, 1988
Fish prey	1 mg/l (lethal)	acc. HOMMEL, 1973

Characteristic effects:

***Humans/mammals:* H_2S is an irritant and a nerve and cell toxin. It may cause irritation of the eyes and respiratory organs, bronchial catarrh, nausea, malfunction of olfactory nerves at large concentrations, spasms, numbness and finally death due to respiratory paralysis. Hypersensitivity to H_2S , once established, may remain for a long time. Illness caused by hydrogen sulphide at the workplace must be reported.**

***Plants:* There is only slight damage to plants. The most sensitive edible plants are radishes, tomatoes, cucumbers, and soya beans.**

ENVIRONMENTAL BEHAVIOUR

Water:
H_2S dissolves in water. The air over such solutions may be explosive. If H_2S infiltrates into groundwater (bank filtrate) it becomes undrinkable.

Air:
When the gas expands, large quantities of cold mist rapidly form in addition to extremely poisonous, explosive

mixtures. The mists are denser than air, creep along the ground and, when ignited, they may flash back over long distances.

Soil:
The occurrence of hydrogen sulphide in soil is not so much the result of the application of sulphurous fertilisers, but rather a consequence of inexpert soil cultivation. Under anaerobic conditions, e.g. due to saturation and compaction of the soil, and in the presence of organic material (e.g. stubble) which is subject to rapid microbial decomposition, the reduction of sulphate and the mineralisation of organic sulphur compounds may cause the formation of hydrogen sulphide.

Degradation, decomposition products, half-life:
H_2S is rapidly oxidised in the organism to form sulphate which is excreted.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:	Drinkw	CDN		0.05 mg/l			acc. DVGW, 1988
	Drinkw	D	G	1)		DIN 2000	acc. DVGW, 1988
	Drinkw	USA	(L)	0.05 mg/l			acc. DVGW, 1988
Air:	Emiss.	D	L	5 mg/m^3		mass flow > 50 g/h	acc. TA Luft, 1986
		D	L	0.005 mg/m^3	IW1	Long-time value	acc. KHN, BIRETT, 1983

		D	L	0.01 mg/m^3	IW2	Short-time value	acc. KHN, BIRETT, 1983
	Workp	D	L	10 ml/m^3	MAK		DFG, 1989
	Workp	DDR	(L)	15 mg/m^3			acc. TAB. CHEMIE, 1980
	Workp	SU	(L)	7 ml/m^3		Skin resorption	acc. SORBE, 1988
	Workp	SU	(L)	10 mg/m^3		Skin resorption	acc. SORBE, 1988
	Workp	USA	(L)	10 ml/m^3	TWA		acc. SORBE, 1988
	Workp	USA	(L)	15 mg/m^3	TWA		acc. SORBE, 1988
	Workp	USA	(L)	15 ml/m^3	STEL		acc. SORBE, 1988
	Workp	USA	(L)	27 mg/m^3	STEL		acc. SORBE, 1988

Note:

1) The hydrogen-sulphide concentration level must be below the odour threshold.

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Groundwater:			

Haltern	D	10 g/l	acc. DVGW, 1988

Assessment/comments

The presence of hydrogen sulphide can be immediately noticed by its offensive odour. Nevertheless, chronic symptoms often occur (occupational disease). Therefore, the air at the workplace has to be monitored on a continuous basis.

Hydrogen sulphide must be kept away from waters since any water which comes into contact with it will be spoiled. Any emission of hydrogen sulphide into the atmosphere should be avoided.

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Lead and its inorganic compounds

DESIGNATIONS

CAS No.: 7439-92-1
Registry name: Lead
Chemical name: Lead
Synonyms, Trade names: Plumbum

Chemical name (German): **Blei**
Chemical name (French): **Plomb**
Appearance: **grey metal, bluish white shine on freshly cut surfaces**

BASIC CHEMICAL AND PHYSICAL DATA

Chemical Symbol:	Pb
Rel. atomic mass:	207.21 g
Density:	11.34 g/cm^3
Boiling point:	1,740C
Melting point:	327.4C
Vapour pressure:	0 hPa
Solvolysis/solubility:	in water: except $Pb(NO_3)_2$ and $Pb(CH_3\text{-}COO)_2$ inorganic lead compounds are virtually insoluble in water

BASIC DATA OF SELECTED COMPOUNDS

CAS No:	1317-36-8	7758-95-4
Chemical name:	Lead(II) oxide	Lead(II) chloride
Synonyms, Trade names:	Lead monoxide, litharge	Lead chloride, lead dichloride
Chemical name (German):	Blei(II)-oxid	Blei(II)-chlorid

Chemical name (French):	Oxyde de plomb(II)	Chlorure de plomb(II)
Appearance:	red crystalline powder	white crystalline solid (needles)
Empirical formula:	PbO	$PbCl_2$
Rel. molecular mass:	223.21 g	278.11 g
Density:	9.53 g/cm^3	5.85 g/cm^3
Boiling point:	1472C	950C
Melting point:	888C	501C
Solvolysis/solubility:	insoluble in water; soluble in acetic acid and dilute nitric acid	in water: 9.9 g/l insoluble in ethanol; slightly soluble in dilute HCl

ORIGIN AND USE

Usage:
In 1987, some 60 % of the lead produced was used to make batteries (ULLMANN, 1990). Further areas of application are lead pipes, alloys, cables, pigments and anti-knock agents in fuel. On average, 25 - 40 % of the lead used throughout the world is obtained by recycling scrap and lead waste (MERIAN, 1984).

Important lead compounds:

Oxides	PbO	glass making

	Pb_3O_4	rust inhibitor for iron
	PbO_2	oxidising agent
Stearate	$Pb(C_{17}H_{35}COO)_2$	stabiliser in PVC compounds
Oleates, naphthenates		drying accelerator for oil-based paints
Tetraacetate	$Pb(CH_3COO)_4$:	oxidising agent
Tetraalkyls	$Pb(CH_3)_4$	anti-knock agent in fuel
	$Pb(C_2H_5)_4$	((ρ) lead compounds - organic)

Origin/derivation:

Lead is an element forming approx. 0.002 % of the Earth's crust. The most important minerals are galena (PbS), cerussite ($PbCO_3$), crocoite ($PbCrO_4$) and pyromorphite ($Pb_5(PO_4)_3Cl$).

Production figures:

Lead production for most important lead producing and consuming countries, 1987:

Country	Mine production (contained Pb), 10^3 t	Refined production (primary and secondary), 10^3 t	Refined consumption; 10^3 t

Soviet Union	510.0	780.0	775.0
Other Eastern Block	503.7	623.9	665.5
Australia, Oceania	486.2	220.7	65.0
Canada	413.4	225.8	102.9
United States	318.3	1027.9	1202.8
Peru	192.0	70.8	21.9
Mexico	177.1	185.1	99.6
Total World	3389.3	5631.4	5622.5

(figures from ULLMANN, 1990)

Toxicity

Mammals:		
Rat:	LD 11,000 mg/kg, oral (lead acetate)	acc. DVGW, 1985
	LD$_{50}$ 100-825 mg/kg, oral (lead arsenate)	acc. DVGW, 1985
Rabbit:	LD$_{50}$ 125 mg/kg, oral (lead arsenate)	acc. DVGW, 1985

Chicken:	LD_{50} 450 mg/kg, oral (lead arsenate)	acc. DVGW, 1985
Dog:	LD 2,000-3,000 mg/kg, oral (lead sulphate)	acc. DVGW, 1985
Aquatic organisms:		
American minnow:	LC_{50} 6.7-10.5 mg/l (24h) (lead chloride)	acc. WHO, 1989
	LC_{50} 4.3-8.7 mg/l (48h) (lead chloride)	acc. WHO, 1989
	LC_{50} 3.9-7.9 mg/l (96h) (lead chloride)	acc. WHO, 1989
	LC_{50} 10.7-63.9 mg/l (24h) (lead acetate)	acc. WHO, 1989
	LC_{50} 7.2-16.7 mg/l (48h) (lead acetate)	acc. WHO, 1989
	LC_{50} 4.9-11.8 mg/l (96h) (lead acetate)	acc. WHO, 1989
Blue perch:	LC_{50} 22.5-30.4 mg/l (24h) (lead chloride)	acc. WHO, 1989
	LC_{50} 20.9-29.1 mg/l (48h) (lead chloride)	acc. WHO, 1989
	LC_{50} 20.0-28.4 mg/l (96h) (lead chloride)	acc. WHO, 1989
	LC_{50} 6.3 mg/l (24h) (lead nitrate)	acc. WHO, 1989

	LC_{50} 6.3 mg/l (48h) (lead nitrate)	acc. WHO, 1989
Rainbow trout:	LC_{50} 1.17 mg/l (96h) (lead nitrate)	acc. WHO, 1989
Cockle:	LC_{50} > 500 mg/l (48h) (lead nitrate)	acc. WHO, 1989
Mya arenaria:	LC_{50} > 50 mg/l (48h) (lead nitrate)	acc. WHO, 1989
Water flea:	LC_{50} 0.45 mg/l (48h) (lead chloride)	acc. WHO, 1989
	LC_{50} 0.24-0.38 mg/l (21d) (lead chloride)	acc. WHO, 1989
	LC_{50} 4.19 - 5.89 mg/l (24h) (lead acetate)	acc. WHO, 1989

Characteristic effects:

***Humans/mammals:* Lead can be absorbed by inhalation of dusts or by eating foods containing lead and - in the case of plants - by way of soluble lead salts in soils. Whereas inhalation is the major source of intake in workplace exposure, ingestion and resorption in the gastro-intestinal tract predominate in the population in general. It has recently become established that considerable quantities of lead enter the human body via drinking water (lead pipes).**

Lead inhibits the various enzymes of the haemoglobin metabolism thus reducing the oxygen balance and the respiratory volume. Lead reduces the activity of the δ -aminolaevulinic acid-dehydratase in the erythrocytes. Damage occurs with long-term intake of less than 1 mg/day. Symptoms of chronic poisoning are lead deposits along the edge of the gums as well as colic fits and spasms. Apathy, irritability, insomnia and - in some cases -

behavioural irregularities in children are indications of damage to the nervous system. Lead passes through the placenta and accumulates in the foetus. In Germany, lead is listed in pregnancy group B (risk of embryonic damage is assumed).

The upper limit for the blood-lead level before it is considered to reach harmful proportions is 35 μ g Pb/100 ml of blood for adults and 30 μ g Pb/100 ml in children and pregnant women. The WHO applies a limit value of 100 g Pb/100 ml of blood but is even considerably lower in most countries.

Inorganic lead compounds are resorbed in the gastro-intestinal tract. Children resorb lead more easily than adults (DVGW, 1985). Some 90 % of the resorbed lead is bonded to the erythrocytes and thus distributed throughout the entire body. It is deposited above all in the bones.

Approximately 90 % of the lead absorbed orally is excreted again; 75-80 % by elimination in the kidneys (MERIAN, 1984). A small quantity is deposited in hair and nails, exuded with sweat or stored in mothers milk.

Plants: Plants mainly absorb lead from the soil, but only to a small extent from the atmosphere. Lead has a toxic effect on growth: application initially results in enhanced growth, but from a concentration of 5 ppm, this is counteracted by severe growth retardation, discoloration and morphological abnormalities (UBA, 1976). There is an adverse influence on photosynthesis, respiration and other metabolic processes. As a final step, lead inhibits the intake of essential nutrients from the soil. Pb^{++} has only a slight effect on the growth of taller plants. Generally speaking, it is the quality rather than the yield which suffers. Compared to the toxicity in humans, the phytotoxicity of lead is of minor importance.

ENVIRONMENTAL BEHAVIOUR

Water:

Surface water forms an accumulation sink for lead compounds. Insoluble lead compounds sink and are adsorbed in the sediment or accumulate on suspended matter (in particular the clay fraction). Aquatic plants likewise

accumulate lead. The biochemical oxidation of organic substances is inhibited at lead concentrations above 0.1 mg/l; fauna is depleted by concentrations above 0.2 mg/l and 0.3 mg/l is the threshold for fish toxicity (trout and white fish) [DVGW, 1985].

Groundwater is adversely affected by soluble lead compounds (e.g. lead chloride, nitrate). Nevertheless, it has been established that drinking water that passes through lead pipes may contain high lead concentrations (depending on the groundwater chemism). Lead is not chemically affected by deoxygenated water. In lead pipes, carbonated water forms lead carbonate deposits on the inner pipe surface.

Air:

Large quantities of lead are released into the atmosphere by combustion processes. There is a major difference between urban and rural areas. Lead compounds may be transported over a considerable distance depending on the speed and direction of the wind as well as precipitation and humidity. However, most of the lead in the atmosphere directly sediments or is removed by precipitation. Lead bonds to small dust particles in the air which in turn are deposited on vegetation and soil. Lead from motor-vehicle emissions accumulates in the immediate vicinity of roads.

Soil:

The absorption rate depends on the properties of the soil. There is a considerable affinity with humic substances. The pH is important for the availability of lead from its compounds. A low pH is linked to a high degree of desorption into the soil solution. However, as lead is quite immobile (e.g. more than cadmium), it remains in the topsoil and is not absorbed by plants to the same extent. Soils thus represent an important sink for lead compounds. Additional contamination results from the deposition of sewage sludge containing lead on farmland. Only extremely high contamination rates constitute a hazard to groundwater.

Half-life:

Lead remains in the atmosphere for roughly 7 - 30 days (FATHI & LORENZ, 1980). The biological half-life in blood is between 20 and 40 days; in bones up to several years (WHO, 1987).

Food chain:

Lead is found in all foodstuffs and fodders because it is ubiquitous. Vegetable foodstuffs generally contain more lead than animal products. This is the result of their special exposure: dust precipitations containing lead cling to the surface of plants and are thus consumed. In higher life forms, the maximum concentrations are found in internal organs such as the liver and kidneys. The increase in concentration is as follows in aquatic systems: water < fish prey < fish < sediment (DVGW, 1985).

Most humans absorb lead through their food (roughly 440 - 550 μ g per day) and drinking water (some 20 μ g per day) (DFG, 1982). At places where lead is produced or processed, atmospheric pollution is an additional problem. Approximately 30 - 50 % of the lead inhaled remains in the lungs (WHO, 1987); the rest is absorbed by the body and usually deposited in the bones.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	**Sector**	**Country/ organ.**	**Status**	**Value**	**Cat.**	**Remarks**	**Source**
Water:	Drinkw	AUS	(L)	0.05 mg/l		1973	acc. MERIAN, 1984
	Drinkw	CDN	L	0.05 mg/l		1978	acc. DVGW, 1985
	Drinkw	CH	(L)	0.05 mg/l			acc. MERIAN, 1984
	Drinkw	D	L	0.04 mg/l	TVO		acc. ROTH, 1989
	Drinkw	EC	L	0.05 mg/l		1)	acc. DVGW, 1985

Drinkw	J	(L)	0.10 mg/l		1968	acc. MERIAN, 1984
Drinkw	SU	(L)	0.10 mg/l		1970	acc. MERIAN, 1984
Drinkw	USA	L	0.05 mg/l	MCL		acc. SCHROEDER, 1985
Drinkw	ZA	(L)	0.05 mg/l			acc. MERIAN, 1984
Surface	CDN		0.05 mg/l		Simple treatment	acc. DVGW, 1985
Surface	CDN		0.25 mg/l		Refined treatment	acc. DVGW, 1985
Surface	D	L	0.03 mg/l		2)	acc. DVGW, 1985
Surface	D	L	0.05 mg/l		3)	acc. DVGW, 1985
Surface	EC	L	0.05 mg/l		4)	acc. DVGW, 1985
Groundw	NL	G	0.015 mg/l		Reference	acc. TERRA TECH 6/94
Groundw	NL	L	0.075 mg/l		Intervention	acc. TERRA TECH 6/94
Troughw	D	G	0.04 mg/l			acc. DVGW, 1985
Troughw	GB		0.10 mg/l			acc. DVGW, 1985
Troughw	USA		0.05 mg/l		1968	acc. DVGW, 1985

	Irrigation	D	G	0.5 mg/l		For field cultivation	acc. DVGW, 1985
	Irrigation	D	G	0.05 mg/l		For cultivation under glass	acc. DVGW, 1985
	Irrigation	GB		2 mg/l			acc. DVGW, 1985
	Irrigation	USA		5 mg/l		1968	acc. DVGW, 1985
Soil:	Soil	CH	G	50 mg/kg	VSBo	HNO_3 extract5)	acc. BUB, 1987
	Soil	CH	G	1 mg/kg	VSBo	$NaNO_3$ extract5)	acc. BUB, 1987
	Soil	GB	G	550 mg/kg		Gardens/vegetable g.	acc. SAUERBECK, 1986
	Soil	GB	G	1,500 mg/kg		Parks	acc. SAUERBECK, 1986
	Soil	GB	G	2,000 mg/kg		Public land	acc. SAUERBECK, 1986
	Soil	NL	G	85 mg/kg DS		Reference	acc. TERRA TECH 6/94
	Soil	NL	L	530 mg/kg DS		Intervention	acc. TERRA TECH 6/94
	Sew. sludge	D	G	100 mg/kg		6)	acc. KLOKE, 1988

	Sew. sludge	D	L	2,000 g/(haa)		7)	acc. KLOKE, 1988
	Fertiliser	D	L	200 g/ha/a		7)	acc. KLOKE, 1988
Air:	Emiss.	D	L	5 mg/m^3		mass flow > 25 g/h11)	acc. TA Luft, 1986
		CH	L	0.1 $mg/(m^2d)$	LRV	dust depos., 1 a	NN
		CH	L	0.001 mg/m^3	LRV	1 a	NN
		D	L	0.002 mg/m^3	IW112)		acc. TA Luft, 1986
		D	L	0.25 $mg/(m^2d)$	IW113)	dust depos.	acc. TA Luft, 1986
		D	L	0.003 mg/m^3	MIK	24 h	NN
		D	L	0.0015 mg/m^3	MIK	1 a	NN
		DDR	L	0.0003 mg/m^3		Long-time value	acc. HORN, 1989

	E	G	0.05 mg/m3		Short-time value	acc. STERN, 1986
	EC	G	0.002 mg/m^3		12 m	acc. STERN, 1986
	H	G	0.0007 mg/m^3		30 min	acc. STERN, 1986
	IL	G	0.005 mg/m^3		24 h	acc. STERN, 1986
	PO	G	0.0005 mg/m^3		24 h	acc. STERN, 1986
	RC	G	0.007 mg/m^3		24 h	acc. STERN, 1986
	WHO	G	0.005-0.001 mg/m^3		1 a	NN
	YV	G	0.005 mg/m^3		12 m	acc. STERN, 1986
Workp	AUS	(L)	0.15 mg/m^3			acc. MERIAN, 1984
Workp	BG	(L)	0.15 mg/m^3			acc. MERIAN, 1984

Workp	CH	(L)	0.15 mg/m^3			acc. MERIAN, 1984
Workp	CS	(L)	0.05 mg/m^3		Long-time value	acc. MERIAN, 1984
Workp	CS	(L)	0.2 mg/m^3		Short-time value	acc. MERIAN, 1984
Workp	D	L	0.1 mg/m^3	MAK	11)	DFG, 1989
Workp	DDR	(L)	0.01 mg/m^3		Short-time value	acc. HORN, 1989
Workp	DDR	(L)	0.005 mg/m^3		Long-time value	acc. HORN, 1989
Workp	H	(L)	0.02 mg/m^3			acc. MERIAN, 1984
Workp	I	(L)	0.15 mg/m^3			acc. MERIAN, 1984
Workp	J	(L)	0.15 mg/m^3			acc. MERIAN, 1984
Workp	NL	(L)	0.15 mg/m^3			acc. MERIAN, 1984
Workp	PL	(L)	0.05 mg/m^3			acc. MERIAN, 1984

	Workp	RO	(L)	0.1 mg/m^3		Long-time value	acc. MERIAN, 1984
	Workp	RO	(L)	0.2 mg/m^3		Short-time value	acc. MERIAN, 1984
	Workp	S	(L)	0.1 mg/m^3			acc. MERIAN, 1984
	Workp	SF	(L)	0.15 mg/m^3			acc. MERIAN, 1984
	Workp	USA	(L)	0.15 mg/m^3	TWA		ACGIH, 1986
	Workp	WHO	(L)	0.03 - 0.06 mg/m^3			acc. MERIAN, 1984
	Workp	YU	(L)	0.15 mg/m^3			acc. MERIAN, 1984
		D	L	70 mg/dl	BAT	Whole blood12)	DFG, 1989
		D	L	30 mg/dl	BAT	Whole blood, women <45 y.12)	DFG, 1989
		D	L	15 mg/l	BAT	Urine13)	DFG, 1989
		D	L	6 mg/l	BAT	Urine, women <45 y.13)	DFG, 1989

Foodstuffs:		WHO/FAO	G	430 mg/(persd)		Adults	acc. DFG, 1982
		USA	G	300 mg/(persd)		Infants	acc. DFG, 1982
Fruit/vegetable juice		CH	L	0.3 mg/l			acc. MERIAN, 1984
Milk		CH	L	0.05 mg/l			acc. MERIAN, 1984
Milk		D	G	0.03 mg/kg			acc. GROKLAUS, 1989
Cheese		D	G	0.25 mg/kg		Except hard cheese	acc. GROKLAUS, 1989
Meat		D	G	0.25 mg/kg		All animal species	acc. GROKLAUS, 1989
Meat		D	G	0.8 mg/kg		Liver/kidneys	acc. GROKLAUS, 1989
Fish		D	G	0.5 mg/kg		Except tins	acc. GROKLAUS, 1989
Fish		D	G	1 mg/kg		Tinned fish	acc. GROKLAUS, 1989
Mineral water		D	L	< 0.05 mg/l			acc. DVGW, 1985

Note:

1) The lead content of a sample taken from a lead pipe after draining off the water should not exceed 0.05 mg/l. If a water sample is taken directly or after the water has been allowed to flow off and if the lead content frequently or considerably exceeds 0.1 mg/l, remedial measures must be taken to reduce the risk of lead intake by consumers.

2) Limit value for natural treatment

3) Limit value for chemophysical treatment

4) Mandatory value for simple and standard physical, chemical and refined chemical treatment and sterilisation

5) Application of sewage sludge to soil used for agricultural or horticultural purposes prohibited (pollutant content of dry, mineral soils)

6) Total tolerable content in cultivated soil

7) Legally permitted additional annual loading of soil

8) Pb and its compounds, stated as Pb

9) Pb and its anorganic compounds as suspended dust, stated as Pb

10) Pb and its anorganic compounds within dust sediments, stated as Pb

11) Exposure of pregnant women to lead can damage the embryo even when in compliance with MAK and BAT value.

12) Parameter: lead

13) Parameter: delta-aminolaevulinic acid

- The lead content of fuel is limited by law in numerous countries in an attempt to reduce the emissions from motor-vehicle traffic. The maximum level in petrol in the Federal Republic of Germany and

Switzerland is 0.15 mg/l. More and more EC countries are starting to prescribe the use of unleaded fuel such as has been in force in several American states for many years.

- Certain industrial lead emissions are likewise subject to legislation. Thus, for example, the German TA-Luft (1986) fixed the IW1 immission values for lead as a constituent part of suspended dust at 2 μ g/m^3 to guard against health hazards and at 0.25 mg/(m^{2}d) to minimise the nuisance level. Furthermore, the amount of inorganic lead dust with a mass flow of 25 g/h may not exceed 5 mg/m^3. During the production of lead batteries the dust emissions must not exceed 0.5 mg/m^3 at a mass flow of 5 g/h or more.

- The German Lead - Zinc Law (1974) stipulates that eating, drinking and cooking utensils may not give off lead after being boiled for 30 minutes with 4 % acetic acid.

- The 1977 Paint Law prohibits the use of lead in paints, foodstuffs, semi-luxury goods and consumer goods.

- The 1988 Order Governing the Use of Pesticides totally prohibits the use of lead compounds for such purposes.

- Usage banned in D in line with 1985 Order on Cosmetics

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Surface water:			
	D	0.2 g/l	acc. DVGW, 1985

Lake Constance (1982)			
Neckar, Berg (1982)	D	4 g/l	acc. DVGW, 1985
Rhine, Cologne (1983)	D	1.5-14 g/l	acc. DVGW, 1985
Rhine, Duisburg (1983)	D	0.1-90.1 g/l	acc. DVGW, 1985
Ruhr, Witten (1983)	D	2-9 g/l	acc. DVGW, 1985
Drinking water:			
The Hague (1976)	NL	2 g/l	acc. DVGW, 1985
Karlsruhe (1975)	D	4 g/l	acc. DVGW, 1985
Drinking water	D	1-22.5 g/l (n=80)	acc. DFG, 1982
Sediment:			
Rhine, Basle (1975-77)	D	90 mg/kg	acc. DVGW, 1985
Rhine, Mannheim (1975 77)	D	370 mg/kg	acc. DVGW, 1985
Rhine, Emmerich (1975-77)	D	600 mg/kg	acc. DVGW, 1985
Ruhr (1975-77)	D	1,200 mg/kg	acc. DVGW, 1985
Danube, Leipheim (1975-77)	D	120 mg/kg	acc. DVGW, 1985
Air:			
Municipal areas		0.5-10 g/m^3	acc. MERIAN, 1986

Rural areas		0.1-1 g/m^3	acc. MERIAN, 1986
North American cities, annual average		0.1-5 g/m^3	acc. MERIAN, 1986
Plants:			
"Natural lead content"		< 3 ppm (dry matter)	acc. MERIAN, 1986
Foodstuffs:			
Milk	D	0.001-0.084 ppm (n=339)	acc. MERIAN, 1986
Ox/calves liver	D	0.01-3.31 ppm (n=1452)	acc. MERIAN, 1986
Wine	D	0.0005-3.08 ppm (n=471)	acc. MERIAN, 1986

Assessment/comments

Lead is not a physiologically essential element. It is most frequently absorbed in foodstuffs and at the workplace. The persistence of lead and its compounds has caused a ubiquitous distribution. Accumulation by way of food chains can thus hardly be prevented, but nevertheless, it can be largely minimised by way of local emission restrictions. Investigations in the field of toxicity in humans should be based on the blood-lead level of children and pregnant women.

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Lead and its organic compounds

DESIGNATIONS

Registry name	Lead compounds - organic	
Note:	As lead tetraethyl and lead tetramethyl are the only commercially important organic lead compounds, the following data will refer to these substances.	
CAS No.:	78-00-2	75-74-1
Chemical name:	Lead tetraethyl	Lead tetramethyl
Synonyms, Trade names:	Tetraethyllead, TEL,	Tetramethyllead, TML,
	Tetraethyl plumbum, Ethyl fluid	
	Tetramethylplumbum, Methyl fluid	
Chemical name (German):	Bleitetraethyl	Bleitetramethyl
Chemical name (French):	Plomb ttrathyle	Plomb ttramthyle
Appearance:	colourless oily liquid	colourless liquid
	sweet odour when highly diluted	sweet odour when highly diluted

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	$C_8H_{20}Pb$	$C_4H_{12}Pb$
Rel. molecular mass:	322.4 g	267.33 g
Density:	1.653 g/cm^3	1.995 g/cm^3
Relative gas density:	11.2	9.23
Boiling point:	>100C decomposition	>110C decomposition
Melting point:	-136.8C	-27.5C
Vapour pressure:	0.3 hPa at 20C 3.0 hPa at 50C	32 hPa at 20C 128 hPa at 50C
Flash point:	80C	<21C
Ignition temperature:		220C
Explosion limits:	1.8 vol.% (lower explosion limit)	1.8 vol.% (lower explosion limit)
Solvolysis/solubility:	in water: virtually insoluble soluble in organic solvents and fat	in water: virtually insoluble soluble in organic solvents and fat
Conversion factors:	1 ppm = 13.4 mg/m^3 1 mg/m^3 = 0.07 ppm	1 ppm = 11.1 mg/m^3 1 mg/m^3 = 0.09 ppm

ORIGIN AND USE

Usage:
Tetraethyllead and tetramethyllead were added to motor-vehicle fuels as anti-knock agents.

Origin/derivation:
TEL is produced either via radical reaction of lead alloys (Na/Mg) with ethylchloride at about 70C or via reaction of triethylaluminium with lead acetate in non polar solvents.

Toxicity

Humans:	LDLo 1.70 g/kg (estimated), (TEL)	acc. UBA, 1986
Mammals:		
Rat	LDLo 17 mg/kg, oral, (TEL)	acc. UBA, 1986
	LC_{50} 850 mg/m^3, inhalation (60 min), (TEL)	acc. UBA, 1986
	LDLo 31 mg/kg, intravenous, (TEL)	acc. UBA, 1986
	TDLo 11 mg/kg, oral, (6.-16. day of pregnancy), (TEL)	acc. UBA, 1986
	TDLo 7,500 g/kg, oral, (4.-14. day of pregnancy), (TEL)	acc. UBA, 1986
	LD_{50} 15 mg/kg, parenteral, (TEL)	acc. UBA, 1986

	LD_{50} 109 mg/kg, oral, (TML)	acc. UBA, 1986
	LDLo 73 mg/kg, intraperitoneal, (TML)	acc. UBA, 1986
	TDLo 80 mg/kg, oral, (9.-11. day of pregnancy), (TML)	acc. UBA, 1986
	LD_{50} 105 mg/kg, parenteral, (TML)	acc. UBA, 1986
Mouse	LCLo 650 mg/m^3, inhalation (7h), (TEL)	acc. UBA, 1986
	LDLo 86 mg/kg, subcutaneous, (TEL)	acc. UBA, 1986
	TDLo 100mg/kg, subcutaneous (21d), intermittent, (TEL)	acc. UBA, 1986
Rabbit	LDLo 24 mg/kg, oral, (TML)	acc. UBA, 1986
	LDLo 3,391 mg/kg, dermal, (TML)	acc. UBA, 1986
	LDLo 90 mg/kg, intravenous, (TML)	acc. UBA, 1986
Guinea pig	LDLo 995 mg/kg, dermal, (TEL)	acc. UBA, 1986
Aquatic organisms:		
Fish	1.4 mg/l fatal	acc. UBA, 1986
Plankton	0.5 mg/l toxic	acc. UBA, 1986

Characteristic effects:

Humans/mammals: **TEL/TML are highly toxic lead compounds. Because of their lipophilic properties they are readily absorbed through the skin. TEL/TML primarily act on the central nervous system causing excitation, epileptic spasms and delirium. Paralysis and Parkinsons Disease may appear as a retarded effect. The toxicity is mainly due to the triethyl lead ion which forms at decomposition. When alkylated they may have a carcinogenic effect. Chronic exposure may result in lead poisoning.**

(Refer also to *Lead and its inorganic compounds*)

ENVIRONMENTAL BEHAVIOUR

Water:
Surface water forms an accumulation sink for organic lead compounds. As TEL/TML are not readily soluble in water, they sink and accumulate in the sediment or they are adsorbed on suspended particles.

Air:
Large quantities of lead are released into the atmosphere from combustion processes. There is a major difference between urban and rural areas. Lead compounds may be transported over a considerable area depending on wind speed, wind direction, precipitation and humidity. The majority is however directly sedimented or removed from the air by way of precipitation. Lead is adsorbed on small particles of dust in the air and these in turn are deposited on vegetation and soil. The accumulation of lead from motor-vehicle emissions takes place in the immediate vicinity of roads.

Soil:
All types of lead compounds accumulate in soil.
(Refer also to *Lead and its inorganic compounds*)

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Air:	Workp	D	L	0.075 mg/m^3	MAK	Skin, calculated as Pb	DFG, 1989
	Workp	SU	(L)	0.005 mg/m^3	PDK	Skin, calculated as Pb	acc. KETTNER, 1979
	Workp	USA	(L)	0.1 mg/m^3	TWA	Skin, TEL, calculated as Pb	ACGIH, 1986
	Workp	USA	(L)	0.15 mg/m^3	TWA	Skin, TML, calculated as Pb	acc. AUER TECHNIKUM 1988

Comparison/reference values

(Refer also to *Lead and its inorganic compounds*)

Assessment/comments

As TEL and TML are highly toxic, their use as an anti-knock agent in fuels has been considerably restricted in industrial nations. Vapour inhalation and skin contact are to be avoided at all costs.

(Refer also to *Lead and its inorganic compounds*)

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Lindane

DESIGNATIONS

CAS No.: **58-89-9**
Registry name: **Lindane**
Chemical name: **γ -Hexachlorocyclohexane**
Synonyms, Trade names: **Lindane, gamma-BHC, benzene hexachloride, γ -HCH, Hortex, Cortilan, Jacutin Fog; known under at least 80 different tradenames (also in mixtures with other agents); a list of trade names is found in: INDUSTRIEVERBAND PFLANZENSCHUTZ e.V., 1982)**
Chemical name (German): **Lindan, γ -Hexachlorcyclohexan, Hexachlorcyclobenzol**
Chemical name (French): **Lindane, hexachlorure de benzne**
Appearance: **colourless, odourless crystals**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	$C_6H_6Cl_6$

Rel. molecular mass:	290.83 g
Density:	1.85-1.90 g/cm^3
Relative gas density:	10
Boiling point:	323.4C (decomposition)
Melting point:	112.5C
Vapour pressure:	0.94 x 10^{-5} Pa at 40C, 1300 Pa at 176.2C
Solvolysis/solubility:	in water 7.3 - 7.8 mg/l at 20C
	in benzene 289 g/l at 20C
	in diethylether 208 g/l at 20C
	in acetone 435 g/l at 20C
	readily soluble in ethanol and chloroform
Conversion factors:	1 ppm = 12.1 mg/m^3
	1 mg/m^3 = 0.083 ppm

ORIGIN AND USE

Usage:

Lindane is an insecticide used to combat biting and sucking species in the fruit-growing, horticultural and agricultural sectors as well as in forestry. It is also used to combat pests in empty food storage tanks and is used in human and veterinary hygiene.

Origin/derivation:

Technical production by photochlorination of benzene which yields a mixture of HCH isomers from which the individual isomers can be extracted. The gamma-HCH content of the mixture is between 10 - 18%. Some 80 - 90% unwanted isomers are produced in the first step. The maximum purity is 99%; 1% are other isomers.

Production figures:

Germany:	1,500 t (1977)	
	250 t (1982)	
	< 1,000 t (1985)	
Worldwide:	5,000 t (1983)	plus 23,000 t in technical HCH

Toxicity

Humans:	LD_{100} 150 mg/kg	acc. UBA 1981, Ber. 10704006/1

	10-20 mg/kg (acute toxicity)	acc. UBA, 1981, Ber. 10704006/1
Mammals:		
Rat	LD_{50} 88-125 mg/kg, oral	acc. CEC, 1981
	LD_{50} 125-230 mg/kg, oral	acc. CEC, 1981
	LD_{50} 500 mg/kg, dermal	acc. IPS, 1982
	LD_{50} >10,000 mg/kg, dermal	acc. RIPPEN, 1991
	NEL 1.25 mg/(kgd)	VETTORAZZI, 1979
Mouse	LD_{50} 86 mg/kg, oral	acc. CEC, 1981
	LD_{50} 245-480 mg/kg, oral	acc. IPS, 1982
Dog	LD_{50} 40 - 200 mg/kg, oral	acc. CEC, 1981)
	NEL 1.6 mg/(kgd)	VETTORAZZI, 1979
Aquatic organisms:		
Leuciscus idus melanotus	LC_0 0.05/0.02 mg/l (48h)	Juhnke & LDEMANN, 1978
	LC_{50} 0.28/0.003 mg/l (48h)	JUHNKE & LDEMANN, 1978

	LC_{100} 0.5/0.07 mg/l (48h)	JUHNKE & LDEMANN, 1978
Brachydanio rerio	LC_0 0.07 mg/l (48h)	acc. UBA, 1981, Ber. 10704006/1
	LC_{50} 0.06/0.09 mg/l (48h)	acc. UBA, 1981, Ber. 10704006/1
Golden orfe	LC_{50} 0.03-0.25 mg/l	acc. ROTH, 1988
Carp	LC_{50} 0.28 mg/l	acc. LOUB, 1975
Brown trout (Salmo trutta)	LC_{50} 0.0017 mg/l (96h, 13C)	acc. DVWK, 1985
Lebistes	LC_0 1.3 mg/l (96h)	acc. ROTH, 1988
Water flea (Daphnia magna)	EC_0 0.02 mg/l (24h)	acc. UBA, 1981, Ber. 10704006/1
	EC_{50} 0.7 mg/l (24h)	acc. UBA, 1981, Ber. 10704006/1
	EC_{100} 7.0 mg/l (24h)	acc. UBA, 1981, Ber. 10704006/1
Green algae	EC_{50} 1.7-3.8 mg/l (96h)	acc. UBA, 1981, Ber. 10704006/1
Green algae (Chlorella spec.)	EC_{50} 0.2-0.3 mg/l (96h)	acc. UBA, 1981, Ber. 10704006/1

Characteristic effects:

***Humans/mammals:* A carcinogenic substance (acc. ROTH, 1989) which causes nausea, vomiting, unrest and spasms. It has a harmful effect on the liver and kidneys and can impair the central nervous system in humans.**

***Insects:* Respiratory poison; toxic for bees.**

***Plants:* Alteration of cell structure, damage to roots, inhibition of growth, problems with respiration.**

ENVIRONMENTAL BEHAVIOUR

Water:

More than 90% of lindane in surface and groundwater is found in dissolved form; little is adsorbed on sediment and suspensions (acc. DVGW, 1988); accumulation in organisms; contamination of groundwater in immediate vicinity of dumps and in sewage-water seepage areas.

Air:

Transport medium; estimated deposition in Germany (West) 6-60 t/a (SRU, 1980).

Soil*:*

Accumulation; in some cases it is an extremely stable chemical which is still present after 11 to 14 years (SIEPER, 1972; LOUB, 1975; KORTE, 1980) depending on the type of soil, content of humic substances, moisture, dosage and combination with other agents. Applied quantities of 0.1 - 1 kg/ha are subject to between 40 and 80% decomposition after roughly one year. Reduction of soil flora; hazardous to groundwater mostly in sandy soils (DVGW, 1988).

Half*-life*:

Soil: 8-18 months (UBA, 1986), 200-260 days (RIPPEN, 1991); surface water or groundwater: 7 months - 4 years (UBA, 1986); 15-20 weeks (DVGW, 1988).

Degradation*, decomposition products:*
By way of dehydrochlorination, dehydrogenation and dechlorination; degradation via hexachlorocyclohexene, pentachlorocyclohexene and tetrachlorocyclohexene to form primarily chlorinated benzenes and phenols; usually due to microorganisms under both aerobic and anaerobic conditions; particularly stable in acid milieu; abiotic degradation through photomineralisation to form CO_2; above 230 nm transformation of gamma-isomer to alpha-isomer; degradation in soil takes place in several stages; initially physical effects such as surface volatilisation, evaporation or condensation with water, elution into deeper soil layers and diffusion, then biological degradation.

Food chain:
Considerable variation in assessment of human intake: US-EPA (1980) = 70% drinking water, 30% fish, air negligible; DFG (1982) = air and drinking water < 1%, primarily in animal-based foodstuffs; accumulation in mother's milk (HAHNE et al. 1986).

ENVIRONMENTAL STANDARDS

Medium/ acceptor	**Sector**	**Country/ organ.**	**Status**	**Value**	**Cat.**	**Remarks**	**Source**
Water:	Drinkw	A	(G)	3 g/l			acc. DVGW, 1988
	Drinkw	CDN	(L)	4 g/l			acc. DVGW, 1988
	Drinkw	D	L	0.1 g/l			TVO, 1990
	Drinkw	DDR	(L)	20 g/l			acc. DVGW, 1988
	Drinkw	USA	(L)	4 g/l			EPA, 1975
	Drinkw	USA	G	0.2 g/l			EPA, 1986

	Drinkw	WHO	G	3 g/l			WHO, 1984
	Groundw	USA	G	0.005 mg/l		State of Illinois	acc. WAITE, 1984
	Surface	1)		0.1 g/l		2)	IAWR, 1986
	Surface	1)		0.5 g/l		3)	IAWR, 1986
	Surface	D	G	1.4 g/l		2)	DVWG, 1988
	Surface	D	G	6.8 g/l		3)	DVWG, 1988
	Surface	USA	G	0.005 mg/l		State of Illinois	acc. WAITE, 1984
	Surface	USA	G	0.01 g/l		Prot. of aquat. org.	EPA, 1976
Soil:		NL	L	2 mg/kg		Intervention	acc. TERRA TECH, 6/94
Air:		DDR	(L)	0.03 mg/m^3	(MIK)	30 min	acc. STERN, 1986
		DDR	(L)	0.01 mg/m^3	(MIK)	24 h	acc. STERN. 1986
	Workp	D	L	0.5 mg/m^3	MAK		acc. DFG, 1994
	Workp	DDR	(L)	0.5 mg/m^3	(MAK)	Short-time value	acc. HORN et al., 1989
			(L)			Long-time	

	Workp	DDR	(L)	0.2 mg/m^3	(MAK)	value	acc. HORN et al., 1989
	Workp	USA	(L)	0.5 mg/m^3	TWA		ACGIH, 1986
	Workp	D	L	0.02 mg/l	BAT	Whole blood	DFG, 1994
	Workp	D	L	0.025 mg/l	BAT	Plasma/serum	DFG, 1994
*Foodstuffs:*4)		D	G	12.5 g/(kg.d)	ADI		WHO/FAO, 1973
		WHO	G	10 g/(kg.d)	ADI		WHO/FAO, 1984
Potatoes		D	L	0.1 mg/kg			acc. DVGW, 1988
Grain		D	L	0.1 mg/kg			acc. DVGW, 1988
Tea		D	L	0.5 mg/kg			acc. DVGW, 1988
Vegetables		D	L	1.5 mg/kg			acc. DVGW, 1988
Green veg.		D	L	2 mg/kg			acc. DVGW, 1988
Fat5)		D	L	0.1 mg/kg			acc. DVGW, 1988
Fat6)		D	L	0.2 mg/kg			acc. DVGW, 1988
Milk		D	L	0.7 mg/kg			acc. DVGW, 1988
Eggs		D	L	2 mg/kg			acc. DVGW, 1988

Notes:

1) Countries bordering the Rhine

2) Limit value when using natural purification methods for drinking water treatment

3) Limit value when using physical and chemical purification methods for drinking water treatment

4) Limit values as per Order Governing Maximum Quantities of Pesticide (1984) referenced to human foodstuffs

5) In fish and meat

6) In poultry
The use of technical HCH is banned in the Federal Republic of Germany.

Comparison/reference values

Medium/origin	Country	Value	Source
Lake Constance	D	0.005 mg/l	acc. DVGW, 1988
Rhine (Karlsruhe)	D	0.05-0.5 mg/l	acc. DVGW, 1988
Danube (Passau)	D	0.001-0.04 mg/l	acc. DVWK, 1985
Elbe	D	0.003-0.123 mg/l	acc. DVWK, 1985
Rivers/lakes (Mississippi)	USA	0.02-0.16 mg/l	acc. DVWK, 1985
Rivers	J	0.01-0.1 mg/l	acc. DVWK, 1985
Lake Mariot	ET	0.14-7.7 mg/l	acc. DVWK, 1985

Assessment/comments

Legal regulations often treat all hexachlorocyclohexane isomers as a substance group and thus give total figures. Approximate values for surface water or groundwater often refer not to single compounds but to pesticides as a substance class. According to DVGW (1988), technical HCH is banned in most European countries and in North America but, however, is used in many Third-World countries. It is estimated that all lindane produced is released into the environment. The amount worldwide may be 38,000 t/a. The high persistence and accumulation in the fatty tissue of humans and mammals is a good reason to further reduce its application.

Special sources: INDUSTRIEVERBAND PFLANZENSCHUTZ e.V., 1980

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Malathion

DESIGNATIONS

CAS No.: 121-75-5
Registry name: Malathion
Chemical name: S-[1,2-bis-(Ethoxy-carbonyl)ethyl]-O,O-dimethyl-dithiophosphate
Synonyms, Trade names: O,O-Dimethyl-S-[1,2-bis(ethoxy-carbonyl)ethyl] dithiophosphate, American Cyanamide 4049, Aphisan, Carbophos, Mercaptothion and many others

Chemical name (German): **Malathion**

Chemical name (French): **Malathion**

Appearance: **clear, yellowish liquid (oil); technical product (95%) is brown**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	$C_{10}H_{19}O_6PS_2$
Rel. molecular mass:	330.36 g
Density:	1.23 g/cm^3 at 25C
Relative gas density:	11.4
Boiling point:	156-157C at 1hPa
Melting point:	2.8-3.7C
Vapour pressure:	16.6 x 10^{-3} Pa
Solvolysis/solubility:	in water: 145 mg/l at 25C; soluble in organic solvents slightly soluble in petroleum ether and certain mineral oils
Conversion factors:	1 ppm = 13.7 mg/m^3 1 mg/m^3 = 0.07 ppm

ORIGIN AND USE

Usage:

Malathion is used in agriculture primarily as a contact pesticide (insecticide and acaricide) to combat insects which damage by sucking.

Origin/derivation:

Reaction of O,O-dimethyl hydrogen phosphorodithioate with diethyl maleate in the presence of triethylamine as catalyst and hydroquinone to prevent polymerisation of maleate.

Production figures:

USA	1978	14,000 t	(WHO, 1983)
India	1980/81	1,264 t	(WHO, 1983)

There are also production facilities in Denmark, France, Italy, Spain, Germany, Japan, Brazil, Mexico and Taiwan.

Consumption:

Mexico	1982	1800 t	(WHO, 1986)
USA	1982	1500 t	(WHO, 1986)
India	1982	800 t	(WHO, 1986)

Italy	1981	552 t	(WHO, 1986)
Jordan	1982	450 t	(WHO, 1986)
Hungary	1982	313 t	(WHO, 1986)
Argentina	1982	235 t	(WHO, 1986)
Egypt	1981	208 t	(WHO, 1986)
Poland	1982	104 t	(WHO, 1986)
Niger	1981	69 t	(WHO, 1986)
Pakistan	1982	68 t	(WHO, 1986)
Turkey	1982	58 t	(WHO, 1986)

Toxicity

Mammals:		
Mouse:	LD_{50} 1,260 mg/kg, oral	acc. WHO, 1983
Mouse:	LD_{50} 193 mg/kg, intravenous	acc. WHO, 1983

Rat:	LD_{50} 1375 mg/kg, oral	acc. PERKOW, 1993
Rat:	LD_{50} 4,400 mg/kg, dermal	acc. WHO, 1983
Dog:	LD_{50} 1,600 mg/kg, intravenous	acc. WHO, 1983
Guinea pig:	LD_{50} 500 mg/kg, intravenous	acc. WHO, 1983
Aquatic organisms:		
American minnow:	LC_{50} 12.5 mg/l (96 h)	acc. ATRI, 1985
Rainbow trout:	LC_{50} 0.1 mg/l (24 h)	acc. ATRI, 1985
Blue perch:	LC_{50} 0.12 mg/l (24 h)	acc. ATRI, 1985
Water flea:	LC_{50} 0.0009 mg/l (24-25h)	acc. ATRI, 1985

Note:
ATRI (1985) quotes countless toxicity levels for fish, aquatic organisms in general and aquatic plants.

Characteristic effects:

Humans/mammals: **Malathion is a nerve toxin and damages the central nervous system (it inhibits the enzyme acetyl cholinesterase). Acute poisoning takes the form of bouts of sweating, increased production of saliva, diarrhoea, bronchitis, heart attack and coma. Death occurs as a result of apnoea.**

There are no conclusive findings on teratogeny and fertility yet. The carcinogenic and mutagenic potential has likewise not yet been proved (WHO, 1983).

Aquatic organisms: **There are numerous toxicity values available for various fish species. Several months of exposure caused deformation in blue perch and inhibited lactate dehydrogenase in the liver of carp spawn. 0.1-5 ppm may prove lethal. Malathion inhibits the growth of algae.**

ENVIRONMENTAL BEHAVIOUR

Air:

Malathion is released into the atmosphere as a result of the application method used in agriculture (use as spray 0.03 - 0.08%, as vapour 4% and as aerosol 2.5-5%, WHO, 1983). After application, a concentration of approx. 0.1 ng/m^3 is found in the air over farmland (WHO, 1983).

Half-life:

The substance is degraded within about 24 hours in the body of an animal and excreted with its urine (substantiated in animal experiments with hens and cows, WHO 1983).

The half-life for chemical decomposition in water (pH = 7.4, 20C) is roughly 11 days and depends on the pH-value (slow hydrolysis with pH < 7 and rapid hydrolysis with pH >7) (ATRI, 1985).

Degradation, decomposition products:

In the organism of insects, malathion is oxidised forming malaoxon. Besides, derivatives of succinic acid and other carboxylic acids, O,O-dimethylthiophosphoric acid and phosphoric acid result from hydrolysis [acc. PERKOW,1994].

Malathion is rapidly degraded in vitro by salt-marsh bacteria to malathion monocarboxylic acid, malathion dicarboxylic acid and various phosphothionates as a result of carboxyesterase cleavage. In addition, phosphatase

activity produces desmethyl malathion, phosphomono- and dithionates, 4-carbon dicarboxylic acids and the corresponding ethylesters [acc. VERSCHUEREN, 1983].

Food chain:

Malathion is assimilated by respiration and skin contact and is absorbed in the intestines. There are no reported cases of malathion polluting groundwater and drinking water (ATRI, 1985). Malathion enters the food chain as a residual substance in foodstuffs such as grain, pulses and vegetables if the areas where they are grown are treated with malathion. This path is significant and has caused the WHO, FAO and EC to publish recommendations on tolerable residue concentrations.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	**Sector**	**Country/ organ.**	**Status**	**Value**	**Cat.**	**Remarks**	**Source**
Air:	Workp	B	(L)	10 mg/m^3			acc. WHO, 1983
	Workp	BG	(L)	0.06 mg/m^3		Maximum value	acc. WHO, 1983
	Workp	CH	(L)	10 mg/m^3		Long-time value	acc. WHO, 1983
	Workp	D	(L)	15 mg/m^3	MAK		DFG, 1989
	Workp	I	(L)	10 mg/m^3		Long-time value	acc. WHO, 1983
	Workp	NL	(L)	10 mg/m^3			acc. WHO, 1983
	Workp	PL	(L)	15 mg/m^3			acc. WHO, 1983

	Workp	RO	(L)	10 mg/m^3		Long-time value	acc. WHO, 1983
	Workp	RO	(L)	15 mg/m^3		Max.	acc. WHO, 1983
	Workp	SF	(L)	10 mg/m^3			acc. WHO, 1983
	Workp	USA	(L)	10 mg/m^3	TWA	Skin	ACGIH, 1986
	Workp	YU	(L)	0.5 mg/m^3			acc. WHO, 1983
Water:	Drinkw	D	L	0.1 g/l		single substance	acc. LAU BW, 1989
	Drinkw	D	L	0.5 g/l		sum of pesticides	acc. LAU BW, 1989
	Drinkw	EC	L	0.1 g/l		single substance	acc. LAU BW, 1989
	Drinkw	EC	L	0.5 g/l		sum of pesticides	acc. LAU BW, 1989
	Surface	EC	L	1 g/l		sum of pesticides	acc. LAU BW, 1989
	Surface	EC	L	2.5 g/l		sum of pesticides	acc. LAU BW, 1989
	Surface	EC	L	5 g/l		sum of pesticides	acc. LAU BW, 1989

Quality requirements for surface water designated for drinking water

- **simple physical treatment**
- **normal physical and chemical treatment**
- **physical and enhanced chemical treatment**

Comparison/reference values

Medium/origin	Country	Value	Source
Water:			
Rhine: (Lobith, 1972)	D	0.01 mg/m^3	acc. ATRI, 1985
Cistern water	USA	0.01 ppb (1970)	acc. ATRI, 1985
Foodstuffs:			
Fruit	D	0.5 ppm (max.)	acc. ATRI, 1985
Grain	D	3 ppm (max.)	acc. ATRI, 1985

Assessment/comments

Malathion is one of the agricultural pesticides used particularly in developing countries. Special precautions must be taken when using it because of the high, acute toxicity for humans and aquatic organisms. Particular attention should be paid to residues in foodstuffs.

***Special sources:* ATRI (1985)**

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Mercury

DESIGNATIONS

***CAS No.:* 7439-97-6**
***Registry name:* Mercury**
***Chemical name:* Mercury**
***Synonyms, Trade names:* Quicksilver**
***Chemical name (German):* Quecksilber**
***Chemical name (French):* Mercure**
***Appearance:* silvery white, shiny metal, liquid at room temperature**

BASIC CHEMICAL AND PHYSICAL DATA

Chemical symbol:	Hg
Rel. atomic mass:	200.59 g
Density:	13.55 g/cm^3
Relative gas density:	6.93
Boiling point:	357.3C
Melting point:	-38.9C

Vapour pressure:	163 x 10^{-3} Pa
Solvolysis/solubility:	in water: 60 g/l at 20C, 250 g/l at 50C
Conversion factors:	1 ppm = 8.34 mg/m^3 1 mg/m^3 = 0.12 ppm

BASIC DATA OF SELECTED COMPOUNDS

CAS No:	7487-94-7	21908-53-2
Chemical name:	Mercury(II) chloride	Mercury(II) oxide
Synonyms, Trade names:	Mercuric chloride, Calochlor	Mercuric oxide
Chemical name (German):	Quecksilber(II)chlorid	Quecksilber(II)oxid
Chemical name (French):	Chlorure de mercure (II)	Oxyde de mercure (II)
Appearance:	white crystalline powder	yellow to red crystalline powder (colour depends on size of crystals)
Empirical formula:	$HgCl_2$	HgO
Relative molecular mass:	271,5 g	216.59 g
Density:	5.43 g/cm^3	11.1 g/cm^3
Boiling point:	303C	
		above 400-450C decomposition

Melting point:	280C	(liberation of toxic Hg vapours)
Vapour pressure:	560 kPa at 280C	0.0012 hPa
Solvolysis/solubility:	in water: 74 g/l at 20C 550 g/l at 100C soluble in most organic solvents (alcohol, ether, benzene)	virtually insoluble in water (0.05 mg/l) and ethanol

ORIGIN AND USE

Usage:
Mercury is used as a cathode in the electrolysis of alkali-metal chlorides, in the production of batteries and pesticides, in the medical sector (amalgams and disinfectants), in the electrical industry (bulbs and components) as well as in pressure gauges and temperature measurement. For toxicological reasons its use in ointments and disinfectants is no longer standard practice.

Origin/derivation:
The Earth's crust contains an average of approximately 0.02 ppm of this element on average. Cinnabar (HgS) is the most widespread mercury mineral.

Mercury is ubiquitous. On average, freshwater contains 0.1 μ g/l, seawater 0.03 μ g/l and air 0.005-0.06 ng/m^3 of mercury. Both inorganic and organic mercury compounds are hazardous to the environment. The organic compounds being much more poisonous. Some 70-80% of the total environmental impact is caused by natural emissions such as volcanoes or by evaporation from the Earth's crust or the oceans. About 20-30% is due to

anthropogenic sources such as the mercury processing and ore dressing industry or the combustion of fossil fuels. Although this contribution is relatively small, there is no reason to underestimate the danger of mercury at high concentrations.

Production figures:

Mining production of mercury in 1984

USSR	1,600 t	USA	657 t
Spain	1,520 t	Mexico	384 t
China	800 t	Algeria	377 t
World	5,814 t		

(figures from ULLMANN, 1990)

Toxicity

Characteristic effects:

Humans/mammals: In comparison with the liquid metal, mercury dusts and vapours are very toxic. It is subject to almost complete resorption via the lungs. The initial symptoms of acute poisoning are a sweet, metallic taste in the mouth together with nausea and vomiting. This is followed by inflammation of the mucous membranes in the respiratory organs. Mercury is finally stored in the liver and kidneys and is only excreted in bursts. Mercury-induced occupational diseases are subject to mandatory reporting in Germany. Chronic poisoning causes malfunction of the central nervous system, the symptoms being apathy, unretentive memory, overexcitability and general trembling.

Mercury poisoning can prove fatal.

Inorganic mercury compounds

Mercury salts corrode the skin and mucous membranes. They are usually absorbed orally or dermally because of their low volatility. The intake of salts causes inflammation of the throat, difficulty in swallowing, drowsiness, vomiting, stomach pains, blood-tinged diarrhoea, circulatory collapse and shock. There is also swelling of the salivary glands, loosening of teeth and inflammation of the liver and kidneys.

Organic mercury compounds

Organic mercury compounds (especially alkyl mercury) are generally much more toxic than the inorganic. Moreover, acute poisoning by organic compounds develops completely different symptoms. In particular, poisoning caused by short-chain alkyl derivatives such as methyl or ethyl mercury only becomes apparent after some time (with the exception of pathological trembling); weeks usually pass following absorption. Typical symptoms include a restricted field of vision, unclear pronunciation and handwriting, abnormal hypersensitivity, irritation of the skin, nose bleeds and depression. Exposure to organic compounds attacks the nervous system (best-known epidemic: Minamata disease, Japan).

Methyl mercury dissolves readily in fat and passes through the blood-brain barrier and the placenta. It has a mutagenic and teratogenic potential (as a substance with a proven foetus-damaging effect, methyl mercury is listed in pregnancy group A in Germany).

Whereas only 0.01% of the metallic and some 15% of the inorganically bonded mercury is resorbed following oral intake, the resorption of organic compounds is up to 95% (DVGW, 1985).

Plants: **Mercury compounds inhibit cell growth and impair permeability.**

ENVIRONMENTAL BEHAVIOUR

Water:
Mercury inhibits the metabolic activity of microorganisms and thus suppresses the self-purification capability of water at concentrations as low as 18 μ g/l. Mercury is adsorbed on sediment and suspended matter.

Air:
Mercury is washed out more or less completely by precipitations.

Soil:
Mercury accumulates in soil, preferably in humous soils.

Degradation, decomposition products:

Mercury is degraded by microorganisms (biomethylation) or oxidised to form Hg^{2+}. Methylation produces methyl mercury in a reaction which is promoted by high pH values. Dimethyl mercury, which is only formed chemically (chemical methylation), escapes into the atmosphere and decomposes to form elemental mercury. Above all, rain impacted by mercury(II) ions can lead to the formation of monomethyl mercury out of inorganic mercury. In addition to methylation, chelate complexes may form from mercury(II) ions. Methyl mercury is a powerful fish toxin.

Food chain:
The mercury content may increase in plankton and aquatic animals by up to 500 times the concentration in seawater (DVGW, 1985). There is considerable accumulation in the food chain on account of its accumulation in the liver and kidneys.

Combination effects:
The effect of mercury is enhanced by the simultaneous intake of copper, zinc or lead.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:	Surface	D	L	0.0005 mg/l		1)	acc. DVGW, 1985
	Surface	D	L	0.001 mg/l		2)	acc. DVGW, 1985
	Surface	EC	G	0.0005 mg/l		3)	acc. DVGW, 1985
	Surface	EC	G	0.001 mg/l		4)	acc. DVGW, 1985
	Drinkw	CDN		0.001 mg/l			acc. DVGW, 1985
	Drinkw	CH		0.003 mg/l		1980	acc. MERIAN, 1984
	Drinkw	D	L	0.001 mg/l			acc. DVGW, 1985
	Drinkw	EC	G	0.001 mg/l			acc. DVGW, 1985
	Drinkw	J		0.001 mg/l		1968	acc. MERIAN, 1984
	Drinkw	SU		0.005 mg/l		1970	acc. MERIAN, 1984
	Drinkw	USA	(L)	0.002 mg/l			acc. DVGW, 1985
	Drinkw	USA	(L)	0.0005 mg/l		In State of Illinois	acc. WAITE, 1984
	Drinkw	WHO	G	0.001 mg/l			acc. LAU-BW, 1989
	Groundw	NL	G	0.2 g/l		Reference	acc. BACHMANN, 1987
	Groundw	NL	L	2 g/l		Intervention	acc. BACHMANN,

							1987
	Waste water	CH	(L)	0.001 g/m^3		For drinking water	acc. LAU-BW, 1989
	Waste water	D	L	0.05 g/m^3			acc. ROTH, 1989
	Irrigation	D		2 g/l		5)	acc. DVGW, 1985
	Trough	D		4 g/l		Maximum value	acc. DVGW, 1985
Soil:	Sewage sl.	D	L	2 mg/kg		6)	KLOKE, 1988
	Sewage sl.	D	L	25 mg/kg		7)	KLOKE, 1988
		CH	G	0.8 mg/kg		8)	acc. BAfUB, 1987
		GB	G	1.5 mg/kg		Domestic gardens	acc. SAUERBECK, 1986
		GB	G	1 mg/kg		Vegetable gardens	acc. SAUERBECK, 1986
		GB	G	50 mg/kg		9)	acc. SAUERBECK, 1986
		NL	G	0.3 mg/kg		Reference	acc. TERRA TECH 6/94
		NL	L	10 mg/kg		Intervention	acc. TERRA TECH 6/94

Air:	eMISS.	d	l	0.2 mg/m^3		mass flow > 1 g/h13)	acc. TA Luft, 1986
		DDR	L	0.0003 mg/m^3	MIK		acc. HORN, 1989
	Workp	AUS	(L)	0.05 mg/m^3			acc. MERIAN, 1984
	Workp	B	(L)	0.05 mg/m^3			acc. MERIAN, 1984
	Workp	BG	(L)	0.0003 mg/m^3		10)	acc. MERIAN, 1984
	Workp	BG	(L)	0.01 mg/m^3			acc. MERIAN, 1984
	Workp	CS	(L)	0.0003 mg/m^3		10)	acc. MERIAN, 1984
	Workp	CS	(L)	0.05 mg/m^3		Long-time value	acc. MERIAN, 1984
	Workp	CS	(L)	0.15 mg/m^3		Short-time value	acc. MERIAN, 1984
	Workp	D	L	0.1 mg/m^3	MAK	Mercury	DFG, 1994
	Workp	D	L	0.01 mg/m^3	MAK	organic mercury compounds	DFG, 1994
	Workp	D	L	200 g/l	BAT	metallic and inorg. compounds, urine	DFG, 1994

Workp	D	L	50 g/l	BAT	metallic and inorg. comp., whole blood	DFG, 1994
Workp	D	L	100 g/l	BAT	metallic and organic comp., whole blood	DFG, 1994
Workp	DDR	(L)	0.005 mg/m^3		Long-time value	acc. HORN, 1989
Workp	DDR	(L)	0.01 mg/m^3		Short-time value	acc. HORN, 1989
Workp	H	(L)	0.02 mg/m^3		Skin	acc. MERIAN, 1984
Workp	IL	(L)	0.001 mg/m^3		11)	acc. MERIAN, 1984
Workp	J	(L)	0.05 mg/m^3			acc. MERIAN, 1984
Workp	NL	(L)	0.05 mg/m^3			acc. MERIAN, 1984
Workp	PL	(L)	0.01 mg/m^3			acc. MERIAN, 1984
Workp	RO	(L)	0.001 mg/m^3		10)	acc. MERIAN, 1984
Workp	RO	(L)	0.05 mg/m^3		Long time value, skin	acc. MERIAN, 1984
Workp	RO	(L)	0.15 mg/m^3		Short time value, skin	acc. MERIAN, 1984

	Workp	S	(L)	0.05 mg/m^3		Skin	acc. MERIAN, 1984
	Workp	SF	(L)	0.05 mg/m^3			acc. MERIAN, 1984
	Workp	SU	(L)	0.01 mg/m^3	PDK		acc. SORBE, 1985
	Workp	USA	(L)	0.01 mg/m^3	TWA	Alkyl compounds	ACGIH, 1986
	Workp	USA	(L)	0.03 mg/m^3	STEL	Alkyl compounds	ACGIH, 1986
	Workp	YU	(L)	0.0003 mg/m3		10)	acc. MERIAN, 1984
	Workp	YU	(L)	0.1 mg/m^3		Skin	acc. MERIAN, 1984
Foodstuffs:		D	G	0.01 mg/kg		Milk, cheese	acc. GROKLAUS, 1989
		D	G	0.03 mg/kg		12)	acc. GROKLAUS, 1989
		D	G	0.1 mg/kg		Animal's liver, kidneys	acc. GROKLAUS, 1989
		D	G	0.05 mg/kg		Meat, sausage products	acc. GROKLAUS, 1989

Notes:
The use of mercury compounds in pesticides has likewise been banned in the Federal Republic of Germany since 1980; their use in cosmetics is restricted to a few exceptions and the maximum content for fish in line with the Mercury Order (1975) is 1 mg/kg.

1) Limit value for natural treatment

2) Limit value for chemical and physical treatment

3) Guideline for physical and refined chemical treatment

4) Mandatory value for physical and refined chemical treatment

5) Maximum value for field and under-glass cultivation

6) Tolerable overall content in air-dry soil (limit value according to the Sewage Sludge Order)

7) Limit value for heavy metals in sewage sludge (limit value according to the Sewage Sludge Order)

8) Pollutant content in air-dried mineral soil (total content, HNO_3 extract)

9) Public parks or open spaces

10) Limit values for mercury forming part of suspended dust

11) Provisional limit value for Israel

12) Hen's egg, beef, veal, pork, minced meat, chicken

13) Hg and its compounds, stated as Hg

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Water:			
Lake Constance (1982)	D	0.003 g/l	acc. DVGW, 1985
Neckar (1982)	D	0.1 g/l	acc. DVGW, 1985
Rhine (Cologne, 1983)	D	0.01-0.2 g/l	acc. DVGW, 1985

Rhine (Duisburg, 1983)	D	0.03-0.13 g/l	acc. DVGW, 1985
Danube (Leipheim, 1976)	D	0.03 g/l	acc. DVGW, 1985
Weser (Bremen, 1979)	D	0.025-3.8 g/l	acc. DVGW, 1985
Seawater	J	12.5 ng/l	acc. RIPPEN, 1989
North Sea		1.9-15 ppt	acc. RIPPEN, 1989
Air:			
Southern hemisphere (Africa):		2.3 ng/m^3	acc. RIPPEN, 1989
USA:		1.9-36 ng/m^3	acc. RIPPEN, 1989
Sediment:			
Rhine (Cologne):	D	10 mg/kg (1975-77)	acc. DVGW, 1985
Neckar (Heidelberg):	D	0.7 mg/kg (1975-77)	acc. DVGW, 1985
Danube (Leipheim):	D	1.2 mg/kg (1975-77)	acc. DVGW, 1985
Port of Hamburg:	D	11.2 mg/kg (1977)	acc. DVGW, 1985
Mammals/humans:			
Blood (human), normal value:		5 - 10 ng/ml	acc. RIPPEN, 1989
Urine (humans), normal value:		1.5-8 g/d	acc. RIPPEN, 1989

Seals:		<100-200 mg/kg	acc. RIPPEN, 1989
Foodstuffs:			
Fruit, vegetables:		0.25-33 ppb	acc. RIPPEN, 1989
Grain:		0.5-640 ppb	acc. RIPPEN, 1989
Meat, liver, etc.:		0.5-1.430 ppb	acc. RIPPEN, 1989
Fish, fish products:		0.5-2.740 ppb	acc. RIPPEN, 1989

Assessment/comments

Solid mercury in the form of pure metal is not poisonous to humans and, therefore, not hazardous. However, the use of mercury alloys (amalgams) as dental fillings is under discussion. Although the release of mercury into saliva is relatively low there is a tendency towards substitution of amalgams with less toxic materials such as ceramics or plastics. Particular attention must be paid to mercury vapours as well as to water pollution. Risk assessment of mercury compounds depends on the properties of the individual substance. Mercury(II) chloride and methyl mercury are particularly significant in this sense.

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Methyl bromide

DESIGNATIONS

CAS No.: **74-83-9**
Registry name: **Methyl bromide**
Chemical name: **Methyl bromide**
Synonyms, Trade names: **Bromomethane, Terabol**
Chemical name (German): **Methylbromid**
Chemical name (French): **Bromure de mthyle**
Appearance: **colourless gas, chloroform-like odour**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	CH_3Br
Rel. molecular mass:	94.95 g
Density:	1.73 g/cm^3 liquid at 0C
Relative gas density:	3.3
Boiling point:	4C
Melting point:	-93C
Vapour pressure:	90 x 10^3 Pa at 20C
Ignition temperature:	535C

Ignition temperature:	535C
Explosion limits:	8.6-20 Vol.%
Solvolysis/solubility:	in water: 13.4 g/l readily soluble in common organic solvents
Conversion factors:	1 mg/m^3 = 0.253 ml/m^3 1 ml/m^3 = 3.946 mg/m^3

ORIGIN AND USE

Usage:
Methyl bromide is an insecticide and nematocide with fungicidal, acaricidal, rodenticidal and herbicidal effects (germinating seed). It is used for the disinfection of soils, the fumigation of grain, the protection of stocks and the disinfection of storehouses and mills (especially against grain beetles and flour moths) as a non-blended gas, or blended with carbon dioxide or ethylidene dibromide.

Origin/derivation:
Methyl bromide is produced from methanol by hydrobromination.

Toxicity

Humans:	LCLo 60,000 ppm (2h), inhalation	acc. UBA 1986
	TCLo 35 ppm (2h), inhalation	acc. UBA 1986

Mammals:		
Rat	LC_{100} 0.63 mg/l (6h), inhalation	acc. UBA 1986
	LCLo 3120 ppm (15 min), inhalation	acc UBA 1986
Guinea pig	LCLo 300 ppm (9h), inhalation	acc. UBA 1986
Rabbit	LCLo 2 mg/l (11h), inhalation	acc. UBA 1986
Aquatic organisms:		
Fish	LC_{50} > 1000 mg/l	acc. UBA 1986

Characteristic effects:

Humans/mammals: **Inhalation of high concentrations of methyl bromide that does not immediately cause anesthesia and respiratory shock may cause a lung oedema after several hours of latency, often followed by a serious pneumonia within a few days. Damage to the central nervous system may result from acute as well as from chronic poisoning. The symptoms are headache and nausea, then disturbance comparable to alcohol poisoning, followed by excitation, tremors and epileptic fits usually attached with paralysis of the limbs. The symptoms resulting from a single exposure may last for several weeks. Skin contact with the liquid substance causes blisters. Methyl bromide is readily absorbed through the skin. It is suspected to have carcinogenic potential.**

ENVIRONMENTAL BEHAVIOUR

Soil:

In soil and in grain, bromine is found bonded inorganically.

***Note*:**
There is hardly information about the environmental behaviour of methyl bromide.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/organ.	Status	Value	Cat.	Remarks	Source
Air:							
	Workp	D	L	5 ml/m^3	MAK	carcinogenic III B	acc. AUER TECHNIKUM, 1988
	Workp	D	L	20 mg/m^3	MAK		acc. AUER TECHNIKUM, 1988
	Workp	SU	(L)	0.25 ppm	PDK		acc. AUER TECHNIKUM, 1988
	Workp	SU	(L)	1 mg/m^3	PDK		acc. AUER TECHNIKUM, 1988
	Workp	USA	(L)	5 ppm	TWA		acc. AUER TECHNIKUM, 1988
	Workp	USA	(L)	20 mg/m^3	TWA		acc. AUER TECHNIKUM, 1988

	Workp	USA	(L)	15 ppm	STEL		acc. AUER TECHNIKUM, 1988
	Workp	USA	(L)	60 mg/m^3	STEL		acc. AUER TECHNIKUM, 1988

Assessment/comments

Methyl bromide is a very insidious chemical. As the odour threshold is much higher than the toxic concentration, there is no warning effect. Symptoms appear after hours of latency and last for weeks even in cases of a single exposure. It reacts strongly or even explosively with alkali and alkaline earth metals and metal powders.

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Naphthalene

DESIGNATIONS

CAS No.: 91-20-3
Registry name: Naphthalene
Chemical name: Naphthalene
Synonyms, Trade names: Antimite, Tar camphor

Chemical name (German): **Naphthalin**
Chemical name (French): **Naphthalne**
Appearance: **white crystalline solid**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	$C_{10}H_8$		
Rel. molecular mass:	128.17 g		
Density:	1.14 g/cm^3		
Relative gas density:	4.42		
Boiling point:	218C		
Melting point:	80C		
Vapour pressure:	0.04 hPa		
Flash point:	80C		
Ignition temperature:	540C		
Explosion limits:	0.9-5.9 % by vol.		
Solvolysis/solubility:	in water: very slightly soluble		30 mg/l
	soluble in	alcohol	77.4-98 g/l
		benzene	1,130 g/l

		quinoline	30.2 g/l
		toluene	910 g/l
		xylene	783 g/l
Conversion factors:	1 ppm = 5.33 mg/m^3 1 mg/m^3 = 0.19 ppm		

ORIGIN AND USE

Usage:
Naphthalene is used as an intermediate in the manufacture of dyes, phthalic anhydride (production of PVC plasticisers), tanning agents, substances used for concrete, wetting agents for the textile industry and solvent components for pesticides (moth repellents).

Origin/derivation:
The raw material source in Germany is coal tar which contains some 10% naphthalene. As coke production is on the decline, increasing use is made of petroleum-based raw materials (gasoline pyrolysis, residual oils following pyrolysis); manufacture by means of distillation and fractioning. The naphthalene content of the technical product is at least 95% while the remainder is made up of impurities such as benzo(b)thiophene (thionaphthene) or, in petroleum-based naphthalenes, of methylindenes only.

Production figures:
World production of naphthalene in 1987

Western Europe	250,000 t

Eastern Europe	200,000 t
Japan	200,000 t
USA	125,000 t
World	1,000,000 t

(figures from ULLMANN, 1991)

Toxicity

Mammals:		
Rat:	LD_{50} 1,110-9,430 mg/kg, oral	acc. BUA, 1989
Rat:	LD_{50} 2,200 mg/kg, oral (male)	acc. BUA, 1989
Rat:	LD_{50} 2,400 mg/kg, oral (female)	acc. BUA, 1989
Rat:	LD_{50} > 2,500 mg/kg, dermal (male,female)	acc. BUA, 1989
Rat:	LD_{50} > 500 mg/m^3, inhalation (8 h)	acc. BUA, 1989
Mouse:	LD_{50} 350-710 mg/kg, oral (female)	acc. BUA, 1989

Mouse:	LD_{50} 533 mg/kg, oral (male)	acc. BUA, 1989
Mouse:	LD_{50} 969-5,100 mg/kg, subcutaneous	acc. BUA, 1989
Aquatic organisms:		
American minnow:	LC_{50} 1.3-6.9 mg/l (96 h)	acc. BUA, 1989
American minnow:	LC_{50} 5.95-6.77 mg/l (48 h)	acc. BUA, 1989
Micropterus salmondes:	LC_{50} 0.31-9.7 mg/l (7 d)	acc. BUA, 1989
Rainbow trout:	LC_{50} 0.1-0.14 mg/l (96 h)	acc. BUA, 1989
Water flea:	LC_{50} 1.79-24.1 mg/l (48 h)	acc. BUA, 1989

Characteristic effects:

***Humans/mammals:* Naphthalene is absorbed orally, dermally or by way of inhalation. The toxic effect is generally slight. Irritation of the mucous membranes and skin is extremely rare. The absorption of a large dose causes haemolytic anaemia, the formation of cataracts and sensitisation. Infants and foetuses are particularly at risk. There have also been cases of allergic reactions in humans.**

The toxicity of chlorinated naphthalenes is considerably higher (refer to the "chloronaphthalene" information sheet).

ENVIRONMENTAL BEHAVIOUR

Water:
Naphthalene dissolves only very slightly in water and sinks as a solid. Because of its toxic effect on aquatic organisms even at low concentrations, naphthalene is considered as a substance hazardous to water (In Germany: Water Hazard Class 2).

Air:
Naphthalene is produced when organic material is incompletely combusted.

Half-life:
The half-life in the atmosphere is estimated at 7 to 24 hours (acc. BUA, 1989).

Degradation, decomposition products:
Naphthalene is degraded microbially or photochemically; mineralisation has however not been substantiated to date under anaerobic conditions. The primary metabolite in the organism is naphthalene-1,2-oxide which is converted to form other compounds. Naphthalene is oxidised in air to form alcohols (naphthols), aldehydes and carboxylic acids.

Food chain:
There is little bioaccumulation by way of food chains.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Water:	Groundw	Nl	G	0.1 g/l		Reference	acc. TERRA TECH 6/94

	Groundw	NL	L	70 g/l		Intervention	acc. TERRA TECH 6/94
Soil:		NL	G	1 mg/kg		Reference, Sum of 10 PAHs	acc. TERRA TECH 6/94
		NL	L	40 mg/kg		Intervention, Sum of 10 PAHs	acc. TERRA TECH 6/94
Air:		D	L	2.5 mg/m^3	MIK	Long-time value	acc. BAUM, 1988
		D	L	7.5 mg/m^3	MIK	Short-time value	acc. BAUM, 1988
	Emiss.	D	L	0.1 g/m^3		mass flow > 2 g/h	acc. TA Luft, 1986
		DDR	(L)	3 mg/m^3		Short-time value	acc. HORN, 1989
		DDR	(L)	1 mg/m^3		Long-time value	acc. HORN, 1989
	Workp	D	L	50 mg/m^3	MAK		DFG, 1989
	Workp	DDR	(L)	50 mg/m^3		Short-time value	acc. HORN, 1989
	Workp	DDR	(L)	20 mg/m^3		Long-time value	acc. HORN, 1989
	Workp	SU	(L)	20 mg/m^3	PDK		acc. SORBE, 1989
	Workp	USA	(L)	50 mg/m^3	TWA		ACGIH, 1986
			(L)				

	Workp	USA	(L)	75 mg/m^3	STEL		ACGIH, 1986

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Surface water:			
Rhine (1987)	D	< 0.01-0.03 g/l	
Lake Constance (summer, 1984)	D	0.002-0.276 g/l	acc. BUA, 1989
			acc. BUA, 1989
Air:			
Urban air (1977-1984)	D	0.3-0.6 g/m^3	
Kiel	D	0.009 g/m^3	acc. BUA, 1989
Tbingen	D	0.191-0.468 g/m^3	acc. BUA, 1989
Cigarette smoke (unfiltered)		0.422 g/cigarette (main stream)	acc. BUA, 1989
			acc. BUA, 1989

Assessment/comments

Naphthalene has only a slight toxic effect, but can cause allergic reactions in humans (single case reports). Because of the emissions from motor-vehicle exhausts, the exposure is higher in urban areas. This can result in enhanced

hypersensitivity to other irritants. There is no information available on carcinogenic or mutagenic potential, but the substance is a proven hazard to foetuses.

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Nickel

DESIGNATIONS

CAS No.: 7440-02-0
Registry name: Nickel
Chemical name: Nickel
Synonyms, Trade names: Nickel, Raney nickel, nickel catalyst
Chemical name (German): Nickel
Chemical name (French): Nickel
Appearance: Nickel is a silvery white, shiny, malleable and ductile heavy metal with cubic-compact metallic lattice (beta-nickel) or a less-stable hexagonal configuration (alpha-nickel). Ni is slightly ferromagnetic.

BASIC CHEMICAL AND PHYSICAL DATA

Chemical symbol:	Ni
Rel. atomic mass.:	58.71 g
Density:	8.9 g/cm^3 at 25C
Boiling point:	2730C
Melting point:	1455C
Vapour pressure:	0 Pa at 20C
Ignition temperature:	self-igniting (Raney nickel, if dry)
Solvolysis/solubility:	insoluble in water soluble in hydrochloric and sulphuric acid as well as in diluted nitric acid

BASIC DATA OF SELECTED COMPOUNDS

CAS No:	13463-39-3	7718-54-9
Chemical name:	Nickel tetracarbonyl	Nickel(II) chloride (hexahydrate)
Synonyms, Trade names:	(T-4) Nickel carbonyl	
Chemical name (German):	Nickeltetracarbonyl	Nickel(II)chlorid

Chemical name (French):	Nickel ttracarbonyle	Chlorure de nickel(II)
Appearance:	colourless liquid	pale yellow crystals
Empirical formula:	$Ni(CO)_4$	$NiCl_2$ (6 H_2O)
Relative molecular mass:	170.75 g	129.6 g (237.7) g
Density:	1.31 g/cm^3	3.55 g/cm^3 (anhydrous)
Relative gas density:	6	
Boiling point:	42.2C (therm. instable)	
Melting point:	-19.3C (acc. ULLMANN) -25.0C (acc. HOMMEL)	987C
Vapour pressure:	44 kPa at 20C; 65 kPa at 30C	
Flash point:	-25C	
Ignition temperature:	60C	
Explosion limits:	3-34 vol%	
Odour threshold:	0.5 ppm	
Solvolysis/solubility:	virtually insoluble in water soluble in most organic solvents	in water: 1,170 g/l (hexahydrate) (hexahydrate)

ORIGIN AND USE

Usage:

Primarily for hard, malleable and corrosion-resistant alloys (81%), coatings ("nickelising", "plating", 11%), coins, catalysts, chemical apparatus, laboratory equipment, thermocouples, Ni-Cd batteries and magnetic materials. The most important compounds are as follows:

- Nickel tetracarbonyl ($Ni(CO)_4$): highly poisonous, colourless liquid; forms explosive mixtures with air; parent substance for manufacture of superpure nickel;

- Nickel oxide (NiO); greyish green powder not soluble in water; used to make glasses grey and to manufacture Ni catalysts for hydration processes;

- Nickel dichloride ($NiCl_2$): for dyeing ceramics, for producing Ni catalysts and for nickel electroplating.

Origin/derivation:

Ni is the 28th most common element. It makes up approx. 0.008% by weight of the Earth's crust. The Earth's core probably contains large amounts of nickel. Ni is not found in elemental form except in meteorites.

Nickel minerals are widespread in small concentrations; extractable deposits would have to be enriched to at least 0.5% Ni content by geochemical processes. Deep-sea manganese nodules contain large quantities of Ni. The most important nickel minerals are magnetic pyrites, pyrrhotine, garnierite, niccolite, arsenical nickel and antimony nickel.

Extraction involves widely differing methods depending on the nature of the ore and the intended use. In some cases the Ni-Fe alloys obtained as intermediate products are passed on directly for steelmaking. In the case of sulphide ores, the first step is to obtain "raw stone" then "fine stone" before using the high-pressure carbonyl process to produce high-purity Ni powder by way of nickel tetracarbonyl. With oxide ores the metal is obtained electrolytically.

Production figures:

The largest deposits are to be found in Canada, the Soviet Union, New Caledonia, Australia and Cuba. Worldwide reserves are estimated at about 50 million tons. Annual worldwide production amounts to roughly 800,000 tons (ULLMANN, 1991).

Emission figures:

Natural emissions (in t/a, acc. BENNETT 1981):

> **Aeolian deposits: 4,800; volcanoes: 2,500; vegetation: 800; forest fires: 200; meteorite deposits: 200; sea spray: 9**

Anthropogenic emissions (in t/a, acc. BENNETT 1981):

> **Oil burners: 27,000; nickel industry: 7,200; refuse incineration: 5,100; steel production: 1,200; industrial processing: 1,000; motor vehicles: 900; coal burners: 700**
>
> **Coal-fired power plants in the Federal Republic of Germany approx. 84 t/a (RMPP, 1988).**

Toxicity

Mammals:			
Rat	LDLo 12 mg/kg (intraperitoneal)		acc. ULLMANN, 1991
Mouse	LDLo 50 mg/kg (intravenous)		acc. ULLMANN, 1991
Guinea pig	LDLo 5 mg/kg (oral)		acc. ULLMANN, 1991

Dog	LDLo 10 mg/kg (intravenous)		acc. ULLMANN, 1991
Aquatic organisms:			
Fish	LC_{100} 5-50 g/l (24-96 h)		acc. ATRI, 1987
Fish larvae, young fish	LC_{50} 0.1-5 g/l		acc. ATRI, 1987
Daphnia	0.1-5 g/l 1)		acc. ATRI, 1987
Plants:			
Various species	20-30 mg/kg	Poor harvest	acc. BAFEF, 1987
Young barley	11-13 mg/kg	Poor harvest	acc. BAFEF, 1987

Note:

1) Low carbonate hardness in water coincides with lower toxicity values.

Characteristic effects:

***Humans/mammals:* Ni is a trace element. The metal and its inorganic compounds are classed as being comparatively non-toxic. Sustained skin contact can however cause "nickel itch". On the other hand, certain organic Ni compounds are extremely toxic (e.g. nickel tetracarbonyl) and have a considerable allergenic/mutagenic potential). Ni vapour and dust are probably carcinogenic as are some other Ni compounds.**

Plants: **Ni is an important trace element for plant growth.**

Synerg./antagon.: **"Laboratory experiments have shown that the toxic effect of nickel changes in the presence of other elements. Copper, zinc and nickel are thought to have an additive effect on the acute toxicity level with rainbow trout. Synergetic effects are attributed to nickel/zinc and nickel/copper combinations. Other laboratory results likewise provide evidence of changes in effect with mixtures of different heavy metal salts... " (ATRI, 1987).**

ENVIRONMENTAL BEHAVIOUR

Water:

Nickel is usually found in the form of Ni^{2+} in aquatic systems. The form in which it is found in water is dependent amongst other factors on the pH value. Nickel compounds in surface water or groundwater are generally recorded and listed as "total nickel" despite the fact that the spectrum of the compounds anthropogenically introduced into stretches of water ranges from soluble salts and insoluble oxides to metallic nickel dust. As yet, there is no evidence of nickel compounds occurring exclusively in water.

Air:

Nickel is encountered in the atmosphere as an aerosol. Its metallic form is stable. The determination of air-specific Ni compounds is extremely difficult since, on the one hand, there are comparatively few compounds and on the other hand, the different analytical methods result in the substances concerned being modified. According to the available emission figures, the atmosphere is primarily impacted by Ni sulphates, complex Ni oxides and Ni oxide itself with metallic nickel dusts playing a far less important role.

Soil:

Nickel is found in various forms in soil, namely as inorganic crystalline mineral (or as precipitation), in complex chelates or as a free ion. The behaviour of Ni compounds in soil depends not only on the properties of the individual compounds, but also on the type of soil. Thus, generalisations are not possible. Desorption and the nickel content in the soil solution increase with decreasing pH.

Degradation, decomposition products, half-life:

Data of this type can only be provided for individual Ni compounds and, for the element itself, only the half-lives of the eight non-stable Ni isotopes. The values range between 0.005 s (^{53}Ni) and 7.5×10^4 a (^{59}Ni).

Food chain:

Numerous plants accumulate nickel from the soil, mainly via the roots (e.g. pines up to 700 times more). Under natural conditions, plants contain less than 1 mg/kg; concentrations of 100 mg/kg have however been found in soils over serpentinites and levels of up to 1150 mg/kg in sewage-sludge soils (acc. U.S. EPA, 1985).

Environmental standards

Medium/acceptor	**Sector**	**Country/organ.**	**Status**	**Value**	**Cat.**	**Remarks**	**Source**
Water:	Drinkw	D	L	0.05 mg/l			TVO, 1986
	Drinkw	EC	G	0.05 mg/l			acc. LAU-BW3), 1989
	Drinkw	WHO	G	0.1 mg/l			acc. TEBBUTT, 1983
	Surface	CH	L	0.05 mg/l			acc. LAU-BW, 1989
	Surface	D	G	0.03 mg/l		1)	DVGW, 1975
	Surface	D	G	0.05 mg/l		2)	DVGW, 1975
	Surface	USA	(L)	1 mg/l		State of Illinois	acc. WAITE,

							1984
	Marine	USA	G	0.1 mg/l		Hazard level	EPA, 1973
	Marine	USA	G	0.002 mg/l		Minimal risk	EPA, 1973
	Groundw	D(HH)	G	0.02 mg/l		Further investigation	acc. LAU-BW, 1989
	Groundw	D(HH)	G	0.2 mg/l		Investigation of rehabilitation measures	acc. LAU-BW, 1989
	Groundw	NL	G	15 μ g/l		Reference	acc. TERRA TECH, 6/94
	Groundw	NL	L	75 μ g/l		Intervention	acc. TERRA TECH, 6/94
	Groundw	USA	(L)	1 mg/l		State of Illinois	acc. WAITE, 1984
	Waste water	CH	(L)	2 mg/l		4)	acc. LAU-BW, 1989
	Waste water	D(BW)	G	3 mg/l			acc. LAU-BW, 1989
	Irrigation	USA		0.2 mg/l		12)	EPA, 1973
	Irrigation	USA		2 mg/l		13)	EPA, 1973

Soil:		CH	(L)	50 mg/kg		Total 5)	acc. LAU-BW, 1989
		CH	(L)	0.2 mg/kg		Soluble 6)	acc. LAU-BW, 1989
		D(HH)	G	300 mg/kg DM			acc. LAU-BW, 1989
		NL	G	35 mg/kg AD		Reference	acc. TERRA TECH, 6/94
		NL	L	210 mg/kg AD		Intervention	acc. TERRA TECH, 6/94
	Sewage sludge	CH	L	10 mg/kg DM		Sludge 9)	acc. LAU-BW, 1989
	Sewage sludge	D	L	50 mg/kg AD		Soil	acc. LAU-BW, 1989
	Sewage sludge	D	L	200 mg/kg DM		Sludge	acc. LAU-BW, 1989
	Sewage sludge	EC	G	30-75 mg/kg DM		Soil 7)	acc. LAU-BW, 1989

	Sewage sludge	EC	G	16-25 mg/kg DM		Sludge 8)	acc. LAU-BW, 1989
	Compost	A	(G)	30-200 ppm DM		Quality stamp 11)	acc. LAU-BW, 1989
	Compost	CH	(L)	50 mg/kg DM		11)	acc. LAU-BW, 1989
	Compost	D	G	50 mg/kg AD		Soil	acc. LAU-BW, 1989
	Compost	D	G	330 g/ha/a		10)	acc. LAU-BW, 1989
Air:	Emiss.	D	L	5 mg/m^3		mass flow > 25 g/h	acc. TA Luft, 1986
	Emiss.	D	L	1 mg/m^3		mass flow > 5 g/h13)	acc. TA Luft, 1986
	Workp	B	(L)	0.1 mg/m^3		8 h average	acc. MERIAN, 1984
	Workp	BG	(L)	0.5 mg/m^3		8 h average	acc. MERIAN, 1984
	Workp	D	L	0.5 mg/m^3	TRK	Respirable dust	DFG, 1989

	Workp	D	L	0.05 mg/m3	TRK	Respirable droplets	DFG, 1989
	Workp	NL	(L)	0.1 mg/m^3		8 h average	acc. MERIAN, 1984
	Workp	I	(L)	1 mg/m^3		8 h average	acc. MERIAN, 1984
	Workp	J	(L)	1 mg/m^3		8 h average	acc. MERIAN, 1984
	Workp	S	(L)	0.01 mg/m3		8 h average 14)	acc. MERIAN, 1984
	Workp	SU	(L)	0.5 mg/m3		8 h average	acc. MERIAN, 1984
	Workp	SU	(L)	0.001 mg/m3		24 h average	acc. STERN, 1986
	Workp	USA	(L)	1 mg/m^3	TWA	Metal and insoluble compounds	acc. ACGIH, 1986
	Workp	USA	(L)	0.1 mg/m^3	TWA	Soluble inorganic compounds	acc. ACGIH, 1986
				0.6 mg/			acc.

Food-stuffs:		D		(persd)	ADI		OHNESORGE, 1985

Notes:

1) Drinking water treatment involving the use of simple physical purification methods

2) Drinking water treatment involving the use of physical/chemical purification methods

3) Baden-Wrttemberg Regional Environment Office

4) Direct and indirect introduction

5) Overall content

6) Available content

7) Content in affected soil; values are to be reduced for pH values < 6; up to 10% excess is permitted

8) *The use of sludges is banned in pastures and fodder growing areas during use and in fruit and vegetable cultivation during vegetation*

9) The use of sewage sludge is not permitted for the following: saturated, snow-covered soil, moorland, hedges, perimeters of forests, banks of rivers/streams, etc., scattering areas and protected groundwater catchment areas; a maximum of 7.5 t of sewage sludge (dry matter) may be spread in 3 years.

10) Application intervals are governed by heavy metal concentration and quantity concerned, making allowance for the last two compost analyses.

11) Quality stamp aimed at better marketing with state and partly state-run supervision

12) On discharge from pumping and/or treatment systems and their secondary systems

13) Respirable dust/aerosols of Ni and its compounds, stated as Ni

14) Listed in group of substances which have been shown to cause cancer in humans, have proven to be carcinogenic in animal experiments or for which a considerable carcinogenic potential can be construed.

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Water:			
Drinking water	USA	<10 g/l (mean)	acc. BENNETT, 1981
Drinking water (Ni extraction)	USA	200 g/l (max)	acc. BENNETT, 1981
Various bodies of surface water (1962-73)	USA	19 g/l (mean)	acc. BENNETT, 1981
Various bodies of surface water (1962-73)	Europe	15 g/l (mean)	acc. BENNETT, 1981
Seawater		0.1-0.5 g/l	acc. BENNETT, 1981
Soil:			
Natural content		5-500 ppm	acc. U.S.EPA, 1985
Normal content		50 ppm	acc. U.S.EPA, 1985
Frequent content	D	2-50 mg/kg	acc. LAU-BW$^{1)}$, 1989
Tolerably contaminated	D	50 mg/kg	acc. LAU-BW, 1989
Particularly contaminated	D	<10,000 mg/kg	acc. LAU.BW, 1989
Air:			

Immissions in suspended dust:			
Rhine/Ruhr area (1984)	D	9-15 ng/m^3 (average fluctuation)	acc. SRU, 1988
Rhine/Ruhr area (1984)	D	12 ng/m^3 (mean)	acc. SRU, 1988
Rural areas	D	5 ng/m^3 (a-mean)	acc. SRU, 1988
Conurbations	D	20-70 ng/m^3 (a-mean)	acc. SRU, 1988
Deposition rates:			
Rural areas	D	5-30 g/(m^{2}d)	acc. SRU, 1988
Conurbations	D	10-80 g/(m^{2}d)	acc. SRU, 1988
Near to source of emissions	D	400-1200 g/(m^{2}d)	acc. SRU, 1988
Plants:			
Various species (normal content)		0.1-3 mg/kg (dry matter)	acc. CES, 1985
Various species (normal content)		0.05-5 mg/kg (dry matter)	acc. BENNETT, 1981
*Foodstuffs:*2)			
Grain, vegetables, fruit	USA	0.02-2.7 mg/kg (original matter)	acc. BENNETT, 1981

Meat	USA	0.06-0.4 mg/kg (original matter)	acc. BENNETT, 1981
Aquatic animals	USA	0.02-20 mg/kg (original matter)	acc. BENNETT, 1981
Oysters		1.5 mg/kg (original matter)	acc. BENNETT, 1981
Salmon		1.7 mg/kg (original matter)	acc. BENNETT, 1981

Notes:

1) Baden-Wrttemberg Regional Environment Office

2) The average human absorption rate is approx. 0.1 - 0.3 mg of nickel per day; the contamination of foodstuffs may also result from preparation in nickel-plated domestic utensils.

Assessment/comments

Nickel is a trace element encountered in large quantities in nature. Naturally-occurring nickel ores are not hazardous. However, the products of synthetic processing are a considerable hazard. Environmental accumulation is caused by sewage sludges and composts. Hazards arise in the nickel processing industry when extremely toxic intermediary and waste products are formed. An outline of the range of possible effects of nickel in various environmental sectors is given by the spectrum of standards quoted. Any assessment of measures used for the extraction, processing or industrial utilisation of nickel presupposes in-depth determination of the individual chemical compounds concerned. Their specific properties must be known before the effect on the environment can be established in detail.

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Nitrate

DESIGNATIONS

CAS No.:
Registry name: Nitrate
Chemical name: Nitrate
Synonyms, Trade names:
Chemical name (German): Nitrat
Chemical name (French): Nitrate
Appearance: colourless (depending on cations) solids, easily soluble in water

ORIGIN AND USE

Usage:
Nitrates are used as fertilisers and in the food industry. Some 90% of all meat products are salted, i.e. nitrate is added to them in the form of potassium nitrate (saltpeter).

Origin/derivation:
Nitric acid salt. Nitrate is part of the nitrogen cycle in nature. 78% of the air is nitrogen. The mineralisation of nitrogen initially produces ammonia which is oxidised by nitrifying bacteria to form nitrite and then nitrate.

Toxicity

Characteristic effects:

Humans/mammals: **Infants assimilating large doses of nitrates may suffer not only from nitrosamine formation (carcinogenic), but also from methaemoglobinaemia (cyanosis). The first stage is the transformation to nitrite caused by small amounts of gastric acid, then the nitrite enters the bloodstream where it oxidises the haemoglobin to form methaemoglobin which inhibits the transportation of oxygen. 60-80% methaemoglobin has a lethal effect due to internal suffocation. The symptoms are similar to those of carbon monoxide poisoning.**

Plants: **An increase in nitrate content results in more water being absorbed; at the same time there is a decrease in the number of valuable constituents such as vitamin C or iron.**

ENVIRONMENTAL BEHAVIOUR

Water:
The elution of nitrate from the topsoil into the groundwater is influenced by numerous factors and often takes months or even years.

Soil:
Various processes are responsible for the translocation of nitrate ions in soil; they are absorbed by plants and microorganisms, they are nitrified, they can be reduced by microbes to form ammonium ions (NH_4^+) or they are eluted into the groundwater by seepage water. Nitrate elution is clearly dependent on the amount and the frequency of rainfall and thus on the seasons (most pronounced in low-vegetation period). A high humus content results in more organically bound nitrogen which is biologically degraded to nitrate.

Degradation, decomposition products:
Nitrate may be transformed into nitrite by microorganisms in the intestines. As nitrites may react with numerous amines to form nitrosamines - especially at low pH values (e.g. in the stomach) - they deserve special attention.

Food chain:

Vegetables are the main nitrite source to humans (more than 70%; HEINZE 1986). The natural nitrate content of meat is insignificant. Nitrate is found in meat and fish as a result of the methods used to preserve such products. 80% of the nitrite assimilated in humans is a consequence of its formation from nitrate.

ENVIRONMENTAL STANDARDS

Medium/acceptor	Sector	Country/organ.	Status	Value	Cat.	Remarks	Source
Water:	Drinkw	CS	(L)	15 mg/l			acc. B.U. INST., 1984
	Drinkw	CH	(L)	20 mg/l			acc. B.U. INST., 1984
	Drinkw	D	L	50 mg/l			acc. LAU-BW, 1989
	Drinkw	DDR	(L)	40 mg/l			acc. B.U. INST., 1984
	Drinkw	DDR	(L)	20 mg/l			acc. B.U. INST., 1984
	Drinkw	EC	G	25 mg/l			acc. LAU-BW, 1989
	Drinkw	EC	G	50 mg/l			acc. LAU-BW, 1989
			(L)	90 mg/l			acc. HEINZE,

	Drinkw	GB	(L)	90 mg/l			1986
	Drinkw	SU	(L)	40 mg/l			acc. HEINZE, 1986
	Drinkw	USA	(L)	45 mg/l			acc. HEINZE, 1986
	Drinkw	WHO	G	44.3 mg/l			acc. LAU-BW, 1989
	Groundw	NL	G	5.6 mg/l			acc. LAU-BW, 1989
	Surface	D	G	25 g/m^3		Investigation	acc. LAU-BW, 1989
	Surface	D	G	50 g/m^3		Rehabilitation	acc. LAU-BW, 1989
	Surface	EC	G	25 g/m^3		$^{1)}$ A_1	acc. LAU-BW, 1989
	Surface	EC	G	50 g/m^3		$^{2)}$ A_2	acc. LAU-BW, 1989
	Waste water	CH	(L)	25 g/m^3		Quality goal	acc. LAU-BW, 1989
Foodstuffs		CH	L	3000 mg/kg		Lettuce	acc. B.U. INST., 1984

		D	(L)	5 mg/(kg.d)	ADI	As sodium nitrate 3)	acc. Groklaus, 1989
		D	(L)	5 mg/(kg.d)	ADI	As potassium nitrate 3)	acc. Groklaus, 1989
		D	(L)	100 mg/(kg.d)	ADI	As potassium nitrate 4)	acc. Groklaus, 1989
		NL	(L)	4,000 mg/kg		Lettuce	acc. B.U. INST., 1984
		WHO	G	3.65 mg/(kg.d)	ADI		acc. B.U. INST., 1984

Notes:

1) For drinking water treatment in each case: quality requirements to be satisfied by surface water used for drinking water supply in member countries: A1 = G for simple physical treatment and sterilisation

2) For drinking water treatment in each case: A1 simple physical treatment and sterilisation, A2 = normal physical and chemical treatment/sterilisation and A3 = physical and refined chemical treatment, oxidation, adsorption and sterilisation

3) In meat, fish, cheese

4) In raw sausage
The use of nitrate as an additive is banned in Norway, Sweden and former East Germany (HEINZE, 1986).

Comparison/reference values

Medium/origin	Country	Value	Source
Lettuce	D	1490 mg/kg	acc. RSU, 1987
Spinach	D	965 mg/kg	acc. RSU, 1987
Tomatoes	D	27 mg/kg	acc. RSU, 1987
Milk	D	1.35 mg/kg	acc. RSU, 1987
Meat products	D	77 mg/kg	acc. RSU, 1987
Fresh vegetables	D	720 mg/kg	acc. RSU, 1987
Baby food	D	81 mg/kg	acc. RSU, 1987

Assessment/comments

Uncontrolled usage of nitrate must be avoided because of its transformation in the human body to form nitrite and carcinogenic nitro-soamines which may be fatal to infants. The use of nitrates (smoking) to preserve foodstuffs should definitely be restricted.

In agriculture, nitrate fertilisers must not be applied in zones of drinking water catchment areas as well as in areas where nitrates can easily infiltrate into the groundwater (hydromorphous soils).

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Nitrogen oxides

DESIGNATIONS

CAS No.:
Registry name: **Nitrogen oxides**
Chemical name: **Nitrogen oxides**
Synonyms, Trade names: **NO_x, N-oxides, Nitrous gases**
Chemical name (German): **Stickstoffoxide, Stickoxide, Nitrose Gase**
Chemical name (French): **Oxydes d'azote**
Appearance: **brownish yellow - reddish brown gases depending on temperature and concentration**
Note: **"Nitrogen oxides" is a collective name of compounds of nitrogen with oxygen (often abbreviated NO_x). Mainly nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are relevant to environmental impacts. Other oxides such as N_2O, N_2O_3 and N_2O_5 are of minor importance in this respect.**

CAS No.	10102-43-9	10102-44-0
Chemical name:	Nitrogen monoxide	Nitrogen dioxide
Synonyms, Trade names:	Nitrogen oxide, Nitrogen(II)oxide	Nitrogen peroxide, Nitrogen(IV)oxide
Chemical name (German):	Stickstoffmonoxid	Stickstoffdioxid

Chemical name (French):	Oxyde d'azote	Bioxyde d'azote
Appearance:	colourless and odourless gas	reddish brown gas with penetrating, acidic odour

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	NO	NO_2
Rel. molecular mass:	30.01 g	46.01 g
Density:	1.34 g/l at 0C	1.45 g/cm^3
Relative gas density:	1.04	
Boiling point:	-152C	21C
Melting point:	-164C	-11C
Vapour pressure:		960 hPa
Solvolysis/solubility:	in water: 73.4 ml/l at 0C	
Conversion:	1 ppm = 1.247 mg/m^3 1 mg/m^3 = 0.8702 ppm	1 ppm = 1.91 mg/m^3 1 mg/m^3 = 0.52 ppm

Note:

NO_2 is in a temperature-dependent equilibrium with its dimer N_2O_4. Below 0C, all NO_2 molecules have dimerised;

at higher temperatures, the equilibrium is shifted towards NO_2. Above 150C, NO_2 begins to dissociate forming NO and O_2. This reaction goes to completion at about 650C.

ORIGIN AND USE

Origin/derivation:
NO_x are major air pollutants. They are produced in all combustion processes. In 1982, total emissions in Germany were about 3 Mio t. The major part of the emissions comes from motor vehicle exhausts (50%), power plants (30%) and industry (15%). Additionally, considerable amounts are produced by soil bacteria (denitrification) [RMPP, 1985].

Use:
Nitrous gases (NO/NO_2) are used in the production of nitric acid (oxidation of NH_3) and sulphuric acid (lead chamber process). Additionally, NO is used in nitrosation processes, and NO_2 (N_2O_4) is used as an oxidising agent and in the manufacture of explosives.

Toxicity

Humans:	LCLo 200 ppm, inhalation (1 min), (NO_2)	acc. UBA, 1986
	TCLo 90 ppm, inhalation (40 min), (NO_2)	acc. UBA, 1986
Mammals:		
Rat:	LC_{50} 88 ppm, inhalation (4 h), (NO_2)	acc. UBA, 1986

	LC_{50} 8.8 ppm, inhalation (4 h), (NO_2)	acc. HORN, 1989
Mouse:	LCLo 250 ppm, inhalation (30 min), (NO_2)	acc. UBA, 1986
Rabbit:	LC_{50} 315 ppm, inhalation (15 min), (NO_2)	acc. UBA, 1986
Dog:	LCLo 123 mg/m^3, inhalation, (NO_2)	acc. UBA, 1986
Guinea pig:	LC_{50} 30 ppm, inhalation (1 h), (NO_2)	acc. UBA, 1986
Hamster:	LC_{50} 36 ppm, inhalation (48 h), (NO_2)	acc. UBA, 1986
Monkey:	MCL 44 ppm (6 h), (NO_2)	acc. HORN, 1989
Aquatic organisms:		
Mosquito fish:	TLm 72 ppm (96 h, freshwater), (NO_2)	acc. UBA, 1986
Cockle:	LC_{50} 330-1,000 ppm (48 h, saltwater), (NO_2)	acc. UBA, 1986

Characteristic effects:

Humans/mammals: **Nitrogen monoxide is oxidised forming nitrogen dioxide when it comes into contact with air.**

Thus, poisoning by nitrous gases is mainly due to nitrogen dioxide. Nitrogen dioxide is highly toxic and irritates both the skin and the mucous membranes. Dilutions of between 0.2 and 0.5 g/m^3 can be inhaled without any adverse effects over a longer period (UBA, 1986). Nitrogen dioxide penetrates the alveoli. The formation of nitrous/nitric acid in the pulmonary tissue damages the capillary walls causing oedema after a latent period of 2-24 hours. Typical symptoms of acute poisoning are burning and running eyes, cough, dyspnoea and finally death.

Plants: **Different species of plants exhibit considerable divergence in terms of resistance. All nitrous gases turn the edges of leaves brown or brownish black and cause blotches. Plant cells start to shrink and protoplasms detach themselves from the cell wall. This process ultimately results in the damaged parts of the cell drying out.**

ENVIRONMENTAL BEHAVIOUR

Air:

90% of nitrogen oxide emissions come from furnaces and combustion engines. Thus, nitrogen monoxide is predominant in the vicinity of the source, whereas some 80% is transformed into nitrogen dioxide following long-distance transportation. Nitrogen oxides play an important role in the formation of ozone in the low atmospheric layer. Nitrogen dioxide is decomposed by sunlight into nitrogen monoxide and atomic oxygen which reacts immediately with atmospheric oxygen molecules, forming ozone. This equilibrium reaction depends on the NO_2/NO ratio and on the intensity of the sunlight. Especially in summer and at high traffic volumes, this ratio is increased by atmospheric reactions of volatile hydrocarbons from automobile exhaust fumes resulting in a strong increase of the ozone concentration. Nitrogen oxides are washed out from the atmosphere by precipitation as nitrous or nitric acid, respectively.

Water:

Nitrogen oxides are only slightly soluble in water but they form nitrous or nitric acid when they come into contact with water. In Germany, nitrogen dioxide is listed in water hazard class 1.

Soil:

The adverse effects in soil result from its acidification which may cause nutrient relocation and elution depending on the soil type.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Nitrogen dioxide							
Air:		CDN	(L)	0.06-0.1 mg/m^3		Annual average	acc. BUB, 1986
		CDN	(L)	0.2 mg/m^3		24 h	acc. BUB, 1986
		CDN	(L)	0.4 mg/m^3		1 h	acc. BUB, 1986
		CH	(L)	0.03 mg/m^3		Annual average	acc. BUB, 1986
		CH	(L)	0.08 mg/m^3		24 h	acc. BUB, 1986
		D	L	0.2 mg/m^3	MIK	30 min	acc. UBA, 1986
		D	L	0.1 mg/m^3	MIK	24 h	acc. UBA, 1986
		D	L	0.05 mg/m^3	MIK	1 a	acc. UBA, 1986
		D	L	0.1 mg/m^3	IW1		acc. TA-Luft, 1986

	D	L	0.3 mg/m^3	IW2		acc. TA-Luft, 1986
	D	G	0.2 mg/m^3		1/2 h, VDI	acc. BUB, 1986
	D	G	0.1 mg/m^3		24 h, VDI	acc. BUB, 1986
	E	L	0.4 mg/m^3		1/2 h	acc. MEINL et al., 1985
	E	L	0.1 mg/m^3		Annual average	acc. MEINL et al., 1985
	E	L	0.565 mg/m^3		Smog alarm level I	acc. MEINL et al., 1985
	E	L	0.75 mg/m^3		Smog alarm level II	acc. MEINL et al., 1985
	E	L	1 mg/m^3		Smog alarm level III	acc. MEINL et al., 1985
	EC	(L)	0.2 mg/m^3		98% percentile, year	acc. LAU-BW, 1989
	EC	(L)	0.05 mg/m^3		50% percentile, year	acc. MEINL et al., 1985
		(L)	0.2 mg/m^3		24 h, 95%	

	F	[illegible]	0.2 mg/m		percentile	acc. MEINL et al., 1985
	GR	L	0.2 mg/m^3		1 h, smog warning	acc. MEINL et al., 1985
	GR	L	0.5 mg/m^3		1 h, smog alarm stage I	acc. MEINL et al., 1985
	GR	L	0.7 mg/m^3		1 h, smog alarm stage II	acc. MEINL et al., 1985
	I	G	0.2 mg/m^3		1 h	acc. MEINL et al., 1985
	J	(L)	0.074-0.112 mg/m^3		24 h	acc. BUB, 1986
	NL	(L)	0.15 mg/m^3		24 h	acc. BUB, 1986
	NL	G	0.095 mg/m^3		4 h	acc. BUB, 1986
	NL	(L)	0.3 mg/m^3		1 h	acc. BUB, 1986
	SF	(L)	0.15 mg/m^3		24 h	acc. OECD, 1988
	SF	(L)	0.3 mg/m^3		1 h	acc. OECD, 1988
	USA	(L)	0.1 mg/m^3		Annual average	acc. BUB, 1986
	WHO	G	0.03 mg/m^3		Annual average	acc. BUB, 1986

		WHO	G	0.095 mg/m^3		4 h	acc. BUB, 1986
		WHO	G	0.4 mg/m^3		1 h, human beings	acc. LAU-BW, 1989
		WHO	G	0.15 mg/m^3		24 h, human beings	acc. LAU-BW, 1989
		WHO	G	0.095 mg/m^3		4 h, vegetation	acc. LAU-BW, 1989
		WHO	G	0.03 mg/m^3		24 h, vegetation	acc. LAU-BW, 1989
	Emiss.	D	L	500 mg/m^3		mass flow > 5 g/h$^{2)}$	acc. TA Luft, 1986
	Workp	D	L	9 mg/m^3	MAK		DFG, 1989
	Workp	SU	(L)	2.mg/m^3			acc. SORBE, 1989
	Workp	USA	(L)	10 mg/m^3	STEL		ACGIH, 1986
Nitrogen monoxide							
Air:		CDN	(L)	0.2 mg/m^3		Long-time value	acc. OECD, 1986
		CH	G	0.2 mg/m^3		Annual average	acc. MEINL et al., 1985

	CH	G	0.6 mg/m^3		30 min, 95% percentile	acc. MEINL et al., 1985
	D	L	1 mg/m^3		30 min	acc. UBA, 1986
	D	L	0.5 mg/m^3		24 h	acc. UBA, 1986
	D	L	0.1 mg/m^3	MIK	1 a	acc. UBA, 1986
	D	L	0.2 mg/m^3	IW1	TA-Luft	acc. UBA, 1986
	D	L	0.6 mg/m^3	IW2	TA-Luft	acc. UBA, 1986
	D	(L)	0.5 mg/m^3		24 h, VDI-R. 2310	acc. LAU-BW, 1989
	D	(L)	1 mg/m^3		30 min, VDI-R. 2310	acc. LAU-BW, 1989
	J	(L)	0.075-0.1 mg/m^3		Long-time value	acc. acc. OECD, 1986
	YU	(L)	0.085 mg/m^3		Long-time value	acc. OECD, 1986
	YU	(L)	0.085 mg/m^3		Short-time value	acc. OECD, 1986
Workp	USA	(L)	30 mg/m^3	TWA		ACGIH, 1986

	Workp	USA	(L)	45 mg/m^3	STEL		ACGIH, 1986

Comparison/reference values

Medium/origin	**Country**	**Value**	**Source**
Air			
NO_3 radical, at night		350 ppt	acc. UBA, 1988
NO_3 on particles	S	0.5-3 mg/m^3 (nitrogen)	acc. UBA, 1987
PAN1), afternoons	USA	40 ppb	acc. UBA, 1988
PAN1)	S	0.1-2 mg/m^3 (nitrogen)	acc. UBA, 1987
HNO_2, motorway intersections	USA	8 ppb	acc. UBA, 1988
HNO_2	S	0.1-0.3 mg/m^3 (nitrogen)	acc. UBA, 1987
HNO_3	S	0.5-3 mg/m^3 (nitrogen)	acc. UBA, 1987

Note:
All values for Sweden relate to rural areas in southern Sweden.
1) pan = peroxide, acetyl nitro

2) **no and NO_2, stated as NO_2**

Assessment/comments

As nitrogen oxides and their related products are highly toxic to humans and hazardous to the environment, their emission should be reduced as far as possible e.g. by using catalysts in automobiles.

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Ozone

DESIGNATIONS

CAS No.: **10028-15-6**
Registry name: **Ozone**
Chemical name: **Ozone**
Synonyms, Trade names: **Trioxygen**
Chemical name (German): **Ozon**
Chemical name (French): **Ozone**
Appearance: **colourless gas or dark blue liquid (at -112C)**

BASIC CHEMICAL AND PHYSICAL DATA

Empirical formula:	O_3
Rel. molecular mass:	48.0 g
Density:	2.15 g/l (gaseous) at 0C and 1013 hPa, 1.571 g/cm^3 at -183C (liquid)
Relative gas density:	1.66
Boiling point:	-112C
Melting point:	-192.7C
Vapour pressure:	7 x 10^6 Pa at -20C
Flash point:	
Ignition temperature:	
Explosion limits:	
Odour threshold:	0.01-0.02 ppm
Solvolysis/solubility:	in water 490 ml/l at 25C; highly soluble in Freon 12

Conversion factors:	1 mg/m^3 = 0.51 ppm
	1 ppm = 1.995 mg/m^3

ORIGIN AND USE

Usage:
Used in laboratories for ozonisation; in industry for bleaching oils, greases, waxes, synthetic fibres, papers, cellulose and textiles; as disinfectant in breweries, cold stores and the like; for artificial ageing of brandy and disinfection of drinking water. It is also used for sterilising swimming-pool water and for the deodourisation of unpleasant smells. Further applications result from the sterilising effect of ozone in the manufacture, preservation and storage of foodstuffs.

Origin/derivation:
Ozone is produced from atmospheric oxygen in the presence of UV light at extremely high temperatures and e.g. in an electrical corona discharge. Its formation under natural conditions presupposes the existence of appropriate precursors (in particular N-oxides and hydrocarbons) which are converted to ozone in the presence of sufficient sunlight. The main sources of workplace impact are inert-gas welding, photocopiers, air filtration systems, UV sterilisation systems and UV lamps where ozone is produced in the respiratory zone from molecular oxygen through UV irradiation. The only economical method of producing ozone is that of electrical corona discharge.

Toxicity

Humans:	LD 15-20 ppm	acc. ULLMANN, 1978
	0.001 mg/l air (definite irritation)	acc. TAB. Chemie, 1980

	0.002 mg/l air (1.5 h; damage)	acc. TAB. Chemie, 1980
Mammals:		
Guinea pigs	LC_{50} 51.7 ppm	acc. ULLMANN, 1978
Mouse	LC_{50} 21 ppm	acc. ULLMANN, 1978

Note:
Young animals react more sensitively to the inhalation of ozone than older ones. Physical exercise increases the toxicity level due to increased ventilation or stress.

Characteristic effects:

Humans/mammals: **Ozone is extremely irritating to the mucous membranes of the eyes, nose and throat. The main damage is however caused in the respiratory tract and this manifests itself in a reduced respiratory volume or even in bronchitis and pulmonary oedemas. Chronic exposure may lead to chest pain, headache and dizziness even if the ozone concentration is low. The toxicity of ozone is attributed in part to the oxidative decomposition of unsaturated fatty acids in the organism.**

Plants: **The direct effect of ozone is the destruction of chlorophyll and in particular chlorophyll b. The extent to which ozone is involved in the phenomenon of "dying forests" has been the subject of discussion for some time. Ozone absorption takes place exclusively via the atmosphere. There is a considerable difference in the sensitivity of various plants. Acute symptoms of ozone damage are necrosis, chlorosis and so-called water marks.**

ENVIRONMENTAL BEHAVIOUR

Water:

The rate at which ozone decomposes in an aqueous solution increases with increasing pH. In the presence of water, ozone oxidises all metals to the maximum possible extent.

Air:

Atmospheric air pollution caused by ozone originates from the photochemical formation of smog. The first step in this process is the photolysis of ozone.

Degradation, decomposition products, half-life:

Gaseous ozone is subject to spontaneous decomposition: O_3 (ρ) O_2 + 1/2 O_2 + 284 kJ with a half-life of 3 days (at 20C), 8 days (at -15C), 18 days (at -25C) or 3 months (at -50C); the decomposition process does however only involve simple allotropic conversion of the same element.

ENVIRONMENTAL STANDARDS

Medium/acceptor	**Sector**	**Country/organ.**	**Status**	**Value**	**Cat.**	**Remarks**	**Source**
Air:		CH	(L)	100 g/m^3		1)	acc. LAU-BW, 1989
		CH	(L)	120 g/m^3		2)	acc. LAU-BW, 1989
		D	G	120 g/m^3		3)	acc. LAU-BW, 1989
		WHO	G	150-200 g/m^3		4)	acc. LAU-BW, 1989

		WHO	G	100-120 g/m^3		5)	acc. LAU-BW, 1989
		WHO	G	200 g/m^3		6)	acc. LAU-BW, 1989
		WHO	G	60 g/m^3		7)	acc. LAU-BW, 1989
		WHO	G	65 g/m^3		8)	acc. LAU-BW, 1989
	Workp	D	L	0.2 mg/m^3	MAK		DFG, 1989
	Workp	DDR	(L)	0.2 mg/m^3			acc. Tab. Chemie, 1980
	Workp	SU	(L)	0.1 mg/m^3			acc. KETTNER, 1979
	Workp	USA	(L)	0.2 mg/m^3	TWA		acc. ACGIH, 1986
	Workp	USA	(L)	0.6 mg/m^3	STEL		acc. ACGIH, 1986

Notes:

1) **Exposure time: 98% of annual half-hour average**

2) **Exposure time: 1 hour average; may be exceeded once**

[3] Exposure time: half-hour average; protection of humans

[4] Exposure time: 1 h; protection of humans

[5] Exposure time: 8 h; protection of humans

[6] Exposure time: 1 h; protection of vegetation

[7] Exposure time: mean value over entire vegetation period

[8] Exposure time: 24 h; protection of vegetation

Assessment/comments

Any assessment of ozone must give consideration to two different aspects. Ozone which pollutes the air just above the ground harms the respiratory organs and plants and thus should be avoided as far as possible. In view of the secondary formation of ozone, this means reducing above all the nitrous emission levels.

At the same time, chlorinated fluorocarbons and nitrous oxides must not be allowed to reach the upper strata of the atmosphere (ozonosphere at an altitude of 50 - 60 km), since such substances deplete the vitally important ozone layer which absorbs dangerous UV radiation. While ozone concentrations close to the ground have a harmful effect, their presence in the upper atmosphere is absolutely vital.

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