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English only

1,1-Dichloroethene in Drinking-water

Background document for development of
WHO *Guidelines for Drinking-water Quality*

Preface

One of the primary goals of WHO and its member states is that "all people, whatever their stage of development and their social and economic conditions, have the right to have access to an adequate supply of safe drinking water." A major WHO function to achieve such goals is the responsibility "to propose ... regulations, and to make recommendations with respect to international health matters ...."

The first WHO document dealing specifically with public drinking-water quality was published in 1958 as *International Standards for Drinking-water*. It was subsequently revised in 1963 and in 1971 under the same title. In 1984–1985, the first edition of the WHO *Guidelines for Drinking-water Quality* (GDWQ) was published in three volumes: Volume 1, Recommendations; Volume 2, Health criteria and other supporting information; and Volume 3, Surveillance and control of community supplies. Second editions of these volumes were published in 1993, 1996 and 1997, respectively. Addenda to Volumes 1 and 2 of the second edition were published on selected chemicals in 1998 and on microbial aspects in 2002. The third edition of the GDWQ was published in 2004, and the first addendum to the third edition was published in 2005.

The GDWQ are subject to a rolling revision process. Through this process, microbial, chemical and radiological aspects of drinking-water are subject to periodic review, and documentation related to aspects of protection and control of public drinking-water quality is accordingly prepared and updated.

Since the first edition of the GDWQ, WHO has published information on health criteria and other supporting information to the GDWQ, describing the approaches used in deriving guideline values and presenting critical reviews and evaluations of the effects on human health of the substances or contaminants of potential health concern in drinking-water. In the first and second editions, these constituted Volume 2 of the GDWQ. Since publication of the third edition, they comprise a series of free-standing monographs, including this one.

For each chemical contaminant or substance considered, a lead institution prepared a background document evaluating the risks for human health from exposure to the particular chemical in drinking-water. Institutions from Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Poland, Sweden, United Kingdom and United States of America prepared the documents for the third edition and addenda.

Under the oversight of a group of coordinators each of whom was responsible for a group of chemicals considered in the GDWQ, the draft health criteria documents were submitted to a number of scientific institutions and selected experts for peer review. Comments were taken into consideration by the coordinators and authors. The draft documents were also released to the public domain for comment and submitted for final evaluation by expert meetings.

During the preparation of background documents and at expert meetings, careful consideration was given to information available in previous risk assessments carried

out by the International Programme on Chemical Safety, in its Environmental Health Criteria monographs and Concise International Chemical Assessment Documents, the International Agency for Research on Cancer, the Joint FAO/WHO Meetings on Pesticide Residues and the Joint FAO/WHO Expert Committee on Food Additives (which evaluates contaminants such as lead, cadmium, nitrate and nitrite, in addition to food additives).

Further up-to-date information on the GDWQ and the process of their development is available on the WHO Internet site and in the current edition of the GDWQ.

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The work of the following working group coordinators was crucial in the development of this document and others contributing to the first addendum to the third edition:

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The draft text was discussed at the Working Group Meeting for the first addendum to the third edition of the GDWQ, held on 17–21 May 2004. The final version of the document takes into consideration comments from both peer reviewers and the public. The input of those who provided comments and of participants in the meeting is gratefully acknowledged.

The WHO coordinator was Dr J. Bartram, Coordinator, Water, Sanitation and Health Programme, WHO Headquarters. Ms C. Vickers provided a liaison with the International Programme on Chemical Safety, WHO Headquarters. Mr Robert Bos, Water, Sanitation and Health Programme, WHO Headquarters, provided input on pesticides added to drinking-water for public health purposes.

Ms Penny Ward provided invaluable administrative support at the Working Group Meeting and throughout the review and publication process. Ms Marla Sheffer of Ottawa, Canada, was responsible for the scientific editing of the document.

Many individuals from various countries contributed to the development of the GDWQ. The efforts of all who contributed to the preparation of this document and in particular those who provided peer or public domain review comment are greatly appreciated.

Acronyms and abbreviations used in the text

$BMDL_{10}$	lower 95% confidence limit on the benchmark dose for a 10% response
CAS	Chemical Abstracts Service
ECD	electron capture detection
FAO	Food and Agriculture Organization of the United Nations
GC	gas chromatography
GDWQ	*Guidelines for Drinking-water Quality*
IARC	International Agency for Research on Cancer
LD_{50}	median lethal dose
MS	mass spectrometry
TDI	tolerable daily intake
USA	United States of America
WHO	World Health Organization

Table of contents

Deleted: 1
Deleted: 2
Deleted: 1
Deleted: 2
Deleted: 1
Deleted: 2
Deleted: 1
Deleted: 2
Deleted: 1
Deleted: 2
Deleted: 1
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1. GENERAL DESCRIPTION

1.1 Identity

CAS No.: 75-35-4
Molecular formula: $C_2H_2Cl_2$

1,1-Dichloroethene is also known as vinylidene chloride.

1.2 Physicochemical properties[1] *(Torkelson & Rowe, 1981; IPCS, 1990)*

Property	*Value*
Melting point	-122.5 °C
Boiling point	31.6 °C
Density	1.21 g/cm^3 at 20 °C
Vapour pressure	78.8 kPa at 25 °C
Water solubility	2.5 g/litre at 25 °C
Log octanol–water partition coefficient	1.66

1.3 Organoleptic properties

1,1-Dichloroethene has a mild, sweet odour (ACGIH, 1986). Its odour thresholds in air and water are 760 mg/m^3 and 1.5 mg/litre, respectively (Amoore & Hautala, 1983).

1.4 Major uses and sources in drinking-water

1,1-Dichloroethene is used mainly as a monomer in the production of polyvinylidene chloride co-polymers and as an intermediate in the synthesis of other organic chemicals, such as methyl chloroform and 1,1,1-trichloroethane (Gibbs & Wessling, 1983; ATSDR, 1989; IPCS, 1990).

1.5 Environmental fate

Most 1,1-dichloroethene released to the environment volatilizes to the atmosphere, where it is oxidized by hydroxyl radicals, with a lifetime of about 1–3 days (Singh et al., 1981; ATSDR, 1989). Rapid photolysis is also expected to occur. Volatilization is the major removal mechanism in surface waters and soils, and anaerobic biotransformation to vinyl chloride is expected to be important in groundwater (ATSDR, 1989).

[1] Conversion factor in air: 1 ppm = 4.0 mg/m^3.

2. ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

2.1 Air

1,1-Dichloroethene has been detected in urban air at mean concentrations of 19.6–120 ng/m^3 (Singh et al., 1981, 1982). The median concentration in ambient air from all areas is less than 4 ng/m^3. Concentrations in the vicinity of industrial plants or hazardous waste sites may be higher. 1,1-Dichloroethene has also been detected in indoor air at an average concentration of 78.8 µg/m^3 (ATSDR, 1989).

2.2 Water

1,1-Dichloroethene was detected in 2.3% of 945 samples of finished drinking-water taken from groundwater sources in the USA at median concentrations of 0.28–1.2 µg/litre and in about 3% of public drinking-water supplies at concentrations ranging from 0.2 to 0.5 µg/litre. It was not detected in a survey of surface water in 105 cities (ATSDR, 1989). It is readily lost to the atmosphere from water and so is rarely detected in surface waters, but spills to groundwater would result in persistent contamination (IPCS, 2003).

2.3 Food

1,1-Dichloroethene residues have been reported in foodstuffs wrapped with co-polymer films at levels ranging from 0.005 to 0.1 mg/kg and in household food wraps at an average concentration of 8.8 mg/kg (ATSDR, 1989). Because of its high volatility, residual levels in food are expected to be low.

2.4 Estimated total exposure and relative contribution of drinking-water

Estimated average exposure from drinking-water in the USA is less than 0.01 µg/day; the maximum is about 1 µg/day (US EPA, 1985). At a mean concentration of 19.6–120 ng/m^3 in urban air, the estimated average inhalation exposure is 0.4–2.5 µg/day (Singh et al., 1981). Food is not expected to be a significant exposure source.

3. KINETICS AND METABOLISM IN LABORATORY ANIMALS AND HUMANS

1,1-Dichloroethene is rapidly and almost completely absorbed from the gastrointestinal tract following administration by gavage (Jones & Hathway, 1978a; McKenna et al., 1978; IPCS, 1990). It is also readily absorbed from the lungs (Dallas et al., 1983), and dermal absorption is expected to occur (ATSDR, 1989). It is rapidly distributed following oral or inhalation exposure, accumulating preferentially in the liver, kidneys and lungs (Jones & Hathway, 1978a; McKenna et al., 1978; IPCS, 1990).

Biotransformation of 1,1-dichloroethene involves the cytochrome P-450 system and pathways that include the formation of 1,1-dichloroethene oxide and chloroacetyl

chloride and detoxification via conjugation with glutathione. The major metabolites include thiodiglycolic acid and *N*-acetyl-*S*-(2-carboxymethyl)cysteine (Jones & Hathway, 1978a,b; McKenna et al., 1978; IPCS, 1990). Mice metabolize more of an oral dose than do rats (Jones & Hathway, 1978b), in which 1,1-dichloroethene metabolism may be a saturable process (McKenna et al., 1978). Excretion occurs mainly via the urine and expired air (Jones & Hathway, 1978a,b; McKenna et al., 1978; IPCS, 1990).

4. EFFECTS ON LABORATORY ANIMALS AND IN VITRO *TEST SYSTEMS*

4.1 Acute exposure

Reported oral LD_{50}s for 1,1-dichloroethene are 1500 (NIOSH, 1983) and 1550 (Jones & Hathway, 1978b) mg/kg of body weight for rats and 194 and 217 mg/kg of body weight for female and male mice, respectively (Jones & Hathway, 1978b). Histopathological changes in the liver and kidneys (rats) and lungs (mice) were observed following administration of single oral doses of 200 mg/kg of body weight (Andersen & Jenkins, 1977; Chieco et al., 1981; Forkert et al., 1985).

4.2 Short-term exposure

Increased cytoplasmic vacuolation of hepatocytes was observed in rats exposed to 1,1-dichloroethene in drinking-water at doses of 19.3 or 25.6 mg/kg of body weight per day in males and females, respectively, for 90 days (Rampy et al., 1977). Beagle dogs given 1,1-dichloroethene in gelatin capsules at doses of 6.25, 12.5 or 25 mg/kg of body weight per day for 97 days experienced no adverse effects on hepatic, haematological, renal or neurological end-points (Quast et al., 1983; IPCS, 1990).

4.3 Long-term exposure

No treatment-related adverse effects were observed in Sprague-Dawley rats dosed with 1,1-dichloroethene at 0.5, 5, 10 or 20 mg/kg of body weight per day by gavage in corn oil for 1 year (Maltoni et al., 1984; IPCS, 1990). Renal inflammation was observed in F344 rats receiving 5 mg/kg of body weight per day by gavage in corn oil for 2 years, but not in those receiving 1 mg/kg of body weight (NTP, 1982). In a study in which $B6C3F_1$ mice were dosed by gavage at 2 or 10 mg/kg of body weight per day, liver necrosis was reported in male mice at the higher dose but not in female mice (NTP, 1982; IPCS, 1990).

Sprague-Dawley rats exposed to 1,1-dichloroethene in drinking-water for 2 years at doses of 7, 10 or 20 mg/kg of body weight per day (males) and 9, 14 or 30 mg/kg of body weight per day (females) experienced no treatment-related effects on mortality, body or organ weights, or haematological, urinary or clinical chemistry end-points (Quast et al., 1983; IPCS, 1990). A statistically significant increase in the incidence of hepatic lesions (hepatocellular swelling and fatty changes) was observed in females at all dose levels and in males at the highest dose.

4.4 Reproductive and developmental toxicity

Administration of 1,1-dichloroethene in drinking-water to rats at doses of up to 28 mg/kg of body weight per day for three generations produced no changes in reproductive outcome or neonatal development (Nitschke et al., 1983; IPCS, 1990). No evidence of toxicity to the dams or offspring was observed in rats exposed to drinking-water containing 1,1-dichloroethene at 200 mg/litre on days 6–15 of gestation (Murray et al., 1979).

4.5 Mutagenicity and related end-points

1,1-Dichloroethene was mutagenic in several strains of *Salmonella typhimurium*, *Escherichia coli* and *Saccharomyces cerevisiae* with metabolic activation but not without (Bartsch et al., 1975; Greim et al., 1975; Bronzetti et al., 1981; Oesch et al., 1983; IPCS, 1990). It increased the frequency of chromosomal aberrations and sister chromatid exchanges in Chinese hamster CHL cells (Sawada et al., 1987) and was also positive in host-mediated gene mutation and conversion assays in yeast (Bronzetti et al., 1981). Negative results were reported in assays for dominant lethal mutations in mice and rats (Anderson et al., 1977; Short et al., 1977) and in a micronucleus test in mice (Sawada et al., 1987).

4.6 Carcinogenicity

In a study in which F344/N rats and B6C3F_1/N mice were administered 1,1-dichloroethene by gavage for 104 weeks at 1 or 5 mg/kg of body weight per day (rats) and 2 or 10 mg/kg of body weight per day (mice), the only significant effect was an increase in the incidence of lymphomas or leukaemias in female mice in the low-dose group (NTP, 1982). Similarly, in a study in which Sprague-Dawley rats received 1,1-dichloroethene in drinking-water at 7, 10 or 20 mg/kg of body weight per day (male) or 9, 14 or 30 mg/kg of body weight per day (female) for 2 years, a significant increase in the incidence of combined mammary gland fibroadenomas and adenofibromas was observed only in the low-dose females (Quast et al., 1983; IPCS, 1990). Neither increase was considered to be treatment-related, because the effects were not seen in high-dose females or in male mice at either dose.

Swiss mice were exposed by inhalation to 1,1-dichloroethene 4 h per day, 4–5 days per week, for 1 year at 40 or 100 mg/m^3 (Maltoni et al., 1985). Carcinomas of the mammary gland were significantly increased in females at both doses, pulmonary adenomas were increased in males at 40 mg/m^3 and in both sexes at 100 mg/m^3 and renal adenocarcinomas were significantly increased in high-dose males.

5. EFFECTS ON HUMANS

1,1-Dichloroethene reportedly induces central nervous system depression at high concentrations (16 g/m^3 in air). A possible association of 1,1-dichloroethene with liver and kidney toxicity following exposure to lower concentrations has also been suggested (ATSDR, 1989).

6. PRACTICAL ASPECTS

6.1 Analytical methods and analytical achievability

Extraction into pentane and analysis by capillary GC with ECD give a limit of detection of approximately 0.025 µg/litre. A limit of detection of 0.07 µg/litre is found by purge-and-trap packed column GC with ECD or microcoulometric detection. Alternatively, purge-and-trap GC or purge-and-trap capillary column GC using a photoionization detector can be used. The limit of detection is 4.7 µg/litre by purge-and-trap packed column GC/MS. Alternatively, purge-and-trap capillary column GC/MS can be used (APHA et al., 1995).

6.2 Treatment and control methods and technical achievability

A concentration in water of 0.01 mg/litre should be achievable using granular activated carbon (Speth & Miltner, 1990) or air stripping (Chiang et al., 1998).

7. CONCLUSIONS

IARC has placed 1,1-dichloroethene in Group 3: not classifiable as to its carcinogenicity to humans (IARC, 1987). It was found to be genotoxic in a number of test systems *in vitro* but was not active in the dominant lethal assay *in vivo*. It induced kidney tumours in mice in one inhalation study but was not carcinogenic in other studies, including several in which it was given in drinking-water.

IPCS (2003) developed a TDI for 1,1-dichloroethene based on the critical effect from oral exposure, which is minimal hepatocellular mid-zonal fatty change in female Sprague-Dawley rats (Quast et al., 1983). A benchmark dose was determined, and the $BMDL_{10}$ was 4.6 mg/kg of body weight per day. An uncertainty factor of 100 (for inter- and intraspecies variation) was applied to the $BMDL_{10}$ to give a TDI of 0.046 mg/kg of body weight.

If it is assumed that a 60-kg adult drinks 2 litres of water per day, one could calculate a health-based value of 140 µg/litre (rounded value) using a conservative (because exposure from food is low) default allocation of 10% of the TDI to drinking-water. However, this health-based value is significantly higher than the concentrations of 1,1-dichloroethene that are normally found in drinking-water. It is therefore considered unnecessary to set a formal guideline value for 1,1-dichloroethene in drinking-water.

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