WHO/SDE/WSH/07.01/4
English only

Cyanogen Chloride 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, the first addendum to the third edition was published in 2005, and the second addendum to the third edition was published in 2007.

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.

Acknowledgements

The first draft of Cyanogen Chloride in Drinking-water, Background document for development of WHO *Guidelines for Drinking-water Quality*, was prepared by Mr J.K. Fawell, United Kingdom, to whom special thanks are due. It is an update of the background document published in the second edition in 1993.

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

Dr J. Cotruvo, J. Cotruvo Associates, USA (*Materials and chemicals*)
Mr J.K. Fawell, United Kingdom (*Naturally occurring and industrial contaminants*)
Ms M. Giddings, Health Canada (*Disinfectants and disinfection by-products*)
Mr P. Jackson, WRc-NSF, United Kingdom (*Chemicals – practical aspects*)
Prof. Y. Magara, Hokkaido University, Japan (*Analytical achievability*)
Dr E. Ohanian, Environmental Protection Agency, USA (*Disinfectants and disinfection by-products*)

The draft text was discussed at the Working Group Meeting for the second addendum to the third edition of the GDWQ, held on 15–19 May 2006. 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, WHO Headquarters. Ms C. Vickers provided a liaison with the International Programme on Chemical Safety, WHO Headquarters. Mr Robert Bos, Public Health and the Environment 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

CAS	Chemical Abstracts Service
FAO	Food and Agriculture Organization of the United Nations
GDWQ	*Guidelines for Drinking-water Quality*
LC_{50}	median lethal concentration
LD_{50}	median lethal dose
NOAEL	no-observed-adverse-effect level
ppm	parts per million
TDI	tolerable daily intake
WHO	World Health Organization

Table of contents

1. GENERAL DESCRIPTION

1.1 Identity

CAS No.: 506-77-4
Molecular formula: CNCl

1.2 Physicochemical properties (Verschueren, 1977; Weast, 1988; Budavari et al., 1989; SRC, 2006)[1]

Property	*Value*
Boiling point	12.7 °C
Melting point	−6 °C
Density	1.186 g/cm^3 at 20 °C
Henry's law constant	2.48 kPa·m^3/mol
Water solubility	Very soluble

1.3 Major uses and sources in drinking-water

Cyanogen chloride is used in tear gas, in fumigant gases, and as a reagent in the synthesis of other compounds (Hawley, 1981). Cyanogen chloride may be formed as a by-product of chloramination or chlorination of water. It is also formed by the chlorination of cyanide ion present in raw water.

1.4 Environmental fate

Cyanogen chloride is unstable in the presence of free chlorine; for example, its half-life in chlorinated water containing a free chlorine concentration of 0.5 mg/l was approximately 1 h (Na & Olson, 2004). At high pH, it is hydrolysed to release cyanide ions (Xie & Reckhow, 1992). Its estimated Henry's law constant of 2.48 kPa·m^3/mol suggests a significant potential for volatilization (SRC, 2006).

2. ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

Cyanogen chloride has been found in finished water supplies, usually at concentrations below 10 µg/l. The concentration in water when chlorination was used for disinfection was reported to be 0.4 µg/l. The level was higher (1.6 µg/l) in chloraminated water (Krasner et al., 19898).

3. KINETICS AND METABOLISM IN LABORATORY ANIMALS AND HUMANS

In an in vitro study with rat blood, cyanogen chloride was metabolized to cyanide ion by haemoglobin and glutathione (Aldridge, 1951).

[1] Conversion factor in air: 1 ppm = 2.5 mg/m^3.

4. EFFECTS ON LABORATORY ANIMALS AND IN VITRO TEST SYSTEMS

Estimates of inhalation LC_{50}s range from 100 mg/m^3 in cats to 7536 mg/m^3 in rabbits (Tarken & Lewis, 1983). In other lethality tests, a concentration of 100 mg/m^3 was fatal to cats within 18 min, 120 mg/m^3 for 6 h was fatal to dogs, 5 mg/m^3 for 2 min was fatal to goats, and a subcutaneous dose of 20 mg/kg of body weight was fatal to rabbits (Flury & Zernik, 1931). An LD_{50} of 6 mg/kg of body weight was reported in rats following oral administration (Leitch & Bauer, 1945). Toxic signs included irritation of the respiratory tract, haemorrhagic exudate of the bronchi and trachea, and pulmonary oedema.

5. EFFECTS ON HUMANS

On inhalation, a concentration of 2.5 mg/m^3 causes irritation. Cyanogen chloride was used as a war gas in the First World War. A concentration of 120 mg/m^3 was lethal (NAS, 1977).

6. PRACTICAL ASPECTS

6.1 Analytical methods and analytical achievability

United States Environmental Protection Agency Method 524.2, in which purge-and-trap gas chromatography is combined with mass spectroscopy, can be used for the determination of cyanogen chloride. This method has a practical quantification limit of 0.3 µg/l (USEPA, 1991).

6.2 Treatment and control methods and technical achievability

There is little information available on the removal of cyanogen chloride, and information on its stability in the distribution system is ambiguous (i.e. its concentration can increase or decrease). However, it is known to be unstable in chlorinated water (Na & Olson, 2004). Cyanogen chloride can be removed by chemical reduction agents such as sodium sulfite, sodium disulfite and sodium thiosulfate (Shang et al., 2005).

7. GUIDELINE VALUE

Cyanogen chloride is rapidly metabolized to cyanide in the body. There are few data on the oral toxicity of cyanogen chloride, and the guideline is therefore based on cyanide (for a review of the toxicology of cyanide, see the background document on cyanide: WHO, 2007).

The NOAEL in a rat chronic study in which cyanide was administered in the feed with the use of special jars to minimize loss by volatilization was 10.8 mg/kg of body weight per day (Howard & Hanzal, 1955). The NOAEL in a more recent rat subchronic study in which animals were exposed through their drinking-water was 5.4 mg/kg of body weight per day for minor changes in the testis (NTP, 1993). This latter study was selected as the critical study on which to base the guideline value. In view of the minor nature of the changes observed and the NOAEL in a previous chronic study, it is not considered necessary to include an additional uncertainty factor to

allow for the length of the study. The application of an uncertainty factor of 100 to the NOAEL of 5.4 mg/kg of body weight gives a TDI of 0.054 mg/kg of body weight. Assuming a 60-kg adult drinking 2 litres of water per day and allowing 20% of the TDI to come from water because of the potential for exposure to cyanogenic glycosides in food (WHO, 2007), the guideline value for long-term exposure is 0.3 mg/l (rounded value).

Although low concentrations of cyanide in raw waters will be converted to cyanogen chloride by chlorination, cyanogen chloride may also be formed during the production of chloramines in situ as a residual disinfectant to maintain the hygienic condition of the distribution system. It is important that treatment be optimized to minimize the formation of cyanogen chloride while maintaining adequate chloramine residuals where chloramination is practised.

8. REFERENCES

Aldridge WN (1951) The conversion of cyanogen chloride to cyanide in the presence of blood proteins and sulphydryl compounds. *Biochemical Journal*, 48: 271–276 [cited in NAS, 1977].

Budavari S, O'Neill M, Smith A, eds. (1989) *The Merck index. An encyclopedia of chemicals, drugs, and biologicals*, 11th ed. Rahway, NJ, Merck.

Flury F, Zernik F (1931). *[Harmful gases.]* Berlin, Springer [cited in NAS, 1977].

Hawley GG (1981) *The condensed chemical dictionary*, 10th ed. New York, NY, Van Nostrand Reinhold, p. 241.

Howard JW, Hanzal RF (1955) Chronic toxicity for rats of food treated with hydrogen cyanide. *Agricultural and Food Chemistry*, 3: 325–329.

Krasner SW et al. (1989) The occurrence of disinfection by-products in U.S. drinking water. *Journal of the American Water Works Association*, 81(8): 41–53.

Leitch JL, Bauer VE (1945) *Oral toxicity of cyanogen chloride in water to rats.* Edgewood Arsenal, MD, United States Chemical Warfare Service (Medical Division Report No. 19) [cited in NAS, 1977].

Na C, Olson TM (2004) Stability of cyanogen chloride in the presence of free chlorine and monochloramine. *Environmental Science and Technology*, 38(22): 6037–6043.

NAS (1977) *Drinking water and health.* Washington, DC, National Academy of Sciences.

NTP (1993) *Sodium cyanide administered in drinking water to F344/N rats and B6C3F1 mice*. Research Triangle Park, NC, National Institutes of Health, National Toxicology Program (Toxicology Report Series No. 37; NIH Publication 94-3386).

Shang C et al. (2005) Kinetics of cyanogen chloride destruction by chemical reduction methods. *Water Research*, 39(10): 2114–2124.

SRC (2006) *Interactive physical properties database*. Syracuse, NY, Syracuse Research Corporation (available at: http://www.syrres.com).

Tarken RL, Lewis RJ Sr, eds (1983) *Registry of toxic effects of chemical substances, Vol. 2*, 1981–82 ed. Cincinnati, OH, National Institute for Occupational Safety and Health (DHHS (NIOSH) Publication No. 83-107).

USEPA (1991) Method 524.2: Measurement of purgeable organic compounds in water by capillary column gas chromatography/mass spectrometry. In: *Methods for the determination of organic*

compounds in drinking water. Cincinnati, OH, United States Environmental Protection Agency, Office of Research and Development, Environmental Monitoring Systems Laboratory (EPA-600/4-88/039, December 1988, revised July 1991).

Verschueren K (1977) *Handbook of environmental data on organic chemicals.* New York, NY, Van Nostrand Reinhold.

Weast RC (1988) *Handbook of chemistry and physics.* Cleveland, OH, CRC Press.

WHO (2007) *Cyanide in drinking-water. Background document for development of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO SDE/WSH/07.01/2).

Xie Y, Reckhow DA (1992) Stability of cyanogen chloride in the presence of sulphite and chlorine. In: *Proceedings of the American Water Works Association Water Quality Technology Conference, Toronto, Ontario, November*. Denver, CO, American Water Works Association.