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Ammonia in Drinking-water

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

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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 in 1998, addressing selected chemicals. An addendum on microbiological aspects reviewing selected microorganisms was published in 2002.

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/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 examined in drinking-water.

For each chemical contaminant or substance considered, a lead institution prepared a health criteria 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 requested health criteria documents.

Under the responsibility of the coordinators for a group of chemicals considered in the guidelines, 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 before the documents were submitted for final evaluation by the experts meetings. A "final task force" meeting reviewed the health risk assessments and public and peer review comments and, where appropriate, decided upon guideline values. During preparation of the third edition of the GDWQ, it was decided to include a public review via the world wide web in the process of development of the health criteria documents.

During the preparation of health criteria documents and at experts 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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GENERAL DESCRIPTION

Identity

CAS no.: 7664-41-7
Molecular formula: NH_3
In what follows, the term "ammonia" covers both the nonionized form (NH_3) and the ammonium cation (NH_4^+) unless stated otherwise.

Physicochemical properties (1,2)

Property	*Value*
Melting point	-77.76 °C
Boiling point	-33.43 °C
Density of vapour	0.6 g/litre at 20 °C
Water solubility	421 g/litre at 20 °C; 706 g/litre at 0 °C
Vapour pressure	882 kPa at 20 °C

Organoleptic properties

The threshold odour concentration of ammonia in water is approximately 1.5 mg/litre [Source: *Hazardous Substances Data Bank: Ammonia.* Bethesda, MD, National Library of Medicine, 1990]. A taste threshold of 35 mg/litre has been proposed for the ammonium cation (*1*).

Major uses

Ammonia is used in fertilizer and animal feed production and in the manufacture of fibres, plastics, explosives, paper, and rubber. It is used as a coolant, in metal processing, and as a starting product for many nitrogen-containing compounds (*3*). Ammonia and ammonium salts are used in cleansing agents and as food additives (*1,4*), and ammonium chloride is used as a diuretic [Source: *Hazardous Substances Data Bank: Ammonium chloride.* Bethesda, MD, National Library of Medicine, 1990].

Environmental fate

On dissolution in water, ammonia forms the ammonium cation; hydroxyl ions are formed at the same time. The equilibrium constant of this reaction, K_B, is 1.78×10^{-5} (*3*). The degree of ionization depends on the temperature, the pH, and the concentration of dissolved salts in the water.

The environmental cycling of nitrogen relies mainly on nitrate, followed by ammonia and the ammonium cation, which predominates. The ammonium cation is less mobile in soil and water than ammonia and is involved in the biological processes of nitrogen fixation, mineralization, and nitrification (*2*).

ANALYTICAL METHOD

Ammonia and ammonium cation at concentrations between 0.025 and 3 mg/litre can be determined by the indophenol reaction (*1,2,5,6*). An ammonia-selective electrode can also be used, as can titrimetry, which is less sensitive (*5,6*).

ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

Air

Air in urban areas contains up to 20 µg of ammonia per mAir in urban areas contains up to 20 µg of ammonia per mAir in urban areas contains up to 20 µg of ammonia per m^3. Air in areas where farm animals are intensively reared may contain levels as high as 300 $\mu g/m^3$ (*7*).

Water

Natural levels in groundwaters are usually below 0.2 mg of ammonia per litre. Higher natural contents (up to 3 mg/litre) are found in strata rich in humic substances or iron or in forests (*8*). Surface waters may contain up to 12 mg/litre (*1*). Ammonia may be present in drinking-water as a result of disinfection with chloramines.

The presence of ammonia at higher than geogenic levels is an important indicator of faecal pollution (*5*). Taste and odour problems as well as decreased disinfection efficiency are to be expected if drinking-water containing more than 0.2 mg of ammonia per litre is chlorinated (*9*), as up to 68% of the chlorine may react with the ammonia and become unavailable for disinfection (*10*). Cement mortar used for coating the insides of water pipes may release considerable amounts of ammonia into drinking-water and compromise disinfection with chlorine (*10*).

The presence of elevated ammonia levels in raw water may interfere with the operation of manganese-removal filters because too much oxygen is consumed by nitrification, resulting in mouldy, earthy-tasting water (*8*). The presence of the ammonium cation in raw water may result in drinking-water containing nitrite as the result of catalytic action (*11*) or the accidental colonization of filters by ammonium-oxidizing bacteria.

Food

Ammonium is a natural component of many foods. Minor amounts of ammonium compounds (<0.001–3.2%) are also added to foods as acid regulators, stabilizers, flavouring substances, and fermentation aids (*1*).

Estimated total exposure and relative contribution of drinking-water

The estimated daily ammonia intake through food and drinking-water is 18 mg, by inhalation less than 1 mg, and through cigarette smoking (20 cigarettes per day) also less than 1 mg. In contrast, 4000 mg of ammonia per day are produced endogenously in the human intestine (*1*).

KINETICS AND METABOLISM IN LABORATORY ANIMALS AND HUMANS

Ammonia is a key metabolite in mammals. It has an essential role in acid–base regulation and the biosynthesis of purines, pyrimidines, and non-essential amino acids (*2*). It is formed in the body by the deamination of amino acids in the liver, as a metabolite in nerve excitation and muscular activity, and in the gastrointestinal tract by the enzymatic breakdown of food components with the assistance of bacterial flora [Source: *Hazardous Substances Data Bank: Ammonia.* Bethesda, MD, National Library of Medicine, 1990]. About 99% of metabolically produced ammonia is absorbed from the gastrointestinal tract and transported to the liver, where it is incorporated into urea as part of the urea cycle. Urea formed in the liver is absorbed by the blood, transferred to the kidney, and excreted in urine (*2*). Of the ammonia found in urine, two-thirds originates from the tubular epithelium of the kidney where, as a product of the glutaminase reaction, it maintains the acid–base equilibrium by the uptake of hydrogen ions (*1*).

EFFECTS ON LABORATORY ANIMALS AND *IN VITRO* TEST SYSTEMS

Acute exposure

Oral LD_{50} values for ammonium salts are in the range 350–750 mg/kg of body weight (*4*). Single doses of different ammonium salts at 200–500 mg/kg of body weight resulted in lung oedema, nervous system dysfunction, acidosis, and kidney damage (*1*).

Short-term exposure

Animals subchronically exposed to different ammonium salts (75–360 mg/kg of body weight as the ammonium ion) in drinking-water exhibited physiological adaptation to induced acidosis, slight organ effects, or increased blood pressure (*1,2*).

Long-term exposure

In male Sprague-Dawley rats given drinking-water containing 1.5% ammonium chloride (about 478 mg of ammonium ion per kg of body weight per day) over a period of 330 days, significant decreases were found in bone mass, calcium content, and blood pH. The treated animals also had lower body weights and lower fat accumulation than controls (*1*).

Reproductive toxicity, embryotoxicity, and teratogenicity

Oral administration of different ammonium compounds at doses of 100–200 mg/kg of body weight to impuberal female rabbits resulted in enlargement of the ovaries and uterus, hypertrophy of the breast with milk secretion, follicular ripening, and formation of the corpus luteum. A dose of 0.9% ammonium chloride (approximately 290 mg of ammonia per kg of body weight per day) in the drinking-water of pregnant rats inhibited fetal growth but had no teratogenic effects (*1*).

Mutagenicity and related end-points

At high concentrations, positive results in the Balb e/3T3-transformation test, the sex-linked dominant/lethal mutation test, and chromosomal aberrations in fibroblasts of Chinese hamsters were observed; other genotoxicity tests gave negative results (*2*).

Carcinogenicity

There is no evidence that ammonia is carcinogenic (*2*).

EFFECTS ON HUMANS

Ammonia has a toxic effect on healthy humans only if the intake becomes higher than the capacity to detoxify.

If ammonia is administered in the form of its ammonium salts, the effects of the anion must also be taken into account. With ammonium chloride, the acidotic effects of the chloride ion seem to be of greater importance than those of the ammonium ion (*1*). At a dose of more than 100 mg/kg of body weight per day (33.7 mg of ammonium ion per kg of body weight per day), ammonium chloride influences metabolism by shifting the acid–base equilibrium, disturbing the glucose tolerance, and reducing the tissue sensitivity to insulin (*2*).

CONCLUSIONS

Ammonia is not of direct importance for health in the concentrations to be expected in drinking-water. A health-based guideline has therefore not been derived.

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