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Zinc 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

Zinc occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulfides, such as sphalerite and wurzite (*1*). The natural zinc content of soils is estimated to be 1–300 mg/kg (*2*).

Physicochemical properties

Property	*Value*
Physical state	Bluish-white metal
Melting point	419.58 °C
Boiling point	907 °C
Density (g/cm^3)	7.14 at 20 °C

Organoleptic properties

Zinc imparts an undesirable astringent taste to water. Tests indicate that 5% of a population could distinguish between zinc-free water and water containing zinc at a level of 4 mg/litre (as zinc sulfate). The detection levels for other zinc salts were somewhat higher. Water containing zinc at concentrations in the range 3–5 mg/litre also tends to appear opalescent and develops a greasy film when boiled (*3*).

Major uses

Zinc is used in the production of corrosion-resistant alloys and brass, and for galvanizing steel and iron products. Zinc oxide, used in rubber as a white pigment, for example, is the most widely used zinc compound. Peroral zinc is occasionally used to treat zinc deficiency in humans. Zinc carbamates are used as pesticides (*1*).

ANALYTICAL METHODS

Atomic absorption spectrophotometry is the most widely used method for the determination of zinc. The detection limit of the direct air–acetylene flame method is 50 µg/litre (*4*). Low concentrations can be measured by chelating zinc with ammonium pyrrolidine dithiocarbamate and extracting it with methyl isobutyl ketone (detection limit 0.5–1 µg/litre) (*5*).

ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

Air

In rural areas, atmospheric zinc concentrations are typically between 10 and 100 ng/m^3, whereas levels in urban areas commonly fall within the range 100–500 ng/m^3 (*2*). Mean concentrations of zinc associated with particulate matter in ambient air in Canada were 85 ng/m^3 (*6*) and in Finland, 170 ng/m^3 (*7*).

Water

In natural surface waters, the concentration of zinc is usually below 10 µg/litre, and in groundwaters, 10–40 µg/litre (*1*). In tapwater, the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings (*2*). The most corrosive waters are those of low pH, high carbon dioxide content, and low mineral salts content. In a Finnish survey of 67% of public water supplies, the median zinc content in water samples taken upstream and downstream of the waterworks was below 20 µg/litre; much higher concentrations were found in tapwater, the highest being 1.1 mg/litre (*8*). Even higher zinc concentrations (up to 24 mg/litre) were reported in a Finnish survey of water from almost 6000 wells (*9*).

Food

Protein-rich foods, such as meat and marine organisms, contain high concentrations of zinc (10–50 mg/kg wet weight), whereas grains, vegetables, and fruit are low in zinc (usually <5 mg/kg) (*1*).

Estimated total exposure and relative contribution of drinking-water

Values of 5–22 mg have been reported in studies on the average daily intake of zinc in different areas (*1*). The zinc content of typical mixed diets of North American adults varies between 10 and 15 mg/day (*10*). In Finland, the average daily intake of zinc from foodstuffs is calculated to be 16 mg (*11*). The recommended dietary allowance for adult men is set at 15 mg/day, for adult women 12 mg/day, for formula-fed infants 5 mg/day, and for preadolescent children 10 mg/day (*12,13*).

Drinking-water usually makes a negligible contribution to zinc intake unless high concentrations of zinc occur as a result of corrosion of pipings and fittings. Under certain circumstances, tapwater can provide up to 10% of the daily intake (*9,14*).

KINETICS AND METABOLISM IN LABORATORY ANIMALS AND HUMANS

Absorption of ingested zinc is highly variable (10–90%) and is affected by a number of factors. Homeostatic mechanisms exist for the gastrointestinal absorption and excretion of zinc. High zinc concentrations are found in prostate, bone, muscle, and liver. Excretion takes place mainly (75%) via the gastrointestinal tract, and only to a smaller extent via urine and sweat. The biological half-time of retained zinc in humans is of the order of 1 year (*1*).
Zinc is an essential element in all living organisms. Nearly 200 zinc-containing enzymes have been identified, including many dehydrogenases, aldolases, peptidases, polymerases, and phosphatases (*15*).

EFFECTS ON LABORATORY ANIMALS AND *IN VITRO* TEST SYSTEMS

Acute exposure

Acute oral LD_{50} values in rats are reported to be as follows: zinc chloride 350, zinc sulfate 2949, and zinc ethanoate 2510 mg/kg of body weight (*16*).

Long-term exposure

Zinc toxicosis has been documented in various mammalian species, including ferrets, sheep, cattle, pigs, horses, and dogs, mostly taking the form of copper deficiency caused by excessive zinc intake (*1,17*). Signs of toxicosis among a herd of 95 calves began to appear when calves were fed 1.2–2 g of zinc per day and exposed to a cumulative zinc intake of 42–70 g per calf (*18*). A high-zinc diet has been shown to induce hypocalcaemia and bone resorption in rats (*19*).

The antagonistic effects of zinc on the toxic effects of other metals, including cadmium, lead, and nickel, have been described in several reports (*20–22*).

Carcinogenicity

One study with rats given zinc ethanoate (1.5 g of zinc per litre) in drinking-water indicated that there was an increase in the number of metastases following the intravenous injection of cells from a benzpyrene-induced sarcoma (*23*).

EFFECTS ON HUMANS

Nutritional zinc deficiency in humans has been reported in a number of countries (*24–27*).

Acute toxicity arises from the ingestion of excessive amounts of zinc salts, either accidentally or deliberately as an emetic or dietary supplement. Vomiting usually occurs after the consumption of more than 500 mg of zinc sulfate. Mass poisoning has been reported following the drinking of acidic beverages kept in galvanized containers; fever, nausea, vomiting, stomach cramps, and diarrhoea occurred 3–12 h after ingestion. Food poisoning attributable to the use of galvanized zinc containers in food preparation has also been reported; symptoms occurred within 24 h and included nausea, vomiting, and diarrhoea, sometimes accompanied by bleeding and abdominal cramps (*1*).

Manifest copper deficiency, which is the major consequence of the chronic ingestion of zinc (*13*), has been caused by zinc therapy (150–405 mg/day) for coeliac disease, sickle cell anaemia, and acrodermatitis enteropathica (*28–30*). Impairment of the copper status of volunteers by dietary intake of 18.5 mg of zinc per day has been reported (*31*). Zinc supplementation of healthy adults with 20 times the recommended dietary allowance for 6 weeks resulted in the impairment of various immune responses (*32*). Gastric erosion is another reported complication of a daily dosage of 440 mg of zinc sulfate (*1*). Daily supplements of 80–150 mg of zinc caused a decline in high-density lipoprotein cholesterol levels in serum after several weeks (*1*), but this effect was not found in some other studies. In an Australian study, no detrimental effect of 150 mg of zinc per day on plasma copper levels was seen in healthy volunteers over a period of 6 weeks (*33*).

Acute toxic effects of inhaled zinc have been reported in industrial workers exposed to zinc fumes (*1*); the symptoms include pulmonary distress, fever, chills, and gastroenteritis.

In a small-scale study on zinc-refinery workers, no evidence was found of increased mortality from any type of cancer (*1*). In subjects with low baseline levels of serum zinc, no significant difference in the risk of death from cancer or cardiovascular diseases, as compared with those with high baseline levels, was observed (*34*).

CONCLUSIONS

In 1982, JECFA proposed a daily dietary requirement of zinc of 0.3 mg/kg of body weight and a provisional maximum tolerable daily intake (PMTDI) of 1.0 mg/kg of body weight (*35*). The daily requirement for adult humans is 15–22 mg/day. It was concluded that, in the light of recent studies on humans, the derivation of a health-based guideline value is not required at this time. However, drinking-water containing zinc at levels above 3 mg/litre tends to be opalescent, develops a greasy film when boiled, and has an undesirable astringent taste.

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