

# Hardness 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*

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce a lather. It is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations, e.g. barium, iron, manganese, strontium and zinc, also contribute. Hardness is most commonly expressed as milligrams of calcium carbonate equivalent per litre, water containing less than 60 mg of calcium carbonate per litre generally being considered as soft. Although hardness is caused by cations, it may also be discussed in terms of carbonate (temporary) and noncarbonate (permanent) hardness.

### *Sources*

The principal natural sources of hardness in water are dissolved polyvalent metallic ions from sedimentary rocks, seepage, and run-off from soils. Calcium and magnesium, the two principal ions, are present in many sedimentary rocks, the most common being limestone and chalk. They are also present in a wide variety of industrial products and are common constituents of food. As mentioned above, a minor contribution to the total hardness of water is also made by other polyvalent ions, e.g. aluminium, barium, iron, manganese, strontium, and zinc.

### *Organoleptic properties*

The taste threshold for the calcium ion is in the range 100–300 mg/litre, depending on the associated anion, but higher concentrations are acceptable to consumers. Hardness levels above 500 mg/litre are generally considered to be aesthetically unacceptable, although this level is tolerated in some communities (1).

## ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

### *Water*

Concentrations of up to 100 mg of calcium per litre are fairly common in natural sources of water; sources containing over 200 mg of calcium per litre are rare. Magnesium salts are soluble, natural water sources typically containing concentrations of up to 10 mg/litre. Such sources rarely contain more than 100 mg of magnesium per litre, and it is usually calcium hardness that predominates (2).

In drinking-water, hardness is in the range 10–500 mg of calcium carbonate per litre (3). Estimated daily intakes of 2.3 and 52.1 mg of magnesium in soft- and hard-water areas, respectively, have been reported, based on adults drinking 2 litres of water per day (4).

### *Food*

Virtually all foods contain calcium and magnesium, and dietary intake is the principal route of exposure. Typical diets provide about 1000 mg of calcium per day and 200–400 mg of magnesium per day. Dairy products are a particularly rich source of calcium, whereas magnesium tends to be associated more with meat and foodstuffs of plant origin (4–6).

### ***Estimated total exposure and relative contribution of drinking-water***

The typical dietary contribution of calcium and magnesium is over 80% of the total daily intake. Of this, approximately 30% of calcium and 35% of magnesium will be absorbed. For calcium and magnesium, the typical contribution from water is 5–20% (2,5,6).

### **EFFECTS ON HUMANS**

There does not appear to be any convincing evidence that water hardness causes adverse health effects in humans. In contrast, the results of a number of epidemiological studies have suggested that water hardness may protect against disease. However, the available data are inadequate to prove any causal association.

#### ***Cardiovascular disease***

In most large-scale studies, an inverse relationship between the hardness of drinking-water and cardiovascular disease has been reported (7–13). However, no such association has been found in some studies (14,15), and in those involving small geographical areas a clear association is often not found (16).

The extent to which confounding variables, such as climatic, socioeconomic, or major risk factors, may account for the inverse relationship is unclear. Nevertheless, in a number of studies, a weak inverse relationship was reported after allowance was made for climatic and socioeconomic factors (17) and after major risk factors such as hypertension, smoking habits, and elevated serum lipids were taken into account (18,19). An inverse relationship between hardness and cardiovascular disease had been reported in men after allowing for climatic and certain social factors, but only up to about 170 mg of calcium carbonate per litre (20).

A variety of hypotheses have been proposed to explain the possible inverse association (21–27). However, none has been fully substantiated, nor has a particular element been found to be conclusively associated with cardiovascular disease.

#### ***Other health effects***

The results of several studies have suggested that a variety of other diseases are also inversely correlated with the hardness of water, including anencephaly (28,29) and various types of cancer (30,31). However, the significance of these results is unclear, and it has been suggested that the associations may reflect disease patterns that can be explained by social, climatological, and environmental factors, rather than by the hardness of the water. Some data suggest that very soft waters with a hardness of less than 75 mg/litre may have an adverse effect on mineral balance, but detailed studies are not available.

### **OTHER CONSIDERATIONS**

Depending on the interaction of other factors, such as pH and alkalinity, water with a hardness above approximately 200 mg/litre may cause scale deposition in the distribution system, as well as increased soap consumption. In contrast, soft water, with a hardness less than about 100 mg/litre, has a greater tendency to cause corrosion of pipes, resulting in the presence of certain heavy metals, such as cadmium, copper, lead, and zinc, in drinking-water (2). The degree to which this corrosion and solubilization of metals occurs also depends on the pH, alkalinity, and dissolved oxygen concentration.

## CONCLUSIONS

Although a number of epidemiological studies have shown a statistically significant inverse relationship between the hardness of drinking-water and cardiovascular disease, the available data are inadequate to permit the conclusion that the association is causal. No health-based guideline value for water hardness is proposed.

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