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# Calcium

There is no evidence of adverse health effects specifically attributable to calcium in drinking water. Insufficient data are available to set a specific value for an aesthetic objective for calcium in drinking water. A guideline for calcium has therefore not been specified.

## General

Calcium is the fifth most abundant natural element. It enters the freshwater system through the weathering of rocks, especially limestone, and from the soil through seepage, leaching and runoff.<sup>(1)</sup> The average concentration of calcium in soil is about  $1.37 \times 10^4$  mg/kg.<sup>(2)</sup> The leaching of calcium from soil has been found to increase significantly with the acidity of rainwater.<sup>(3)</sup>

Calcium oxide (lime) is used extensively in mortar, stucco and plaster in the building industry. It is used in pulp and paper production, sugar refining, petroleum refining and tanning.<sup>(4)</sup> Lime is also widely used as a wastewater treatment chemical. In 1985, the total consumption of lime in Canada was estimated to be 1 842 800 tonnes.<sup>(5)</sup>

## Occurrence

The concentration of calcium in water depends on the residence time of the water in calcium-rich geological formations.

Measurements of water samples collected from 71 municipalities across Canada showed that the mean calcium concentrations were 21.8 (1.3 to 77.3), 18.2 (1.6 to 55.8) and 21.4 ( $\leq 1.1$  to 112.8) mg/L for raw, treated and distributed water, respectively. Raw water supplies that received lime treatment showed significant increases in the amount of calcium in the treated water (e.g., for Ottawa, the calcium concentration increased from 8.6 mg/L in raw water to 16.3 mg/L in treated water).<sup>(6)</sup>

Surface water generally contains lower concentrations of calcium than groundwater.<sup>(7)</sup> A 1977 survey of Canadian surface waters reported low calcium concentrations in Newfoundland, Quebec, British Columbia and the Northwest Territories.<sup>(8)</sup> The highest concentration, 365 mg/L, was recorded in Prince Edward Island, and the lowest, 0.3 mg/L, in Newfoundland. Data collected from 24 stations in Saskatchewan in 1980 and 1981 showed that the

concentration of calcium in surface waters ranged from 2 to 141 mg/L,<sup>(9)</sup> whereas the average concentrations from sampling stations in all provinces ranged from 1 to 336 mg/L.

The concentration of calcium in the Great Lakes ranges from 13 to 40 mg/L<sup>(10,11)</sup>; industrial effluent loadings of calcium in these lakes during 1973 to 1975 were 14 800 tonnes/year for Lake Superior and 6200 tonnes/year for Lake Huron.<sup>(10)</sup> The environmental concentration of calcium in Canadian surface waters during 1980 to 1985 ranged from <0.002 mg/L to a high of 1370 mg/L, the high being recorded in Bench Mark Creek in Alberta.<sup>(9)</sup>

Atmospheric calcium is derived mainly from industrial activities.<sup>(12)</sup> A major source of atmospheric calcium is the burning of fossil fuels, which contain calcium at concentrations of approximately 10 000 mg/kg.<sup>(13)</sup> Atmospheric loading of calcium in the Great Lakes basin is estimated to be greater than 100 000 tonnes.<sup>(10,14)</sup> Reported concentrations of calcium (in particulates) in air over Edmonton in 1978 to 1979 showed a marked seasonal variation, peaking in the summer. For the three one-month periods (November, March/April and July/August) during which air concentrations were measured, the mean concentrations were 1.6, 2.2 and 2.6  $\mu\text{g}/\text{m}^3$ , respectively. Low enrichment factors support the conclusion that a substantial portion of the calcium was of natural origin.<sup>(15)</sup> Calcium concentrations measured over Windsor, Ontario, averaged 0.078 mg/ $\text{m}^3$  during a day of abundant particulate pollution and 0.009 mg/ $\text{m}^3$  when pollution was less abundant.<sup>(16)</sup> Calcium concentrations in rainwater in a rural area near Toronto ranged from 0.1 to 0.4 mg/L.<sup>(17)</sup>

The concentrations of calcium in certain foods are as follows: 12 800 mg/kg in dried skimmed milk, 8000 mg/kg in cheese, 100 mg/kg in meat, 250 to 1200 mg/kg in fish, 30 to 2220 mg/kg in fruit and vegetables and 0 to 150 mg/kg in fats.<sup>(18,19)</sup>

## Canadian Exposure

It has been estimated that the daily intake of calcium from the average Canadian diet is 1000 mg,<sup>(20)</sup> although some women consume less than 800 mg/day.<sup>(21,22)</sup> Drinking water in Canada usually

contains between 1.1 and 112.8 mg/L calcium.<sup>(6)</sup> These values are used in Table 1 to estimate the contribution of drinking water to the total calcium intake.

**Table 1. Contribution of Drinking Water to Intake of Calcium**

Type of water	Water (mg/day)*	RNI** (mg/day)	Total	Percent from water
Soft water (1.1 mg/L Ca <sup>2+</sup> )	1.65	800	801.7	0.2
Hard water (112.8 mg/L Ca <sup>2+</sup> )	169.2	800	969.2	17.5

\* Based on an estimated intake of 1.5 L/day of drinking water by Canadians.<sup>(23)</sup>

\*\* Typical recommended nutrient intake (RNI) for adult males.<sup>(20,24)</sup>

## Analysis

Air-acetylene flame atomic absorption spectrometry (AAS) and inductively coupled plasma (ICP) emission spectrometry are accurate methods for determining calcium in water. Two other methods, titration with permanganate and titration with ethylenediaminetetraacetic acid (EDTA) or its salts provide good results for control and routine applications at higher concentrations. The EDTA titration procedure is preferable to the permanganate method because of its simplicity and rapidity.<sup>(25)</sup>

The detection limit of the AAS method on direct aspiration is 3 µg/L, and the optimum concentration ranges from 0.2 to 20 mg/L. The recovery of added calcium in a spiked sample is between 85 and 115 percent. The detection limit of the ICP method is 10 µg/L at a 317.93 nm wavelength.<sup>(25)</sup>

## Treatment Technology

Calcium is one of the principal cations associated with hardness in drinking water. The hardness of water can range from less than 75 mg/L as CaCO<sub>3</sub> (considered a soft water) to more than 300 mg/L as CaCO<sub>3</sub> (considered a very hard water).<sup>(26)</sup>

Calcium can be efficiently removed from source water by softening the water either by ion exchange or by chemical precipitation. Because of the variation in consumer acceptance of hardness in drinking water, the finished water hardness produced by different utility softening plants will range from 50 to 150 mg/L as CaCO<sub>3</sub>.<sup>(26)</sup>

## Health Considerations

### Absorption, Distribution and Excretion

Calcium is primarily absorbed in the proximal portion of the small intestine by a vitamin D-enhanced active transport process. The amount of calcium absorbed from the diet depends on the concentrations of a number of dietary components, as well as on non-dietary factors, such as pH of the intestine. Absorption

ranges widely, from 12 to 67 percent, and is the chief means of controlling body calcium concentrations.

The total body burden of calcium in an adult male is about 1010 g, of which >99 percent is associated with the skeleton and only 0.1 percent with the extracellular fluids. The extracellular concentrations are regulated by parathyroid hormone and calcitonin, which, respectively, increase and decrease the calcium concentrations. A calcium buffer is provided by the bones, where 0.5 to 1.0 percent of the total bone mass, consisting of calcium phosphate compounds, is rapidly available.

About 180 mg calcium are excreted daily in the urine, compared to 740 mg in the faeces and 30 to 150 mg in sweat. Both faecal and urinary calcium vary with intake.<sup>(27)</sup>

### Adverse Effects

Because of the efficient homeostatic mechanisms that control calcium metabolism, adverse effects are observed only following the intake of extremely large quantities of calcium. High dietary calcium levels may adversely affect the bioavailability of other minerals in the diet. Calcium, in association with phosphate, may reduce iron absorption.<sup>(28)</sup> Magnesium balance is reportedly affected by dietary calcium,<sup>(29,30)</sup> although there is some evidence to the contrary.<sup>(31)</sup> There is evidence that the relationship between dietary calcium and magnesium may vary with age and sex.<sup>(32)</sup> Zinc absorption is affected by dietary calcium in animals<sup>(33)</sup> but apparently not in humans.<sup>(34,35)</sup> Foods that are high in both calcium and phosphorus, however, may inhibit zinc absorption.<sup>(36)</sup> Both chromium<sup>(37)</sup> and manganese<sup>(38)</sup> absorption appear to be inhibited by high dietary calcium concentrations. The presence of calcium in drinking water could reduce the availability of copper as a result of the less aggressive leaching of copper in the delivery system.<sup>(39)</sup>

### Beneficial Effects

Calcium blocks the absorption of heavy metals, and it has been found, for example, that a low-calcium diet increases the susceptibility of rats to lead poisoning.

Adequate calcium in the diet of humans under the age of 30 is thought to retard the development of osteoporosis through an increase in bone mass. For post-menopausal women and men over 60 years of age, it has been suggested,<sup>(40)</sup> but is not universally accepted,<sup>(41)</sup> that increased dietary calcium could slow down the process of bone resorption. A greater incidence of eclampsia during pregnancy is reported in populations on a low-calcium diet.<sup>(42)</sup> Calcium supplements have been shown to lower the blood pressure of pregnant women.<sup>(43)</sup>

A diet rich in calcium may prevent colon cancer in humans<sup>(44)</sup> and may, in fact, reverse early signs of colorectal cancer.<sup>(45)</sup> Colorectal cancer occurs more

frequently than anticipated in people drinking soft, low-calcium water.<sup>(46)</sup>

Dietary calcium has also been proposed as an anti-hypertensive agent. This is supported by evidence from large-scale epidemiological studies,<sup>(42,47)</sup> dietary surveys,<sup>(48,49)</sup> intervention dietary studies<sup>(50–52)</sup> and experimental physiological studies.<sup>(53–55)</sup>

Supplemental dietary calcium reduced plasma cholesterol in young goats.<sup>(56)</sup> However, when both calcium and vitamin D were supplemented in these studies, there was a significantly greater incidence of aortic calcification, which is also considered to be a sign of atherosclerotic lesions. Hard drinking water could, therefore, be an important supplementary calcium source, as its beneficial effects would not be offset by increased vitamin D intake, as would occur upon intake of dairy products supplemented with vitamin D.

There are several proposed biological mechanisms involving calcium that could account for some of the statistical relationships provided by epidemiological studies<sup>(57,58)</sup> between hard drinking water and a lower incidence of cardiovascular disease (see “Hardness” review in the Supplementary Documentation).

## Other Considerations

As a contributor to hardness, calcium can have detrimental effects on drinking water quality. These effects are mainly aesthetic and are discussed in the “Hardness” review in the Supplementary Documentation.

## Conclusion

1. There is no evidence of adverse health effects specifically attributable to calcium in drinking water.
2. Undesirable effects due to the presence of calcium in drinking water may result from its contribution to hardness. These effects have been dealt with in the “Hardness” review in the Supplementary Documentation.
3. A separate maximum acceptable concentration for calcium has, therefore, not been specified.

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