Magnesium

There is no evidence of adverse health effects specifically attributable to magnesium in drinking water. A guideline for magnesium has therefore not been specified.

General

Magnesium is the eighth most abundant natural element. It makes up 2.5 percent of the Earth's crust and is commonly found in such minerals as magnesite, dolomite, olivine, serpentine, talc, and asbestos.[1–3] It is present in all natural waters and is a major contributor to water hardness. Ferromagnesian mineral igneous rocks and magnesium carbonates in sedimentary rocks are generally considered to be the principal sources of magnesium in natural waters.

Over 55 percent of the magnesium consumed in 1984 was used as an alloying agent with aluminum. Aluminum–magnesium alloys are used in beverage cans, pressure die-cast products, electrical equipment, portable tools, sports equipment, and many other products.[4] Magnesium is used as a deoxidizing and desulphurizing agent in the ferrous metal industry and as a reducing agent in the production of titanium, zirconium, and other reactive metals. Pure magnesium metal is used to protect steel structures from corrosion and has many applications in the chemical industry, including use as Grignard reagents. Total consumption of magnesium in Canada in 1984 was 6830 tonnes.[4] In 1984, 8000 tonnes of magnesium were produced in Canada, 4287 tonnes were imported into the country, and 4022 tonnes were exported.[4]

Occurrence

Water from areas rich in magnesium-containing rocks may contain magnesium in the concentration range 10 to 50 mg/L. The sulphates and chlorides of magnesium are very soluble, and water in contact with such deposits may contain several hundred milligrams of magnesium per litre.[5] Industrial effluents may contain similarly high levels of magnesium per litre;[5] loadings of magnesium in Lake Superior and Lake Huron during the period 1973 to 1975 were 3146 and 650 tonnes/year, respectively.[6]

In surveys of surface water quality in Canada, it was found that magnesium levels vary greatly with location and often with season. Concentrations were usually below 25 mg/L, although concentrations as high as 168 mg/L have been found.[7] Magnesium concentrations in ground water in Prince Edward Island averaged 4 mg/L, with a range of 0.6 to 21 mg/L.[8] Two national surveys of drinking water supplies, encompassing 115 municipalities across Canada, were conducted in 1976 and 1977;[9,10] magnesium concentrations in distributed water ranged from 0.2 to 59.5 mg/L. The highest median concentrations were found in Alberta, Saskatchewan, and Manitoba (17, 28, and 23 mg/L, respectively), whereas median concentrations in most other locations were below 5 mg/L. The magnesium contents of raw, treated, and distributed waters were approximately the same for most samples, exceptions occurring where raw water was softened by treatment. In a recent survey of 65 municipalities in Ontario, the median concentration of magnesium was 4 mg/L, with a range of <1 to 56 mg/L.[11]

Magnesium levels in air are closely related to the extent of particulate pollution.[12] In Windsor, Ontario, the average magnesium concentration on a day with heavy particulate pollution was 0.009 mg/m^3; the corresponding average when there was little particulate pollution was 0.00046 mg/m^3.[12] Studies of magnesium levels in urban air over several U.S. cities showed a wide range of magnesium concentrations in particulates, from 0.00036 to 0.00721 mg/m^3.[13–15] Air samples collected over an industrialized area in northwest Indiana contained magnesium at a concentration of 0.00135 mg/m^3 in particulates; in comparison, a concentration of 0.0009 mg/m^3 was reported in a semirural area. The sources of emission were cement and steel industries and the combustion of coal.[16]

The average Canadian diet provides about 130 mg of magnesium per 1000 kcal (31.1 mg/1000 kJ); about two-thirds of the magnesium is supplied by cereals and vegetables, and about one-fifth is provided by dairy products.[17] Average magnesium concentrations in some foods are: seafood, 0.35 mg/g; meat, 0.27 mg/g; cereals

and grains, 0.8 mg/g; dairy products, 0.15 mg/g; vegetables, 0.22 mg/g; fruits, 0.08 mg/g; nuts, 1.97 mg/g; and oils and fats, 0.007 mg/g.[18,19]

Canadian Exposure

The estimated daily intake of magnesium for Canadians consuming an average diet is 205 mg for children and between 200 and 300 mg for adults.[1] The intake of magnesium from drinking water varies widely, depending on the hardness of the water. Daily intake from ingesting 1.5 L of water daily would range from 1.5 mg (soft water, 1 mg/L magnesium) to 37.5 mg (hard water, 25 mg/L magnesium). Magnesium in air is not considered to contribute significantly to the total intake of this element.

Total daily intake of magnesium from all sources ranges between 200 and 340 mg. Drinking water contributes 0.6 and 13 percent of the total intake in soft and hard water areas, respectively.

Health Considerations

The body contains about 25 g of magnesium, making it the fourth most common mineral constituent in the body.[17] More than half the magnesium is in bone (67 percent); the remainder is found intracellularly in soft tissues (31 percent) and, to a lesser degree, in body fluids (approximately 1 percent).

Essentiality

Magnesium is an essential element in human metabolism and is required for over 300 enzyme reactions,[20] including all reactions requiring adenosine triphosphate.[21] Magnesium is required to regulate cell permeability, and inadequate levels of magnesium will severely affect cardiovascular, neuromuscular, and renal functions.

Under normal conditions, magnesium levels are carefully regulated, and short-term dietary deficiencies can be overcome by the large available pool of magnesium in bone. However, depletion can occur as a result of vomiting, diarrhoea, use of certain diuretics, alcoholism, and protein malnutrition.[22] Deficiency produces weakness, mental disorder, lessening of muscle control, and gastrointestinal disorders. Because magnesium in the myocardium exchanges more readily than does the magnesium in skeletal muscles, it has been suggested that long-term magnesium deficiency may be a factor in cardiovascular disease.[23–26]

In Canada, the recommended daily requirement for magnesium is 300 mg for males and 250 mg for females.[17]

Absorption, Distribution, and Excretion

Magnesium is absorbed in the small intestine with an efficiency of between 45 and 55 percent.[27] It has been proposed that magnesium is absorbed via a passive, concentration-dependent mechanism, quite possibly facilitated diffusion.[27] Hormonal control of magnesium absorption is still unclear; however, it has been proposed that vitamin D may play a role.[28] Other inorganic ions such as calcium, phosphorus, potassium, and certain trace metals have been reported to influence magnesium absorption, but the nature and extent of these interactions are not yet known.[27] Dietary fibre may decrease magnesium absorption in man, whereas some carbohydrates may increase it.[27] Dietary proteins have also been reported to increase magnesium absorption in man.[26,29]

The concentration of magnesium in plasma is maintained between 1.9 and 2.6 mg/dL (1.6 to 2.1 meq/L), of which about 20 percent is bound to protein.[30] The magnesium content of soft tissues ranges from 15 to 22 mg/100 g (6 to 9 mmol/kg) and is mainly intracellular or membrane-bound.[31]

Magnesium levels in the body are primarily controlled by the kidney, with as little as 2 percent of endogenous magnesium excreted in the faeces.[32,33] Normal renal regulation of magnesium usually consists of glomerular filtration and tubular reabsorption, which are hormonally controlled. Because the renal threshold for magnesium (between 1.3 and 1.7 meq/L) is near normal serum values, a portion of dietary magnesium will appear in the urine, regardless of magnesium status.[30] The maximum renal capacity is over 2.0 g/day.

Adverse Effects

The most readily observable adverse effect of magnesium in drinking water is the laxative effect, particularly with magnesium sulphate at concentrations above 700 mg/L.[34] However, the human body can adapt to this laxative effect with time. Toxicity has been reported in the elderly as a result of the extensive use of certain laxatives (magnesium sulphate) and antacids (magnesium hydroxides).[22] This population, however, may also have a reduced renal clearance.[22] At serum concentrations of 5 to 10 meq/L (6 to 12 mg/dL), changes in heartbeat may occur.[35] Skeletal muscle paralysis, respiratory depression, coma, and death occur at plasma concentrations of 15 meq/L (18 mg/dL).

Beneficial Effects

There is evidence that hard drinking water is associated statistically with reduced mortality.[36–39] Although causality has yet to be agreed upon, it is possible that this protective action could be due to the presence of an intrinsic factor in the water, such as calcium, magnesium, and/or other trace elements.

Alternatively, it could be due to the fact that hard water prevents the mobilization of known toxins, such as cadmium, lead, and other toxic substances, which can be leached out of the delivery systems. It is also possible that hard water prevents the toxic effects of a natural soft water constituent.

Numerous studies from different parts of the world have linked magnesium content in drinking water to a decrease in cardiovascular disease;[23,25,40–42] however, it has been argued that all of the protective effects of hard drinking water cannot be due to magnesium alone.[37,38] (See section on hard water.)

Other Considerations

Magnesium is one of the major contributors to water hardness, which is discussed in a separate review. Magnesium may also contribute undesirable tastes to drinking water. The taste threshold has been reported to be 100 mg/L for sensitive individuals and about 500 mg/L for the average person.[34] These levels are well above the magnesium concentrations encountered in most Canadian drinking waters.

Conclusion

1. There is no evidence of adverse health effects specifically attributable to magnesium in drinking water.

2. Undesirable effects may result indirectly from the laxative effect of magnesium in association with the sulphate ion. These effects are dealt with in the review of sulphate.

3. Therefore, a maximum concentration for magnesium has not been specified.

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