Rolling Revision of the
WHO Guidelines for Drinking-Water Quality

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Consensus of the Meeting:

Nutrient minerals in drinking-water and the potential health consequences of long-term consumption of demineralized and remineralized and altered mineral content drinking-waters

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Introduction

Desalination of sea and brackish water is widely practiced and rapidly growing as the principal source of new fresh water in the world. Water treatment processes including desalination followed by remineralization alter the mineral composition of drinking water compared to water derived from many conventional fresh water sources. The WHO Guidelines for Drinking-water Quality (GDWQ) provide a point of reference for drinking water quality regulations and standards setting world-wide. The Guidelines are kept up-to-date through a process of 'rolling revision' which include the development of accompanying documents substantiating the contents of the guidelines and providing guidance on experience with good practice in achieving safe drinking-water. This plan of work includes the development of guidance on good practices of desalination as a source of safe drinking water.

To examine the nutritional aspects of water consumption as part of the process for guidance development, WHO assembled a group of nutrition, medical and scientific experts on November 11-13, 2003 in Rome, Italy at the WHO European Centre for Environment and Health. The meeting was attended by 18 technical participants from Canada, Chile, Czech Republic, Germany, Ireland, Italy, Moldova, Singapore, Sweden, UK and USA. The task was to examine the potential health consequences of long term consumption of water that has been 'manufactured or modified' to add or delete minerals and thus may have altered mineral content.

We wish to express our appreciation and gratefully acknowledge the organizations that provided financial and other support for the meeting. These included the International Life Sciences Institute (ILSI); the U.S. Environmental Protection Agency Offices of Ground Water and Drinking Water (Washington, D.C.), and Research and Development (Research Triangle Park, North Carolina); the American Water Works Association Research Foundation; the Center for Human Nutrition, University of Nebraska Medical Center, Omaha, Nebraska USA; and Health Canada, Water Quality and Health Bureau, Ottawa, Ontario Canada. WHO, Water Sanitation and Health, Geneva. WHO European Regional Office, Rome. WHO, EMRO, Cairo.

Expert Committee Members: Roger Aertgeerts, Rebecca Calderon, Gerald Combs, Joseph Cotruvo, Gunther Craun, Jan Ekstrand, Floyd Frost, John Fawell, Ann Grandjean, Suzanne Harris, Frantizek Kozisek, Michael Lennon, Silvano Monarca, Denis O'Mullane, Manuel Olivares, Choon Nam Ong, Souleh Semalulu, Ion Shalaru, Erika Sievers. Contributors: Charles Abernathy, Kunal Bagchi, Jamie Bartram, Leslie Klevay, F. Donato, Joyce Donohue, George Hallberg, Peter Lassovszky, Curtis Morris, Ricardo Uauy, Helen Whelton, I. Zerbini.

In 1999, WHO's Eastern Mediterranean Regional Office had initiated a proposal to develop Guidance on desalination because numerous existing facilities had developed on a case-by-case basis with potentially inconsistent consideration of important principles of siting, coastal zone protection, chemicals and contact surfaces used in plant operation, water treatment and plant construction , contaminants, water distribution, microbial control and final product water quality. International consensus guidance would reduce *ad hoc* decision making, facilitate informed decision making and thus reduce costs and allow more rapid project completion. Such guidance would be timely given the rapidly-increasing application of desalination world-wide. In 2000, the proposal to proceed was endorsed at a WHO Guidelines on Drinking-water Quality Committee meeting in Berlin, Germany. In May 2001, the proposal was examined at a dedicated expert consultation in Manama, Bahrain and an operating plan and program were proposed.

This Expert Meeting addressed several health considerations potentially arising from long-term consumption of water derived from water that has undergone major alteration in its mineral content, such that it must be remineralized to be compatibile with piped distribution systems. It examined the relationship between calcium and magnesium in drinking water on certain cardiovascular disease risks, and also health consequences of consumption of fluoride in drinking water.

Background

Drinking water, regardless of its source, is usually subjected to one or more of a variety of treatment processes aimed at improving its safety and/or aesthetic quality. These processes are selected according to the source water and the constituents and contaminants that require removal. Surface fresh waters will often undergo coagulation, sedimentation, rapid sand filtration and disinfection. Ground waters, which are often naturally filtered, usually undergo less treatment which could be limited to disinfection alone. Additional treatment processes could include pH adjustment, softening, corrosion control chemicals addition, alkalinity adjustment, carbon filtration/adsorption, membrane filtration, slow sand filtration and supplemental fluoridation. The disinfectants applied could include chlorine, chlorine dioxide, ozone, or chloramines. Some substances will be added by the chemicals used for treatment i.e. direct and indirect additives.

For waters with high salinity (e.g. up to ~ 40,000 ppm) such as sea water or brackish waters, treatment processes must remove most of the dissolved salts in order to make the water potable. The major methods include reverse osmosis, membrane treatments or several distillation/vapor condensation processes. These processes require extensive pretreatment and water conditioning, and subsequent remineralization so that the finished water which is now significantly different from the source water will not be overly aggressive to the piped distribution systems that it will pass through on the way to consumers. In the course of water treatment, contaminants and some potentially beneficial nutrients will be removed and some might be added. Other waters, although not deliberately demineralized may also undergo significant changes in their mineral content due to the treatment processes.

Remineralization and increased alkalinity for stabilization of the water are often accomplished by use of lime or limestone. Caustic soda, bicarbonate, sodium carbonate, phosphates, and silicates are sometimes used alone or in combination. The mineral composition of limestone is highly variable depending upon the quarry location and it is usually predominantly calcium carbonate, but often contains significant amounts of magnesium carbonate along with numerous other minerals. Quality specifications exist for chemicals and materials used in the treatment of drinking water. These specifications are intended to assure that drinking water treatment grade chemicals will be used and that their addition will not inadvertently contribute significant levels of potentially harmful contaminants to the finished drinking water under typical use conditions.

Charge to the Expert Group

The group was asked to examine several issues relating to the composition of drinking water that has undergone significant treatment relevant to drinking water guidelines aimed at protecting and enhancing public health:

- What is the potential contribution of drinking water to total nutrition?
- What are the drinking water intake requirements for individuals considering climate, exercise, age etc.?
- Which substances are often found in drinking water that can contribute significantly to health and well-being?
- Under what conditions can drinking water be a significant contribution to the total dietary intake of certain beneficial substances?
- What conclusions can be drawn on the relationship between calcium, magnesium, and other trace elements in water and mortality from certain types of cardiovascular disease?
- For which substances, if any, can a case be made for supplementation of mineral content in treated drinking water from the public health perspective?
- What is the role of fluoride in drinking water with respect to dental benefits and dental fluorosis, and skeletal fluorosis?

Topics examined in the meeting

Drinking water consumption

It is important to estimate the water needs of populations because: water is essential for life; inadequate intake can result in dehydration; dehydration can result in impaired work performance and morbidity; and health benefits can be derived from the liberal intake of fluids of appropriate composition. An individual’s daily aqueous fluid ingestion requirement can be said to roughly equate to the obligatory water losses plus sweat/perspiration losses resulting from increased physical exertion and climate. WHO (Howard, 2003) and others (e.g. Grandjean) have reviewed water consumption and hydration needs under a variety of conditions. Physical exertion, especially in extreme heat, can significantly increase water requirements beyond reference estimates. Sweat rates can reach 3 – 4 liters per hour, with variations in rate depending upon work/exercise intensity and duration, age, sex, training/conditioning, heat acclimatization, air temperature, humidity, wind velocity, cloud cover and, clothing. The US Army has estimated hourly water intake in relation to heat categories and also concludes that liquid intake should not exceed 1.03 litres/hr or 11.35 litres/day. Persons under thermal and physiologic stress need to pay special attention to fluid and total salt (sodium chloride) intake, with salt requirements ranging from 2 to 4 grams per day in cool environments to 6 to12 grams per day in very hot environments.

Humans ingest water as plain drinking water, water in other beverages, and water in food (inherent, and/or added during preparation) and also obtain some water from metabolism of food. Approximately one third of the daily average fluid intake is thought to be derived from food. Thus, the remaining water requirement must be met from consuming fluids. Availability, ambient temperature, flavor, flavor variety, beverage temperature, proximity of the beverage to the person, and even beverage container have all been shown to impact intake. Cultural variations are also known to impact the types of beverages consumed. Obviously, the total daily intake of both potentially harmful contaminants and beneficial elements will be directly associated with the total amount and type of water that is being consumed.

Table 1 - Volumes of water tequired for hydration reference value estimates, WHO 2003

	Average Conditions	Physically active and increased temperature
Female Adult	**2.2**	**4.5**
Male Adult	**2.9**	**4.5**
Children	**1.0**	**4.5**

Drinking water as a source of essential minerals

Some 21 mineral elements are known or suspected to be essential for humans. This number includes four that function physiologically as anions or in anionic groupings {chlorine as Cl^-, phosphorus as PO_4^{-3}, molybdenum as MoO_4^{-2}, fluorine as F^-}, eight that function in their simple cationic forms {calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), ferrous iron (Fe^{+2}), copper (Cu^{+2}), zinc (Zn^{+2}), manganese (Mn^{+2}) } and which are subject to chelation by either intact proteins or a variety of small, organic molecules; ions of two non-metals {iodine (I) and selenium (Se)} that function as constituents of covalent compounds (e.g., iodothyronine, selenocysteine) that are formed metabolically; and ions from five additional elements: boron (B), chromium (Cr), nickel (Ni), silicon (Si), vanadium (V)} the nutritional signficance of which remain to be fully elucidated. Thus, fourteen mineral elements are established as being essential for good health; these elements in combined form affect bone and membrane structure (Ca, P, Mg, F), water and electrolyte balance (Na, K, Cl), metabolic catalysis (Zn, Cu, Se, Mg, Mn, Mo), oxygen binding (Fe), and hormone functions (I, Cr).

Health consequences of micronutrient deficiencies include increased morbidity, mortality due to reduced immune defense systems and impaired physical and mental development. Deficiencies of several mineral elements, particularly iron and iodine, are the basis of health problems in many parts of the world. Nearly 40% of the world's women are estimated to be anemic due, to a great extent, to poorly bioavailable dietary iron. Low intakes of Ca, and perhaps Mg, contribute to rickets in children and osteoporosis in women worldwide. Due to inadequate diets, many children are deficient in Fe, Zn, and Cu and other micronutrients especially in developing countries. A third of the world's children fail to reach their physical and mental potentials and many are made vulnerable to infectious diseases that account for half of all child deaths. Nearly 750 million people have goiter or myxedematous cretinism due to Iodine deficiency, and almost 2 billion people have inadequate iodine nutrition. These nutritional deficiencies decrease worker productivity and increase the rates of disease and death in adults. Many result from diets that may also involve insufficient intakes of Cu, Cr and B. In developed countries changing dietary patterns such as reduced milk consumption may predispose to conditions like osteoporosis.

Fresh water supplies may contain some of these essential minerals naturally or through deliberate or incidental addition. Water supplies are highly variable in their mineral contents and, while some contribute appreciable amounts of certain minerals either due to natural conditions (e.g., Ca, Mg, Se, F, Zn), intentional additions (F), or leaching from piping (Cu), most provide lesser amounts of nutritionally essential minerals. Many persons consume mineral waters because of the possibility that they may be more "healthful" than non-mineralized water.

The enteric absorption of minerals from drinking water is determined by several factors including the intrinsic properties of particular chemical species that are present, physiological conditions of the gut environment, and exogenous factors related to the meal/diet in which the minerals are ingested. Accordingly, waterborne selenium (selenite, selenate) is passively absorbed at somewhat lower efficiencies (60-80%) than the selenoaminoacids in foods (90-95%) that are actively transported across the gut. The inorganic oxidized iron in water will be absorbed at very low (<5%) efficiencies similar to that of non-heme iron in plant foods. Mineral absorption is also subject to age-related declines in efficiency (Cu, Zn), early post-natal lack of regulation (Fe, Zn, Cr), adaptive increases in efficiency by receptor up-regulation during periods of deficiency (Fe, Zn, Cu, Mn, Cr), dependence on other co-present nutrients for metabolism (Se-I, Cu-Fe), and to anabolic and catabolic effects on tissue sequestration (Zn, Se, Cr).

Minerals in water are subject to most of the same determinants of bioavailabilty that affect the utilization of those minerals in foods. For example, phytate, phosphorus and triglycerides can each reduce the lumenal solubility and, hence, the absorption of calcium. Phytate and other non-fermentable fiber components can bind Fe, Zn, Cu and Mg, and sulfides can bind Cu, reducing the absorption of each. Minerals that share transporters can be mutually inhibitory (SO_3^{-2} vs. SeO_3^{-2}; Ca^{+2} vs. Zn^{+2}; Cd^{+2} vs. Zn^{+2}; Zn^{+2} vs. Cu^{+2}). In contrast, the bioavailability of the divalent cations (Ca^{++}, Fe^{++}, Cu^{++}, Zn^{++}) can be enhanced by certain chelating substances (e.g., unidentified factors in meats, ascorbic acid) that promote their enteric absorption, and by certain pro-biotic factors (e.g., inulin and other fructo-oligosaccharides) that promote their hind gut absorption. In general, poor bioavailability can be expected of water-borne iron consumed with plant-based diets containing phytates and/or polyphenols and a few promotor substances. Similarly, waterborne calcium will be poorly utilized when consumed with oxalate-containing vegetables (amaranth, spinach, rhubarb, beet greens, chard); and water-born Ca, Fe, Mg, P or Zn will be poorly utilized when consumed with foods/diets high in unrefined, unfermented cereal grains or high phytate soy products. This complexation between calcium and oxalate in the gut could reduce the potential for kidney stone formation. The typical bioavailability and occurrence of these minerals is summarized in Table 2.

Table 2 – Typical bioavailability and occurrence of nutritionally important minerals in drinking-water

Bioavailability	Occurrence	
	Moderate Amounts in Some Supplies	Low Amounts in Most Supplies
High	Se* Na Cl F	P K* Mo I*B*
Moderate/Variable	Ca* Mg* Cu* Zn*	Mn
Low	Fe*	Cr

*sub-optimal consumption and/or prevalent deficiency in at least some countries

The potential contributions of drinking water to nutritional status also depend on water consumption, which is highly variable depending on both behavioural factors and environmental conditions. Individuals with the greatest relative consumption of water include infants, residents in hot climates, and individuals engaged in strenuous physical activity.

With all of these considerations in mind, the following nutrients commonly found in drinking water at potentially significant levels are of particular interest in this assessment are:

- Calcium – important in bone health
- Magnesium – important in bone and cardiovascular health
- Fluoride – effective in preventing dental caries
- Sodium – an important extracellular electrolyte, lost under conditions of excess sweat
- Copper – important in antioxidant function, iron utilization and cardiovascular health
- Selenium – important in general antioxidant function and in immune system

- Potassium is important for a variety of biochemical effects but it is usually not found in natural drinking waters at significant levels.

Vulnerable groups

The needs of water and essential minerals in infancy and childhood are increased compared to adults in relation to body weight. The highest intake per body weight water volume is needed in the neonate and it decreases with age. Special situations require additional water intake, e.g. premature or low birth weight infants or diarrhoeal disease. The elderly and infirm often do not consume sufficient water or other fluids and can become dehydrated with significant adverse health consequences.

The WHO Global Strategy on Infant and Young Child Feeding promotes exclusive breastfeeding in the first six months of life. If this is not feasible, it may be necessary to consider feeding formula. Variable mineral content of drinking water used to reconstitute feeding formula will result in variability in the mineral content of formula milk. Some types of water may not be suitable for use in the reconstitution of infant formula due either to deficiency of appropriate minerals or to the presence of excess salts that may be harmful to infants and young children. Sodium is a good example since the requirements of infants for sodium is low.

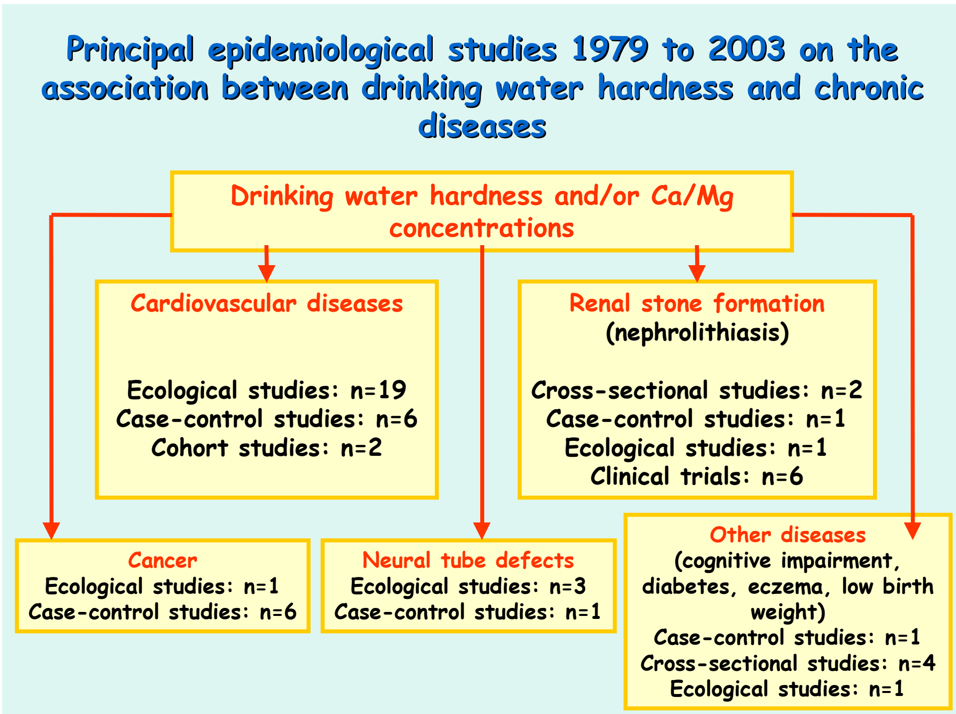
Formula-fed infants are also a group at risk for excess intake of potentially toxic elements in drinking water, e.g. copper or lead leaching from copper or lead pipes associated with highly corrosive water. In the latter case not using 'first draw' water for formula preparation, by allowing the tap water to run to waste for a short time, would reduce the metal content in the water significantly. Remineralization/stabilization of demineralized water for drinking water supply should take into account the special requirements of infants and children, including calcium, magnesium, and other minerals based upon regional dietary composition..

Drinking-water and health relationships

Water hardness and cardiovascular disease

Over 80 observational epidemiological studies have been reported in the published literature since 1957 (Calderon) relating water hardness and cardiovascular disease risks (see Table 3 for a summary from 1979 to 2003)(Monarca). Most, but not all, of the studies found an inverse (protective) association between cardiovascular disease mortality and increased water hardness (measured by calcium carbonate or another hardness parameter and/or the calcium and magnesium content of water). The associations were as reported in countries throughout the world by different investigators with different study designs. Both population and individual-based studies have observed benefits. The most frequently reported benefit was a reduction in ischemic heart disease mortality. In addition, there is supporting evidence from experimental and clinical investigations suggesting a plausible mechanism of action for calcium and magnesium. The significance of the epidemiological findings is that beneficial health effects can possibly be extended to large population groups on a long-term basis by adjusting the water quality.

Table 3 - Principal epidemiological studies 1979-2003



The strongest epidemiologic evidence for beneficial effects was for drinking water magnesium concentrations; there was also evidence but not as strong for drinking water calcium concentrations. Magnesium and possibly calcium may be effective in reducing blood pressure in hypertensive individuals. Studies have shown magnesium exerts multiple cellular and molecular effects on cardiac and vascular smooth muscle cells which is a plausible basis to explain its protective action. Treatment of suspected myocardial infarction cases with intravenous magnesium salts dramatically reduced mortality due to arrhythmia and infarction thirty days post therapy. Other micronutrients and trace elements have not been extensively considered in these epidemiologic studies, but nutritional studies suggest that some may have an indirect or direct beneficial role associated with their presence in drinking water. On the other hand, a recently published study in Finland suggested that iron and copper in drinking water may be associated with increased risks of heart attack. More studies are needed to better understand the possible risks and benefits of these essential and other trace elements found in water.

Hard water is a reliable and stable source of calcium and sometimes magnesium although the absolute and relative concentrations will vary greatly by source. Consumption of moderately hard water containing typical amounts of calcium and magnesium may provide an important incremental percentage of their daily intake. Inadequate total dietary intakes of calcium and magnesium are common worldwide. Therefore, an incremental contribution from drinking water can be an important supplement to approach more ideal total daily intakes. Moreover, hard water can reduce the losses of calcium, magnesium and other essential minerals from food during cooking. If low mineralized water is used for food and beverage production, reduced levels of Ca, Mg, and other essential elements would also occur in those products. Low intakes would occur not only because of the lower contribution of these minerals from water used in beverages, but also because of the high losses of the minerals from food products (e.g., vegetables, cereals, potatoes or meat) into water during cooking.

The group concluded that there is sufficient epidemiological evidence of an inverse relationship between calcium and magnesium concentrations in drinking water and ischemic heart disease mortality, and that consumption of water containing calcium and magnesium, and therefore also the reintroduction of Mg and Ca into demineralized water in the remineralization process would likely provide health benefits in those consumer populations. There are no known harmful human health effects associated with the addition of calcium and magnesium within a large range and the nutritional benefits are well known. In addition, limited but suggestive evidence exists for benefits associated with other diseases (stroke, renal stone formation, cognitive impairment in elderly, very low birth weight, bone fractures among children, pregnancy complications, hypertension, and possibly some cancers). Adding calcium and magnesium to the demineralized water would be a relatively inexpensive preventive intervention that does not require individual behavioural change, and it is already done as part of many water treatment processes. The intervention could not only provide health benefits but also help reduce medical care costs.

Epidemiological studies in the United Kingdom, United States, Sweden, Russia, and France and research on changes in calcium/phosphorus metabolism and bone decalcification provide information about drinking water levels of calcium and magnesium (and water hardness) that may provide beneficial health effects. It has been suggested (Kozisek) that reduced cardiovascular mortality and other health benefits would be associated with minimum levels of approximately 20 to 30 mg/l calcium and 10 mg/l magnesium in drinking water. The percentage of the recommended daily allowance (RDA) of calcium and magnesium provided by drinking water at these minimum levels will vary among and within countries. Thus, lower levels in water may be sufficient to provide health benefits in some areas, but higher levels may be beneficial in others. Some limited information suggests that the desirable levels may be higher in some circumstances. Overall health benefits will be dependent upon total dietary intakes and other factors in addition to water levels. Because the exposure-response information is limited, further analyses, and possibly additional studies, are needed to determine the levels of calcium and magnesium that may provide most favorable population benefits in each location.

Fluoride in drinking-water

Most drinking waters contain some fluoride. Fluoride is present in seawater at concentrations of about 1.2 to 1.4 mg/l, in groundwater at concentrations from nil to about

67 mg/l, and in surface waters sometimes at concentrations as low as 0.1mg/litre or less. The amount of fluoride in treated drinking water is also affected by processes such as anion exchange which will remove it along with the target contaminant (e.g.arsenic). Demineralization and some other treatment processes will also remove fluoride.

High levels of excess fluoride intake cause crippling skeletal fluorosis and it is almost always associated with high fluoride intake from drinking water. This is a significant irreversible health problem in parts of India, China and Africa, for example. Ingestion of excess fluoride during tooth development , particularly at the maturation stage, may also result in dental fluorosis, and these effects may also be modified by co-exposure to some minerals.. Mild dental fluorosis presents as barely detectable whitish surface striations in which the enamel is fully functional. As the excess intake of fluoride increases the severity of dental fluorosis also increases. Severely fluorosed enamel is more prone to wear and fracture, and may present as pitted, darkly stained and porous enamel.

Fluoride intake has been known for the past 50 to 60 years to play a beneficial role in dental health; there is some evidence that it may be beneficial for bone formation, but this has not been proved. The optimal drinking water concentration of fluoride for dental health is generally between 0.5 to 1.0 mg/litre and depends upon volume of consumption and uptake and exposure from other sources. These values are based on epidemiological studies conducted over the past 70 years in communities in many countries with natural and added fluoride in their drinking water. In this concentration range the maximum caries preventative effect is achieved while minimizing the levels of dental fluorosis. The WHO drinking water quality Guideline value for fluoride is 1.5 mg/l. The US Environmental Protection Agency has set a Maximum Contaminant Level of 4.0 mg/l in the U.S. based upon prevention of crippling skeletal fluorosis, and a guidance level of 2.0 mg/l to avoid moderate to severe dental fluorosis. The actual prevalence of dental and skeletal fluorosis will be influenced by inhalation exposure to fluoride from other sources such as the use of high fluoride coal (in parts of China); other dietary sources and total water consumption. Other water factors, such as lack of calcium and magnesium may possibly also exert some influence.

Dental caries (tooth decay) is the result of an interaction on the tooth surface between certain bacteria in the mouth and simple sugars (e.g. sucrose) in the diet. The level of oral hygiene care and habits of the community, including the use of fluoridated toothpaste, dental treatment such as the topical application of fluoride, and consumption of fluoridated water are major factors contributing to reduction of caries incidence. Dietary sugar intake is a significant contributing tooth decay factor. Communities in which sugar intake is low (approximately less than 15 kg per person/year) will usually have a low risk for dental caries, while communities in which sugar intake is high (approximately greater than 40 kg per person/year) will be at high risk.

Where the risk for skeletal and dental fluorosis is high as a consequence of excess fluoride intake from drinking water, it is essential to reduce fluoride levels in drinking-water to safe levels, or to provide a lower fluoride source such as bottled water, especially for young children.. Control of significant non ingestion exposure such has from use of high fluoride coal may be necessary in some cases. Where the aggregate risk factors for dental caries are low (and are remaining low) consuming low fluoride water would probably have little or no impact on dental caries, but to guard against possible net loss of fluoride from the skeleton, the group felt that consideration should be given to maintaining a baseline level of 0.1 to 0.3 mg/l.

Where caries risk is high or increasing authorities may consider addition of fluoride to the public supply to the WHO recommended levels of 0.5 to 1.0 mg/l.. However, other factors must also be considered. For example, in countries such as those in Scandinavia, where public dental awareness is very high and alternative vehicles for fluoride (e.g. fluoridated toothpaste) are widely available and widely used, a decision to not fluoridate the water, or remove fluoride, or to supply drinking water with suboptimal levels of fluoride would likely be of little consequence. On the other hand in developing countries, and developed countries where public dental health awareness in some population groups (e.g. lower income) might be much lower, water containing either natural or added fluoride at concentrations of 0.5 to1.0 mg/l would be important for dental health. Some countries use fluoridated table salt as a means of supplementing fluoride in deficient areas.

A decision to use demineralized water as a drinking water source without addition of fluoride during remineralization will depend upon: the concentration of fluoride in the existing local supply; the volume of water consumed; the prevalence of risk factors for dental caries (including sugar consumption data); oral hygiene practices; the level of public dental health awareness, and the presence of alternative vehicles for dental care and fluoride available to the whole population.

Recommendations

There is a need for more precise data on the impact of fluid composition and intake, including water and other aqueous beverages, on nutrient intake under a broader range of physiologic and climatic conditions for sensitive population segments in order to more precisely evaluate the importance of minerals in drinking water on mineral nutrition.. Studies on the mineral nutritional content and adequacy of world diets should be conducted so that adequacies and inadequacies can be documented and mitigated.

National governments and water suppliers should be encouraged to practice stabilization of demineralized water with additives that will increase calcium and magnesium levels and to conduct studies that monitor public health impacts.

Community and bottled water suppliers should provide information to the general public and health professionals on the composition of water for constituents including possibly beneficial substances. Water bottlers should also consider providing waters with mineral compositions that are beneficial for population segments.

Additional studies should be conducted on potential health consequences associated with consumption of both high and low mineral content waters in addition to consideration of water hardness. When studies are conducted, investigators should consider exposures to both calcium and magnesium levels in addition to other minerals and trace elements that may be present in hard and soft waters

Unless properly stabilized demineralized and some natural waters are corrosive to plumbing resulting in damage to the plumbing systems and also potentially increased exposure to metals such as copper and lead.. Properly stabilized water should be provided by suppliers, and appropriate plumbing materials should be used.

Information should be provided on methods of application of home water softening devices so that consumers will also have access to mineralized water for drinking and cooking.

In the revisions of the GDWQ, WHO should consider the beneficial roles of nutrient minerals and also water hardness characteristics when it establishes numerical drinking water guidelines for those substances.

Chemicals used in the treatment of drinking water should be assured to be of suitable quality for that application so as not to contribute unacceptable amounts of potentially harmful chemicals to the finished water.

Additional epidemiologic studies of populations that consume low mineral or demineralized water need to be conducted. Studies should be focused on consumption of low mineral content or distilled waters by population subgroups.

Investigators may take advantage of natural experiments (communities changing water sources and treatment) to conduct population intervention studies to evaluate potential health impacts. For example, studies could compare communities before and after changing source waters, or the introduction of treatment technologies that significantly change water composition. Studies should evaluate a number of potentially relevant health outcomes (e.g., renal stone formation, CVD, mineral balance, mineral nutritional deficiencies). Exposure assessments should include analyses for calcium, magnesium, and trace elements.

Water utilities are encouraged to periodically analyse their waters for calcium, magnesium, and trace elements . This would be helpful in assessing trends and conducting future epidemiologic studies.

Clinical trials of people at high risk of heart attacks should be conducted to assess the potential benefits of mineral water supplementation. Results of previous studies have been inconsistent.

The Group feels that this subject is of such general public health significance that a detailed state-of-the-art review should be prepared prior to consideration in the next revision of the WHO Guidelines for Drinking-water Quality.

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