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SADRŽAJ / CONTENT

POSTERI

HEALTH SIGNIFICANCE OF ESSENTIAL NUTRIENTS IN DRINKING WATER

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ABSTRACT

Safe and high-quality drinking water is not only pure H_2O, but a system of minerals and gases dissolved in water. These minerals are vital for the pleasant taste of water, but, at the same time, it represents an important source of some essential nutrients, and ensures some basic osmotic characteristics of water in order not to disturb water and mineral homeostasis of human beings. Certain intake of these nutrients through drinking water is important for health, even if food seems to provide sufficient amounts. Low content of some macro-minerals in drinking water is related to higher incidence of number of diseases, which has been scientifically proven by many epidemiological studies over the last 50 years. The most powerful relationship exists between low magnesium (Mg) in water and higher mortality of cardiovascular diseases (CVD), and as the CVDs are the most common cause of death in Europe, low content of Mg in drinking water represents higher population health risk than probably all other regulated chemical parameters in drinking water together. Current knowledge allows us to define minimum, optimum and maximum levels of macro-minerals in drinking water due to its health effects. The aim of this paper is to indicate health importance of the neglecting aspect of water quality and safety and to provide stimulus for public health authorities to think how to approach this issue in the national context. The regulation is feasible and is mostly focused on requiring minimum amount of calcium, magnesium or hardness in case of water softening or desalination, or recommending optimum levels of these elements as a goal and asking water producers, where possible, to strive for it.

Key words: drinking water, calcium, magnesium, bicarbonates, beneficial effects, desalination, softening, health risks

1. INTRODUCTION

The future form of EU drinking water legislation [1] has been discussed in the Council and the European Parliament since February 2018. Inter alia, some new chemical substances were included on the list of quality parameters, limit values of other are proposed to be lower. However, most of chemical parameters listed in Annex I can cause harm to health only theoretically; there is no scientific evidence they would be dangerous in concentrations which usually occur in drinking water, or there is the evidence of its minimum health risk. They are regulated because of precautionary principle – which is correct approach.

On the other side, another health risk related to chemical composition of drinking water, which may occur in all EU member states and is proved to be several orders of magnitude higher or causing probably more death than all other chemicals regulated in drinking water together, is systematically neglected [2]. It is the issue of content of beneficial or essential (needful) minerals in drinking water.

If water is free of dissolved minerals (distilled, osmotic, or demineralized water by other technical means), it is perfectly complying with current and proposed model of drinking water safety in the Drinking Water Directive 98/83/EC (DWD) – however, its regular consumption presents clear health risks, both acute and chronic health effects. And it is not only a matter of water, which is completely demineralized, but also of water too softened or naturally low in minerals.

2. HEALTH RISKS OF DEMINERALIZED OR LOW MINERAL WATER

Acute health effects, which may appear within weeks to months after starting regular consumption of demineralized water, comprise signs of profound deficiency of calcium, magnesium, or sodium: extreme fatigue, malaise, nausea, headache, brittleness of nails and hairs, leg and abdominal cramps, preeclampsia, twitch, metabolic acidosis, cardiovascular disorders (arrhythmia), higher diuresis, etc. [3]. Nowadays, the most common source of demineralized water is water treated by reverse osmosis without any by-pass (as so called remineralization cartridge is absolutely insufficient to supplement water with minerals needed).
Chronic health effects of naturally occurring low mineral water or artificially softened water – or specifically water low in magnesium, calcium or bicarbonates – have been consistently proved by hundreds of epidemiologic studies completed in different countries by different teams of researchers since 1960. The most comprehensive review of about 2 thousand papers, including more than 100 studies with primary data, had been ordered by the Drinking Water Inspectorate (England and Wales) and completed by the University of East Anglia in Norwich in 2005 [4].
Subsequent systematic review and meta-analysis of 14 analytical observational studies (i.e. the most valid epidemiological studies) investigating the association between cardiovascular disease and drinking water hardness brought convincing epidemiological evidence about the protective role of Mg in drinking water, as a pooled odds ratio and showed a statistically significant inverse association between Mg and cardiovascular mortality (OR 0.75 (95%CI 0.68, 0.82), p = 0.001). It means that the highest exposure category (people consuming drinking water with magnesium 8.3 – 19.4 mg/L) was significantly associated with a decreased likelihood of cardiovascular mortality (by 25%), compared with the baseline, i.e. people drinking water with Mg content of 2.5 – 8.2 mg/L [5]. The protective role of water Ca towards cardiovascular disease was also confirmed by some studies, but the evidence is not as strong as for magnesium [5]. Two recent and independent meta-analyses confirmed these findings. The first paper included only ten studies (of which 3 were new) and found that drinking water magnesium level is significantly inversely associated with coronary health disease mortality: RR = 0.89, 95% CI = 0.79–0.99 [6]. The other one included seven epidemiological studies and for magnesium found similar magnitude of effect like Catling et al. [5], but found also statistically significant protective effect of calcium (effect-size of 0.82 (95% confidence interval CI = [0.70–0.95], p = 0.008)) [7].
A number of other papers [partially summarized in 2, 8,] suggests a beneficial or protective effect of water Ca and Mg on other diseases. These include Ca in neurological disturbances, Ca and Mg in amyotrophic lateral sclerosis, Mg in preeclampsia in pregnant women, Ca in high blood pressure, Mg in high blood pressure and metabolic syndrome. One study concluded that a regular life-long daily intake of drinking water with highly bio-available Ca may be of importance for maintaining the calcium balance and improving the spinal bone mass. Calcium mineral water supplementation for one year showed an increase in the bone mass density in postmenopausal women. An association between low Ca content of drinking water and higher incidence of fractures in children was found in Spain. Studies done at least in two different countries proved protective effect of water calcium and magnesium against several kinds of cancer [2, 9]. Large Slovak study suggests health impact of low mineral water also for other diseases [10].
Existing scientific evidence of health risks of low mineral water is much stronger than for most of other chemical substances regulated by the DWD.

3. COMPARING TWO DIFFERENT CHEMICAL RISKS

One example from real life may be provided for illustration of magnitude of discussed risk. The example is based on the study done by Czech National Institute of Public Health (NIPH) for one Czech municipality.
Czech town X., whose population is 10,000 inhabitants, uses local groundwater sources polluted by both tetrachloroethene (PCE) and trichloroethene (TCE). Water is treated by aeration (stripping), and concen-

tration of sum TCE+PCE in finished water is about the limit value 10 µg/L. The health risk from this level of pollution in this town is about 1 case of cancer per 25 years. The operator considered two options for improvement: either to renew and intensify treatment of local water or to connect with adjacent water supply with unpolluted groundwater. However, local groundwater has magnesium level about 30 mg/L, but adjacent water supply only 5-8 mg/L. For this reason, the operator turned to the NIPH to calculate health risks from both options to have scientific ground for proper decision.
If the town switches to adjacent source with much lower Mg content for consumers, it would represent about 25% higher risk of death from cardiovascular diseases [4]. If we take into account high incidence of cardiovascular diseases in European population, the change of water source may lead to several deaths per year – in comparison with "benefit" lowering 1 case of cancer per 25 years. The operator decided not to switch the source, but continued to treat local water to avoid substantial increase of health risk for consumers.

4. REGULATORY ASPECTS OF CALCIUM AND MAGNESIUM IN DRINKING WATER

Considering the high number of epidemiological studies confirming the beneficial effects of certain amounts of Ca and Mg in drinking water and the large body of supporting evidence from experimental animal and clinical studies, as well as zero health risk relating to usual levels found in drinking water (dozens of mg/L), it is surprising to see the restrained attitude of the World Health Organization (WHO) over the last 20 years to recommend any guideline value. It is even more surprising if we realise that in the 1970s and 1980s, the WHO acknowledged the importance of water hardness for population health and supported new research in this area. One can just try to guess the true motives behind the current WHO position.
It is really strange and hardly understandable to read the WHO background documents (Hardness in Drinking-water) for development of WHO Guidelines for Drinking-water Quality from 1996 [11] to 2011 [12] and to find that methodically poor epidemiological studies are referred to in support of the importance of water hardness while advanced studies are mentioned only as footnote or omitted (e.g. there are also supporting animal experimental studies or clinical studies which are not taken into account by the WHO at all), and to read conclusion: "*Although there is some evidence from epidemiological studies for a protective effect of magnesium or hardness on cardiovascular mortality, the evidence is being debated and does not prove causality. Further studies are being conducted. There are insufficient data to suggest either minimum or maximum concentrations of minerals at this time, and so no guideline values are proposed.*" [12].
This view is in contrast to the statement of two prominent epidemiologists R. Calderon and P. Hunter, who concluded their chapter on epidemiological studies and the association of cardiovascular disease risks with water hardness in the WHO monograph on Ca and Mg in drinking water (2009): "*Information from toxicological, dietary and epidemiological studies supports the hypothesis that a low intake of magnesium may increase the risk of dying from, and possibly developing, cardiovascular disease or stroke. Thus, not removing magnesium from drinking-water, or in certain situations increasing the magnesium intake from water, may be beneficial, especially for populations with an insufficient dietary intake of the mineral. This raises a significant policy issue. How strong does the epidemiological and other evidence need to be before society acts to reduce a potential public health threat rather than await further evidence that such a threat is real? Such a decision is a political rather than a purely public health issue. There is a growing consensus among epidemiologists that the epidemiological evidence, along with clinical and nutritional evidence, is already strong enough to suggest that new guidance should be issued.*" [13].
It is really surprising that the WHO applies precautionary principle and recommends guidelines values for a number of toxic substances, but refuses to apply the same principle in the case of minimum amount of magnesium and calcium, where the evidence is much stronger and impact on public health is much higher. There is already enough scientific information allowing establishing minimum, optimum, and maximum concentrations of both calcium and magnesium (and also total dissolved solids, bicarbonates, and fluoride)

in drinking water, at least on precautionary principle [7, 8, 14].
Introduction of regulatory measures concerning the minimum levels of Ca and Mg in drinking water seems to be justified and highly desirable. They should be based on the fact that it is much simpler and much more effective to keep the existing Ca and Mg drinking water levels than to add these minerals to water artificially. Practically, this means restricting the use of technologies leading to the removal of Ca and Mg from water only to the cases where the Mg and Ca levels are too high (i.e. of hundreds of mg/L or more) provided that the required minimum of ∑ Ca+Mg is retained in the water after treatment.
A certain requirement for the minimum required concentration of hardness (≥ 60 mg/L as calcium or equivalent cautions) for softened and desalinated water, set up in Council Directive 80/778/EEC [15] appeared obligatorily in national legislation of all EEC members in the past. Nevertheless, this Directive was in force only until December 2003 since Directive 98/83/EC replaced it. The latter directive does not present any requirement for the Ca and Mg levels or water hardness (apart from the lower limit for pH ≥ 6.5 which requires indirectly a certain level of dissolved solids); on the other hand, it does not prevent the member states from implementing such a requirement, if needed, into their national legislation.
Nevertheless, apart from the WHO approach and EU Drinking Water Directive (98/93/EC), more than 10 European countries have established some form of minimum requirements on hardness level after softening or a generally optimum range (e.g. Austria, Belgium, Czech Republic, Denmark, Germany, Hungary, Italy, Netherlands, Poland, Slovakia, Sweden, Switzerland). Some countries have these requirements legally based, while others issued recommendations in form of technical standards or guidelines. Other countries try to educate the consumers through information leaflets or websites how to use any softening device with respect to keeping Ca and Mg in the water for drinking and cooking purposes (UK).

5. CONCLUSIONS

Ca and Mg, and probably also bicarbonates and total dissolved solids, are important components of drinking water and are of both direct and indirect health significance. A certain minimum amount of these elements in drinking water is desirable not only for technical (decreased corrosivity of water), but also for health and aesthetic (taste) reasons.

There are several options how to ensure the minimum and optimum Ca and Mg levels in drinking water:

a) To select an adequate water source. If several water sources are available or can be blended, preference should be given to the sources containing the optimum, or at least the minimum, Mg and Ca levels, as considered in the context of general water composition.
b) To set strict rules for water treatment technologies decreasing the amount of Ca or Mg in drinking water (e.g. distillation, membrane technologies, such as reverse osmosis, ion exchange, precipitation, etc.) or to keep some minimum content of Mg and Ca, in case of water softening or desalination. To soften drinking water only if needed for health reasons, i.e. not for technical reasons. In the light of rapid growth in membrane technologies and their applicability to drinking water treatment (desalination), such rules will be more and more urgently needed to avoid considerable health problems [16, 17].
c) To promote stabilisation of naturally soft and low mineral water during the treatment. This technology is often used to reduce water corrosivity either by passing the water through a CaCO3 filter (sometimes preceded by dosing with CO_2) or by adding a Ca compound such as lime milk directly to water. Unfortunately, this results only in a negligible increase in the Mg level. Nevertheless, this procedure can be at least partly optimised, on the one hand, by means of improvement of the treatment design, and on the other hand, by selection of an adequate filtration material with a higher magnesium content, e.g. material on a basis of $CaCO_3$ + $MgCO_3$ or $CaCO_3$ + MgO, like dolomite.
d) The issue of increasing the Mg level by the addition of Mg salts directly to water while treated, which

has not been much tested in practice, but some case studies have shown that central fortification with Mg is technically feasible. This step may be necessary if water is initially completely desalinated when producing drinking water from seawater. However, we still do not know how the chemical forms available for water fortification are bioavailable and if addition of only magnesium salts is enough to receive desirable protective effect [18].

Public health education seems to be an easily applicable measure for the moment. The public, in particular those living in the areas supplied with water low in Ca or Mg, should be discouraged from using water softeners or other home water treatment units removing Ca or Mg from water intended for drinking and cooking. At the same time, the consumption of Ca/Mg-rich water (e.g. some bottled natural mineral water) could be encouraged to replace at least partly tap (well) water low in the minerals. We have to realize that naturally low mineral water used for drinking water production cannot be – due to technical and financial reasons – supplemented into minimum protective levels, and we have to acknowledge that this is kind of natural and unavoidable health risk. However, we have to ensure as much as possible to avoid unnecessary removal of nutrients from drinking water.

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