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Magnesium deficiency in tap water in Israel: The desalination era

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ABSTRACT

Water desalination has been extensively developed in Israel, particularly in the last decade. The desalination process provides fresh water that typically lacks minerals, and among these are ions that are essential to human health and/or to agricultural production, such as Mg. We analyzed 28 tap water samples originating from different cities across Israel to document their concentrations of Mg and other elements. The data from this survey (summer 2016) were compared with the results of similar observations conducted in 2008. Regarding toxic elements, tap water across Israel does not pose any health risk for consumers and may be used as drinking water without any household pretreatment. This condition has not changed since 2008. However, the problem of Mg deficiency due to the use of desalinated water was observed in about half of the sampling locations in 2016, whereas no Mg deficiency had been detected in 2008. Moreover, household filtration of tap water prior to consumption as drinking water may worsen the situation due to the Mg status resulting from rejection of this ion; this could be harmful to the consumer, particularly under prolonged exposure.

1. Introduction

Drinking water is essential for human life. An adult human requires from 2 to 5 L of water per day [7,1,13], and the quality of potable water is crucial to public health. Moreover, safe water is required for all other domestic purposes, namely food preparation and personal hygiene [22]. Water-quality standards employed in the State of Israel include maximum contaminant levels (MCLs) for over 90 chemical contaminants, including metals, pesticides, radionuclides, and industrial organic pollutants, as well as microbial water-quality parameters [6,2].

The three main natural sources of freshwater supply in Israel are Lake Kinneret, the coastal aquifer and inland mountain aquifer [16]. As these resources are dwindling, seawater desalination has seen intensive development, especially in the last decade. In 2015, about 600 million m^3 of desalinated sea water was produced in Israel. This is about 32% of all domestic water consumed, and that proportion is expected to increase to 75% by the year 2025 [1]. Desalinated water in Israel is usually mixed with other water sources [23]. The problem results from the fact that the desalination process provides fresh water that typically lacks minerals essential to human health and to agricultural productivity [1]. Among others, Mg is of great concern because many researchers have observed a positive correlation between its deficiency and mortality due to coronary heart disease (CHD) (see review by [10]).

Consumption of drinking water containing at least 10mg L^{-1} and up to 40 mg L^{-1} Mg or higher can be expected to reduce CHD-related mortality by 30–35% [11].

Intake recommendations for Mg are provided by many organizations worldwide. The dietary reference values usually used by researches are: (i) recommended dietary allowance (RDA) or reference nutrient intake (RNI) – the average daily intake level that meets the nutrient requirements of nearly all (97%–98%) healthy individuals [3,8]; (ii) estimated average requirement (EAR) – the average daily intake level that is estimated to meet the requirements of 50% of healthy individuals. The latter is usually used to assess the adequacy of nutrient intake in population groups but not individuals [12]. As an example, the following values have been established in the USA and UK, respectively: the EAR for a male aged 19–30 years is 330 mg day^{-1} (RDA 400 mg day^{-1}), and for a female, 255 mg day^{-1} (RDA 310 mg day^{-1}) [8]; the EAR for a male aged 19–50 years is 250 mg day^{-1} (RNI 300 mg day^{-1}), and for a female, 200 mg day^{-1} (RDA 270 mg day^{-1}) [3,24]. Age, gender, pregnancy and other factors strongly influence the required intake value [3]. In the present research, we used a RNI value for Mg of 300 mg day^{-1} for our calculations.

Abbreviations: CHD, coronary heart disease; CRM, certified reference material; EAR, estimated average requirement; MCL, maximum contaminant level; RDA, recommended dietary allowance; RNI, reference nutrient intake

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Table 1
Precision and accuracy of the analysis of the main constituents determined in low- and high-concentration matrices.

Element/wavelength (nm)	Low-concentration matrix					High-concentration matrix				
	Concentration added	Average	SD[a]	Precision	Accuracy	Concentration added	Average	SD	Precision	Accuracy
	mg L^{-1}			%		mg L^{-1}			%	
Ca/317.933	25	27.36	0.045	0.17	109	200	207.9	0.600	0.29	104
K/766.491	0.5	0.49	0.002	0.48	98	50	57.2	0.428	0.75	114
Mg/279.079	0.5					50	49.0	0.693	1.41	98
Mg/279.553	0.5	0.50	0.003	0.60	99	50				
Na/330.237	10					200	198.4	1.482	0.75	99
Na/589.592	10	9.99	0.035	0.35	100	200				
S/182.034	2	1.95	0.016	0.84	103	50	48.1	0.435	0.90	96

[a] Standard deviation.

Table 2
Precision and accuracy of the analysis of trace elements determined in low- and high-concentration matrices.

Element/wavelength (nm)	Low-concentration matrix + trace elements					High-concentration matrix + trace elements			
	Concentration added	Average	SD[a]	Precision	Accuracy	Average	SD	Precision	Accuracy
	mg L^{-1}			%		mg L^{-1}		%	
As/189.042	0.01	0.012	0.001	10.9	115	0.0111	0.0023	20.3	111
Cd/226.502	0.005	0.005	0.00004	0.89	94	0.0045	0.0002	4.28	90
Pb/220.353	0.01	0.0092	0.0032	35.4	92	0.0099	0.0046	46.4	99

[a] Standard deviation.

Table 3
Calcium content and total tap water hardness (Ca + Mg) in 28 samples from the 2016 survey.

Descriptive statistics	Ca (mg L^{-1})	Total (Ca + Mg) hardness
Mean	57.4	194.6
Standard error	4.4	16.5
Median	49.7	174.5
Standard deviation	23.4	87.2
Minimum	31.0	91.1
Maximum	129	382
Confidence level (95.0%)	9.1	33.8
CV (%)	41	45

In 2008, adults of four communities in Israel were interviewed to assess their intake of Mg and Ca from water, other beverages and food. The communities had different water supplies: one had desalinated water only and the three others had the regular fresh water from the Israeli National Water Carrier (NWC) or mixed water. The proportion of individuals with Mg intake below the EAR was found to be higher in communities supplied with desalinated water (30.6%) than in cities supplied by the NWC (16.7%). Moreover, the results of modeling analyses indicated that if desalinated water replaced NWC or mixed water, with no other changes in water-intake patterns, the prevalence of Mg intake below the EAR would range from 26.3 to 30.6% [18].

The most recent medical research, conducted by Shlezinger et al. [15], demonstrated all-cause mortality in hospitalized patients with acute myocardial infarction in all general hospitals in Israel. The authors found mortality to be significantly higher among patients living in regions supplied with desalinated water—mainly the coastal and central regions of Israel. In agreement with Shlezinger et al. [15] we hypothesize that this phenomenon is related to the fact that these areas are often supplied with Mg ion-depleted desalinated water. Low serum Mg content was also found in these patients [9].

The goal of the present survey was to record the Mg status of tap water from different regions in Israel and to corroborate the concentration of other important macro- and microminerals in the tap water. This survey was needed because the Israel Ministry of Health controls the water mineral content at the water source or in the distribution system, but does not provide information to the public on current Mg concentrations in different towns [16].

2. Materials and methods

During the period of May–June 2016, 28 tap water samples were

Table 4
Element concentrations (mg L^{-1}) in Israeli tap water determined by ICP-OES.

Descriptive statistics	Na	K	B	Ba	Cu	Fe	Li	Si	Sr	Zn
	Macrominerals		Microminerals							
Mean	39.2	2.74	0.216	0.048	0.069	0.048	0.004	4.40	0.36	0.46
Standard error	5.20	0.70	0.034	0.009	0.022	0.015	0.001	0.68	0.090	0.120
Median	37.7	1.97	0.205	0.039	0.021	0.013	0.002	3.09	0.230	0.171
Standard deviation	27.5	3.72	0.180	0.049	0.082	0.068	0.005	3.61	0.476	0.634
Minimum	14.2	0.53	0.024	0.003	0.005	0.003	0.001	0.179	0.027	0.020
Maximum	146	20.8	0.95	0.25	0.22	0.30	0.02	12.2	2.52	2.29
Count	28	28	28	28	14	20	26	28	28	28
Confidence level (95.0%)	10.67	1.44	0.07	0.02	0.05	0.03	0.002	1.40	0.18	0.25
CV (%)	70.2	136	83	102	119	143	126	82	131	139