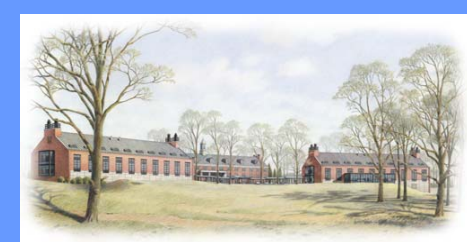


The Mineral Content of US Drinking and Municipal Water

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Abstract

The mineral composition of tap water may contribute significant amounts of some minerals to dietary intake. The USDA's Nutrient Data Laboratory (NDL) conducted a study of the mineral content of residential tap water, to generate new current data for the USDA National Nutrient Database. Sodium, potassium, calcium, magnesium, iron, copper, manganese, phosphorus, and zinc were determined in a nationally representative sampling of drinking water. The sampling method involved: serpentine ordering of the US population by census region, division, state and county; division of the population into 72 equal size zones; and random selection of one county per zone and two residences per county (144 locations). Chromy's probability-proportional-to-size (population density), probability of minimum replacement method was used. Participants collected samples in HDPE bottles at two points in time (winter and spring, n=288) and provided information on water source (municipal, well), pipes and use of water softeners and treatments. Samples were analyzed by inductively coupled plasma atomic emission spectrometry; resulting data were analyzed using a mixed model approach. Assuming two liters of tap water are consumed daily, only four minerals provided more than 1% of the U.S. Daily Value (DV): copper, 10%; calcium, 6%; magnesium, 5%; and sodium, 3%. Significant decreases in calcium were observed with chemical water softeners (mean 3.2 v. 2.0; median 2.73 v. 0.44 mg/100g), and between pickups for Mg and Ca (p<0.05). The variance of sodium was significantly different among regions (p<0.05); no differences were observed as a result of collection time, water source or treatment. Based on the weighted mixed model results, there were no significant differences in overall mineral content between municipal and well water. These results, the first nationally representative dataset of mineral values for municipal drinking water, will provide valuable information for assessment of dietary mineral intake, including from water.

Background

Growing global research interests in the association between cardiovascular (CV) disease (CVD), other chronic diseases, and electrolyte balance with water hardness, underline the importance of expanded, current data on minerals in US water supplies. The known benefits of minerals contributed by water and diet are: 1) calcium and magnesium: bone and CV health; 2) sodium: electrolyte balance; and 3) copper: antioxidant properties, iron utilization, and CV health¹. Epidemiological research in the US, Europe, and Russia suggests health benefits may be associated with at least 20-30 mg/l calcium and 10 mg/l magnesium in drinking water¹. Hard water contributes calcium and sometimes magnesium to the diet but the concentrations and relative amounts vary widely according to levels of water consumption through drinking and food preparation and the sources of water. Naturally occurring nutrients with potential health benefits may be removed with water treatment; some may be added or removed deliberately (e.g., by membrane filtration or softening)². The World Health Organization (WHO) recommends water utilities regularly analyze their water for calcium, magnesium, and trace elements to support assessment of intake trends and epidemiologic studies between water hardness and a number of health outcomes¹. The purpose of this study was to provide national data on important minerals in the US water supply in the USDA National Nutrient Database for Standard Reference: www.ars.usda.gov/nutrientdata.

Methods and Materials

Step 1. Develop sampling design

- US population ordered by county and divided into 72 equal zones, 1 county per zone selected, probability minimum replacement, 2 locations (residential, retail outlets) selected in each sampled county (Figure 1)

Step 2. Obtain study approval

- Federal Register announcement and approval by OMB process, survey and incentives

Step 3. Recruit participants

- Phone call recruitment (neighborhood clusters)
- Substitution list used to replace refusals in water collection
- Followup letters confirming collection dates
- USDA vehicle emergency packs – first collection incentive

Step 4. Obtain water samples (2 pickups)

- Contracted agents picked up samples, issued surveys
- Water was run for 3 minutes before sampling
- First residential tap water pickup – February-March, 2003
- Second residential tap water pickup – April-June, 2003
- Tap water included municipal and well water

Step 5. Analyze samples

- Leeman PS 3000 ICP-AES (inductively coupled plasma atomic emission spectrometry).
- Ca, Cu, Fe, Mg, Mn, P, Zn, Na and K: all run in the simultaneous mode except Na and K, which were sequential.
- Prior to ICP analysis, samples were acidified with 0.25 mL concentrated nitric acid and then run directly
- Detection limits (DL) (in µg/ml solution concentration): Ca (0.0126); Cu(0.008); Fe (0.020); Mg(0.0015); Mn (0.007); P (0.130); Zn (0.007); Na (0.058); K (0.029). Our quantitation limit is defined as 5 times the DL.

Step 6. Data Analysis

Figure 1. Counties sampled

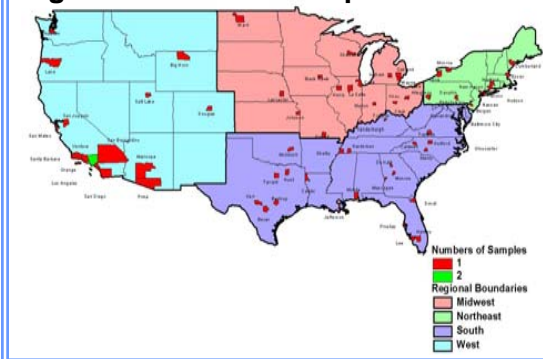


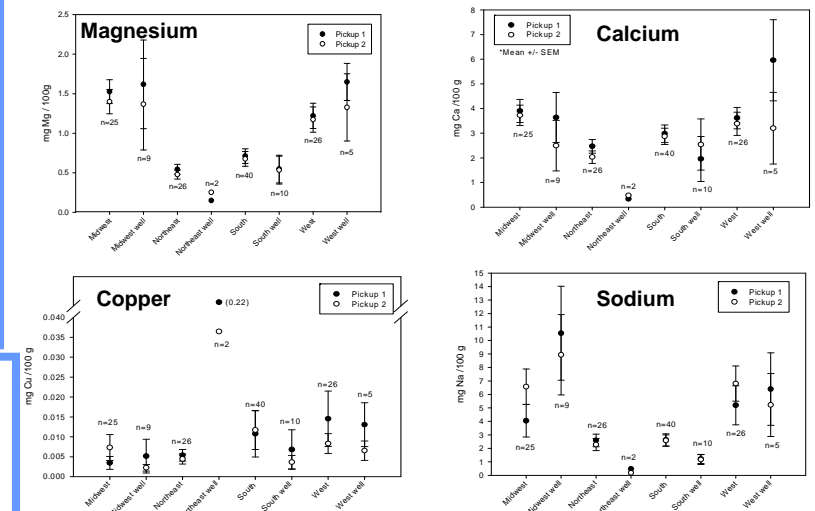
Table 1. Mineral content of water samples (mg/100g)

	Mean	Median	Min	Max	Avg mg in 2 liters	DRI* mg/day (male 31-50y)
Ca	3.0	2.7	0.0	10.0	61	1000
Cu	0.0098	0.0017	ND	0.4073	0.20	0.90
Fe	0.002	0.0003	ND	0.065	0.04	8
K	0.5	0.2	ND	20.4	9.8	4700
Mg	0.9	0.8	0.0	4.6	19	420
Mn	0.0002	ND	ND	0.0099	0.005	2.3
Na	3.8	1.9	0.1	39.1	76	1500
P	0.01	0.01	ND	0.2	0.29	700
Zn	0.005	0.001	ND	0.075	0.10	11

Observations and Results

- Of the 144 sites where water samples were obtained, 26 (18%) were from wells and 118 (82%) were from municipal water supplies.
- Assuming a daily intake of water to be 2 liters³, the water would provide >1% of recommended intake for only four minerals; copper, 10%; calcium, 6%; magnesium, 5%; and sodium, 3% (Table 1).
- Even the maximum concentration would supply only about 20% of Ca, 23% of Mg, 10% of Zn, and 33% of Na. The highest value for Cu would, however, supply 400%.
- The results for Mg, Ca, Cu, and Na by region and type of water are shown in Figure 2.
- The very high Cu was found only on the first pickup at the one site. For the second pickup, the value was only 12% of the first. The high value may have been the result of insufficient flushing of the copper pipes before taking the sample.
- Significant decreases in Ca were observed with chemical water softeners (mean 3.2 v. 2.0; median 2.73 v 0.44 mg/100g), and between pickups for Mg and Ca (p<0.05).
- The variance of Na was significantly different among regions (p<0.05); no differences were observed as a result of collection time, water source or treatment.
- Based on the weighted mixed model results, there were no significant differences in overall mean mineral content between municipal and well water.

Figure 2. Mineral Content of Water Samples by Region



Conclusions

- On average, the content of calcium and magnesium in the drinking water meets the 20-30 mg/L calcium and 10 mg/L magnesium suggested by epidemiological research for health benefits.
- The sodium and magnesium values, on average, were the lowest for the Northeast and South samples.
- The Midwest and West well water showed the most overall variability in mineral content (Mg, Ca, and Na).
- These data support studies of the contributions of drinking water to total intake of important minerals in the US diet and resulting recommendations.⁴

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