Calcium Content Variability in San Francisco Bay Area Tap Water and its Implication to Dietary Calcium Intake

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ABSTRACT

Calcium concentrations in household tap water are highly variable and have important consequences with respect to human health. This study was undertaken to determine the variability of calcium concentrations throughout the San Francisco Bay Area. Sixty-one samples were analyzed using the Perkin-Elmer Analyzer 200 Atomic Absorption Spectrophotometer for Ca^{2+} concentrations. The results indicated that concentrations were dependent upon differences in water sources. The highest source of concentration was found in Pleasanton at 66.039 $\pm$ 13.8 μg mL^{-1}, while the lowest concentration was found in Lathrop at 0.007 $\pm$ 13.8 μg mL^{-1} and the mean concentration was 20.969 μg mL^{-1}. The pH was measured using an ExStickII pH meter. This distinguished the reason for the varying level of calcium concentrations in tap water. High concentrations can be beneficial to those requiring supplements to their calcium diets while being detrimental to those that do not need the extra enhancement.

INTRODUCTION

In the San Francisco Bay Area, there are four main sources of water [1], which are the state water project, the Central Valley Project, groundwater, and the local streams and reservoirs. In the South Bay, the East Bay Municipal Utility District is a state water project that supplies Albany, Danville, El Cerrito, San Ramon, Brentwood, San Francisco East and San Francisco West primarily using the Sierra Nevada [5] snowmelt as well as the Mokelumne River water. Another state water project is the 444-mile-long aqueduct that carries water from the Delta through the San Joaquin Valley to southern California. From the Tehachapi Mountains and the California Aqueduct, the aqueduct pumps water into Dublin, Livermore, and Pleasanton.

In the Central Valley, groundwater is used extensively and is regulated by the California Public Utilities Commission, and is used to serve Lathrop. Also, the Central Valley Project is also very important as some of its main facilities include Shasta Dam and reservoir on the Sacramento River, Trinity Dam and Trinity Lake on the Trinity River, Folsom Dam and reservoir on the American River, New Melones Dam and reservoir on the Stanislaus River, Friant Dam and reservoir on the San Joaquin River; the Tracy Pumping Plant; Delta-Mendota Canal; and the joint-use (federal and state) San Luis Reservoir [2]. The Central Valley Project supplies water to Tracy, Stockton, and Manteca.

The source of water can greatly vary the amount of calcium that it contains. Calcium, the most abundant mineral in the body, is found in some foods, added to others, available as a dietary supplement, and present in some medicines (such as antacids) [3]. An average person between the age of 10 and 18 requires about 1,000 mg of Ca^{2+} and someone who is 19 or above would require about 1,300 mg of Ca^{2+}. Calcium consumption is very essential and is required for

vascular contraction and vasodilation, muscle function, nerve transmission, intracellular signaling and hormonal secretion. Most of the body's calcium supply is stored in the bones and teeth where it supports their structure and function. Bone itself undergoes continuous remodeling, with constant resorption and deposition of calcium into new bone [3]. The balance between bone resorption and deposition changes with age. Bone formation exceeds resorption in periods of growth in children and adolescents, whereas in early and middle adulthood both processes are relatively equal. In aging adults, particularly among postmenopausal women, bone breakdown exceeds formation, resulting in bone loss that increases the risk of osteoporosis over time [3].

For bone health, vitamin D and calcium usually are related, because this vitamin must be present in order for calcium to be absorbed from the digestive tract. The steady increase in life expectancy and the already epidemic levels of osteoporosis and fractures among older Americans, showed that women are especially vulnerable, because estrogen loss at menopause can cause a precipitous decline in bone density [4]. Older women are usually required to take Ca^{2+} supplements to reach their recommended amount of 1,300 mg of Ca^{2+} [3].

RESULTS

After analyzing the sixty-one water samples from around the San Francisco Bay Area, the calcium concentrations in tap water varied greatly from 0.007 $\pm$ 13.8 μg mL^{-1} to 66.039 $\pm$ 13.8 μg mL^{-1} with a mean concentration was 20.969 μg mL^{-1} (Figure 1). This variance in calcium concentration was caused due to the source of water.

For the most of the South bay, the East Bay Municipal Utility District supplies water to the surrounding cities like Albany, Danville, El Cerrito, San Ramon, Brentwood, San Francisco East and San Francisco West. The main source of water for the East Bay Municipal Utility District is the Sierra Nevada snowmelt, which is when the snow melts and flows downstream into lakes and man-made reservoirs [6]. Since the snowmelt is all natural water, the amount of calcium is very low compared to the rest of the San Francisco Bay Area. This is a reasonable explanation as to why Brentwood has the lowest calcium concentration in the entire San Francisco Bay Area.

For the other part of the South bay, another state water project carries water from the Tehachapi Mountains and the California Aqueduct into Dublin, Livermore, and Pleasanton. The California Aqueduct is the nation's largest state-built water and power development and conveyance system [7]. This aqueduct is built with concrete, which contains aggregate, the large chunks of material in a concrete mix. This generally consists of coarse gravel or crushed rocks such as limestone, or granite, along with finer materials such as sand. When limestone ($CaCO_3$) is combined with water (H_2O), the following reaction occurs:

$$CaCO_3(s) + H_2O(l) \text{ <-------> } CO_2(g) + Ca(OH)_2(aq)$$

Calcium hydroxide ($Ca(OH)_2$) is soluble in water [9], thus releasing Ca^{2+} into solution from the California Aqueduct. This is why Pleasanton’s calcium concentration is the highest compared to the rest of the San Francisco Bay Area.

In the Central Valley, the majority of the water supply comes from the Sacramento River as well as the Shasta Dam. The Shasta Dam and Reservoir project, is a curved, gravity-type, concrete structure, and was constructed by the U. S. Bureau of Reclamation as an integral element of the Central Valley Project. Since this Dam consists of concrete [8], the calcium concentrations in Tracy, Stockton, and Manteca are relatively high as well. However, since the Central Valley has a filter, it filters out a lot of the calcium as well as other essential minerals, the concentration is not as high in the Central Valley compared to the Tri Valley.

Lastly, the only water sample that was analyzed from the North Bay in this experiment was San Anselmo. The water is supplied from Lake Lagunita and Bon Tempe Lake, which are a part of the Marin Municipal Water District. This particular water supplier tests the quality of the water and maintains all the minerals that it contains. For this reason, the calcium concentration in San Anselmo is rather low, compared to the South Bay. Water Mixing is used to maintain water quality and thus low calcium concentrations.

The equation listed above, showing the dissociation of $CaCO_3$ commonly called limestone, is known as an equilibrium expression. In this equation, the rate of the forward reaction is equal to the rate of the reverse reaction. By using this equation, the equilibrium constant (K) can be calculated. By knowing the concentration of H^+ (which is the same thing as pH) and the concentration of CO_2, the isotherm of $CaCO_3$ can be determined (Figure 2). An isotherm is a graph that compares the pH (x-axis) and the concentration of a mineral (y-axis) to show the relation between the two. This isotherm allowed for the following conclusion to be made: the concentrations of calcium in the Tri Valley, represented by the black diamonds, are caused due to the interaction that the flowing water has with the $CaCO_3$ or limestone.

DISCUSSION

Calcium is a dietary mineral that is present in the human body in amounts of about 1.2 kg. Calcium greatly assists bone and tooth growth, along with vitamin D. Calcium is also present in muscle tissue and in the blood. It is required for cell membrane development and cell division, and it is partially responsible for muscle contractions and blood clotting. Calcium regulates membrane activity, it assists nerve impulse transfer and hormone release, stabilizes the pH of the body, and is an essential part of conception [9]. In order to stimulate all of these bodily functions, a daily intake of about 1,300 mg of Ca^{2+} is recommended for adults of the age 19 and older.

On the other hand, excess calcium in the body is also a very serious problem. It can cause problems heart disease, stroke, and kidney stones. One of the gravest problems that too much calcium can cause is called hypercalcemia. This is a condition in which the calcium level in the blood is above normal. This issue interferes with the way the heart and brain works. If this negative pattern is continued, it can ultimately lead to early onset of osteoporosis, arrhythmia (abnormal heart rhythm), nervous system problems (like confusion, dementia and coma), and even kidney failure [13].

The analysis of the water samples shows that on average (in the San Francisco Bay Area), one glass of tap water contains about 20.969 $\mu g\ mL^{-1}$, which is approximately 6.553 mg of Calcium per glass of water. Women who are lactating or going through menopause require a higher dose

of calcium than the average person. Usually, doctors would recommend about 300 to 700 mg of additional Ca^{2+} per day [3]. Also, the elderly who suffer from osteoporosis should consume about 300 mg of additional Ca^{2+} daily. On average, one tablet of calcium supplement contains about 600 mg of Ca^{2+}, which is nearly 60% of the daily-required intake.

Consuming the recommended 8 glasses of water per day, an average person will consume about 52.424 mg of Calcium just by drinking tap water. This would be 4% of the daily requirement of calcium recommended. For those who need calcium supplements (or not), drinking tap water can significantly decrease the amount of calcium that one needs to consume via tablets. Drinking tap water can supply up to 4 to 10 percent of the daily calcium intake.

CONCLUSION

Calcium concentrations in the San Francisco Bay Area tap were found to be highly variable, ranging from 0.007 $\pm$ 13.8 μg mL^{-1} in Lathrop to 66.039 $\pm$ 13.8 μg mL^{-1} in the Pleasanton area. This is due in part to the water source. Water supplied from the California Aqueduct contained high calcium values while water sourced from the Sierra Nevada snowmelt was very low in calcium. Individuals that require calcium supplements can utilize the benefits of tap water for their dietary needs. It is advised that those individuals who need close monitoring of calcium utilize laboratory analysis of their tap water as a supplement to their calcium requirements.

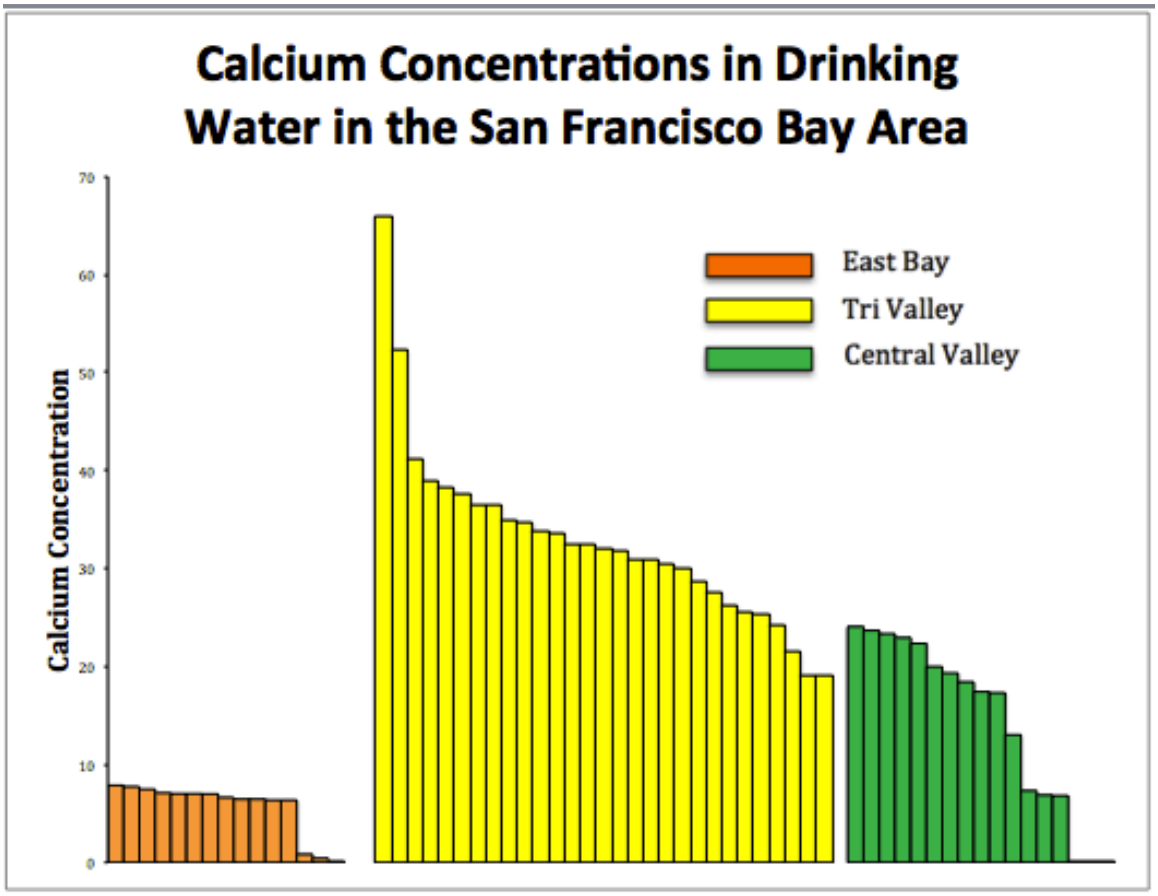

Figure 1: The comparison of the sixty-one samples of drinking water from the Bay Area with respect to their individual calcium concentrations

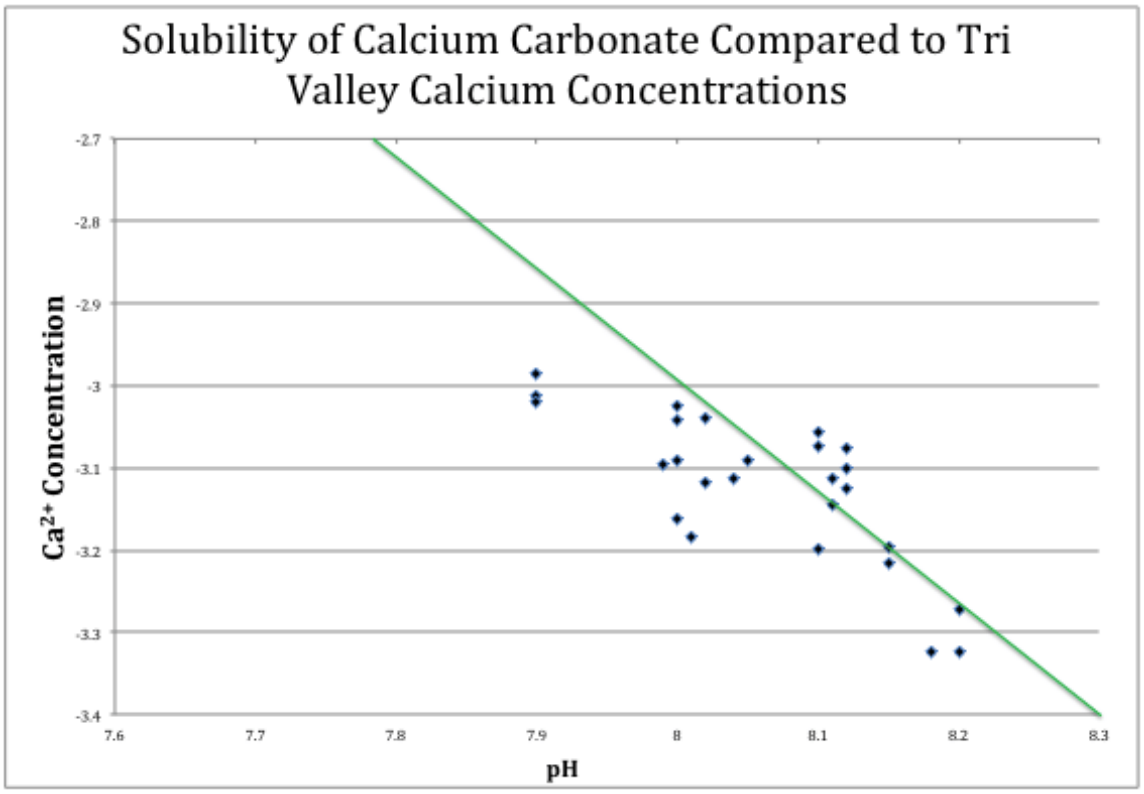

Figure 2: $CaCO_3$ Isotherm determined by using the concentration of H^+ (equivalent to pH) and the concentration of CO_2

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