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Mineral Element Concentrations in Vegetables Cultivated in Acidic Compared to Alkaline Areas of South Sweden

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Abstract: A study in 1997, on mineral levels in acidic compared to alkaline well waters, and in women's hair, revealed higher concentrations of a number of mineral elements like Ca, Mo and Se in alkaline waters and hair. Thus, median Ca levels were six times higher in well water and five times higher in hair from the alkaline area compared to the acidic area. This finding raised the probability of similar differences in vegetables from these areas. Thus, in the year 2006, 60 women who had participated in the study in 1997 were asked to cultivate parsley, lettuce, carrot and chive. During the spring of 2006, the women from the water and hair study of 1997, 30 of them from the acidic area and 30 women from the alkaline district cultivated vegetables: carrot (Daucus carota L), parsley (Petroselinum crispum), chive (Allium schoenoprasum) and lettuce (Eruca sativa). The vegetables were harvested, and rinsed in tap water from the kitchens of the participating women in August. The concentrations of about 35 elements and ions were determined by ICP OES and ICP-MS predominantly. In addition, soil samples from the different cultivators were also analyzed for a number of elements.

Lettuce and parsley showed the highest concentrations of mineral elements per gram dry weight. Only Mo concentrations were significantly higher in all the different vegetables from the alkaline district compared to vegetables from the acidic areas. On the other hand, the concentrations of Ba, Br, Mn, Rb and Zn were higher in all the different vegetables from the acidic area. In the soil, only pH and exchangeable Ca from the alkaline area were higher than from the acidic area, while exchangeable Fe, Mn and Na concentrations were higher in soils from the acidic area. Soil elements like Al, Fe, Li, Ni, Pb, Si, Ti, V, Zn and Zr were found in higher concentrations in lettuce and parsley, which were attributed to soil particles being splashed on the plants by the rain and absorbed by the leaves. Strong correlations appeared between Ca and Sr in all the vegetables, except for carrot. No strong correlations were found between soil elements and vegetable elements, except for soil Mn and carrot/lettuce Mn. The differences in mineral levels in both, vegetables and soils were however small, compared to differences in well waters and hair. It was also suggested that the garden soils on limestone bedrock had been drained of minerals and thereby, the soil had an acidic pH. The contribution of mineral elements to daily intake in humans was considered minor from the analysed vegetables, except for some samples of lettuce that should give significant contributions of Ca, Zn, Mn and Mo.

The main conclusion is that, differences in water and hair mineral levels between the two areas in the earlier study (1997) were not mirrored in vegetables cultivated in 2006. Principally, this suggests that, for humans the mineral intake of some elements from water may be more important than from vegetables.

Introduction

The content of mineral elements in vegetables and soils has been studied for a number of decades. Fertilizers including the mineral elements N, P and K have been used, and the focus has partly shifted towards the addition of several other elements. Nowadays, Mo, B, Mn and Zn may be added to NPK-fertilizers, whereas Se is added in Finland (Oral comm. Gunilla Frostgård, Jara, Landskrona, Sweden).

Several investigations regarding the influence of soil pH have been performed. For example Crooke and Knight[1] reported that monocotyledon roots, but not always dicotyledon roots, grown in a soil with pH raised by liming, increased the content of the four dominating exchangeable minerals in the soil (Ca, Mg, K, Na) as well as of N. Mn uptake is usually lower if the soil pH is high,[2] due to decreased solubility of this element with increasing pH.

A study by Sinha et al.[3] showed that leafy vegetables like lettuce were unsuitable to grow in Cr-contaminated soils, since they accumulated Cr more than fruit bearing vegetables/crops. The microelement selenium (Se) intake from drinking water, as well as from plants has been highlighted

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for some decades. In Keshan in China, there was a widespread occurrence of a lethal cardiomyopathy, affecting mostly children in the 1930s. The Keshan disease was associated with Se deficiencies in soil and food. Also, the Se concentrations in plants were inversely associated with death rates from hypertensive heart diseases in the United States.[4] The presence of soluble SO_4^{2-} in soil significantly reduced Se accumulation in alfalfa.[5] Reference levels of some elements in vegetables are presented in Table 1.

Consumption of about 1–3 L of water per day is common in adults. Children and infants consume an even larger daily volume compared to their body weight. Thus, the composition of drinking water is even more important in this group. A number of studies show the importance of mineral concentrations in drinking water for health. Mortality rates from arteriosclerotic heart diseases were found to be highest in areas that were deficient in trace elements.[4] Hard water, with high concentrations of especially Ca and Mg, has been found to be protective against cardiovascular diseases.[9–11] Some recent studies, have shown that hard water has a protective effect and helps prevent death caused by diabetes mellitus[12,13] and different malignancies.[14–17]

The mineral concentrations in ground water and surface water are mainly influenced by precipitation, atmospheric deposition, weathering of soil and fractured bedrock, and soil chemistry. Primary rocks like gneiss and granite which are hard and slowly weathered dominated in the acidic region of this study which is located in southwest Sweden. The most important minerals in these soils and bedrock were quartz (SiO_2 dominating), potassium-feldspar (K, Al, SiO_2), sodium-feldspar (plagioclase, Na, Ca, Al, SiO_2), hornblende (Ca, Mg, Fe, Al, OH, SiO_2, Na, K, heavy metals) and mica (Mg, K, Fe, F, OH, SiO_2, heavy metals). The silicate mineral epidot (SiO_2, Ca, Al, Fe) was sparsely spread throughout the soil minerals originating from the granite/gneiss bedrock. Thus, Swedish natural water and soils outside calcareous areas may contain detectable and significant concentrations of elements like Al, Fe, Ca, K, Na, Si, Mn, Mg and some heavy metals.[18,19]

However, the Kristianstad flatland in Skåne, in the southernmost county of Sweden, the alkaline area chosen for this study, was dominated by limestone, on top of sandstone, about 100 m deeper down in the bedrock. The easily weathered limestone had high concentrations of a number of elements and ions, e.g. Ca, Mg, HCO_3, K, Na, Fe, P and S in ground water and soil.[18] Moreover, Al, Cd, Co, Cr, Cu, Ni, Pb, V and Zn were also present in Ignaberga limestone from the Kristianstad flatland. The concentrations of Ca and Mg may vary widely in limestone areas from approximately 55% CaO and less than 1% MgO in calcite, which dominates the bedrock of Southern Sweden, to about 30% CaO and 12% MgO in Central European dolomite.[20] The minerals calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) increase the exchangeable amounts of alkaline cations such as Ca and Mg. Sandstone is composed of grains of sand, connected mostly by silicic acid, and more rarely by limestone, clay or iron-hydrate.[19] Elements like Si, Al, Ca, Fe, Mg, K, Na and Ti dominate in the ground water of sandstone rocks.[18]

The study of well water from acid districts in southern Sweden, which was dominated by gneiss and granite, showed low concentrations of HCO_3, Ca, Mo and Se compared to the levels of these minerals in the alkaline well water from the plains around the city of Kristianstad.[21] On the other hand, the well water concentrations of Cu, F and Pb were all significantly higher in the

Table 1. Dry weight concentrations from Furr et al[6] and Kirkham[7] of a number of mineral elements in carrot, lettuce and parsley.

Carrot	**As**	**B**	**Mg**	**Ca**	**Cu**	**Fe**	**Hg**	**I**	**K**	**Mo**	**Ni**	**Sb**	**Se**	**Unit**
Furr et al.[8]	0.05	15	1203										0.02	µg/g
Furr et al.[6]	0.01	19	730	1650	2.0	143	0.1	0.9	25300	0.2	2.7	0.9		µg/g
Kirkham[7]	**N**	**P**	**K**	**Ca**	**Mg**	**Fe**	**Zn**	**Cu**	**Ni**	**Unit**				
Lettuce	5700	1400	25000	12000	4300	217	28	18	12	µg/g				
Parsley	6000	900	15000	10000	3800	260	16	12	27	µg/g				

acidic regions. Corresponding metal concentrations were also determined in hair samples from women who had been drinking their well water for at least five years. The hair concentrations of boron (B) and Ba were significantly higher in hair samples obtained in the acidic region compared to hair of women from the alkaline area. On the contrary, the levels of Ca, Sr, Mo, Fe and Se were significantly higher in hair samples from the alkaline region. Strong positive correlations were observed between element concentrations in water and hair for Ca, Sr, Mo and Pb respectively. Strong positive correlations were also noted between Ca and Sr concentrations in both water and hair. The ratio in hair of Se/Hg was significantly higher in hair samples collected in the alkaline region.[22] Thus, elements like Ca, Mo and Se were all significantly higher in alkaline well waters and women's hair than from acidic regions.

Mineral elements in vegetables have their origin mainly from soil water and root uptake. The uptake thus depends on the environment of the root system. When the pH level of acid soils have been raised by the addition of limestone, the concentrations of minerals in monocotyledons, at least for the mineral elements related to the Cation Exchange Capacity (CEC) level; Ca, Mg, K and Na increase, while Mn decreases.[1] The use of fertilizers with high P concentrations may also depress the Mn uptake.[2] The uptake by vegetables, of elements like N is different at low and high pH levels, respectively. Thus, N is taken up predominantly as NO_3^- ions at high soil pH and predominantly as NH_4^+ in acid soils. Ammonium ions formed by decomposition of organic matter is oxidised to nitrate by special bacteria, forming nitric acid (nitrification). In alkaline soil this acid assists the release of mineral ions, which can then be assimilated by crops. This may partly explain higher mineral values in plants from alkaline areas. NH_4 fertilisers may depress the concentrations of Ca, Mn, K and Na in vegetables and crops, since the positively charged NH_4-ions increase the positive charges inside the cells of vegetables and crops, increasing the in-flow of negatively charged ions, such as Cl, SO_4, NO_3 and PO_4. Soils derived from glaciated igneous rocks are inferior sources of Se.[23] Soluble SO_4 in the soil may reduce Se uptake in alfalfa.[5]

An illustration of how mineral elements are taken up by vegetables is presented in Figure 1.

In the present study it was intended to find out the potential effect on minerals, from the soils and vegetables of the alkaline and acid regions respectively, and their eventual links to the

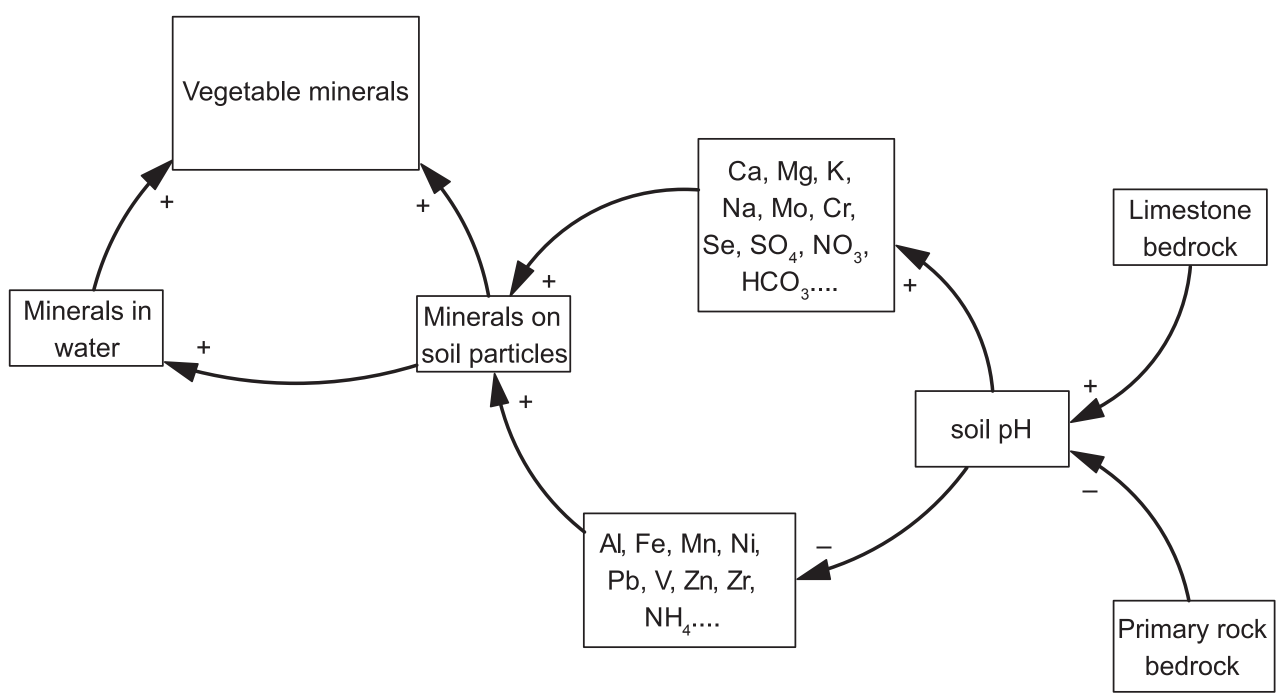

Figure 1. CLD (Causal Loop Diagram) of mineral elements uptake by vegetables.

humans studied earlier. The specific aims of this study were

- to compare the concentration of a number of mineral element in carrot, lettuce, chive and parsley cultivated in acidic areas, with samples from an alkaline area in south Sweden
- to estimate the impact of soil chemistry on the mineral content of the different vegetables
- to increase the understanding of the potential influence of minerals from locally cultivated vegetables on the mineral content of humans.

Material and Methods

Forty-seven women living in separate houses with private wells (no water filter) in an acidic area in the northern region of the county of Skåne, and in the southern part of the counties of Småland and Västergötland (SW Sweden) were randomly selected for well water and hair sampling in 1997. All participants had a pH in tap water below 6.5 as tested by a field pH meter (Knick model 912). The bedrock in this area was dominated by primary rocks of ortogneiss and granite. For comparison, 43 women from a district in southern Sweden localised on lime sediments, with a pH in tap water from private wells above 7, and no water filter, were randomly selected. A sample of 250 mL of water was collected from the kitchen tap of the homes of all participants, and a hair sample from the woman's neck was taken. In addition, participating women were interviewed about their health changes during the time when they had been drinking the well water.[24]

In year 2006, 30 women who participated in the water and hair study from the acidic area,[21,22] and 30 women from the alkaline district, were requested to cultivate vegetables; carrot (Daucus carota L), parsley (Petroselinum crispum), chive (Allium schoenoprasum) and lettuce (Eruca sativa). The women were required to irrigate the vegetables only with their own well water, and to make notes about the number of litres used. In addition, they were also required to make notes of the amount and the kind of fertilizers used, and whether there was any use of alkalizers. In August, the vegetables were harvested. All vegetables were rinsed in tap water from the kitchens of the participating women. If the women were not at home when the vegetables were being harvested, deionised water was used. Lettuce, parsley, chive leaves and the roots of carrot were sampled for analysis. At the Department of Plant Ecology, Lund University, Sweden, the vegetables were dried at 40 °C in an oven and analysed. Approximately 0.2 g of the vegetables were digested in ultra clean nitric acid (HNO_3) in a microwave oven with multi-wave function, and transferred to a 50 mL flask for analyses of the concentrations of 35 elements, which showed the following: (detection limit; precision); Al (0.1 μg/g, 0.2 μg/g), As (1 ng/g, 4 ng/g), B (1 ng/g, 10 ng/g), Ba (10 ng/g, 50 ng/g), Be (4 ng/g, 8 ng/g), Br (3 μg/g, 30 μg/g), Ca (2.5 μg/g, 5 μg/g), Cd (5 ng/g, 10 ng/g), Co (5 ng/g, 10 ng/g), Cr (5 ng/g, 10 ng/g), Cu (0.005 μg/g, 0.05 μg/g), Fe (0.5 μg/g, 1.0 μg/g), Hg (5 ng/g, 10 ng/g), I (0.5 μg/g, 2 μg/g), K (2.5 μg/g, 10 μg/g), Li (1 ng/g, 5 ng/g), Mg (1 μg/g, 2 μg/g), Mn (5 ng/g, 50 ng/g), Mo (1 ng/g, 5 ng/g), Na (2.5 μg/g, 5 μg/g), Ni (5 ng/g, 50 ng/g), P (0.5 μg/g, 50 μg/g), Pb (1 ng/g, 10 ng/g), Rb (5 ng/g, 10 ng/g), S (2.5 μg/g, 25 μg/g), Sb (5 ng/g, 10 ng/g), Se (5 ng/g, 20 ng/g), Si (1 μg/g, 5 μg/g), Sn (5 ng/g, 10 ng/g), Sr (1 ng/g, 10 ng/g), Ti (5 ng/g, 20 ng/g), U (0.2 ng/g, 1 ng/g), V (2 ng/g, 5 ng/g), Zn (0.01 μg/g, 0.1 μg/g) and Zr (30 ng/g, 150 ng/g).

The vegetables were analyzed similar to earlier studies[21,22] of hair samples at the Department of Plant Ecology, on especially ICP OES (Inductively Coupled Plasma Optical Emission Spectroscopy; Perkin-Elmer, Optima, 3000 DV) and ICP-MS (Inductively Coupled Plasma Mass-Spectrometry; Perkin Elmer, ELAN-6000).

Soil samples were extracted in 0.2 M $BaCl_2$ and analysed for exchangeable Na, K, Ca, Mg, Al, Fe, Mn and Zn on ICP OES. Soil pH was analysed both, in the extract of water (soil:water 1:2) and in the $BaCl_2$-extract.

All elements presented in this article refer to ions, for e.g. Ca means Ca^{2+}.

Parametric statistics (Students t-test) were used for comparison of elements in water, hair and vegetables that showed a normal distribution (checked by Normal Probability Plots, Levene's test). For elements with a skewed distribution, nonparametric statistical processing was applied (Mann-Whitney's U-test). Possible associations between the concentrations of elements were investigated by calculating correlation coefficients (r_s = Spearman's rho). P-values <0.05 were regarded as statistically significant (two-tailed tests). Simple linear regression analysis was used to elucidate the impact of different predictors on the variation in element concentrations in hair and vegetables. All calculations were performed with the Statistical Package for the Social Sciences (SPSS version 14.0).

Results

No alkalizers were used by the participating cultivators. 14 (total alkaline = 29) women in the alkaline area had used fertilizers compared with only 7 (total acid = 30) in the acidic areas. 13 of the cultivators in the acidic areas had not performed any irrigation compared with 2 in the alkaline district. The average irrigation in the acidic areas was 68 mm, while it was 170 mm in the alkaline area. The rainfall during this period was 172 mm in the acidic area, and 132 mm in the alkaline (oral comm. SMHI, The Swedish Meteorological Office, 2008).

The number of harvested samples of the different vegetables in the two areas is presented in Table 2.

Concentrations of elements in different vegetables and soils

Concentrations of elements in carrot, lettuce, parsley and chive are presented in Tables 3–7, and in soils in Tables 8 and 9.

Generally, lettuce and parsley appeared to have the highest concentrations of mineral elements among the four different vegetables. The elevated concentrations of Al, Fe, Li, Ni, Pb, Si, Ti, V, Zn and Zr in lettuce and parsley indicate uptake from the leaves, probably as a result of splashing of soil on the plants due to rains. This is probably the most correct explanation of the differences in concentrations.

The soil particles are most likely flushed away from chive, while they may remain on the leaves of lettuce and parsley, as they have a larger horizontal leaf area than chive, which has more vertically directed leaves.

Carrot

The median concentrations of Ba, Br, Cd, Cr, (Hg,) Mn, Ni, Pb, Rb, Se, Zn and Zr were significantly higher in carrot cultivated in the acidic area. On the other hand, Mo concentrations (and U) were higher in carrot from the alkaline area.

The magnitude of the differences was between 1.5 and 5. The median Ba concentration was 5 times higher in carrot from the acidic area compared to the alkaline whereas, for Zr the corresponding difference was 3 times.

The concentrations of Hg, Sn and U were close to the respective detection levels in all the different vegetables, which hampered further comparisons.

Table 2. Number of harvested samples from the two areas.

	From the acidic areas	From the alkaline area
Carrot	19	22
Lettuce	24	26
Parsley	20	24
Chive	24	25

Lettuce

The median concentrations of Ba, Br, Cu, Mg, Mn, Ni, Pb, Rb and Zn were significantly higher in lettuce cultivated in the acidic area. On the other hand As, Ca, I, Mo, S, Si (and U) were higher in lettuce from the alkaline area.

The magnitude of the differences was between 1.5 and 3. Median Ba, Rb and Zn concentrations were 3 times higher in lettuce from the acidic area compared to the alkaline area.

Parsley

The median concentrations of Ba, Br, Cd, Co, Cr, Cu, (Hg,) Mg, Mn, Na, Ni, Rb, S, Se, Ti and Zn were significantly higher in parsley from the acidic area. On the other hand As and Mo were higher in parsley from the alkaline region.

The magnitude of the differences was between 1.5 and 4. The median Ba concentration was 4 times higher in parsley from the acidic areas, and Mn was 3 times higher. On the other hand, Mo was 3 times higher in parsley from the alkaline area compared to the acidic area.

Chive

The median concentrations of Ba, Br, Cd, Mg, Mn, Rb and Zn were significantly higher in chive cultivated in the acidic area. On the other hand As, Ca, I, Li, Mo, Rb, S, Sb, Si (and U) concentrations were higher in chive from the alkaline area.

The magnitude of the differences was between 1.5 and 3.5. The median Br concentrations were 3 to 3.5 times higher in chive from the acidic area.

The median concentrations of exchangeable elements and pH-levels in soils are presented in Table 8, and significant differences between acid and alkaline areas in Table 9.

Table 3. Median dry weight concentrations and ranges, plus means and standard deviations in carrot, lettuce, chive and parsley of analyzed elements. The highest concentrations are emphasised and bold marked.

	Chive (median, range)	Chive (mean, stdev)	Parsley (median, range)	Parsley (mean, stdev)	Unit
Al	46.7 (7.9–335)	68.5, 62.5	**120 (13–610)**	**173, 147**	µg/g
As	0.076 (0.008–1.6)	0.15, 0.25	0.069 (0–0.9)	0.13, 0.18	µg/g
B	17.4(3.9–53)	18.1, 8.4	**22.7 (12–34)**	**22.1, 3.8**	µg/g
Ba	4.67 (0.6–79)	10.1, 15.4	**18.3 (2.3–126)**	**30.7, 30.9**	µg/g
Be	0.002 (0–0.02)	0.004, 0.003	0.006 (0.0006–0.04)	0.008, 0.007	µg/g
Br	4.0 (1.0–16)	4.9, 3.7	4.8 (2.4–29)	6.3, 4.7	µg/g
Ca	13900 (6500–25900)	14000, 4000	12000 (4600–36000)	13200, 5900	µg/g
Cd	0.14 (0.05–1.4)	0.22, 0.26	0.218 (0.06–1.2)	0.31, 0.24	µg/g
Co	0.052 (0.02–0.7)	0.074, 0.11	0.075 (0.02–0.3)	0.09, 0.06	µg/g
Cr	0.501 (0.4–1.3)	0.55, 0.17	0.549 (0.3–2.3)	0.74, 0.47	µg/g
Cu	5.52 (3.4–19)	6.18, 2.29	6.63 (1.2–21)	7.8, 3.6	µg/g
Fe	87.9 (54–440)	106, 67.1	**155 (64–690)**	**213, 149**	µg/g
Hg	0.014 (0.005–0.3)	0.021, 0.046	0.014 (0.009–0.03)	0.015, 0.005	µg/g
I	0.255 (0.06–0.9)	0.29, 0.16	**0.341 (0.04–1.0)**	**0.39, 0.25**	µg/g
K	23800 (14600–41500)	25400, 6700	**52600 (15700–73400)**	**52300, 12600**	µg/g
Li	0.090 (0.007–1.0)	0.14, 0.19	0.133 (0.02–1.0)	0.19, 0.20	µg/g
Mg	1470 (1150–3000)	1660, 440	1860 (730–5300)	1920, 804	µg/g
Mn	35.2 (12–1800)	87.5, 265	54.7 (14–910)	*90.9, 142*	µg/g
Mo	3.92 (0.1–39)	6.06, 7.44	2.81 (0.1–13)	3.24, 2.72	µg/g
Na	53.2 (18–2600)	120, 380	**970 (205–14000)**	**1610, 2220**	µg/g
Ni	0.668 (0.3–3.1)	0.75, 0.44	**1.16 (0.4–4.1)**	**1.49, 0.92**	µg/g
P	**4173 (1500–7300)**	**4360, 1160**	**4010 (1670–7100)**	**4070, 1230**	µg/g
Pb	0.162 (0.02–3.3)	0.28, 0.54	**0.360 (0.1–1.8)**	**0.47, 0.34**	µg/g
Rb	11.1 (1.9–44)	13.7, 11.6	19.8 (3.4–87)	29.9, 22.6	µg/g
S	5370 (2200–9200)	5350, 1490	2620 (1400–4600)	2800, 590	µg/g
Sb	0.002 (0–0.02)	0.0035, 0.0052	**0.015 (0.005–0.06)**	**0.018, 0.01**	µg/g
Se	0.078 (0–0.8)	0.097, 0.114	0.055 (0.01–0.2)	0.07, 0.05	µg/g
Si	139 (0–450)	150, 108	**270 (52–795)**	**330, 183**	µg/g
Sn	0.051 (0.01–0.3	0.067, 0.059	**0.070 (0.02–0.6)**	**0.09, 0.10**	µg/g
Sr	29.1 (11–95)	30.4, 12.7	28.1 (7.0–70)	30.5, 13.1	µg/g
Ti	2.85 (0.06–24)	4.41, 5.34	**9.3 (0.7–63)**	**13.2, 13.6**	µg/g
U	0.007 (0.001–0.1)	0.016, 0.027	**0.020 (0.002–0.3)**	**0.04, 0.07**	µg/g
V	0.076 (0–0.8)	0.11, 0.14	**0.25 (0.02–1.6)**	**0.36, 0.35**	µg/g
Zn	37.8 (18–247)	47.6, 36.6	**63 (24–571)**	**98, 97**	µg/g
Zr	0.049 (0–0.6)	0.079, 0.114	**0.171 (0.03–0.6)**	**0.17, 0.12**	µg/g
	Carrot (median, range)	**Carrot (mean, stdev)**	***Lettuce* (median, range)**	***Lettuce* (mean, stdev)**	**Unit**
Al	15.8 (3.9-!07)	23.7, 21.7	**151 (27–490)**	**167, 112**	µg/g
As	0.032 (0.005–0.29)	0.040, 0.045	**0.113 (0.01–1.7)**	**0.22, 0.27**	µg/g
B	16.3 (9.0–40)	15.7, 5.11	9.41 (0–26)	9.89, 6.22	µg/g
Ba	2.91 (0.29–37)	7.27, 10.2	18.6 (2.4–87)	15.8, 16.4	µg/g

(*Continued*)

Table 3. (*Continued*)

	Carrot (median, range)	Carrot (mean, stdev)	*Lettuce* (median, range)	*Lettuce* (mean, stdev)	Unit
Be	0.0008 (0–0.01)	0.002, 0.002	**0.0077 (0–0.03)**	**0.01, 0.01**	μg/g
Br	2.15 (0.6–11.8)	2.7, 1.9	**10.6 (2.2–36)**	**9.07, 5.91**	μg/g
Ca	2480 (1840–3630)	2450, 403	**26300 (10001–64700)**	**32900, 12200**	μg/g
Cd	0.157 (0.03–1.2)	0.23, 0.23	0.652 (0.3–2.8)	0.74, 0.44	μg/g
Co	0.014 (0.006–0.11)	0.021, 0.021	**0.120 (0.06–0.4)**	**0.14, 0.06**	μg/g
Cr	0.268 (0.08–0.44)	0.234, 0.089	**0.804 (0.4–1.6)**	**0.85, 0.27**	μg/g
Cu	3.54 (0.9–9.8)	3.96, 1.84	6.21 (2.2–33)	6.57, 4.96	μg/g
Fe	24.1 (11.4–91)	30.0, 17.0	**180 (69–605)**	**213, 115**	μg/g
Hg	0.0052 (0.001–0.03)	0.0056, 0.0051	0.015 (0.01–0.17)	0.02, 0.02	μg/g
I	0.011 (0–0.07)	0.018, 0.018	0.176 (0.06.1.0)	0.25, 0.16	μg/g
K	25300 (9130–75300)	26300, 11800	**43700 (17000–65500)**	**41800,108**	μg/g
Li	0.009 (0–0.09)	0.014, 0.017	**0.209 (0.02–3.2)**	**0.37, 0.49**	μg/g
Mg	1250 (660–2090)	1300, 386	**3770 (1300–6700)**	**3380, 1210**	μg/g
Mn	8.47 (2.9–290)	24.6, 49.2	49.1 (9.1–1100)	81.8, 174	μg/g
Mo	0.090 (0.02–1.7)	0.24, 0.27	3.19 (0.3–58)	6.03, 8.50	μg/g
Na	1380 (250–8000)	1110, 1460	323 (82–7700)	598, 1100	μg/g
Ni	0.221 (0.03–1.9)	0.374, 0.431	1.14 (0.5–17)	1.44, 2.29	μg/g
P	2620 (1180–5210)	2800, 1020	**4500 (1200–5900)**	**4300, 1030**	μg/g
Pb	0.136 (0.01–0.84)	0.143, 0.147	**0.591 (0.09–3.8)**	**0.56, 0.55**	μg/g
Rb	10.8 (1.8–58)	16.8, 14.5	**34.7 (3.6–88)**	**26.6, 19.7**	μg/g
S	870 (530–2150)	950, 290	**8010 (2300–17600)**	**9500, 3600**	μg/g
Sb	0.003 (0.0003–0.008)	0.004, 0.002	**0.019 (0.01–0.09)**	**0.02, 0.01**	μg/g
Se	0.045 (0–0.37)	0.038, 0.060	**0.114 (0.01–0.6)**	**0.14, 0.12**	μg/g
Si	21.7 (0.9–173)	36.1, 37.5	**202 (39–560)**	**263, 118**	μg/g
Sn	0.008 (0–0.07)	0.011, 0.015	**0.065 (0.02–6.5)**	**0.23, 0.92**	μg/g
Sr	10.4 (5.7–17)	10.4, 2.99	**75.2 (21–145)**	**76.3, 29.5**	μg/g
Ti	0.805 (0.007–5.6)	1.13, 1.26	**9.80 (1.2–58)**	**13.2, 12.2**	μg/g
U	0.002 (0.0007–0.02)	0.004, 0.005	**0.020 (0–0.8)**	**0.05, 0.12**	μg/g
V	0.066 (0–0.34)	0.080, 0.073	**0.299 (0.02–1.4)**	**0.40, 0.32**	μg/g
Zn	19.2 (10.9–96.5)	29.8, 20.4	**150 (15–590)**	**120, 127**	μg/g
Zr	0.024 (0–0.28)	0.035, 0.053	**0.147 (0.01–0.5)**	**0.18, 0.12**	μg/g

Soil

The median concentrations of Al, Fe, Mn and Na were significantly higher in soil from the acidic area. pH($BaCl_2$) and pH(H_2O) as well as the concentrations of Ca were higher in soil from the alkaline area.

The magnitude of the differences was between 1.5 and >>10. The median Al, Fe and Mn concentrations were >>10 times higher in soil from the acidic area, while the median Ca concentrations, as well as pH of soils, were only 1.5 times higher in the alkaline compared to the acidic region.

Vegetable and soil minerals in summary

The concentrations of Ba, Br, Mn, Rb and Zn were significantly higher in all the different vegetable species from the acidic areas. Only Mo was higher

Table 4. Elements in carrot with significantly different concentrations in acid and alkaline areas.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
Ba	8.91 (12.8)	1.65 (1.8)	µg/g	0.008	5 times	
Br	3.43 (2.21)	1.56 (0.79)	µg/g	0.000	2 times	
Cd	0.25 (0.29)	1.08 (0.07)	µg/g	0.000	4 times	
Cr	0.27 (0.059)	0.17 (0.090)	µg/g	0.000	1.5 times	
Hg	0.006 (0.007)	0.004 (0.002)	µg/g	0.000	1.5 times	
Mn	21.0 (66.6)	5.39 (2.3)	µg/g	0.000	4 times	
Mo	0.09 (0.36)	0.23 (0.13)	µg/g	0.000		2.5 times
Ni	0.39 (0.54)	0.14 (0.12)	µg/g	0.000	2.5 times	
Pb	0.14 (0.19)	0.08 (0.07)	µg/g	0.034	1.5 times	
Rb	19.1 (16.1)	8.03 (6.8)	µg/g	0.000	2 times	
Se	0.04 (0.015)	0.014 (0.08)	µg/g	0.001	3.5 times	
Sn	0.008 (0.019)	0.005 (0.009)	µg/g	0.039	1.5 times	
U	0.002 (0.003)	0.005 (0.006)	µg/g	0.020		2.5 times
Zn	40.2 (21.8)	16.2 (6.6)	µg/g	0.000	2.5 times	
Zr	0.024 (0.04)	0.007 (0.07)	µg/g	0.043	3 times	

Table 5. Elements in lettuce from acidic and alkaline areas with significantly different concentrations.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
As	0.11 (0.17)	0.20 (0.33)	µg/g	0.007		2 times
Ba	18.7 (20.6)	6.83 (4.67)	µg/g	0.001	3 times	
Br	10.6 (6.85)	5.83 (3.95)	µg/g	0.008	2 times	
Ca	26.3 (12.4)	34.8 (10.9)	mg/g	0.005		1.5 times
Cu	6.21 (6.57)	4.99 (1.51)	µg/g	0.007	1.5 times	
I	0.18 (0.12)	0.26 (0.17)	µg/g	0.002		1.5 times
Mg	3.77 (1.09)	3.04 (0.98)	mg/g	0.000	1.5 times	
Mn	49.1 (240)	23.4 (31.8)	µg/g	0.000	2 times	
Mo	3.19 (4.49)	4.54 (10.8)	µg/g	0.014		1.5 times
Ni	1.14 (3.26)	1.00 (0.43)	µg/g	0.043	1.5 times	
Pb	0.59 (0.73)	0.36 (0.28)	µg/g	0.050	1.5 times	
Rb	34.7 (19.5)	11.6 (10.7)	µg/g	0.000	3 times	
S	8.01 (3.8)	10.6 (3.2)	mg/g	0.022		1.5 times
Si	202 (95.9)	307 (108)	µg/g	0.000		1.5 times
U	0.02 (0.03)	0.038 (0.16)	µg/g	0.048		2 times
Zn	150 (151)	49.0 (28)	µg/g	0.000	3 times	

Table 6. Elements in parsley with significantly different concentrations in acidic and alkaline areas.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
As	0.04 (0.16)	0.10 (0.13)	µg/g	0.002		2.5 times
Ba	46.6 (37.2)	11.7 (9.6)	µg/g	0.002	4 times	
Br	7.15 (5.79)	3.82 (2.27)	µg/g	0.000	2 times	
Cd	0.41 (0.28)	0.17 (0.08)	µg/g	0.000	2.5 times	
Co	0.10 (0.06)	0.06 (0.05)	µg/g	0.010	1.5 times	
Cr	0.71 (0.53)	0.48 (0.38)	µg/g	0.032	1.5 times	
Cu	8.46 (4.45)	6.17 (2.19)	µg/g	0.021	1.5 times	
Hg	0.02 (0.005)	0.01 (0.004)	µg/g	0.018	2 times	
Mg	2.24 (0.817)	1.32 (0.426)	mg/g	0.000	2 times	
Mn	97.9 (191)	32.2 (15.6)	µg/g	0.000	3 times	
Mo	1.29 (1.54)	3.39 (2.91)	µg/g	0.000		3 times
Na	1.39 (1.19)	0.64 (2.85)	mg/g	0.030	2 times	
Ni	1.81 (1.04)	0.93 (0.61)	µg/g	0.005	2 times	
Rb	39.0 (21.9)	14.7 (14.3)	µg/g	0.000	2.5 times	
S	2.99 (0.606)	2.52 (0.55)	mg/g	0.011	1.5 times	
Se	0.07 (0.04)	0.04 (0.06)	µg/g	0.014	2 times	
Ti	12.3 (16.2)	5.13 (8.2)	µg/g	0.008	2 times	
Zn	110 (125)	49.8 (28)	µg/g	0.000	2 times	

Table 7. Elements in chive with significantly different concentrations in acidic and alkaline areas.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
As	0.05 (0.11)	0.11 (0.33)	µg/g	0.015		2 times
Ba	5.86 (20.3)	4.24 (1.96)	µg/g	0.022	1.5 times	
Br	6.09 (3.71)	2.13 (2.06)	µg/g	0.000	3 times	
Ca	11.8 (2.52)	15.8 (3.92)	mg/g	0.000		1.5 times
Cd	0.19 (0.35)	0.10 (0.05)	µg/g	0.001	2 times	
I	0.19 (0.09)	0.36 (0.17)	µg/g	0.000		2 times
Li	0.05 (0.21)	0.12 (0.16)	µg/g	0.017		2 times
Mg	1.79 (0.46)	1.32 (0.30)	µg/g	0.001	1.5 times	
Mn	53.4 (370)	21.8 (14.4)	µg/g	0.000	2.5 times	
Mo	2.46 (8.2)	5.34 (6.6)	µg/g	0.022		2 times
Rb	17.7 (12.0)	4.71 (4.46)	µg/g	0.000	3.5 times	
S	4.87 (1.06)	6.17 (1.55)	mg/g	0.001		1.5 times
Sb	0.002 (0.003)	0.005 (0.006)	µg/g	0.006		2.5 times
Si	78.5 (97.6)	170 (103)	µg/g	0.001		2 times
U	0.005 (0.01)	0.010 (0.03)	µg/g	0.004		2 times
Zn	43.2 (48)	34.0 (13)	µg/g	0.025	1.5 times	

Table 8. Median concentrations, ranges, mean and standard deviation of analyzed elements in soils.

	Median (range) mean	Unit	Stdev
Al	0.04 (0–74.7) 5.46	mg/g	14.3
B	0.30 (0–0.58) 0.22	mg/g	0.12
Ca	3170 (170–7740) 2550	mg/g	1320
Fe	0.06 (0–2.24) 0.26	mg/g	0.48
K	172 (22–742) 157	mg/g	147
Mg	181 (22.5–920) 139	mg/g	147
Mn	1.8 (0.55–47.2) 7.8	mg/g	11.4
Na	5.6 (1.8–443) 23.6	mg/g	64.1
N	2.75 (1.32–7.75) 2.96	mg/g	1.24
C	36.3 (14.0–342) 48.4	mg/g	46.9
pH ($BaCl_2$)	6.3 (3.8–7.0) 5.6		1.0
pH (H_2O)	7.2 (5.1–7.7) 6.8		0.7

in vegetables from the alkaline district (Table 10). pH and Ca concentrations were higher in soil from the alkaline area.

Correlations

Parsley

Ca in parsley correlated with Sr ($r_s = 0.0.797$, $p < 0.001$).

In addition, there were strong correlations ($r_s > 0.5$, $p < 0.001$) between all the elements Al, Be, Co, Cr, Fe, I, Pb, Sb, Si, (Sn,) Ti, (U,) V and Zr in parsley.

There was a strong negative correlation between Na and K. However, Na covariated with Ni and Zn. ($r_s > 0.5$, $p < 0.001$) in parsley.

The only significant correlation between specific water elements and parsley elements was found between Ni in water and Ni in parsley ($r_s > 0.5$, $p < 0.001$). There were no significant correlations between elements in soil and in parsley.

Chive

There were strong correlations between Ca and Sr, as well as between Ca and I, and Ca and Rb in chive. All the elements Al, Be, Co, Fe, Pb, Si, Ti, U and V covariated in chive. Na and K also correlated significantly.

There were no significant correlations between specific elements in water and chive elements, or soil elements and chive.

Table 9. Exchangeable elements and pH-levels in soils with significantly different concentrations in acidic and alkaline areas.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
Al	1.13 (19.1)	0.00 (0.03)	µg/g	0.000	>10 times	
Ca	2010 (1690)	2780 (734)	µg/g	0.010		1.5 times
Fe	0.36 (0.60)	0.001 (0.062)	µg/g	0.000	>>10 times	
Mn	12.0 (13.1)	1.03 (0.66)	µg/g	0.000	12 times	
Na	10.7 (24.8)	5.87 (84.9)	µg/g	0.003	2 times	
pH $BaCl_2$	4.50 (0.88)	6.47 (0.36)		0.000		1.5 times
pH H_2O	6.22 (0.63)	7.25 (0.22)		0.000		1.5 times

Table 10. Elements with the largest differences between median concentrations in all the four different vegetables cultivated in the acidic areas compared to the alkaline district.

	Highest in acid	Highest in alkaline
Ba	3–5 times	
Br	2–3 times	
Mn	2–4 times	
Mo		1.5–3 times
Rb	2–4 times	
Zn	1.5–3 times	

Carrot

Ca correlated strongly with B in carrot ($r_s = 0.575$, $p < 0.001$).

All the elements Al, Ba, Be, (Co), Fe, I, Ni, Pb, Sr, Ti, (U) and V covariated in chive.

Hg, Mn, Rb and Zn in carrot correlated with S in hair ($r_s > 0.5$, $p < 0.001$).

There were no significant correlations between specific water elements and carrot elements, but a strong positive correlation between soil exchangeable Mn and carrot Mn ($r_s > 0.5$, $p < 0.001$).

Lettuce

Ca correlated strongly with Sr in lettuce ($r_s = 0.66$, $p < 0.001$).

All the elements Al, Be, Co, Cr, Fe, Ni, and Zr covariated in lettuce. This was also the case for Pb, Ti, V and Zr.

There were no significant correlations between specific elements in water and in lettuce, but there was a strong positive correlation between soil exchangeable Mn and lettuce Mn ($r_s > 0.5$, $p < 0.001$).

Soils

pH in soils ($BaCl_2$ and H_2O) correlated negatively with Rb and Mn in all vegetables ($r_s > 0.5$, $p < 0.001$), indicating higher levels of the elements in vegetables cultivated in soils with lower pH-values. The only significant correlation between elements in soils and vegetables appeared between exchangeable Mn in soils and lettuce and carrot, respectively ($r_s > 0.5$, $p < 0.001$).

Correlations in summary

There were strong correlations between Ca and Sr in all the vegetables, except for carrot. There were no strong correlations between soil elements and vegetable elements, except for soil Mn and carrot/lettuce Mn.

Differences between fertilized and non-fertilized soils and vegetables

Only cultivators from the alkaline area had used NPK-fertilizers. There were no significant differences in mineral concentrations in alkaline soils, and in parsley. Median Cr concentrations were significantly higher in chive without NPK-fertilizing ($p = 0.01$).

In carrot, the concentrations of Ba ($p = 0.03$), Mg ($p = 0.04$), Sr ($p = 0.01$) and Ti ($p = 0.05$) were all higher where no NPK-fertilizers were added. The concentrations were between 1.3 and 3 times higher in carrot where no NPK-fertilizers were used. Cr concentrations were significantly higher in chive without NPK-fertilizers, and Ca concentrations in lettuce ($p = 0.004$), where the median concentrations were 8 times higher in lettuce without NPK.

Cultivators in the acidic area had only used organic fertilizers, like e.g. manure. There were no significant differences in mineral content in soil, lettuce, carrot or parsley. However, the median concentration of Sr were 1.5 times higher in fertilized chive with $p = 0.02$.

Irrigation did not make any differences in the mineral contents of soils or vegetables.

Discussion

Since no alkalizers were used by the participating cultivators, there has been no addition of minerals, for e.g. limestone. NPK-fertilizers were used only by women in the alkaline area, while women from the acidic area used biological fertilizers. The differences in the mineral concentrations in vegetables and soils were minor, between fertilized and non-fertilized. NPK-fertilizers only decreased mineral concentrations; Cr in chive, Ba, Mg, Sr and Ti in carrot, and Ca in lettuce. Organic fertilizers almost did not affect mineral concentrations in vegetables or soils. Only Sr was significantly different in organic-fertilized chive, compared to the non-fertilized, as the concentration was higher where organic fertilizers were used. Irrigation did not make any differences in mineral contents in vegetables and soils.

The only element, for which there were significantly higher concentrations in all vegetables

Table 11. pH, median element concentrations, standard deviation, unit, and significance, of parameters with significant differences in well waters from acid and alkaline areas.

	Median acid (stdev)	Median alkaline (stdev)	Unit	Sign.	Highest in acid	Highest in alkaline
pH	5.9 (0.49)	7.7 (0.39)		0.001		1.3 times
Ca	9.9 (0.16)	54.6 (0.82)	mg/L	0.001		5.5 times
HCO_3	14.2 (11.8)	169 (61)	mg/L	0.001		12 times
Cr	0.1 (0.1)	3.6 (2.9)	ug/L	0.001		36 times
Mo	0.1 (0.08)	3.5 (3.8)	ug/L	0.001		35 times
Se	0.3 (0.2)	1 (2.3)	ug/L	0.001		3.3 times
As	0.2 (0.1)	1 (1.8)	ug/L	0.001		5 times
Sr	49.8 (34.6)	165 (96.4)	ug/L	0.001		3.3 times
Ba	48.8 (29.5)	11.7 (14.7)	ug/L	0.001	4 times	
Cd	0.1 (0.1)	0 (0.1)	ug/L	0.001		$<$det. Lim.
Cu	0.34 (0.64)	0.085 (0.25)	ug/L	0.001	4 times	
F	361 (298)	39.3 (60)	ug/L	0.001	9 times	
Pb	0.9 (0.9)	0.3 (0.3)	ug/L	0.001	3 times	

cultivated in the alkaline district compared to the acidic areas, was Mo. Higher pH-levels in the alkaline soils indicate higher mineralization rates, and this is especially well known concerning nitrification, i.e. the formation of nitrate from ammonium.[18] A higher nitrogen uptake in the form of nitrate from these soils creates automatically an increased demand for Mo in the plants, as Mo is needed in the enzyme that reduces NO_3 to NH_2 groups. In soils of lower pH, nitrogen appears mostly in NH_4-form. There was no correlation between use of fertilizers and Mo-concentration in the vegetables. The concentration of Mo was significantly higher also in alkaline well waters and women's hair.

There was a strong correlation between Ca and Sr in all the vegetables, as in well water and hair of women. Both these elements appear dissolved in ground water or absorbed to soil particles as 2+ ions, and plants cannot distinguish between them.[25] There were also strong correlations between Ca, Sr, Mo and Pb in well water and as well as in hair according to the study done in 1997. However, there were almost no correlations between well waters and vegetables, indicating that irrigation water minerals, in this case, from their own well water, is less important than soil minerals. In addition, the rainfall was comparable to the irrigation in mm. Though well waters were analyzed in 1997, almost the same levels of the different elements were expected in 2006.

The levels of the mineral elements in lettuce are on the same levels as in the study by Awadallah et al[26] and Ca levels in vegetables of the present study are at the same level as Ca in lettuce, according to a study by Kawashima.[27] Se levels are in general, low in soils in Scandinavia. However, Se levels in cereals, treated with non Se-supplemented fertilizers, generally are $<$100 μg/g,[28] which is approximately at the same level as in the vegetables of this study.

The standard deviations were partly large, reflecting large variation in mineral concentrations in vegetables and soils in both the areas of this study.

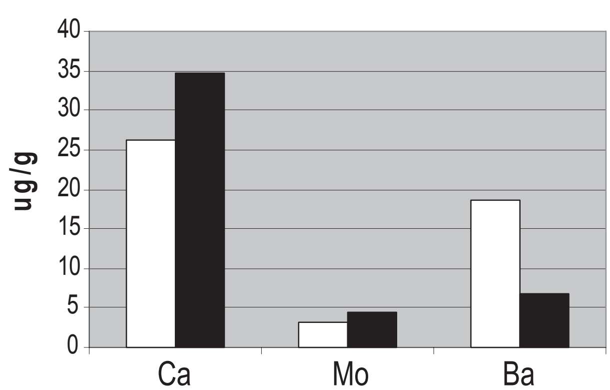

Figure 2. Median concentrations of Ca, Mo and Ba in lettuce cultivated in the acidic area (white) and the alkaline (black).

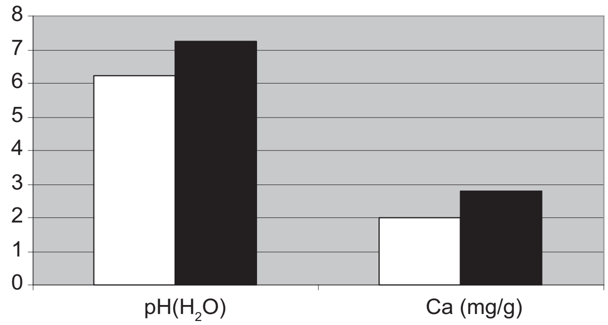

Figure 3. Median exchangeable Ca concentrations and pH-levels in soils from the acidic area (white) and alkaline (black). Exchangeable Ba and Mo were not analyzed in soils.

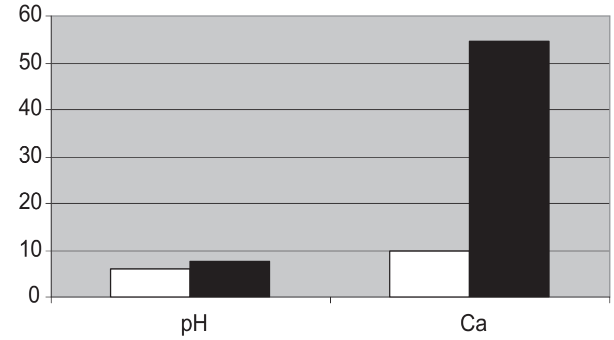

Figure 4. Median pH and Ca (mg/L) in acid (white) and alkaline (black) well waters.

Vegetables compared to well waters and hair

The differences in mineral concentrations between vegetables cultivated in acidic areas compared to the alkaline area in this study were smaller than the differences in well water and in hair. The differences between the median concentrations were largest for Ba, Br, Mn, Rb and Zn, with significantly higher concentrations in vegetables cultivated in the acidic area, while Mo concentrations were highest in vegetables from the alkaline area (Table 10, Fig. 2). In accordance with these findings Ba concentrations were also significantly higher in acid well waters and hair of women from the acidic area, and Mn uptake is usually lower if the soil pH is high.[2] Mo uptake is higher in soils with higher pH and higher nitrification rate.[25] In addition, Zn levels generally increase with decreasing pH.[29]

pH and some well water elements, with significantly different concentrations in acid and alkaline well waters are presented in Table 11. Median Ca concentration and pH of soils is presented in Figure 2. For comparison, pH and Ca concentrations in well waters are presented in Figure 3.

The median concentrations of Ca, Mo and Ba in lettuce are presented in Figure 4.

Water, a more important mineral source than vegetables for humans?

The vegetables, in general did not show higher levels of Ca, Cr, Se or Sr in vegetables from the alkaline district, as did the well waters and hair of women. Only soils, lettuce and chive from the alkaline district had slightly higher Ca levels. The reason why there were no significant differences in Ca, Cr, K, Mg, Na, Se, Sr and P concentrations from vegetables cultivated in the different areas may be that:

– the soluble amounts of elements partly have been taken up by plants and harvested, as the areas has been cultivated for hundreds or thousands of years, and eventual primary differences may have evened out
– the use of NH_4 fertilizers in the alkaline area, which may decrease the Ca uptake
– the studied vegetables only take up what they need.

Table 12. The general percentage from vegetables estimated by NSFA consumption of carrot: 10 g per day, and (mixed) lettuce 19 g/day,[30] based on the recommended or average daily intake, women only.[24] (Since chive and parsley are sparsely consumed these vegetables are not included). "Daily intake" inside brackets, refers to used intervals in,[24] Table 9.

	Carrot	Lettuce	Daily intake
Ca	0.5–0.9	2.4–15.4	800 mg
Mg	0.5–1.5	0.9–4.5	280 mg
P	0.2–1.0	0.2–1.1	(0.8–1.2) 0.6–0.7 g
Na	0.03–0.8	0.008–0.7	$<$2 g
K	0.5–3.8	0.8–3.1	(4) 3.1 g
Fe	0.2–1.5	1.0–9.2	(10–15) 10 mg
Zn	0.3–2.8	0.4–16	7 mg
Mn	0.1–11.6	0.3–42	(5) 1.8 mg
Cr	0.1–0.8	0.7–2.8	(110) 30 µg
Cu	0.07–0.8	0.2–2.5	(2–3) 1.2–1.4 mg
Mo	0.02–2.0	0.3–68	(163) 45 µg
Se	0–1.9	0.05–2.9	40 µg

Table 13. Median wet weight concentrations of Cd and Pb in the different vegetables compared to EU Guide Line Values.[31]

	Cd	Cd	Pb	Pb	Unit
	Median	Guide line value	Median	Guide line value	
Chive	0.014	0.2	0.016	0.3	mg/kg wet weight
Parsley	0.022	0.2	0.036	0.3	mg/kg wet weight
Lettuce	0.065	0.2	0.046	0.3	mg/kg wet weight
Carrot	0.016	0.1	0.009	0.1	mg/kg wet weight

NH_4 fertilisers may depress the uptake of Ca, Mn, K and Na in vegetables and crops.[23] The last statement may partly be in accordance with the findings of Crooke and Knight,[1] since three of their four vegetables were monocotyledons, cultivated in soils alkalized with limestone, and they showed higher mineral concentrations than those cultivated in acid soils. The vegetables in this study are dicotyledons, except for chive that is a monocotyledon, and Ca levels were higher in chive from the alkaline area, while Na, K and Mg were not.

Soil elements on leaves

The elements Al, Fe, Li, Ni, Pb, Si, Ti, V, Zn and Zr, all of which were elevated in lettuce and parsley, have their origin probably in soil particles that have splashed on them due to rain. Along with possible remaining soil particles on leaves, the elements may be absorbed as ions directly through the leaves. Even if vegetables are rinsed thoroughly, chemically bound ions remain on the leaves and roots and may be absorbed.

Only Mn in lettuce and carrot from the acidic area, along with Mo, Ca and Zn from the alkaline area, seem to contribute significantly with more than 10% to the daily intake of the minerals.

The contributions to the daily intake of K were minor from these analysed vegetables (1.5–3.8), while vegetables/root crops in general give a contribution of 16%.[30]

All concentrations of elements in vegetables in this study are "dry weight" concentrations. To be able to compare the concentrations of Cd and Pb in the vegetables with the EU Guide Line Values,[31] the median concentrations were multiplied by 10, which provided the "wet weight"approximately, 1/10 of the weight being water (Table 13).

The median concentrations of Cd and Pb in the vegetables of this study were all below the Guideline values.

Conclusions

1. Lettuce and parsley had the highest concentrations of mineral elements among the four different vegetables.
2. Only Mo concentrations were significantly higher in all the different vegetables cultivated in the alkaline area.
3. The concentrations of Ba, Br, Mn, Rb and Zn were higher in all the different vegetables from the acidic area.
4. Soil elements like Al, Fe, Li, Ni, Pb, Si, Ti, V, Zn and Zr were higher in lettuce and parsley, as soil particles are probably splashed on the leaves and elements in the ionic form can be directly absorbed by the leaves.
5. Only Ca levels and pH values were higher in soils from the alkaline district.
6. In general, the potential contribution of mineral elements to daily intake from vegetables was low in humans. Only samples of lettuce from alkaline areas could be expected to contribute significantly to the daily intake of Ca, Mo and Zn and lettuce and carrot from acidic areas to the uptake of Mn.
7. Mineral levels in vegetables from the two areas with totally different bedrock were not as different as expected. The differences seem to have evened out by time.

Disclosure

The authors report no conflicts of interest.

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