SILICON IN HUMANS: BENEFICIAL OR ESSENTIAL?

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Epstein (1999): An element is defined as quasi-essential if it is ubiquitous in plants, and if a deficiency of it can be severe enough to result in demonstrable adverse effects or abnormalities in respect to growth, development, reproduction, or viability.

Summary

url= http://www.agrisilica.co.za/testimonies.html

Relevant data on silicon research in humans have been inventoried. Although there are reliable data on the clinical effects of Si in humans this mineral is almost completely neglected in Medicine. These clinical effects are compared with the results of an open label study with a liquid food supplement with bioavailable and stabilized oligomeric silicic acid and a low dose of boric acid (OSAB) in Amsterdam during 2004-2007. OSAB showed to be a safe and beneficial food supplement with significant effects on connective tissue, bone, cartilage, skin, hair, nails, etc. The data confirm earlier clinical data in which show that Si is at least beneficial for humans and animals. Due to a lack of sufficient data on the metabolism of Si in humans essentiality has not (yet) been established. Silicon must be considered 'quasi-essential' as defined by Epstein (1999) for plants.

Introduction

Silicon is contained in plants and also present in animals including humans.. The quantity in humans is 7 grams being more than all other trace elements together. Nevertheless Si is not (or hardly) considered as beneficial: there is a lot of scepticism in regular Medicine because silicon has been considered to be inert in humans. In 1973 the Joint FAO/WHO Expert Committee on Food Additives says: 'data *on orally administered silica and silicates appear to substantiate the biological inertness of these compounds'.*
This negative attitude is surprising because for several hundreds of years extracts of Si-accumulating plants like Equisetum arvense (horsetail) have been used therapeutically for aging disorders, Alzheimer's disease, atherosclerosis, brittle hair, fractures, fragile nails, back pain, osteoporosis, skin disorders, tendinitis, improved wound healing and wrinkles.
On the other hand there is a lack on sufficient data on the metabolism of silicon in animals and humans. The absorption and bioavailability of silicon of the different silicon sources (silicates, metasilicates, etc.) is hardly known. There are neither standardised methods nor assays for assessing the silicon status in humans and animals.

In part 1 the clinical effects of Si in men are described followed by the data on metabolism of Si in part 2. In part 3 the preliminary results of the Amsterdam Silicon Study in humans are published, which will be compared with literature data.

1. Effects of silicon on tissues, organs and diseases

Bone and cartilage

In 1972, Carlisle showed that a Si deficient diet in chickens induces skeletal deformities and joint abnormalities. Also in 1972, Schwartz published the same results in rats: deformities of the skull and peripheral bones, characterized by poorly formed joints, defective endochondral bone growth and reduced contents of articular cartilage, hexosamine, collagen and water. The concentrations of minerals like calcium, magnesium, zinc and manganese were also to low in the femur and vertebrae due to the diet only Si deficient.

Both studies mark the beginning of the recognition of the importance of silicon as an beneficial even essential trace element that plays an important biological role in the processes by which connective tissue, bone, cartilage and skin are formed.

A growing number of publications appear on the effects of Si on bone and cartilage as well in men as in animals:

Schiano a.o. (1979) studied the activity of a soluble salt (drinkable and injectable) of Si on the evolution of the trabecular bone volume (TBV) in men. They note a significant increase in the TBV compared to controls.

Eisinger e.a. (1993) showed in a prospective study that Si induced a significant ($P < 0.05$) increase in femoral bone mineral density in osteoporotic women compared to controls.
Rico et al. showed in 2000 the effects of Si supplement on preventing bone mass loss induced by ovariectomy in rats. They proved that Si has an inhibitory effect on bone mass loss as well as the stimulatory effect on bone formation, so Si may have a potential therapeutic application in the treatment of involutive osteoporosis.

Calomme et al. showed the positive effects of orthosilicic acid on bone density in chicks (2002) and on the bone density in ovariectomized rats (2004)..

Skin, hair and nails

The effects of Si on hair, skin and nails appear in regular literature:

Lassus performed an open study in 1993 with oral Si (colloidal silicic acid) during 3 months. He found a (statistically significant) improvement in the thickness and turgor of the skin, wrinkles and condition of the hair and nails.

Barel et al. investigated the Si supplementation on skin, nails and hair in a double-blind, placebo controlled study. The (extra) Si had a significant positive effect on skin surface and mechanical properties, and on brittleness of hair and nails.
The application of topical silicone gel is shown to be efficacious, both in the prevention and in the treatment of hypertrophic scar.

Cardiovascular system / Atherosclerosis

Animal studies f.e. in rabbits (Loeper 1979) indicate that Si can reduce the formation of atheromatous plaques. *There is a low incidence of atherosclerosis in less developed countries where foods are not heavily processed before consumption and the diet has a higher Si content.* In western diets the Si content is much lower and atherosclerosis is much higher. Moreover Si intakes decrease significantly with age (Jugdaohsingh, et al., 2002) suggesting that high Si intake is a factor in (partial) preventing atherosclerosis (Schwartz, 1977).

Other observations supporting the concept that sufficient silicon intake is important for healthy blood vessels is that of an inverse relationship between the concentration of silicic acid in drinking water and the prevalence of cardiovascular disease in Finland (Schwartz 1977).

Underlying mechanism: Silicon is ‘essential’ for the strength and integrity of the tunica intima, the inner membrane of arteries.

Alzheimer's disease

Some evidence suggests that aluminum may increase the risk of developing Alzheimer's disease. Si has been found to significantly reduce the absorption of aluminum by the body, and researchers hypothesize that dietary Si may therefore reduce the risk of developing aluminum induced Alzheimer's disease.

The protective role of silicon against aluminum was also confirmed in a French population study of elderly subjects: high levels of aluminum in drinking water had a deleterious effect upon cognitive function when the silicon concentration was low, but when the concentration of silicon was high, exposure to aluminum appeared less likely to impair cognitive function.(14)

Other effects

There are several articles on silicon’s effect on the immune system:

Schiano et al (1979) showed that supplementation of soluble silicon in humans causes a clear rise in the circulating lymphocytes and the immunoglobulins (especially IgG).

Seaborn et al. (2002) showed in rats that silicon has a functional role in lymphocyte proliferation and that inadequate dietary silicon impairs splenic lymphocyte proliferation in response to an immune challenge.

Mineo e.a. (2004) showed in in-vitro experiments that that silicon treatment is able to induce proliferation of unstimulated macrophages and to maintain their viability

2. Silicon metabolism

General

Until now there are no validated methods for assessing the silicon status in humans and animals. There are neither data nor validation of normal values of silicon in blood and different tissues.
Moreover there are few reliable laboratory facilities available for analyzing blood and tissue silicon levels.

Occurrence in food, food supplements and medicines

High levels of silicon are found in foods derived from plants, particularly grains such as oats, barley or rice. After food processing much lower concentrations are found. Silicon levels in foods from animal sources are relatively low.

Absorption and bioavailability

The bioavailability of silicon depends on the solubility of the compound or speciation concerned. There is a lack of reliable data about the metabolism of silicon in humans. This is partly due to the fact that there are many different forms of dietary silicon, all with different absorptions. In one study, humans absorbed only about 1 % of a large single dose of an aluminosilicate compound, while in other studies a single dose of stabilized monosilicic acid is absorbed up to 80%.

Silicic acid is the bioavailable form, especially as mono (= ortho) and di silicic acid. It is easily absorbed from the gastro-intestinal tract (50 – 80%). In the gastrointestinal tract Si, as orthosilicic acid, is available from fluids (20-30%) and from silica in solid foods (70-80%), which is hydrolyzed to orthosilicic acid.

The average absorption of daily Si intake is less than 50%.

The absorption is facilitated by aquaporins (a family of small (channel) proteins present in the intracellular membranes, where they facilitate the transport of water and/or small neutral solutes like urea, boric acid, silicic acid). In humans several aquaporins for OSA are identified.

Average daily intakes of Si vary between 13 and 62 mg/d. Mean Si intakes in men (33 mg/d) are significantly higher than in women (25 mg/d).

Silicon intake decreases with age.

The dietary silicon intake is significantly correlated with urinary silicon excretion.

Another possibility for silicon uptake by the body is transdermal absorption. Lassus (1993) showed the effects of oral and topical treatment of aged skin by a silicic gel. Because of the combined method of administration the effects of dermal absorption alone remain unclear. Still this dermal route can be an interesting option because foliar sprays with soluble silicon used on plants show considerable biological effects.

Distribution
The human body contains approximately 7 grams of silicon, widely distributed in the tissues. High levels are present in bone, nails, tendons and the walls of the aorta, with nails containing the highest levels (up to 1500 mg/kg) and kidneys. Lower levels are present in red blood cells or serum (approximately 44 mg/kg for red cells and 20 mg/kg for bound silicic acid in plasma, in liver, spleen and lung. Silicon is found in breast milk.

Excretion
Silicon is predominantly and rapidly excreted in the urine, with smaller amounts being eliminated in the feces.

Functions
Silicon is involved in the formation of bone and connective tissues:
1. Si facilitates the deposit of calcium and other minerals into bone tissue.
2. Silicon supplementation reduces the number of osteoclast cells, thus partially preventing bone resorption and bone loss.
3. Si stimulates the osteoblasts
4. Si stimulates the synthesis of collagen.
5. Si facilitates the formation of glycosaminoglycan and collagen components of the bone matrix through its role as a constituent of the enzyme of prolylhydrolase.

In the extracellular matrix (ECM) of the connective tissue in humans two main classes of extracellular macromolecules are found: (1) polysaccharide chains of the class of *glycosaminoglycans* (*GAGs*), which are usually found covalently linked to protein in the form of *proteoglycans,* and (2) fibrous proteins, including *collagen, elastin,* a.o., which have both structural and adhesive functions.
1. Glycosaminoglycans (GAGs) are unbranched, negatively charged molecules with a long chain of repeating disaccharide units. Silicon is an integral component of four GAGs of physiological importance: hyaluronic acid from umbilical cord, dermatan sulfate from mucosal tissue, chondroitin-4-sulfate, and heparan sulfate. Si provides links within and between polysaccharide chains of GAGs and also helps link GAGs to their respective protein. It is found covalently linked to each GAG as a silanolate, an ether or ester-like derivative of silicic acid, and forms R_1—O—Si—O—R_2 or R_1—O—Si—O—Si—O—R_2 continuous bridges. Thus, Si helps form the structural framework of connective tissues by linking polysaccharide chains together and contributes to the overall pliability of connective tissue.
2. Silicon-dependent enzymes link together simple chains of amino acids into collagen fibres.

Deficiency
Silicon deficiency has been produced experimentally in chicks and rats (Carlisle, 1972; Schwartz, 1972).

Silicon deficiency has not been officially established as such in humans. Although silicon is thought to be beneficial and maybe essential too many data are still lacking. For the definition of essentiality and deficiency validated methods for assessing the silicon status in humans is needed. The available data are also inadequate for recommendations on adequate nutritional intakes on silicon.

Nevertheless brittle nails and thin hair, loss of elasticity of the skin, osteopenia and other conditions should be regarded as deficiency symptoms, because they can be improved by supplementation with (bioavailable) silicon.

Interactions
Silicon has been reported to interact with a number of minerals including copper, zinc and germanium.
Silicon promotes the calcium absorption and metabolism to be absorbed.
Silicon and boron have synergistic effects.

Toxicity
Limited data are available on the oral toxicity of silicon in humans and no acute or chronic toxicity data have been identified. The occurrence of silica stones has been reported in patients on long term antacid therapy with magnesium trisilicate.

If inhaled at high concentrations over prolonged periods, certain forms of silica can cause silicosis. Silica particles are inhaled into the alveoli of the lung, causing tissue damage that ultimately results in fibrosis, which reduces the efficiency of the lungs and results in shortness of breath.

Carcinogenicity and genotoxicity
Silicon was not carcinogenic in mice or rats at 5% in the diet. Silica was negative in the *Bacillus subtilis rec* assay and was not mutagenic in the Ames test. Overall, inorganic silicon compounds do not appear to have genotoxic potential.

Hazards
The interaction between silicon and aluminum has been researched in more detail as a means of inhibiting aluminum toxicity. However the results are conflicting and it is possible that silicon levels may be to low for significant effects *in vivo*.

Recommended amounts
Although silicon is thought to be beneficial and maybe essential to many data are still lacking. This is the reason that recommendations on adequate nutritional intakes not have been established.

There is an urgent need for assessing the silicon status in humans.

3. Amsterdam open label Silicon Study

Introduction
During the last 4 years (2004-2008) the possible side-effects of food supplement OSAB were studied based on 13.500 users / year. Next the reported clinical effects after 3 and 9 months in 98 consecutive patients (76 women and 22 men) were collected by standardized questionnaires.
In an (offspring) observational study the efficacy of OSAB and glucosamine was compared in patients with mild and moderate gonarthrosis (arthrosis of the knee joint).

OSAB is a liquid food supplement containing PEG-400 stabilized oligomeric (non colloidal) silicic acid and a low dose of boric acid. By the (patented) stabilization procedure this solution contains 0,9% silicic acid, while normally a saturated solution of silicic acid polymerizes beyond 0,1%.

The choice for stabilized Si was based on a comparative study of Calomme et al. (2000) on the bioavailability of several silicon sources. Stabilized silicic acid showed a superior bioavailability compared to colloidal silicon, herbal silica and placebo. Moreover, OSAB is a food supplement with stabilized silicic acid with a biological bioavailability of 70 – 80%.

Results
Safety / side effects.
During the 4 years period 15 side-effects were reported: nausea (5), pyrosis (3), diarrhoea (3), rash (1), insomnia (2) and itching (1). No other event happened.
Some side effects like itching are related to the stabiliser PEG-400, as described in literature. Based on literature data and this study non-colloidal silicic acid can be considered as (very) safe.

Reported effects
A. Frequent reported effects (> 10%) were:
- (significant) improvement of the skin and wrinkles,

- improvement of brittleness of hair and nails / thicker hair / strong nails,
- improvement of arthralgia (joint pain) and back pain.
- boost in general wellbeing / boost of immunity / vitality

B. Less frequent reported effects (< 10%) were:
- improvement of skin disorders like psoriasis and eczema,
- improvement of arthritis (rheumatoid arthritis and psoriatic arthritis),
- improvement of wound healing (ulcus cruris),
- lowering of infection rate of URI's (upper respiratory tact infections),
- improvement of allergy like hay fever and food allergy,
- antihypertensive effects,
- improvement of constipation,
- improvement of insomnia,
- improved sexual potency.
- improved fracture healing

C. Comparison of the effects of silicon and glucosamine on mild and moderate gonarthrosis. The results of the reported effects showed in 9 of the 12 users (75%) a significant improvement of the complaints in the silicon group (9 of 12), while the positive effects in the glucosamine group were very limited to only 2 of the 13 (15,4%) after 4 months. A longer follow-up was not possible because most of the glucosamine users stopped the glucosamine.

Discussion

The reported effects of this study match with literature data. OSAB proved to be a safe nutrient with significant effects of hair, skin, nails and the locomotory system.
Moreover effects were reported against hypertension, insomnia and URI's. The lowering effect on hypertension can be due to a direct effect or to an improved absorption of antihypertensive medication.

The effects on URI maybe related to the effects on allergies like hay fever. This can be correlated with the described effects of the supplementation of soluble silicon on the immune system showing a clear rise in the circulating lymphocytes and the immunoglobulins (especially IgG) by Schiano et al (1979).

The reported affects against constipation and the side effect of diarrhoea must be regarded as the effect of the stabilizer PEG-400 in the food supplement.

Improved sleep as reported by 7% seems to be related to the reported 'boost' in energy and general well being. The effects continued at least for a one year's period.
The (possible) effects of improved fracture healing are in line with silicon's functions on bone growth and mineralization.

The potential use of silicon as a therapeutic in arthritis and arthrosis needs more research. Based on the preliminary results in mild and moderate gonarthrosis silicon could haves a potential as a medicine because its significant better effects than glucosamine after 4 months. More extensive double-blind clinical trials are needed.

4. Conclusion

There is a parallel in the recognition of the importance of silicon in Agriculture and Medicine. Although silicon gets more attention and appreciation in Agriculture it has been, up til now, a relatively unknown trace element in Medicine. The essentiality of silicon for man has not been established and the functional role for silicon in humans lacks sufficient data, also due to the absence of validated blood and tissue levels. A world wide lack of reliable facilities for silicon analyses is another important factor. Much more information on metabolism is needed. There are hardly reliable laboratory facilities available.

Silicon intake seems to be a major dietary determinant of bone mineral density in humans. Optimal bone health depends on many factors amongst silicon, which facilitates bone growth

and bone calcification and mineralization. The dietary shift to low silicon intake in western diet and a decreased intake with aging must be considered as a major risk factor for osteoporosis and bone fractures. Increasing the body silicon content by foods, plant extracts or supplements has the promise of anti aging effects and prevention on osteoporosis and possibly Alzheimer's. Silicon's potential for other diseases needs much more research in Medicine.

Based on all research so far silicon should be considered in humans as 'quasi-essential' as defined by Epstein(1999).

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