Silicon (Si) and water

Silicon and water: reaction mechanisms, environmental impact and health effects

Silicon is the most abundant element on earth after oxygen. Large amounts of silicon can be found in various minerals and it is abundant in oceans and nearly all other waters as silicic acid. In the surface layers of oceans silicon concentrations are 30 ppb, whereas deeper water layers may contain 2 ppm silicon. Rivers generally contain 4 ppm silicon. Silicon is usually not ionized when dissolved; it is present as ortho silicic acid (H_4SiO_4 or $Si(OH)_4$). These compounds are the result of slow dissolution of silica in water. Rivers transport large amounts of silicon to sea. Most likely, less than 20% of dissolved silicon is removed from rivers by means of biological or chemical transformation processes.

In what way and in what form does silicon react with water?

Silicon is never found in nature in free form. In crystallized form it is only reactive under conditions of extremely high temperatures. Water and water vapor probably have little influence upon silicon solubility, because a protective surface layer of silicon dioxide is rapidly formed.
There are many examples of silicon compounds reacting with water. Silicon tetra fluoride reacts with water to hydrogen fluoride. Silicon tetra chloride reacts with water quite violently. Silicides of the first and second group are generally more reactive than transitory metals. Typical reaction products include hydrogen and/ or silanes (SiH_4), for example $Na_2Si + 3H_2O \rightarrow Na_2SiO_3 + 3H_2$.

Solubility of silicon and silicon compounds

Silicon compounds differ in water solubility.
Silicon oxide is relatively water insoluble compared to other minerals. Upon dissolution the following equilibrium is formulated:

$SiO_2(s) + 2\ H_2O(l) \leftrightarrow H_4SiO_4(s)$

This balance contains silicic acid, a weak acid that also forms during silicon mineral hydrolysis:

$H_4SiO_4(s) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_3SiO_4^-(aq)$

Silicon dioxide has a water solubility of 0.12 g/L, whereas for example silicon carbide is water insoluble.

Why is silicon present in water?

As was explained earlier, silicon is part of various minerals, from which it may be released during weathering processes. It is also released under water during volcanic activity. Water in interspaces of marine sediments contains more silicon than the sea surface. The present current causes silicon to flow from sediments to seawater. Antarctic weathering also releases silicon. Silicon is removed from waters naturally, through plankton fixation, sediment settling, or reactions of dissolved silicon with clay minerals (reverse weathering).
Sand is the primary substance for commercially produced silicon. Minerals such as talc, mica, feldspar, nepheline, olivine, vermiculite, perlite and kaolinite also contain silicon. Gemstones such as opal and amethyst also contain silicon.
Construction processes silicon compounds in sand and cement, a calcium silicate. Glass and porcelain production is based on sand.
Silicon is applied as an aid in steel, chemical and electron industries, where it is processed under high temperatures. Steel and other alloys are eventually processed to for example engine blocks or cylinder heads.
Industrially significant silicon compounds are rubber- or resin-like compounds, which are generally water resistant and also withstand oxidation processes and chemical weathering. These are applied as lubricants under high temperatures, as a sealing kit for windows, roofs and pipes, in rubber hoses and in plastic parts for car engines. Silicon oils are applied in cosmetics, and for textile impregnation. In microchips this element is a semi conductor, as it is in transistors and other electronic parts.
Solar panels consist of n-semi conductors of silicon and arsenic and p-semi conductors of silicon and boron. It occurs in elementary form in optic lenses and prisms for infrared light.
Silicon carbide is nearly as hard as diamond and is applied as an abrasive. Quartz crystals that exist naturally and are produced chemically have the characteristic of vibrating in very exact frequencies, when they come in contact with electricity. This may be applied in watches, radios and televisions. Alkali silicones are added to cleansing agents, glue and bleaching agents for textiles.
Zeolites are silicones that are applied as foam regulators in detergents. These directly influence water quality. Other silicon compounds may be applied as absorbents.

What are the environmental effects of silicon in water?

Silicon dioxide is a dietary requirement for various organisms. The mechanism of intake is currently unclear. Diatoms and sea sponges apply silicon for skeleton strengthening. Small hairs on nettles also consist of silicon. Chickens and rats require silicon for bone development. It is very likely that silicon is a dietary requirement for humans, as the skin and connective tissue contains significant amounts of this element.
Silicon is also essential for plant growth. Various plant species contain about 200-62,000 ppm (dry mass) of silicon. Plants such as dandelions and bamboo contain silicon in stems and leaves, increasing stability.
Silicon is generally harmless when present in water, because it is naturally present in large amounts. Abnormally high concentrations might limit algal growth. Water organisms may be affected by zeolite, a phosphate replacement in detergents.
Silicon has three natural isotopes that are all non-radioactive. We now know of the existence of seven instable isotopes.

What are the health effects of silicon in water?

The human body contains a total amount of 1 g of silicon, which decreases at a later age. For a number of organisms silicon is a dietary requirement, and consequently it is considered a dietary requirement for humans, as well. Organisms mainly require silicon for bone development, whereas the element is found mostly in skin and connective tissue. Daily intake may vary between 20 and 1200 mg, and is mostly met by eating grains. Shortages are unknown.
All naturally occurring types of silicon, sand and silicon compounds are non-toxic. Elementary silicon has no clear mechanisms of toxicity. High concentrations of soluble silicon compounds may disturb phosphorilation. A number of silicon compounds have a fiber-like texture and are carcinogenic, for example asbestos. Fine particles of silicon compounds may cause silicosis, a typical profession related illness of for example mine workers or stone grinders. Pulmonary alveoluses harden and their flexibility decreases. This results in shortness of breath, panting and couching. Only inhalation of silicon particles may cause these effects.
Silicon breast implants may cause auto immune disorders and even cancer. There is however no scientific prove to substantiate these claims. Silicon is present in stomach tablets to treat colic and intestinal gases.
A number of silicon compounds, such as silicon halogens, are corrosive and extremely toxic. Silicon tetra chloride is an eye irritant, and may also cause breathing problems and skin irritation.
In drinking water only silicic acid is present, which is relatively safe.

Which water purification technologies can be applied to remove silicon from water?

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