

Selenium Compounds

Hazard Summary

Selenium is a naturally occurring substance that is toxic at high concentrations but is also a nutritionally essential element. Hydrogen selenide is the most acutely toxic selenium compound. Acute (short-term) exposure to elemental selenium, hydrogen selenide, and selenium dioxide by inhalation results primarily in respiratory effects, such as irritation of the mucous membranes, pulmonary edema, severe bronchitis, and bronchial pneumonia. Epidemiological studies of humans chronically (long-term) exposed to high levels of selenium in food and water have reported discoloration of the skin, pathological deformation and loss of nails, loss of hair, excessive tooth decay and discoloration, lack of mental alertness, and listlessness. Epidemiological studies have reported an inverse association between selenium levels in the blood and cancer occurrence and animal studies have reported that selenium supplementation, as sodium selenate, sodium selenite, and organic forms of selenium, results in a reduced incidence of several tumor types. The only selenium compound that has been shown to be carcinogenic in animals is selenium sulfide, which resulted in an increase in liver tumors from oral exposure. EPA has classified elemental selenium as a Group D, not classifiable as to human carcinogenicity, and selenium sulfide as a Group B2, probable human carcinogen.

Please Note: The main sources of information for this fact sheet are EPA's Integrated Risk Information System (IRIS) (4), which contains information on oral chronic toxicity and the RfD, and the carcinogenic effects of selenium, the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Selenium (1), and EPA's Drinking Water Criteria Document for Selenium. (2)

Uses

- Selenium is used in the electronics industry; the glass industry; in pigments used in plastics, paints, enamels, inks, and rubber; as a catalyst in the preparation of pharmaceuticals; in antidandruff shampoos (selenium sulfide); and as a constituent of fungicides. (1)
- Selenium is also used as a nutritional feed additive for poultry and livestock, in pesticide formulations, and as an accelerator and vulcanizing agent in rubber production. (1)

Sources and Potential Exposure

- Food is the primary source of exposure to selenium, with an estimated selenium intake for the U.S. population ranging from 0.071 to 0.152 milligrams per day (mg/d). (1)
- Humans are usually exposed to very low levels of selenium in₃ air, with an average selenium concentration estimated to be below 10 nanograms per cubic meter (ng/m³). (1)
- Drinking water usually contains selenium at very low levels (usually less than 0.01 milligrams per liter [mg/L]). However, occasionally, higher levels of selenium may be found in drinking water, usually in areas where high levels of selenium in soil contribute to the selenium content of the water. (1)
- Occupational exposure to selenium in the air may occur in the metal industries, selenium-recovery processes, painting, and special trades. (1)

Assessing Personal Exposure

- Selenium can be measured in the blood, urine, and fingernails or toenails of exposed individuals. (1)

Health Hazard Information

Acute Effects:

- Acute exposure of humans via inhalation to selenium compounds (selenium dioxide, hydrogen selenide) results primarily in respiratory effects. Acute inhalation exposure to elemental selenium dust results in irritation of the mucous membranes in the nose and throat, producing coughing, nosebleeds, dyspnea, bronchial spasms, bronchitis, and chemical pneumonia. (1)
- Gastrointestinal effects including vomiting and nausea; cardiovascular effects; neurological effects such as headaches and malaise; and irritation of the eyes were reported in humans acutely exposed to selenium compounds via inhalation. (1)
- Acute human exposure to selenium compounds via the oral route has resulted in pulmonary edema and lesions of the lung; cardiovascular effects such as tachycardia; gastrointestinal effects including nausea, vomiting, diarrhea, and abdominal pain; effects on the liver; and neurological effects such as aches, irritability, chills, and tremors. (1,2)
- "Blind staggers" disease is a disease in livestock that results from acute consumption of plants high in selenium. It is characterized by impaired vision, aimless wandering behavior, reduced consumption of food and water, and paralysis. (1,2,4)
- Acute animal tests in rats, mice, and guinea pigs, have shown hydrogen selenide to have **extreme** toxicity from inhalation exposure, sodium selenite to have **extreme** toxicity from oral exposure, and elemental selenium to have **low** toxicity from oral exposure. (1,3)

Chronic Effects (Noncancer):

- No information is available on the chronic effects of selenium in humans from inhalation exposure.
- In epidemiological studies of populations exposed to high levels of selenium in food and water, discoloration of the skin, pathological deformation and loss of nails, loss of hair, excessive tooth decay and discoloration, garlic odor in breath and urine, lack of mental alertness, and listlessness were reported. (1,2)
- "Alkali disease" is a disease in livestock resulting from chronic consumption of high levels of selenium; it is characterized by hair loss, deformation and sloughing of the hooves, erosion of the joints of the bones, anemia, and effects on the heart, kidney, and liver. (1,2)
- EPA has not established a Reference Concentration (RfC) for selenium. (4)
- The California Environmental Protection Agency (CalEPA) has calculated a chronic reference exposure level of 0.02 milligrams per cubic meter (mg/m^3) for selenium and selenium compounds based on clinical selenosis in humans, and a chronic reference exposure level of $0.00008 \text{ mg}/\text{m}^3$ for hydrogen selenide based on respiratory effects in guinea pigs. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. (5)
- The Reference Dose (RfD) for selenium is 0.005 milligrams per kilogram body weight per day ($\text{mg}/\text{kg}/\text{d}$) based on clinical selenosis in humans. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups), that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime. It is not a direct estimator of risk but rather a reference point to gauge the potential effects. At exposures increasingly greater than the RfD, the potential for adverse health effects increases. Lifetime exposure above the RfD does not imply that an adverse health effect would necessarily occur. (4)
- EPA has medium confidence in the study on which the RfD was based; although this is a human epidemiological study in which a sizable population with sensitive subpopulations was studied, there are still several possible interactions that were not fully accounted for (e.g., fluoride intake and protein status). Also, except for clinical signs of selenosis, there are no other reliable indicators, biochemical or clinical, of selenium toxicity. EPA ranked confidence in the database as high because many animal studies and epidemiologic studies support the principal study, and high confidence in the RfD based upon support of the critical study and the high level of confidence in the database. (5)
- Selenium is an essential element in human nutrition, with recommended daily allowances of 0.070 mg/d for men, 0.055 mg/d for women, and $8.7 \times 10^{-4} \text{ mg}/\text{kg}/\text{d}$ for infants. (1)
- Two diseases, "Keshan disease" and "Kashin-Beck disease" have been reported in humans in selenium-deficient populations in China. Keshan disease is characterized by heart failure, cardiac enlargement,

abnormalities of EKG, and cardiogenic shock. Kashin–Beck disease, which occurs primarily in children between the ages of 5 and 13 years, is characterized by atrophy, degeneration, and necrosis of cartilage tissue. (1,2)

- Some epidemiological studies have suggested that selenium deficiency may contribute to cardiovascular disease in humans. However, these studies are inconclusive due to confounding factors. (1,2)

Reproductive/Developmental Effects:

- No information is available on the developmental or reproductive effects of selenium in humans. (1)
- The consumption of high levels of selenium in the diet by pigs, sheep, and cattle has been shown to interfere with normal fetal development and to produce fetal malformations. (1,2)
- Sodium selenate, administered in the drinking water to mice, did not result in birth defects, but did result in an increased incidence of fetal deaths and a high proportion of runts, while chronic exposure of mice to selenium in the diet has been shown to affect their fertility and to reduce the viability of the offspring of pairs that are able to breed. (1,2)

Cancer Risk:

- In one study of workers exposed to selenium (form not specified) over a 26–year period, no statistically significant increase in cancer deaths was reported. (1)
- Human studies have reported that patients with cancer, particularly gastrointestinal cancer, prostate cancer, or Hodgkin's lymphoma, had significantly lower selenium levels in the blood than healthy patients. (1,2,4)
- Epidemiological studies that used the selenium concentration in crops as an indicator of dietary selenium have generally reported an inverse association between selenium levels and cancer occurrence. (1,2,4)
- Animal studies have reported that selenium supplementation, as sodium selenate, sodium selenite, and organic forms of selenium, results in a reduced incidence of several tumor types. (1,2,4)
- The only selenium compound that has been shown to be carcinogenic in animals is selenium sulfide, which resulted in an increase in liver tumors in rats and mice and lung tumors in female mice from oral exposure. Selenium sulfide is a pharmaceutical compound used in anti-dandruff shampoos and is very different than the inorganic or organic selenium compounds found in foods and the environment. (1,2,4)
- EPA has classified elemental selenium as a Group D, not classifiable as to human carcinogenicity, and selenium sulfide as a Group B2, probable human carcinogen. (4)

Physical Properties

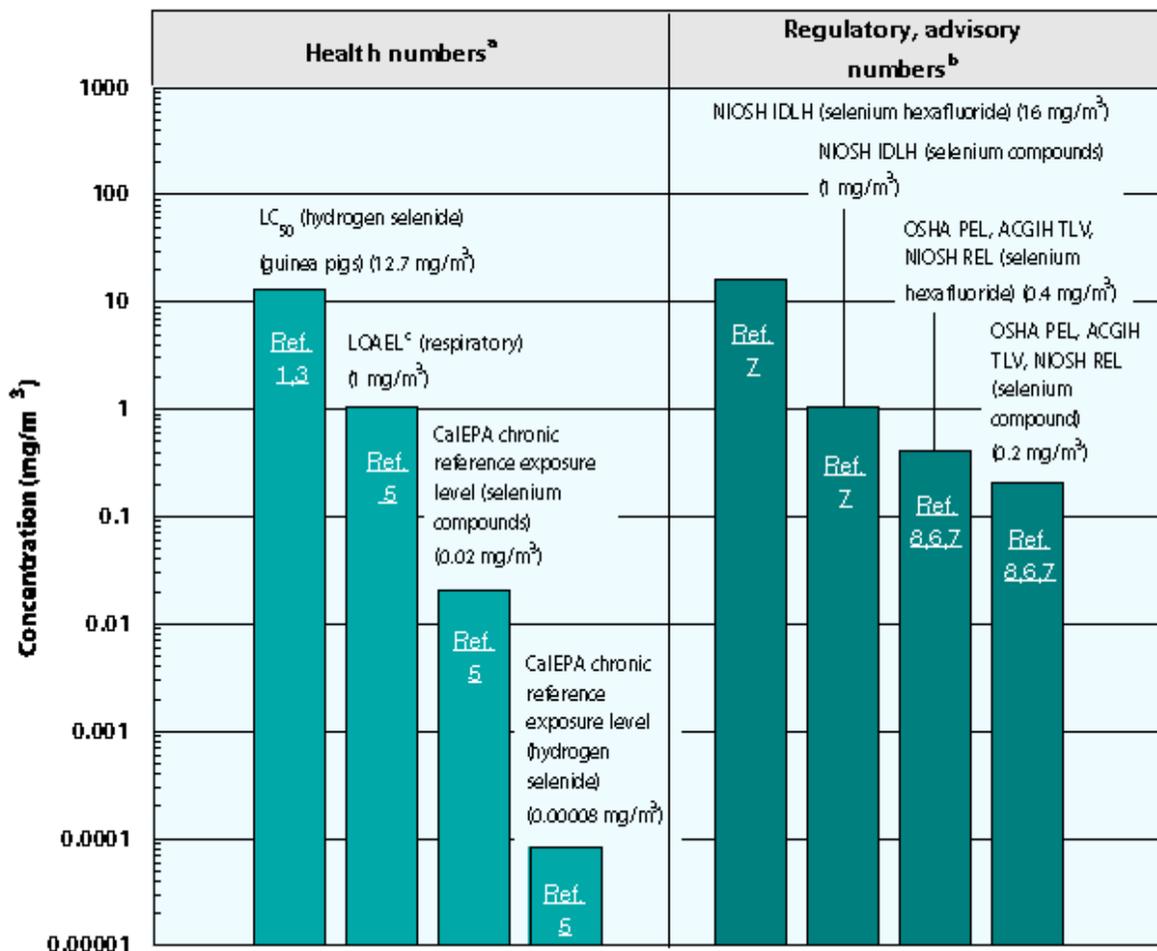
- Selenium is a naturally occurring substance that is widely distributed in the earth's crust and is commonly found in sedimentary rock. (1)
- Selenium is usually combined with other compounds in the environment, such as sulfide minerals or with silver, copper, lead, and nickel. (1)
- The chemical symbol for selenium is Se, the atomic weight is 78.96 g/mol, and the vapor pressure is 1 mm Hg at 356 °C. (1)
- Hydrogen selenide is a selenium compound that exists as a colorless gas at room temperature. (1)
- The chemical formula for hydrogen selenide is H₂Se, the molecular weight is 80.98 g/mol, and the vapor pressure is 9,120 mm Hg at 30.8 °C. (1)

Conversion Factors:

To convert concentrations in air (at 25 °C) from ppm to mg/m³: $\text{mg/m}^3 = (\text{ppm}) \times (\text{molecular weight of the compound}) / (24.45)$. For hydrogen selenide: 1 ppm = 3.31 mg/m³; For selenium hexafluoride, 1 ppm = 7.89 mg/m³.

Health Data from Inhalation Exposure

Selenium



ACGIH TLV--American Conference of Governmental and Industrial Hygienists' threshold limit value expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effects.

LC₅₀ (Lethal Concentration₅₀)--A calculated concentration of a chemical in air to which exposure for a specific length of time is expected to cause death in 50% of a defined experimental animal population.

NIOSH IDLH--National Institute of Occupational Safety and Health's immediately dangerous to life or health value; the maximum environmental concentration of a contaminant from which one could escape within 30 minutes without any escape-impairing symptoms or irreversible health effects.

NIOSH REL--NIOSH's recommended exposure limit; NIOSH-recommended exposure limit for an 8- or 10-h time-weighted-average exposure and/or ceiling.

OSHA PEL--Occupational Safety and Health Administration's permissible exposure limit expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-h workday or a 40-h workweek.

The health and regulatory values cited in this factsheet were obtained in December 1999.

^a Health numbers are toxicological numbers from animal testing or risk assessment values developed by EPA.

^b Regulatory numbers are values that have been incorporated in Government regulations, while advisory numbers are nonregulatory values provided by the Government or other groups as advice. OSHA numbers are regulatory, whereas NIOSH and ACGIH numbers are advisory.

^c This LOAEL is from the critical study used as the basis for the CalEPA chronic reference exposure level for hydrogen selenide.

References

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2. U.S. Environmental Protection Agency. Final Draft for the Drinking Water Criteria Document for Selenium. Criteria and Standards Division. Office of Drinking Water, Washington, D.C. 1986.
3. U.S. Department of Health and Human Services. Registry of Toxic Effects of Chemical Substances (RTECS, online database). National Toxicology Information Program, National Library of Medicine, Bethesda, MD. 1993.
4. U.S. Environmental Protection Agency. [Integrated Risk Information System \(IRIS\) on Selenium and Compounds](#). National Center for Environmental Assessment, Office of Research and Development, Washington, DC. 1999.
5. [California Environmental Protection Agency \(CalEPA\)](#). Air Toxics Hot Spots Program Risk Assessment Guidelines: Part III. Technical Support Document for the Determination of Noncancer Chronic Reference Exposure Levels. SRP Draft. Office of Environmental Health Hazard Assessment, Berkeley, CA. 1999.
6. American Conference of Governmental Industrial Hygienists (ACGIH). 1999 TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices. Cincinnati, OH. 1999.
7. National Institute for Occupational Safety and Health (NIOSH). [Pocket Guide to Chemical Hazards](#). U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. Cincinnati, OH. 1997.
8. Occupational Safety and Health Administration (OSHA). Occupational Safety and Health Standards, Toxic and Hazardous Substances. Code of Federal Regulations. 29 CFR 1910.1000. 1998.