Strontium

What Is It? Strontium is a soft, silver-gray metal that occurs in nature as four stable isotopes. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Strontium-88 is the most prevalent form, comprising about 83% of natural strontium. The other three stable isotopes and their relative abundance are strontium-84 (0.6%), strontium-86 (9.9%), and strontium-87 (7.0%). Strontium is present in nature chiefly as celestite ($SrSO_4$) and strontianite ($SrCO_3$), and it comprises about 0.025% of the earth's crust.

Symbol: **Sr**

Atomic Number: **38**
(protons in nucleus)

Atomic Weight: **88**
(naturally occurring)

There are 16 major radioactive isotopes of strontium, but only strontium-90 has a half-life sufficiently long (29 years) to warrant any concern for Department of Energy environmental management sites such as Hanford. The half-lives of all other strontium radionuclides are less than 65 days. Strontium-90 decays to yttrium-90 by emitting a beta particle, and yttrium-90 decays by emitting a more energetic beta particle with a half-life of 64 hours to zirconium-90. The main health concerns for strontium-90 are related to the energetic beta particle from yttrium-90.

Radioactive Properties of the Key Strontium Isotope and an Associated Radionuclide

Isotope	Half-Life	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha *(α)*	Beta *(β)*	Gamma *(γ)*
Sr-90	29 yr	140	β	-	0.20	-
Y-90	*64 hr*	*550,000*	*β*	-	*0.94*	<

Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable, and a "<" means the radiation energy is less than 0.001 MeV. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Properties of yttrium-90 are included here because this radionuclide accompanies strontium decays. Values are given to two significant figures.

Where Does It Come From? While four stable isotopes of strontium occur naturally, strontium-90 is produced by nuclear fission. When an atom of uranium-235 (or other fissile nuclide) fissions, it generally splits asymmetrically into two large fragments – fission products with mass numbers in the range of about 90 and 140 – and two or three neutrons. (The mass number is the sum of the number of protons and neutrons in the nucleus of the atom.) Strontium-90 is one such fission product, and it is produced with a yield of about 6%. That is, about six atoms of strontium-90 are produced per 100 fissions. Strontium-90 is a major radionuclide in spent nuclear fuel, high-level radioactive wastes resulting from the processing of spent nuclear fuel, and radioactive wastes associated with the operation of reactors and fuel reprocessing plants.

How Is It Used? Strontium has a variety of commercial and research uses. It has been used in certain optical materials, and it produces the red flame color of pyrotechnic devices such as fireworks and signal flares. Strontium has also been used as an oxygen eliminator in electron tubes and to produce glass for color television tubes. Further, strontium-90 has been used as an isotopic energy source in various governmental research applications, including in SNAP (Systems for Nuclear Auxiliary Power) devices to power remote weather stations, navigational buoys, and satellites.

What's in the Environment? In addition to the four stable isotopes naturally present in soil, strontium-90 is present in surface soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Average strontium-90 concentrations in surface soil are about 0.1 picocurie per gram (pCi/g). The transport of strontium in the environment is strongly influenced by its chemical form. Strontium-90 is relatively mobile and can move down with percolating water to underlying layers of soil and into groundwater. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (water in

the pore space between soil particles); concentration ratios are typically higher (110) in clay soil. The highest concentrations of strontium-90 at the Hanford Site are in areas that contain waste from processing irradiated fuel, such as in tanks in the central portion of the site and to a lesser degree in the liquid disposal areas along the Columbia River. The maximum contaminant level established by the Environmental Protection Agency (EPA) for strontium-90 in public drinking water supplies is 8 pCi per liter (pCi/L). Considerably higher concentrations have been measured in contaminated groundwater at the Hanford Site, but this groundwater is not used as a public drinking water supply. The strontium-90 groundwater plume near the N Reactor has reached the Columbia River in detectable amounts, about 0.1 pCi/L. There is essentially no difference between upstream and downstream concentrations.

What Happens to It in the Body? Strontium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the principal source of internally deposited strontium in the general population. On average, 30 to 40% of ingested strontium is absorbed into the bloodstream. Absorption is higher (about 60%) in children in their first year of life. Adults on fasting and low-calcium diets can also increase intestinal absorption to these levels, as the body views strontium as a replacement for calcium. Strontium behaves similarly to calcium (but is not homeostatically controlled, i.e., where the body actively regulates levels within the cells), but living organisms generally use and retain it less effectively. About 15% of what enters the bloodstream is deposited in bone; the remainder goes to soft tissue (mainly the kidney) and plasma extracellular fluid and is excreted in urine. The biological half-life of strontium remaining in the body is about 30 years.

What Are the Primary Health Effects? Strontium is a health hazard only if it is taken into the body. External gamma exposure is not a major concern because strontium-90 emits no gamma radiation and its decay product yttrium-90 emits only a small amount. Strontium-90 concentrates in bone surfaces and bone marrow, and its relatively long radioactive half-life (29 years) combined with the long biological half-life for removal (30 years) make it one of the more hazardous products of radioactive fallout. The health effects associated with strontium-90 were studied concurrent with development of the atomic bomb during World War II by the Manhattan Engineer District. Bone tumors and tumors of the blood-cell forming organs are the main health concern. These tumors are associated with the beta particles emitted during the radioactive decay of strontium-90 and yttrium-90.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including strontium-90 *(see box at right).* Most of the risk is associated with the high-energy beta particle emitted by yttrium-90. While the risk coefficient for ingestion is lower than for inhalation, ingestion is generally the most common means of entry into the body. Similar to other radionuclides, the risk coefficient for tap water is about 80% of that for dietary ingestion.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. The recommended default absorption type was used for inhalation, and the dietary value was used for ingestion. These values include the contribution from the decay product yttrium-90. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10^{-9} is a billionth, and 10^{-12} is a trillionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	**Ingestion** *(pCi^{-1})*
Strontium-90	1.0×10^{-10}	7.5×10^{-11}

For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.

In addition to potential radiogenic effects, strontium has been shown to inhibit calcification and cause bone deformities in animals, notably at high doses. The EPA toxicity value for estimating the potential for non-cancer effects is termed a reference dose. This is an estimate of the highest dose that can be taken in every day without causing an adverse non-cancer effect. The reference dose used to estimate non-cancer effects for strontium from oral exposure is 0.6 milligrams per kilogram body weight per day (mg/kg-day). This value was developed by studying test animals given relatively high doses over their lifetimes, then adjusting and normalizing those results to a mg/kg-day basis for humans.