

ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

STRONTIUM ENTRY

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Like a library or many large databases (such as EPA's national STORET water quality database), this document contains information of variable quality from very diverse sources. In compiling this document, mistakes were found in peer reviewed journal articles, as well as in databases with relatively elaborate quality control mechanisms [366,649,940]. A few of these were caught and marked with a "[sic]" notation, but undoubtedly others slipped through. The [sic] notation was inserted by the editors to indicate information or spelling that seemed wrong or misleading, but which was nevertheless cited verbatim rather than arbitrarily changing what the author said.

Most likely additional transcription errors and typos have been added in some of our efforts. Furthermore, with such complex subject matter, it is not always easy to determine what is correct and what is incorrect, especially with the "experts" often disagreeing. It is not uncommon in scientific research for two different researchers to come up with different results which lead them to different conclusions. In compiling the Encyclopedia, the editors did not try to resolve such conflicts, but rather simply reported it all.

It should be kept in mind that data comparability is a major problem in environmental toxicology since laboratory and field methods are constantly changing and since there are so many different "standard methods" published by EPA, other federal agencies, state agencies, and various private groups. What some laboratory and field investigators actually do for standard operating practice is often a unique combination of various standard protocols and impromptu "improvements." In fact, the interagency task force on water methods concluded that [1014]:

It is the exception rather than the rule that water-quality monitoring data from different programs or time periods can be compared on a scientifically sound basis, and that...

No nationally accepted standard definitions exist for water quality parameters. The different organizations may collect data using identical or standard methods, but identify them by different names, or use the same names for data collected by different methods [1014].

Differences in field and laboratory methods are also major issues related to (the lack of) data comparability from media other than water: soil, sediments, tissues, and air.

In spite of numerous problems and complexities, knowledge is often power in decisions related to chemical contamination. It is therefore often helpful to be aware of a broad universe of conflicting results or conflicting expert opinions rather than having a portion of this information arbitrarily censored by someone else. Frequently one wants to know of the existence of information, even if one later decides not to use it for a particular application. Many would like to see a high percentage of the information available and decide for themselves what to throw out, partly because they don't want to seem uninformed or be caught by surprise by potentially important information. They are in a better position if they can say: "I knew about that data, assessed it based on the following quality assurance criteria, and decided not to use it for this application." This is especially true for users near the end of long decision processes, such as hazardous site cleanups, lengthy ecological risk assessments, or complex natural resource damage assessments.

For some categories, the editors found no information and inserted the phrase "no information found." This does not necessarily mean that no information exists; it

simply means that during our efforts, the editors found none. For many topics, there is probably information "out there" that is not in the Encyclopedia. The more time that passes without encyclopedia updates (none are planned at the moment), the more true this statement will become. Still, the Encyclopedia is unique in that it contains broad ecotoxicology information from more sources than many other reference documents. No updates of this document are currently planned. However, it is hoped that most of the information in the encyclopedia will be useful for some time to come even without updates, just as one can still find information in the 1972 EPA Blue Book [12] that does not seem well summarized anywhere else.

Although the editors of this document have done their best in the limited time available to insure accuracy of quotes or summaries as being "what the original author said," the proposed interagency funding of a bigger project with more elaborate peer review and quality control steps never materialized.

The bottom line: The editors hope users find this document useful, but don't expect or depend on perfection herein. Neither the U.S. Government nor the National Park Service make any claims that this document is free of mistakes.

The following is one chemical topic entry (one file among 118). Before utilizing this entry, the reader is strongly encouraged to read the README file (in this subdirectory) for an introduction, an explanation of how to use this document in general, an explanation of how to search for power key section headings, an explanation of the organization of each entry, an information quality discussion, a discussion of copyright issues, and a listing of other entries (other topics) covered.

See the separate file entitled REFERENC for the identity of numbered references in brackets.

HOW TO CITE THIS DOCUMENT: As mentioned above, for critical applications it is better to obtain and cite the original publication after first verifying various data quality assurance concerns. For more routine applications, this document may be cited as:

Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese, and W. Basham. 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. Distributed within the Federal Government as an Electronic Document (Projected public availability

on the internet or NTIS: 1998).

Strontium (Sr, CAS number 7440-24-6)

NOTE: This entry contains information not only on elemental strontium, but also on the strontium 90 isotope and various strontium compounds.

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Strontium is a soft, silvery metal with physical and chemical properties similar to those of calcium [376]. It is a fairly common alkaline earth metal [190].

Strontium is present in small quantities in most plant tissues though it has not been shown to be essential for their growth & development (Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969) [366]. In localities where it is elevated, strontium is an important freshwater quality ion which contributes to water "hardness" [302].

Many radioactive isotopes of strontium are produced in nuclear reactors [376]. Strontium 90 is a radioactive nuclide which is considered to be one of the more undesirable fission products [190]. Highly elevated amounts of radioactive isotopes of strontium are usually the result of nuclear activity. Strontium 90, with a relatively lengthy half-life of 28 years, is formed in nuclear explosions [376].

Strontium-85 has an atomic number of 38, a half-life of 64.8 days, and has X-ray emission as the major form of decay [674]. The atomic number for Strontium-89 is 38, the half-life is 50.5 days, and beta emission is the major form of decay [674]. The atomic number for Strontium-90 is 38, the half-life is 29 years, and beta emission is the major form of decay [674].

As is the case for barium and calcium, there are relatively few organometallic compounds of strontium; their industrial uses are few and their toxicology is of limited concern [483].

Strontium, along with barium, is sometimes a marker for contamination from produced water from the oil industry (Brian Cain, Fish and Wildlife Service, Personal Communication, 1997). Strontium is found in small quantities associated with barium minerals [940]. High concentrations of strontium is also sometimes a marker for pollution from cattle feedlots (Roy Irwin, National Park Service, personal communication, 1997).

Br.Haz: General Hazard/Toxicity Summary:

In studies of subsurface agricultural irrigation drainage waters of the San Joaquin Valley of California, strontium was determined to be a "substance of concern, additional data needed" [445]. However, most references to strontium seem to minimize the hazard of strontium in its natural form.

The adequacy of calcium nutrition is a critical factor regarding strontium toxicity; rachitic changes to bones of rats are exacerbated by inadequate calcium levels [893]. Skeletal abnormalities have been observed in dogs administered oral doses of strontium (1-3 g strontium phosphate/day) in conjunction with low levels of dietary calcium [893].

In addition to the effects exerted on bones, strontium can also physiologic processes such as heart and other skeletal muscle contraction, and ionic transport across red blood cell membranes and nerve cells [893]. However, these effects are reported following intravenous infusion of large doses of strontium, which is of questionable relevance to oral exposures [893].

Certain doses of strontium are effective in stimulating bone formation without affecting bone mineralization in rats [893].

Non-radioactive strontium has usually not been thought of as being particularly hazardous (same is not true for all strontium compounds). A typical statement is that strontium is a "a harmless element in its natural form, resembles calcium chemically and is therefore readily incorporated into bone" (Yamada, S.B.; Mulligan, T.J. 1987. Marking nonfeeding salmonid fry with dissolved strontium. Can. J. Fish. Aquat. Sci.; pp. 1502-1506).

Although pure strontium does not appear to be very toxic, many strontium compounds are hazardous to fish and wildlife. Strontium chromate is carcinogenic and several strontium compounds are very reactive or explosive [161].

Toxic Hazard Rating of Strontium [366]:

Chronic systemic: No harm under any conditions or harmful only under unusual conditions or overwhelming dosage. [Sax, N.I. Dangerous Properties of Industrial Materials. 4th ed. New York: Van Nostrand Reinhold, 1975. 1126].

Human Toxicity Excerpt of Strontium [366]:

It has been stated to be non-toxic when pure. [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969.] 2. Low toxicity. [Hawley, G.G. The Condensed Chemical Dictionary. 9th ed. New York: Van Nostrand Reinhold Co., 1977. 819].

No toxic effects from industrial use of non-radioactive strontium have been recorded in humans (Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 305) [940].

Major hazard of exposure to Sr is from general environmental pollution from radioactive fallout of (90)Sr (Patty, F. (ed.). Industrial Hygiene and Toxicology: Volume II: Toxicology. 2nd ed. New York: Interscience Publishers, 1963. 1132) [366].

Because strontium 90 accumulates in the bones, it is considered the most dangerous component of radioactive fallout [376].

Body burden issues are not well understood. Some studies indicate that 70 to 90 percent of cattle's strontium 90 intake came from native grass hay and that farm to farm differences in the strontium-90 concentrations in the hay fed correspond to differences in the concentration of strontium 90 in the milk [382].

The toxicology of organometallic compounds of strontium is of limited concern [483].

Strontium chloride is used in chemical production, pyrotechnics, and in antifreeze manufacturing. Acute toxicity is of a low order to man and fish. Decomposition products are highly toxic [Anon, 1988, Strontium chloride. Dang. Proper. Ind. Mater. Rep; vol. 8, no. 4, pp. 55-58].

Br.Car: Brief Summary of Carcinogenicity/Cancer Information:

EPA 1996 IRIS database information [893]:

Carcinogenicity Assessment: empty

The isotope Sr 90 has been implicated as a causative agent in leukemia (National Research Council. Drinking Water & Health, Volume 4. Washington, DC: National Academy Press, 1981. 189) [940].

The hazard of (90)Sr is primarily that of internal contamination. In the body it is deposited mainly in the bones & due to its long biological half-life, it may

result in beta-ray induced hemopoietic tissue lesions & malignant bone growth (International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 2112) [940].

Strontium chromate is carcinogenic [161].

Br.Dev: Brief Summary of Developmental, Reproductive, Endocrine, and Genotoxicity Information:

Results from dog experiments concluded that the fetal dog was not more sensitive than the adult to either the lethal or oncogenic effect of radiostrontium. Underdeveloped jaws, disproportionate growth of the long bones & many fractures were found in fetuses after admin of 1 mCi/kg to the mother 6 days before delivery (Shepard, T.H. Catalog of Teratogenic Agents. 5th ed. Baltimore, MD: The Johns Hopkins University Press, 1986. 527] [940].

Five to 110 uCi of (90)Sr were injected IP into pregnant mice at various times during pregnancy & an increase in skeletal defects was found (Shepard, T.H. Catalog of Teratogenic Agents. 5th ed. Baltimore, MD: The Johns Hopkins University Press, 1986. 527) [940].

Pregnant mice were injected on 11th or 16th gestational day with 20 uCi of (90)Sr. A general reduction of fetal oocytes was found (Shepard, T.H. Catalog of Teratogenic Agents. 5th ed. Baltimore, MD: The Johns Hopkins University Press, 1986. 527) [940].

Strontium chloride is clastogenic [399], sometimes associated with chromosomal aberrations.

Oral administration of different concentrations of Strontium chloride to laboratory bred mice in vivo induced chromosomal aberrations in bone marrow cell metaphase preparations [399]. The degree of clastogenicity was directly proportional to concentration used at 6, 12, and 24 h of treatment [399]. Duration of treatment could only be related positively in the lower doses [399]. The females showed greater susceptibility than the males at all concentrations used [399].

One study reported no teratogenic effects of strontium, but the small number of dams exposed and fetuses examined preclude a definite evaluation of the results [893].

Br.Fate: Brief Summary of Key Bioconcentration, Fate, Transport, Persistence, Pathway, and Chemical/Physical Information:

Since it has physical and chemical properties similar to those of calcium [376], strontium should be expected to have similar fate characteristics. Strontium 90, with a half-life of 28 years, is formed in nuclear explosions [376].

Synonyms/Substance Identification:

Molecular Formula [940]:

Sr

Associated Chemicals or Topics (Includes Transformation Products):

Associated Chemicals [940]:

Strontium, isotope of mass 90; CAS 10098-97-2

Strontium, isotope of mass 84; CAS 15758-49-3

Strontium, isotope of mass 86; CAS 13982-14-4

Strontium, isotope of mass 88; CAS 14119-10-9

Strontium, along with barium, is sometimes a marker for contamination from produced (oil industry) water (Brian Cain, Fish and Wildlife Service, Personal Communication, 1997). High strontium is also sometimes a marker for pollution from cattle feedlots (Roy Irwin, National Park Service, personal communication, 1997).

Strontium is found in small quantities associated with calcium or barium minerals (The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266) [940].

Water Data Interpretation, Concentrations and Toxicity (All Water Data Subsections Start with "W."):

W.Low (Water Concentrations Considered Low):

No information found.

W.High (Water Concentrations Considered High):

Freshwater Concentrations Considered to be Elevated or High [190]:

USGS 1985: 1 mg/L

W.Typical (Water Concentrations Considered Typical):

Medium Concentration of Strontium for Large U.S. Water Supply Systems: USGS 1985: 0.11 mg/L [190].

In sea water 10 ppm [940].

Strontium is present in seawater at a concentration of

8X10+4 (sic) ug/L (Kirk-othmer Encyc Chem tech 3RD ED 1978-PRESENT V16 p.279) [366].

Super(90)Sr and super(137)Cs were analyzed in the Elbe river. The average super(90)Sr concentration before the Chernobyl accident was approximately 0.015 Bq/l. The average super(137)Cs-concentration was about 0.001 Bq/l in the inner estuary. Due to emissions from reprocessing plants in Great Britain and France the concentration in the outer estuary was about a factor of 10 higher. The super(137)Cs concentration is now again in the range of the values measured before the accident. A rough estimate of the amounts transported into the North Sea from May to July 1986 are 150-300 GBq for super(90)Sr and 500-2000 GBq for super(137)Cs. Since sampling for super(137)Cs was probably not representative, this figure could be a factor of 2-5 higher. These values are small compared to the natural radioactivity of super(40)K, and to the amounts of super(137)Cs emitted by the reprocessing plants in Sellafield/Windscale and La Hague [Wilken, R.-D. and R. Diehl. 1989. Strontium-90 and cesium-137 in the Elbe River before and after the Chernobyl accident. (Strontium-90 und Caesium-137 in der Elbe vor und nach dem Tschernobyl-Unfall). Vom Wasser 72:65-81].

W. Concern Levels, Water Quality Criteria, LC50 Values, Water Quality Standards, Screening Levels, Dose/Response Data, and Other Water Benchmarks:

W. General (General Water Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Water Concentrations Versus Mixed or General Aquatic Biota):

EPA 1996 IRIS database information [893]:

Water Quality Criteria for protection of aquatic life: empty (no information given).

Oak Ridge National Lab, 1994: Ecological Risk Assessment Freshwater Screening Benchmarks for concentrations of contaminants in water [649]. To be considered unlikely to represent an ecological risk, field concentrations should be below all of the following benchmarks [649]:

CAS 7440-24-6, STRONTIUM (ug/L):

NATIONAL AMBIENT WATER QUALITY CRITERION - ACUTE: No information found.

NATIONAL AMBIENT WATER QUALITY CRITERION -

CHRONIC: No information found.

SECONDARY ACUTE VALUE: 6100

SECONDARY CHRONIC VALUE: 620

LOWEST CHRONIC VALUE - FISH: No information found.

LOWEST CHRONIC VALUE - DAPHNIDS: 42,000

LOWEST CHRONIC VALUE - NON-DAPHNID INVERTEBRATES: No information found.

LOWEST CHRONIC VALUE - AQUATIC PLANTS: No information found.

LOWEST TEST EC20 - FISH: No information found.

LOWEST TEST EC20 - DAPHNIDS: No information found.

SENSITIVE SPECIES TEST EC20: No information found.

POPULATION EC20: No information found.

NOTE: Although most of the lab tests done to develop water quality criteria and other benchmarks were originally based on "total" values rather than "dissolved" values, the lab settings were typically fairly clean and the numbers generated by the lab tests are therefore often even more comparable to field "dissolved" values than to field "total" values (Glen Suter, Oak Ridge National Lab, Personal Communication, 1995).

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

No information found.

W.Fish (Water Concentrations vs. Fish):

No information found.

W.Wildlife (Water Concentrations vs. Wildlife or Domestic Animals):

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Wildlife derived from No-Observed-Adverse-Effect (NOAEL) levels (see Tis.Wildlife, B) for these). To be considered unlikely to represent an ecological risk, wet-weight field concentrations should be below the following benchmarks for each species present at the site [650]:

CAS 7440-24-6 STRONTIUM (STABLE, CHLORIDE)

SPECIES	WATER CONCEN- TRATION (ppm)
Rat (test species)	0.0000
Short-tailed Shrew	3380.3750
Little Brown Bat	5842.6270
White-footed Mouse	2184.6270
Meadow Vole	3823.4850
Cottontail Rabbit	1811.7340
Mink	1878.7230
Red Fox	1340.8120
Whitetail Deer	750.2040

W.Human (Drinking Water and Other Human Concern Levels):

EPA 1996 IRIS database information for strontium in general [893]:

Crit. Dose: 190 mg/kg-day [Study 1
NOAEL(adj)] UF: 300 MF: 1

RfD: 6E-1 mg/kg-day Confidence: Medium

Drinking Water Health Advisories, MCL, MCLG, Criteria for Water and Fish Routes and Fish only route: all empty (no information given)

Federal Drinking Water Guidelines [940]:

EPA 17000 ug/l [USEPA/Office of Water; Federal-State Toxicology and Risk Analysis Committee (FSTRAC). Summary of State and Federal Drinking Water Standards and Guidelines (11/93)].

EPA 1995 Region 9 preliminary remediation goal (PRG) concentration for tap water: 2.2E+04 ug/L of "stable strontium," CAS 7440-24-6 [868].

EPA 1995 Region III risk based concentration (RBC) for tap water: 22000 ug/L of "stable strontium," CAS 7440246 [903].

State Drinking Water Standards [940]:

(AL) ALABAMA 8 ug/l [USEPA/Office of Water; Federal-State Toxicology and Risk Analysis Committee (FSTRAC). Summary of State and Federal Drinking Water Standards and Guidelines (11/93)].

State Drinking Water Guidelines [940]:

(ME) MAINE 2400 ug/l [USEPA/Office of Water; Federal-State Toxicology and Risk Analysis Committee (FSTRAC). Summary of State and Federal Drinking Water Standards and Guidelines (11/93)].

Standards for Strontium-90 in Drinking Water: EPA 1976: 8 pCi/L [190]. As of 1992, EPA was considering future MCL development for strontium [480].

W.Misc. (Other Non-concentration Water Information):

Phytoremediation [1023]:

Rafts with sunflowers growing on them float on a small pond at the Chernobyl nuclear accident site in the Ukraine [1023]. No, its not some touching monument to the 1986 disaster [1023]. The plants are helping to clean the pond; their roots dangle in the water to suck up the radionuclides cesium 137 and strontium 90 [1023]. The plants preferentially absorb cesium and strontium from a mixture of metals, he notes [1023]. The plants don't metabolize the radionuclides, but the cesium stays in the roots and most of the strontium moves to the shoots [1023]. The company disposes of the plants as radioactive waste after about 3 weeks on the pond [1023]. This summer, Phytotech and DOE researchers began a project using sunflowers to remove uranium from contaminated springs at the Oak Ridge (Tenn.) National Laboratory [1023]. "I've heard of uranium contamination at DOE sites of 100 parts per million [ppm], and we couldn't clean that up [1023]. We could go up to 2,000 ppb," Ensley says [1023].

Sediment Data Interpretation, Concentrations and Toxicity (All Sediment Data Subsections Start with "Sed."):

Sed.Low (Sediment Concentrations Considered Low):

For 2,737 (minus-80-mesh) stream sediments (United States

NURE samples) run by INAA, the following are uncensored values (Maurice A. Chaffee, USGS, Denver, personal communication, 1995):

Minimum: 9 ppm

Four ephemeral row-crop agriculture playa lakes in the Texas panhandle had strontium concentrations of 38.9 to 68.6 mg/kg dry weight (Roy Irwin, Personal Communication, 1995). A Mann-Whitney statistical test showed strontium concentrations from the four row-crop agriculture samples to be significantly lower than the concentrations in the four samples known to be impacted by feedlot wastes (significant at 0.0304) (Roy Irwin, National Park Service, personal communication, 1995).

In the Texas panhandle, Strontium concentrations in three sediment samples from the upstream Tierra Blanca Creek site and three sediment samples from the playa lake off-stream site were at or below 56 mg/kg dry weight (Roy Irwin, National Park Service, personal communication, 1995).

Sed.High (Sediment Concentrations Considered High):

For 2,737 (minus-80-mesh) stream sediments (United States NURE samples) run by INAA, the following are uncensored values (Maurice A. Chaffee, USGS, Denver, personal communication, 1995):

75th percentile: 541 ppm
90th percentile: 896 ppm
95th percentile: 1,050 ppm

Some highly mineralized areas or areas of past mining in the west have notable levels of strontium in riverine sediments. Concentrations below mining tailings and even in some streams of Yellowstone National Park can range as high as 900-1,000 ppm (based on minus-60-mesh sediment) but would be considered pretty normal for the types of rocks present in the area. Much of the strontium in Yellowstone NP rocks is thought to be entirely lithologic in origin and is coming from calcium-rich carbonate and volcanic rocks (Maurice A. Chaffee, USGS, Denver, personal communication, 1995).

Three samples from the Texas panhandle Tierra Blanca Creek site suspected of being polluted by a large feedlot had higher strontium concentrations (from 209-226 mg/kg dry weight) and the waste water pond in the feedlot had highly elevated strontium concentrations (300-310 mg/kg). Strontium occurs in most plants, one potential source in cattle feed. A Mann-Whitney statistical test showed

strontium concentrations from the six upstream samples to be significantly lower than the concentrations in the six samples known or suspected of being influenced by feedlot wastes (significant at 0.0051) [401].

Sed. Typical (Sediment Concentrations Considered Typical):

For 2,737 (minus-80-mesh) stream sediments (United States NURE samples) run by INAA, the following are uncensored values (Maurice A. Chaffee, USGS, Denver, personal communication, 1995):

50th percentile: 425 ppm
Arithmetic mean: 575 ppm

Dry weight concentrations of strontium in four cattle feedlot-impacted playa lakes (in the Texas Panhandle) the author has studied ranged from 149-189 mg/kg (Roy Irwin, Personal Communication, 1995).

Averages and ranges of concentration of elements in soils and other surficial materials in the United States (1971): The mean concentration of strontium was 240 ppm. The range was <5-3,000 ppm [347].

Sed. Concern Levels, Sediment Quality Criteria, LC50 Values, Sediment Quality Standards, Screening Levels, Dose/Response Data and Other Sediment Benchmarks:

Sed. General (General Sediment Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Sediment Concentrations Versus Mixed or General Aquatic Biota):

No information found.

Sed. Plants (Sediment Concentrations vs. Plants):

No information found.

Sed. Invertebrates (Sediment Concentrations vs. Invertebrates):

No information found.

Sed. Fish (Sediment Concentrations vs. Fish):

No information found.

Sed. Wildlife (Sediment Concentrations vs. Wildlife or Domestic Animals):

No information found.

Sed.Human (Sediment Concentrations vs. Human):

No information found.

Sed.Misc. (Other Non-concentration Sediment Information):

No information found.

Soil Data Interpretation, Concentrations and Toxicity (All Soil Data Subsections Start with "Soil."):

Soil.Low (Soil Concentrations Considered Low):

No information found.

Soil.High (Soil Concentrations Considered High):

No information found.

Soil.Typical (Soil Concentrations Considered Typical):

Averages and ranges of concentration of elements in soils and other surficial materials in the United States (1971): The mean concentration of strontium was 240 ppm. The range was <5-3,000 ppm [347].

Strontium in plants was 20 ppm in areas where rocks were 150 ppm; concentration in igneous rocks can be 350 ppm and concentrations in soils 300 ppm [951].

World wide sampling of soils revealed strontium compd contents around 300 mg/kg (Seiler, H.G., H. Sigel and A. Sigel, eds., Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 632) [940].

Soil.Concern Levels, Soil Quality Criteria, LC50 Values, Soil Quality Standards, Screening Levels, Dose/Response Data and Other Soil Benchmarks:

Soil.General (General Soil Quality Standards, Criteria, and Benchmarks Related to Protection of Soil-dwelling Biota in General; Includes Soil Concentrations Versus Mixed or General Soil-dwelling Biota):

No information found.

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

No information found.

Soil.Wildlife (Soil Concentrations vs. Wildlife or Domestic Animals):

No information found.

Soil.Human (Soil Concentrations vs. Human):

EPA 1995 Region III risk based concentration (RBC) for soil in residential area: 47000 mg/kg of "stable strontium," CAS 7440246 [903].

EPA 1995 Region 9 preliminary remediation goal (PRG) concentration for soil in residential area: 4.6E+04 mg/kg of "stable strontium," CAS 7440-24-6 [868].

EPA 1995 Region III risk based concentration (RBC) for soil in industrial area: 1E+06 mg/kg of "stable strontium," CAS 7440246 [903].

EPA 1995 Region 9 preliminary remediation goal (PRG) concentration for soil in industrial area: 1.0E+05 mg/kg of "stable strontium," CAS 7440-24-6 [868].

Soil.Misc. (Other Non-concentration Soil Information):

No information found.

Tissue and Food Concentrations (All Tissue Data Interpretation Subsections Start with "Tis."):

Tis.Plants:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Plants:

No information found.

B) Body Burden Residues in Plants: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Strontium in plants was 20 ppm in areas where rocks were 150 ppm [951]. All members of the genus Gramineae contain 26-410 ppm strontium, which has only slight toxicity to plants [951].

Tis.Invertebrates:

A) As Food: Concentrations or Doses of Concern to Living

Things Which Eat Invertebrates:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Invertebrates:

No information found.

C) Body Burden Residues in Invertebrates: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found.

Tis.Fish:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Fish (Includes FDA Action Levels for Fish and Similar Benchmark Levels From Other Countries):

EPA 1995 Region III risk based concentration (RBC) for fish flesh: 810 mg/kg of "stable strontium," CAS 7440246 [903].

B) Concentrations or Doses of Concern in Food Items Eaten by Fish:

No information found.

C) Body Burden Residues in Fish: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Misc. abstract (Copied with permission of Compact Cambridge):

TITLE: Marking nonfeeding salmonid fry with dissolved strontium.

AUTHOR: Yamada, S.B.; Mulligan, T.J.

AUTHOR AFFILIATION: Zool. Dep., Oregon State Univ., Corvallis, OR 97331, USA

SOURCE: CAN. J. FISH. AQUAT. SCI.; pp. 1502-1506; 1987

ABSTRACT:

Chemical marking is a simple, inexpensive, and rapid technique for marking young salmon. The authors have marked nonfeeding embryos by adding strontium to their rearing water. Strontium, a harmless element in its natural form, resembles calcium chemically and is therefore readily incorporated into bone. Their data show that the best time for inducing a Sr mark into nonfeeding salmon fry is after hatching, when bone development

begins. The addition of 1 $\mu\text{g Sr/mL}$ to the rearing water of salmon fry for a period of 49 d resulted in a 10-fold increase in their vertebral Sr concentration. As the salmon grew, the induced mark became diluted in a predictable manner, but was still detectable after 169 d.

PUBLICATION YEAR: 1987.

Tis.Wildlife: Terrestrial and Aquatic Wildlife, Domestic Animals and all Birds Whether Aquatic or not:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Wildlife, Domestic Animals, or Birds:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Wildlife, Birds, or Domestic Animals (Includes LD50 Values Which do not Fit Well into Other Categories, Includes Oral Doses Administered in Laboratory Experiments):

The adequacy of calcium nutrition is a critical factor regarding strontium toxicity; rachitic changes to bone are exacerbated by inadequate calcium levels [893]. In one study, the effect of dietary calcium on strontium toxicity was demonstrated when rachitic changes were observed in weanling Sprague-Dawley rats fed a diet containing 0.95% strontium (950 mg/kg-day) and "optimal" 0.69% calcium for 4 weeks [893]. When dietary calcium was raised to 1.6%, no rachitic changes were seen at the same dose of strontium [893].

Skeletal abnormalities have been observed in dogs administered oral doses of strontium (1-3 g strontium phosphate/day) in conjunction with low levels of dietary calcium [893].

A chronic NOAEL of 263 mg/kg-day was identified in one rat study [893].

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Wildlife derived from No-Observed-Adverse-Effect (NOAEL) levels (mg contaminant per kg body weight per day). To be considered unlikely to represent an ecological risk, wet-weight field concentrations should be below the following (right column) benchmarks for each species present at the site [650]:

CAS 7440-24-6 STRONTIUM (STABLE, CHLORIDE)

SPECIES	NOAEL (mg/kg/day)	FOOD CONCEN- TRATION (ppm)
Rat (test species)	263.0000	0.0000
Short-tailed Shrew	743.6820	1239.4710
Little Brown Bat	934.8200	2804.4610
White-footed Mouse	655.3880	4240.7470
Meadow Vole	521.3840	4588.1820
Cottontail Rabbit	175.1340	886.7560
Mink	185.9940	1357.6180
Red Fox	113.2240	1132.2410
Whitetail Deer	49.1280	1595.2610

C) Body Burden Residues in Wildlife, Birds, or Domestic Animals: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found.

Tis.Human:

A) Typical Concentrations in Human Food Survey Items:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Humans (Includes Allowable Tolerances in Human Food, FDA, State and Standards of Other Countries):

EPA 1996 IRIS database information [893]:

Crit. Dose: 190 mg/kg-day [Study 1
NOAEL(adj)] UF: 300 MF: 1

RfD: 6E-1 mg/kg-day Confidence: Medium

EPA 1995 Region III risk based concentration (RBC) for fish flesh: 810 mg/kg of "stable strontium," CAS 7440246 [903].

C) Body Burden Residues in Humans: Typical, Elevated, or of Concern Related to the Well-being of Humans:

No information found.

Tis.Misc. (Other Tissue Information):

The use of strontium levels precipitated into coral skeletal material has long been recognized as an indicator of oceanic temperature at the time of coral growth. Muir (1984) suggested anthropogenically induced factors on the nearby mainland may blur the temperature record. Further research indicates strontium concentrations within the aragonite skeleton are closely

linked to use of agricultural fertilisers flushed from the nearby mainland. Elevated levels of phosphate are inversely associated with decreasing concentrations of strontium in the corals. Associated morphological alteration of the coral skeleton with increased levels of phosphate suggests strontium concentrations provide an excellent indicator of environmental stress related to anthropogenically induced elevated nutrient levels [Rasmussen, C.E. 1988. The use of strontium as an indicator of anthropogenically altered environmental parameters. "Proceedings of the Sixth International Coral Reef Symposium," Townsville, Australia, 8th-12th August 1988. pp. 325-330. ISBN 0-7316-5607-5].

Chemical marking is a simple, inexpensive, and rapid technique for marking young salmon. The authors have marked nonfeeding embryos by adding strontium to their rearing water. Strontium, a harmless element in its natural form, resembles calcium chemically and is therefore readily incorporated into bone. Their data show that the best time for inducing a Sr mark into nonfeeding salmon fry is after hatching, when bone development begins. The addition of 1 μ g Sr/mL to the rearing water of salmon fry for a period of 49 d resulted in a 10-fold increase in their vertebral Sr concentration. As the salmon grew, the induced mark became diluted in a predictable manner, but was still detectable after 169 d [Yamada, S.B.; Mulligan, T.J. 1987. Marking nonfeeding salmonid fry with dissolved strontium. CAN. J. FISH. AQUAT. SCI.; pp. 1502-1506].

Bio.Detail: Detailed Information on Bioconcentration, Biomagnification, or Bioavailability:

ABSTRACT from Rasmussen, C.E. 1988. The use of strontium as an indicator of anthropogenically altered environmental parameters. "Proceedings of the Sixth International Coral Reef Symposium," Townsville, Australia, 8th-12th August 1988. pp. 325-330. ISBN 0-7316-5607-5:

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phosphate suggests strontium concentrations provide an excellent indicator of environmental stress related to anthropogenically induced elevated nutrient levels.

The following abstract containing pertinent information on strontium was copied with permission of Cambridge Scientific Abstracts:

AUTHOR: Beddington JR; Mills CA; Beards F; Minski MJ; Bell JNB
TITLE: Long-term changes in strontium-90 concentrations within a freshwater predator-prey system.
SOURCE: J. FISH BIOL.; vol. 35, no. 5, pp. 679-686; 1989
PUBLICATION YEAR: 1989
ABSTRACT: It proved possible to determine the levels of Sr-90 in the opercular bones of individual pike, *Esox lucius*, and in pooled samples of bones from perch, *Perca fluviatilis*. Results from both species from Windermere demonstrated that Sr-90 levels rose from below the detection limits in the 1940s to a peak in the 1960s, followed by a decline in the subsequent two decades. This decline was slower than would have been expected from the decline in northern hemisphere Sr-90 fallout, indicating the likelihood of recycling within the environment. Sr-90 levels were consistently lower in pike than in perch, their main prey fish. Thus, there is no concentration of Sr-90 up this part of the aquatic food chain. Tracking Sr-90 in bones taken in successive years from ages 3 to 8 for a single cohort of pike showed that the quantity of Sr-90 was closely related to opercular bone (and hence fish) weight. No significant increase in Sr-90 concentration in the bone with increasing age was demonstrated.

Interactions:

As summarized in more detail in the sections above, strontium behaves much like calcium, and the adequacy of calcium nutrition is a critical factor regarding strontium toxicity; rachitic changes to bone are exacerbated by inadequate calcium levels [893].

Uses/Sources:

Several strontium compounds are used in pyrotechnics [161].

Major Uses [940]:

In fireworks, red signal flares, on tracer bullets [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Added to alloys of tin & lead to add hardness & durability, deoxidizer in copper & bronze [Browning, E.

Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 302].

"Getter" in electron tubes [Sax, N.I. and R.J. Lewis, Sr., eds., Hawley's Condensed Chemical Dictionary. 11th ed. New York: Van Nostrand Reinhold Co., 1987. 1097].

Igneous coloring agent, material for condenser, optical glass, lead removing [ITII. Toxic and Hazardous Industrial Chemicals Safety Manual. Tokyo, Japan: The International Technical Information Institute, 1982. 493].

Source of electric power /Artificial isotope 90/ [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Misc. Uses [366]:

Manufacture of glass for color television picture tube faceplates, 53%; Pyrotechnics and signals, 14%; Ferrite ceramic magnets, 11%; Other, 22% (1985) /primary strontium compounds/ [Bureau of mines. Mineral commodity summaries 1986 p.152].

Natural Sources [940]:

Strontium occurs in nature in celestite (strontium sulfate) and strontianite (strontium carbonate). In earth's crust the total amount is estimated to be 430 g/ton; in sea water 10 ppm. /TOTAL STRONTIUM/ [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 302].

Occurs as sulfate, celestine; or carbonate, strontianite; Found in small quantities associated with calcium or barium minerals. /TOTAL STRONTIUM/ [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Artificial Sources [940]:

Reactor releases of (90)Sr or from bomb tests.

Forms/Preparations/Formulations:

Grades: Technical (Sax, N.I. and R.J. Lewis, Sr., eds., Hawley's Condensed Chemical Dictionary. 11th ed. New York: Van Nostrand Reinhold Co., 1987. 1097) [940].

Radionuclides of strontium include Strontium 85, Strontium 89, and Strontium 90 (see Br.Class) section above for details).

Chem.Detail: Detailed Information on Chemical/Physical Properties:

Strontium is a soft, silvery metal with physical and chemical

properties similar to those of calcium [376].

Solubilities [940]:

Sol in alcohol, liq ammonia [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-134].

Sol in nitric acid, hydrochloric acid & dilute sulfuric acid [ITII. Toxic and Hazardous Industrial Chemicals Safety Manual. Tokyo, Japan: The International Technical Information Institute, 1982. 493].

Vapor Pressure [940]:

10 MM HG AT 898 DEG C [Sax, N.I. Dangerous Properties of Industrial Materials. 6th ed. New York, NY: Van Nostrand Reinhold, 1984. 2469].

Molecular Weight [940]:

87.62 [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Density/Specific Gravity [940]:

2.6 g/cu m [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 21(83) 763].

Boiling Point [940]:

1366 DEG C [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Melting Point [940]:

757 + OR - 1 DEG C [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Color/Form [940]:

Silvery-white metal; face-centered cubic structure [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Other Chemical/Physical Properties [940]:

Natural strontium is a mixture of four isotopes; twelve other unstable isotopes are known to exist [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-35].

Alkaline earth metal; valence of 2; isotopes: 88

(82.56%), 86 (9.86%), 87 (7.02%), 84 (0.56%); Heated metal combines with hydrogen to form strontium hydride & with nitrogen to form strontium nitride. [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Three allotropic forms exist, with transition points at 235 & 540 DEG C [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-35].

Strontium will displace hydrogen from water [Clayton, G. D. and F. E. Clayton, eds., Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1896].

Sr 90 has a half life of 28 yr & is a high energy beta emitter ^{90}Sr [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-35].

Lattice constant: 6.05; latent heat of fusion: 104.7 kJ/kg; electrical resistivity: 22.76 uohms/cm [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 21(83) 763].

Specific heat: 0.0719 cal/g/K @ 25 deg C [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. D-179].

Entropy of formation: 12.5 cal/deg mole @ 298.15 K (25 deg C); heat capacity: 6.3 cal/deg mole @ 298.15 K (25 deg C) & std pressure [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. D-86].

Its common cationic salts are water-soluble; it forms chelates with compounds such as EDTA; strontium coordination compounds are not common. [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 60].

Yellowish white, upon exposure to air. [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266].

Fate.Detail: Detailed Information on Fate, Transport, Persistence, and/or Pathways:

Absorption, Distribution, Excretion [366]:

1. Absorption of Sr given by mouth is poor. Retention by

skeleton...3 Times as great with IV as with oral admin.
[Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 304] 2. Excretion following oral admin, whether as single dose or with long-continued feeding...Mainly by feces; following sc injection...By urine at first...After few days...Occurs in ca equal amt by urine & feces...After IV...Small amt...Excreted...By urine. [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 304] 3. In bones, accumulation was greater in trabecular than in cortical tissue & greater in epiphysis than in diaphysis; uptake was specially high in healing fractured bones. In pregnancy...Sr fixed in bones migrates to skeleton of fetus toward end of gestation...Also excreted in milk. [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 304].

Data from the extensive routine environmental monitoring programme around the nuclear reprocessing plant at Sellafield, West Cumbria, are analysed for soil to plant uptake of strontium, iodine and caesium. Relative to the top 10 cm of soil, dry weight concentration ratios derived for lowland pastures for strontium, caesium and iodine are 9, 3 and 2 respectively. Long-term trends indicate a 'spring flush' of activity in vegetation, although this is not statistically significant. Uptake of caesium and iodine is highest generally for mosses and lichen and lowest for grass. The vegetational field loss of these elements over the first 50 days following deposition, is described by: Sr: $Reff(t) = 0.7e^{-0.15t} + 0.25e^{-0.049t} + 0.05e^{-0.011t}$ I: $Reff(t) = 0.7e^{-1.26t} + 0.25e^{-0.17t} + 0.05e^{-0.092t}$ Cs: $Reff(t) = 0.6e^{-0.87t} + 0.2e^{-0.20t} + 0.16e^{-0.065t} + 0.04e^{-0.011t}$ where t is in days. The functions are consistent with the effects of washoff and grazing. Equilibrium plant:soil concentration ratios are established for caesium within about 8 months following short-term deposition. Soil distribution profiles for caesium imply a half-time for transfer through the surface layers of about 6 years (Jackson D; Smith AD, 1989. Uptake and retention of strontium, iodine and caesium in lowland pasture following continuous or short-term deposition. Sci Total Environ 85, P63-72].

Laboratory and/or Field Analyses:

ICP analysis are often used, with detection limits of 0.50 ppm dry weight in tissues, 5.0 ppm in sediments and soils; and 0.001 ug/mL (ppm) in water (Roy Irwin, National Park Service, Personal Communication, 1996). EPA method 200.7 gives a water detection limit of 0.77 ug/L [1006]. Radiological methods include EPA method 303 for total strontium and strontium 90 (40 CFR Part 141.25).

It is important to understand that contaminants data from different labs, different states, and different agencies, collected

by different people, are often not very comparable (see also, discussion in the disclaimer section at the top of this entry).

As of 1997, the problem of lack of data comparability (not only for water methods but also for soil, sediment, and tissue methods) between different "standard methods" recommended by different agencies seemed to be getting worse, if anything, rather than better. The trend in quality assurance seemed to be for various agencies, including the EPA and others, to insist on quality assurance plans for each project. In addition to quality control steps (blanks, duplicates, spikes, etc.), these quality assurance plans call for a step of insuring data comparability [1015,1017]. However, the data comparability step is often not given sufficient consideration. The tendency of agency guidance (such as EPA SW-846 methods and some other new EPA methods for bio-concentratable substances) to allow more and more flexibility to select options at various points along the way, makes it harder to insure data comparability or method validity. Even volunteer monitoring programs are now strongly encouraged to develop and use quality assurance project plans [1015,1017].

At minimum, before using contaminants data from diverse sources, one should determine that field collection methods, detection limits, and lab quality control techniques were acceptable and comparable. The goal is that the analysis in the concentration range of the comparison benchmark concentration should be very precise and accurate.

It should be kept in mind that quality control field and lab blanks and duplicates will not help in the data quality assurance goal as well as intended if one is using a method prone to false negatives. Methods may be prone to false negatives due to the use of detection limits that are too high, the loss of contaminants through inappropriate handling, or the use of inappropriate methods.

Filtration and Holding Times:

For ICP water samples for metals, EPA recommends the following (40 CFR Part 136, Appendix C, 1994 edition of CFR Part 40, page 642):

- 1) For samples of "total or total recoverable elements," samples should be acidified to a pH of two or less at the time of collection or as soon as possible thereafter.
- 2) For determination of dissolved elements, the samples must be filtered through a 0.45 micron membrane filter as soon as soon as practical after collection, using the first 50-100 ml to rinse the filter flask. Acidify the filtrate with nitric acid to a pH of 2 or less. Normally 3 mL of (1+1) of nitric acid per liter should be sufficient to preserve the sample.
- 3) For determination of suspended elements, the

samples must be filtered through a 0.45 micron membrane filter as soon as soon as practical after collection. The filter is then transferred to a suitable container for storage and shipment, with no preservation required.

More detailed discussion of sources of potential variation in metals data:

The way one person collects, filters, and acidifies in the field may be different than the way another does it. Sources of potential variation include the following:

1) "As soon as practical." Different situations can change the elapsed time considered by the field collector to be "as soon as practical." It may take different amounts of time to get to a safe or otherwise optimum place to filter and acidify. In one case precipitation and other changes could be going on in the collection bottle while the bottle is on the way to filtration and acidification, while in another case the field collector filters and acidifies the samples within minutes. Weather, safety concerns, and many other factors could play a role.

2) "Normally 3 mL of (1+1) of nitric acid per liter should be sufficient to preserve the sample." Sometimes it is not, depending on alkalinity and other factors. What field collectors sometimes (often?) do is just use pop tabs of 3 mL of nitric acid and hope for the best rather than checking to see that the acidity has been lowered to below a pH of two. EPA CFR guidelines just call for a pH of below two, whereas samples meant to be "acid soluble" metals call for a pH of 1.5 to 2.0 [25]. See also, various USEPA 1984 to 1985 Ambient Water Quality Criteria Documents for individual metals.

3) One person might use triple distilled concentrated nitric acid rather than reagent grades of acid to avoid possible contamination in the acid, while another may not. When using very low detection limits, some types of acid may introduce contamination and influence the results (Pat Davies, Colorado Division of Wildlife, personal communication, 1997).

4) Holding times can strongly influence the results and there can be quite a bit of variation even within EPA recommended limits (see Silver entry for details). Holding times previously recommended for EPA for NPDES water samples of metals other than mercury or Chromium VI have been as long as 6

months (Federal Register, Volume 49, No. 209, Friday, October 28, 1984, page 43260). In the 1994 version of the CFR, NPDES holding times for mercury and Chromium VI are the same ones listed in 1984, but no EPA holding times are given for other metals (40 CFR, Part 136.3, Table 2, page 397, 1994).

Differences in the details of the method used can drastically change the results. Some cold, wet, hurried, or fire ant-bitten collectors might decide that it is not "practical" to filter and acidify quite so immediately in the field, and may decide the shore, a vehicle, a motel room, or even a remote lab are more "practical" locations. Filtering and acidifying in the field immediately is a better option for consistency (see copper entry for an example of what can happen if there is a delay). If one field filters and acidifies, one may be changing metals and colloidal content. Acidifying effects microbial changes. If one holds the samples a while before filtering and acidifying, the situation changes. In collection bottles there are potential aging effects: temperature changes, changes in basic water chemistry as oxygen and other dissolved gasses move from the water into the headspace of air at the top, potential aggregation of colloidal materials, precipitation of greater sizes with time, development of bigger and more colloids, and more sorption (Roy Irwin, NPS, personal communication, 1997).

The bottom line: since standard EPA methods for holding times and field preservations change, updates are not always convenient to obtain, since the wording is somewhat imprecise, and since field collectors may actually do different things in different situations, variation in metals concentrations may sometimes be due to differences in how individual investigators treat samples in the field and lab (Roy Irwin, National Park Service, Personal Communication, 1997).

EPA 1996 IRIS database information [893]:

No information given on lab methods.