EVALUATION OF FIELD SAMPLING AND PRESERVATION METHODS FOR STRONTIUM-90 IN GROUND WATER AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

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CONVERSION FACTORS

For readers who prefer to use International System (SI) units rather than units used in this report, the following conversion factors may be used:

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
curie (Ci)	3.70×10^{10}	becquerel
microcurie (μCi)	37.0	becquerel
picocurie (pCi)	0.037	becquerel

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

From 1952 to 1988, about 140 curies of strontium-90 have been discharged in liquid waste to disposal ponds and wells at the INEL (Idaho National Engineering Laboratory). The U.S. Geological Survey routinely samples ground water from the Snake River Plain aquifer and from discontinuous perched-water zones for selected radionuclides, major and minor ions, and chemical and physical characteristics. Water samples for strontium-90 analyses collected in the field are unfiltered and preserved to an approximate 2-percent solution with reagent-grade hydrochloric acid.

Water from four wells completed in the Snake River Plain aquifer was sampled as part of the U.S. Geological Survey's quality-assurance program to evaluate the effect of filtration and preservation methods on strontium-90 concentrations in ground water at the INEL. The wells were selected for sampling on the basis of historical concentrations of strontium-90 in ground water. Water from each well was filtered through either a 0.45- or a 0.1-micrometer membrane filter; unfiltered samples also were collected. Two sets of filtered and two sets of unfiltered water samples were collected at each well. One set of water samples was preserved in the field to an approximate 2-percent solution with reagent-grade hydrochloric acid and the other set of samples was not acidified.

Laboratory analytical results showed strontium-90 concentrations that ranged from below the reporting level to 52±4 picocuries per liter. Descriptive statistics were used to determine reproducibility between the

analytical results for strontium-90 concentrations in water from each well. Analytical results were compared to the results from unfiltered, acidified samples at each well. Water from well 88 had strontium-90 results that were not in statistical agreement between the different filtration and preservation methods. The strontium-90 concentration for water from well 88 was below the reporting level.

For water from wells with strontium-90 concentrations at or above the reporting level, 94 percent or greater of the strontium-90 was in true solution or in colloidal particles smaller than 0.1 micrometer. These results suggest that within-laboratory reproducibility for strontium-90 in ground water at the INEL is not significantly affected by changes in filtration and preservation methods used for sample collection.

INTRODUCTION

The INEL (Idaho National Engineering Laboratory) comprises about 890 mi^2 of the eastern Snake River Plain in southeastern Idaho (fig. 1). The INEL was established in 1949 and is used by the U.S. Department of Energy to test nuclear reactors. The INEL is one of the main centers in the United States for developing the peacetime use of atomic energy, nuclear-safety research, defense programs, and development of advanced energy concepts.

Aqueous chemical and radioactive wastes generated at the INEL were discharged to ponds and wells from 1952 to 1983. Since 1983, most of the aqueous wastes have been discharged to unlined infiltration ponds. Many of the waste constituents enter the aquifer indirectly following percolation through the unsaturated zone; however, some constituents--including strontium-90--may be immobilized by interaction with minerals in the unsaturated zone.

From 1952 to 1988 about 140 Ci (curies) of strontium-90 were in liquid waste disposed at the INEL. As part of a cooperative program with the U.S. Department of Energy, the U.S. Geological Survey routinely samples ground

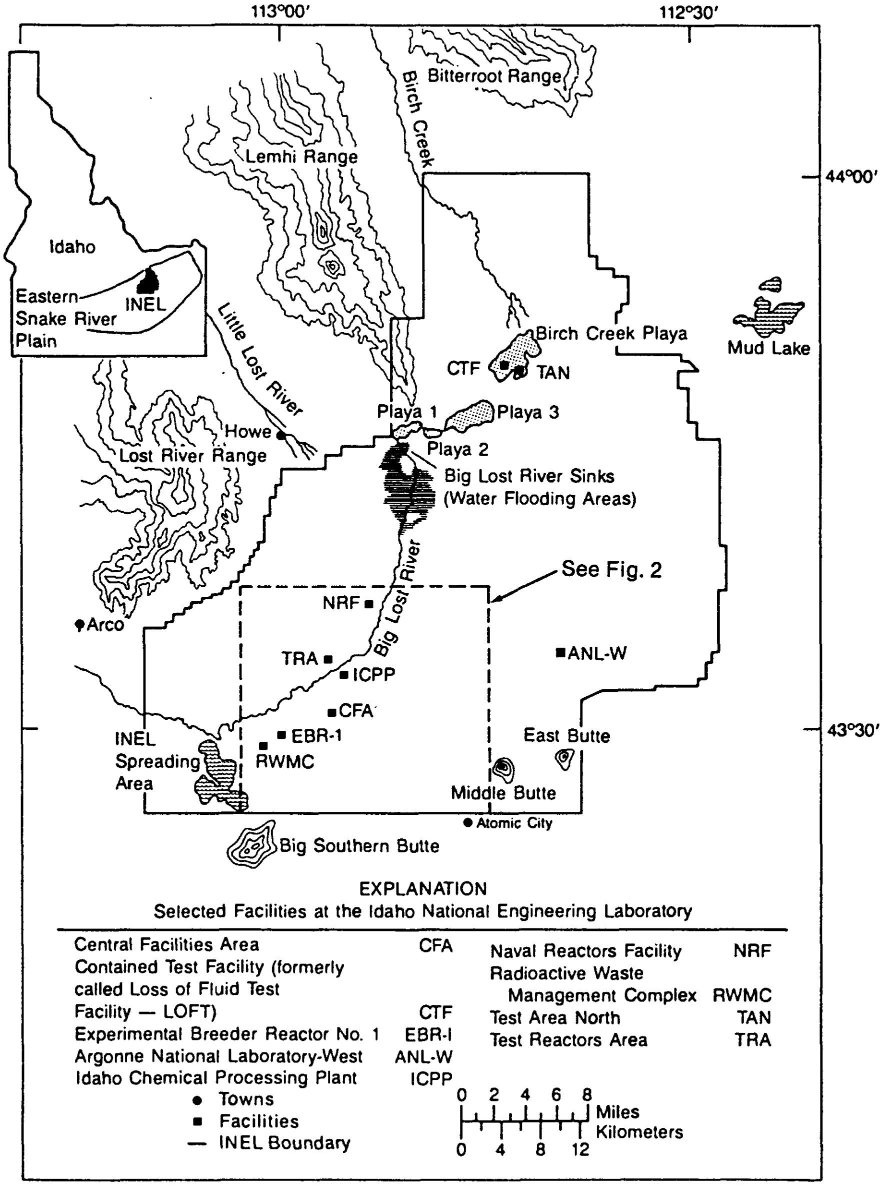

Figure 1.--Location of the Idaho National Engineering Laboratory and selected facilities.

water from 92 wells completed in the Snake River Plain aquifer and 40 wells completed in discontinuous perched-water zones at the INEL. These samples are analyzed for selected radionuclides, major and minor ions, and chemical and physical characteristics. Water samples for strontium-90 analyses are unfiltered and preserved to an approximate 2-percent solution with reagent-grade hydrochloric acid.

Purpose and Scope

As part of the U.S. Geological Survey's quality-assurance program, four wells were selected for water-sample collection and laboratory analyses for strontium-90 (fig. 2). This study was done to determine the effect of filtration and preservation methods on strontium-90 concentrations in ground water and to determine if current collection procedures minimize loss by sorption of this radionuclide on the walls of sample containers. The four wells sampled were selected on the basis of historical concentrations of strontium-90 and on the presence or absence of organic complexing agents which may influence the solubility of strontium-90.

Geohydrologic Setting

The eastern Snake River Plain is a northeast-southwest trending structural basin about 200 mi long and 50 to 70 mi wide. The plain is underlain by a layered sequence of basaltic lava flows and cinder beds intercalated with alluvium and lakebed-sedimentary deposits. Individual lava flows range from 10 to 50 ft in thickness, although the average thickness may be from 20 to 25 ft (Mundorff and others, 1964, p. 143). The sedimentary deposits consist mainly of lenticular beds of sand, silt, and clay, with lesser amounts of gravel. Locally, rhyolitic lava flows and tuffs are exposed at the land surface or occur at depth. The basaltic lava flows and intercalated sedimentary deposits combine to form the Snake River Plain aquifer. This aquifer is the main source of ground water on the plain (Mann, 1986, p. 4). The altitude--relative to sea level--of the water table for the Snake River Plain aquifer in July 1985 and July 1978 ranged from

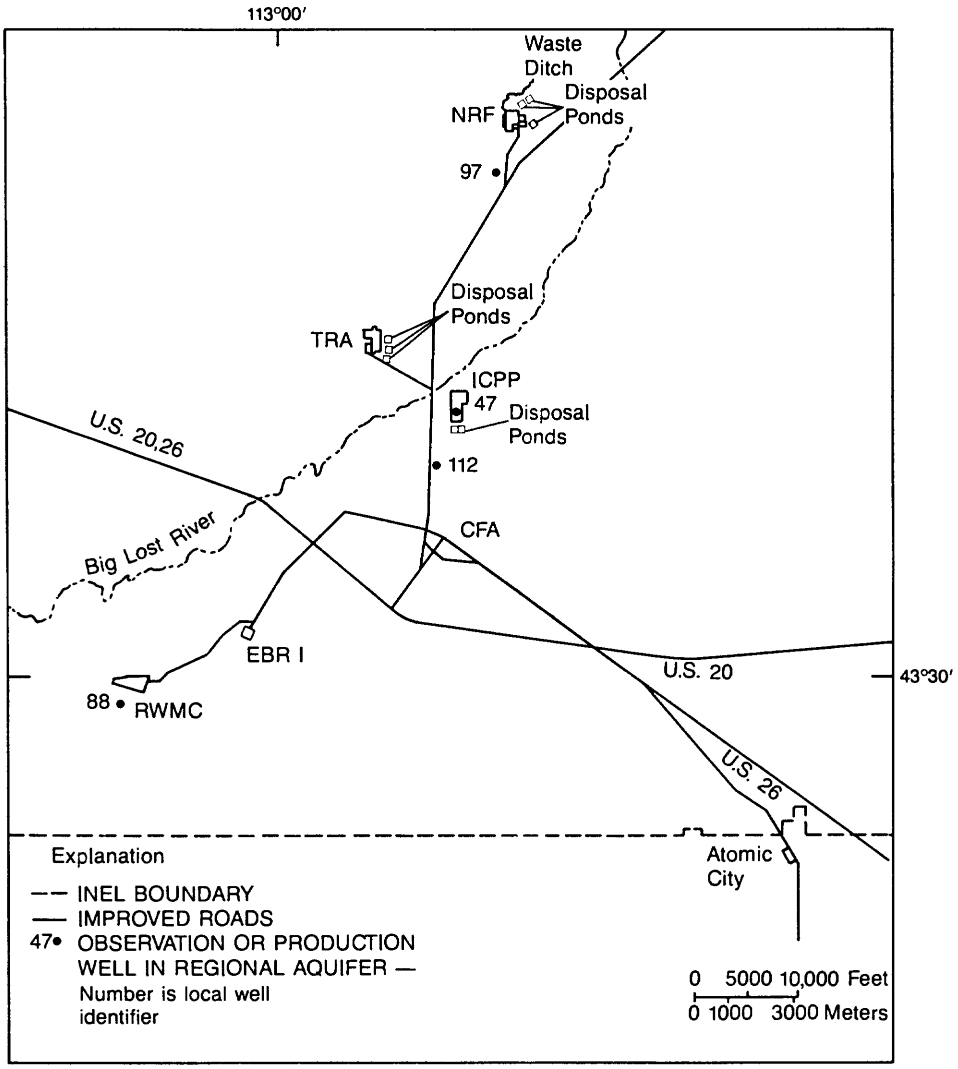

Figure 2.--Location of selected wells sampled for strontium-90.

about 4,580 ft in the northern part of the INEL, to about 4,430 ft in the southern part (Pittman and others, 1988, fig. 9; Barraclough and others, 1981, fig. 7). The corresponding depths to water below land surface ranged from about 200 ft in the northern end to as much as 1,000 ft in the southern end (Barraclough and others, 1981, fig. 8). The INEL obtains its entire water supply from the aquifer.

Much of the northern part of the INEL is contained in a topographically closed depression that includes the Big Lost River Sinks, Little Lost River Sinks, Birch Creek Sinks, the Big Lost River playas--playa 1, playa 2, and playa 3--and the Birch Creek playa. The Big Lost River, Little Lost River, and Birch Creek terminate in the Birch Creek playa (Robertson and others, 1974, p. 8)(fig. 1).

Previous Investigations

The effects of filtration and preservation on strontium-90 concentrations in ground water samples at the INEL have not been previously studied. However, the U.S. Department of Energy conducted a study on actinide concentrations in ground water at the INEL in the mid 1970's to determine: (1) if reproducible background concentrations could be determined; (2) if positive analytical results could be reproduced from a well in which small but detectable concentrations of plutonium might be present; and, (3) if reproducible results on either detectable or nondetectable concentrations could be obtained for water samples collected from the aquifer underlying the RWMC (Radioactive Waste Management Complex) (fig. 1). The results of this study were summarized by Polzer and others (1976). Five wells were sampled three times each by the U.S. Geological Survey. Ten-liter water samples collected from each of the five wells were analyzed by the RESL (Radiological and Environmental Sciences Laboratory) in a decontaminated laboratory. Special analytical procedures were used to minimize the possibility of sample contamination and to enhance detectability of small concentrations of actinides in the ground water. The analytical results indicated that mean background concentrations in ground water at the INEL could be estimated for plutonium-238, plutonium-239, -240 (undivided), and americium-241. The estimated mean background concentrations are less than 0.08×10^{-11}, 0.04×10^{-11}, and 0.10×10^{-11} μCi/mL (microcuries per milliliter), respectively. Mean concentrations of $0.65\pm0.29\times10^{-11}$ μCi/mL for plutonium-238 and $0.24\pm0.19\times10^{-11}$ μCi/mL for plutonium-239, -240 (undivided) were identified in well 47 (fig. 2).

Although Polzer and others (1976) demonstrated that small concentrations of actinides can be identified in ground water at the INEL, they did not address the question of what effect field filtration and preservation of samples had on the analytical results. Cleveland and Rees (1982) addressed this question during a study to characterize plutonium speciation in ground water near the ICPP (Idaho Chemical Processing Plant, fig. 1). They determined that the small concentrations of plutonium in ground water were statistically the same whether or not filtered sequentially through 5-, 0.4-, and 0.05-μm (micrometer) membrane filters. They attributed this to the lack of strong organic complexing agents such as EDTA (ethylenediaminetetraacetic acid) or DOC (dissolved organic carbon).

The presence of these complexing agents in elevated concentrations would prevent plutonium from precipitating out of solution or adsorbing onto exchanging substrates in the aquifer. Cleveland and Rees (1982) concluded that the lack of the organic complexing agents (EDTA and DOC) in the ground water has allowed more than 80 percent of the plutonium disposed of through the deep injection well at ICPP to be removed from solution by precipitation or sorption along the aquifer flow path between the injection well and a sampling well located 1,030 ft away. The deep injection well has not been routinely used for waste disposal since February 9, 1984 (Mann and others, 1988, p. 1).

Cleveland and Rees (1982) also concluded--because of the geochemical characteristics of the ground water at the INEL--that the plutonium in the water samples was truly in solution as the uncomplexed, perhaps hydrolyzed, tetravalent ion and that filtration does not significantly affect the analytical results. Because the effects of sampling methodology on plutonium concentrations in ground water at the INEL are well known, this study focused on how sampling methodology affects strontium-90 concentrations.

Acknowledgments

The authors gratefully acknowledge the many employees of the U.S. Department of Energy and its contractors at the INEL who aided in the sampling program. Analytical work for strontium-90 concentrations was conducted by the U.S. Department of Energy's RESL, Analytical Chemistry Branch--Don B. Martin, Chief--at the INEL. Special thanks are due to D.R. Percival of the U.S. Department of Energy for providing helpful discussions regarding project design.

SAMPLING AND PRESERVATION METHODS

The methodology used in sampling for strontium-90 generally followed the guidelines established by the U.S. Geological Survey (Thatcher and others, 1977). Some modifications were incorporated to determine the effects of changes in field-filtration and preservation procedures on strontium-90 concentrations. Six 500-mL (milliliter) polyethylene bottles were filled with water from each well. Acidified and unacidified pairs of samples were collected unfiltered, filtered through a 0.1 μm membrane filter, and filtered through a 0.45 μm membrane filter. Ten milliliters of reagent-grade hydrochloric acid were added to preserve the samples for strontium-90 analyses.

Samples were collected at four ground-water quality monitoring wells equipped with dedicated submersible pumps. For sample collection, a portable discharge line was attached at the well head. The line was 1.5 in. I.D. (inside diameter) galvanized steel pipe with a stainless steel sampling line attached at a T-joint so that excess discharge could be directed away from the sampling location. Brass valves were used at the well head and before the sampling line to aid in flow control. All pipes and fittings were rinsed with boiled, deionized water before they were attached at the well head. The lines then were flushed with sample water until the temperature, pH, and specific conductance of the water stabilized (Wood, 1981; Claassen, 1982). When these measurements stabilized, indicating probable hydraulic and chemical stability, a water sample was collected.

Conditions at the well during sample collection were recorded in a field logbook. A chain-of-custody record was used to track samples from the time of collection until delivery to the analyzing laboratory.

ANALYTICAL METHODS

The beta-counting method was used to analyze for dissolved strontium-90 in water samples after a sequential chemical separation procedure that removed other fission products that could cause interference with this technique. This method is applicable for the determination of strontium-90 artificially introduced into water by nuclear-power and waste-disposal facilities. This method may be applicable to industrial wastes if recovery tests are performed to insure that organic matter does not keep the strontium-90 in solution. The chemical separation procedure and the beta-counting method for strontium-90 concentrations were performed on all the water samples for this study as one group.

Strontium was precipitated from the sample, purified, and redissolved in nitric acid. After a 2-week ingrowth period, yttrium was precipitated from the strontium solution. The concentration of strontium-90 was determined by beta-counting its yttrium-90 daughter.

Strontium-85 tracer was added to each 400 mL water sample along with stable calcium and stable strontium carriers. After evaporation of the sample to 30-50 mL, strontium was precipitated as a carbonate. To further separate strontium from interferences, the strontium carbonate was dissolved, and strontium was reprecipitated as a nitrate using fuming nitric acid. The strontium nitrate was dissolved and any yttrium present was precipitated as yttrium hydroxide and then centrifuged. The supernatant containing the strontium was decanted into a counting bottle and gamma-counted to determine the strontium yield. After 10 mg (milligram) of stable yttrium carrier were added, the sample was stored for 2 weeks to allow yttrium-90 ingrowth.

After the ingrowth period, yttrium was removed from the sample solution again as a hydroxide. The yttrium hydroxide was dissolved and yttrium was reprecipitated as an oxalate and filtered onto a glass-fiber filter of known weight. The yttrium yield was determined gravimetrically. The yttrium oxalate was beta-counted on a low-background, gas-flow, proportional counter. The concentration of strontium-90 was determined from the yttrium-90 beta counts.

REPORTING OF STRONTIUM-90 DATA

Concentrations of strontium-90 are reported with an estimated sample standard deviation, **s**, that is obtained by propagating sources of analytical uncertainty in measurements. The following guidelines for interpreting analytical results are based on an extension of a method proposed by Currie (1984).

In the analysis for strontium-90, laboratory measurements are made on a target sample and a prepared blank. Instrument signals for the sample and the blank vary randomly. Therefore, it is essential to distinguish between two key aspects of the problem of detection: (1) the instrument signal for the sample must be greater than the signal observed for the blank to make the decision that strontium-90 was detected; and (2) an estimation must be made of the minimum strontium-90 concentration that will yield a sufficiently large observed signal to make the correct decision for detection or nondetection of strontium-90 most of the time. The first aspect of the problem is a qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an intuitive estimation of the detection capabilities of a given measurement process.

In the laboratory, instrument signals must exceed a critical level to make the qualitative decision whether strontium-90 was detected. Strontium-90 concentrations that equal 1.6**s** meet this criterion; at 1.6**s**, there is a 95 percent probability that the correct decision--not detected--will be made. Given a large number of samples, up to 5 percent of the samples with measured concentrations greater than or equal to 1.6**s**, which were concluded as being detected, might not contain strontium-90. These measurements are referred to as false positives and are errors of the first kind in hypothesis testing.

Once the critical level of 1.6**s** has been defined, the minimum detectable concentration may be determined. Strontium-90 concentrations that equal 3**s** represent a measurement at the minimum detectable concentration. For true concentrations of 3**s** or greater, there is a 95 percent or greater probability that strontium-90 was detected in a sample. Given a large number of samples, 5 percent of the samples with true concentrations equal to 3**s**, which were concluded as being non-detected, could contain strontium-90 at the minimum detectable concentration. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

True strontium-90 concentrations between 1.6**s** and 3**s** have larger errors of the second kind. That is, there is a greater than 5 percent probability of false negative results for samples with true concentrations between 1.6**s** and 3**s**. Although strontium-90 might have been detected, such detection may not be considered reliable; at 1.6**s**, the probability of a false negative is about 50 percent.

The critical level and minimum detectable concentration are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values, 1.6**s** and 3**s**, vary slightly with background or blank counts, and with the number of gross counts for individual analyses and for different selected radionuclides. In this report, if the strontium-90 concentration was less than 3**s**, the concentration was considered to be below a "reporting level". The use of the critical level, minimum detectable concentration, and reporting level aid the reader in the interpretation of analytical results and do not represent absolute concentrations of radioactivity which may or may not have been detected.

QUALITY ASSURANCE

Field quality assurance included eight blind replicates--samples collected at the same time and sent to the same laboratory with different identifiers--from well 112 (fig. 2) and a blank sample consisting of boiled deionized water. Six of the blind replicates were analyzed for strontium-90 concentrations by the RESL (table 1) (all tables are located at the end of this report). One set of three samples was acidified and another set was unacidified. Each set of samples contained an unfiltered sample and two samples filtered with either a 0.1- or a 0.45-μm filter. No statistical differences were identified between sets of blind replicates (table 2), between the blind replicate sample from well 112 and the blind replicates for the alternative sampling methods (table 3), or between primary samples and their blind replicates (table 4).

A blind replicate and a blank sample were analyzed for 36 purgeable organic compounds by the U.S. Geological Survey's NWQL (National Water Quality Laboratory) in Arvada, Colorado using U.S. Environmental Protection Agency Method 524. The results of the analyses are shown in table 5. The analytical results of the blind replicate and primary samples for well 112 (table 5) were essentially the same. The blank sample was free of purgeable organic compounds except for 0.2 μg/L (micrograms per liter) of toluene, which is defined by the NWQL as the reporting level of the analytical method.

Another blind replicate for well 112 was submitted to the NWQL for analysis of DOC. The primary and replicate samples had identical DOC concentrations--0.4 mg/L.

PRECISION OF ANALYTICAL RESULTS

Statistical comparisons of strontium-90 concentrations for each well were made between analytical results for filtered and unfiltered samples, and for acidified and unacidified samples. Statistical summaries of the reproducibility of analytical results for strontium-90 in ground water are given in tables 2-4.

Comparisons of analytical results were made to unfiltered, acidified samples for each well using the following equation:

$$R = \frac{x}{y} \qquad (1)$$

where R = ratio of analytical results,
x = filtration and preservation method to be compared with the unfiltered, acidified method, and
y = unfiltered, acidified method

The within-laboratory reproducibility of analytical results was determined in part by the use of the following equation:

$$S_R = R\,[(S_x)^2 + (S_y)^2]^{0.5}, \qquad (2)$$

where S_R = uncertainty in the comparison of the analytical results,
S_x = reported uncertainty as a decimal fraction of the analytical result for filtration and preservation method to be compared with the unfiltered, acidified method, and
S_y = reported uncertainty as a decimal fraction of the analytical result for the unfiltered, acidified method.

If $R \pm 2S_R$ includes 1.0, there is about a 95-percent probability that the analytical results are statistically the same. If $R \pm 2S_R$ does not include 1.0, there is about a 95-percent probability that the analytical results are not statistically the same. These calculations determine reproducibility of the analytical results for the different filtration and preservation methods compared with the unfiltered, acidified collection method used at the INEL since 1980.

Concentrations of strontium-90 in ground water ranged from below the reporting level to 52±4 pCi/L (picocuries per liter). With the exception of the analytical results for water from well 88, all results were in statistical agreement regardless of the filtration and preservation method used during sample collection. The analytical results of the acidified water sample for well 88, filtered through a 0.45 μm membrane filter, were not in statistical agreement with the results for the unfiltered and acidified sampling method (table 3). The strontium-90 concentration for water from well 88, -2.9±1.4 pCi/L, was less than the reporting level. At these small concentrations, the lack of reproducibility between analytical results is due primarily to uncertainties inherent in any attempt to measure the count rate of a random process such as radioactive decay. The results of the statistical comparisons also suggest that within-laboratory reproducibility at the INEL for strontium-90 concentrations in ground water is not significantly affected by the filtration and preservation methods used.

In water from well 47, 94 percent of the strontium-90 detected was in true solution or present in colloidal particles smaller than 0.1 μm. In water from well 112, 98 percent of the strontium-90 detected was in true solution or present in colloidal particles smaller than 0.1 μm. Concentrations of strontium-90 in water from wells 97 and 88 were less than the reporting level.

At the Eh-pH conditions in the Snake River Plain aquifer as indicated by the dissolved oxygen and pH data in table 6, strontium sulfate and strontium carbonate should be the predominant phases. These strontium phases are insoluble at these conditions (Brookins, 1988, p 166-167). Additionally, the absence of strong-organic complexing agents (tables 5 and 6, and Cleveland and Rees, 1982) should increase the possibility of precipitation of strontium from solution or the adsorption of strontium onto exchanging substrates. However, the elevated concentrations of strontium-90 in water from wells 47 and 112--52±3 and 44±3 pCi/L, respectively--suggest that other geochemical processes, such as cation exchange reactions, may control the solubility and mobility of strontium in ground water at the INEL.

CONCLUSIONS

Laboratory analytical results for strontium-90 in ground water from the Snake River Plain aquifer at the INEL are not measurably affected by the filtration and preservation method used in the field during sample collection. The descriptive statistics presented here suggest that reproducibility increases with increasing strontium-90 concentrations. On the basis of the results of this study and the results presented by Cleveland and Rees

(1982), it is not necessary to filter or preserve water samples for strontium-90 or plutonium analyses during field collection at the INEL. However, field preservation with reagent-grade hydrochloric acid should be continued to ensure that these radionuclides remain in solution during transportation and storage prior to analysis.

REFERENCES CITED

Barraclough, J.T., Lewis, B.D., and Jensen, R.G., 1981, Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho, Emphasis: 1974-1978: U.S. Geological Survey Water Resources Investigations Open-File Report 81-526 (IDO-22060), 77 p.

Brookins, D.G., 1988, Eh-pH diagrams for geochemistry: Springer-Verlag, New York, 176 p.

Claassen, H.D., 1982, Guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer: U.S. Geological Survey Open-File Report 82-1024, 49 p.

Cleveland, J.M., and Rees, T.F., 1982, Characterization of plutonium in ground water near the Idaho Chemical Processing Plant: Environmental Science and Technology, v. 16, no. 7, p. 437-439.

Currie, L.A., 1984, Lower limit of detection: definition and elaboration of a proposed position for radiological effluent and environmental measurements: U.S. Nuclear Regulatory Commission, NUREG/CR-4007, 139 p.

Mann, L.J., 1986, Hydraulic properties of rock units and chemical quality of water for INEL-1--a 10,365-foot deep test hole drilled at the Idaho National Engineering Laboratory, Idaho, Water Resources Investigative Report 86-4020 (IDO-22070), 23 p.

Mann, L.J., Chew, E.W., Morton, J.S., and Randolph, R.B., 1988, Iodine-129 in the Snake River Plain aquifer at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 88-4165 (DOE/ID-22076), 27 p.

Mundorff, M.J., Crosthwaite, E.G., and Kilburn, Chabot, 1964, Ground water for irrigation in the Snake River Basin in Idaho: U.S. Geological Survey Water-Supply Paper 1654, 224 p.

Pittman, J.R., Jensen, R.G., and Fischer, P.R., 1988, Hydrologic conditions at the Idaho National Engineering Laboratory, 1982-1985: U.S. Geological Survey Water-Resources Investigations Report 89-4008 (DOE/ID-22078), 73 p.

Polzer, W.L, Percival, D.R., and Barraclough, J.T., 1976, Special analyses for plutonium and americium in water from the Snake River Plain aquifer: U.S. Department of Energy, Idaho Operations Office Publication IDO-12081, 9 p.

Robertson, J.B., Schoen, Robert, and Barraclough, J.T., 1974, The influence of liquid waste disposal on the geochemistry of water at the National Reactor Testing Station, Idaho: U.S. Geological Survey Open-File Report (IDO-22053), 231 p.

Thatcher, L.L., Janzer, V.J., and Edwards, K.W., 1977, Methods for determination of radioactive substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chap. A5, 95 p.

Wood, W.W., 1976, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 1, Chap. D2, 24 p. (Reprinted 1981).

Table 1.--Strontium-90 concentrations and associated analytical uncertainties in ground water from selected wells at the Idaho National Engineering Laboratory, Idaho

[Analyses by U.S. Department of Energy's Radiological and Environmental Sciences Laboratory. Analytical results and associated uncertainties are in pCi/L (picocuries per liter). Well identifer: location is shown on figure 2; blind replicate indicates a duplicate sample was collected. Type of filtration: entries, 0.1 and 0.45, indicate that a 0.1 or 0.45 micrometer membrane filter was used to filter the sample. Remarks: QA indicates quality assurance]

Well identifier	Date sampled	Type of filtration	Acidified sample	Unacidified sample	Remarks
47	9/30/88	Unfiltered	52±3	48±3	
		0.1	49±3	49±3	
		0.45	51±4	52±4	
88	9/29/88	Unfiltered	-2.9±1.4	-1.3±1.5	
		0.1	-0.4±1.4	-0.1±1.5	
		0.45	1.1±1.5	-0.4±1.4	
97	9/26/88	Unfiltered	-2.1±1.6	-2.9±1.6	
		0.1	-3±2	-2.8±1.6	
		0.45	-1.5±1.7	-2.4±1.6	
112	9/28/88	Unfiltered	44±3	36±3	
Blind replicate		Unfiltered	43±3	42±3	QA sample
112		0.1	43±3	42±3	
Blind replicate		0.1	42±3	42±3	QA sample
112		0.45	45±3	41±3	
Blind replicate		0.45	39±3	42±3	QA sample

Table 2.--Statistical comparison of strontium-90 concentrations and associated analytical uncertainties in acidified and unacidified samples of ground water from selected wells, Idaho National Engineering Laboratory, Idaho

[Analytical results and associated uncertainties are in pCi/L (picocuries per liter). Well identifier: location is shown on figure 2. Type of filtration: entries, 0.1 and 0.45, indicate that a 0.1 or 0.45 micrometer membrane filter was used to filter the sample.]

Well identifier	Date sampled	Type of filtration	Strontium-90 concentration in acidified sample	Uncertainty of acidified sample	Strontium-90 concentration in unacidified sample
47	9/30/88	unfiltered	52	3	48
		0.1	49	3	49
		0.45	51	4	52
88	9/29/88	unfiltered	-2.9	1.4	-1.3
		0.1	-0.4	1.4	-0.1
		0.45	1.1	1.5	-0.4
97	9/26/88	unfiltered	-2.1	1.6	-2.9
		0.1	-3.0	2.0	-2.8
		0.45	-1.5	1.7	-2.4
112	9/28/88	unfiltered	44	3	36
Blind replicate		unfiltered	43	3	42
112		0.1	43	3	42
Blind replicate		0.1	42	3	42
112		0.45	45	3	41
Blind replicate		0.45	39	3	42

---

[1] $R = x/y$ where R is the ratio of the concentrations of the unacidified sample (x) to the acidified sample (y).

[2] $S_R = R[(S_x)^2+(S_y)^2]^{0.5}$, where R is defined above, S_x is the reported uncertainty as a decimal fraction of the analytical result for the unacidified sample, and S_y is the reported uncertainty as a decimal fraction of the analytical result for the acidified sample.

[3] The statistical test for reproducibility is met if $R-2S_R<1.0<R+2S_R$.

Table 2.--Statistical comparison of strontium-90 concentrations and associated analytical uncertainties in acidified and unacidified samples of ground water from selected wells, Idaho National Engineering Laboratory, Idaho--Continued

Uncertainty of unacidified sample	R[1]	S_R[2]	$R+2S_R$	$R-2S_R$	Meets statistical test for reproducibility[3]
3	0.9	0.1	1.1	0.7	yes
3	1.0	0.1	1.2	0.8	yes
4	1.0	0.1	1.2	0.8	yes
1.5	0.4	0.6	1.6	-0.8	yes
1.5	0.3	3.9	4.2	-7.5	yes
1.4	-0.4	1.4	2.4	-3.2	yes
1.6	1.4	1.3	4.0	-1.2	yes
1.6	0.0	0.8	2.5	-0.7	yes
1.6	1.6	2.1	5.8	-2.6	yes
3	0.8	0.1	1.0	0.6	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	0.9	0.1	1.1	0.7	yes
3	1.1	0.1	1.3	0.9	yes

Table 3.--Statistical comparison of the unfiltered and acidified sample collection method to the alternative sampling methods at the Idaho National Engineering Laboratory, Idaho

[Analytical results and associated uncertainties are in pCi/L (picocuries per liter). Well identifier: location is shown on figure 2; blind replicate indicates duplicate samples from well 112. Comparison sample type: RU indicates sample is unfiltered and unacidified. (continued on next page)

Well identifier	Date sampled	Comparison sample type	Strontium-90 concentration of unfiltered and acidified sample	Uncertainty of unfiltered and acidified sample	Strontium-90 concentration of comparison sample
47	9/30/88	RU	52	3	48
		FU(0.1)			49
		FU(0.45)			52
		FA(0.1)			49
		FA(0.45)			51
88	9/29/88	RU	-2.9	1.4	-1.3
		FU(0.1)			-0.1
		FU(0.45)			-0.4
		FA(0.1)			-0.4
		FA(0.45)			1.1
97	9/26/88	RU	-2.1	1.6	-2.9
		FU(0.1)			-2.8
		FU(0.45)			-2.4
		FA(0.1)			-3
		FA(0.45)			-1.5
112	9/28/88	RU	44	3	36
		FU(0.1)			42
		FU(0.45)			41
		FA(0.1)			43
		FA(0.45)			45
Blind replicate	9/28/88	RU	43	3	42
		FU(0.1)			42
		FU(0.45)			42
		FA(0.1)			42
		FA(0.45)			39

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[1] R = x/y where R is the ratio of the concentrations of the comparison sample (x) to the unfiltered, acidified sample (y).

[2] $S_R = R[(S_x)^2+(S_y)^2]^{0.5}$, where R is defined above, S_x is the reported uncertainty as a decimal fraction of the analytical result for filtration and preservation method to be compared to the unfiltered, acidified sample, and S_y is the reported uncertainty as a decimal fraction of the analytical result for the unfiltered, acidified sample.

[3] The statistical test for reproducibility is met if $R-2S_R<1.0<R+2S_R$.

Table 3.--Statistical comparison of the unfiltered and acidified sample collection method to the alternative sampling methods at the Idaho National Engineering Laboratory, Idaho--Continued

FA(0.1) indicates sample is filtered and acidified, number in parentheses is the size of openings in the membrane filter (in micrometers); FU(0.1) indicates sample is filtered and unacidified, number in parentheses is the size of openings in the membrane filter (in micrometers).]

Uncertainty of comparison sample	R[1]	S_R[2]	$R+2S_R$	$R-2S_R$	Meets statistical test for reproducibility[3]
3	0.9	0.1	1.1	0.7	yes
3	0.9	0.1	1.1	0.7	yes
4	1.0	0.1	1.1	0.7	yes
3	0.9	0.1	1.1	0.7	yes
4	1.0	0.1	1.2	0.8	yes
1.5	0.4	0.6	1.6	-0.8	yes
1.5	0.0	0.5	1.0	-1.0	yes
1.4	0.1	0.5	1.1	-0.9	yes
1.4	0.1	0.5	1.1	-0.9	yes
1.5	-0.4	0.5	0.6	-1.4	no
1.6	1.4	1.3	4.0	-1.2	yes
1.6	1.3	1.3	2.6	-1.3	yes
1.6	1.1	1.2	3.5	-1.3	yes
2	1.4	1.4	4.2	-1.4	yes
1.7	0.7	1.0	2.7	-1.3	yes
3	0.8	0.1	1.0	0.6	yes
3	1.0	0.1	1.2	0.8	yes
3	0.9	0.1	1.1	0.7	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	1.0	0.1	1.2	0.8	yes
3	0.9	0.1	1.1	0.7	yes

Table 4.--Statistical comparison of strontium-90 concentrations and associated analytical uncertainties in quality assurance samples from well 112, Idaho National Engineering Laboratory, Idaho

[Analytical results and associated uncertainties are in pCi/L (picocuries per liter). Well identifier: location is shown on figure 2. Sample type: RA indicates sample is unfiltered and acidified; RU indicates sample is unfiltered and unacidified; FA(0.1) indicates sample is filtered and acidified, number in parentheses is the size of openings in the membrane filter (in micrometers); FU(0.45) indicates sample is filtered and unacidified, number in parentheses is the size of openings in the membrane filter (in micrometers).]

Well identifier	Date sampled	Sample type	Primary sample	Uncertainty of primary sample	Blind replicate	Uncertainty of blind replicate	R[1]	S_R[2]	$R+2S_R$	$R-2S_R$	Meets statistical test for reproducibility[3]
112	9/28/88	RA	44	3	43	3	1.0	0.1	1.2	0.8	yes
		RU	36	3	42	3	1.2	0.1	1.4	1.0	yes
		FA(0.1)	43	3	42	3	1.0	0.1	1.2	0.8	yes
		FU(0.1)	42	3	42	3	1.0	0.1	1.2	0.8	yes
		FA(0.45)	45	3	39	3	0.9	0.1	1.1	0.7	yes
		FU(0.45)	41	3	42	3	1.0	0.1	1.2	0.8	yes

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[1] R = x/y where R is the ratio of the concentrations of the blind replicate (x) to the primary sample (y).

[2] $S_R = R[(S_x)^2+(S_y)^2]^{0.5}$, where R is defined above, S_x is the reported uncertainty as a decimal fraction of the analytical result for the blind replicate, and S_y is the reported uncertainty as a decimal fraction of the analytical result for the primary sample.

[3] The statistical test for reproducibility is met if $R-2S_R<1.0<R+2S_R$.

Table 5.--Concentrations of purgeable organic compounds in ground water from selected wells, Idaho National Engineering Laboratory, Idaho

	Well identifier[1]					
Compound[2]	47	88	97	112	Blind replicate[3]	Blank sample[4]
Date sampled	9/30/88	9/29/88	9/26/88	9/28/88	9/28/88	10/03/88
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbon tetrachloride	<0.2	1.9	<0.2	<0.2	<0.2	<0.2
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2-Chloroethyl vinyl ether	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	0.4	<0.2	<0.2	<0.2	<0.2
Chloromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cis-1,3-Dichloropropene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dibromochloromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dibromoethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,3-Dichlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,4-Dichlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorobromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	0.2	<0.2	<0.2	<0.2	<0.2
1,1-Dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,3-Dichloropropene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Methyl bromide	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Methylene chloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,2,2-Tetrachloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
1,2-trans-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trans-1,3-Dichloropropene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	<0.2	0.4	<0.2	0.6	0.7	<0.2
1,1,2-Trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	0.9	<0.2	<0.2	<0.2	<0.2
Trichlorofluoromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Vinyl chloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Xylenes, mixed	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

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[1] See figure 2 for location of wells.

[2] Analyses by U.S. Geological Survey's National Water Quality Laboratory using U.S. Environmental Protection Agency Method 524. Analytical results are in micrograms per liter; < indicates that the reported value is less than the specified detection limit.

[3] Quality assurance sample, replicate of well 112.

[4] Quality assurance sample, blank sample containing boiled, deionized water.

Table 6.--Chemical analyses and physical characteristics of water samples from selected wells, Idaho National Engineering Laboratory, Idaho

Constituent or physical characteristic[1]	Well identifer[2]				
	47	88	97	112	Blind replicate[3]
Date	9/30/88	9/29/88	9/26/88	9/28/88	9/28/88
Time	1230	1005	1300	1050	1050
Temperature, °C[4]	15.0	14.0	12.5	14.0	14.0
Specific conductance, field[5]	455	595	560	770	770
Specific conductance, laboratory[5]	461	609	566	782	781
Sodium adsorption ratio	0.4	2	0.4	1	1
Sodium percent	11	37	11	31	32
Solids, sum of constituents, dissolved	267	348	327	418	419
Hardness, total (as $CaCO_3$)	210	170	260	250	250
pH, field, units[6]	7.99	8.28	7.93	7.85	7.85
pH, laboratory, units[6]	8.00	8.10	8.00	7.90	7.90
Alkalinity (as $CaCO_3$),dissolved[4]	175	88	216	148	148
Alkalinity (as $CaCO_3$),dissolved, laboratory	174	90	216	137	137
Calcium, dissolved	58	32	68	69	69
Magnesium, dissolved	16	23	23	19	19
Potassium, dissolved	2.0	7.0	2.1	4.2	4.2
Sodium, dissolved	12	48	15	52	53
Strontium, dissolved[7]	270	190	280	400	400
Sulfate, dissolved	29	65	39	38	38
Chloride, dissolved	23	91	28	130	130
Fluoride, dissolved	0.2	0.3	0.2	0.2	0.2
Silica, dissolved	22	27	22	23	23
Nitrite, dissolved (as N)	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrite + nitrate, dissolved (as N)	1.40	1.70	1.80	5.00	5.00
Phosphorus, ortho, dissolved (as P)	0.021	<0.010	0.010	0.021	0.010
Carbon, organic, dissolved	0.4	0.9	0.6	0.4	0.4
Oxygen, dissolved[8]	8.6	8.9	9.2	9.3	9.3
Aluminum, dissolved[7]	<10	<10	<10	<10	<10
Bromide, dissolved	0.047	0.25	0.065	0.052	0.050
Chromium, hexavalent[7]	4	21	5	6	6
Chromium, total[7]	7	56	8	8	9
Iron, dissolved[7]	7	39	9	6	8
Lead, dissolved[7]	<5	<5	<5	<5	<5
Manganese, dissolved[7]	<1	14	<1	<1	<1
Mercury, dissolved[7]	0.5	<0.1	<0.1	0.3	0.3

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[1] Analyses by U.S. Geological Survey's National Water Quality Laboratory. Results are in milligrams per liter unless otherwise indicated; < indicates that the reported value is less than the specified detection limit.

[2] See figure 2 for location of wells.

[3] Quality assurance sample, duplicate of well 112.

[4] Field measurement.

[5] Microsiemens per centimeter at 25° Celsius.

[6] Negative base-10 logarithm of hydrogen ion activity in moles per liter.

[7] Micrograms per liter. One milligram equals 1,000 micrograms.

[8] Field measurement using Winkler titration.