

A RAPID METHOD FOR DETERMINING ^{89}Sr AND ^{90}Sr FROM NUCLEAR ACCIDENTS

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ABSTRACT. An accident in a nuclear facility can result in a release of radioactive isotopes, such as ^{89}Sr and ^{90}Sr , the latter of which cause long-term environmental contamination and a major health hazard. To assess the radiation dose to the public and to mitigate the radiation burden, one must determine the isotopic concentration of environmental samples as quickly as possible. We describe here a method for measuring ^{89}Sr and ^{90}Sr in less than a day using liquid scintillation spectrometry. After radiochemical separation of the strontium isotopes from the sample and interfering nuclides, the precipitated solid strontium carbonate is mixed directly with a cocktail and measured spectrometrically. Chemical yield is determined gravimetrically; a simple program computes the results. We also discuss the influence of type and volume of cocktails and of type and mass of precipitate on the reproducibility of the results and on the detection limits.

INTRODUCTION

In the event of an accident in a nuclear facility, the radioactive isotopes, ^{89}Sr and ^{90}Sr , can be released to the environment. The activity of ^{89}Sr can be up to 20 times greater than that of ^{90}Sr , which is a long-lived isotope. It is a source for long-term environmental contamination and a major health hazard. To assess the radiation dose to the public and to mitigate the radiation burden, one must determine the isotopic concentration of environmental samples as quickly as possible.

The usual method is to separate the strontium isotopes from the daughter nuclide, yttrium, measure the total activity of both Sr isotopes and determine the activity of ^{90}Sr from the increase of the total count rate or from the activity of the separated yttrium after *ca.* 1 week; this is not quickly done. Thus, for example, Tait and Wichen (1989) or Winkelmann and Gesewsky (1988) used liquid scintillation spectrometry (LSS) to determine Sr isotopes independently. The Sr is separated radiochemically from the sample matrix and from interfering elements as a precipitated compound, then is dissolved and mixed with a scintillation cocktail for radiometric measurement. Earlier techniques required at least 1 h sample storage time for chemiluminescence decay before beta counting. The method we developed counts the precipitate directly, without Cab-O-Sil® suspension (Piltingsrud & Stengel 1972).

METHODS AND RESULTS

We placed up to 0.7 g of a Sr compound and between 0.2–0.5 ml of scintillation cocktail into a scintillation vial and measured it for 60 min. The first experiments demonstrated that LSS reproducibility for Sr carbonate was much better than for Sr sulfate. Of the scintillation cocktails that were used, QUICKSZINT 501 gave better results than QUICKSZINT 701 or 400, with QUICKSAFE N the most unsuitable. We prefer plastic vials to glass vials because they have a slightly higher efficiency and a lower background rate, especially at higher energies (Fig. 1). At least 2 ml of cocktail is optimal, because smaller volumes suppress the higher-energy parts of the spectra (Fig. 2). The mass of the Sr compound had minor influence on the efficiency; thus, we chose 0.2 g of Sr carbonate, which is obtainable from nearly all samples and can be weighed precisely.

Figure 3 shows spectra of ^{89}Sr , ^{90}Sr and ^{90}Y , each with an activity of 10 Bq measured in a Packard Tri-Carb® 2250CA. Samples consisted of 0.2 g Sr carbonate and 2 ml QUICKSZINT 501. Windows A, channels 20–200, and B, channels 200–1000, were selected to optimize the reduction of background count rate and the determination of ^{90}Sr activity at an excess of ^{89}Sr activity. We produced 20 artificial samples with the same activity of ^{89}Sr and ^{90}Sr each and measured them for

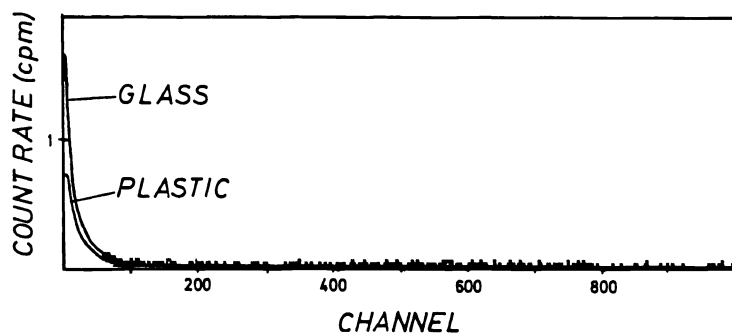


Fig. 1. Background spectra of glass and plastic vials

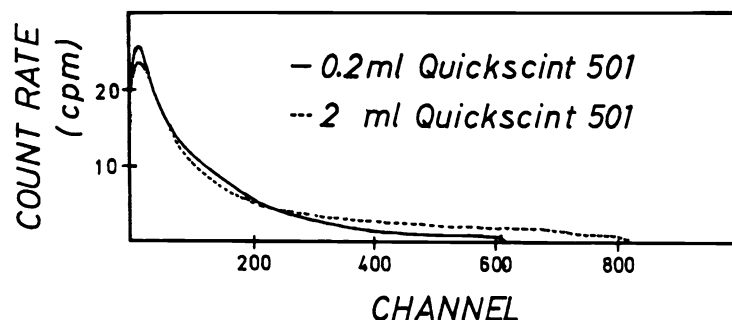


Fig. 2. Spectra of ^{89}Sr with 0.2 and 2 ml QUICKSZINT 501

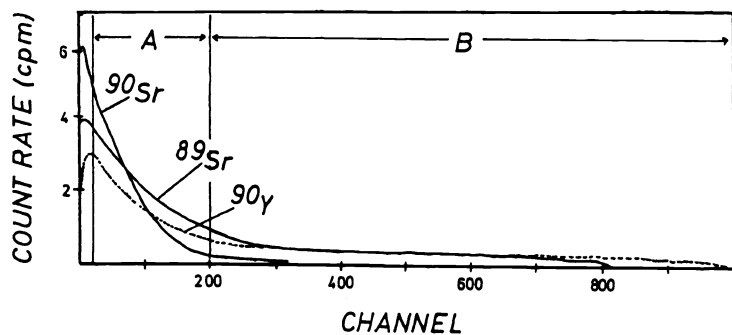


Fig. 3. Spectra of ^{89}Sr , ^{90}Sr and ^{90}Y with similar activity

60 min. The measured efficiency of ^{90}Sr in window A was 0.72 ± 0.01 and the efficiency of ^{89}Sr in window B was 0.32 ± 0.01 . The ratio of the efficiencies of ^{89}Sr in windows A and B was 1.94 ± 0.05 . Table 1 shows the calculated detection limits for various activities of Sr isotopes.

Figure 4 shows our procedure for radiochemical separation. The chemical yield is determined gravimetrically. After separation, the Sr carbonate that contains no Y is dried for *ca.* 15 min; 0.2 g is mixed with 2 ml QUICKSZINT 501 in a plastic vial and is immediately measured for 60 min. The count rates in windows A and B are taken, and, by employing a simple, in-house computer program, the corresponding background count rates are subtracted. The activities of ^{89}Sr and ^{90}Sr are calculated using the above-mentioned efficiencies.

TABLE 1. Calculated Lower Detection Limits of Sr as a Function of Activity*

Activity (Bq)		Lower detection limit (Bq)	
⁸⁹ Sr	⁹⁰ Sr	⁸⁹ Sr	⁹⁰ Sr
0.1	0	--	0.1
1	0	--	0.3
10	0	--	1
100	0	--	3
0	0.1	0.03	--
0	1	0.1	--
0	10	0.3	--
0	100	1	--

*Measurement time = 60 min

SAMPLE PRETREATMENT

Aerosol filter	Vegetation sample	Soil sample	Water
Leaching with HCl for 2 h	Ashing at 600°C for 4 hours Digest with HCl for 2 h	Ashing at 600°C for 6-8 hours Digest with HCl for 4 h	Precipitate as sulfate

SEPARATION

Add 5-50 g ammonium sulfate
Wait ca. 15 min

Precipitation as strontium sulfate

Adjust pH > 7
Add 3 g Na₂CO₃
Heat for 30 min and stir

Precipitation as strontium carbonate

Dissolve with minimum amount of HCl
Add 150 ml concentrated HNO₃
Cool to less than 5°C

Precipitation as strontium nitrate

Dissolve with 60 ml H₂O
Remove interfering trace elements by coprecipitation with iron hydroxide
Add ammonium acetate
Precipitate barium as barium chromate
Add 10 mg yttrium-carrier
Add 1g ammonium carbamate
Adjust to pH 11

Precipitation as strontium carbonate

Filter and weigh strontium carbonate

Fig. 4. Radiochemical separation procedure for Sr

TABLE 2. Comparison of True and Measured Activity and Calculated Errors*

Spike activity (Bq)		Measured activity (Bq)		Calculated error (%)	
⁸⁹ Sr	⁹⁰ Sr	⁸⁹ Sr	⁹⁰ Sr	⁸⁹ Sr	⁹⁰ Sr
0	0.9	0.1	1	--	11
5	0.9	5.1	0.8	2	11
10	0.9	9.8	0.7	2	22
50	0.9	50	--	0	--
0	9	0.1	9.5	--	6
5	9	4.9	8.3	2	8
10	9	12	9.4	20	4
25	9	26	7.8	4	13
50	9	52	6.3	4	30
250	9	270	--	8	--

*Measurement time = 60 min

We applied this method to a set of artificial samples containing ⁸⁹Sr and ⁹⁰Sr, as well as to soil samples taken from the surroundings of Chernobyl. Table 2 shows the true and measured activities of the spiked samples and the calculated errors. The lower detection limit of the ⁸⁹Sr and ⁹⁰Sr activity depended on the ratio of the activities of both isotopes, and was as low as 0.1 Bq.

CONCLUSION

Using our method of measuring precipitated solid Sr carbonate directly in scintillation cocktails by LSS immediately after separation, we can measure the activities of ⁸⁹Sr and ⁹⁰Sr in *ca.* 8 h, excluding the drying of soil and vegetation samples. The lower detection limit of both isotopes is ~0.1 Bq and depends on the activity of the other isotope. The method is faster than other procedures and consumes less scintillation cocktail.

REFERENCES

- Piltingsrud, H. V. and Stengel, J. R. 1972 Determination of ⁹⁰Y, ⁹⁰Sr and ⁸⁹Sr in samples by use of liquid scintillation beta spectroscopy. *Health Physics* 23: 121-122.
- Tait, D. and Wiechen, A. 1989 A fast method for isolating Sr radioisotopes from raw milk. *Milchwissenschaft* 44(12): 765-768.
- Winkelmann, I. and Gesewsky, P. 1988 Sachlicher Bericht zum Forschungsvorhaben, Entwicklung und praktischer Einsatz von Schnellmethoden zum Nachweis unfallbedingter Umweltkontaminationen. *Bericht des Institutes für Strahlenhygiene ABE-290.*