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Cherenkov radiation technique for the determination of fission product ^{90}Sr in milk

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ABSTRACT

Monitoring of the anthropogenic radionuclides (^{90}Sr, ^{135}Cs and ^{137}Cs) in different components such as spinach, milk, meat, soil and the grass is important for the environmental radiological survey. Nuclear weapons testing in the atmosphere, nuclear power plant accidents and leaks from the nuclear fuel cycle are the main sources of these radionuclides. The amounts of ^{90}Sr/^{90}Y detected in the environment are mostly due to fallout from nuclear weapons testing. Because of its long physical (28.5 years) and biological half-lives (approximately 12 years) and high fission yield, the measurement of ^{90}Sr is also necessary for radiation protection purposes. It accumulates in bone tissue when ingested by humans through the food chain, and ^{90}Y, a daughter nuclide of ^{90}Sr, emits high-energy beta particles, raising the risk of bone cancer. Strontium has been widely measured in milk samples by using various classical methods. In this study, the procedure we used is based on the separation of ^{90}Y by HDEHP extraction and counting the Cherenkov radiation using a liquid scintillation spectrometer, Quantulus 1220. Prior to analyses, spiked milk samples were dried and prepared as milk powder. The microwave ashing programme was optimised, and recovery of the radiochemical separation steps was tested for spiked milk powder samples before routine analysis. This method is found to be applicable for the routine analysis of ^{90}Sr in milk samples after validation of the method by measuring IRMM milk powder samples, too. A lower limit of detection of about 0.02 Bq.kg^{-1} was obtained for samples in the case of 84–99% Y chemical yield, 1.45 cpm reagent blank, 4 × 60 minutes counting time and about 83.5 ± 2.1% counting efficiency.

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Cherenkov counting; microwave ashing; ^{90}Sr; milk

1. Introduction

In many countries around the world, milk is an important food product, especially for children and babies. It includes several macro- and micronutrients such as proteins, lipids, vitamins and enzymes [1]. As a result, milk quality must be tightly controlled. Contaminants such as chemical, biological and radiological are important environmental concerns that require ongoing monitoring and assessment to protect people and the environment from toxicity and radiation risks [2,3].

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^{90}Sr is one of the most long-lived components of radioactive fallout from the nuclear power plant [4]. The presence of ^{90}Sr in the biosphere creates a long-term threat due to its chemical similarities to calcium and its longer biological half-life. When radioactive strontium is discharged into the environment as a result of nuclear power plant accidents, it can then enter the human body through a chain of events, including soil to plant, cow's milk and finally people. Effective ^{90}Sr monitoring procedures in water and food samples are therefore essential, both for routine monitoring at nuclear sites and in the event of a radiological disaster [5].

Radiostrontium transmission from the environment to humans is monitored using milk and milk powder [6]. When ^{90}Sr is ingested or inhaled, the body processes it similar to calcium, and approximately 20–30% of total ingested ^{90}Sr accumulates in the bones and teeth. It decays into ^{90}Y, a β-emitter in equilibrium with ^{90}Sr that raises the risk of cancer, especially bone cancer and leukaemia.

In this sense, it is reasonable to assume that the accuracy and reliability of the overall process will be directly related to the quality of the data used. Since the radionuclide activity is an important parameter for predicting the radiation exposure, the reliability of calculated activities of target radionuclides will affect the accuracy of exposure [7]. As a result, reliable and precise methods for measuring radionuclide activity in various types of samples are desired.

Radioanalytical techniques such as gross beta counting with proportional gas detectors, liquid scintillation counters and Cherenkov counters are the most extensively used radioanalytical techniques for determining ^{90}Sr [8–10].

Since the ^{90}Sr isotope is a pure beta-emitter, the chemical separation of strontium from other elements by appropriate procedures such as ion exchange and/or extraction chromatography and co-precipitation should be applied. These procedures consist of several steps, starting with the isolation of small quantities of strontium from sample matrices and ending with strontium purification.

Analysing for ultra-low levels of ^{90}Sr is difficult in routine environmental monitoring due to the long analytical time and high MDL. Therefore, many rapid analytical methods have recently been developed. These methods were modified by reducing the counting time or combining the use of a liquid scintillation counter (LSC) and Cherenkov counter [11–13].

Currently, the availability of analytical methods based on Mass Spectrometry (MS) detection is expanding, including systems such as inductively coupled plasma MS [14], inductively coupled plasma quadrupole MS (ICP-QMS) [15], multiple collector ICP-MS (MC-ICP-MS) with a collision reaction cell [16], thermal ionisation MS (TI-MS) [17] and laser ablation ICP-MS (LA-ICP-MS) [18]. However, the MDLs of the MS method are generally higher than those of the radiometric methods.

As a result, a simple method for monitoring ^{90}Sr in contaminated areas that allows for quicker processing periods could be beneficial [19].

The general measurement procedure of ^{90}Sr is based on chemical separation and low-level beta counting. ^{90}Sr decays to ^{90}Y before finally decaying to stable nuclide ^{90}Zr. It is ^{90}Sr's daughter and has a half-life of 64.1 hours. When a beta particle emitted by a radionuclide has an energy more than 263 keV, it can create Cherenkov radiation when passing through water [20]. The charged particles polarise the molecules in that medium, which quickly return to their ground state, producing radiation. ^{90}Y emits beta particles (E_{max} = 2.28 MeV) with higher energies than that of ^{90}Sr (E_{max} = 0.546 MeV), and in environmental samples, this pair is thought to be in secular equilibrium. By measuring ^{90}Y activity in a sample, the sample's ^{90}Sr activity can be determined [21].

Here, we propose the optimisation and validation of a simple approach for ^{90}Sr screening in milk samples using HDEHP extraction and Cherenkov counting. This method for detecting high-energy beta emitters in aqueous solution is rapid, reliable and non-destructive; however, it is colour quench correction sensitive [22]. As a consequence, clear and colourless samples are required in order to obtain reliable results. The prepared samples by dissolving the ash in 0.1 M HCl solution were transparent, despite the milk samples being non-transparent white colloid solutions.

The occurrence of Cherenkov radiation is not a fluorescence process, as is commonly supposed in typical LSC procedures. As a result, there is no chemical quenching because no scintillation cocktail is used. This advantage of the Cherenkov counting method means, first, a significant cost decrease and, second, the elimination of chemiluminescence/photoluminescence.

2. Experimental

2.1. Materials and instrumentation

2.1.1. Reagents

Analytical grade reagents were utilised throughout. A $^{90}Sr/^{90}Y$ (Cat. No. 7020) standard solution of 634.7 $kBq.g^{-1}$ from Eckert Ziegler Isotope Products was used for spiking experiments. Dilution of precisely measured amounts of this reference solution in 1.0 M HCl provided a stock standard solution with an activity of 2.534 $kBq.mL^{-1}$. Di(2-ethylhexyl)phosphoric acid (HDEHP) was supplied from Merck, and toluene was used to make a 10% (v/v) solution of it. Dissolving 1.27 g of Y_2O_3 in 1–2 mL of concentrated HNO_3 and diluting to 100 mL with deionised water yielded an yttrium carrier (10 mg Y^{3+}/mL). Eckert Ziegler Isotope Products supplied the tritium reference solution (Cat. No. 7003). High-purity deionised water was used.

The IRMM reference milk powder sample was used for developing the methods and testing the results (Reference value ($Bq.kg^{-1}$); 7.40 ± 0.60).

2.1.2. Equipment

A Perkin Elmer 1220 Quantulus Ultra Low-Level Liquid Scintillation Spectrometer equipped with Wallac WinQ Windows software for controlling Wallac 1220 Quantulus and Wallac EASY View Spectrum analysis program was used in this study. All measurements were carried out with Teflon coated low-diffusion polyethylene vials. A milestone microwave ash furnace was used for ashing.

2.2. Sample preparation

Chemical procedures should be used to separate ^{90}Sr from the sample matrices before Cherenkov radiation detection using a liquid scintillation counter, as indicated in the introduction section. The method used in this work was based on the one developed by Soumela et al. (1993) [23] with small modifications in the ashing procedure. The main advantages of this technique are the simplicity of the chemical method and rapidity of the measurement.

2.2.1. Sample digestion

1000 mL of fresh cow milk purchased from the market was placed into a 2 litre beaker. Concentrated acetic acid (CH3COOH) was added and thoroughly mixed. A 500 mL milk sample is slowly added to a 250 mL porcelain capsule and evaporated to dryness by heating under an IR lamp. About 5 g of milk powder samples were spiked with 7.13 Bq 90Sr standard solution and ashed in the microwave furnace by applying several ashing programmes in order to optimise the ashing step. The optimised microwave ashing programme was powered at 310°C for 1 h and then at 610°C ashing.

2.2.2. Liquid–liquid extraction of ^{90}Y by HDEHP

After cooling to room temperature, 50 mL of 1 M HCl was added, covered with a watch glass and heated on a hot plate for a few minutes until all the ash was dissolved. The solution was filtered through 2 × 10 mL of 1 M HCl, and the filtrate was collected in a beaker with a capacity of 200 mL. Then, 1 mL of yttrium carrier (10 mg/mL) was added and the pH of the solution was adjusted to 1.0–1.2 with 6 M NH_4OH. The aim was to determine the chemical recovery factor throughout the radiochemical separation procedure. The solution was transferred into a separatory funnel and extracted with 50 mL of 10% HDEHP by shaking for 1 minute. Because yttrium forms a stronger complex than other monovalent and divalent cations including caesium, potassium, strontium, calcium and others, yttrium-90 was transferred into the organic phase using HDEHP. Thus, ^{90}Y was separated from the other interfering radionuclides. The time and date were recorded for later use in activity calculation of ^{90}Sr. Before removing yttrium from the organic HDEHP phase, it was washed with 0.08 M HCl. Yttrium hydroxide was precipitated by adjusting the pH to 9–10 with concentrated NH_3 and centrifuged at 3000 rpm for 5 minutes.

The supernatant was removed, and the precipitate of yttrium hydroxide was dissolved in 1 mL of concentrated HNO_3. The resulting solution was diluted with 14 mL of distilled water before being transferred to a 20 mL teflon-coated polyethylene (PE) scintillation vial. Simultaneously, a blank sample was prepared, with the addition of 1 mL of conc. HNO_3 into a 14 mL of deionised water.

2.3. Counting efficiency of the LSS

The LSS was calibrated by counting for 60 minutes with a set of calibration solutions prepared by diluting a ^{90}Sr/^{90}Y reference solution with 15 mL 0.1 M HCl to match the estimated Cherenkov counting activity range of the samples. Throughout the measurement period, the LSS's efficiency was evaluated for consistency. A blank vial containing 15 mL 0.1 M HCl was also prepared for the ambient and reagent blank background correction.

The counting efficiency of a single calibration solution can be calculated using the below formula:

$$\varepsilon = \frac{(R_{Sr-90,std} - R_0)}{A_{Sr-90,std}} \tag{1}$$

where

$R_{Sr-90,std}$ is the gross count rate of ^{90}Sr (cps),
R_0 is the count rate of the blank (cps) and
$A_{Sr-90,std}$ is the activity of ^{90}Sr (Bq).

2.4. Determination of chemical yield for Yttrium

After the measurement of Cherenkov radiation, the solution in scintillation vial was diluted to 50 mL with ultra pure water. Sodium acetate and xylenol orange in KNO_3 were added, and pH was adjusted to 5–6 with NaOH and titrated with Titriplex III. The same procedure was applied to Yttrium carriers, and the chemical yield of ^{90}Y, *f*, may be calculated as

$$f = \frac{T_{sample}}{T_{std.}} \tag{2}$$

where $T_{std.}$ and T_{sample} are the volume of Titriplex III solution in mL consumed during the titration of the $^{90}Sr/^{90}Y$ standard solution and the sample, respectively.

2.5. Minimum detectable activity (MDA)

The minimum detectable activity (MDA) was estimated according to Equation (3) reported by Currie [24],

$$MDA = \frac{\left[2.71 + 4.65\sqrt{N_b}\right]}{\varepsilon \times m \times t} \tag{3}$$

where N_b is the total count in the blank sample spectrum, cps, *t* is the counting time for the blank (s), ε is the counting efficiency and *m* is the sample mass, in gram.

2.6. The activity determination of ^{90}Sr

The following ^{90}Y activity build up at different time intervals is used to determine ^{90}Sr by Cherenkov counting. 15 mL of the sample in PE vial was counted on a Perkin Elmer Wallac Quantulus 1220 Ultra Low-Level Liquid Scintillation Spectrometer. The spectrum is given in Figure 1, and the measurement parameters of the method used are summarised in Table 1. Equation (4) was used to determine the activity by consecutive counting,

$$A_{(Sr-90)} = \frac{(R - RB)e^{\lambda_{Y90}\left(t_{meas.} - t_{ref.}\right)}}{\varepsilon x f x m} \tag{4}$$

A is the activity concentration of ^{90}Sr (= ^{90}Y) in $Bq.g^{-1}$,

R is the gross count rate for the sample in cps,

RB is the count rate for blank vials in, cps,

λ is the decay constant of ^{90}Y in s^{-1},

Δt is the time interval between the extraction of ^{90}Y (t_1) and the time at the middle of counting (t_2) in s^{-1},

ε is the counting efficiency for ^{90}Y, $cps.Bq^{-1}$,

f is the chemical recovery and

m is the mass of the sample, g

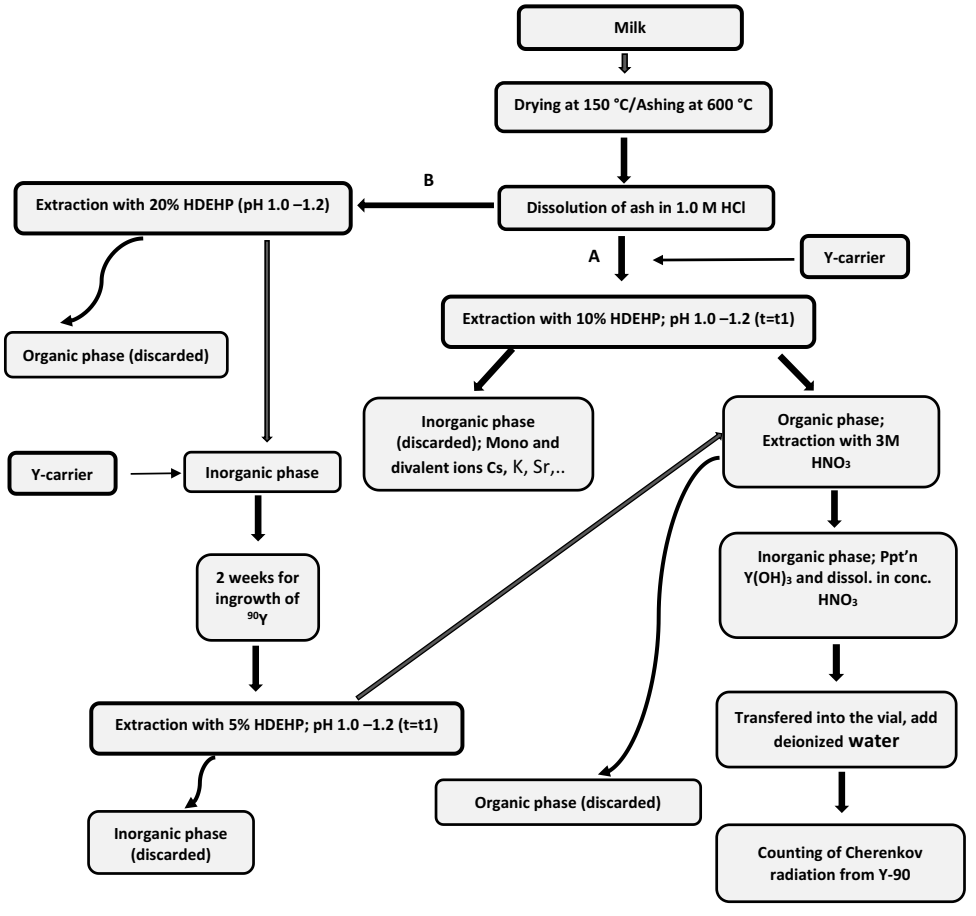

Figure 1. Radiochemical separation and determination of ^{90}Sr in equilibrium with ^{90}Y by HDEHP-extraction.

Table 1. The measurement parameters for Cherenkov counting.

Measurement parameters	^{90}Y high energy
Channel	10–350
Counting time, min	240 (4 cycles × 60 min.)
Sample amount, g	5
Solvent	Conc. HNO_3
Coctail type	Ultra pure water
Coctail volume, mL	14

2.7. Method validation

Two validation methods were used to evaluate the procedure for measuring ^{90}Y: one was a comparison with known spiked activity of a standard radioactive source ^{90}Sr/^{90}Y and the other was a comparison with a verified reference milk powder sample (IRMM-528).

2.7.1. ^{90}Sr in spiked milk samples

We spiked five milk samples with a ^{90}Sr/^{90}Y standard solution of known activity before analysing reference material. The solutions were analysed using the analytical procedure described in the sample preparation section. The purpose of this experiment was to see how matrix elements affected strontium determination.

2.7.2. ^{90}Sr in reference milk powder sample

About 25 g of reference milk powder sample was dried in an oven at 85°C overnight. The moisture content was found as 3.65%. Triplicate milk powder samples, each weighing about 5 g, were ashed in a microwave furnace using the ashing program found to be the most efficient by trials with spiked milk powder samples. The sample contained radionuclides such as ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu and $^{239+240}$Pu that form complexes with HDEHP and interfere with the subsequent counting of Cherenkov radiation from ^{90}Y. Therefore, the ashes were dissolved in 1 M HCl and steps in path B given the experimental flowchart were followed which includes additional extraction with 20% HDEHP and two-week waiting period for the ingrowth of ^{90}Y (Figure 1). Cherenkov radiation from ^{90}Y was counted for 60 minutes in a Quantulus Ultra Low-Level Liquid Scintillation Spectrometer, and chemical recovery was determined by titration with Titriplex III.

2.7.3. Uncertainty budget of the method

Uncertainty components for all measurements and calculations were performed according to the Guide to the Expression of Uncertainty in Measurement (GUM) (ISO, 2008) [25]. The parameters contributing to the uncertainty budget of ^{90}Sr activity concentration included the uncertainties in the counting statistics, the nature of radioactive decay and background radiation, detector counting efficiency and mass of the sample. The combined uncertainty ($_{A_{smpl}}$) is the estimated standard deviation equal to the positive square root of the total variance obtained by combining all variance and covariance components using the following equation:

$$\sigma^2_{Asmpl} = A^2_{smpl} \times \sqrt{\frac{\sigma^2_{R_{smpl}}+\sigma^2_{R_0}}{(R_{smpl}-R_0)^2}+\frac{\sigma^2_m}{m^2}+\frac{\sigma^2_f}{f^2}+\frac{\sigma^2_\epsilon}{\varepsilon^2}+\left[\frac{\ln(2)\times \Delta t_{Y-90}}{T_{1/2,Y-90}}\right]^2\times\frac{\sigma^2_{T_{1/2,Y-90}}}{T^2_{1/2,Y-90}}+\left[\frac{\ln(2)\times \Delta t_{Sr-90}}{T_{1/2,Sr-90}}\right]^2\times\frac{\sigma^2_{T_{1/2,Sr-90}}}{T^2_{1/2,Sr-90}}} \quad (5)$$

In the above equation, A_{smpl} is the ^{90}Sr activity concentration of the sample, Bq/g;

m is the sample mass, g;

R_{smpl} is the gross count rate of the sample, cpm;

R_0 is the count rate of the blank sample, cpm;

f is the chemical yield;

ε is the ^{90}Y efficiency of the liquid scintillation counter;

$T_{1/2,Y-90}$ is the half-life of ^{90}Y;

$T_{1/2,Sr-90}$ is the half-life of ^{90}Sr;

Δt_{Sr-90} : is the time between the start of decay of ^{90}Y and the middle of the measurement period and

Δt_{Y-90} is the decay correction during the counting period (60 min.) and is included in the decay correction factor by taking the time difference Δt at the middle of the measurement period.

Expanded uncertainty is calculated by multiplying the combined standard uncertainty by a specified coverage factor.

3. Results and discussion

The objective of the present work is to outline the determination of ^{90}Sr in equilibrium with ^{90}Y by HDEHP extraction and counting the Cherenkov radiation of highly energetic beta particles (2.27 MeV) from ^{90}Y in a liquid scintillation spectrometer. Milk was chosen as a sample to be analysed because of being an important food component for people in many countries, especially for children and babies. In this study, the measurement parameters for Cherenkov counting are given in Table 1.

The Cherenkov counting efficiency of the instrument was calculated from four calibration solutions, ranging from 4.30 to 21.48 Bq. The Cherenkov spectrum of ^{90}Sr/^{90}Y is given in Figure 2. The mean counting efficiency was found to be 83.5 ± 2.1% (Table 2).

After Cherenkov counting of the sample, the chemical recovery in Yttrium titration was determined by titration with titriplex III. The recovery values obtained with the optimum ashing program were in the range of ~84–95% (Table 3 and Table 4). The minimum detectable activity (MDA) for 60 min. counting times was 0.02 Bq.kg^{-1}. The method has an acceptable low detection limit (0.5 Bq.kg^{-1}) for analysis in emergency situations.

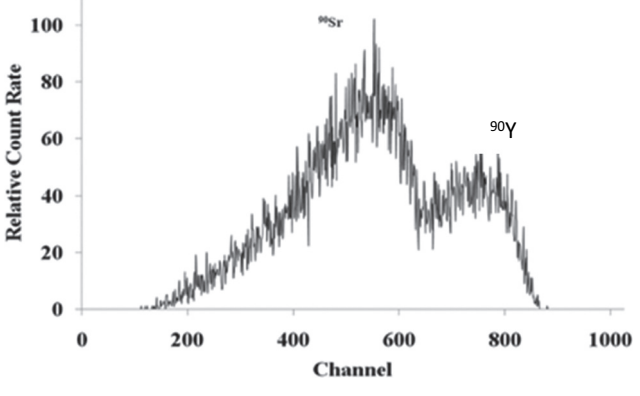

Figure 2. Cherenkov spectra of ^{90}Sr and ^{90}Y.

Table 2. The Cherenkov efficiency in counting ^{90}Y.

Activity prepared, Bq	Activity measured, Bq	Eff., %
4.30 ± 0.06	3.60 ± 0.09	83.6 ± 2.3
8.60 ± 0.13	7.18 ± 0.19	83.4 ± 2.0
10.74 ± 0.16	8.97 ± 0.23	83.6 ± 2.1
21.48 ± 0.32	17.94 ± 0.47	83.5 ± 2.1
	Mean Eff., % ± U	**83.5 ± 2.1**
	SD	**0.06**
	RSD, %	**0.07**

SD: Standard deviation; RSD: Relative standard deviation; U: Combined standard uncertainty (k = 1)

Table 3. Ashing program optimised for milk powder samples.

Time (h)	Power (watt)	Temperature (°C)
1	500	150
1	500	310
1	1000	600
6	1000	600

Table 4. Chemical recovery of milk powder samples spiked with $^{90}Sr/^{90}Y$ standard solution.

Sample Code	$V_{TitriplexIII}$, mL	$f_{chem.\ yield}$
S-1	1.07	0.95
S-2	0.98	0.87
S-3	1.02	0.91
S-4	1.00	0.89
S-5	0.95	0.84
Blank	1.13	0.92
	MEAN	**0.89**
	SD	**0.04**

Method's accuracy and precision were tested on milk samples spiked with the known activity concentration of ^{90}Sr. All samples contained the same amount of strontium standard that was spiked before ashing was carried out. As shown in Table 5, there was good agreement in each experiment, and the recovery rates were always greater than 80%.

From these recovery values, it is concluded that the deviations are lower than 10%, which indicates that satisfying accuracy for the mentioned purpose, proposed methods are highly accurate. Also, compared with the analysis time (about 1–2 days) for the separation of ^{90}Y were reduced in the extraction method. The extraction method produced much smaller amounts of acid waste solution than the acid leaching method due to the short radiochemical procedure. For routine analysis, the reduction in time and expense in the ^{90}Sr determination is a considerable improvement.

To create the uncertainty budget of the method, all uncertainty components and their contributions to measurement outcomes were first identified from the beginning to the end of the processes. Uncertainty budget of the method at the 1σ level (k = 1) is given in Table 6.

The measurement uncertainty is primarily due to the counting statistics, chemical yield and detection efficiency as expected.

Table 5. The results of measurements of spiked milk samples.

Sample No	Added activity, $Bq.L^{-1}$	Measured activity, $Bq.L^{-1}$	Recovery (R), %
1	7.13 ± 0.23	6.23 ± 0.29	87.4
2	7.13 ± 0.23	5.89 ± 0.27	82.6
3	7.13 ± 0.23	6.89 ± 0.32	96.6
4	7.13 ± 0.23	6.71 ± 0.31	94.1
5	7.13 ± 0.23	7.50 ± 0.35	105.2
6	7.13 ± 0.23	6.96 ± 0.33	97.6
7	7.13 ± 0.23	7.48 ± 0.35	104.9
		Mean Recovery, %	**95.6**
		SD	**7.1**
		RSD%	**7.5**

SD: Standard deviation; RSD: Relative standard deviation; U: Combined standard uncertainty (k = 1)

Table 6. Uncertainty budget and the contribution of the major components for ^{90}Sr in spiked milk sample.

Uncertainty component	Type	Relative uncertainty, %	% Contribution to combined uncertainty
Counting statistics (including background)	A	2.7	44.0
Detection efficiency	A	2.1	20.2
Chemical yield (f)	B	2.6	30.9
Half-life of ^{90}Y	B	0.15	0.10
Half-life of ^{90}Sr	B	0.02	0.002
Sample mass	B	0.14	0.09
Water content	B	1.00	4.58
Combined uncertainty, k = 1		***4.67***	

a Efficiency includes the reference standard uncertainty, volume and mass uncertainties during the dilution of the reference standard and counting statistics uncertainties of the reference material and background
b Chemical yield includes the uncertainties of the titration solution amount used for the standard and the sample.

The method was then tested by analysing IRMM reference milk powder material. The results obtained are compared to the reference values in Table 7. No outlier values are found in any of the activity concentration determined.

where X_{ref} is the reference value, X_{exp} is the experimental value, U_{ref} is the combined standard uncertainty of reference material and U_{exp} is the combined standard uncertainty of the experimental value.

Table 7 shows the results in terms of A1, A2, P (%) and Z-score. The obtained results are labelled 'Acceptable' for trueness evaluation if A1 ≤ A2. '***P'*** expresses the precision evaluation of the obtained results and directly related to the measurement uncertainty of the reported activity values. The IAEA sets the precision acceptance limit (LAP) for each analyte in advance, taking into account any adjustments due to the concentration or activity level of the analytes in concern, as well as the complexity of the analytical process [26].

When (P < LAP) or (P = LAP), the precision of the analysis is evaluated as ***'Acceptable'***. The P value for our study is 14.63, and it is lower than the LAP value for ^{90}Sr (20%). The z-scores are used to analyse the activity values acquired in this study [27]. If the z-scores were less than or equal to 2, the validity of the proposed method was acceptable. A z-score of two to three indicates that the results are doubtful. If |Z| > 3, the analysis was regarded uncontrollable. The results reported in Table 7 for the determination of ^{90}Sr in milk samples demonstrate the improved method's excellent precision and trueness.

After getting good recoveries from the spiked samples and acceptable results from the certified reference material, the method was decided to be suitable to use routine analysis of milk and milk powder. Cherenkov counters can also be used for the rapid determination of ^{90}Sr via its ^{90}Y daughter.

Table 7. The results of the ^{90}Sr analysis on standard reference material.

Sample	Recommended activity (Bq.kg^{-1})	Measured activity (Bq.kg^{-1})	A1	A2	P (%)	z-score
IRMM Milk Powder	7.40 ± 0.60	7.39 ± 0.90[a]	0.01	2.79	14.63	0.009

$A1 = |X_{ref} - X_{exp}|$; $A2 = 2.58\sqrt{U_{ref}^2 + U_{exp}^2}$; $P = \sqrt{\left(\frac{U_{ref}}{X_{ref}}\right)^2 + \left(\frac{U_{exp}}{X_{exp}}\right)^2} \times 100\%$; $Z - score = \frac{|X_{ref} - X_{exp}|}{\sqrt{U_{ref}^2 + U_{exp}^2}}$; a = *Expanded uncertainty at 99% confidence level (k = 1).*

4. Conclusion

The separation of ^{90} Y by HDEHP extraction and counting the Cherenkov radiation in a liquid scintillation spectrometer gives reliable results for ^{90}Sr determination in milk samples. The validity of the results was tested by performing the same procedure on IRMM milk powder standard reference material. There is no need to wait for ^{90}Sr and ^{90}Y to reach a state of equilibrium. Counting efficiency and chemical recovery were determined to be 95% and 84–95%, respectively. The time required for radiochemical separation and source preparation after ashing the sample in a microwave furnace was approximately 6 hours. The detection limit was also found to be 0.02 Bq.kg^{-1} (for 5 g sample, 88% recovery, 83.55% counting efficiency, and 60 min. counting time).

The main disadvantage of the method is the requirement for a secular equilibrium between ^{90}Sr and ^{90}Y, which means it cannot be used in an emergency. However, as the foundation of an annual environmental survey program, this method represents a significant improvement in terms of operator working time, chemical separation duration and analysis cost. Furthermore, this method will provide reliable and accurate results for both low and high activity values. The most significant advancement of this method is also the effective dissolution of the samples. Back titration of yttrium is a more accurate and faster method of determining yttrium recovery than traditional gravimetrical determination of yttrium recovery.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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