

Non radiochemical technique for ^{90}Sr measurement

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Abstract. Nondestructive methods of ^{90}Sr determination were developed for small biological objects, such as small rodents, to keep biological object going for further research even in presence of essential contamination of the same object by ^{137}Cs . To carry out ^{137}Cs input registration in proper way, we used 2 different methods: a) The method of Cs and Sr electrons filtering using thin filters with subsequent measurement of residual Y-spectrum. Comparative results of measurements for calibrated and studied samples were found not hard to obtain the amount of ^{90}Sr . Obtained result is close to the real one if the ratio between Cs and Sr is comparable. In opposite case the method requires several measurements depending on $^{137}\text{Cs}/^{90}\text{Sr}$ relation b) Method of beta-gamma spectrometry with specially elaborated beta-gamma spectrometer and corresponding software. General distinction of this spectrometer from the standard one is using the special procedure of experimental spectrum operation, and the use of thin (~1mm and 0,1mm) scintillator as a detector that allows to have the effectiveness of registration of gamma quanta of 661 keV in one-two orders less than for electrons with the same energy. The experimental spectrum operation was realised by the method of inserting into one of the calibrated spectrums, which had been measured on the same spectrometer from specially fabricated phantoms of mice with known contents of ^{137}Cs and $^{90}\text{Sr}+^{90}\text{Y}$. Method provides contemporary content of ^{90}Sr and ^{137}Cs . Procedure of standard radiochemical determination for ^{90}Sr contents conducted in 13 mice on the final stage of studies has confirmed the method reliability.

1. INTRODUCTION

Cost of measurement of ^{90}Sr restricts very often the possibility of researchers to achieve the purposes of study. In some cases, when it is necessarily to measure a lot of samples with approximately known and the same contamination there are methods that permit to change standard radiochemistry methods to more simple radiometry and spectrometry.

2. METHODS AND RESULTS

The method of filter of electrons of Cs and Sr by thin filters with subsequent measurement of residual spectrum of ^{90}Y , which is in balance with ^{90}Sr , is used often for non-radiochemical measurement of ^{90}Sr . Comparing together results of measurements of calibrated and studied samples is not hard to obtain found amount of ^{90}Sr . Obtained result will be close to real if it would be known in advance, that content of ^{90}Sr in the studied sample prevails or is comparable with content of other isotopes, for example ^{137}Cs , which is presence practically in every sample from Chernobyl Zone. But seeing that Chernobyl samples have Cs essentially more than Sr, it is necessary to make specific finesse to take into account the input of Cs. It is important to take into account some factors. ^{137}Cs and ^{90}Sr beta-spectrums are practically coincident. Cutting these β -spectra by absorbers we will not solve problem of accurate estimation of Y content on residual spectrum, because registration of residual electrons will be on the background of concurrent registration of irradiation, which will pass through a filter and form a superfluous radiation background. In case of the sample containing mainly ^{137}Cs and $^{90}\text{Sr}+^{90}\text{Y}$, it would be gamma-quanta 661 keV, characteristic radiation of Ba 32-37,5 keV, arising owing to process of internal conversion for M 4 transition ^{137}Ba , and also bremsstrahlung of electrons, which are braking in absorber.

To reduce registration probability of gamma-quanta 661 keV is possible by using thin detector. Perfect detector thickness would be corresponded to run of Y beta-electrons in the detector material. We used for measurement film detector of $D = 44$ mm diameter. Scintillation layer of $L \leq 1$ mm thickness provides detection efficiency by order less for γ 662 keV than for electrons with energy $E_\beta \geq 1.0$ MeV. Spectrometer is calibrated using ^{137}Cs and $^{90}\text{Sr}+^{90}\text{Y}$ calibration sources.

Characteristic radiation of Ba eventuate in connection with decay of nearly 10% ^{137}Cs by process of internal conversion of M4 gamma conversion with following irradiation of X-ray quanta K_X with energy of 32-37,5 KeV. This X-radiation in its penetrative ability roughly corresponds to electrons with energy of 3-4 MeV. It is highly uneasy factor for correct account of potential input of ^{137}Cs in measured activity of ^{90}Y , because input of Cs in measured activity became comparable with input of Y at $^{137}\text{Cs}/^{90}\text{Cr}$ ratio nearly ten. And input of characteristic radiation of Ba becomes in order more than desired activity of Y at $^{137}\text{Cs}/^{90}\text{Sr}$ ratio nearly 100 (what isn't rarity). We shall consider evaluation technique of correct input of characteristic radiation below.

The usage of filters leads not only to electron absorption, but to bremsstrahlung derivation. So this factor must be taking into account also. Ionization loss to radiation emission ratio is defined as

$$\frac{dE_{rad}}{dx} / \frac{dE_{ion}}{dx} = \frac{E_\beta Z}{1600 m_\beta}$$

where E_β and m_β – electron energy and mass in MeV, Z – absorber charge.

It is easily seen that bremsstrahlung yield from ^{137}Cs electrons does not exceed 0.1% when using hydrogen-containing polymers. In case of Al-absorber bremsstrahlung yield from ^{137}Cs electrons rises up to 1%. At $^{137}\text{Cs}/^{90}\text{Sr}$ ratio exceeding 50 this results on significant changes in spectrometer sensitivity and requires additional measurement with Al+Pb combined filters.

First of all we carried out measurements with Al-absorber of 1 and 4 mm thickness. In the case of counting ratio $N(1)/N(4) \leq 1$, which means very high pollution with Cs in comparison with Sr, measurements carried out with polystyrene absorbers of 2, 4, 8 mm thickness in order to escape additional input of bremsstrahlung from Cs electrons. In the region of $1 \leq N(1)/N(4) \leq 10$ three measurements with combined filters must be carried out (with Al-absorber of 1, 3, 9 mm thickness, polystyrene of 2, 6, 12 mm thickness accordingly). Using reference data about electrons and K_X Ba absorption in these absorbers, K_X Ba contribution in measured ^{90}Sr activity is determined. If $N(1)/N(4)$ ratio exceeds 10 in measurement with Al-absorber, Ba K_X -radiation is not taken into account, because contribution in ^{90}Sr activity in this case with self-absorption taken into account does not exceed 10%, which is in device accuracy limits.

In $N(1)/N(4) \leq 10$ area and experiments with polystyrene absorbers three measurements were carried out (with Al-absorbers of 1, 3, 9 mm thickness and polystyrene of 2, 6, 12 mm).

To check this technique we have carried out measurement of bones more than 60 mice trapped in the Exclusion Zone. Measurements were carried out as with the help of standard radiochemistry methods, so by the method, described above. Comparative diagram of results of Sr content evaluation by these two methods and correlation graph are demonstrated on the fig. 1 and 2 consequently.

This technique has allowed to determine $^{90}\text{Sr} \geq 0.2$ Bq per sample activity and ratio $A(^{137}\text{Cs})/A(^{90}\text{Sr})$ even more than 100 with accuracy of 20-25%.

This technique works successfully for samples with small fraction of ^{40}K . ^{40}K presence requires using of another absorbers and special account of ^{40}K β -spectra.

The operated methodology of simultaneous and lifetime determination of ^{90}Sr and ^{137}Cs contents in small mammals organisms has many advantages, as it differs in efficiency, fulfilment simplicity, retains animals life and allows to realise repeated measurements of the same specimens in dynamics.

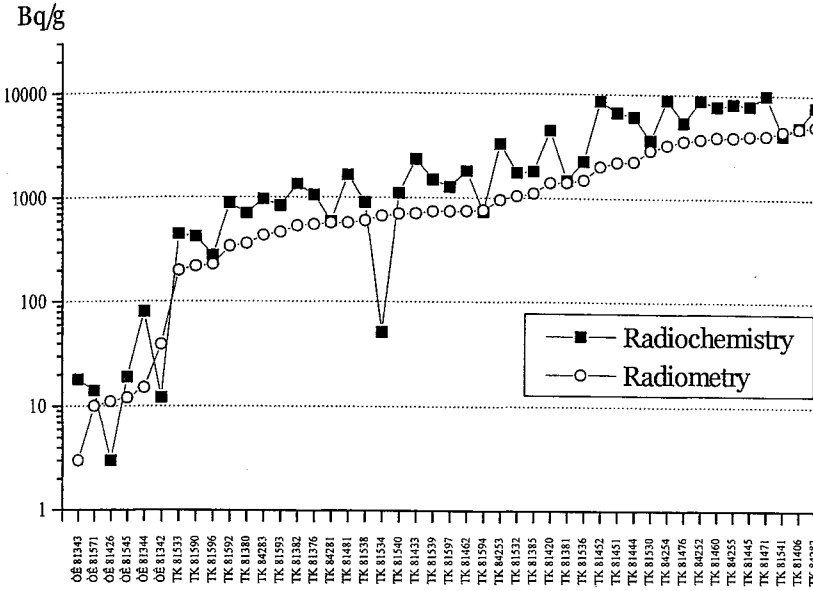


Figure 1: Comparative diagram of results of Sr content evaluation by radiochemistry and radiometry methods

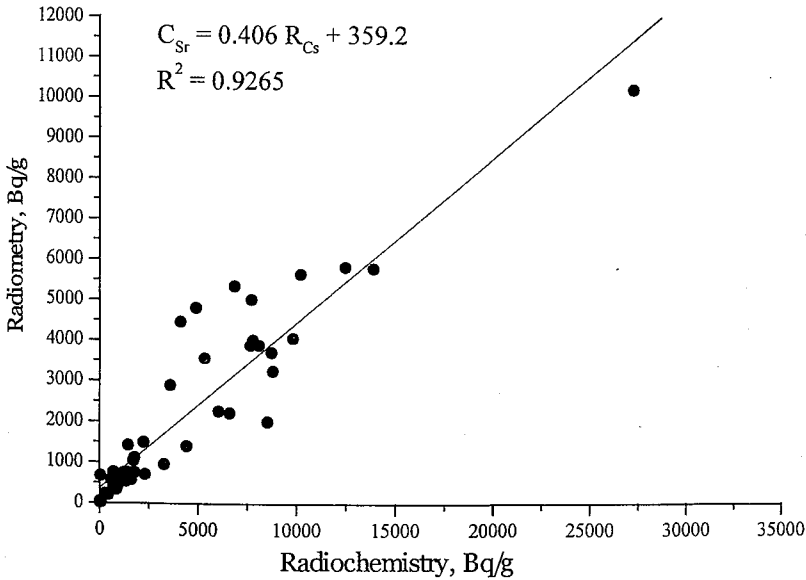


Figure 2: Correlation of results received by radiochemistry and radiometry methods

Another technique, in which instead of described radiometry, is used method of beta-gamma spectrometry with specially elaborated beta-gamma spectrometer and corresponding software. General distinction of this spectrometer from the standard one is using the special procedure of experimental spectrum operation, and the use, as in radiometry, of thin (~1mm and 0.1mm) scintillator as a detector that allows to have the effectiveness of registration gamma quanta of 661 keV up to two orders less than for the same energy electrons. The experimental spectrum operation was realized by the method of inserting into one of the calibrated spectra, which had been obtained on the same spectrometer from

specially fabricated phantoms of mice with known contents of ^{137}Cs and $^{90}\text{Sr}+^{90}\text{Y}$. To fit experimental spectra we have elaborated special programs on the same base as we did for the analysis of X-ray spectra [1]. Method provides contemporary content of ^{90}Sr and ^{137}Cs . Procedure of standard radiochemical determination for ^{90}Sr contents conducted in 10 mice on the final stage of studies has confirmed the method reliability. An example of beta-gamma spectra and its fitness by two calibrated spectra presented for detectors with 1mm and 0.1mm thickness correspondingly on the Fig.3 and 4 Comparative diagram results of Sr content evaluation by these two methods (radiochemistry and spectrometry) are demonstrated on the Fig 5.

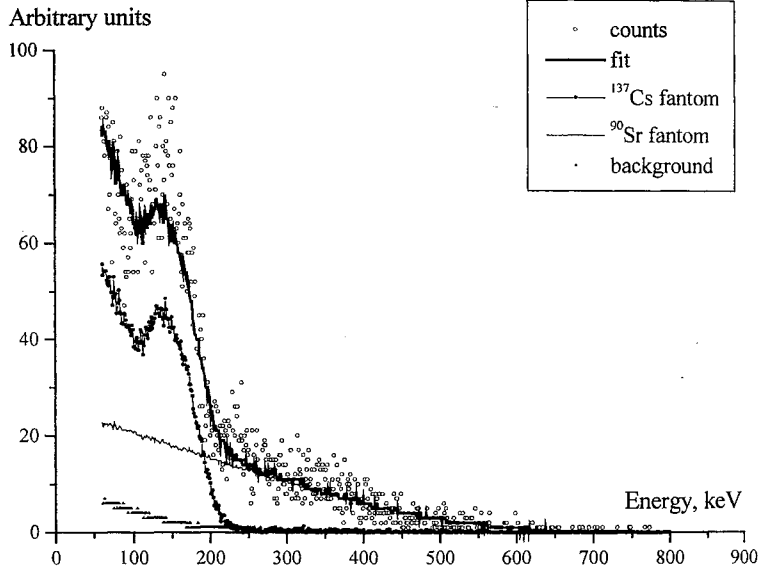


Figure 3: Beta-gamma spectra and its fitness by calibrated spectra presented for the detector with 1mm thickness

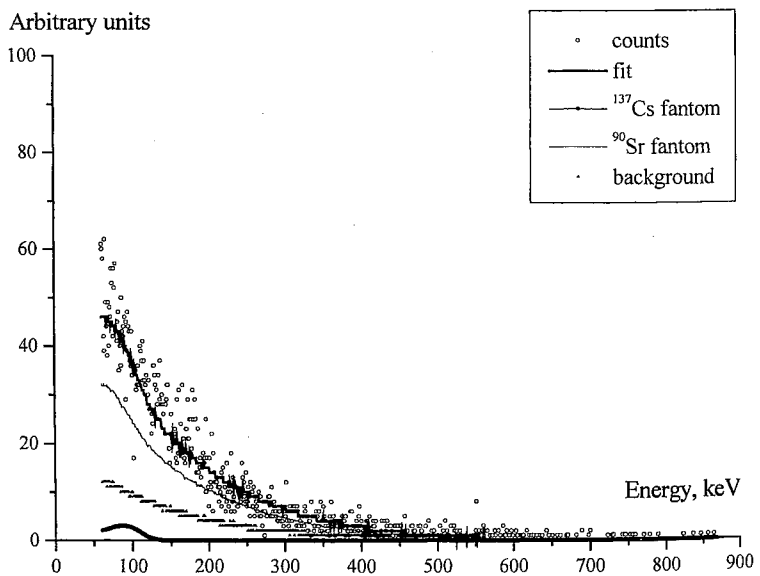


Figure 4: Beta-gamma spectra and its fitness by calibrated spectra presented for detector with 0.1 mm thickness

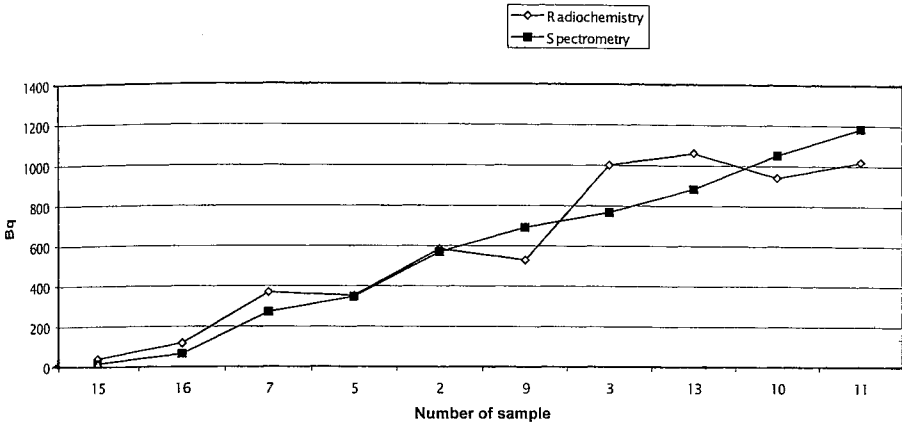


Figure 5: Comparative diagram results of Sr content evaluation by radiochemistry and spectrometry methods

Reference

[1] Vishnevsky I.N., Bondarkov M.D., Zheltonozhky V.A. Izvestija RAN, ser. fiz., 1995, v.59, p. 78.