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SEMI-EMPIRICAL CONTROL METHOD OF SOLID WASTES OF MEDIUM AND HIGH ACTIVITY

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Semi-empirical method has been developed to monitor medium and high level solid radioactive wastes based on direct measurement of wastes radioactivity and nuclide composition in lorry body. The energy range of measurements was from 80 to 3000 keV. The radioactive waste activity was from 10^6 to 10^{12} Bq. The proposed method was certified and measurement of basic errors were determined that not exceeding 60 %.

Introduction

According to the current regulations monitoring radioactive nuclide composition and activity of solid radioactive wastes (SRW) is a necessary procedure [1]. When detecting the listed characteristics for medium and high level SRW there appear a number of problems connected with, performance of all operations distantly and with minimal personnel involvement on the one hand [1, 2]. On the other hand, the objects measured (counter samples) often are of complex geometrical form as well as irregular material and activity distribution over the content of sample. This causes significant uncertainty of results in monitoring SRW activity.

The purpose of the given paper was to develop gamma-spectrometric method of monitoring activity and nuclide composition of medium and high level SRW including the appropriate methodical and metrological equipment.

Gamma-spectrometric method of monitoring activity and nuclide composition of medium and high level SRW

The method developed is based on direct measurement of waste activity and nuclide composition by gamma-spectrometer with extended uncertainty (P=0,95) not more than 60 % in the energy range from 80 to 3000 keV and activity range of SRW from $10^6...10^{12}$ Bq/kg. Measurements are made in the geometry corresponding to a lorry body intended for wastes of the given type.

The essence of the suggested measurement method consists in registration and subsequent analysis of instrumental gamma-radiation spectrum of SRW counter samples by means of Monte-Carlo method [3, 4]. In the first stage on the basis of instrumental spectra of sample standard sources of gamma-radiation the dependence of gamma-radiation registration efficiency on its energy is to be determined in the «point» geometry. Hereafter, using datum statistic model, the gamma-radiation registration efficiency on its energy for the «lorry body» geometry (volume sources in terms of absorption) is simulated. In simulation the geometrical body parameters, density and element composition of radioactive wastes and material of lorry body are used.

Monitoring SRW, in terms of the suggested method, is performed in the course of successive technological operations which are preceded by semi-empirical efficiency calibration of spectrometric track. For this purpose the wastes are loaded into the body; the weight of loaded SRW is defined; the body with SRW is placed on the radiation monitoring place. With the help of gamma-spectrometer the calculation rate for discrete energy of SRW gamma radiation is measured in the specified energy range. Measurements are performed in one of the two geometries, their schemes being presented in Fig. 1, 2. «Simple» geometry assumes a single measurement of SRW radiation by detector placed above the body (Fig. 1).

In «averaged» geometry (Fig. 2), to consider irregularity in distribution of SRW activity over the body volume a series of three measurements in horizontal plane of body section is performed. The detector is placed with respect to the ramps successively with 90° step. The results of measurements are averaged. For all geometries of measurements the solid angle of detector formed by lead collimator encompasses the whole visible body surface. The collimator axis coincides with the detector axis, which permits for application of efficient detecting centre concept in measurements. Identification and calculation of specific activity of waste gamma-radiation in the body is made using the results of calculation rate determination in the peaks of complete absorption and in terms of the results of detector semi-empirical calibration with registration efficiency of SRW gamma-radiation photons.

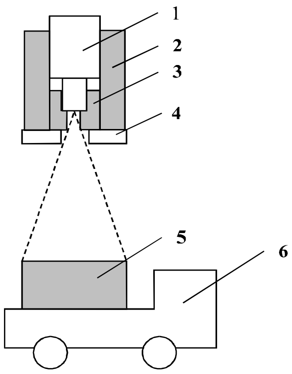

Fig. 1. *Scheme of SRW monitoring with gamma-radiation detector above the body (side view): 1) detector; 2) lead shield; 3) collimating device; 4) distant ground; 5) lorry body with SRW; 6) vehicle*

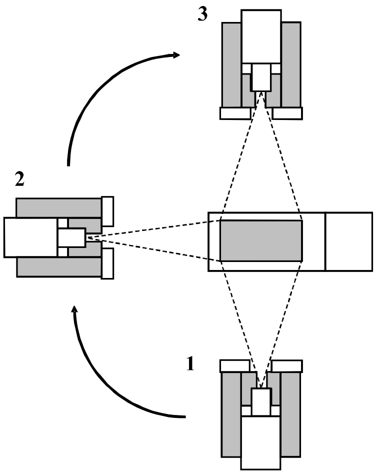

Fig. 2. *Scheme of SRW monitoring with gamma-radiation detector on horizontal plane (top view): → – direction of detector displacement on horizontal plane; 1–3 – monitoring positions of detector for measurements*

The suggested technique of monitoring activity and nuclide composition of medium and high level SRW can be applied not only for lorry body geometry, but also for that of container of any size intended for temporary (long-term) storage of medium and high level wastes.

The developed technique of monitoring nuclide composition and activity of medium and high level is submitted and certified by the State Standard of Russia (by the Centre of Ionizing Radiation Metrology of Federal State Enterprise «All-Russian Scientific Research Institute of Physico-Technical and Radio Engineering Measurements») and introduced at the Federal State Enterprise «Siberian Chemical Combine» (SCC).

Metrological certification of gamma-spectrometric method and analysis of certification results

To check the determination of SRW gamma-emitting nuclides by means of the suggested semi-empirical calibration method as well as to reveal the boundaries of uncertainties (errors) metrological certification of the technique has been performed.

The essential feature required of the metrological certification procedure is to perform control measurements in the geometries similar to the conditions of SRW measurements at SCC (volume source in the «lorry body» geometry in terms of self-absorption). Therefore the following operations are to be performed for certification:

1. Production of sample sources of special assignment (SSSA) in «lorry body» geometry using standard certified point sources of gamma radiation and nonradioactive materials of different densities to imitate the composition of radioactive wastes. The point sources are placed inside the nonradioactive material in special containers to avoid their damage. SSSA are made with different activity distribution (point sources) over the body geometry and of different density of loaded nonradioactive materials.
2. By means of gamma-spectrometer the calculation rates for discrete energies of SSSA gamma radiation are measured in «lorry body» geometry for two suggested geometries of measurement («simple» and «averaged»).
3. Based on the results of semi-empirical determination of measurement efficiency identification and definition of gamma radiation activity in sample sources of special assignment is carried out with subsequent comparison with the nameplate activity values of the point sources used.

For the certification three types of SSSA have been prepared in «lorry body» geometry:

- without absorbing material – there are only spacer board layers and point sources of gamma radiation photons in the lorry body;
- with absorbing nonradioactive material of different packed density – in the body the nonradioactive material is placed in layers (sawdust, clean cloth, film, board, elastron, metal plates) and point sources of gamma radiation photons;
- with absorbing nonradioactive material suitable in waste composition of medium and high level activity of SCC reactor production (aluminium briquettes of assembly channels, graphite inserts, steel plates etc.) – nonradioactive material and point sources of gamma radiation photons are placed in the body in layers.

In terms of comparison of nameplate values for radionuclide activity of point sample sources (from the test certificate on the sources used), with average values of SSSA measured radionuclide activity in «lorry body» geometry the analysis of the certifying measurements is performed.

Table. *Analysis of applicability of semi-empirical calibration method*

Conditions of measurements			$\frac{\lvert A_0-\overline{A}\rvert}{A_0}$, %	$\overline{A}-A_0$, Bq	$\sqrt{U(P)^2+\delta(A)^2}$, Bq
SSSA type	Geometry	Isotope			
1	Simple	Cs-137	7	1,12·10^8	2,91·10^8
		Co-60		2,23·10^7	5,78·10^7
	Averaged	Cs-137	6	9,60·10^7	2,71·10^8
		Co-60		1,90·10^7	5,39·10^7
2	Simple*	Cs-137	39	6,24·10^8	5,78·10^8
		Co-60		1,24·10^8	1,05·10^8
	Averaged	Cs-137	25	4,00·10^8	5,80·10^8
		Co-60		7,95·10^7	1,01·10^8
3	Simple*	Cs-137	52	8,32·10^8	7,12·10^8
		Co-60		1,65·10^8	1,22·10^8
	Averaged	Cs-137	29	4,64·10^8	7,08·10^8
		Co-60		9,22·10^7	1,08·10^8

**The condition (1) is not met*

For the results of measurements to meet methodical requirements it is necessary to observe the following condition [5]:

$$\left|\overline{A}-A_0\right|\le\sqrt{U(P)^2+\delta(A)^2}, \qquad (1)$$

where $\overline{A}$ is the average value of sample source activity of special assignment in «lorry body» geometry, obtained after calculation, Bq; A_0 is the value of sample source activity (from the source test certificate), Bq; $U(P)$ is the extended uncertainty in calculation of activity value of the sample source of special assignment in «lorry body» geometry, Bq; $\delta(A)$ is the error in activity value of sample source (from the certificate of source test), Bq.

Some results of SSSA certified measurement analysis with the sources Cs-137 and Co-60 of $1{,}6\cdot10^9$ and $3{,}18\cdot10^8$ Bq activity respectively are shown in the Table.

It follows from the presented data that the measuring technique is applicable only for «averaged» geometry of SRW measurements.

Conclusion

The suggested and tested gamma-spectrometric monitoring method allows for determination of nuclide composition and calculation of specific and absolute activity of medium and high level SRW in lorry body geometry intended for transportation of radioactive wastes of the given type. The method is suitable for monitoring solid radioactive wastes in containers of different sizes under the condition that the measurement results of SRW activity are averaged from several positions (not less than three).

Realised in the suggested gamma-spectrometric method algorithm (Monte-Carlo statistic method) permits for determination of SRW specific activity placed in the lorry body (non-homogeneous volume source with regard to self-absorption of radiation), with extended uncertainty in the permissible range to 60 %.

The efficiency of the method has been proved in the series of experiments and in practice of treating radioactive wastes at SCC. The developed gamma-spectrometric method is suitable for monitoring SRW at the other radiation-dangerous enterprises.

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