Possibilities of FSUE "VNIIFTRI" for the manufacture and calibration of special measures of radionuclide activity for metrological support of measurements of radionuclide activity during radiation monitoring

V G Dyachkova, M D Kraynova

All-Russian Scientific Research Institute of Physicotechnical and Radio Engineering Measurements, 141570, Russia, Moscow Region, Mendeleevo

E- mail: kraynovamarie@yandex.ru

Abstract. Measuring the activity of radionuclides is one of the most popular directions in the field of ionizing radiation measurements. The fact that ensuring the unity and reliability of measurements of the activity of radionuclides is the most important task is obvious. Radionuclide sources of ionizing radiation for metrological purposes are necessary for the calibration and graduation of radiometers and spectrometers and are also used as control sources. VNIIFTRI develops and manufactures various types of metrological sources: point sources, surface sources, simulators of radioactively contaminated environmental objects, which, in turn, are divided into solid-state and bulk sources. The use of these sources avoids a significant increase in the error of measuring instruments.

Ensuring the unity and reliability of measurements of the activity of radionuclides in environmental objects is an important task, since it allows to significantly reduce the error of measuring instruments and prevent obtaining unreliable measurement results. One of the main activities of the Research Department of the Metrology of ionizing radiation of the All-Russian Scientific Research Institute of Physicotechnical and Radio Engineering Measurements (VNIIFTRI) is to develop and produce the certified reference material (CRM)/measure of all kinds of possible radionuclide products, including various simulators of radioactive contamination of environmental objects, nuclear and construction materials, agricultural products. These emitters can be obtained both in the form of monolithic and granular bulk samples with variable parameters (radionuclide composition, granule dispersion, bulk density). These simulators of radioactive contamination of environmental objects are widely used for metrological support of radiometric and spectrometric measuring instruments, as they allow to verify, calibrate and calibrate measuring equipment in conditions closest to real, and not by recalculation from one measurement geometry to another, which introduces a significant additional error in the measurement results [1].

The special activity measures/CRMs for radionuclides (special purpose sources) are prepared both the measure of the approved type - metrological sealed photon radiation sources (MS-G), inscribed in the Federal Information Fund on Uniformity of Measurements under 44591-10 [2] and produced in accordance to the specifications [3], and for specific needs of the customer according to particular specifications.
The MS-G sources are intended for use as reference and working measures of activity (specific and volumetric activities) for calibration of energy scale and sensitivity of gamma-radiometric and spectrometric units, and for use as control ones as a part of measuring instruments.

Activity measures manufactured at VNIIFTRI can be conditionally divided into 4 groups, which determine the measurement geometry, i.e. mutual location of the object under study and the detection unit of the radiometric or spectrometric measuring instrument, and represent a radioactive substance in a particular design. Sources are closed, the design ensures that they do not contaminate the environment or equipment when used under the intended operating conditions.

The first group includes point radiation sources, the active part of which is made by localized application of an aliquot of a nuclide solution of known specific activity to a substrate, followed by sealing.

The appearance of the point sources is shown on the Figure 1.

The second group of the sources includes surface sources, the active part of which is made by uniform distribution of a nuclide solution of known specific activity on the surface of the substrate, followed by sealing.

The appearance of the surface sources is shown on the Figure 2.
The third group of the sources includes bulk solid-state sources, the active part of which is made by uniform distribution of a nuclide solution of known specific activity in the volume of the sources with subsequent sealing. The source volume may be organized by metal or organic forms. The source can also be made by means of a temporary mold, followed by its removal.

The appearance of the bulk solid-state sources is shown on the Figure 3.

![Figure 3](image)

**Fig. 3** The appearance of the solid-state volumetric sources

The 4th group of sources includes bulk granular sources consisting of sealed granules with radionuclides or radionuclide mixtures evenly distributed inside them. The appearance of bulk sources is shown on the Figure 4.

![Figure 4](image)

**Fig. 4** The appearance of the bulk sources: a) in a Petri dish, b) in a Marinelli vessel.
When making the special measures of the radionuclide activity, practically any material characterizing various objects of the natural environment can be used as the source base, i.e. as matrix:

- agricultural products (grain and leguminous crops, flour, cereals, seeds, seedlings, tea, spices, etc.);
- construction material (sand, cement, concrete, crushed stone, etc.);
- soil.

When making the special measures of the radionuclide activity, which should be imitators of samples of water, air, soil, food, plants, etc., the basis is an epoxy resin with known activity content, and the degree of equivalence to real samples is determined by the density of the source:

- For the bulk simulants, the density range can be from 0.5 to 2.4 g/cm³.
- For the solid state simulants that are housed in a given shaped vessel, the density range can be from 0.05 to 2.4 g/cm³.

The list of radionuclides, on the basis of which the activity measures can be produced, is presented in the Table 1.

| Radionuclide | Half-life (T₁/₂) | Radionuclide | Half-life (T₁/₂) | Radionuclide | Half-life (T₁/₂) |
|--------------|----------------|--------------|----------------|--------------|----------------|
| ²⁰⁷Bi        | 32.9 years     | ²³⁹Pu        | 2,411-10⁴ years| ⁹⁴Nb        | 2,03-10⁴ years |
| ¹³³Ba        | 10,51 years    | ⁵⁴Mn         | 291 days       | ¹⁵⁵Gd       | 241,6 days     |
| ¹³⁷Cs        | 30,17 years    | ¹⁰⁹Cd        | 461,4 days     | ²⁴⁴Cf       | 351 years      |
| ⁴⁴Ti         | 60,0 years     | ⁵⁷Co         | 271,74 days    | ¹³⁹Ce       | 137,641 days   |
| ²²Na         | 2,6 years      | ⁶⁵Zn         | 243,66 days    | ¹⁴⁴Ce       | 284,91 days    |
| ²⁴¹Am        | 432,6 years    | ⁸⁶Y          | 108,1 days     | ¹⁰⁶Ru+¹⁰⁶Rh | 373,59 days    |
| ²²⁶Ra        | 1600 years     | ¹¹³Sn        | 115 days       | ¹³⁴Cs       | 2,0648 years   |
| ²³²Th        | 1,4-10⁶ years  | ¹⁸⁰W         | 69,4 days      | ²⁴³Am       | 7,37-10³ years |
| ⁴⁰K          | 1,248-10⁹ years| ⁶⁰Co         | 5,2713 years   | ²²⁸Th       | 1,9116 years   |
| ⁹⁰Sr         | 28,79 years    | ¹⁵²Eu        | 13,537 years   | ²³⁷Np       | 2,144-10⁶ years|
| ³⁶Cl         | 3,1-10⁶ years  | ⁵⁵Fe         | 2,737 years    |             |                |

Metrological and technical characteristics of the sources are given in the Table 2 [1].

| Characteristic                                      | Value of characteristic |
|----------------------------------------------------|-------------------------|
| Photon radiation energy range, keV                | from 4 to 6130          |
| Measuring range of activity (ImN-G-1, ImN-G-2), Bq | from 1 to 1·10⁶         |
| Display range of specific (volumetric) activity (IMN-G-3-T, IMN-G-3-H), Bq/kg (Bq/L) | from 1 to 1·10⁶         |
| Measuring range of external gamma radiation at E=6,13 MeV (IMN-G-3-V) in 4π, s⁻¹ | from 300 to 3000        |
| Relative error limits of activity reproduction, % | ± 5 (IMH-Г-1) ± 10 (IMH-Г-2) |
| Relative error of reproducing specific (volumetric) activity (at confidence probability 0,95), % | ± 20                    |
The sources are controlled to be acceptance and periodic tested, during which the conformity of the certified characteristics to the established requirements is assessed.

Thus, providing the modern fleet of spectrometric measuring instruments for ionizing radiation with volumetric reference sources that simulate real environmental samples contaminated with radionuclides avoids a significant increase the error of measuring instruments due to matrix affect and making false decisions based on unreliable measurement results.

References
[1] Sarkisov E R 2005 Standards of activity units of radionuclides of VNIFTRI and metrological release of radiation ecology Collection of scientific works of VNIFTRI (M.) issue 52 (144) p. 74 (in Russian)
[2] Radionuclide sources of photon radiation of metrological purpose closed IMN-G Federal Information Fund for Ensuring the Uniformity of Measurements (in Russian), http://www.fundmetrology.ru/10_tipy_si/11/7list.aspx
[3] MGFC.412128.001 2005 TC Sources of radionuclide photon radiation of metrological purpose closed IMN-G, Technical specifications, FSUE «VNIIFTRI» (in Russian)