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Determination of radionuclides in soil by gamma spectrometry

土壤中放射性核素的 γ 能谱分析方法

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Analytical method of radionuclide in soil by gamma energy spectrum

1 Scope

This standard specifies a routine method for the laboratory to analyze the activity concentration of radionuclides in soil with a gamma spectrometer.

This standard applies to the analysis of gamma radionuclides in soil.

2 Equipment

2.1 gamma spectrometer

2.1.1 Detector

2.1.1.1 Sodium iodide [NaI(Tl)] detector A cylindrical NaI(Tl) detector with a size not less than $\phi 7.5\text{cm} \times 7.5\text{cm}$ should be used to measure soil samples. Prefer low potassium NaI (Tl) Crystal and low-noise photomultiplier tube. The entire crystal is sealed in a sealed container with a light-transmitting window, and the crystal and the photomultiplier tube form an optocoupler Together. The resolution of the detector to the 661.6keV peak of ^{137}Cs should be better than 9%.

2.1.1.2 Semiconductor detector Different materials and different types of semiconductor detectors should be used according to the gamma-ray energy range. Single-opening is preferred for measuring soil samples the energy resolution (FWHM) of ^{60}Co 1332.5keV gamma rays should be better than 2.5keV, compared with the relative efficiency of the $\phi 7.5\text{cm} \times 7.5\text{cm}$ (3"x3") NaI(Tl) detector is not less than 20%.

2.1.2 Shield

The detector device should be placed in a metal shielded room with an equivalent lead equivalent of not less than 10cm, and the distance between the wall of the shielded room and the crystal surface >13cm, on the inner surface of the lead chamber, there should be a multilayer inner shielding material with a decreasing atomic number, and the inner shield shall be lined with thickness from the outside to the inside.

Cadmium or tin with $\geq 1.6\text{mm}$, copper with $\geq 0.4\text{mm}$ and plexiglass with 2mm~3mm to reduce the energy of 72keV~95keV the influence of Pb characteristic X-ray. For example, it can be composed of 0.4mm copper, 1.6mm cadmium and 2mm~3mm thick plexiglass.

The shielded room should have doors or windows that are convenient for taking and placing

samples.

2.1.3 High voltage power supply There should be a high-voltage power supply to ensure the stable operation of the detector, and its relative ripple voltage should not be greater than $\pm 0.01\%$.

0V~ ± 5000 V, continuously adjustable within the range of 1 μ A~100 μ A, without discontinuity.

2.1.4 Spectrum amplifier There should be an amplifier with waveform adjustment that matches the preamplifier and pulse height analyzer.

2.1.5 Pulse height analyzer the number of channels of the NaI(Tl) spectrometer should be no less than 512, and for the high purity germanium gamma spectrometer, the number of channels should be no less than 8192.

2.1.6 Computer System it is required to match the hardware of the entire spectrometer system, and the spectrum acquisition and de-spectrum software suitable for the entire spectrometer system have been installed, as well as the supporting output terminal.

Terminal, such as a printer, etc.

2.2 Measuring vessel According to the number of samples and the shape and size of the detector, select sample boxes of different sizes and shapes, such as. the diameter of the bottom of the container is equal to or smaller A cylindrical sample box with the diameter of the detector or a ring-shaped sample box matching the size of the detector. The container should use natural radionuclide content it is made of materials with low and no artificial radioactive pollution, such as ABS (acrylonitrile-styrene-butadiene copolymer) resin or polyethylene.

3 Calibration of gamma spectrometer

3.1 Energy scale

3.1.1 Calibrate the gamma spectrum system with a calibration source of known nuclides the energy scale should range from 40keV to.2000keV. Refer to Appendix A for the single-energy and multi-energy nuclides applicable to the energy scale. Energy engraved the degree includes at least four scale points with energy evenly distributed in the required scale energy zone. Record the characteristic gamma-ray energy and the corresponding all-power peak of the calibration source Peak position and road address can be plotted on Cartesian coordinate paper or the data can be fitted with least squares straight line or parabola. The energy of high purity germanium gamma spectrometer the absolute value of linearity should not exceed 0.5%, and the absolute value of energy nonlinearity of NaI(Tl) gamma spectrometer should not exceed 5%.

3.1.2 Changes in the relationship between energy and road sites If the absolute value of the slope and intercept of the energy scale curve does not exceed 0.5%, the existing scale data can be used, otherwise it should be re-engraved degree. The better the stability of the

gamma spectrometer, the less likely the energy scale is to change.

3.2 Efficiency scale

3.2.1 Standard source of efficiency scale for general soil sample measurement, the body standard source of uranium, radium, thorium, and potassium is used for efficiency calibration. Used as a standard source for efficiency scales. Its geometry the shape should be the same as the tested sample, and the matrix density and effective atomic number should be as close as possible to the tested sample. For some involving long-life labor for the measurement of radionuclide ^{137}Cs , another standard source of ^{137}Cs body should be prepared for use.

3.2.2 Efficiency scale curve when the cascade and span effects are negligible, the detection efficiency of the gamma-ray total absorption peak is a function of the gamma-ray energy. Find several different energies After the detection efficiency of the single-energy gamma-ray total absorption peak, the relationship curve between the detection efficiency and the gamma-ray energy (efficiency curve) can be drawn on the graph paper or used the computer performs the weighted least squares curve fitting on the experimental points to obtain the efficiency curve. Use n logarithms in the range of 40keV~2000keV Polynomial fitting can achieve satisfactory results, and the expression is shown in equation (1).

$\ln \epsilon = \sum$

$a_i (\ln E_{\gamma})^i \quad (1)$

Where.

ϵ ---Experimental gamma-ray total absorption peak efficiency value;

a_i ---fitting constant;

E_{γ} ---the corresponding gamma-ray energy, in kiloelectron volts (keV).

The relative standard uncertainty of the efficiency scale should be less than 5%.

4-body standard source preparation

4.1 Body standard source requirements the volume standard source used for the efficiency calibration of the gamma spectrometer is made by uniformly mixing a simulated matrix and a standard solution of a specific nuclide or a standard mineral powder.

It should meet the requirements of good uniformity, accurate nuclide activity, stability, and sealing.

4.2 Simulation matrix the material with low radioactive background, easy to mix uniformly, and density similar to the sample to be tested is selected as the simulation matrix. For the packing density at the volume standard source of soil samples of 0.8g/cm³~1.6g/cm³ uses a certain proportion of alumina and silica as the simulation matrix.