Method MMK 605

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Determination of activity index, radium index and gamma radiation in stone-based construction material.

1. Scope

The method is intended for laboratory and field laboratory for measurement, calculation and reporting of the concentration of those in nature, as well as in various construction materials, of existing radionuclides K-40, Ra-226 (Uranium 238/235) and Th-232. The results from the measurement of these radionuclides is calculated for the determination of activity index (AI), radium index (RI) and gamma radiation (µSv/h) for the construction material.

2. Definitions

Activity index (AI) is the sum of the weighted concentrations of K-40, Ra-226 (U238 / 235) and Th-232. Activity index (AI) and radium index (RI) are a measure of the concentration of nuclides.
Activity index (AI) is a tool for determining the suitability for a material regarding the effective dose.

Radium index (RI) is a tool for determining the quality of radon production from the material.

Gamma radiation refers to dose-rate expressed in µSv/h (micro sievert per hour) from the material.

3. Principle for the method

The activity concentration of gamma-emitting radionuclides in the construction material is determined with gamma spectrometry. The activity concentration is a property of the material and not a function of the physical form of the construction product.

The activity concentration is measured in a sample of 150 mm x 150 mm x 150 mm ± 5 mm.

The sample is placed in a sample chamber with predefined geometry.

This determination of activity concentration in a sample reflects the building material under the intended form of use.

The calculation of activity index, radium index and gamma radiation is performed and is reported in the report to the client.

The measurement is instantaneous and can be performed at all times during the year.

4. Measurement method

4.1 Measurement instrument

The measurement of gamma spectra must be done with a gamma spectrometer.
The following is recommended for the gamma spectrometer:
A detector (BGO crystal) with a volume exceeding 100 cm^3, and is shielded as required with, for example, steel mantled lead. Detection limit of the measurement instrument must be known so that the obtained measurement result can be compared to it for the quality assurance purposes;

The instrument shall be equipped with an efficient and continuous operating compensation for spectrum positioning. The instrument shall use the radioactivity of the measurement object for this purpose;

Equipped with memory function and automatic transfer of measurement data to defined network;

Calibration function programme for background checks;

A NORM-based verification cube for control measurement before each measurement series, supplied by the instrument producer or other authorised party.

The table below shows the internationally recommended channels, which shall be used for the analysis

Analyzed element	Isotope used	Gamma energy, MeV	Energy interval, MeV
Potassium	K-40	1,46	1,33 – 1,59
Uranium	Bi-214	1,76	1,63 – 1,89
Thorium	Tl-208	2,61	2,46 – 2,77

4.2 Calibration

The calibration must be performed by the instrument manufacturer or other authorized party with a minimum of two-year interval.

The calibration certificate must show traceability against the primary calibration source for NORM according to IAEA/AL/148.

4.3 Sample preparation

The construction material in solid state shall be of the following geometry (volume): outer dimensions of 150 mm x 150 mm x 150 mm ± 5 mm. The sample is placed in the sample chamber.

Minimum of two samples from the same production batch.

The building material in loose state consist of a volume of ≥ 10 litres. The sample is placed in the sample chamber which has a geometry (volume) with the inner dimensions of 150 mm x 150 mm x 150 mm ± 5 mm.

Minimum of two samples from the same production batch.

The relative humidity should be less than 90 %, alternatively with a moisture ratio of the material that meets the requirements for the specified material.

The sample temperature should be in the range from + 5 degrees Celsius to + 60 degrees Celsius.

4.4 Sample chamber

The sample chamber shall be made of a material with high absorption of gamma radiation, for instance of lead with a thickness of ≥ 50 mm, shielded against external gamma radiation. The sample chamber inner dimensions are 160 mm x 160 mm x 160 mm ± 1 mm.

4.5 Measurement and measurement time

The measurement is performed on the surface directly on the sample with an instrument that reports the radioactive natural nuclides in % for potassium, ppm for uranium and ppm for thorium.

Minimum measurement time = 300 seconds.

The measurements shall be carried out at least twice on each sample. The result is given by the mean value of all measurements on a sample.

4.6 Background correction

The sample is shielded from external background radiation from the soil, from cosmic background radiation as well as from other materials in the environment.

The sample chamber is shielded by, for instance ≥ 50 mm lead, so that the external background radiation is reduced by a factor ≥ 5.

No correction of the reported values is made other than within the measurement uncertainty calculation.

5. Calculation of index and gamma radiation

The element Uranium in the calculations (C_{Ra}) refers to the content of radium or equivalent amount of uranium.

5.1 Radium index (RI)

Element	Content	Activity concentration, Bq/kg
U – Uranium 238/235	1 ppm	12,35*

The radium index of the material is calculated as follows:

$RI = (C_{Ra} \times 12{,}35) \div 200;$

where
C_{Ra} = content of radium (uranium 238/235) in the unit ppm.

5.2 Activity index (AI)

Element	Content	Activity concentration, Bq/kg
K – Potassium	1 %	313
U – Uranium 238/235	1 ppm	12,35*
T – Thorium	1 ppm	4,06*

The activity index of the material is calculated as follows:

$AI = (C_K \times 313) \div 3000 + (C_{Ra} \times 12{,}35) \div 300 + (C_{Th} \times 4{,}06) \div 200$;

where
C_K = content of potassium in the unit %.
C_{Ra} = content of radium (uranium 238/235) in the unit ppm.
C_{Th} = content of thorium in the unit ppm.

5.3 Gamma radiation (µSv/h)

Element	Content	Dose rate, µSv/h	Dose rate, µR/h
K – Potassium	1 %	0,0151	1,505
U – Uranium 238/235	1 ppm	0,0065	0,653
T – Thorium	1 ppm	0,0029	0,287

The gamma radiation is calculated, on a flat surface 2π measurement, as follows:

$\mu Sv/h = (C_K \times 0{,}0151) + (C_{Ra} \times 0{,}0065) + (C_{Th} \times 0{,}0029);$

where
C_K = the content of potassium in the unit %.
C_{Ra} = the content of radium (uranium 238/235) in the unit ppm.
C_{Th} = the content of thorium in the unit ppm.

6. The calculation work before presentation of the report

The calculation is performed in 3 steps as follows:

Step 1
Sample No. 1 measurement (No 1 + No 2)/2 = Sample mean value result.
Sample No. 2 measurement (No 1 + No 2)/2 = Sample mean value result.

Step 2
(Sample No 1 mean value result + Sample No 2 mean value result)/ 2 =
Mean value for the sample (material in the production batch).

Step 3
Activity index, radium index and gamma radiation are calculated and are documented in the report.

6. Measurement uncertainty

Is based on the following:

Measurement time uncertainty 300 seconds	$*X_t$
Activity concentration	$*X_a$
Calibration uncertainty	$*X_c$
Cosmic background radiation	$*X_s$

Measurement reliability for individual components (K, U and Th) increases with the level of activity. The reliability for the level that corresponds to their minimum determinable activity shall be taken as minimal level. See instrumental detection limit.

Total measurement uncertainty calculation (K2):

$$K2 = \sqrt{(X_t^2 + *X_a^2 + *X_c^2 + *X_s^2)}, (\%)$$

7. Report

The report on the measurement shall include the following information:

- Requesting organisation
- Place and responsible person
- Time of the measurement
- Manufacturer of samples contact details and address of production site
- Identification of the sample tested
- Sample dimensions/volume, temperature and humidity
- Institution or company that performed the measurement
- Measurement method
- Type of measurement instrument
- Date of calibration
- Measured mean activity concentration per sample, Bq/kg
- Calculated activity index (AI), radium index (RI) and gamma radiation value with associated measurement uncertainty (K2, increased measurement uncertainty)
- Detection limit of the measurement instrument
- Signature measurement responsible person and the quality controller.

References

**1. Naturally Occurring Radioactivity in the Nordic Countries – Recommendations the Radiation Protection Authorities in Denmark, Finland, Iceland, Norway and Sweden, 2000 ISBN 91-89230-00-0.*
**2. Radiological Protection Principles concerning the Natural Radioactivity of Building Materials, EC RP 112 (1999), 1999.*
**3. IAEA-TECDOC-1363 Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data (ISBN:92-0-108303-3).*
**4. IAEA-RL-148 Preparation and Certification of IAEA Gamma-Ray Spectrometry Reference Materials.*
**5. SS-EN 206:2013+A1:2016 Concrete - Specification, performance, production and conformity.*