STUK

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THE RADIOACTIVITY OF BUILDING MATERIALS AND ASH

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Authorization

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Under section 70, paragraph 2, of the Radiation Act (592/1991), STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

Translation. In the event of any differences in interpretation of this guide, the Finnish and Swedish versions shall take precedence over this translation.

1 General

All building materials contain small amounts of radioactive substances. Building materials originating from rock and soil contain mainly natural radioactive substances. These substances include the radioactive substances in the uranium and thorium decay series (^{238}U and ^{232}Th) and the radioactive isotope of potassium (^{40}K). In addition to natural radioactive substances, some industrial by-products also contain radionuclides, caesium (^{137}Cs) in particular, which are spread into the environment due to fallout from nuclear weapons tests and industrial nuclear accidents. If such a by-product is incorporated into building material, the final product will also contain these artificial radionuclides.

Ash, which is generated during combustion of peat, coal, wood, forest processed chips, field biomass, by-products of wood industry or other comparable materials, contains both natural radioactive substances and artificial radionuclides originating from fallout. In this guide, "ash" means any ash being generated in the combustion of the substances listed above. Ash is used as landfill, in landscaping, and as an additive in concrete. It is also used as bulk material under roads, taken to dumps, or mounded.

This guide applies to all building materials to be introduced into the market. The guide presents the action levels related to limiting gamma radiation exposure caused by materials used in building construction, or in road, street or related building work, or by materials used in mounding, landfill, or landscaping. It also presents the action levels for the handling and disposal of ash. In addition, it presents the guidelines for the action levels.

This guide applies only to external gamma radiation caused by materials. The guide applies only to naturally occurring radioactive substances and radionuclides spread into the environment as a result of radioactive fallout. This guide does not apply to radioactive substances produced in nuclear industry or in the use of radiation.

2 The radioactivity of building materials and ash is limited through action levels

The purpose of the action levels laid down for building materials and ash is to limit the radiation exposure due to the radioactivity of these materials. In this Guide, "action level" stands for the excess of effective dose due to their gamma radiation to the dose from radioactive nuclides in the ground.

If it is discovered or there is reason to suspect that the radioactivity in building materials or ash is liable to cause doses greater than action level, the party running the radiation practice (hereafter the responsible party) is required to investigate the radiation exposure caused by the practice. The report of the investigation shall be made available to the Radiation and Nuclear Safety Authority (STUK). When necessary, STUK will issue instructions on limiting the exposure.

Materials used in building construction

The action level for the radiation dose of the public due to the gamma radiation caused by building materials used in building construction is 1 mSv per year.

When ash is used as an additive in any building material intended for use in building construction, the excess of effective dose due to gamma radiation from the caesium (^{137}Cs) in the ash, to the dose caused by the other building materials, shall not exceed 0.1 mSv per year. However, the total dose due to building material shall not exceed 1 mSv per year.

Materials used in road, street and related construction work

The action level for the radiation dose of the public due to the gamma radiation caused by materials used in road, street, yard, and related construction work is 0.1 mSv per year.

Mounding, landfill and landscaping
The action level for the radiation dose of the public due to the gamma radiation caused by landfill and mounding materials, and materials used in landscaping is 0.1 mSv per year.

Handling of ash
The action level for a worker's radiation dose due to handling ash is 1 mSv per year (effective dose). Guidelines regarding the radiation exposure of workers are presented in Guide ST 12.1.

Provisions concerning the investigation of operation liable to cause exposure to natural radiation are laid down in section 45 of the Radiation Act (592/1991). Provisions concerning the duty of the responsible party to report the results of the investigation to STUK are laid down in section 26 of the Radiation Decree (1512/1991). Provisions concerning limiting a worker's exposure to natural radiation are laid down in section 27 of the Radiation Decree.

3 Activity index to assess exceeding of action levels

Activity indexes are used to assess whether or not the action level is exceeded. The activity index is calculated from activity concentration measurements of the material.

When activity indexes are calculated, radium (^{226}Ra) in the uranium decay series, thorium (^{232}Th) in the thorium decay series, potassium (^{40}K) and caesium (^{137}Cs) from fallout are taken into account. Other nuclides may need to be taken into consideration in special cases.

If the activity index exceeds 1, the responsible party is required to show specifically that the relevant action level set for the particular material is not exceeded. The report of the investigation shall be made available to the STUK. If the activity index is 1 or less than 1, the material can be used, so far as the radioactivity is concerned, without restriction.

If necessary, the radiation exposure due to the practice can be investigated case-specifically without a separate examination of the activity index.

3.1 Materials used in building construction

The activity index I_1 for final building materials intended for use in building construction is

$$I_1 = \frac{C_{Th}}{200} + \frac{C_{Ra}}{300} + \frac{C_K}{3000},$$

where C_{Th}, C_{Ra} and C_K are the activity concentration values of ^{232}Th, ^{226}Ra and ^{40}K in the final product expressed in Bq kg^{-1}. "Final building material" refers to e.g. building boards and concrete dried to operating moisture content.

Activity index I_1 is also applied for filling materials used under buildings.

If the activity index I_1 is 1 or less than 1, the material can be used as building material, so far as radioactivity is concerned, without restriction.

In case of surface materials and other materials with a minor use in building construction (such as thin tiles), no separate investigation is needed if the activity index I_1 of the material is less than or equal to 6.

3.2 Materials used in road, street and related construction work

The activity index I_2 for materials used in road, street and related construction work is

$$I_2 = \frac{C_{Th}}{500} + \frac{C_{Ra}}{700} + \frac{C_K}{8000} + \frac{C_{Cs}}{2000},$$

where C_{Th}, C_{Ra}, C_K and C_{Cs} are the activity concentration values of ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs in the material, expressed in Bq kg^{-1}.

If the activity index I_2 is 1 or less than 1, the material can be used, so far as radioactivity is concerned, without restriction.

In case of materials with a restricted use (such as usual paving stones or paving tiles), no separate investigation is needed if the activity index I_2 of the material is equal to or less than 1.5.

3.3 Materials used in mounding, landfill and landscaping

The activity index I_3 for materials used in mounding, landfill and landscaping is

$$I_3 = \frac{C_{Th}}{1500} + \frac{C_{Ra}}{2000} + \frac{C_K}{20000} + \frac{C_{Cs}}{5000},$$

where C_{Th}, C_{Ra}, C_K and C_{Cs} are the activity

concentration values of ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs in the material, expressed in Bq kg^{-1}.

If the activity index I_3 is 1 or less than 1, the material can be used, so far as radioactivity is concerned, without restriction.

3.4 Handling of ash

The activity index I_4 for handling of ash is

$$I_4 = \frac{C_{Th}}{3000} + \frac{C_{Ra}}{4000} + \frac{C_K}{50000} + \frac{C_{Cs}}{10000},$$

where C_{Th}, C_{Ra}, C_K and C_{Cs} are the activity concentration values of ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs in dry ash, expressed in Bq kg^{-1}.

If the activity index I_4 is equal to or less than 1, then so far as radioactivity is concerned, no restrictions are laid down for handling the ash or for disposing of the ash in a controlled landfill site without a separate investigation.

If the activity index I_4 exceeds 1, the protection of workers involved in ash handling shall be dealt with as laid down in Guide ST 12.1.

4 Safety shall be ensured

4.1 Obligations of the responsible party

The responsible party shall ensure that all aspects of radiation safety regarding production, use, handling and disposal of ash and materials are met. Furthermore, the responsible party shall ensure that all investigations and measurements needed to guarantee safety are carried out.

The professional producer of such materials, their refiner and their user are all obligated to inform the next user in the chain of the radioactivity contained by the material.

4.2 Practical guidelines

When must stone aggregate in building construction be investigated?

It is necessary to measure the activity concentration of any stone aggregate intended for use in building construction if it is acquired from an area in which background radiation from the ground is known to be greater than the usual. However, the activity concentrations of all stone aggregates used in building element production shall be measured everywhere in Finland.

Industrial wastes and by-products incorporated as additives into building materials

When there are plans to incorporate industrial by-products or wastes as additives into building materials intended for use in building construction and it is discovered or there is reason to suspect that these contain radioactive substances referred to in this guideline in greater amounts than the usual, the activity concentrations of these final products shall be measured. Where necessary, radioactive nuclides other than those listed in chapter 3 shall be taken into consideration as well. If a by-product or waste containing radioactive substances is incorporated into building material, it must be confirmed that the action level of 1 mSv per year laid down in the third paragraph of chapter 2 is not exceeded.

Fuel peat

The radioactivity of fuel peat should be measured especially where the area of the peat bog under production is larger than 50 hectares or where the annual peat production exceeds 20 000 m^3. If the ash percent is not known, the activity concentration of a nuclide in peat ash can be estimated by multiplying the activity concentration of that nuclide in peat by 20.

Use of material when the activity index is greater than 1

If activity index I_2 or I_3 exceeds the value 1, material can often be used for the purposes described in items 3.2 and 3.3, provided that the material is covered with a sufficiently thick layer of material that absorbs gamma radiation. In such cases, the thickness of the absorbing material layer shall be separately determined. A report of the investigation shall be delivered to the STUK for approval.

Mounding of ash

To safeguard against the inhalation of radioactive substances, ash mounds shall always be covered by a material layer that prevents dust from rising.

Ash as an additive in concrete

When ash is used as an additive in concrete, the action level 0.1 mSv per year presented in paragraph 4 of chapter 2 is not exceeded, if the activity concentration of the ^{137}Cs in the ash is less than 1 000 $Bq \cdot kg^{-1}$ and the portion of ash in concrete is 120 $kg \cdot m^{-3}$, maximum. If the portion of ash is less, its activity concentration may be greater, respectively.

When ash containing ^{137}Cs is used in concrete production for building construction, it must be ascertained, in addition to the above, that the radiation exposure due to the total of the raw materials in the concrete does not exceed the action level of 1 mSv per year.

Representativeness of material samples and determination of activity concentrations

The activity concentrations of building materials and ash are determined on the basis of samples taken from the material or ash. If there is reason to suspect that the activity concentration of the building material or ash varies remarkably, sampling shall be planned in such a way that the measured samples reliably represent all of the material or ash in the respective lots. The measurements shall be carried out using a method designed for activity concentration measurement. The measuring equipment must be calibrated in an appropriate way.

More information

The bases of activity index calculations and the calculation methods for the assessment of radiation doses caused by materials are presented in bibliographical reference 2 of this Guide.

Bibliography

1. European Commission. Radiological protection principles concerning the natural radioactivity of building materials. Radiation Protection 112. Luxembourg: Office for Official Publications of the European Communities; 2000.
2. Markkanen M. Radiation dose assessments for materials with elevated natural radioactivity. Report STUK-B-STO 32. Helsinki: Radiation and Nuclear Safety Authority; 1995.

APPENDIX

Definitions and concepts

Activity

The activity A of a radionuclide is the number of spontaneous nuclear transformations dN taking place in the relevant number of nuclides N in a time interval dt, divided by this time interval:

$$A = \frac{dN}{dt}$$

The unit of activity is the Becquerel (Bq). 1 Bq = 1 s^{-1}.

Activity index

Activity indexes are used to assess whether or not the action level is exceeded. The activity index is calculated from activity concentration measurements of the material.

When activity indexes are calculated, radium (^{226}Ra) in the uranium decay series, thorium (^{232}Th) in the thorium decay series, potassium (^{40}K) and caesium (^{137}Cs) from fallout are taken into account. Other nuclides may need to be taken into consideration in special cases.

Activity concentration

The activity concentration c is the activity A of a radioactive substance in the monitored volume or mass, divided by the said volume V or mass m:

$$c = \frac{A}{V} \text{ or } c = \frac{A}{m}.$$

The unit of activity concentration is $Bq \cdot m^{-3}$ or $Bq \cdot kg^{-1}$.

Activity concentration is most commonly used when measuring radioactive substances in air. The activity concentration of radon in inhaled air is generally abbreviated to radon concentration.

The quantity obtained on dividing by the volume may also be called the volume activity and the quantity obtained on dividing by the mass may also be called the mass activity.

Dose

In this Guide, a dose means the effective dose. The effective dose is used to assess the effects of radiation detrimental to human health. The unit of effective dose is sievert (Sv). Its multiples, millisievert (mSv) and microsievert (µSv), are often used. 1 Sv = 1 000 mSv = 1 000 000 µSv.

Party running a radiation practice (the responsible party)

In this Guide, a party running a radiation practice (responsible party) means any business or sole trader, enterprise, corporation, or institution engaged in operations in which the exposure of human beings to natural radiation causes or is liable to cause a detriment to health.