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| APPROVEDby Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_\_ dated \_\_\_\_\_\_\_\_\_\_ 2025 |

**Safety Guide
in the Use of Atomic Energy
“Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities”**

**(RB-042-24)**

1. General
2. The Safety Guide in the use of atomic energy “Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” (RB 042 24) (hereinafter referred to as the Safety Guide) has been developed to facilitate compliance with the requirements of clauses 6 and 67 of the federal rules and regulations in the field of the use of atomic energy “Safety in Radioactive Waste Management. General Provisions” (NP-058-14)[[1]](#footnote-2), clauses 24 and 60 of the federal rules and regulations in the field of the use of atomic energy “Radioactive Waste Disposal. Principles, Criteria and Basic Safety Requirements” (NP 055-14)[[2]](#footnote-3), clauses 8 and 18 of the federal rules and regulations in the field of the use of atomic energy “Near-Surface Disposal of Radioactive Waste. Safety Requirements” (NP-069-14)[[3]](#footnote-4) (hereinafter referred to as NP-069-14), as well as clause 21 of the federal rules and regulations in the field of the use of atomic energy “Safety Requirements for Special Radioactive Waste Disposal Sites and Special Radioactive Waste Preservation Sites” (NP-103-17)[[4]](#footnote-5).
3. The Safety Guide contains recommendations of the Federal Environmental, Industrial and Nuclear Supervision Service for selection, justification of selection and application of BCMs (see the list of abbreviations in Appendix No. 1 to the Safety Guide) in the development of ESBs for RW storage facilities intended for storage of special RW (SRWDFs and SRWPFs) and RW storage facilities intended for near-surface disposal of RW without the intention of its subsequent retrieval (NSRWDFs, including tailing NSRWDFs).
4. The Safety Guide applies to activities on RW storage facility operation, including conversion of SRWDFs and SRWPFs into SRWPFs and NSRWDFs, respectively, siting, design, construction, operation and closure of NSRWDFs in terms of justification of selection of BCM-based ESBs and their application as part of RW storage facilities.
5. The Safety Guide is recommended for use by:

organizations involved in the operation of RW storage facilities, siting, design, construction and closure of NSRWDFs;

organizations performing activities and/or providing services to operating organizations on design, construction, operation and decommissioning (closure) of the said facilities, including performance of research and development for BCM-based ESBs.

1. General recommendations on justification of selection and application of barrier clay materials in radioactive waste storage facilities
2. BCMs (products of processing of clay raw materials used for the making of ESBs) should be used for the making of the following types of ESBs of RW storage facilities:

buffer barriers;

impervious top[[5]](#footnote-6), bottom[[6]](#footnote-7) and side shields;

impervious curtains.

1. Structural and spatial solutions for the making of BCM-based ESBs, including the selection of types of BCM-based ESBs (for a recommended diagram of the process of selection of BCM-based ESBs and its justification see Appendix No. 2 to the Safety Guide) and the safety functions to be performed by them (for recommended safety functions of different types of BCM-based ESBs see Appendix No. 3 to the Safety Guide) should be envisaged in the design and justified in the SAR of RW storage facilities on the basis of:

results of engineering surveys conducted in the area and on the site of RW storage facilities;

design features of RW storage facilities, including the method of RW placement (burial) (in structures located above, at the same level or below the ground surface at a depth of up to one hundred meters);

assessment of mutual influence of ESBs (being designed and/or existing), including corrosion aggressiveness of ESB materials;

safety classes of BCM-based ESBs to be adopted in the design of RW storage facilities in accordance with the federal rules and regulations in the field of the use of atomic energy “General Safety Provisions of Nuclear Fuel Cycle Facilities” (NP-016-05)[[7]](#footnote-8);

composition and characteristics of ESBs not based on BCMs;

geotechnical, climatic and other natural and anthropogenic conditions of the area and site of RW storage facilities;

class of RW disposed (to be buried), its volume, activity and characteristics in accordance with the nomenclature established by the federal rules and regulations in the field of the use of atomic energy “Criteria of Acceptability of Radioactive Waste for Disposal” (NP-093-14)[[8]](#footnote-9)

availability of proven technologies that have been tested in engineering and construction practice and the possibility of their implementation in RW storage facilities;

results of a comprehensive engineering and radiation survey of RW storage facilities;

results of radiation control and monitoring of RW storage facilities;

results of predictive analyses of LTSA of RW storage facilities;

economic factors.

1. BCMs should be selected and justified on the basis of:

structural and spatial solutions for the making of BCM-based ESBs;

analysis of available sources of BCMs, including assessment of reserves, consistency of composition, structure and properties, possibility of supplying batches of required volumes with specified characteristics;

quantitative values of indicators of composition, structure and properties of BCMs provided by the supplier and/or obtained by laboratory tests.

1. In addition to the main sources of BCMs, additional sources of BCMs should be provided for in case of supply interruption from the selected source or non-compliance of BCMs with the quantitative values of composition, structure and properties established in the design when supplying the next batch.
2. Laboratory tests to determine the characteristics of BCMs should be performed in laboratories that comply with sections 1-8 of GOST ISO/IEC 17025 “Interstate Standard. General Requirements for the Competence of Testing and Calibration Laboratories” introduced on September 1, 2019 by Order of the Federal Agency for Technical Regulation and Metrology dated July 15, 2019.
3. At all stages of the making of BCM-based ESBs, quality control of BCMs and BCM-based ESBs should be carried out in accordance with Section 12 of GOST 27751-2014 “Interstate Standard. Reliability of Building Structures and Foundations. Basic Provisions” enacted from July 1, 2015 by Order of the Federal Agency for Technical Regulation and Metrology No. 1974-st dated December 11, 2014.
4. When using processes and technologies that have not been previously used in the making, construction and monitoring (control) of BCM-based ESBs, pilot testing should be carried out on experimental test benches as part of research and/or development.
5. Quality assurance programs for RW storage facilities developed in accordance with the federal rules and regulations in the field of the use of atomic energy “Requirements for Quality Assurance Programs for Nuclear Energy Facilities” (NP-090-11)[[9]](#footnote-10) should include provisions for quality assurance of BCM-based ESBs, including those when selecting BCMs, when designing and constructing BCM-based ESBs.
6. Recommendations to justify the selection of barrier clay materials depending on the safety functions performed by engineered safety barriers based on them
7. Selecting and justifying a BCM should be based on the need for BCM-based ESBs to fulfill the safety functions specified in Appendix No. 3 to the Safety Guide for the RW storage facility design during the service life without maintenance and repair justified in the design.
8. The performance of safety functions of BCM-based ESBs should be justified on the basis of quantitative indicators of functional properties of BCMs responsible for the performance of safety functions of BCM-based ESBs and determining filtration, migration, deformation, strength, and rheological characteristics of BCM-based ESBs and their swelling indicators.
9. Quantitative values of indicators of functional properties of BCMs should be determined in the course of laboratory tests on the basis of:

values of the indicators of technological characteristics of BCM-based ESBs established when designing BCM-based ESBs;

composition, structure, properties and technical characteristics of BCMs studied at the stage of their selection.

Recommended characteristics and indicators of BCMs, including as part of ESBs, and methods of their determination are given in Annex No. 4 to the Safety Guide.

1. It should be taken into account that the list of required characteristics and indicators of BCM properties can be extended in the design to carry out predictive analyses of the LTSA of the RW storage facilities depending on the parameters used in the analysis models.
2. If the results of the predictive analyses of the LTSA of RW storage facilities show that the designed BCM-based ESBs with the obtained quantitative values of the indicators of the functional properties of BCMs will not ensure the fulfilment of the safety functions, it is necessary to revise the structural and spatial solutions for the making of BCM-based ESBs and/or selection of BCMs, or to develop other design solutions affecting the prevention of RW radiation impact on the public and the environment.
3. Quantitative values of the indicators of the functional properties of BCMs, at which, based on the results of the predictive analyses of a RW storage facility, the established safety functions of BCM-based ESBs are ensured, should be given in the design and justified in the SAR of RW storage facilities.
4. Recommendations for the use of barrier clay materials in radioactive waste storage facilities
5. When designing buffer barriers, the placement of BCM-based buffer materials[[10]](#footnote-11) should be envisaged in the internal space of RW storage facilities in a way that ensures maximum possible filling of voids. When selecting a BCM-based buffer material, the swelling ability of BCMs should be used as a determining property.
6. When designing buffer barriers, it should be taken into account that the contact of a BCM-based buffer material with water may result in the formation of cavities and, as a consequence, deterioration of the functional properties of the buffer barriers.
7. When designing the top, bottom and side shields of RW storage facilities, impervious layers should be provided by means of layer-by-layer compaction of BCMs at optimum moisture content determined in accordance with Sections 3, 4 and 8 of GOST 22733-2016 “Interstate Standard. Soils. Method of Laboratory Determination of Maximum Density,” enacted on January 1, 2017 by the order of the Federal Agency for Technical Regulation and Metrology No. 891-st dated July 28, 2016.
8. When designing impervious curtains envisaged to limit further migration of radionuclides released from RW storage facilities, Section 8 of SP 250.1325800.2016 “Buildings and Structures. Protection from Groundwater” approved by Order of the Ministry of Construction, Housing and Communal Services of the Russian Federation No. 484/pr dated July 8, 2016 should be applied.
9. When designing BCM-based ESBs, the impact of new hazardous geologic and geotechnical processes that may become active during the construction of BCM-based ESBs should be assessed.
10. In order to limit the penetration of atmospheric water into the inner space of RW storage facilities, as well as to preserve the functional properties of impervious layers, the top screens should be arranged using the following:

drainage layer of sand and/or gravel;

protective layer of local soil;

soil and vegetation cover;

capillary-breaking layer (should be used in the SRWDF top shields (when converted to SRWPFs and/or NSRWDFs), where the buffer barrier and impervious layer of the top shield have direct contact).

1. One or more impervious layers should be provided in the top, bottom and side shield structures.
2. In order to form an integral BCM-based ESB (clay retainer) around RW storage facilities, the roof and bottom of the impervious layers of the side shields should be covered with impervious layers of top and bottom shields, respectively.
3. If natural clay soils with the thickness and quantitative values of the indicators of the functional properties, which ensure the performance of safety functions of the impervious layer of the bottom shield, lie directly under the RW storage facility structure, impervious layers should not be built in the base of the RW storage facilities or their thickness should not be limited.
4. In order to preserve the functional properties of BCMs of the impervious layers and to reduce the water permeability of the top, bottom and side shields, impermeable geosynthetic rolled materials (geomembranes, bentonite mats) should be placed on the inner side of the impervious layers. The requirements to characteristics of the said materials should be defined in the design of RW storage facilities in accordance with the manufacturers’ technical specifications.
5. When swelling BCMs are used as part of BCM-based ESBs, also as additives, the possible impact of BCM swelling on the functioning of ESBs should be assessed, and BCM-based ESBs should be designed on the basis of the assessments.
6. Quality requirements for the materials used as additives to BCMs and the integrated compositions should be established and justified in the design and presented in the SAR of RW storage facilities.
7. When mixtures of two or more BCMs are used to make BCM-based ESBs, the selection of the BCM composition should be justified in laboratory conditions.
8. Characteristics of composition, structure and property indicators of mixed BCMs should be determined both for the mixture as a whole and for each of its components separately. The results of laboratory tests of selected mixed BCMs should be given in the design and SAR of RW storage facilities with indication of the mass ratio of the mixed components.
9. For mixed BCMs, uniformity of composition (consistency of composition and properties for the entire amount of the BCM used) should be achieved.
10. In the absence of the possibility of industrial processing of BCMs at the supplier’s facility, production sites should be envisaged for preparation of necessary BCM compositions and pilot testing of the processes and technologies of BCM-based ESB construction at the sites of RW storage facilities.
11. Recommendations for quality control and assurance of barrier clay materials at radioactive waste storage sites prior to and during the construction of engineered safety barriers
12. In order to ensure the quality of BCMs intended for the making of BCM-based ESBs of RW storage facilities, the following should be performed when accepting BCMs at the sites of RW storage facilities:

incoming control of BCMs;

acceptance of BCMs for accounting;

preparation for placement and placement of BCMs for temporary storage.

1. For all batches received, incoming control of BCMs should include:

control of availability of accompanying documentation certifying the quality and completeness of BCMs;

control of the integrity of the packaging of BCMs (if any);

control of composition, structure, properties and technical characteristics of the supplied BCMs with laboratory tests in accordance with the requirements for the indicators of specific types of BCMs established in the design of the RW storage facilities;

registration and documentation of the results of control of the indicators of tested BCMs in the logbooks (incoming control).

1. BCM samples should be transported and stored in accordance with section 4 of GOST 12071-2014 “Interstate Standard. Soils. Selection, Packing, Transportation and Storage of Samples” introduced on July 1, 2015 by Order of the Federal Agency for Technical Regulation and Metrology No. 2023-st dated December 12, 2014.
2. If the test results show that BCMs do not comply with the quantitative values of the indicators for at least one of the indicators established in the design, and if the results of repeated tests are unsatisfactory, the use of this BCM batch should be rejected.
3. In order to preserve the quality of BCMs to be used for ESB construction, the following should be ensured at the sites of the RW storage facilities:

placement of BCMs in temporary storage warehouses in accordance with the requirements of the BCM supplier to storage conditions;

integrity of BCM packaging (if any);

reduction of the influence of external factors on BCMs in terms of composition, structure and properties of BCMs.

1. BCMs should be stored in covered warehouses or bunkers separately by grades. In order to maintain the established indicators of BCMs, they should be temporarily stored in accordance with the BCM supplier’s and/or manufacturer’s requirements to BCM storage conditions, including the prevention of clogging and contamination of BCMs, as well as their flooding as a result of exposure to atmospheric water.
2. When placing BCMs for temporary storage, they should be handled in accordance with sections 1-6 of GOST 12.3.009-76 “Handling. General Safety Requirements” enacted on January 1, 1977 by the Resolution of the State Standards Committee of the USSR Council of Ministers No. 670 dated March 23, 1976.
3. When constructing BCM-based ESBs, the requirements of the siting design of RW storage facilities should be followed to ensure the functional properties of RW storage facilities, including preventing the construction of impervious layers during precipitation and/or waterlogging of the RW storage facility site.
4. Prior to the start of the work on construction of BCM-based ESBs, a working plan and process flow charts should be developed, which should specify the controlled parameters and methods of their control.
5. When constructing BCM-based ESBs, general and special work logs (log of incoming control of construction materials, including BCMs, structures and equipment) should be kept, and as-built documentation should be drawn up in accordance with the procedure established by the urban planning legislation.
6. Immediately prior to the construction of BCM-based ESBs, the moisture content of the stored BCMs should be measured to determine whether action to bring the BCMs to optimum moisture content (wetting or drying) is required.
7. If the BCMs provided for in the design of RW storage facilities are replaced with other BCMs, this replacement should be made provided that their functional properties are not worse than those specified in the design of RW storage facilities.
8. The following should be monitored when constructing buffer barriers:

constancy of the process parameters in accordance with the process flow chart when making a BCM-based buffer material;

uniformity of filling the internal space of RW storage facilities with a BCM-based buffer material;

consumption rate of the used BCMs, on the basis of which the density of the created buffer material should be determined by calculation.

1. The following shall be monitored when constructing impervious layers:

preparation of the bases of foundation pits and trenches in accordance with the design (for bottom and side shields);

thickness of the BCM filled-in layer;

number of passes (blows) of soil compacting machines on one trail;

sampling in the impervious layer under construction and subsequent sealing of the sampling locations;

preparation of the surface of the previous layer for filling the subsequent layer;

uniformity of the compaction factor and the resulting density of the impervious layer.

1. The following should be monitored when constructing the impervious curtains:

integrity and high continuity of the impervious curtains;

sampling in the impervious curtain under construction and subsequent sealing of the sampling locations.

1. The value of the compaction factor and the required skeletal density of compacted BCMs should be monitored for compliance with the BCM indicators established in the design of RW storage facilities for each type of BCM-based ESBs.
2. BCMs should be compacted at air and clay temperature above 0°C and at optimum humidity, unless otherwise stipulated by the design of the RW storage facilities.
3. If the impervious layer technology involves wetting BCMs to achieve optimum moisture content directly at the production site, the chemical composition of the water to be used or the source of the water intake (e.g. water intake well, water body) should be specified in the process flow chart so that the water used does not adversely affect the functional properties of the impervious layer BCMs.
4. If the acceptance results show that the skeletal density values deviate from the required value specified in the design of RW storage facilities, taking into account the deviation allowed by the design and the error of the measurement method, compensatory measures aimed at fulfilling the established safety functions of BCM-based ESBs should be provided.
5. In the case of phased construction and/or upon completion of the impervious layers, measures should be taken to prevent any change in their characteristics until the subsequent protective layers and top structures are in place.
6. If geosynthetic materials are used as part of the top, bottom and side shields, their individual sheets should be bonded in accordance with the construction practice specified by the manufacturer; while geomembranes should be bonded by welding the sheets together; bentonite mats should be laid in an overlapping manner without stitching, and the joints should be filled with bentonite granules for horizontal surfaces or coated with bentonite paste for vertical surfaces.
7. The geosynthetic materials installed as part of the top and side shields should be protected from wetting before the weighting layer is placed on top of them.
8. To protect the geosynthetic materials (geomembranes and bentonite mats) from tensile or tearing damage, a layer of leveling soil or a compacted subgrade free of debris, sharp rocks, plants, wide or deep cracks and signs of soil swelling should be arranged prior to their installation.
9. Recommendations for monitoring the condition of engineered safety barriers based on barrier clay materials
10. When performing periodic radiation control and monitoring at the stages of operation, construction, closure and post-closure of RW storage facilities, their integrity should be monitored to confirm that BCM-based ESBs fulfill the safety functions established by the design of RW storage facilities.
11. Monitoring of the integrity of BCM-based ESBs should be performed in accordance with the ESB monitoring program approved by the operating organization using direct and indirect methods during the entire period of radiation control and monitoring with the frequency established in the design of RW storage facilities.
12. The methods, technical means, duration and scope of monitoring BCM-based ESBs should be determined and justified in the design and SAR of RW storage facilities, including that on the basis of their siting conditions.
13. The integrity of BCM-based ESBs should be monitored by methods the application of which will not compromise the integrity of ESBs.
14. The recommended methods for monitoring the integrity of BCM-based ESBs should include:

stress and strain measurement methods, including tensity-resistive, piezoelectric and piezoresistive methods;

geodetic methods of control, including geometric and trigonometric leveling methods, scanning methods using optical, electronic and laser scanners;

stationary regime observations of groundwater through a system of monitoring and observation wells located in the territory around RW storage facilities (determination of absolute levels and depths of free and piezometric surfaces of aquifers, sampling of aquifers for radiation and chemical analysis);

geophysical monitoring methods, including seismic, electrical and radioactive logging methods.

1. In selecting and justifying the method of monitoring the integrity of BCM-based ESBs, the need to monitor the condition of other ESBs, including building structures, should be taken into account.
2. When analyzing samples taken from monitoring wells, the specific activity values of radionuclides[[11]](#footnote-12) in the samples should be compared with the specific activity values of these radionuclides measured prior to the construction of BCM-based ESBs (background values).
3. If radionuclides are detected in groundwater outside ESBs in amounts exceeding the background values, the location (a separate structure or part of an RW storage facility, module, compartment, ESB) and intensity of their release, and dynamics of changes in specific activity of radionuclides and groundwater levels in monitoring wells should be established, and appropriate technical solutions should be developed and taken to minimize possible radiation impact on the environment, e.g., to provide for the making of additional BCM-based ESBs, including impervious curtains.
4. Based on the results of monitoring of the condition of BCM-based ESBs, technical and organizational solutions should be provided for the maintenance of BCM-based ESBs and elimination of identified deficiencies that reduce the safety functions of BCM-based ESBs.
5. The results of monitoring BCM-based ESBs should be taken into account when assessing the current safety level and conducting LTSA of RW storage facilities.
6. Recommendations to justify the performance of established safety functions by engineered safety barriers based on barrier clay materials
7. The fulfillment of the established safety functions of BCM-based ESBs during the design life should be justified in the design and SAR of RW storage facilities on the basis of:

results of predictive LTSA calculations of RW storage facilities using quantitative values of the indicators of the functional properties of BCMs within ESBs, confirming the absence of radiation impact of the RW placement (disposal) system on the public and the environment in excess of permissible limits established by sanitary rules and hygienic standards;

results of experimental studies and calculated predictions of degradation of the properties of BCMs within ESBs, confirming the fulfillment of the safety functions of BCM-based ESBs within the established timeframes.

1. Experimental studies should be performed in accordance with certified methods. In order to perform predictive LTSA calculations, electronic computer programs should be used that have undergone expert review in accordance with the Procedure for Expert Review of Electronic Computer Programs Used to Build Computational Models of Processes Affecting the Safety of Atomic Energy Facilities and/or Activities in the Field of the Use of Atomic Energy, approved by Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 141 dated April 4, 2023 (registered by the Ministry of Justice of the Russian Federation on June 8, 2023, registration No. 73783).
2. When justifying the established safety functions of BCM-based ESBs in the design and SAR of RW storage facilities, safety functions and quantitative values of the indicators of the functional properties of BCMs within ESBs, as accepted in the predictive LTSA calculations of RW storage facilities should be described in tabular form (for a recommended sample see Appendix No. 5 to the Safety Guide) or in graph form (for changes in the values of the indicators of the functional properties of BCMs over time).
3. Filtration, migration, chemical and thermodynamic calculations, as well as calculations of settlement, strength and stability of the structures and ESBs of RW storage facilities should be included in the predictive LTSA calculations.
4. Experimental and computational studies aimed at justifying the safety functions of BCM-based ESBs should include studied of:

influence of the mineral composition of BCMs and specifics of clay mineral structure on physicochemical and physicomechanical properties of BCMs;

sorption processes that unite all mechanisms of radionuclide fixation on BCMs, filtration and diffusion processes in BCMs;

swelling processes of BCMs;

compactability of BCMs, strength and deformation characteristics of compacted BCMs;

interactions between BCMS and other ESB materials (e.g., concrete, cement, steel);

dependence of strength and deformation characteristics of BCMs on humidity;

changes in functional properties of BCMs in time as a result of external influences.

1. Experimental and computational studies of BCM properties should take into account events, phenomena and factors[[12]](#footnote-13) inherent to the area and site of RW storage facilities, which may lead to deterioration of the properties of BCM-based ESBs during the service life justified in the design.

The results of experimental and computational work related to the study of BCM properties should be used as input data in the design of BCM-based ESBs and safety justification of RW storage facilities.

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|  | APPENDIX No. 1to Safety Guide in the Use of Atomic Energy“Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” approved by Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_ dated \_\_\_\_\_\_\_2025 |

List of Abbreviations

|  |  |
| --- | --- |
| BCMs | Barrier clay materials |
| BCM-based ESBs | Engineered safety barriers based on barrier clay materials |
| ESBs | Engineered safety barriers |
| LTSA | Long-term safety assessment |
| NSRWDFs | Near-surface radioactive waste disposal facilities |
| RW | Radioactive waste |
| SAR | Safety analysis report |
| SRWDFs | Special radioactive waste disposal facilities |
| SRWPFs | Special radioactive waste preservation facilities |

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|  | APPENDIX No. 2to Safety Guide in the Use of Atomic Energy “Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” approved by Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_ dated \_\_\_\_\_\_\_2025 |

# **Recommended diagram for selection of engineered safety barriers based on barrier clay materials and its justification**

**Legend[[13]](#footnote-14)**

|  |  |  |
| --- | --- | --- |
|  | **–** | beginning/ending |
|  | **–** | process |
|  | **–** | data |
|  |  |  |
| **–** | cycle boundary |
|  |  |
|  | **–** | commentary |
|  | **–** | connecting lines |



BCM selection cycle

BCM-based ESB selected

Meeting target values

Actual values of indicators of functional properties

Laboratory tests to determine functional properties

Table No. 3 of Appendix No. 4 to Safety Guide

Technological properties of BCM-based ESBs

Laboratory tests to determine technological properties of BCM-based ESBs

Tables No. 1 and 2 of Appendix No. 4 to Safety Guide

Composition, structure, properties, technical characteristics of BCM

Selection of BCM

Indicators of functional properties are determined during laboratory tests

Target values of indicators of functional properties

Predictive analysis that confirms long-term safety of RW storage facility

Table No. 4 of Appendix No.4 to Safety Guide

Required indicators of functional properties

Determination of BCM-based ESB parameters for predictive analysis of estimate of long-term safety of RW storage facility

Appendix No.3 to Safety Guide

Safety functions of BCM-based ESBs

Establishment of safety functions of BCM-based ESBs

Selection of BCM-based ESBs

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|  | APPENDIX No. 3to Safety Guide in the Use of Atomic Energy “Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” approved by Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_ dated \_\_\_\_\_\_\_2025 |

Recommended safety functions of various types of engineered safety barriers based on barrier clay materials

| **Types of BCM-based ESBs** | **Safety functions** |
| --- | --- |
| **Insulating** | **Retaining** | **Mechanical** |
| Buffer barrier  | limiting penetration of precipitation and/or ground water into RW packages (unpacked RW) | sorbing radionuclides in case of release from RW packages (unpacked RW) | resisting deformation by gravity |
| Impervious layer of top shield | protecting RW from penetration of precipitation and surface water into internal space of RW storage facility | sorbing radionuclides in case of release beyond buffer barrier | accommodating and allocating load from overlying layers of top shield |
| Impervious layer of bottom shield | protecting RW from penetration of ground water and protection of ground water from radioactive contamination in case of radionuclide release from RW packages (unpacked RW) | maintaining load bearing capacity in the composition of RW storage facility base |
| Impervious layers of side shield | accommoding horizontal thrust of surrounding soil |
| Impervious curtain | reducing ground water velocity at RW storage facility site | sorbing radionuclides detected within limits outlined by impervious curtain | accommodating hydrodynamic and lateral pressure of surrounding soil |

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|  | APPENDIX No. 4to Safety Guide in the Use of Atomic Energy “Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” approved by Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_ dated \_\_\_\_\_\_\_2025 |

# **Recommended characteristics and indicators of barrier clay materials, including those within engineered safety barriers, and methods of their determination**

Table No. 1

**List of characteristics of composition and structure and indicators of properties of barrier clay materials**

| **No.** | **Characteristics and indicators** | **Recommended methods of determination** |
| --- | --- | --- |
| 1 | mineral composition  | Sections 7–11 FR.1.31.2023.45452 “Quantitative X-ray Diffraction Analysis (QXDA) of rock formations, ores and materials by Rietveld method”  |
| 2 | chemical composition | Sections 4–5 of GOST 21216-2014 “Raw Clay Materials. Test Methods,” enacted on July 1, 2015 by Order of the Federal Agency for Technical Regulation and Metrology No. 1832-st dated November 26, 2014; Sections 4–5 of GOST 23740-2016 “Soils. Methods of Laboratory Determination of Organic Composition,” enacted on July 1, 2017 by Order of the Federal Agency for Technical Regulation and Metrology No. 2096-st dated December 27, 2016 |
| 3 | granulometric composition | Section 4 of GOST 12536-2014 “Soils. Laboratory Methods for Determination of Granulometric (Grain) and Microaggregate Composition,” enacted on July 1, 2015 by Order of the Federal Agency for Technical Regulation and Metrology No. 2022-st dated December 12, 2014 |
| 4 | density of solid particles  | Sections 13 and 14 of GOST 5180-2015 “Interstate Standard. Soils. Laboratory Methods for Determination of Physical Characteristics,” enacted on April 1, 2016 by Order of the Federal Agency for Technical Regulation and Metrology No. 1694-st dated November 3, 2015 (hereinafter referred to as GOST 5180-2015) |
| 5 | specific surface | Sections 1–5 of GOST 28794-90 “Reagents. Method for Determination of Specific Surface of Chromatographic Materials by Thermal Desorption,” enacted on January 1, 1992 by the Resolution of the State Standard Committee of the USSR Council of Ministers No. 3180 dated December 18, 1990 |
| 6 | swelling number | Appendix B to GOST R 70090-2022 “Geosynthetic Bentonite Rolled Waterproofing Materials. General Specifications,” enacted on June 1, 2022 by Order of the Federal Agency for Technical Regulation and Metrology No. 273-st dated May 5, 2022 |
| 7 | water return | GOST R 56946-2016 “Materials of Drilling Fluids. Specifications and Tests,” enacted from December 1, 2016 by Order of the Federal Agency for Technical Regulation and Metrology dated June 6, 2016 |
| 8 | upper-yield point | Section 7 of GOST 5180-2015  |
| 9 | cation exchange capacity | Sections 4–13 FR.1.31.2022.44411 “Methodology for Measuring Cation Exchange Capacity by Adsorption of Copper Complex (II) with Triethylene Tetramine – Cu-TRIEN” |

Table No. 2

**List of technical characteristics of barrier clay materials**

|  |  |  |
| --- | --- | --- |
| **No.** | **Characteristic** | **Recommended methods of determination** |
| 1 | fractional composition | In accordance with technical specifications for barrier clay material |
| 2 | bulk density |
| 3 | moisture content | Section 5 of GOST 5180-2015 |
| 4 | hydroscopic moisture (for powder-like BCMs with moisture percentage of 1–9%) |

Table No. 3

**List of technological characteristics of engineered safety barriers based on barrier clay materials**

|  |  |  |
| --- | --- | --- |
| **No.** | **Characteristic** | **Recommended methods of determination** |
| 1 | density of soil skeleton  | Section 12 of GOST 5180-2015  |
| 2 | porosity | Appendix A to GOST 25100-2020 “Soils. Classification,” enacted on January 1, 2021 by Order of the Federal Agency for Technical Regulation and Metrology No. 384-st dated July 21, 2020 |
| 3 | moisture content | Section 5 of GOST 5180-2015  |

Table No. 4

**List of indicators of functional properties of barrier clay materials as part of engineered safety barriers**

| **No.** | **Indicator** | **Recommended methods of determination** |
| --- | --- | --- |
| 1 | filtration coefficient | Sections 4–13 of FR.1.31.2022.44414 “Methodology for Measuring the Filtration Coefficient of Barrier Clay Materials” |
| 2 | relative swelling, swelling humidity, swelling pressure, volume and linear shrinkage, shrinkage limit humidity | Sections 4–9 of GOST 12248.6-2020 “Soils. Method for Determination of Swelling and Shrinking Characteristics”, enacted from June 1, 2021 by Order of the Federal Agency for Technical Regulation and Metrology No. 826-st dated October 14, 2020 |
| 3 | angle of internal friction, specific cohesion | Sections 4–9 of GOST 12248.1-2020 “Soils. Determination of Strength Characteristics by the Method of In-plane Shear,” enacted on June 1, 2021 by Order of the Federal Agency for Technical Regulation and Metrology No. 821-st dated October 14, 2020; Sections 4–9 of GOST 12248.3-2020 “Soils. Determination of Strength and Deformation Characteristics by the Method of Triaxial Compression,” enacted on June 1, 2021 by Order of the Federal Agency for Technical Regulation and Metrology No. 823-st dated October 14, 2020 (hereinafter referred to as GOST 12248.3-2020) |
| 4 | modulus of deformation | Sections 4–9 of GOST 12248.3-2020;Sections 4–10 of GOST 12248.4-2020 “Soils. Determination of Deformation Characteristics by the Method of Compressive Stress,” enacted on June 1, 2021 by Order of the Federal Agency for Technical Regulation and Metrology No. 824-st dated October 14, 2020 (hereinafter referred to as GOST 12248.4-2020) |
| 5 | coefficients of filtering (primary) and secondary consolidation | Sections 4–10 of GOST 12248.4-2020  |
| 6 | coefficient of diffusion, effective porosity | Sections 8–14 of FR.1.31.2022.44415 “Methodology for Measuring Effective Diffusion Coefficient and Effective Porosity of Barrier Clay Materials” |
| 7 | coefficient of radionuclide distribution | Sections 8–16 of FR.1.31.2022.44412 “Methodology for Measuring Radionuclide Distribution Coefficient for Characterization of Barrier Clay Materials”  |
| 8 | buffer pH value, cation composition, total dissolved solids of water extract | Sections 8–12 of FR.1.31.2022.44413 “Methodology for Measuring the Effect of Barrier Clay Materials on the Composition of Contacting Solutions”  |

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|  |  |
| --- | --- |
|  | APPENDIX No. 5to Safety Guide in the Use of Atomic Energy “Recommendations for Justification of Selection and Application of Barrier Clay Materials in Radioactive Waste Storage Facilities” approved by Order of the Federal Environmental, Industrial and Nuclear Supervision ServiceNo. \_\_\_\_\_ dated \_\_\_\_\_\_\_2025(recommended sample) |

# **Description of safety functions and quantitative values of indicators of functional properties of barrier clay materials as part of engineered safety barriers to be used in predictive analyses of long-term safety assessment of radioactive waste storage facilities**

|  |
| --- |
| **Name of BCM-based ESBs** |
| **No.** | **Indicators of functional properties[[14]](#footnote-15)** | **Value or time dependence of the functional property indicator** |
| **during the period when the safety function (service life) of BCM-based ESBs is performed** | **during the period after the performance of the safety function of BCM-based ESBs** |
| 1 | Description of safety function No. 1 |
| 1.1 |  |  |  |
| 1.N |  |  |  |
| 2 | Description of safety function No. 2 |
| 2.1 |  |  |  |
| 2.N |  |  |  |
| … |

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1. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 347 dated August 5, 2014 (registered by the Ministry of Justice of the Russian Federation on November 14, 2014, registration No. 34701), as amended by Orders of the Federal Environmental, Industrial and Nuclear Supervision Service No. 582 dated November 22, 2018 (registered by the Ministry of Justice of the Russian Federation on December 12, 2018, registration No. 52986) and No. 163 dated May 18, 2022 (registered by the Ministry of Justice of the Russian Federation on July 14, 2022, registration No. 69272). [↑](#footnote-ref-2)
2. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 379 dated August 22, 2014 (registered by the Ministry of Justice of the Russian Federation on February 2, 2015, registration No. 35819), as amended by Orders of the Federal Environmental, Industrial and Nuclear Supervision Service No. 582 dated November 22, 2018 (registered by the Ministry of Justice of the Russian Federation on December 12, 2018, registration No. 52986) and No. 163 dated May 18, 2022 (registered by the Ministry of Justice of the Russian Federation on July 14, 2022, registration No. 69272). [↑](#footnote-ref-3)
3. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 249 dated June 6, 2014 (registered by the Ministry of Justice of the Russian Federation on August 14, 2014, registration No. 33583), as amended by Orders of the Federal Environmental, Industrial and Nuclear Supervision Service No. 582 dated November 22, 2018 (registered by the Ministry of Justice of the Russian Federation on December 12, 2018, registration No. 52986), No. 163 dated May 18, 2022 (registered by the Ministry of Justice of the Russian Federation on July 14, 2022, registration No. 69272). [↑](#footnote-ref-4)
4. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 418 dated October 10, 2017 (registered by the Ministry of Justice of the Russian Federation on November 2, 2017, registration No. 48779), as amended by Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 163 dated May 18, 2022 (registered by the Ministry of Justice of the Russian Federation on July 14, 2022, registration No. 69272). [↑](#footnote-ref-5)
5. Paragraph nine of clause 8 of NP-069-14. [↑](#footnote-ref-6)
6. Paragraph eight of clause 8 of NP-069-14. [↑](#footnote-ref-7)
7. Resolution of the Federal Environmental, Industrial and Nuclear Supervision Service No. 11 dated December 2, 2005 (registered by the Ministry of Justice of the Russian Federation on February 1, 2006, registration No. 7433), as amended by Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 326 dated July 28, 2014 (registered by the Ministry of Justice of the Russian Federation on August 28, 2014, registration No. 33890). [↑](#footnote-ref-8)
8. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 572 dated December 15, 2014 (registered by the Ministry of Justice of the Russian Federation on March 27, 2015, registration No. 36592). [↑](#footnote-ref-9)
9. Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 85 dated February 7, 2012 (registered by the Ministry of Justice of the Russian Federation on March 19, 2012, registration No. 23509), as amended by Order of the Federal Environmental, Industrial and Nuclear Supervision Service of June 3, 2013 (registered by the Ministry of Justice of the Russian Federation on July 8, 2013, registration No. 29011). [↑](#footnote-ref-10)
10. Paragraph six of clause 8 of NP-069-14. [↑](#footnote-ref-11)
11. Appendix No. 2 to the Safety Guide in the use of atomic energy “Recommendations for Formation of the List of Radionuclides Monitored in Conditioned Radioactive Waste of Nuclear Fuel Cycle Enterprises” (RB-004-21), approved by Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 251 of July 7, 2021. [↑](#footnote-ref-12)
12. Appendix No. 3 to the Safety Guide in the use of atomic energy “Assessment of Long-Term Safety of Deep Disposal Facilities for Radioactive Waste” (RB-003-21), approved by Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 101 dated March 19, 2021. [↑](#footnote-ref-13)
13. Section 3 of GOST 19.701-90 (ISO 5807-85) “Unified System of Program Documentation. Diagrams of Algorithms, Programs, Data and Systems. Legend and Rules of Execution,”, approved and enacted on January 1, 1992 by the Resolution of the State Standard Committee of the USSR Council of Ministers No. 3294 dated December 26, 1990. [↑](#footnote-ref-14)
14. Table No. 4 of Appendix No. 4 to the Safety Guide. [↑](#footnote-ref-15)