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STATE-OF-ART IN THE DEVELOPMENT AND USE OF CLAY MATERIALS AS ENGINEERED SAFETY BARRIERS AT RADIOACTIVE WASTE CONSERVATION AND DISPOSAL FACILITIES IN RUSSIA

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The article covers research data from R&Ds carried out in Russia to identify barrier properties of clay mineral raw materials and to develop relevant recommendations regarding the decision making on the use of engineered safety barrier materials performed during design development and construction of RW conservation and disposal facilities. The paper also provides some recommendations concerning the enhancement of R&D management system and increasing R&D applied value to ensure the safety of RW conservation and disposal facilities.

Keywords: *radioactive waste, barrier materials, safety barrier, clay materials, nuclear disposal, engineered barriers, research, conservation of radioactive waste, safety assessment, design development.*

Introduction

Federal Target Program "Nuclear and Radiation Safety in 2016—2030" involves construction and development of a large number of disposal and storage (referred to as conservation) facilities for various radioactive waste (RW) classes. These facilities are developed to minimize harmful and hazardous effects associated with the RW disposed therein ensuring safety for people and the environment in the long term. Engineered safety barriers (EBS) play a significant role in addressing this challenge — EBS materials and design shall provide for relevant properties ensuring the safety of RW disposal in a long term (hundreds and thousands of years). During this time period their properties and characteristics should remain reliably predictable and measurable. Decisions on the use of certain EBS materials are based on scientific research being performed to demonstrate whether the required characteristics can be achieved and to identify the parameters reflecting their alterations. The latter one enables the development of facility models, evolution scenario calculations, demonstration of repository's long-term safety throughout its life cycle.

Due to their unique properties, cay materials are believed to be extremely promising as materials for EBS construction [1]. At the same time, despite a wide-spread natural occurrence of clays, the decision making on clay material selection for EBS construction should involve analytical work on the assessment and selection of deposits being considered suitable in terms of resources available and logistics, as well as correct sampling of these materials as early as at the design stage of a disposal project. Organizations pertaining to the State Atomic Energy Corporation Rosatom are currently performing various research and development activities (R&D) to study clay properties and its applications at different types of nuclear facilities. Obviously, with no such analytical study being performed, only some insufficiently mature and sound design solutions may be proposed with relevant material characteristics assumed in the designs that cannot be neither achieved nor controlled. Thus, inevitable excessive conservatism of the design solutions will ultimately result in an increased cost of the developed facility. Oftentimes no unbiased information about the characteristics of the applied materials is available at the design development stage, therefore, literature data is used in relevant calculations that does not always reflect actual properties of the considered material. Thus, during the procurement process the contractor provided with no requirements on the EBS material in the design documentation will be giving preference to material suppliers offering lower prices. This issue, also pointed out in [2], seems to be of a complex nature and driven by the imperfection of the regulatory framework and standards on the use of clay-based materials at nuclear facilities.

This article focuses on the systematization of available data on the development and testing of clay materials, summarizing data on R&Ds, RW disposal facilities (RWDF) being currently developed, as well as experience on the decommissioning of production uranium-graphite reactors (PUGR).

Summary of R&Ds on the development of clay-based barrier materials

At present time, JSC SCC being commissioned by SC Rosatom's project office responsible for the Development of a Unified State System for RW Management performs R&Ds to study barrier properties of clay mineral raw materials and to develop recommendations for engineered barrier materials ensuring the safety of RW conservation and disposal facilities [3]. The R&Ds involve laboratory and bench tests, including preparation of dispersed natural raw material samples, evaluation of their composition and primary characteristics, compression properties and mobility of dry samples, water resistance of samples under low hydraulic gradient, compression and filtration properties of samples in a water-saturated state, diffusion properties of samples, their colloid formation capacity, as well as stability of the main minerals of clay barrier materials. The R&Ds are planned to be completed on November 30, 2020. Clay samples presented in Table 1, as well as 8 other kaolin-bentonite clay mixtures were selected to perform this research.

The research will enable to compile a list of parameters applicable to various types of barrier materials and their values covering the materials used in construction and operation of near-surface disposal facilities (NSDF) for radioactive waste Class 3 and 4; PUGR conservation facilities at JSC SCC, FSUE PA Mayak, FSUE MCC; deep disposal facility (DDF) for radioactive waste Class 1 and 2 being developed in the Nizhnekansk rock mass, i. e. for all categories of RW disposal facilities (Figure 1). At the same time, it should be particularly noted that public hearings and a state environmental review was held on the NSDF projects [4] with relevant construction activities scheduled to be started in

Table 1. Clay samples applied in the R&Ds being performed by JSC SCC [3]

Clay samples	Application (based on Rosgeolfond inventory data)
Kaolin, Kantatsk deposit	Turan LLC has a license for exploration and production of high-melting fire clays from subsoil block no. 2
Kaolin, Kampanovsk deposit	LLC Silit holds a license for exploration and production of kaolin and fire clays
Fireclay, Kampanovsk deposit	
Bentonite, Kamalinsk deposit	License is currently terminated
Bentonite, 10th hamlet	License for exploration and mining is held by Bentonit Khakassia LLC
Phlogopite (in mixture), Tatarsk deposit	The license for geological exploration, exploration and production of vermiculite ores in the northern section of the first ore zone of the Tatar phosphate-niobium deposit is held by LLC Magnezit Group
Clay mixture (kaolin, bentonite, vermiculite)	Applied for PUGR EI-2 entombment by JSC SCC
Clay mixture (kaolin, bentonite)	Applied to backfill the inter-container space at FSUE NO RAO's Novouralsk NSDF site

Figure 1. Geography of operating and planned RWDFs [4]

2019 [5]. In 2013—2015, PUGR EI-2 was decommissioned at SCC site: it was entombed using a natural clay-based composition. In 2020, another PUGR at MCC site is planned to be entombed as well [6]. Each category of RW conservation and disposal facilities and the barrier materials being applied are considered below.

Near-surface disposal facilities for radioactive waste of Class 3&4

FSUE NO RAO is acting as the customer for design development and construction of RW Class 3&4 final disposal facilities and their operator. NP-055-14 [7] is a regulation on RWDF construction stating the multi-barrier principle as the fundamental one. RWDF safety is provided by consistent implementation of the defense-in-depth concept based on a system of physical barriers limiting the spread of ionizing radiation and radioactive substances into the environment. According to NP-055-14, EBS function is seen to limit the contact between RW packages and natural waters (waterproofing properties) and to limit the spread of radionuclides into the host rocks (antimigration properties). Typically, NSDF structure involves 5 types of safety barriers:

- the first barrier is the RW package: matrix material, including RW, ballast filler, container;
- the second barrier is the buffer material filling the void space inside the compartments;
- the third barrier is the material used to construct the walls and slabs of the RW disposal structures;
- the fourth barrier is the underlying insulation screen constructed around the perimeter (walls, bottom, slabs) of the structures;
- the fifth barrier is the covering waterproof screen, installed at the DF closure stage.

It should be noted that provision of NP-055-14, as well as of other regulations provide no specific requirements or recommendations on the selection of barrier materials and their characteristics. Thus, specific materials should be selected and relevant requirements and characteristics should be specified at the design stage of a project. Below are discussed some case studies demonstrating how the barrier materials were actually selected taking into account these requirements. Materials supporting NSDF construction and operation license applications (SLM), including environmental impact assessments, are publicly available at official websites [8—11].

NSDF for RW Class 3 and 4 in the Novouralsk settlement area (the Sverdlovsk region)

The first section of NNDF in the vicinity of Novouralsk settlement has been operated since 2016 (10th map). In 2018, construction of the second section (maps 11—13) was started [4]. SLM on the operation of the first section [8] indicate that to ensure its primary conservation being arranged by backfilling the void space between RW packages (second engineered barrier) clay powder, namely, bentonite according to GOST 28177-89 [12] is applied. This standard applies to bentonite molding clays used in foundries as mineral binders in molding and core mixtures and non-stick coatings. According to the standard, at least 30% of the mass fraction should account for montmorillonite being considered as the main mineral of the bentonite clay. At the same time, SLM technical specifications indicate that the content of montmorillonite should be at least 30% with the kaolinite mass fraction of at least 50%, i. e., implying the use of a mixture with two clays which is not provided for by GOST 28177-89. According to the designs, the void space between RW containers in the second section of the repository being under construction, will be backfilled by pouring a cement-bentonite mixture [9]. This method raises concerns due to the low resistance of the proposed material to physical and chemical leaching by groundwater, as well as the effects of potential temperature differences due to freezing and thawing, and, the resulting quick loss of its containment properties. Fourth barrier, namely, the underlying layer is indicated in the SLM for the second section of the repository suggesting the installation of a clay screen and bentonite mats around the perimeter (walls, bottom) of DFRW. Clay screen along the perimeter performs waterproofing (for at least 500 years) and sorption functions. Bentonite mats perform waterproofing function for an unlimited time period while their integrity is maintained. Characteristics of clay and bentonite mats that could be considered essential in terms of the declared service life, have not been indicated. The fifth engineered barrier, the covering screen installed during closure of the filled repository is made up of clay with a water conductivity coefficient of not more than 10^{-5} m/day, a drainage layer made of gravel and sand mixture, a protective layer of crushed stone and a top protective layer of loam with a soil and vegetation cover [9]. Requirements concerning the nature or mineral composition of clay, layer thickness and compaction coefficient have not been indicated as well. It should be noted that the application of such important indicators of waterproofing properties as water conductivity coefficients suggests that the compaction rate of the resulting material (or the required compaction rate) should be mandatory indicated, since the same material is characterized by different waterproofing capacities depending on the compaction rate, which was not accounted for in most cases.

NSDF for RW Class 3&4 in the restricted administrative and territorial entity Seversk of the Tomsk region

SLM for siting and construction of a near-surface disposal facility for Class 3 & 4 solid radioactive waste suggested the use of a clay retainer as the fourth engineered barrier - the underlying layer was made of a plastic pugged clay being installed around the perimeter (wall, bottom) of repository structures [10]. At the same time, specification for the "plastic pugged clay" has not been provided in the document, as well as relevant requirements for its quality indicators. A buffer material made of SBMK grade (mechanically activated composite barrier mixture, TU 5729-002-3045284-2013) mud powder involving kaolin, bentonite and vermiculite was indicated as the second engineered barrier designed to fill the void space in the compartments. SBMK was used at SCC site during PUGR EI-2 decommissioning. The covering screen involves several layers, namely: bentonite mat, sand, a layer of compacted clay or loam, another layer of bentonite mat, drainage layer, soil and vegetation layer.

NSDF for RW Class 3&4 in the restricted administrative and territorial entity Ozersk of the Chelyabinsk Region

This NSDF has the same modular design as the one in RATE Seversk [11] (Figure 2). Its designs imply the use of a clay screen and bentonite mats installed along the perimeter of NSDF walls, bottom and slabs as the underlying layer. The second engineered barrier designs imply the use of a buffer backfilling material, filling the void space inside the compartments. Clay powder or pellets were indicated as such a material. Similar to Novouralsk NSDF designs, the covering screen involves a clay waterproofing layer being a 1 m thick clay retainer, a drainage layer of gravel and sand mixture, a protective layer of crushed stone, a protective layer of local soil and a vegetation cover.

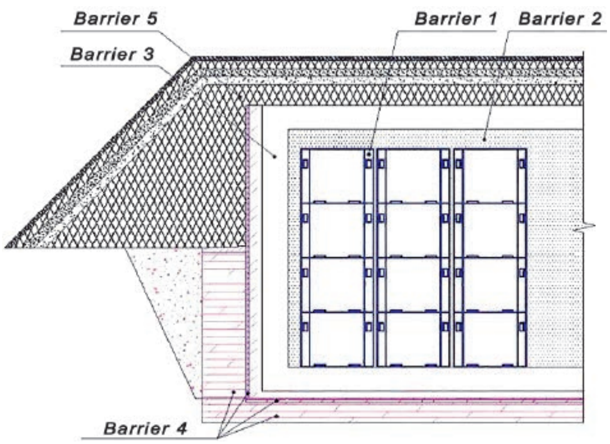

Figure 2. The system of engineered safety barriers at the Ozersk NSDF.
Source: JSC "FTsNIVT" SRPO "Eleron" - "UPII VNIPIET" [10]

Table 2 summarizes the types of clay materials used for engineered barrier construction under the above NSDF designs. The table shows that the design documentation for NSDF construction may not always contain relevant requirements on EBS clay materials. Oftentimes it provides only qualitative

Table 2. Selected clays under NSDF designs

	Novouralsk 1st section [1]	Novouralsk 2nd section [9]	Ozersk [11]	Seversk [10]
EB2: Buffer material backfilling the void space inside compartments	Bentonite and kaolin mixture	Cement-bentonite mixture (pouring)	Clay powder or pellets	Kaolin, bentonite, vermiculite mixture
EB4: Underlying screen	Data n/a	Clay screen and bentonite mats	Clay screen and bentonite mats	Plastic pugged clay
EB5: Covering screen	Clay Sand and gravel mixture Crushed stone Soil and vegetation cover			Bentonite mats Sand Layer of compacted clay or loam Bentonite mats Drainage layer Soil and vegetation layer

characteristics or the name of the mineral, which is, obviously, not enough to compile correct terms of reference for the purchase of a barrier material and conduct its input control.

Deep disposal facility for radioactive waste Class 1&2. PUGR decommissioning

Unlike the above NSDFs, the construction of which is already underway or will be started in the near future, R&D and construction of a deep disposal facility for RW hazard class 1&2 will be carried out over the next two decades. Scientific and technical support of the deep disposal project was consolidated within IBRAE RAS (Nuclear Safety Institute of RAS) under a strategic master plan (SMP NKM) framework [13]. The program of experiments to be conducted in the currently constructed underground research laboratory (URL) includes 7 research areas and will to be performed by IBRAE RAS with the engagement of experts from the Institute of Physical Chemistry and Electrochemistry of RAS; Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry of RAS; National Research Technological University of Moscow, Institute of Steel and Alloys and the Geophysical Center. In these organizations, laboratory-based experiments were launched in 2019, URL experiments are partially conducted during its construction, the rest will be started after 2025. Various types of bentonites, alternative materials, barrier mixtures, bentonite-sand mixtures and etc. will be tested as potential EBS materials. It should be noted that each executing organization chooses on its own the materials subject to such testing.

In 2013—2015, during PUGR EI-2 decommissioning at SCC site, reactor shaft and reactor spaces were backfilled with a kaolin-based barrier mixture from the Kampanovsk deposit (80—90%) (see Table 1) [14]. One should note that PA ECP previously planned to use this kaolin to manufacture porcelain products, but in terms of its quality it appeared to be suitable only as a raw material for refractory material and lining brick production [15].

Comparison of kaolin and bentonite clays

Almost all the RW disposal strategies being currently implemented around the globe involve the use of bentonite clays as buffers, seals or backfills [16]. Russian and foreign studies [17—29] demonstrate that bentonite is a much more favorable material in terms of its waterproofing and anti-migration properties compared to kaolin. Table 3 summarizes the main characteristics of these clays allowing their comparison.

Moreover, authors of [23] conclude that bentonite reserves are limited and its cost is high compared to kaolin. On the other hand, this conclusion contradicts the views expressed by other experts [1, 31]. Indeed, bentonite raw materials with various properties are currently available on the Russian market. Estimated reserves of A+B+C1 category bentonite clay in Russia amount to 189 million tons, whereas those of C2 category amount to 146 million tons. Total production in 2017 amounted to more than 700 thousand tons [31].

The implemented project on EI-2 reactor entombment, namely, the official monitoring data on the state of the established storage facility were found to be satisfactory, were reported at IAEA session and got favorable reviews from the international community. A number of countries expressed their interest in the technology suggesting the use of natural barrier materials for PUGR conservation purposes. However, to date the license for exploration and production of kaolin and high-melting clays of the Kampanov deposit no longer belongs to the structure of Rosatom companies, therefore JSC SCC is now considering local clays occurring on the territory of the enterprise as a safety barrier component. Thus, in 2019, JSC SCC commissioned

Table 3. Comparison of bentonite and kaolin clay properties

Kaolin clay	Bentonite clay
Material structure [18–22] (Figure 3)	
Natural layered aluminosilicate with its structure being based on a 1:1 layer involving one mesh of silicon-oxygen tetrahedrons and an aluminum-hydroxyl-oxygen mesh of octahedrons connected to it. Due to almost zero charge of the layer, as well as the occurrence of strong electrostatic and hydrogen bonds, the kaolinite lattice becomes rigid, which prevents the occurrence of favorable adsorption properties	Natural layered aluminosilicate with its structure being based on a 2:1 layer involving two tetrahedral meshes and one octahedral mesh enclosed between them. Owing to isomorphic substitutions in the structure, mainly those of the octahedral meshes, a layer charge of some 0.4–0.6 el. units is formed being neutralized by exchange interlayer cations (Na^{+}, Ca^{2+}, Mg^{2+}, etc.) commonly available in a hydrated form [18–20]. This ensures the lability of the structure and makes external and internal surfaces in crystallites accessible for adsorption. Similar structural features of montmorillonites determine the specific properties of bentonite clays, such as high sorption capacity, including heavy metals, isotopes of cesium, plutonium and other substances being contained in the RW
Water conductivity factor, m/day	
10^{-4}–10^{-3} (testing method and sample density not indicated) [23]; $4 \cdot 10^{-6}$ (testing via soil compression method according to GOST 12248-2010) [25]	10^{-5}–10^{-4} (testing method and sample density not indicated) [23]; less than $4 \cdot 10^{-6}$ (testing method and sample density not indicated) [24]; $7 \cdot 10^{-7}$ (testing via soil compression method according to GOST 12248-2010) [25]; 10^{-10}–10^{-9} (highly compacted high-quality bentonites, ASTM D 5084-03 tests) [26]
Swelling capacity, %	
3–5 [23]	40–200 and more [23]
Cation exchange capacity, mg-Eq/100 g	
2–10 [27]	80–150 [21, 22, 27]
Distribution coefficient, cm^3/g	
Sr, Cs, Pu, Am – 10^3; Np, U – 10^2 [23]	Sr, Cs, Pu, Am – 10^2–10^3 [23]; U – 10^2 (mean) [28]; Np – 10^3 [29]

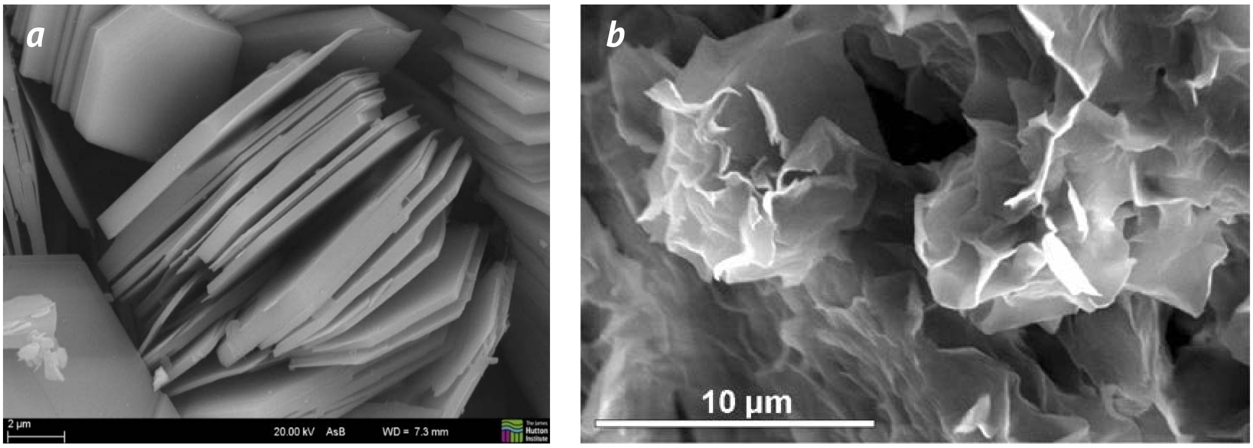

Figure 3. Microphotographs of kaolinite (a) and montmorillonite (b) [30]

an R&D on the Development of a Technology Designed to Produce Barrier Materials Based on Clays Occurring at SCC Territories [32]. The research will enable the development of barrier materials based on local clays suggesting that some fraction of industrially produced pre-treated clays, clay mixtures and SCC production waste is introduced to them as additives. It's supposed that these developments will be applied to establish a storage facility for non-retrievable RW during PUGR ADE-4, ADE-5 decommissioning; conservation of sludge storage facilities PKh-1, PKh-2 and surface SRW storage facilities at the site № 16 of the chemical and metallurgical plant; the establishment of M1, M2 conservation facilities for non-retrievable radioactive waste.

Moreover, the designs developed to decommission structure 4 (building 804) at JSC Angarsk Electrolysis Chemical Combine provide for its foundation pit backfilling with very low-level radioactive waste being disposed therein as well. In the specifications for the supply of the backfill material [33] argillaceous material, loamy sand complying with GOST 25100-2011 provisions [34] is indicated as such. At the same time, neither technical specification for the soil nor any supporting material demonstrating its effectiveness and reliability as an anti-filtration and anti-migration EBS is available.

In 2018–2020, FSUE MCC has been implementing AD PUGR decommissioning project [6]. The reactor shaft is being backfilled with a barrier material having similar composition to the one used by SCC, involving kaolin, vermiculite and bentonite [35]. Starting from 2021, decommissioning of two SCC PUGRs, reactors ADE-4 and ADE-5, is scheduled with yet two more reactors ADE-2 and I-1 to be decommissioned following the completion of the former ones.

Another research on Identifying the Parameters of Radionuclide Migration in Safety Barrier Materials and Host Rocks Due to Phosphate Glass Components Leaching under Deep RW Disposal Conditions is carried out by the Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences under a contract with the State Corporation Rosatom [36]. The research program was started on May 15, 2019 and will be completed by November 30, 2020. Under the study, bentonites of different mineral composition from two deposits: Kamalinsk (Krasnoyarsk Territory) and 10th Hamlet (Republic of Khakassia) should be used as barrier materials (Figure 4).

Figure 4. Bentonite deposit 10th Hamlet, Khakassia. Source: Bentonit Khakassia LLC

Thus, as discussed in the above case studies, for different RW conservation and disposal facilities, design and operating organizations select barrier material composition on their own based on their own expertise, taking no account of R&Ds commissioned by Rosatom (see section "Summary of R&Ds on the development of clay-based barrier materials"). Such research is performed independently and involves various samples, the choice of which is not regulated and is not derived based on analytical study of the deposits and a critical literature review of already available research data. Such an approach obviously involves certain risks suggesting that this can only yield some discrete data on clay samples of different mineral composition with a different set of waterproofing properties, since it's believed difficult to extrapolate the data to industrially developed deposits and derive patterns enabling to compile regulatory and technical documentation for EBS design development and operation.

Recommendations for subsequent R&Ds

The State Atomic Energy Corporation Rosatom is up to identifying a list of parameters and their values that are to be applied to various types of barrier materials for NNDF and conservation facilities, i.e. to establish regulatory requirements for barrier materials and to specify what kind of clay materials or their mixtures should be considered suitable to meet these regulatory requirements (see the section "Summary of R&Ds on the development of clay-based barrier materials"). However, clay samples involved in the SCC study were obviously selected based on SCC's previous operations with no proper analytical review of the clay raw material market, no evaluations of its quality and characteristics based on literature data and not taking into account the best Russian and international practice in the research and clay materials application. The selected kaolin and bentonite deposits are located in the Krasnoyarsk Territory, while other promising clay deposits in other regions were not considered at all, although the latter ones could have certain advantages in terms of logistics being located closer to conservation and disposal RW facilities of the central region. As shown in Table 3, waterproofing and anti-migratory properties of bentonite significantly exceed those of kaolinite clays. Thus, we believe that additional research should be aimed at refining both the properties of bentonite clay, taking into account the global practice in EBS construction, and the conditions at the proposed disposal sites and characteristics of RW packages.

Moreover, as shown above, operating organizations are making decision on EBS material selection on their own based on its cost or geographical availability. This approach hinders significantly the analytical study summarizing the applications of various clay material of Russian origin and their effectiveness. It should be particularly noted that scientific groups from different RAS institutes (including IBRAE RAS, IGEM RAS and GEOKHI RAS) and leading universities (for example, Moscow State University named after M.V. Lomonosov and RCTU named after D.I. Mendeleev) are conducting fundamental and applied studies of clay minerals investigating their behavior under RW conservation and disposal facility conditions. Their findings are regularly published in scientific periodicals and presented at Russian and international conferences. Such globally acknowledged practice, indeed, allows the customers to find the required specialists and stay updated on the research findings, and the scientific community to maintain discussion and consider different points of view. The contractor responsible for such R&Ds performed under this specific subject matter should be primarily selected taking into account the competence of its scientific workers, the availability of modern equipment, the scientific capacity of organization and the citation rate of the papers released by its employees in international databases.

Technologies and equipment for basic and applied research are upgraded annually. Hardware and software tools used in scientific research, information technologies, collection and analysis of big data open up the potential for using digital R&Ds to solve interdisciplinary problems, with the safe radioactive waste management challenge being certainly considered as such. When making a decision on selecting a particular contractor to perform research on the development of effective EBS associated with forecasting the disposal safety and its demonstration for a period of up to 10,000 years, measurement methods, their accuracy and potential human factor influence on the experimental data should be compared against the accuracy of further analysis and constructed models. The studies required to demonstrate the feasibility of a certain barrier material should be planned staking on research teams applying advanced equipment and techniques and being able to produce results in the form of data arrays under a format suitable for further calculations and forecasting using software packages.

The authors are sure that a competence center or a consortium of specialists is needed to coordinate such large-scale R&Ds. Information technologies can significantly facilitate R&D management if scientific organizations and organizations run by SC Rosatom become united under a single research and development management platform. The use of modern information technologies will enable the development of a data base on the knowledge and competencies of scientific organizations and effectively manage their projects. Tanks to a modular architecture of the platform systems required for R&D implementation can be readily assembled with necessary components being connected and engaged.

Such a competence center would be able to perform the following functions:

1. Coordination of test programs and test methods to justify the relevance and sufficiency of particular clay material properties, taking into account hypotheses based on RW packaging design solutions, forecasts regarding RW and package behavior, the geological environment, repository structures and disposal method, etc.

2. Selection of clay materials for testing with primary information about them being compared against the data on the amount of available reserves and production forecasts. Oversight over the use of the same samples during the tests being performed by different organizations and feeding of the results obtained into a single database.

3. Tracking and comparison of research findings obtained by different laboratories and test centers. Development of a system for research data management and their application in feasibility studies of particular EBS materials.

4. Monitoring scientific articles being published in Russian and in international peer-reviewed journals, compilation of technical reports, monographs, reference books that could be used in the development of technical guidelines and methodological documents enabling the design development, construction, operation, supply and testing of clay materials relying on evidence-based and validated data.

5. Monitoring clay EBS applications at RW disposal and conservation facilities and nuclear sites, summarizing the best practices and, if necessary, developing recommendations on EBS safety enhancement.

Conclusion

The authors are convinced that with no unified R&D management system allowing to select and demonstrate the feasibility of certain clay material application as EBS during conservation and construction of RW disposal facilities and with no proper oversight over the design development, examination, construction and operation of these facilities, it will be difficult and sometimes impossible to forecast their safety over the required time period with the challenge of storage facilities overhaul, their re-conservation, additional RW isolation or re-disposal to be sooner or later faced by future generations. Arranging for a consistent work execution and application of advanced technologies in the research and development of clay-based EBS materials, primarily bentonite, will increase R&D efficiency, allow to obtain scientifically-founded data on the need and sufficiency of EBS properties, to select the materials being considered as most suitable in terms of "quality—stocks—price" trinity ensuring the long-term safety of RW disposal facilities over their entire life cycle.

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