DBE TECHNOLOGY GmbH

Untersuchungen zur Endlagerung in Großbohrlöchern (02E9642)

Abschlussbericht Kurzfassung

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SECOND PHASE
OF THE ASSESSMENT OF THE REPOSITORY AT NOVAYA ZEMLYA

FINAL REPORT
EXECUTIVE SUMMARY

A Report Produced by a Consortium of Western Companies on the Basis of Information Supplied under Subcontract by VNIPI PT

ВНИПИ ПРОМТЕХНОЛОГИИ

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SECOND PHASE
OF THE ASSESSMENT OF THE REPOSITORY
AT NOVAYA ZEMLYA

FINAL REPORT
EXECUTIVE SUMMARY

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This report has been approved for issue according to the requirements of the project QA procedure.

Executive Summary

This document summarises the project “Second Phase of the Assessment of the Repository at Novaya Zemlya”. The details of the work are reported in one report for each task.

1. Background

Large amounts of radioactive waste are accumulated and are expected to arise at the Kola Peninsula and in the Archangelsk district in North-West Russia as a result of the operation, maintenance and decommissioning of nuclear powered ships and submarines. All waste is currently kept in temporary surface storage facilities, either on land or in ships. These storage facilities are almost full to capacity, are not suitable for long-term storage and in many cases do not meet Russian or international safety requirements.

The construction of a near-surface repository on Novaya Zemlya for final disposal of low- and intermediate-level waste (LILW) from operation, maintenance and dismantling of nuclear powered vessels was identified by the Russian Government as a high priority project that could be realised in the short-term and that could provide an early disposal solution. The repository would allow disposal of about 40,000 m^3 of conditioned waste with a total radioactive inventory of 3.2×10^{15} Bq in about 90 m deep shafts in a limestone host rock. The special feature of the Novaya Zemlya repository concept would be the presence of permafrost, which could prevent release of radionuclides from the repository.

A pilot repository concept was approved in principle in 1992. Following a comprehensive process over many years to develop the concept and the design for the repository and to obtain all necessary approvals by central and regional government bodies, a governmental expert commission provided its positive conclusion on the repository project in March 2002. Based on the approval by the Ministry of Ecology, by Minatom and finally by the Russian Government, it was planned that design and construction phase could start as early as in 2004.

In the process Minatom expressed interest to have the repository concept analysed and reviewed for its compliance with Western safety standards. A first review study, carried out by a Western team (including the companies involved in this project) and funded by the European Commission and the governments of Norway, Sweden and Germany, concluded in 2001 that there were no findings that indicated that a safe repository could not be built. It was found however that a number of steps were required to optimise the design and build confidence that the facility could in fact be designed, constructed, operated and closed in accordance with international standards and best practice. In particular, it was considered that further improvements in the structure of the safety assessment and in the methodology applied were required in order to conform to international best practice.

Discussions on a further Western European-Russian collaboration led to the launching of this project. The scope of work was adapted to the levels of available funding, focusing on the long-term safety aspects, especially the issue of possible future permafrost melting as a result of a climate change, and on those issues which were thought to be indispensable in order to support an appropriate design of the facility. When the project was started in June 2002 (formal contracts with all donors were in place on August 2, 2002) it was not fully financed. It was agreed between the donors and the consortium to seek EC funding for work which was planned for the concluding long-term safety assessment.

2. Overview of the project

The objective of the project was to demonstrate how the Novaya Zemlya repository should be designed, constructed, operated and closed in order to comply with internationally accepted safety standards and best practice. The formal start of the project was on July 1, 2002 and completion was planned for December 31, 2003.

The project was broken down into the following tasks:

1. Preparation of the safety case

2. Waste characterisation and waste acceptance criteria

3. Engineered barriers

4. Near field host rock

5. Waste emplacement

6. Long-term safety assessment

Task 1 provided the plan for the long-term safety assessment in task 6. Tasks 2-5 were designed to generate the input for task 6 identified in task 1.

Minatom statements that the repository was no longer in the Russian plans and the stop of Minatom funding to VNIPI PT for work on the repository project caused the donors to cancel their interest in funding further work (task 6). It was subsequently agreed with the donors that the project would not include the actual long-term safety assessment but be limited to tasks 1-5.

The project has been carried out in close co-operation between the Western team and VNIPI PT. Many difficulties have been solved by constructive efforts from all involved. The main achievements are summarised below.

3. Results

Task 1. Preparation of the safety case

The objective of Task 1 in the second phase of the assessment of the repository at Novaya Zemlya was to prepare a detailed plan for the work to be carried out in Task 6 Long term safety assessment and to define the input from other tasks that is needed for the safety assessment.

The scope of work for Task 1 was as follows:

- To define the methodology and detailed structure of the safety assessment
- To develop first versions of conceptual model(s) for the permafrost melting scenario

- To check what is already available/completed in the assessment structure and prioritize remaining activities
- To define in detail the input to Task 6 Long term safety assessment to be generated by tasks 2, 3, 4 and 5
- To define procedures for technical co-ordination between all tasks, and
- To prepare a task report.

All this has been done and is presented in the Task 1 report.

Task 2. Waste characterisation and waste acceptance criteria

The main objectives of Task 2 were to improve the waste characterization and to develop preliminary waste acceptance criteria as an input the long-term safety assessment of the Novaya Zemlya pilot repository. Particularly the following data should be provided according to task 1 of the project:

- Expected radionuclide inventory;
- Inventory of volatile nuclides;
- Type and quantity and dimensions of metals in waste and packaging that can generate gas;
- Type and quantity of decontamination chemicals in the waste;
- Quantity of concrete in concrete containers and of cement grout in containers;
- Total void volumes inside waste containers;
- Quantity of materials and chemicals that can generate/act as strong complexing agents for radionuclides after water ingress.

The most part of the required information has been determined in the framework of task 2.

The up-dated reference radionuclide inventory is a more justified basis of the safety assessment, particularly in regard to radionuclides of importance for the long-term safety analysis. Furthermore the other collected data provided by the report give the reason that a comprehensive long-term safety analysis of the Novaya Zemlya pilot repository can be performed.

A substantial progress in comparison with the Novaya Zemlya project phase 1 was achieved in characterization of radioactive waste to be disposed of at the Novaya pilot repository. An improved reference radionuclide inventory was determined based on measurements of radionuclide composition and activity of some waste streams, as well as based on a detailed analysis of earlier performed measurements and calculations and of the treatment and conditioning methods. However, this reference inventory includes some uncertainties caused mainly by the sampling methods and problems of generalization of the measurement results.

Nevertheless, the results of the corresponding work have shown, that the updated radionuclide composition is in line with the reference radionuclide inventory developed during the Novaya Zemlya project phase 1. The updated activity of radionuclides of relevance for the long-term safety of the repository is in the same order, thus it should not be expected that the long-term safety assessment of the repository to be performed based on the up-dated inventory will require any changes of the repository design due to characteristics of the radionuclides.

Factors causing gas generation were analyzed including kind and amount of gas generating materials and free surfaces of materials, which can generate gas. The corresponding data still include some uncertainty because no chemical analyses related to gas generating materials were performed due to the limited financing and time. Thus, the amount of the major gas generating materials aluminum and zinc were assessed based on the knowledge of waste origin and the treatment and conditioning methods.

No progress was achieved related to the materials generating complexing agents, because no chemical analyses were performed. VNIPI PT has stated, that there are no free radicals of complex-generating substances. However, this has to be verified by measurements.

Other characteristics of relevance for the long-term safety analysis, as void volume inside the waste packages and quantities of concrete and cement grout were determined.

A draft of the preliminary waste acceptance criteria of the Novaya Zemlya pilot repository was prepared by VNIPI PT based on the corresponding Russian legislation and the methodology developed by the western project partners. It should be mentioned that no WAC for radioactive waste disposal exist up to now in Russia. Thus, the work of VNIPI PT on WAC is the first such work in Russia. The developed WAC should be regarded as a first raw draft. The main problem of the preliminary WAC is that it is not explained in what way the different criteria were determined, or which was the basis for derivation of the limitation values.

Summarized, can be noted, that the up-dated reference radionuclide inventory is a more justified basis for the safety assessment, particularly in regard to radionuclides of importance for the long-term safety analysis. Furthermore, together with the other collected data given in the report, it supports that a comprehensive long-term safety analysis of the Novaya Zemlya pilot repository can be performed.

Recommendations in Task 2

The work on improvement of the radionuclide composition and activities of the different waste streams should be continued based on the recommendations of the Methodology and the requirements of WAC development in order to verify and complete the accumulated data. Further improvement of the radionuclide composition of the waste streams polymer blocks, large-scale metallic waste, bituminized waste, and solidified liquids is needed, as well as determination and completion, respectively, of the content and activity of the individual plutonium and uranium isotopes, and of volatile isotopes. Most important to measure are those radionuclides which have a major impact for the long-term repository safety.

Furthermore, chemical analyses of the waste streams should be carried out in order to verify and complete the data on gas generation materials and materials generating complexing agents.

The work on development of WAC should be continued in order to verify and complete it, primarily based on the results of safety analyses and the updated characteristics of the waste inventory. The determination of qualitative and quantitative protection aims based on the corresponding legal requirements should be a part of this work. The work should be performed in close cooperation and interaction with the waste producers, the developer and producer of the primary and disposal containers, as well as with the corresponding Russian authorities, primarily Gosatomnadsor. Quality assurance and quality control systems and procedures should be developed in close connection with the further work on the WAC.

Task 3. Engineered barriers

A number of important issues regarding the engineered barriers have been treated within Task 3. The various parts of the engineered barrier system have been identified with a clear description of the function of each engineered barrier and methods to verify that the requirements on the barriers are going to be fulfilled. Based on the requirements on the engineered barriers the design data have been evaluated and updated. For instance, data are specified for the thickness of the bottom plate, distance between waste container layers, and distance from containers to the shaft wall. Further, the requirements on the cement-bentonite backfill barrier have initiated work on developing a suitable backfill mix.

The expected processes for gas evolution have been identified and gas production from a typical waste has been estimated. Preliminary calculations on gas pressure build-up show that the pressure build-up will be small, but if a safety assessment is carried out, it is important that western and Russian experts jointly evaluate the gas calculations.

Conclusions and recommendations on future work within Task 3

According to the results presented in Task 3, the concrete mixture developed for the backfilling process should be suitable for use in the repository. For detailed specifications however, further tests are necessary; in particular regarding the flow characteristics of the fresh concrete and its temperature development, especially at temperatures below 15 °C.

The cement-bentonite backfill mix properties have been measured on a few samples only and during a short experimental time (weeks instead of years). Therefore, the measurements must be repeated during a longer time frame. A more thorough long-term evaluation of the backfill properties will be needed before it can be finally concluded that the backfill will comply with all the specified requirements.

With a water-tight backfill the degradation processes of the repository are expected to be very slow. By comparing with the calculated degradation of the SFR-repository in Sweden, it is expected that it will take many thousands of years before there will be any degradation of the Novaya Zemlya repository. In a safety assessment it may be sufficient to make some qualified estimates about the permeability development of the backfill as a function of time, but it may be necessary to have a modelled estimation of the matrix development, e.g. by using a coupled chemistry-transport model like PHREEQC-2 used in the SFR degradation modelling.

It can be concluded that no obvious reason has been identified in the present study that a repository of the proposed Novaya Zemlya type would be unsuitable for storing low- and intermediate level radioactive waste.

Task 4. Near field host rock

Task 4 has provided methodology for construction of a near-field geosphere model, shaft selection procedure and sorption experiments of host rock – radionuclide interaction.

Near-field geosphere model

Important requirement to the near-field geosphere model was to establish a data background to be used for numerical hydrological modeling. The intention is to use commercial software tools designed for fluid flow in fractured rocks, such as NAPSAC, FRACMAN or ROCKFLOW. Important input parameters to these tools are:

- Large-scale fracture/fault zones, which will be given as deterministic input in the model.
- A description of a stochastic fracture network model. This should include identification of flow domains.

VNIPI PT has constructed maps showing the location of large-scale fracture zones. Reasonable assumptions on orientations of these fracture zones can also be made.

A stochastic fracture network model is more difficult to establish. This is partly related to lack of some data types and partly to limited availability to other data types. Unfortunately most data types are only available as summaries rather than as original raw data. Assumptions have however been made to partly amend these difficulties in order to provide a necessary background for modeling. A model consisting of two flow domains is suggested: –an upper zone approximately 20 m thick corresponding to the unloaded, exogenous zone and a lower zone, extending to depths greater than 350 m. Four to five sets of small scale fractures can be used as input to this model.

Shaft selection procedure

VNIPI PT has made a procedure for shaft selection, which follows Russian regulations. This procedure deviates at some points from the methodology suggested in this project (see recommendations below). The procedure will include some additional investigations of the fracture network, which has not been available at the present time:

- Orientation of cores during pre-drilling of bore holes, which will provide opportunity of a more complete core description.
- Geological mapping during trial shaft excavation (only summaries available at present time).

Sorption experiments

Sorption experiments with 5 radionuclides have been performed. Data for distribution coefficients of radionuclides (or the corresponding element) between aqueous fluids and carbonates/calcareous rocks can also be found in the international literature. The necessary data background for modeling purpose should therefore be available.

Recommendations in Task 4

The abovementioned problems with limited availability or lack of data for the stochastic fracture network model can be amended during the shaft selection procedure. However, in order to ensure a successful result, we will recommend that the proposed Russian procedure should be extended with the following investigations/methods:

- Bore hole imaging tools.
- Cross hole tomography based on geophysical methods.
- A numerical tool for hydrological modelling such as NAPSAC, FRACMAN, ROCKFLOW.

The two first points will ensure a more accurate description of the fracture network. A numerical tool is necessary for assessment of fluid flow in the near-field geosphere in the scenario of permafrost melting. An effective quality assurance program must be applied. Data must be carefully stored and documented.

Task 5. Waste emplacement

The specific objectives of task 5 “Package Emplacement” were:

- to generate a reliable description of the waste package emplacement technology, for using it as input to the planned safety assessment
- to provide assurance that the engineered barrier system can be properly implemented based on the selected emplacement technology

The work performed by DBE TECHNOLOGY and VNIPI PT on this task included:

- definition of methodology for deriving functional requirements by DBE TECHNOLOGY, as reviewed and commented by VNIPI PT
- definition of functional requirements by VNIPI PT, as reviewed and commented by DBE TECHNOLOGY
- review by DBE TECHNOLOGY of the existing conceptual design provided by VNIPI PT
- recommendations and specifications for the document “General Design Specification of Major Safety Relevant Devices” by DBE TECHNOLOGY
- development of the general design specification of major safety relevant devices including main technical drawings, requirements, and boundary conditions by VNIPI PT
- review of general design specifications of major safety relevant devices including main technical drawings, requirements, and boundary conditions by DBE TECHNOLOGY

Based on western experience a description of the methodology for deriving functional requirements was prepared which included an overall approach to defining the set of functional requirements. The definition of applicable norms and technical rules, compilation of operational and safety requirements for the system as a whole, compilation of boundary conditions as well as external requirements and constraints, and definition of interfaces between external and internal equipment was included with examples.

Based on this information, the safety and functional requirements were defined, and reviewed based of experience gained from the German projects Gorleben and Konrad and from the Swedish SFR silo.

Conclusions and Outlook in Task 5

Following the support and recommendations based on western experience, VNIPI PT defined the requirements to the total system as well as those to the subsystems and components.

Due to the Minatom decision not to proceed with the implementation of the Novaya Zemlya repository project, the detailed description of the emplacement equipment has not been performed.

The prepared paper “General design specification and specification of safety relevant devices”, as reviewed by DBE TECHNOLOGY, describes the safety and functional requirements, the applicable technical standards and regulations, and the operations and devices at the emplacement shaft. It constitutes a sound basis for performing the detailed design in a next step.

Long term safety of the repository will not be impeded if the equipment is manufactured in the specified manner and if the emplacement work is performed in compliance with the general design specifications and the instruction manual.

The detailed safety assessment to be performed in the future may have an impact on the results of task 5. But on the basis of the work carried out so far, it should be simple to adjust the repository system design to comply with the safety assessment findings.

4. Summary and Conclusions

The “Second Phase of the Assessment of the Repository at Novaya Zemlya” has gained further knowledge about the benefits and shortcomings of a repository for low- and intermediate-level radioactive waste.

It has been verified that no technical problems are foreseen for the construction of the repository. The repository can be constructed using existing technology, only that everything has to be carefully planned and executed.

However, it is obvious that the technique and especially documentation used so far for producing the waste packages are not sufficient to make a complete thorough analysis of what radionuclides are present in each individual waste package. Thus, it may not be possible to have a complete database of which radionuclides and what level of activity each container placed in a repository will contain.

Therefore, for the continuous work with repositories in Russia it can be concluded that the technique for producing a repository exist, however, it is urgent to develop WAC and apply them to the radwaste production. Further, with defined WAC a safety assessment of a suitable repository site needs to be performed.

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18. Abstract

The project contributed to a multinational project with the objective to assess the safety and feasibility of a novel technical concept for near-surface disposal of ILLW in permafrost formations proposed by the Russian MINATOM. The German contribution was focussed on the development of waste acceptance criteria, cementous backfill material and waste emplacement technology. Main emphasis was given to the development of sound methodological approaches. Thus, in the framework of the project were developed methodologies for

· deriving waste acceptance criteria from safety requirements,
· qualifying high dense backfill materials in comprehensive laboratory tests and
· deriving safety related design requirements for waste emplacement in large boreholes.

These methodologies may be of interest to other repository programmes as well.

19. Keywords
Final disposal, radioactive waste, Permafrost, performance assessment, waste acceptance criteria, backfill material, emplacement technology

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