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PHARE PH 4.12/95 Project
SAFETY ANALYSIS OF THE PŰSPŐKSZILÁGY RADIOACTIVE WASTE TREATMENT AND DISPOSAL FACILITY
EXTENDED PROJECT SUMMARY

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Author: R. Burcl (EC/JRC-IE)
Reviewed by: J. F. Vivier (EC/JRC-IE)
Approved by: M. Bieth 30.9.05 (EC/JRC-IE)

SUMMARY

The Püspökszilágy Radioactive Waste Treatment and Disposal Facility is located on the top of a hill near the village Püspökszilágy, about 40 km NE of Budapest, Hungary. The repository is a typical near-surface engineered facility consisting of concrete vaults for disposal of conditioned low and intermediate level radioactive waste and steel–lined wells for disposal of disused sealed sources. The repository is located above the water table in the unsaturated zone within heterogeneous Quartenary rocks. Various institutional radioactive waste from research facilities and hospitals, as well as some operational waste from Paks nuclear power plant has been disposed in the facility. Some vaults have been backfilled with cementitious material, other vaults not yet. A number of disused sealed sources have also been disposed in steel-lined wells.

In order to evaluate the post-closure performance and safety of the disposal facility and also to assess the ability of the facility to accommodate additional radioactive waste, the PHARE project PH 4.12/95 "Safety analysis of the Püspökszilágy radioactive waste treatment and disposal facility" was launched. The post-closure safety assessment was performed within this project, resulting to a number of recommendations related to management of the site and building confidence in the understanding of the facility post-closure performance.

AEA Technology was contracted for this project and the Institute of Nuclear Sciences of the Hungarian Academy of Science (ATOMKI) was the local subcontractor. The work was based on data and research results provided by the Public Agency for Radioactive Waste Management (PURAM), which is now the operator of the facility, and its predecessors.

The methodologies and approaches, based on recognised international practices and IAEA guides [1], [2], [3], were applied in the project implementation together with powerful computer software to prepare different models and perform detailed safety related calculations.

Project commenced in September 1999 and was completed in March 2001. The project was performed according to the Terms of reference and Work plan and the project aims and objectives, defined in the Terms of reference, were fulfilled.

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INTRODUCTION

The Püspökszilágy Radioactive Waste Treatment and Disposal Facility is located on the top of a hill near the village Püspökszilágy, about 40 km NE of Budapest, Hungary. The repository is a typical near-surface engineered facility consisting of concrete vaults for disposal of conditioned low and intermediate level radioactive waste and steel–lined wells for disposal of disused sealed sources. The repository is located above the water table in the unsaturated zone within heterogeneous Quartenary rocks. Various institutional radioactive waste form research facilities and hospitals, as well as some operational waste from Paks nuclear power plant has been disposed in the facility. Some vaults have been backfilled with cementitious material, other vaults not yet. A number of disused sealed sources have also been disposed in steel-lined wells.

The facility is practically full and most of the vaults have already been closed. However, considering the delay in siting and construction of a new radioactive waste repository in Hungary a question raised on increasing of repository capacity through retrieval, detailed segregation and re-conditioning of already disposed waste. Retrieval and removal from the facility of Paks NPP operational waste is also considered as an option depending on availability of a new waste repository.

An unavoidable condition for better understanding of the long term performance of the repository as well as for any consideration on accommodation of additional radioactive waste is to develop the model of the performance of the system and to perform detailed post-closure safety assessment of the disposal facility. The safety assessment should cover but not be limited to following aspects:

- Transport of radionuclides in groundwater and discharge in the area of Szilágy stream, resulting in contamination of the territory used for agricultural purposes and fishing lake;
- Potential for abstraction of contaminated water from wells for irrigation of agricultural land;
- Potential future human ingress into the facility after control of the territory and vicinity of repository has lapsed;
- Deterioration of waste as a result of natural processes.

Considering safety importance of these problems and related environmental risk, the European Commission decided to open the PHARE project PH 4.12/95 "Safety analysis of the Püspökszilágy radioactive waste treatment and disposal facility" and grant the contract aimed in review and completion of already performed safety assessment with the aim to evaluate whether post-closure long term performance could be guaranteed Another target was to provide the recommendations for future improvements of the repository, propose the plan of future research activities and identify requirements for regular updating of the safety assessments. Project commenced in September 1999 and was completed in March 2001.

1 OBJECTIVES

The overall objective of this project was to establish whether the repository site will perform safely in the future or whether remedial actions are necessary to achieve adequate performance. Another objective was to provide input for considerations on potential extension of the repository capacity.

The specific objective of this project was to:

- Review the existing data and conceptual models of the site, in particular, related to the geology and hydrogeology;
- Develop recommendations for a programme of site characterization and research;
- Develop models appropriate for use in a safety assessment;
- Undertake a comprehensive safety assessment of the site;
- Evaluate the feasibility of remedial actions, if required, and of other potential refurbishment and development actions;
- Transfer technology concerning safety assessments to ATOMKI for future use;
- Provide a review of the safety of the Püspökszilágy Radioactive Waste Treatment and Disposal Facility and advice on possible modifications.

The project was designed in such a way that after review and analysis of existing data, the realistic model of repository performance was developed and, based on estimated potential release of radionuclides from the engineered system in groundwater, doses to the exposed groups arising from the groundwater pathway were estimated.

2 IMPLEMENTATION

2.1 Distribution of responsibilities

PHARE project PH 4.12/95 on "Safety analysis of the Püspökszilágy radioactive waste treatment and disposal facility" was started in September 1999 after signing the contract No. 99 – 0167. The tasks were performed according the Terms of reference and Work plan and project was completed in March 2001.

AEA Technology (the United Kingdom) was responsible for project implementation. Institute of Nuclear Sciences of the Hungarian Academy of Science (ATOMKI) was contracted as the local subcontractor. The data and research results, provided by the Public Agency for Radioactive Waste Management (PURAM – current operator of the facility) and its predecessors, were used as a basic source of information for project implementation.

The final version of the technical project report [6] was submitted by the contractor and distributed in March 2001. Besides the safety assessment issues, the report [6] covers also the subjects of previous two interim reports, in particular, recommendations for relevant research programme [4] as well as information on radioactive waste inventory in repository and hydrogeological conditions at the repository site [5].

2.2 Scope of work and work description

The project was divided into several tasks, aimed in acquainting necessary inputs to provide an answer for principal question on post closure performance of the repository and to summarize the recommendations related to waste management, future research activities and items which should be considered in future safety assessments. The tasks covered:

- Radioactive waste inventory for use in safety assessment;
- Development of conceptual hydrogeological model of the site and site vicinity;
- Set of models of repository engineered system and barriers;
- Model of biosphere of the site and its vicinity;
- Assessment of groundwater pathways;
- Human intrusion scenarios;
- Evaluation of risk of disruptive events, in particular soil erosion;
- Long term deterioration of waste packages and/or waste forms.

A special emphasis was given to radioactive waste inventory assessment to ensure that a good basis is available for the modeling and identification of uncertainties. Various simple equilibrium models were used to describe the release of radionuclides from unsaturated vaults.

The assessment was undertaken using the approach developed and tested within the framework of BIOMASS and ICRP81 projects [1], [2]. NAMMU and MASCOT programmes, which have been used in many other radioactive waste disposal projects, were the basis for calculations.

3 PRESENTATION OF PROJECT RESULTS

The project results were presented in four basic directions:

- Results of safety assessment and conclusion on post-closure performance of the repository;
- Recommendations on potential improvements of the site and for waste management;
- Recommendations on approach to future safety assessment;
- Proposal of future research activities, related to the repository.

3.1 Safety assessment and post-closure performance of the repository

In the preparatory phase prior to undertaking the safety assessment, following work was performed:

- Simplified inventory of radioactive waste, disposed at the site, was developed to be used in actual stage of safety assessment. However, for the future assessments an effort should be made to precise activities and better understand the form of key radionuclides and the uncertainties in the inventories;
- Conceptual model and 3-D regional and site scale models of groundwater flow around the site were developed and calibrated using the data from observed groundwater levels and control boreholes. The groundwater travel time from the site in the Szilágy stream was estimated for about 100 years, and this pathway is considered as critical one which will lead to the largest doses from natural groundwater discharge;

- Various scenarios were developed for safety assessment and for each of them the radiation doses for concerned population groups were calculated. A special emphasis was given to post-closure period of the repository;
- Biosphere was modelled using simple linear models relating doses to activities of radionuclides in key environmental media, in particular in soil. Equilibrium conditions used in calculations are regarded as conservative.

Considered radionuclides discharge scenarios and related doses were, but not limited to:

- Natural discharge to soil in the vicinity of the Szilágy stream or to the stream itself. Estimated doses for this scenario are less than 100 μSv yr^{-1}, which is comparable with a proposed dose constraint in Hungary;
- Consequences of use of wells for the irrigation of agricultural land. Estimated dose rate values for the wells in the vicinity of the Szilágy stream are below 200 μSv yr^{-1}, higher values are expected for the wells closer to the site. However the last ones are not certain to be present and depending on the results of future safety assessments and relevant dose limits, it might be necessary to prevent the construction of wells at the repository slope by managerial measures for a period of at least a few hundred years;
- Human intrusion into the facility was considered in three scenarios: exposure of geotechnical worker who examines contaminated repository core, exposure of an excavation worker and exposure of population member who inhabits the site after a previous intrusion event has contaminated the soil surface. The probability of the first two options is very low, the consequence of the last option is quick leaking of the radionuclides into the environment. Estimated doses depend on the concerned vault as well as on the intervention time from the site closure. They are in the range of 100 mSv yr^{-1} - 1 Sv yr^{-1}. High doses (possibly leading to death) might occur if some of the disused sealed sources are returned to the accessible environment within a few hundreds years after repository closure. Considering this fact, the requirement for remedial action (retrieval of disused highly active sealed sources should be considered in order to obtain acceptable post-closure performance;
- Naturally occurring disruptive events might arise after several thousands of years and could lead to significant doses even after such a long period. The risk of such scenario is directly related to the stability of the site slopes.

Based on work performed it was demonstrated that given appropriate management action and some reductions in the uncertainties about repository performance, it is likely that, in the future, a post-closure safety case could be developed for the facility demonstrating compliance with relevant constraints and limits. Certain improvements and further research and site characterization work were proposed to achieve this position. Proposal was also made that current safety assessment should be updated periodically.

It was considered that continued operation of the facility is unlikely to result in the release of unacceptable amount (activity) of radionuclides to the environment. Some release of tritium, observed in the past, does not give rise to significant radiological concerns. Recommended correct approach would be to monitor the situation and keep the option of remedial action once the origin of these releases is better understood.

The results of safety assessment calculations are an important input for decision on waste management approaches and the design and planning of remediation work on the facility. They are also an important input for the specification of waste acceptance criteria.

3.2 Recommendations on potential improvements of the site and for waste management

Based on safety assessment, the key recommendations, related to the improvement of the site and waste management approach were:

- The presence of large Cs-137 and some other long lived disused sealed sources (placed mainly in A vaults and B and D wells) gave cause for concern. Therefore it was recommended to arrange for careful evaluation of the nature of the sources and analyze/evaluate the merits of their recovery. If recovery is feasible, removal of the sources from the facility should be considered and proper retrieval and further handling technologies identified. In the case of sources, mixed with other waste in backfilled vaults, it was recommended to perform a systematic review for each significant source, to decide on retrieval or leaving in the repository. The decision should be made considering all aspects of post-closure safety of the facility and, in some cases, improvement of engineered barriers (inc. repository cap) should be considered as option instead of sources recovery. In the case of sources placed in not backfilled waste, the retrieval was recommended as preferred option;
- Engineered cap of the repository vaults is considered as one of the main construction parts of the repository. The design of the cap should provide for minimization of groundwater flow through repository, minimize the possible human disturbance, reduce the likelihood that waste might become exposed as a result of natural waste packages and/or engineered barriers deterioration processes as well as prevent soil erosion. It was recommended to use in cap design a very good impermeable clay with good performance also under drying conditions, layer of stones or boulders (to discourage intrusion) and all other measures to assure high susceptibility of cap against slumping or erosion over long time periods. Another very important suggestion was to fill the free space between the waste and vault roof (cap) with the high integrity concrete;
- It is still considered an option to dispose additional waste to the repository after retrieval and reconditioning (volume reduction, repacking) of some waste or after retrieval and removal from the facility of some operational waste from Paks NPP. It was recommended to perform careful evaluation of already disposed radionuclide inventory and determine, whether an additional inventory would be acceptable in the light of future safety assessments. It was strongly suggested to develop specific waste acceptance criteria for this case;
- Some concerns were expressed, related to the fact that only a part of disposed waste in A vaults was backfilled with concrete. In the aim to avoid future settlement of waste, to reduce the direct contact of ground water flow with disposed waste, limit the potential exposure to the public, minimize potential human disturbance, etc., it was recommended to backfill the void space in repository vaults with a low permeability concrete and/or cement grout. Backfilling of the repository vaults void space has to be considered as a complex measure together with repository cap design;
- Considering post closure risks, related to the repository, proper administrative control including relevant records keeping system implementation were recommended. Administrative control should be arranged until any disused sources remaining in A vaults decay substantially – this time might be over 200 years. A combination of active (personnel located at the site) and passive (e.g. retaining ownership of the land) control should be implemented. One of the principle measures is to control the abstraction of water from the repository slopes and the repository vicinity. Arranging for relevant record on maps and in governmental archives as well as proper maintaining of long-time records on radionuclide inventory is recommended;

- As a part of active measures for administrative control a long-time monitoring of the facility was recommended, with the special emphasis on monitoring of the release of radioactivity to the environment. Remedial actions should be prepared and planned in the case of significant radionuclide release identified. Detailed examination of the inventory and state of the waste already disposed in the repository is considered as a base line for future monitoring.

3.3 Approach to future safety assessment

For the future safety assessment of the facility it was recommended to consider following general issues:

- Emphasise systematic development of understanding of the key factors, controlling the performance of the facility;
- Systematically work on upgrade of assessment models in the aim to improve description of the facility behaviour, in particular releases from the facility;
- Reduce the uncertainties of information on the radionuclide inventory and state of disposed waste;
- Provide for simplification and validation of geological and hydrogeological models of the system and demonstrate that they can reproduce the observations of the real system;
- Consider the design of the facility cap as one of the main safety features;
- Pay specific attention in future safety assessments to disused sealed radiation sources if their removal from vaults is not feasible and they were left in the vaults;
- The results of safety assessment should be considered as one of the basic inputs for development of waste acceptance criteria for the operation of the facility.

3.4 Future research activities, related to the repository

In the course of project implementation all available data and information on the site and disposed waste were analysed and consolidated. It was recognised that unavoidable condition for future safety assessments as well as implementation of some recommendations is to perform additional research work and investigations. Following research and investigation works were identified as particularly important:

- Optimisation of repository cap design and demonstration of adequate performance over a long time;
- More detailed investigation of stability and long time performance of other engineered barriers;
- Experiments to precise information on equilibration between the waste and water in the vaults – this is one of the key area for future safety assessments;
- Study of potential gas generation in the vaults and its potential impact on the waste and engineered barriers;
- Further investigation of geology and hydrogeology of the site to get more integrated understanding of the problem and provide adequate input for transport models;
- Hydrogeological testing at greater distances from the repository facility (might be also drilling of additional control wells) and performing of long term tracer tests considered as demonstration experiments;

- Further analysis of runoff data for the site and its vicinity, in particular geological testing of slopes stability.

Other, less principal subjects for further research and investigation activities are identified in the Project final report [6].

General target is to collect additional data and/or precise available information for more advanced safety assessments as well as site flow streams modelling, which are a basis for assessment and prognosis of long term post-closure performance of the repository site.

4 PROJECT CONCLUSIONS AND ACHIEVEMENTS

Comparing the achievements, as described in the preceding chapter, with objectives and work plan of this project it can be concluded that the overall objective as well as the specific objectives of the project were achieved. The main results and conclusions, structured according presentation of project results in the Final project report, can be summarized as follows:

- Simplified inventory of disposed radioactive waste, conceptual model and 3-D models of groundwater flow, various scenarios for safety assessment and biosphere model of the site were developed and radiation doses for concerned population groups were calculated within the preparatory step to safety assessment;
- Natural discharge of radionuclides to soil, use of wells for irrigation of agricultural land, human intrusion and naturally occurring disruptive events were considered as the most probable scenarios for environmental and population impact of the repository;
- Based on performed analysis it was concluded that continued operation of the facility is unlikely to result in the release of unacceptable activity of radionuclides to the environment;
- It was also demonstrated that given appropriate management action and some reductions in the uncertainties about repository performance, it is likely that, in the future, a post-closure safety case could be developed for the facility demonstrating compliance with relevant constraints and limits;
- A set of recommendations was proposed to improve the management of radioactive waste and site safety. They cover a wide spectrum of activities from the management of disused sealed radiation sources, engineered barriers improvement, disposal of additional waste, post-closure administrative control of the site, etc.;
- Recommendations for future safety assessments were prepared, identifying main inputs and general issues, which should be considered in a future work. Development of waste acceptance criteria for the operation of the facility was identified as the most important practical result of future safety assessment;
- Additional inputs, unavoidable for future safety assessments and repository post-closure performance evaluation, were identified and directions of main research and investigation activities were proposed. They are covering precision/extension of some inputs as well as investigation of some new problems, which should be analysed and solved in the aim to collect reliable data for future safety assessments.

5 REFERENCES, PROJECT DELIVERABLES

[1] ICRP, Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste, ICRP Publication 81, Pergamon Press, Oxford and New York, 2000

[2] ISAM Scenario Generation and Justification for the Safety Assessment of Near–Surface Radioactive Waste Disposal Systems, ISAM/SGWG/WD01, Ver. 1.0, IAEA Vienna, 2000

[3] NEA Safety Assessment of Radioactive Waste Repositories; An International debate of Features, Events and Processes, NEA, OECD Paris, 1998

[4] Safety Analysis of the Pűspőkszilágy radioactive waste treatment and disposal facility, Project PH 4.12/95, Phase 1 Report – Recommendations for Research Programme, AEA Technology Report PH4.12/95(00)N1, 2000

[5] Safety Analysis of the Pűspőkszilágy radioactive waste treatment and disposal facility, Project PH 4.12/95, Phase 2 Report – Inventory and Hydrogeology, AEA Technology Report PH4.12/95(00)N1, 2000

[6] Safety Analysis of the Pűspőkszilágy radioactive waste treatment and disposal facility, An Assessment of Post-Closure Safety, Project PH 4.12/95, Final Report, AEA Technology Report PH4.12/95(00)N2, 2001