DECOMMISSIONING PROJECT OF A1 BOHUNICE NPP

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INTRODUCTION

The first (pilot) nuclear power plant A1 in the Slovak Republic, situated on Jaslovské Bohunice site (60 km from Bratislava) with the capacity of 143 MWel, was commissioned in 1972 and was running with interruptions till 1977. A KS 150 reactor (HWGCR) with natural uranium as fuel, D_2O as moderator and gaseous CO_2 as coolant was installed in the A1 plant. Outlet steam from primary reactor coolant system with the temperature of 410°C was led to 6 modules of steam generators and from there to turbine generators. Refueling was carried out on-line at plant full power.

The first serious incident associated with refueling occurred in 1976 when a locking mechanism at a fuel assembly failed. The core was not damaged during that incident and following a reconstruction of the damaged technology channel, the plant continued in operation. However, serious problems were occurring with the integrity of steam generators (CO_2 gas on primary side, water and steam on secondary side) when the plant had to be shut down frequently due to failures and subsequent repairs.

The second serious accident occurred in 1977 when a fuel assembly was overheated with a subsequent release of D_2O into gas cooling circuit due to a human failure in the course of replacement of a fuel assembly. Subsequent rapid increase in humidity of the primary system resulted in damages of fuel elements in the core and the primary system was contaminated by fission products. In-reactor structures had been damaged, too. Activity had penetrated also into certain parts of the secondary system via leaking steam generators. Radiation situation in the course of both events on the plant site and around it had been below the level of limits specified.

Based on a technical and economical justification of the demanding character of equipment repairs for the restoration of plant operation, and also due to a decision made not to continue with further construction of gas cooled reactors in Czechoslovakia, a decision was made in 1977 to terminate plant operation. The decision on the A1 plant decommissioning was issued in 1979.

PREPARATORY PHASE OF A1 DECOMMISSIONING

The initial period of the A1 plant decommissioning (1980-1994) was focused on the following 3 main areas:

1. Management of spent fuel and its transport from the plant into the Russian Federation.
2. Disassembly of process components in the secondary system and of certain auxiliary systems including civil construction structures.
3. Improvement in the technology for radwaste treatment and conditioning.

1. With regard to the fact that the transport of spent fuel had not been resolved in the course of plant operation, all the fuel had been stored in a spent fuel pool on the plant site. Even during plant operation it was found that the designed and implemented method for storing the spent fuel assemblies from A1 operation results in the corrosion of fuel elements associated with the release of fission products into the coolant in long-term spent fuel storage and deformation of their geometry. Out of 182 fuel assemblies stored in this way, 128 assemblies became non-manipulated.

Following the accident in 1977 the problem became more complicated by the fact that other fuel with damaged cladding was stored in the spent fuel pool.

These conditions became an extremely complex matter requiring a gradual searching, verification and application of new technology procedures and technical tools for decontamination of materials, surfaces and components, their separation and disassembly and withdrawal and transport of the damaged spent fuel from the plant.

Out of the total amount of 572 fuel assemblies, 440 fuel assemblies were withdrawn and transported into the Russian Federation in the period 1983 - 1990. For the treatment and removal of the rest of spent fuel, it was necessary to develop and produce a special technology equipment by means of which the fuel was withdrawn from the long-term storage facility and transported in special containers into the Russian Federation. This phase proceeded in the period 1996 - 1999. By removing fuel from the plant, conditions were established for the implementation of the design phase of the A1 decommissioning up to 2007.

2. In the period following 1981, disassembly of technology equipment from the second system (process equipment in the machine hall, turbines with auxiliaries, feedwater tanks, diesel generator station, pumps, cooling towers, electric equipment) was carried out. At the same time disassembly was going on other systems – turbine generators with auxiliaries, gas systems, oil systems and other equipment and systems in the main production building and in nearby buildings.

The areas following the disassembly were cleaned, decontaminated and prepared for the assembly of new technologies related to the subsequent phase of the plant decommissioning.

The amounts of disassembled metal materials used as secondary raw materials are as follows:

steel	1641 t
brass	259 t
aluminum	22 t
alloy steel	163 t.

In relation to the implementation of disassembly activities, a facility for the decontamination of low-level contaminated materials was built.

Subsequent decontamination of technology equipment from the primary system is the content of the current phase of the A1 decommissioning.

3. In the area of processing of liquid radwaste, a serious issue occurred at the beginning of the disposal activities. Due to extensive decontamination works after the plant accident, the storage tanks of liquid radwaste concentrates have been filled up to 95% and no other storage volumes were available. A method was chosen to install another evaporator by means of which all the concentrates (1500 m^3) were processed down to the reduced volume of 150 m^3 during 2 years and in this way a back-up volume was established in the tanks for subsequent continuation of activities related especially to the disposal of spent fuel.

A decisive action was the implementation of the Bohunice Complex for Radwaste Treatment and Conditioning (BSC) and the completion of the National Radwaste Repository (RU RAO) which covers the capacities needed also for other nuclear power plants in operation in the Slovak Republic.

The main result of the solution of research and development projects was that new technologies for radwaste processing by means of bitumination, cementation, incineration and vitrification, including the construction of experimental and semi-operational facilities used up to now, were developed and mastered.

The goal was to upgrade the safety standard in plant buildings and to address the decontamination of rooms and radwaste disposal.

A1 DECONTAMINATION – PHASE I

Following the period of preparation, the decommissioning process has started by developing the „Project of bringing A1 into radiation safe conditions" (1995). The activities defined in the project are included in Phase I of the A1 decommissioning. The basic objective of the phase I is to remove spent nuclear fuel and radioactive materials occurring in non-fixed state in the A1 plant. These radioactive materials had come from A1 operation and from activities during the decommissioning till 1994.

The second basic objective is to create conditions for improving the protection of the environment and to establish conditions for complete decommissioning of the A1 plant in Phase II. The basic deadline – the completion of decommissioning Phase I and beginning of Phase II - is 2007.

Since 1995, technical problems and production of equipment associated with the gradual removal and transport of liquid radwaste into the processing center and with the preparation for removal of spent fuel in assemblies with degraded integrity from the plant has been addressed predominantly. (Non-damaged fuel assemblies had been transported into the Russian Federation during the first years following the accident). This phase was managed successfully till 1999 when the last transport of spent fuel in special containers from the plant into the Russian Federation was carried out.

A pre-condition for launching another phase of the A1 decommissioning was the construction of a radwaste processing center on the plant site and completion of the construction of a national repository of low-level and medium-level radioactive waste in Mochovce (90 km distant from A1). These pre-conditions were met in 1999. The project of A1 decommissioning is split into 4 main groups of tasks:

- group 1: Environment
- group 2: Main production unit
- group 3: Radwaste treatment and conditioning
- group 4: Technical support for A1decommissioning

ENVIRONMENT

Tasks in group 1 are focused on the solution of selected problems that have immediate impact on the environment. It is mainly the solution of problems in the building of cleaning station of wastage water and in the building with underground storage tanks for wastage water and solid radwaste, including the prevention of wash-out and penetration of contaminated soil from these buildings into surface and underground waters. The main objective is to avoid both acute and potential sources of environmental contamination. The provision of monitoring of gaseous and liquid discharges belongs also into this circle of problems – this task is addressed within the operation of systems that create necessary conditions for the actions of personnel during the decommissioning.

Main areas of solution of the decommissioning of technology equipment from A1 external buildings

A part of addressing the tasks in group 1 is to ensure disassembly and decontamination work with the help of remotely controlled tools the development and design of which are carried out based on the monitoring of actual conditions and based on the modeling of computer simulations.

The results are used for designing tools and technology procedures mainly for methods how to decontaminate not easily accessible equipment (underground storage tanks, components in cleaning station, intermediate storage tanks, pumping and piping systems.

The outputs are DENAR-41 systems – arm column manipulator and hydraulic manipulator MT-80 with 6 degrees of freedom with end additional tools for cleaning by means of pressurized water (up to 220 bar) res. of mechanical effects. They are designed mainly for decontamination and disassembly of contaminated and damaged tanks of various volumes (from 100 m^3 up to 700 $m^{3)}$ and wit various diameters (from 6 m up to 16 m). These tanks were made out of reinforced concrete segments and their surface was finished by polyester bitumen that has been damaged under effects of various factors. Various equipment for remote manipulations with additional equipment are designed to eliminate these damaged points and to decontaminate them subsequently.

A part of addressing these tasks is a controlled management of generated radwaste – predominantly sludge with various physical and chemical properties. Radwaste is verified based on determination of physical and chemical properties (fraction of dry parts, fractions of cations – Na^+, K^+, Ca^{2+}, Mg^{2+}, anions – CO_3^{2-}, SO_4^{2-}, Ce^-) and based on radionuclide composition α, β, γ - nuclides, various methods of solidification – mainly cementation. In combination with concentrates from the V1 res. V2 plants, properties of the cemented product for possible filling into fiber-concrete containment (VBK) are verified.

In the task group 1, mainly decisions on the management with cleaned up underground storage tanks, res. sumps, with their possible modification for interim storage of barrels with the volume of 200 dm^3 with pre-processed radwaste, is addressed. Also the supply of new, or repair and tightening of the existing piping distribution systems for provision of high quality and safe manipulations with liquid radwaste by means of redundant pipelines via the systems of active piping drainage is also included in this group of tasks.

Selected, grouped radwaste is led mainly to technology systems for its treatment and conditioning at existing systems – densification, cementation, bitumination, incineration and high pressure compaction. A part of emptied storage rooms, mainly the building 44/20, will be used for the interim storage of 200 dm^3 barrels. For this purpose, certain underground rooms in this building are tightened and equipped with radwaste monitoring systems.

MAIN GENERATION BUILDING

The group 2 tasks – following the removal of spent fuel - are focused on the disposal of all radwaste in the long-term storage facility, in the short-term storage facility, equipment of transport and technology part, equipment in hot boxes. A part of tasks in this group are the following tasks: Optimization of technology distribution piping of pressurized air and cooling water, facility for decontamination of A1 rooms and equipment and the decontamination of rooms and equipment itself.

Main areas of addressing decommissioning of the main generation building

With regards to significance, the most important task in the group 2 is decommissioning of the A1 long-term storage facility where most of contaminants have remained following the removal of spent nuclear fuel (spent nuclear fuel) from the point of radiation hazard.

The main attention has been focused on re-storage res. drainage of penals in the long-term storage facility (technical facility for storing spent nuclear fuel in cool-down media such as chrompic, i.e. 2-3 % water solution of potassium bi-chromane, res. dowtherm, which is an eutectic mixture of difenyl and difenyl-oxide). For these types of liquid radwaste, available technologies are used, specifically vitrification for chrompic and incineration for dowtherm. Empty penals in the long-term storage facility will be fragmented on a fragmentation facility, which has been developed within the solution of the project and will be supplied at the end of 2002.

At the same time specific problems of sludge solidification have been addressed in situ, such as in 200 dm^3 barrels using various inorganic binding materials.

A significant problem in task group 2 is the solution of decommissioning res. of decontamination of the complex of equipment in the so called A1 hot box. It is a complex of equipment used for post-radiation monitoring, inspection and sampling of spent nuclear fuel res. of spent nuclear fuel structural elements during A1 experimental operation.

The equipment of hot box such as chamber of hot box, decay shaft and mainly a special pump of hot box, are contaminated by radionuclides and specifically by α - nuclides.

Problems related to distant manipulations for the decontamination and disassembly of the equipment in question thus have been addressed. Procedures leading to removal of contaminants mainly from the special pump in hot box have been proposed.

A part of the solution in this task group is also solution of specific problems of decontamination using electric-chemical decontamination and using mobile tools for decontamination of surfaces of civil structures and of technology equipment.

For the purpose of safe, continual operation of technology modules mainly in the area of radwaste management, decontamination and disassembly, new distribution system of pressurized air is innovated and supplemented, the distribution of cooling water (closed system with cool-down in micro-towers) is optimized and discharge of drain water by means of safe separation of the instrumentation and control system from the drainage system on Bohunice site is optimized.

RADWASTE TREATMENT AND CONDITIONING

The group 3 tasks are focused on the development of technology procedures for treatment and conditioning of sludge, contaminated soils and concrete crush, saturated ionexes and ash from incineration facility of the Bohunice radwaste treatment and conditioning complex. Within this group also technologies for processing of metal radwaste and problems of utilization of special technologies (vitrification facility, discontinual bitumination facility) for processing special cooling and storing media are addressed. In this group also treatment of such radwaste is addressed which cannot be disposed in radwaste surface repository.

Main areas of solution of radwaste treatment and conditioning

In the area of treatment and conditioning mainly of sludge, the development has been focused on the addressing of treatment and conditioning in the existing facilities, mainly the cementation facility in BSC (for the so called sludge transported by water from storage tanks – see tasks in group 1). In combination with saturated sorbents, possible procedures for decantation, drying and bitumination have been verified both in laboratory and quarter-operational scale. Analytical methods for the evaluation of technology-related parameters (residual humidity, ratio of additives to defoaming, elimination of stickiness and so on) have been verified. The results are proposals for modifications of equipment design in the discontinual bitumination facility.

By verifying the procedures for in-situ solidification in 200 dm^3 barrels, problems of treatment and conditioning of the so called bottom sludge, gravel sands and so on by means of their cementation directly in 200 dm^3 barrels have been addressed. The ratio of dry substances, concentrations of decisive radionuclides, leaching capacity and volumetric stability (strength) have been mainly verified.

From the addressing of problems related to the management of contaminated soil, after establishing lysimetric fields, experimentally-based results for the determination of conditions for storing the above mentioned soil, res. the knowledge leading to decisions about the construction of central storage facility of contaminated soil have been obtained.

Another important issue being addressed in the group 3 tasks is the treatment and conditioning of chrompic (2-3 % of water solution of potassium di-chromate) used for spent nuclear fuel cool-down, mainly of its sludge components.

A possibility to vitrify the above mentioned sludge has been verified experimentally in model-scale in small cold furnace.

A part of addressing the above mentioned group of tasks is the solution for the management of metal radwaste by supplying specific facilities for fragmentation – scissors for longitudinal and cross shearing, technical tools for cleaning the atmosphere, auxiliary handling tools. The result of the performance of these facilities will be fragmented metal radwaste, selected and designed for further management – either by decontamination with the objective to discharge it into the environment, res. by re-melting.

A significant problem in addressing this group of tasks is to provide input documents (studies and intentions according to EIA) for the construction of the so called modular-like integral storage facility which will have enough capacity for large-scale radwaste, res. for processed radwaste and non-disposable radwaste in the National Radwaste Repository Mochovce.

An important part of addressing problems related to the safe management of liquid radwaste (mainly with high content of α - nuclides) with spent fuel cool-down media (chrompic, sludge) is the reconstruction of technology systems for chrompic vitrification by supplying new mechanical equipment, instrumentation and control systems and technology procedures. The result seems to be the use of the existing technology system of the vitrification facility also for the treatment and conditioning of sludge resulting from chrompic from storage tanks KS-2, MSN following sludge drainage from penals in the long-term storage facility.

TECHNICAL SUPPORT FOR DECOMMISSIONING

Tasks in group 4 are focused on the methodology and technical support for the particular activities applicable during plant decommissioning with the emphasis on the A1 decommissioning. The project thus gets a complex character and provides not only the preparation for the A1 decommissioning itself, but also the preparation of a supplier system for the decommissioning of other nuclear installations. In this group of tasks, methodological questions of decommissioning procedures, proposals of information databases for decommissioning and their input, proposals of technologies and equipment for the decontamination of surfaces of civil structures and technology equipment, development of technology procedures and tools for the disassembly and fragmentation of equipment and remotely-controlled tools for handling and for recognition are addressed. A part of the solution are methodological questions related to monitoring and radiation safety and the protection of personnel and of the environment in the course of decommissioning of nuclear installations including safety questions related to the handling and disposal of treated radwaste in the National Radwaste Repository.

Main areas of addressing the technical support

1. Conceptual plans for the decommissioning of the Bohunice Radwaste Treatment and Conditioning Complex (BSC) and of the Bitumination Facility (BL) – The development of both plans was incorporated into the solution of the task due to a provision in the basic „atomic“ law "*odkaz?*" according to which the submission of conceptual plan for decommissioning is a precondition for issuing a permission for the construction of any nuclear installation. The BSC and BL installations situated on the site of the A1 plant were commissioned at the end of nineties which means at the time where the phase I of the A1 planned decommissioning was started. Both documents were developed and approved by the Slovak Nuclear Regulatory Authority (ÚJD SR).

2. Methodology for the evaluation and selection of the most suitable option for the decommissioning of nuclear installation. The objective of this project part is to develop and verify a comprehensive algorithm and a computer code for the comparison of cost evaluation and of main parameters for nuclear installation decommissioning (possibly of a diverse set of buildings in the nuclear installation) and for the selection of the most suitable option of decommissioning. The whole problem was addressed based on the principle of modules with the particular activities evaluated with regards to technical and safety parameters. The following activities were evaluated:

- pre-disassembly decontamination,
- disassembly,
- post-disassembly decontamination,
- decontamination of civil structural surfaces
- demolition,
- treatment, conditioning, storage, transport and disposal of radwaste,
- dozimetry control,
- personnel exposure,
- impact on the environment,
- measurement of the activity of technology and civil construction materials,
- maintenance and repairs during the decommissioning process,
- project planning and management, including hazard incorporation,
- other costs of decommissioning (guarding, insurance, taxes ...).

In the process of solution, necessary input data for the evaluation of activities during decommissioning, their structures, the contents and methods of obtaining including a databank of technical and economical parameters, technical and other procedures and technical tools for carrying out decommissioning activities were specified.

The result of solution is the computer tool "Omega" designed for the following set of computer options:

- for the calculation of nuclear installation decommissioning parameters,
- for the optimization of the particular decommissioning options,
- for the comparison of options, and
- for the selection of the most suitable option based on multi-criterial analysis.

The computer tool runs with data in the „Oracle“ environment. The code able is able to take and process the data from external sources, in this case from a database for the A1 decommissioning, taken as a separate problem of technical support for nuclear installation decommissioning.

The fundamental properties of the computer tool Omega are as follows:

- automated generation of computer sets according to defined conditions and the extent of the database,
- the computer set is structured according to a list of cost items for decommissioning, standardized internationally,
- a part of the solution is a database of technical and economical parameters for the hardware, processes, personnel, working hours and other parameters used,
- the computer tool makes it possible for the user to cooperate extensively in local parameters and settings and with database parameters at the level of individually calculated items which makes it possible to optimize technically the decommissioning option,
- the computer tool cooperates with the Microsoft Project in both directions; this cooperation provides time optimization of the decommissioning option, and the output set for the display in the Microsoft Project and relevant sources are generated automatically in line with the conditions defined,
- the computer tool enables to work with output sets in the Microsoft Project and Excel environments, the output sets have table character and the character of time evolution of parameters, and they are used for the comparison of options and for the selection of an option of decommissioning according to multi-criterial analysis,
- the computer tool runs with nuclide discrimination at the level of the particular radionuclides which makes it possible to work with limits and conditions for radwaste disposal, for release of materials, with technology limits defined according to the particular radionuclides.

3. The database for nuclear installation decommissioning is included in the tasks of technical support with the objective to collect data and develop a database to be used in the computer tool for the comparison and selection of the most suitable option of decommissioning (see the previous task), and also for the incorporation of advanced CA technologies for the creation of the above mentioned database on the basis of photo and video documentation and the application of laser technology for the documentation of the actual conditions. A significant part of the solution is also digitalization of the existing documentation of selected technology systems, civil construction structures and mechanical equipment by means of scanning and subsequent vectorization into the AutoCad environment.

During the solution, a design of a pilot workplace with advanced CA technologies was developed based on which the procurement, installation and bringing into use of modern HW and SW tools was implemented which made it possible to create digitalized 2D a 3D documentation, the validation of existing and the creation of missing documentation including the utilization of laser sensors for these purposes. A significant part of the pilot workplace is spatial modeling of systems, equipment and rooms for the design and simulation of procedures for dismantling and handling with parts of equipment in technology units under complex and limited spatial conditions.

Note: the pilot workplace will be supplemented by a figure during the presentation.

Also an information database for A1 decommissioning was proposed and developed during the solution, operating in the SW Oracle environment. The task has continued and addition and updating of the database during the whole A1 decommissioning process is assumed.

4. Technology and equipment for the decontamination of civil structure surfaces and technology equipment. During the solution of this task related to technical support, the objective is to design experimentally verified decontamination procedures for external and internal surfaces of technology equipment in the main production building (HVB) and to propose, design and supply a mobile complex for the decontamination of surfaces of technology equipment and civil structures in the main production building, including super-structures and replaceable fixtures for various decontamination methods and procedures.

A decontamination facility for circuit chemical decontamination for its incorporation in the decontamination of technology parts in the main production building, or possibly in other technology systems, decontamination of which will be carried out in the project, was proposed, designed, implemented and tested during the solution of the task.

A significant part of the solution is a simulation of decontamination procedures for decontamination tools being developed, used under demanding spatial conditions using HW equipment and SW being developed in the previous task.

5. Radwaste monitoring and radiation safety and protection of personnel and of the environment during nuclear installation decommissioning and radwaste management. The following problems have been addressed in this task:

- Technical and economical background materials for the evaluation of activities carried out in the course of decontamination and disassembly work and during the release of materials into the environment according to ALARA principles. The ALARA principles require to keep continual attention and to project experience into guides and procedures for the performance of the activities given. Practical knowledge and experience obtained during the implementation of selected activities in the course of the A1 decommissioning were used and projected into the legislation for the assurance of radiation protection, including the release of materials from nuclear installation decommissioning into the environment (mainly financial evaluation of benefits from measures for the reduction of radiation exposure of personnel working with radiation and of population depending on the amount of the dose avoided).

- Methods for the control and evaluation of radiation situation and personal doses of personnel for specific scenarios modeling the working conditions applicable during nuclear installation decommissioning. The attention was focused mainly on the evaluation of particular work procedures in cooperation with ALARA committee. In the methodology area, generally acceptable tools for the evaluation of personnel radiation exposure using computer codes were incorporated, modified for various scenarios of activities and for actual rooms with regard to the location of sources of ionization radiation.

- Methods and tools for the evaluation of health hazard for personnel performing their work under demanding conditions for the protection against the effect of ionization radiation, enabling to look for and evaluate casual relations among the radiation exposure and possible damage of health.

The control and evaluation of the impact of the decommissioning of A1 and BSC on the environment was carried out with increased attention paid to radionuclides detectable with difficulties. A specific situation is created by cumulating radiation sources in space (the A1 main production building, the building with the cleaning station of drain water and radwaste tanks, the Bohunice radwaste treatment and conditioning complex and bitumination facilities, and also VÚJE laboratories are located in close vicinity). Increased attention is thus paid to a systematic evaluation of the radiation situation around the above mentioned buildings (monitoring of the level of activities of aerosols and wash-down in the ground layer of atmosphere, continual measurement of external dose rates connected to PC and measurement of the level of monthly doses of external radiation at the elevation of 1 m above terrain using TLD). This evaluation in the area given has been carried out without interruptions since 1992 (since the beginning of the construction of the Bohunice complex) which makes it possible to follow the impact of activities that characterize comprehensively the A1 decommissioning from long-term point of view and also enables to evaluate trends.

Note: the presentation will be supplemented by pictures.

6. Improvement in the usability of the National Radwaste Repository. The task is focused on the establishment of assumptions for the improvement of the National repository of low-level and medium-level radwaste in Mochovce. The following measures were chosen to achieve this objective:

- the analysis of the performance of repository cover and the review of its basic properties by modeling tools,
- the analysis of the need to extend the repository in time relations with regard to the expected development in radwaste generation, including the analysis of a possibility to dispose non-standard low-level and medium-level radwaste,
- the consideration of a possibility to extend the radwaste repository in Mochovce accounting for the results of precized safety analyses, the modifications implemented in the course of repository completion and the operating experience using the database of technology parameters and results of monitoring accounting for the results of areal non-destructive geophysical survey of the repository site and of its closest vicinity.

Based on the safety analyses performed within the framework of the repository completion, the parameters of the ultimate cover affect significantly the total assessment of the repository impact on the environment. A decision was thus made to consider alternative solutions of the ultimate cover and to verify the performance of the particular solutions and particular important parameters of the cover by means of model tools. While doing this, the following possibilities were used:

- experimental research of material parameters entering the particular structures of the cover under laboratory conditions,
- mathematical modeling of geotechnical issues of the cover,
- physical research of properties of particular structures of the cover in their interrelation in the geotechnical laboratory,
- research of such cover properties that cannot be obtained by any of the above mentioned methods on physical model „in-situ“ just on the repository site.

The principle objective of this work is to obtain a more reliable background for the design solution of the ultimate cover with regard to the long-term requirements laid on it. It is based on the assumption that the cover performance will be maintained during the period of the cover institutional control as a minimum, which will last for the time period of the order of 300 years according to current considerations.

The clear conclusion from the solution up to now is that it is most effective to use all the forms of modeling. A significant part of the solution is to review suitable natural materials (first of all clay) suitable for the particular structures of the ultimate cover with regard to their availability (amount, distance, properties). From this point of view, the actually available materials will be used also for the physical research in the geotechnical laboratory. The objective is to keep essentially only those tasks for the model „in-situ“ that cannot be resolved by simpler means.

Even though considerations related to the extension of the Mochovce repository significantly run ahead of the actual needs, a detailed geophysical survey of the site and its closest vicinity was carried out in relation to the up to now results of engineering, geological and hydrogeological surveys which indicated benefits and disadvantages of the particular alternatives of the extension. Another assessment of the particular options of extension will be performed in the process of the Environmental Impact Assessment (EIA).

Within the framework of considering a possibility for disposing non-standard radwaste, the task was to consider first the disposal of metal waste with dimensions limited by box dimensions in the existing national radwaste repository. It was shown that the issues related to the management of heavy and bulky metal waste from the decommissioning of nuclear power plants prior to its possible disposal in the repository, that is handling the waste, possible fragmentation down to suitable dimensions and mass, preparation for transport, the transport itself, handling on repository site, will be safety significant at least in the same way as the disposal itself. Based on this it was shown that the disposal of metal waste with large dimensions directly into the repository is acceptable from the safety point of view only after a sufficient time period (approximately 30 years) during which such facilities should remain closed with inspections, which essentially corresponds to the accepted concepts.

The second group of radwaste needed for dealing with is the disposal of such waste types not explicitly included in safety analyses with regard to the possibilities of mathematical codes used for the safety analyses. The safety analyses were explicitly done for such a form of waste that is disposed into the repository in fiber-concrete containers (VBK) in metal barrels with solid waste, res. with waste fixed by cementation or bitumination inside the containers. Barrels are filled by cemented filling. The ratio of non-cemented and cemented waste forms for the whole repository is expressed by the so called coefficient β with the value of 0.62. For „non-standard“ waste, the problem is mainly to dispose fiber-concrete containers with cemented 200 l barrels with inserted dried residues of ionexes, sludge, or possible with ash which are not fixed homogeneously by cemented filling. For the resolution of this issue, it was shown that it is necessary to adapt and introduce for the demonstration of the long-term safety of repository another mathematical model and associated SW code that will be sensitive also for the sort (type, composition) of the packed form of the disposed radwaste. This issue is included in the solution of a task shown below.

7. Assessment of radwaste repository safety. Within the solution of this task, attention was paid mainly to the elaboration of safety analyses for the Mochovce repository. With regard to the need to evaluate the trial operation of the repository and to the requirements of authorities, the impact of various options of the parameters characterizing the properties of fiber-concrete containers and of radwaste cemented in them with regard to their release into the environment (sensitivity analysis) was reviewed.

It was shown by the sensitivity analysis, that the flow of radionuclides ^{41}Ca, ^{59}Ni, ^{79}Se, ^{93}Zr, ^{93}Mo, ^{129}I from the repository is determined by the hydraulic conductivity of clay in the cover and in the clay bath. For ^{135}Cs, the most important parameters are distribution coefficients for concrete and clay and the hydraulic conductivity of the clay bath. Release of ^{239}Pu from the repository is the most sensitive on the clay distribution coefficient (in a less degree on the clay hydraulic conductivity in the cover and in the clay bath and on the distribution coefficient of concrete). The release of ^{90}Sr is sensitive on the clay distribution coefficient and clay hydraulic conductivity in the clay bath. For ^{14}C, the most important parameter is the clay hydraulic conductivity in the cover.

Besides the above mentioned parameters, also the limit of nuclide solubility has a significance. The solubility limit has been important mainly for nuclides ^{94}Nb, ^{99}Tc, ^{107}Pd, ^{126}Sn, ^{151}Sm, ^{238}Pu, ^{241}Am, so that these radionuclides cannot get into the environment in the amount not permitted by generally accepted limits for the exposure of the public. This means that these radionuclides are not limited for the repository.

Based on this knowledge it was shown that for the ultimate release of radionuclides into the environment, with the availability of all other barriers, also the option with a possible reduced integrity of fiber-concrete containers is acceptable.

The solution of such an issue is limited by the code used for safety analyses. Basically the same approach was used as in the previous safety analyses, i.e. a modified Belgian code "*chýba odkaz 0*", enabling stochastic calculations. In this code, container plays the role of one of barriers characterized by parameters of lifetime and hydraulic conductivity. By changing the values of these parameters, it is possible to simulate in calculations also containers with reduced integrity. A more sophisticated solution of this issue is expected by using a code making possible to precise the source term in safety analyses. An adaptation of the DUST code for the safety analyses of radwaste repositories of surface type has been elaborated and databases of parameters have been prepared for the application of this code for decision-making about the safety of disposal of various forms of the waste disposed, i.e. also of „non-standard" radwaste.

CONCLUSIONS

REFERENCES

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