International Decommissioning Network as a Forum to Support Decommissioning Activities In Countries with Limited Resources and Experience: the Serbian Case - 9026

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ABSTRACT

Vinca Institute Nuclear Decommissioning Program (VIND Program) is aimed to improve nuclear and radiation safety in the Vinca Institute of Nuclear Sciences, Serbia, by repatriation of the leaking spent nuclear fuel, expanding the capabilities for radioactive waste treatment and storage, and the decommissioning of several nuclear legacy sites. In this paper the case of heavy water research reactor decommissioning is considered, some specific needs for the support through IAEA International Decommissioning Network are elaborated, and proposals for events and activities which could help the preparation and implementation of key decommissioning tasks are made.

INTRODUCTION

Republic of Serbia is a non-nuclear country with several research and waste storage facilities located within the Vinca Institute of Nuclear Sciences near Belgrade.

Vinca site accommodates two research reactors, interim spent nuclear fuel storage, facilities for the low and intermediate radioactive waste storage, irradiation facility, and underground tanks for liquid radioactive waste. Heavy water research reactor RA (6.5 MW) [1-4] is out of operation since 1984, with its partly leaking spent fuel still on site [5,6]. Waste storage facilities are in poor condition, with no capacity of receiving new waste expected to be generated during the spent fuel removal and reactor decommissioning activities. Capabilities for waste treatment in the Institute are very limited. There is no disposal facility in the country. For decades Vinca staff has been oriented towards the research and development activities, and without any prior experience in decommissioning. National legislation is not well developed to regulate the decommissioning activities.

In such conditions Serbia is facing serious nuclear and radiation safety and security concerns related to the spent nuclear fuel, RA reactor decommissioning, and management of the radioactive waste.

The RA research reactor first went critical in December 1959 and was temporarily shut down in August 1984. Its full thermal power was 10 MW, and it was operated at nominal power of 6.5 MW, except last several years of operation at reduced power of 2 MW. From the commissioning in 1960 up until 1975 ex-USSR origin low enriched TVR-S type uranium fuel (2% of U-235) was used. From 1976 the original fuel was gradually replaced by highly enriched uranium fuel (80% of U-235). Reactor was stopped in 1984 for modernization and partial reconstruction of control and safety systems.

Due to numerous technical, regulatory, and economic reasons the RA reactor had not been restarted during the long period of extended shutdown [7]. A proposal for final shutdown and decommissioning was submitted to the Government in 2001. Final shutdown of the reactor was declared in July 2002.

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During RA reactor design, construction, operation and extended shutdown stages there was no decommissioning-oriented team assembled and no initial decommissioning plan was prepared. RA reactor staff had been significantly reduced during the period of extended shutdown and the decommissioning project was faced with the lack of experienced personnel from the operating phase.

APPROACH TO MAIN SAFETY PROBLEMS

Immediately after the decision for final shutdown of the reactor was made, the complete stock of fresh, highly enriched uranium fuel was shipped to the country of origin (Russian Federation) in August 2002. Preparatory activities for the reactor decommissioning have been supported by the IAEA through Technical Co-operation Programme (TCP) since 2003, while the Serbian Government established regular funding of the RA reactor decommissioning project since October 2004. Decommissioning project is part of the VIND Program [8], which main objective is to improve nuclear and radiation safety in the Vinca Institute by repackaging and shipping the spent nuclear fuel back to Russian Federation, by decommissioning the RA reactor and improving radioactive waste storage and treatment capabilities in the Institute.

The approach chosen to accomplish RA reactor decommissioning [9] is that the Vinca Institute will be the licensee, performing the project with in-house resources supplemented by specialist contractors as needed. The project team has been established from the available personnel of the Institute organizational units: Centre for Nuclear Technologies and Research NTI and Radiation and Environmental Protection Laboratory, and organized in two main functional divisions – Planning and Operations division. Planning division, consisting of experts in reactor physics, nuclear engineering, radiation protection, and waste management, is in charge of the planning, cost estimate, quality assurance, health and safety, personnel training, and administration services. Operations division includes maintenance, characterization, cleanout, waste management, and record keeping group. The core of the second division has been formed out of existing RA reactor staff, in order to gain maximum benefit from their experience gathered during the extended shutdown period and their familiarity with the reactor systems and the site.
Support to the RA reactor decommissioning team is provided by the existing Institute services: health physics, medical protection, fire protection, physical protection, export-import, and administration.

Since 2002 many transitional activities (from operation towards the decommissioning) [10,11] have been performed at the RA reactor. These include characterization survey, planning, preparation of safety related documentation, upgrade of certain reactor systems (ventilation, radiation monitoring, internal transport system, power supply) [12], removal of operational and transitional waste, some dismantling operations in the spent fuel storage area [13], and improvement of the physical protection systems. At the same time work has been done to improve Institute radiation protection and environmental monitoring infrastructure, and to construct new waste storage and waste treatment facilities.

In the next phase of VIND Program – after the shipment of spent fuel to Russian Federation scheduled for 2010 – focus will be moved to the implementation of dismantling activities at RA reactor, application of the dismantling technologies and tools, further elaboration of the safety assessments for particular dismantling operations, as well as the material clearance and waste management. An effective way of the Vinca staff training for that phase can be provided through visits to other decommissioning sites, attendance of the various training courses, exchange of video materials, active participation in forum discussions, and exchange of experts and working teams. All these forms of information and experience exchange are to some extent already available through the existing networks (R2D2, DeSa/FaSa) and planned to be offered by the IAEA International Decommissioning Network (IAEA IDN).

As VIND Program teams have gathered experience oriented mostly to transition, planning and characterization activities, the discussion and proposals elaborated in this paper will primarily be related to these issues.

INTERNATIONAL COLLABORATION IN DIFFERENT DECOMMISSIONING ASPECTS

Realization of the VIND Program is supported by IAEA through several TC Projects. Vinca's personnel attended trainings and workshops on team building, basics of decommissioning, planning, characterization, project management, cost estimate, and safety assessment. Several IAEA expert missions were organized in order to assess conditions and give recommendations for the project preparation and planning. Visits to other sites with similar facilities undergoing decommissioning were organized for the key members of the decommissioning team. Participation in the IAEA regional and international projects has been enabled (DeSa, R2D2P, RER/9/058, RER/3/005). VIND Program realization has also been supported by providing the necessary equipment for sampling, radiological surveys, laboratory analyses, decontamination, material handling, cutting and cleanout activities as well as the portable ventilation, contamination control and personal safety equipment.

Several organizations, mainly from developed countries, are supporting VIND Program realization by funding some activities, providing equipment or expert support in planning, preparation or review of technical and safety related documentation. This contribution is also coordinated by the IAEA.

Decommissioning Planning

Since 2003 RA rector decommissioning planning team has prepared first draft of the decommissioning plan according to the IAEA guidelines [14]. In this process significant expert support has been provided through the national IAEA TC project. Numerous expert missions and several training events (project management, cost estimate) have been held in the Vinca Institute. Participation of key project staff in the international events has also been enabled (IAEA RER/9/058, RER/3/005 projects). Members of the planning team have been involved in couple IAEA expert missions in order to transfer Serbian planning experience to other countries with similar facilities to be decommissioned (China).

During preparation of some portions of the RA reactor decommissioning plan, planning team tried to find and look into the plans developed for other similar facilities. Keeping in mind that all the decommissioning activities are plant specific, some areas with good transferability have been found anyway. These include emergency provisions, elements of the QA program, health and safety considerations and the final survey approach. Even though main parts of the plan have been recognized as too specific, an insight to plans developed for other facilities has been considered as very useful in the planning process. Therefore, Serbian decommissioning team considers an open-archive of decommissioning plans (at least these developed with the IAEA support), which will be available for the member states can help countries with limited experience to develop their decommissioning plans.

Similar approach has been adopted regarding the decommissioning safety assessment, where good guidance was provided through the IAEA DeSa project. Existing Vinca Institute experience in safety assessments for operational facilities, for spent fuel related activities and for some other transition activities has been evolved with the assessment approach and methodology to be applied for decommissioning purposes. Participation in development of the safety assessments for three DeSa test cases was of particular importance. Knowledge and experiences in this field have been transferred to other countries by participation in the IAEA organized events (national workshop on safety assessment in Bulgaria). Opinion of the Vinca team is that existing safety assessments provide good basis for development of assessments for similar facilities, at least in the part of approach, hazard identification (although majority of them are plant specific and depend on the design, operational history, incidents and accidents), methodologies and tools used. Thus continuation of the IAEA activities through the FaSa follow-up project is highly appreciated and supported.

It has also been concluded that an overview of the decommissioning environmental impact assessments done for ongoing and completed projects can be useful for teams with limited experience, giving examples for level of the details needed (depth and complexity of the analyses) and examples of optimal monitoring schemes applied.

An internationally coordinated work on the simplification of methodologies and tools for the NPPs decommissioning cost estimate and its application for research reactors and other small facilities is also recommended.

Large amount of documents and records from the design, construction and operation of the facility have been used in the planning process [15]. In order to enable team members to access these documents efficiently, the classification and organization of all RA reactor related documents was done, technical documents were carefully reviewed, drawings and data were compared with the existing facility layout, and an electronic database application was created.

Relational database model was designed in 2003, by using Microsoft Access 2000 (ver. 9.0) software tool that runs under Windows 9 x. This file server database application was later updated to Microsoft Access 2002 that runs under Windows XP.

RA documentation database application currently stores the information on 3331 documents, created by 251 authors. Each paper-based document has its representative in the electronic database, described with the following fields: unique identification number, title, document type, authors, location, place and year of publishing, key words, reference to the employee with the best knowledge of document contents, cross-reference to related document, flag for the data that may be of particular importance to decommissioning, and additional comments.

RA documentation database application enables various searches by selected criteria (e.g. document type, title, location, key words etc.). Document control system has been established as an integral part of the application, enabling to detect the duplicate identification numbers, to present the current status and rental history of any document, as well as the current rentals and rental history for any employee.

Serbian experience in creating RA documentation database application was presented to other countries through the IAEA international workshops. What initially started as an exchange of information and experiences, developed further to full knowledge transfer between Serbia and Bulgaria in October 2008, within the frame of IAEA regional project RER3005.

The main objective of RER3005 15 assignment, performed by Serbian expert, was to create relational database model and database application software for the documentation of IRT reactor in Sofia, Bulgaria. The electronic database application for the documents belonging to different departments at IRT reactor was designed, set to operate in the multi-user environment, and the user interface was made both in English and Bulgarian language.

Although the initial idea was to adjust the existing Serbian database application, detailed analysis of IRT specifics has shown that a simple adjustment of the existing application won't be adequate. It was necessary to introduce new data entities and to make significant changes in the properties of the existing ones, so the entire process of modeling and design was done from the beginning. All this resulted in more complex application, with some features that are completely new and others which are improved (Table I).

Table I. Documentation database application – comparison of Serbian and Bulgarian application main features

	Serbian application	***Bulgarian application***
Year of production	2003	2008
Type of application	desktop	multi-user
Queries by selected criteria	Included	Included
Document control/tracking system	Included in 2004	Included immediately
Printable objects (reports)	Not included	Included

The transfer of knowledge gained in the planning activities between developing countries undergoing the decommissioning is highly useful, because it increases efficiency and saves resources, at the same time giving the opportunity for progress – by improving the existing solutions through new applications. We suggest that this type of collaboration should be more extensively applied among the member states with similar project tasks, and even propose that some "common tasks" – tasks completely planned/carried out by joint engagement of the experts from different countries – could be introduced in the future.

Characterization

Characterization plan for the RA research reactor [16] has been prepared according to the IAEA guidance [17]. Both sampling/measurement and calculation approaches have been used for determination of the radiological inventory of the facility [18]. Looking at number of characterization plans for different types of facilities, publicly available on the Internet, many common issues have been found as well as similar plan content and structure. Thus, creation of an open archive of characterization plans developed within the frames of the IAEA supported projects could be an addition to the existing IAEA services on this topic.

Here several cross-cutting points with the development of the decommissioning plans can be recognized. One of them is the document database, which serves as a source of information for both decommissioning planning and reconstruction of the facility operational history which is essential for the radiological characterization.

The RA reactor in Vinca Institute as heavy water and tank type facility is expected to have higher activation of the shielding structures around the core than light water reactor of the same power. Due to lower absorption in the heavy water moderator and coolant, fraction of the neutron escaped from the core is higher. There are well documented decommissioning projects for heavy water reactors for which neutron induced activity was significantly higher than the activity in the spent nuclear fuel [19]. As the most activated parts of the shielding structures are usually difficult to sample until dismantling work starts, computational modeling and calculation tools are the main approach for determination of the activation inventory. Here two components are essential – neutron fluence and activation cross-sections in different zones. Determination of both factors is not an easy task to fulfill. Small amounts of trace elements with high activation cross-sections can rapidly change the activation levels in the bulky volumes of reflector and shielding structures. Main parent nuclides and reactions of interest for neutron activation can be found in Table II of the reference [17]. In many cases services for chemical determination of all the elements of interest are not available locally. That is the reason for us to propose to the IAEA to find one referent institution and make it available for the member states, where inactive material samples can be sent for chemical analysis of trace elements of interest.

An important issue for the sampling and measurement approach to the radiological characterization is the application of the scaling factors for determination of “hard to detect” nuclides (low-energy gamma and pure beta emitting nuclides). Basic idea of this concept is to limit analyses of large number of samples only to “easy to measure” gamma activity, while the activities of other contributors are determined based on the ratios established from the detailed analyses of limited set of representative samples. It is known that these factors are plant specific, material specific, may vary in different facility zones and are not constant in time, so their determination and application is rather complicated. It is important to know how to determine the number of representative samples and scaling factors needed for proper application. Thus any example from the practice is more than welcome for teams trying to apply this approach.

Material sampling for characterization purposes is connected to some extent with the application of drilling and cutting tools. Purchasing several types of such machines for taking limited number of samples can be expensive for small decommissioning projects. Exchange of the sampling equipment and tools among the different decommissioning teams and projects, coordinated by the IAEA, can be an acceptable alternative. Good example for such an approach is sharing the available transport containers for spent nuclear fuel from the research reactors.

During the implementation of radiological characterization large number of data in different formats (plans, forms and procedures; logs and reports; drawings, photos, and maps; numerical results and spectra; input/output files of calculation/simulation codes, etc.) is generated to be processed and analyzed. Various calculations and comparisons are needed for correct interpretation of the primary data. Different types of reports are produced to support the characterization. Permanent data analysis, consequent decision making and certain iterative actions are adherent to any ongoing characterization process.

RA characterization survey results have been fully available in the electronic format since the beginning of November 2008. Complete set of raw data – around 67 000 data entries – was entered into the spreadsheets first, then processed to obtain analyzable formats (by application of appropriate formulas and comparison with guideline values), and finally arranged in separate files and folders named by survey units. Various summary descriptions were prepared as well (e.g. summary of all gamma spectrometry analyses on smears, etc.), and each data entry was verified.

Radiological and non-radiological portrait of each RA survey unit contains:

- Short description of inner unit structure, existing equipment and systems, and information about eventual incidents that might have occurred in the area (data format: Word 2003 document)
- Complete survey results for a given unit - raw and processed data, background and instrument source check information (data format: Excel 2003 document). The recorded data from survey measurements, background measurements, and instrument calibration, originate from paper based forms: radiological survey form ZP.4.DEC.150.201, and daily instrument check form ZP.4.DEC.150.208
- Detailed schematic drawing of each unit (data format: CorelDraw 12 file), including: the complete map of the survey unit, with separate drawings of the walls with overlaid grid
- Templates for the dose map printouts (paper format: A3; file format: CorelDraw 12 file)
- Laboratory analysis reports (origin: Genie™ 2000 generated; format: text document, preferred editor: WordPad)
- Notes on actual radiological status of a survey unit – conclusions, revisions, comments (file format: Word 2003 document).

Although complete, well organized, and verified, RA characterization survey results in electronic format could be further exploited for various analyses and conclusions if being kept within unique electronic database system. Development of an adequate data base application for the characterization survey data maintenance may be considered as an ultimate task, because it satisfies the following requirements:

1) Common storage for different data types (provided that they are all in electronic format, the database can simultaneously maintain, for example, textual files, digital photographs and drawings, spectra files, etc.);
2) Storage for large amounts of data;
3) Data formatting (predefined data format in database fields minimizes the possibility of errors during data input);
4) Efficient data processing and analysis (formulas for the calculation of activity, uncertainties, MDA, MDC, comparison with guideline values, etc);
5) Decision making tool (e.g. filtering the survey results from two neighboring survey units above some defined levels of radiation may help to make comparative case studies, draw some common conclusions, etc);
6) Multiple use of the application (e.g. the same application, with minor adjustments, may later be used in the final radiological survey).

When modeling a relational database for the characterization survey results, data entities to be considered, with their most important properties, are proposed in the list below:

- Single result (a numerical result from dose rate / surface contamination / mass activity direct measurement; or from the laboratory analysis) data entity, with properties: unique identifier or measurement label, survey date, name of surveyor (sampler or analyst), point location; measured quantity, sample and measurement type, used instrument
- Sample data entity, with properties: sample type, and associated label to be used in reports, sampling equipment, written sampling procedure.
- Measurement data entity, with properties: measurement type, unique label internally given and used in reports, brief description of methodology used.
- Instrument data entity, with properties: model and serial number, manufacturer, efficiency and calibration data, background, instrument specification, embedded photograph and written procedure.
- Personnel data entity, with properties: name and surname of the employee, position, responsibilities, contact phone, working team, supervisor's remarks.
- Survey unit data entity, with properties: number, schematic drawing, description, linked datasheet with all the measurements.
- Spectrum data entity, with properties: unique spectrum identifier, measured concentration of the specific radionuclide in Bq/g or Bq/cm^2, link to spectrum file
- Radionuclide inventory data entity, with properties: nuclide label, mass number, half life, decay type, minimal detectable activity (MDA), and clearance level.

It is our opinion that an internationally coordinated effort to design and create such software would be appreciated among the decommissioning community.

Waste Management

Waste management is one of the critical aspects for decommissioning activities in the Vinca Institute. The Institute served for decades as national storage facility for the radioactive waste from all institutional (scientific, medical, industrial, etc.) activities. The main fraction of the wastes is stored in two metallic hangars (H1 and H2). In addition, underground stainless steel tanks in concrete shields were constructed to accept liquid waste from the RA reactor. The current situation at Hangar H1 ("old hangar") with the significant deterioration of the building structures, presence of contamination inside the hangar and generally bad condition of the wastes is unacceptable from a safety point of view. Hangar H2 does not have enough capacities to accept all the waste from the spent fuel removal and reactor decommissioning project.

In order to improve waste management practice, several actions are planned:

- commissioning of new waste processing facility for waste characterization and treatment
- commissioning of new storage facility H3 with the secure storage for high intensity sources
- decommissioning of the H1 storage facility including proper treatment of the historical waste, repackaging and storage in a new storage facility is planned.
- decommissioning of the liquid waste storage tanks

RA reactor decommissioning project is also faced with significant challenges regarding the treatment of liquids (200 m^3 of water from the spent fuel storage pools contaminated by fission products, 6 m^3 of contaminated and tritiated heavy water). Exchange of good practice in this field is topic of interest for the Vinca team.

During the repackaging and preparation for the shipment of the leaking spent fuel, radiological conditions in the storage pools will be maintained by the water chemistry cleaning system (WCCS) which will absorb large quantities of Cs-137 from the water. During the operation, ion exchange resins of the WCCS will become the most active waste existing in Vinca Institute. Support from experienced teams is needed for safe handling and treatment of that waste.

Other decommissioning aspects

Several main topics of interest for the Vinca team with regard to the implementation of the decommissioning activities include:

- Selection and application of dismantling and demolition technologies
- Exchange of equipment and tools for dismantling and demolition of systems, structures and components
- Criteria for clearance of materials – restricted and unrestricted reuse
- Handling of bulky waste – experiences in optimization of waste minimization vs. exposure minimization
- Possibility for hands-on trainings on facilities undergoing dismantling

Decommissioning community in the small countries can also benefit from the exchange of knowledge and experiences in the following areas:

- Approach/transition
- Team composition and organization
- Strategy selection
- Treatment of mixed waste – contaminated chemically hazardous materials
- Use of external services/involvement of stakeholders
- Approach to the relations with public

Vinca Institute gives the contribution to this exchange appreciating provided international support and trying to transfer gained experience to similar institutions in other developing countries mainly through the IAEA coordinated activities and projects.

CONCLUSION

Decommissioning activities related to the research facilities in small developing countries are usually task for the personnel of the former operator institution. Limited human and financial resources, lack of experience and supporting services make this task difficult to prepare and implement in a safe manner. There are available international programs and projects that offer expert and technical support in the field of decommissioning. Through the International Decommissioning Network, organized and coordinated by the IAEA, problems and needs but also experiences and expertise of different organizations are collected in order to adapt type and content of the events that may help to the member states with limited capabilities. Feedback of the IDN participants is highly appreciated in this process. Serbian experience with the IAEA services in decommissioning planning and implementation is very good. Topics proposed in this paper for further joint elaboration through the international decommissioning projects, forums and networks are selected based on the specific Serbian needs, but authors believe they might be of interest for other developing countries also.

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