REPUBLIC OF CROATIA

NATIONAL REPORT

ON IMPLEMENTATION OF

THE OBLIGATIONS UNDER THE

JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT

2nd report

Zagreb, October 2005

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Section A. Introduction

The Republic of Croatia signed the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) on 9 April 1998, and ratified it on 5 February 1999. The first National Report on implementation of the obligations under the Joint Convention was prepared at the beginning of 2003, and Croatia actively participated at the Review Meeting later that year.

This National Report contains updated information on matters covered in the first report, focusing on the safety advancement achieved in the meantime. The Report has the same structure as the previous one, and in each section new developments are presented together with the most important previous statements which still hold true.

Also, the issues raised during the Review Meeting are given adequate consideration, which is briefly discussed in the Section L introduced in this Report.

Major developments during the two years since the previous report were:

a) advancement of the regulatory framework, including the establishment of new regulatory bodies;

b) advances in specific radioactive waste management practices; and

c) preparation, by a joint Slovenian/Croatian team, of the NPP Krško revised decommissioning plan, including spent fuel and radioactive waste management and disposal plan.

Regulatory framework development was aimed at the separation of nuclear safety from the radiation protection issues. The nuclear safety law adopted in October of 2003, together with the radiation protection law from 1999, finally replaced the 1984 law inherited from the former state in which both areas had been integrated. The nuclear safety law introduced State Office for Nuclear Safety as the regulatory body for nuclear practices, removing this regulatory function from the Ministry of Economy and thus resolving the issue of potential conflict of interest. Similarly, though not to the same extent, the regulatory authority for radiation protection was transferred from the Ministry of Health to the State Office for Radiation Protection, which was achieved by amendments to the radiation protection law that were also adopted in October of 2003. These regulatory developments are described in more detail in the Section E, whereas the list of all relevant laws and regulations is given in the Annex I.

Main advances in radioactive waste management practices have been:

i) The waste inventory in the Croatian only operational store at the Institute Ruđer Bošković (IRB) has been updated and completed. Since in the previous report the inventory was not specified (being still under review), it is here briefly described in the Section D, and fully listed in the Annex II.

ii) Management of sealed sources, and in particular control of orphan sources, is advanced through ongoing projects supported by the IAEA. More details are given in the Section J.

In the Summary Report from the Joint Convention Review Meeting, among the "factors of special interest" (paragraph 17) there was identified "a growing recognition of the need for the development and implementation of *integrated decommissioning and radioactive waste management plans*". The Program of NPP

Krško Decommissioning and SF & LILW Disposal, prepared during 2003/2004 by a joint Slovenian/Croatian team, is such an integrated plan. More significantly, it is an important initial step towards formulation of the long-term spent fuel and waste management policies in Croatia.

Although the Program of NPP Krško Decommissioning and SF & LILW Disposal ("NPPK Program") will be discussed or referred to in the subsequent sections of the Report, this Introduction is the most appropriate place for a concise account of its preparation and features.

The Slovenian-Croatian Agreement on the NPP Krško came into force on 11 March 2003. Its article 10 requires that the two governments "ensure efficient joint solution" for the NPP decommissioning and RW&SF disposal, "both in economic and environmental protection regard". In order to achieve that, "RW and SF disposal program" and "Decommissioning program", both "compliant with the international standards", will be prepared "in co-operation with the NPP, by the expert organizations appointed by the contracting parties". These programs should be prepared within one year after ratification of the Agreement, then approved by the governments appointed bipartite commission ("Intergovernmental Body") and subsequently revised at least every five years.

The Agreement provision that "the NPP Krško site may be used for interim storage of radioactive waste and spent fuel until the end of NPP lifetime" relaxes the requirements on the program proposals, in particular regarding the unspecified issue of how complete and final they should be. But if the contracting parties do not reach agreement on joint disposal by the end of the NPP lifetime, it is their obligation to complete the removal of all RW&SF from the NPP site within two years after that date, in this case, however, taking "one half each" (article 10).

Finally, in the article 11 the contracting parties declare their obligation to ensure financing of the decommissioning and disposal programs "in equal parts". If joint disposal is not agreed upon, each government will independently finance those disposal program activities which are not of common concern.

The Program of NPP Krško Decommissioning and SF & LILW Disposal was indeed completed within a year, but the peer review and approval in both countries took almost as long; it was finally approved by the Intergovernmental Body at the beginning of 2005.

The NPPK Program is a limited revision (and re-evaluation) of the previous NPP decommissioning plan (adopted by Slovenia alone), but it introduced specific SF and RW disposal concepts, and integrated NPP decommissioning and waste management and disposal into inter-related scenarios with well-defined time schedules.

The primary purpose of the NPPK Program was to make costs estimates, based on rational and mutually acceptable scenarios. Therefore it did not attempt to make choices for which sensitive political decisions would be necessary, but it did lay out some premises for further negotiations which were accepted by both countries:

- all LILW from the NPP Krško operation and decommissioning will be disposed of in one near-surface repository, either in Slovenia or in Croatia;
- spent fuel will be disposed of in one deep geological repository, either in Slovenia or in Croatia – or it will be exported into a third country;

- until disposal or export, spent fuel will be dry-stored in an independent storage facility on unspecified location, either in Slovenia or in Croatia.

The costs of the integrated decommissioning and disposal program were estimated, and a financing model was proposed. Each country shall accumulate one half of the planned amount: national power companies will provide annual installments into the respective national decommissioning funds. Whereas the Slovenian fund has been operating for about ten years, the establishment of the Croatian fund is under preparation.

The entire document "Program of NPP Krško Decommissioning and SF & LILW Disposal" is available at www.apo.hr, and the Executive Summary of the Program is reproduced in the Annex III of this Report.

Section B. Policies and Practices

Spent fuel

Spent fuel management has not been practiced in Croatia. The NPP Krško spent fuel management policy is expected to be defined through a joint project with Slovenia. First steps have been made by preparation of the NPPK Program during 2003/2004, as described in the Introduction.

Radioactive waste management policy

Long-term radioactive waste management policy has not yet been developed.

For the waste accumulated in Croatia (few tens of cubic meters), the option of a new storage facility has been considered but not yet decided upon.

For the NPP Krško operational and decommissioning LILW, preliminary preparations were made for possible development of a Croatian near-surface repository several years ago. In the last few years, however, no further steps have been taken as it is expected that a joint solution with Slovenia will be negotiated within the context of the NPPK Program.

Under the circumstances, it would be premature to even consider the option of disposing both the NPP Krško and the other LILW into the same repository.

Radioactive waste management practices

Only small quantities of waste from medicine, research and few industrial applications have been managed in Croatia. The waste which could not be disposed of as communal waste after a brief on-site delay storage, is presently stored in two facilities described in the Section D.

Radioactive waste categorization

The regulation on radioactive waste defines solid, liquid and gaseous radioactive waste. For the solid radioactive waste, the categories I, II, and III are defined in the following table:[1]

Radioactive waste category	**Specific activity A_{sp} (Bq/m^3)**	**Waste category description**
I. High level	$A_{sp} > 5 \cdot 10^{14}$	high beta/gamma, and significant alpha activity, high radiotoxicity, significant heat power (requires cooling)
II. Intermediate level with alpha emitters	$5 \cdot 10^{14} > A_{sp} > 5 \cdot 10^{9}$	medium beta/gamma, and significant alpha activity, medium radiotoxicity, low heat power
Intermediate level with beta/gamma emitters	$5 \cdot 10^{14} > A_{sp} > 5 \cdot 10^{7}$	medium beta/gamma, negligible quantity of alpha emitters, low/medium radiotoxicity, insignificant heat power
III. Low level with alpha emitters	$5 \cdot 10^{9} > A_{sp}$ $\frac{Ai}{IKi} \geq 1$	low/medium beta/gamma, low alpha, low/medium radiotoxicity, insignificant heat power
Low level with beta/gamma emitters	$5 \cdot 10^{7} > A_{sp}$ $\frac{Ai}{IKi} \geq 1$	low beta/gamma, insignificant alpha, low radiotoxicity, insignificant heat power

The fractions *Ai/IKi* in the III. category compare the measured radionuclide concentration with its allowed concentration, i.e. with the "derived limit for drinking water".

Section C.[2] Scope of Application

Regarding the obligations under Article 3:

(a) Croatia has not declared reprocessing to be part of spent fuel management;

[1] It is the same table as in the previous report, since the new regulation is not yet adopted.

[2] Sections C, G and I are the only ones that were not modified since the previous report. As they are very brief, they are included in this Report for completeness.

(b) Croatia has not declared any waste that contains only naturally occurring radioactive material and does not originate from the nuclear fuel cycle as radioactive waste for the purposes of the Convention; and

(c) Croatia has not declared any spent fuel or radioactive waste within military or defense programs as spent fuel or radioactive waste for the purposes of the Convention.

Section D. Inventories and Lists

Spent fuel facilities and decommissioning of nuclear facilities

No spent fuel or waste from nuclear cycle is presently in the Croatian territory or under its effective jurisdiction. Also, there are no spent fuel management facilities.

No nuclear facilities are presently in operation or being decommissioned.

Radioactive waste management facilities

There are two storage facilities in Croatia, both located in the city of Zagreb, within national research institutes, the Institute Ruđer Bošković (IRB) and the Institute for Medical Research and Occupational Health (IMI).

The IMI store

IMI hosts an old facility for disused sources which is no longer in operation: the last radioactive source was received in 1998 or 1999. The Institute has no formal inventory: is estimated that there are 300 sources in the store. The sources in the heavier shields are left on the entrance steps next to the door, as they are too heavy to be carried into the bunker. Radiation can be detected from these sources outside the closed door. Most of the sources would be of low activity, such as lightning rod sources, fire detection sources, medical sources and industrial gauges.

The IMI storage has not been licensed by the present regulatory body (SORP) and inventory of the sources has not been established. This partially underground storage was built more than 60 years ago. Water has been observed on the floor, some of the source shields standing in the water. There is no intrusion detection; a locked metal door controls the access. The reception desk located at the entrance of the IMI main building is permanently staffed and the key is kept there.

The IRB Temporary Store of Radioactive Material (TSRM)

TSRM at the IRB is the only Croatian active store, accepting all radioactive waste produced or found in Croatia which needs to be stored.

The facility consists of two rooms at different levels. Access to both levels of the building and its perimeter have been reinforced, and an intrusion detection system has been installed. Keypads located inside the building or a remote control can be used to activate or deactivate the alarm system. In addition, the building is under video surveillance and pictures are reported both at the central alarm station of the Institute and in the office of the general manager of the building.

A notable portion of the inventory (described below) consists of spent radium sources, which have been conditioned on the upper level and are now stored in the lower room of the TSRM (more details in the Section J).

Radioactive waste inventory

All radioactive waste stored in Croatia originates from medicine, research and industrial applications in the country. The entire quantity does not exceed several tens cubic meters.

No radioactive waste has yet been disposed of into any repository.

Waste inventory lists were under review by the Ministry of Health at the time of the first report. The State Office for Radiation Protection (SORP), which overtook most regulatory functions from the Ministry, has established a database with the central RW inventory. The IRB reports every transaction and, pursuant to its legal obligations, submits annually a complete inventory list to the SORP. The list is, simplified and translated, given in the Annex II of this Report.

Section E. Legislative and Regulatory System

According to the Constitution of the Republic of Croatia, article 134, "international treaties, signed and ratified in accordance with the Constitution... are part of the national legislation of the Republic of Croatia". By this article of the Constitution, all requirements of the Joint Convention can immediately be interpreted as extensions or modifications of the national law, until development of national legislation incorporates them more explicitly into the laws and regulations. This process is well under way, but not yet completed.

Even at this transition period, the national regulatory framework in the field, as well as the national policy and practices, reasonably well reflect the recognized international standards and good practices, and thereby also the requirements of the Convention. But they still need considerable improvement, in particular towards more rational organization and internal consistency.

The present system of laws and regulations is briefly outlined below. However, a note on the history is necessary to understand this system. In 1991, after the dissolution of the former state (SFRY) and the proclamation of independence, the Republic of Croatia passed the Constitutional Decision on Sovereignty and Independence, Part III of which stated that all the laws concluded by the SFRY, would be valid on the territory of the Republic of Croatia if they were not in contradiction with the Constitution of the Republic of Croatia and its legal system.

The most important law, inherited from the former state, was

- *The Law on Protection against Ionizing Radiation and on Special Safety Provisions for Use of Nuclear Energy* from 1984 ("Old SFRY law").

Though it is no longer in force, several of its subordinate regulations still are, until adequate regulations are prepared under new Croatian laws.

The basic laws

Two new Croatian laws, which have superseded the Old SFRY law, are aimed at separation of the radiation protection issues from the nuclear safety concerns. Together, they constitute the basis for spent fuel and radioactive waste management regulatory framework:

1. *The Law on Protection against Ionizing Radiation* is the Croatian law adopted in 1999 and amended in 2003 ("Radiation Protection Law")[3] and
2. *The Law on Nuclear Safety* is the Croatian law adopted in 2003 ("Nuclear Safety Law").

The Radiation Protection Law, which was enacted four years before the nuclear law, updated the concepts and requirements of radiation protection, but did not address nuclear safety at all, explicitly retaining in power those segments of the Old SFRY law which regulate safety of nuclear facilities.

The intention of the new law was to be concise and to reflect the most relevant international recommendations, in particular the *ICRP Publication No. 60* and the general requirements of the IAEA Safety Series No. 115 *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* ("The BSS").

The Radiation Protection Law from 1999 consisted of 54 articles in ten chapters: general provisions, principles of radiation protection, requirements for the practices, exposures, sources, emergencies, radioactive waste, supervision and authorities including the establishment of the Croatian Institute for Radiation Protection and the Commission for Radiation Protection, penalties for offences of the provisions, transitional and final provisions.

The basic principles of justification of practices, optimization of protection and safety, and of limitation of individual doses are explicitly formulated as the provisions of the law. Authorization for all practices with ionizing radiation is obligatory except for excluded or exempted sources of ionizing radiation. The conditions and procedure for authorization are formulated as the provisions of the law, as well as the principles for exemption.

Primary responsibility for implementation of prescribed measures has the user, the person or legal entity who obtained the authorization for conducting certain practice. The import of radioactive waste in the Republic of Croatia is explicitly forbidden.

According to the 1999 version of the Radiation Protection Law, Ministry of Health was the Competent Authority for radiation protection. In order to ensure more effective implementation of radiation protection, pursuant to the *Law on Health Care*, the Croatian Institute for Radiation Protection (CRPI) was founded, a medical institution for providing expert assessment and other expertise in the field of radiation protection, and for keeping and maintaining records on the sources, source users and radiation workers.

The 2003 amendments to the Radiation Protection Law transformed the CRPI into the State Office for Radiation Protection (SORP), independent of the Ministry of Health, and transferred to the SORP the function of the regulatory body for radiation protection. However, the amended law has retained the supervision and enforcement

[3] In the previous report, before the Nuclear Safety Law was adopted and with the Old SFRY law still in force, the Radiation Protection Law was refered to as "the new Croatian law".

of the radiation safety measures as the responsibility of the Sanitary Inspection Department of Ministry of Health, pursuant to the *Law on Sanitary Inspection*.

Radioactive waste management is addressed in a very brief section of the Radiation Protection Law, which empowers the SORP to prescribe all the relevant regulations based on most recent internationally recognized standards and recommendations. A number of regulations subordinated to the law have been adopted in the meantime, including the new regulation on the limits of exposure (which will be mentioned below). However, new regulation on radioactive waste management is not yet completed (so the old one is listed below). Besides, the Radiation Protection Law designated most waste management facilities as nuclear facilities (for example, RW repositories, though not RW storage facilities). Therefore, they remain under nuclear safety regulations.

However, a new edition of the Radiation Protection Law has been prepared, and it is now in the legislative procedure. In this edition, repositories and other RW management facilities will not generally be designated as nuclear objects. Also, it is expected that some international recommendations will be explicitly included in the law, such as the IAEA recommendations on reentry of disused sources and the security measures from the Code of Conduct.

The new regulation on radioactive waste management (mentioned above) will probably not go into the procedure before the new law is adopted, although it has actually been prepared. The SORP insists that an important element of RW management policy should be defined before finalizing the RW regulation: designation of the central Croatian RW storage facility. The TSRM at the IRB is the only operating RW store, but it does not have the formal status of the central national facility.

The Nuclear Safety Law has adopted a concise style similar to the Radiation Protection Law, and also heavily relies on the international conventions and IAEA recommendations. It consists of only 37 articles grouped in seven chapters: general provisions (definitions), nuclear safety (conditions for a nuclear practice, including safety and protection requirements; quality assurance, monitoring, staff qualifications, records-keeping and emergencies including technical support center), state office for nuclear safety (SONS), financial resources, supervision, penalties, and transitional and final provisions.

The Nuclear Safety Law defines nuclear practices instead of nuclear facilities. These practices involve *nuclear material* (as defined in the IAEA Statute) and *specified equipment* (as defined in the Protocol Additional for application of the Safeguards in connection to the Non-Proliferation Treaty). Spent fuel facilities are clearly under jurisdiction of this law, whereas RW repositories are defined as the facilities for disposal of RW from nuclear fuel cycle.[4]

The Nuclear Safety Law declares that the Old SFRY law is no longer in power, but retains its subordinated regulations until new ones are adopted.

Art. 8 requires that in the process of determining the siting, planning, construction, operation and decommissioning of a facility in which a nuclear practice is to be

[4] This definition has no further use in the law itself, but may be the basis for subordinated regulations.

performed, the conditions for nuclear safety and protection set forth in this law and in conventions and other international agreements ratified by the Republic of Croatia, as well as international recommendations and standards in the area of nuclear safety, must be met.

Administrative supervision of the implementation of the Nuclear Safety Law and regulations adopted on the basis of this law shall be carried out by the State Office for Nuclear Safety. Inspections based on this law shall be carried out by inspectors from the State Office for Nuclear Safety (nuclear safety inspectors).

Based on Articles 3, 11-16 and 18, the nuclear material or specified equipment user shall be solely responsible for safety and protection in performing a nuclear activity. He is also responsible for emergency preparedness, environmental monitoring, education of personnel and record-keeping. All these requirements are specified in more detail in the regulations.

The holder of the license is also liable for any nuclear damage according to the Act on Third Party Liability for Nuclear Damage. It is the responsibility of the regulatory body to control that the licensee fulfils these regulations.

The most important subordinated regulations

Most regulatory requirements on radioactive waste and spent fuel management are contained in three regulations based on the old SFRY law:

- *The Regulation on Conditions for Location, Construction, Testing Operations, Start-up and Operation of Nuclear Facilities,* from 1988 ("Regulation on facility development");
- *The Regulation on Preparation and Contents of Safety Reports and Other Documents Required to Determine Safety of Nuclear Facilities* ("Regulation on safety reports"), also from 1988, but sequel to the regulation on facility development; and
- *The Regulation on Procedures for Collecting, Accounting, Treatment, Final Disposal and Release of Radioactive Waste Materials into Human Environment,* from 1986 ("Regulation on radioactive waste").

The waste categorization in the Section B is reproduced from this old Regulation on radioactive waste. Since its update is due soon, the issue of regulating radioactive materials as radioactive waste is not addressed here, as the new regulation will in that respect take due account of the objectives of the Joint Convention.

Although the above old regulations address nearly all aspects of waste and spent fuel management facilities, most details of radiological protection are specified in a 1999 regulation which is subordinated to the Radiation Protection Law:

- *The Regulation on Limits of Exposure to Ionizing Radiation and on Conditions for Exposure in Emergency Situations and for Interventions in Case of Accident* ("Regulation on exposure limits").

This regulation supports the Radiation Protection Law by providing the dose definitions and the limits of exposure, all taken from the BSS and their schedules.

Other elements of the legislative and regulatory framework

In addition to the basic framework outlined above, a number of other legal acts have some bearing on the national practices in radioactive waste and spent fuel management.

- Among them, the most relevant are other regulations based on the Old SFRY law or the Radiation Protection Law.
- In addition, some other acts affect implementation of these laws and their regulations.
- Finally, the ratified international conventions and treaties, as well as the bilateral agreements, should also be considered as constituents of the national framework in a broader sense.

All the above items are presented in the Annex I on the regulatory framework. Although they address some general aspects of radiological protection or nuclear safety, or their specific implementations, they are generally not discussed in this report.

Regulatory body

Based on the provision of the Nuclear Safety Law and the Radiation Protection Law, the SONS is the regulatory body for nuclear safety, whereas the SORP is the regulatory body for radiation protection.

As mentioned earlier, the Ministry of Health, with its Sanitary Inspectorate, has retained the authority for supervision and enforcement in radiation protection matters.

About the Article 19 specific requirements

Although it is still a mosaic of new and old regulations, the Croatian regulatory framework adequately meets most requirements which should be addressed in this section of the report. The points which need improvement have been discussed in the preceding paragraphs.

General radiation protection provisions and nuclear safety requirements on practices have been described in the above brief account of the Radiation Protection Law and Nuclear Safety Law. Specific provisions on licensing, control, reporting and enforcement of safety for the spent fuel and radioactive waste management facilities (referred to in the Article 19 of the Joint Convention) are given in more detail by the retained regulations of the Old SFRY law. At the highest level they are formulated for nuclear facilities in general.

Licensing requirements are defined in the Regulation on facility development, which is divided into the following sections:

(i) General provisions,

(ii) Conditions for siting of a nuclear facility,

(iii) Conditions for construction of a nuclear facility,

(iv) Conditions for commissioning of a nuclear facility,

(v) Conditions for start of operation and use of a nuclear facility, and

App: Methodology for preparation of the quality assurance program.

The Regulation on safety reports specifies that SAR is the basic licensing document for nuclear installations. The SAR shall be supplemented during the lifetime of the facility with any new data and with analyses of all changes which may be undertaken. The regulation defines three categories of changes to the SAR. For the first category a notification to the regulatory authority is required after the completion of the modifications. For the second category a notification to the regulatory authority is required before implementation. For the third category an approval by the regulatory authority is required before implementation.

In its lengthy annexes, the Regulation on safety reports clarifies the concepts and elaborates the provisions of the Regulation on facility development. The annexes very prescriptively delineate the form and content of SAR for successive stages of facility development, each of them for a specific type of nuclear facility, including the spent fuel and radioactive waste disposal facilities.

The Regulation on facility development also addresses the obligation of a licensee to monitor and analyze the level of nuclear safety, whereby he must take into account the experience of other nuclear facilities and new technological developments. Any changes of technical specification should be subject to independent evaluation, and approved by the regulatory authority.

Section F. Other General Safety Provisions

Safety provisions of the Joint Convention articles 21-26 are generally delineated in the Radiation Protection Law and the Nuclear Safety Law, and further specified by the regulations cited above.

Responsibility of the license holder

The article 4 of the Radiation Protection Law broadly defines sources of ionizing radiation to include, among other, radioactive materials and waste, as well as nuclear facilities and all materials from the nuclear fuel cycle which are not exempt from the regulatory control. The SORP gives authorization for practices involving the sources (article 24). Radioactive waste management is included among the measures for protection against ionizing radiation (article 9).

The person or legal entity which was granted the authorization for the practice bears *"the responsibility and the expenses for implementing the measures for protection against ionizing radiation"* (article 28 of the Radiation Protection Law). Inspection, enforcement and penalties are provided for in later articles.

As described in the previous section, the Nuclear Safety Law sets appropriate nuclear safety requirements on the licence holder.

The regulations specify more details. In particular, the Regulation on radioactive waste requires (article 8) that all entities which produce radioactive waste must collect, classify, etc. and ensure treatment, transport and storage of the waste.

Operational radiation protection

The Radiation Protection Law and its Regulation on exposure limits provide for radiation protection in all practices involving sources of ionizing radiation. Although they do not separately address spent fuel and radioactive waste management, they closely follow the BSS recommendations on radiation protection, both in general approach and in specific limits.

In addition, spent fuel and radioactive waste management facilities are subject to the Nuclear Safety Law and the old regulations mentioned above. For their operation license, or earlier in their development, safety analyses and reports are required to demonstrate that they will meet all operational radiation protection provisions.

Other provisions of this section

Other general safety provisions of this section are met by the Croatian regulatory framework in a similar manner as in the above two paragraphs: by new laws on a general level, and by the old regulations as specific requirements for nuclear facilities.

Human and financial resources are among the general responsibilities of the license holder. Post-closure institutional control arrangements are required in the final SAR before operational license for disposal facilities. Decommissioning arrangements for nuclear facilities (where applicable) are also required before operational license.

Quality assurance is particularly extensively elaborated in the Regulation on facility development.

In addition to general requirements on emergency preparedness for nuclear facilities in the country, the Nuclear Safety Law has defined a Technical Support Center for the case of nuclear accident, and a Manual which includes all the necessary specific elements of preparedness in the event of a nuclear accident (especially at the Krško NPP and at the Pakš NPP) has been developed.

Section G. Safety of Spent Fuel Management

Croatian legislative and regulatory framework contains basic provisions for the safety of spent fuel management, although no spent fuel has yet been managed in Croatia, and no facilities for its management have been planned.

Most of the provisions for spent fuel are included either among general requirements of the Nuclear Safety Law, or within more specific old regulations on safety of nuclear facilities and radioactive waste management.

Section H. Safety of Radioactive Waste Management

Overview

The specific requirements of the Convention articles which should be reported on in this section are generally met by the provisions of the two laws and four regulations described in the Section E.

However, there is no dedicated regulation in the present Croatian framework which comprehensively and specifically addresses radioactive waste management in the manner described in this section of the Joint Convention. Instead, the requirements are met somewhat indirectly, i.e. they can be deduced from two lines of regulatory provisions:

- One line is provided by the general requirements on measures for protection against ionizing radiation in the Radiation Protection Law and its regulations. As noted in the Section E, these measures reflect the BSS recommendations, and include radioactive waste management as an important requirement, but only briefly address specific aspects of the waste management itself.
- The other line of regulatory provisions comes from the Nuclear Safety Law and the and from retained regulations of the Old SFRY law. They address nuclear facilities and related practices in much detail, but as much as possible (sometimes perhaps beyond the appropriate) they are formulated for all these facilities in general. Radioactive waste management facilities are singled out only occasionally.

Specific provisions

Siting of the proposed facilities, their design and construction, as well as the safety of their operations, are extensively dealt with in the Regulation on facility development, as described in the Section E. All the Joint Convention requirements pertaining to these activities, which are common to the safety of nuclear facilities in general, are met by these provisions.

Furthermore, in a few articles of the Regulation on facility development some requirements are specifically formulated for the radioactive waste management. Article 2 describes near surface disposal for LILW, article 15 lists general requirements on site characteristics for such repository, while article 23 specifies main requirements on disposal facility design. Article 24 introduces a rather stringent requirement on the near surface repository design, namely that it "must grant the prescribed safety" without active maintenance after a 5 year transitional period following the facility closure. Article 40 addresses the waste form for LILW disposal, limits the concentration of long lived alpha emitters and prohibits disposal of waste with other hazardous properties. Article 41 somewhat superficially and schematically distinguishes between disposal of LILW and of high level waste. Finally, the article 49 specifies the requirements on the closure of a LILW repository.

Safety assessment of facilities is elaborated in the Regulation on safety reports. Safety report is defined as "a document with information on a nuclear facility and its environmental impact, design of the facility and analysis of possible accidents as well as measures needed for diversion of hazards and minimization of effects of accidents on general population and workers in nuclear facility".

Contents and form of the safety reports are formally outlined in great detail in the annexes of the Regulation on safety reports, and its annex 4 is devoted to radioactive waste disposal. It is a rather lengthy and prescriptive text, in many respects comparable to the IAEA 1995 TECDOC *"Preparation of safety analysis reports (SARs) for near surface radioactive waste disposal facilities"*. The annex 4 alone would effectively suffice to ensure safe siting, design, construction, operation and closure of a radioactive waste repository.

Successive safety reports during repository development are based on the safety analyses of increasing complexity, which are described in the chapter 4 of that annex. Probabilistic analyses are required before the operation license. Closure arrangements are described in the chapter 13, which together with the chapter 4 specifies that duration and scope of the post-closure active institutional control will be determined from the results of safety analyses. The Regulation on safety reports also clarifies that the five-year transitional period after the repository closure (introduced in preceding regulations) is the period for verification of safety (as predicted by safety analyses), and that institutional control begins after that period.

The old Regulation on radioactive waste classifies the waste, defines waste categories, sets limits on waste release into the environment, specifies requirements on waste collecting and record keeping, and briefly outlines technical provisions on waste management facilities. However, it does not systematically address the general safety provisions (Joint Convention article 11), but it is expected that this will be corrected in the pending new regulation on radioactive waste.

Application in current practices

While it cannot be claimed that every single Joint Convention requirement has been given an appropriate weight in the current national provisions, this need not have adverse effects on the actual safety. In the present and planned radioactive waste management practices, guidance is sought in the RADWASS program of the IAEA, as recommended by the BSS (and therefore by the Convention as well).

Implementation of this approach could best be seen in the preparation of the NPPK Program. The Program specifies that it shall observe a regulatory framework based on (a) EU directives, (b) BSS and other IAEA recommendations, (c) national regulations which are not contradictory, and (d) Slovenian regulations for NPP dismantling.

Whereas this could have been expected from an international project, the preliminary preparations for the establishment of a LILW repository in Croatia followed a similar approach several years ago. The preparations have been going on for more than a decade, and included a thorough site-selection process which resulted in designation of the Trgovska gora region for the potential repository site in the national land use plan. Based on the available data on the location, and on rather generic design of near surface disposal facilities, a preliminary safety assessment report was completed in the year 2000. Finally, during 2002, a safety analysis plan was prepared for the prospective repository on Trgovska gora.

The safety analysis plan is a comprehensive document which can be used as a basis for the entire repository project development from this point on. It was prepared after a thorough analysis of the national regulatory requirements, international conventions and recommendations, and of good practices in this field. It assumes the safety assessment iterative approach as recommended in the IAEA RADWASS program and applied in the IAEA sponsored ISAM project. The plan is an example of the approach in which national regulatory requirements are interpreted and complemented by reference to the best contemporary international standards.

Section I. Transboundary Movement

The Radiation Protection Law bans any import of spent fuel and radioactive waste. Apart from full commitment to binding international instruments, no other particular issues of transboundary movement needed to be specifically addressed in the Croatian regulations.

Section J. Disused Sealed Sources

General provisions

Safety of disused sealed sources is generally ensured by the regulatory provisions for radioactive waste management.

According to the *Regulation on the Conditions and Measures for Protection Against Ionizing Radiation in Practices Involving Radioactive Sources* (issued in 2000, under the Radiation Protection Law), the authorization for use of any source will be granted only if all measures for protection against ionizing radiation are ensured. Also, the regulation specifies that spent sealed sources are radioactive waste. As noted in the Section F, radioactive waste management is included among the measures for protection against ionizing radiation required by the Radiation Protection Law.

No regulatory provisions are presently needed for reentry of disused sources to be returned to the manufacturer, because there are no manufacturers in Croatia. However, as noted in the Section E, pending changes to the Radiation Protection Law are expected to explicitly incorporate the IAEA recommendations on the subject.

Management of spent sources and control over orphan sources

In last several years significant steps have been undertaken to increase safety of the spent sources at the IRB store, including completion and update of the waste inventory.

Also, the State Office for Radiation Protection is engaged in three international projects aimed at further improvement of the management of spent sources and control over orphan sources:

- IAEA/CRO/9/009: Management and Safe Storage of Spent or Disused Sealed Sources;
- IAEA-RER-9.073: Implementation of National Strategies for Regaining Control over “Orphan Sources”; and
- U.S.A. Ministry of Defense and FBI: International Counter Proliferation Program.

The most recent orphan source recovery was made in November 2004, in a truck transporting scrap metal across the Croatian/Slovenian border (one radioactive lightning rod with 3.7 GBq of $^{152,154}Eu$). More impressive, however, was the recovery of 17 cesium sources (level gauges, total activity 71.24 GBq of ^{137}Cs) in 2002, which had been used as weights on hay in a small village near Obrovac.

Spent radium sources management

All spent radium sources from medical applications in Croatia have been collected, conditioned and properly stored.

Several years ago a thorough search followed by characterization and conditioning of all radium sources in Croatia was undertaken. Data on the sources provided by regulatory body, found in radiological histories, in hospitals records etc., were investigated and altogether 298 sources were collected, with approximately 1400 mg of Ra-226.

The sources were of different forms (needles, tubes, plates) and all came from medical applications. They were collected in Zagreb and conditioned in the Institute Ruđer Bošković.[5] The sources were first packed into stainless steel containers (approximately 50 mg of radium in each container), which were then welded and bubble tested. Stainless steel containers (in bundles of 10) were placed into three lead containers. The lead containers were packed into standard 200 l drums filled with concrete, two containers in one drum, and the third container in another drum. Drums were properly marked.

Characterization and conditioning of the sources were done by the IAEA approved procedure and supervised by the Agency. Presently, the drums are at the IRB store (TSRM). Their long term future is still not decided.

Additional information on the conditioning campaign was provided in the Annex II of the previous report.

Section K. Planned Activities to Improve Safety

As already indicated in this Report, the most important planned (or ongoing) activities are:

- development of the long-term policy for spent fuel and radioactive waste management, primarily through joint projects with Slovenia;
- the central national RW storage facility should soon be designated; and
- regulatory framework needs completion: several regulations are in preparation, particularly a dedicated regulation on radioactive waste management.

Section L. Review Meeting Issues

Croatia was actively participating at the First Review Meeting of Contracting Parties to the Joint Convention in 2003.

The most important issues raised at the Meeting regarding the Croatian previous report have been addressed in this Report.

Questions to Croatia were most frequently concerned with the disused sealed sources management and waste inventory, and the long-term policies particularly regarding the NPP Krško SF and RW joint management. These issues were given particular attention in the current Report.

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[5] In addition to 298 spent sources, one sample of radium contaminated soil was included (5th row in the Table 4 of the Annex II of this Report), which lead to the number of 299 sources mentioned in the Annex II of the previous report (and to occasional querry at the Review Meeting).

Annex I Regulatory Framework

In addition to the laws and regulations listed in the Section E, a number of other legal acts have some bearing on the national practices in radioactive waste and spent fuel management.

Regulations not listed in the Section E

- Regulation on education, experience, examination and certification of personnel conducting specific work at the nuclear installation *(Off. Gaz. SFRY No. 86/87)*;
- Regulation on material balance areas and the mode of keeping records accounting for nuclear raw materials and nuclear materials as well as to the submission of data contained in such records *(Off. Gaz. SFRY No. 9/88)*;
- Regulation on the conditions, methods, premises and intervals of systematic environmental radiological monitoring *(Official Gazette No. 86/00);*
- Regulation on the conditions and measures for the protection against ionizing radiation in practices involving radioactive sources *(Official Gazette No. 84/00);*
- Regulation on the health conditions, criteria, content, methods and intervals of maintaining of the records about health surveillance of persons who operate sources of ionizing radiation *(Official Gazette No. 01/05);*
- Regulation on the conditions and manner of obtaining the professional qualifications as a precondition for work with the sources of ionizing radiation *(Official Gazette No. 67/00);*
- Regulation on the methods and time intervals of the surveillance of the sources of ionizing radiation, personnel monitoring, monitoring of exposure of the patients, on maintaining records and registers and on reporting *(Official Gazette No. 63/00);*
- Regulation on the conditions for authorization of legal entities to perform specific expert practices in the field of ionizing radiation protection *(Official Gazette No. 44/05)*.

Other laws

Several other laws are either related to nuclear safety or to the implementation of the three basic laws from the Section E:

- The Law on Third Party Liability for Nuclear Damage (from 1998)
- The Law on Sanitary Inspection (from 1999)
- The Law on Protection from Natural Disasters (from 1997),

- The Law on Organization and Field of Activities of the Ministries and Other Governmental Bodies (from 1999 and 2000),
- The Law on General Administrative Procedures (from 1991),
- The Law on Criminal Procedure (from 1997, 1998 and 2000),
- The Law on Transport of Hazardous Material (from 1993),
- The Law on Internal Affairs (from 1991, 1992, 1994, 1998 and 2000).

Conventions, treaties and bilateral agreements

Furthermore, based on the Croatian Constitution, all announced and ratified international treaties also constitute an integral part of Croatian legislation and can be applied directly. So the following international legal instruments, to which Croatia is a party, should be mentioned as a part of Croatian legislative framework in this field:

- Statute of the International Atomic Energy Agency,
- Agreement on the Privileges and Immunities of the International Atomic Energy Agency,
- Vienna Convention on Civil Liability for Nuclear Damage,
- Convention on the Physical Protection of Nuclear Material,
- Convention on Early Notification of a Nuclear Accident,
- Convention on Assistance in the Case of a Nuclear Accident of Radiological Emergency,
- Convention on Nuclear Safety,
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention,
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Finally, the bilateral agreements in this field also constitute a part of the national legislative and regulatory framework:

- Agreement Between the Republic of Croatia and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-proliferation of Nuclear Weapons;
- The Protocol Additional to the Agreement Between the Republic of Croatia and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-proliferation of Nuclear Weapons;
- Agreement Between the Republic of Croatia and the Republic of Slovenia on the Early Exchange of Information in the Event of a Radiological Emergency;
- Agreement Between the Government of the Republic of Croatia and the Government of the Republic of Hungary on the Early Exchange of Information in the Event of a Radiological Emergency.

Bilateral agreements between Croatia and Slovenia/Hungary on the early exchange of information in the event of a radiological emergency prescribe that both parties are obliged to support each other in protective measure implementation. In the case of radiological emergency, relevant information such as the type of accident, time of its occurrence, location, cause of the accident, source term data, effective height of radioactive release, weather conditions etc, should be exchanged between appropriate national authorities without any delay.

Agreement between the Republic of Croatia and the Republic of Italy on the Early Exchange of Information in the Event of a Radiological Emergency is still in preparation for signature, and the content is foreseen to be similar to the agreements with Slovenia and Hungary.

Annex II Radioactive Waste Inventory

As explained in the Report, the only Croatian operational RW storage facility is the IRB temporary store of radioactive material (TSRM).

This Annex contains TSRM radionuclides inventory lists as reported to the SORP. In order to save space, it is here reproduced without columns containing less interesting information such as ordinal number and registration number of sources.

The TSRM radionuclides inventory on December 31, 2004

Table I. ^{60}Co sources (from level gauges)

RADIONUCLIDE	ACTIVITY (A)	FORM
^{60}Co	3 sources 1. $A_{init.}$ 254.9 MBq, $A_{31.12.2004}$ 57.5 MBq 2. $A_{init.}$ 254.9 MBq, $A_{31.12.2004}$ 57.5 MBq 3. $A_{init.}$ 68 MBq, $A_{31.12.2004}$ 15.2 MBq	
^{60}Co	6 sources 1. $A_{init.}$ 4 x 92.4 MBq, $A_{31.12.2004}$ 4 x 22.3 MBq 2. $A_{init.}$ 2 x about 111 MBq, $A_{31.12.2004}$ 2 x 26.8 MBq	
^{60}Co	3 sources 1. $A_{init.}$ 2 x 4.6 GBq, $A_{31.12.2004}$ 2 x 1.24 GBq 2. $A_{init.}$ 1GBq, $A_{31.12.2004}$ 0.27 GBq	
^{60}Co	3 sources $A_{init.}$ 3 x 180MBq, $A_{31.12.2004}$3 x 52.8 MBq	sources in working containers
^{60}Co	18 sources 1. $A_{init.}$ 14 x 100 MBq, $A_{31.12.2004}$ 14 x 44.8 MBq 2. $A_{init.}$ 4 x 1.1 GBq, $A_{31.12.2004}$ 4 x 492.3 MBq	sources from level gauges
^{60}Co	2 sources 1. $A_{init.}$ 8.29 GBq, $A_{31.12.2004}$ 3.976 GBq 2. $A_{init.}$ 6.02 GBq, $A_{31.12.2004}$ 2.887 GBq	
^{60}Co	3 sources 1. $A_{init.}$ 365 MBq, $A_{31.12.2004}$ 177.15 MBq 2. $A_{init.}$ 216 MBq, $A_{31.12.2004}$ 105.0 MBq 3. $A_{init.}$ 95 MBq, $A_{31.12.2004}$ 38.5 MBq	
^{60}Co	$A_{init.}$ about 20 kBq , $A_{31.12.2004}$ 11.5 kBq	a piece of filter paper
^{60}Co	2 sources 1. $A_{init.}$ about 222 MBq, $A_{31.12.2004}$ 127.3 MBq 2. $A_{init.}$ about 3.15 GBq, $A_{31.12.2004}$ 1.815 GBq	sources in protective containers
^{60}Co	$A_{init.}$ 380 MBq, $A_{31.12.2004}$ 254.25 MBq	in a locked container

RADIONUCLIDE	ACTIVITY (A)	FORM
^{60}Co	$A_{INIT.}$ 7.77 GBq, $A_{31.12.2004}$ 5.094 GBq	a source in a lead container - defectoscope
^{60}Co	unknown activity	in a protective container
^{60}Co	unknown activity	in a lead container
^{60}Co (possibly)	unknown activity B.D. is 5 μSv/h	looks like a differential of a big vehicle
^{60}Co	$A_{init.}$ 165.5 MBq, $A_{31.12.2004}$ 140.37 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 165.5 MBq, $A_{31.12.2004}$ 140.37 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 168.1 MBq, $A_{31.12.2004}$ 142.56 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 165.5 MBq, $A_{31.12.2004}$ 140.37 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 162.9 MBq, $A_{31.12.2004}$ 138.18 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 162.9 MBq, $A_{31.12.2004}$ 138.18 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 162.9 MBq, $A_{31.12.2004}$ 138.18 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 165.5 MBq, $A_{31.12.2004}$ 140.37 MBq	a sealed source
^{60}Co	$A_{INIT.}$ 162.9 MBq, $A_{31.12.2004}$ 138.18 MBq	a sealed source
^{60}Co	3 sources individual activities unknown; $A_{31.12.2004}$ 239.35 MBq	sealed sources in a common container
^{60}Co	$A_{init.}$ 5.759 GBq (13.09.1991) $A_{31.12.2004}$ 1.002GBq	a sealed source, no.: 1934-7-91/3
^{60}Co	$A_{init.}$ 5.768 GBq (03.09.1997) $A_{31.12.2004}$ 2.205 GBq	a sealed source, no.: 1289-7-97/3
^{60}Co	$A_{31.12.2004}$ 157.9 MBq	a sealed source (a spent level gauge in own protective container)
^{60}Co	$A_{init.}$ 1.9 GBq 1996. $A_{31.12.2004}$ 650.7 MBq	a sealed source (spent radioactive source), no.: Z-0150/0230

Table II. Radioactive lightning rods with ^{60}Co and $^{152/154}Eu$

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{60}Co	$A_{INIT.}$ 0,12 GBq, $A_{31.12.2004}$ 78.9 MBq	a lighting rod
^{60}Co	$A_{INIT.}$ 7.4 GBq, $A_{31.12.2004}$ 1.64 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 7,9 GBq, $A_{31.12.2004}$ 4.03 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 6,62 GBq, $A_{31.12.2004}$ 4.31 GBq	a lighting rod
$^{152/154}Eu$	unknown activity	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 6.1 GBq each source (2 sources) $A_{31.12.2004}$ 2 x 4.04 GBq	lighting rods
$^{152/154}Eu$	1 source - unknown init. activity	a lighting rod
$^{152/154}Eu$	1 source - unknown init. activity	a lighting rod
$^{152/154}Eu$	1 source - unknown init. activity	a lighting rod
$^{152/154}Eu$	2 sources 1. $A_{INIT.}$ 6.05 GBq, $A_{31.12.2004}$ 5.16 GBq 2. $A_{INIT.}$ 6.07 GBq, $A_{31.12.2004}$ 5.18 GBq	lighting rods
^{60}Co	$A_{INIT.}$ 142 MBq, $A_{31.12.2004}$ 110.5 MBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 2.71 GBq, $A_{31.12.2004}$ 2.32 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 8.0 GBq, $A_{31.12.2004}$ 6.92 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 2.55 GBq , $A_{31.12.2004}$ 2.23 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 4.2 GBq, $A_{31.12.2004}$ 3.75 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 5.1 GBq, $A_{31.12.2004}$ 4.55 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 9.7 GBq, $A_{31.12.2004}$ 8.73 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 3.1 GBq, $A_{31.12.2004}$ 2.80 GBq	a lighting rod
^{60}Co	$A_{INIT.}$ 0.8 GBq, $A_{31.12.2004}$ 0.69 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 5.0 GBq, $A_{31.12.2004}$ 4.53 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 7.0 GBq, $A_{31.12.2004}$ 6.33 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 11.1 GBq, $A_{31.12.2004}$ 10.10 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 8.5 GBq, $A_{31.12.2004}$ 7.81 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 5.9 GBq, $A_{31.12.2004}$ 5.42 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 8.5 GBq, $A_{31.12.2004}$ 7.81 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 8 GBq, $A_{31.12.2004}$ 7.38 GBq	a lighting rod
$^{152/154}Eu$	$A_{INIT.}$ 2.8 GBq, $A_{31.12.2004}$ 2.62 GBq	a lighting rod IJS-2243
$^{152/154}Eu$	$A_{INIT.}$ 2.6 GBq, $A_{31.12.2004}$ 2.44 GBq	a lighting rod IJS-2253
$^{152/154}Eu$	$A_{INIT.}$ 7.4 GBq, $A_{31.12.2004}$ 6.91 GBq	a lighting rod Y-0024

RADIO-NUCLIDE	ACTIVITY (A)	FORM
$^{152/154}Eu$	$A_{INIT.}$ 7.4 GBq, $A_{31.12.2004}$ 6.91 GBq	a lighting rod E-0023
$^{152/154}Eu$	1. $A_{INIT.}$ 5 GBq, $A_{31.12.2004}$ 4.75 GBq 2. $A_{INIT.}$ 8 GBq, $A_{31.12.2004}$ 7.60 GBq	lighting rods, no. 2070 and 190
$^{152/154}Eu$	1. $A_{INIT.}$ 5 GBq, $A_{31.12.2004}$ 4.77 GBq 2. $A_{INIT.}$ 5 GBq, $A_{31.12.2004}$ 4.77 GBq	lighting rods, two rings, one on the another, no. 2203 and 2
$^{152/154}Eu$	1. $A_{INIT.}$ 6 GBq, $A_{31.12.2004}$ 5.74 GBq 2. $A_{INIT.}$ 6 GBq, $A_{31.12.2004}$ 5.74 GBq	lighting rods, two rings, one on the another, no. 2379 and 11
$^{152/154}Eu$	$A_{INIT.}$ 14.8 GBq (1991), $A_{31.12.2004}$ 6.27GBq	a lighting rod, ring, no. 2145
$^{152/154}Eu$	$A_{INIT.}$ 14.8 GBq (1991), $A_{31.12.2004}$ 6.27GBq	a lighting rod, ring
$^{152/154}Eu$	$A_{INIT.}$ 14.8 GBq (1991), $A_{31.12.2004}$ 6.27GBq	a lighting rod, no. 2322, cylinder, bigger
$^{152/154}Eu$	$A_{INIT.}$ 14.8 GBq (1991), $A_{31.12.2004}$ 6.27GBq	a lighting rod, no. 2322, cylinder, bigger
$^{152/154}Eu$	Estimated 6 GBq (June 2004), $A_{31.12.2004}$ 5.73 GBq	a lighting rod, serial no. 1466
$^{152/154}Eu$	Estimated activity 6 GBq (June 2004), $A_{31.12.2004}$ 5.73 GBq	a lighting rod, serial no. 314 R
$^{152/154}Eu$	Estimated activity 6 GBq (June 2004), $A_{31.12.2004}$ 5.73 GBq	a lighting rod, serial no. 313 R
$^{152/154}Eu$	Estimated activity 6 GBq (July 2004) $A_{31.12.2004}$ 5.83 GBq	a lighting rod, serial no. 2214
$^{152/154}Eu$	Estimated activity 6 GBq (July 2004)	a lighting rod, serial no. 2252
$^{152/154}Eu$	Estimated activity 6 GBq each source (July 2004) $A_{31.12.2004}$ 5.83 GBq	lighting rods, no. 2380 and 2393
^{60}Co	Estimated activity 1.11 GBq (July 2004.) $A_{31.12.2004}$ 1.08 GBq	a lighting rod, loop, no. 2026
$^{152/154}Eu$	Estimated activity 6 GBq each source (Nov. 2004) $A_{31.12.2004}$ 5.93 GBq	lighting rods, no. 1208 and 1265
$^{152/154}Eu$	Estimated activity 8 GBq (Nov. 2004) $A_{31.12.2004}$ 7.93 GBq	a lighting rod, no. 2273

RADIO-NUCLIDE	ACTIVITY (A)	FORM
$^{152/154}Eu$	1. Estimated activity 8 GBq, A $_{31.12.2004}$ 7.94 GBq 2. Estimated activity 6 GBq each of two sources (Nov. 2004), A $_{31.12.2004}$ 5.96 GBq	a lighting rod, no. 2295, cylinder, smaller lighting rods, no. 2294 (smaller cylinder) and 2358. (bigger cylinder)
$^{152/154}Eu$	Estimated activity A $_{31.12.2004}$ 5-6 GBq	a lighting rod, YVG 2346 (cylinder, smaller)

Table III. ^{137}Cs sources

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{137}Cs	$A_{31.12.2004}$ about 34.5 MBq	a needle
^{137}Cs	20 sources $A_{31.12.2004}$ about 70.4 MBq each	needles
^{137}Cs	$A_{31.12.2003}$ about 103.4 MBq	a needle
^{137}Cs	$A_{INIT.}$ 22. 02. 1972. 111 MBq $A_{31.12.2004}$ 51.95 MBq	a sealed source which looks like a flat-iron
^{137}Cs	$A_{31.12.2004}$ 86.14 GBq	a source in a lead container
^{137}Cs	$A_{31.12.2004}$ 3 x 68.89 MBq	the sources are in a wooden case from inside coated with lead
^{137}Cs	$A_{31.12.2004}$ 1.39 kBq	an old source in a lead case from a disused beta counter
^{137}Cs	$A_{Init.}$ 19.82 GBq (total, 11 sealed sources) 2 sources $A_{INIT.}$ 1.07 GBq 2 sources $A_{INIT.}$ 1.21 GBq 2 sources $A_{INIT.}$ 1.21 GBq 1 source $A_{INIT.}$ 1.23 GBq 1 source $A_{INIT.}$ 1.53 GBq 1 source $A_{INIT.}$ 1.53 GBq 1 source $A_{INIT.}$ 3.97 GBq 1 source $A_{INIT.}$ 4.58 GBq $A_{31.12.2004}$18.46 GBq (total)	the sources are in a common locked cylindrical container
^{137}Cs	Source without protective container, $A_{init.}$ 2.66 GBq, $A_{31.12.2004}$ 2.50 GBq	a source (tube) placed into a lead container
^{137}Cs	$A_{init.}$ 3.1 GBq, $A_{31.12.2004}$ 2.92 GBq	(type:LAB) No.: 1349, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.7 GBq, $A_{31.12.2004}$ 2.54 GBq	(type:LAB) No.: 1635, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.55 GBq, $A_{31.12.2004}$ 2.40 GBq	(type:LAB) No.: 301, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.45 GBq, $A_{31.12.2004}$ 2.31 GBq	(type:LAB) No.: 316, the source placed into a lead container
^{137}Cs	$A_{31.12.2004}$ 696.81 MBq	corroded, number unreadable, the source placed into a lead container

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{137}Cs	$A_{init.}$ 12.84 GBq, $A_{31.12.2004}$ 12.09 GBq	(type:LAB) No.: 402, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.85 GBq, $A_{31.12.2004}$ 2.69 GBq	(type:LAB) No.: 1625, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.51 GBq, $A_{31.12.2004}$ 2.60 GBq	(type:LAB) No.: 312, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.85 GBq, $A_{31.12.2004}$ 2.69 GBq	(type:LAB) No.: 1414, the source placed into a lead container
^{137}Cs	$A_{init.}$ 0.85 GBq, $A_{31.12.2004}$ 0.80 GBq	(type:LAB) No.: 1506, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.51 GBq, $A_{31.12.2004}$ 2.36 GBq	(type:LAB) No.: 313, the source placed into a lead container
^{137}Cs	$A_{init.}$ 13.60 GBq, $A_{31.12.2004}$ 12.81 GBq	(type:LAB) No.: 681, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.55 GBq, $A_{31.12.2004}$ 2.40 GBq	(type:LAB) No.: 317, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.67 GBq, $A_{31.12.2004}$ 2.51 GBq	(type:LAB) No.: 1217, the source placed into a lead container
^{137}Cs	$A_{init.}$ 10.91 GBq, $A_{31.12.2004}$ 10.27 GBq	(type:LAB) No.: 404, the source placed into a lead container
^{137}Cs	$A_{init.}$ 2.91 GBq, $A_{31.12.2004}$ 2.74GBq	(type:LAB) No.: 1337, the source placed into a lead container
^{137}Cs	$A_{init.}$ < 37 MBq, $A_{31.12.2004}$ < 35 MBq	a part of an equipment of unknown purpose
^{137}Cs	unknown activity	unusual shape, unknown purpose
^{137}Cs	$A_{INIT.\ 31.12.2000}$ 111 MBq, $A_{31.12.2004}$ 101.2 MBq	a long needle (RS)
^{137}Cs	$A_{INIT.\ 31.12.2000.}$ 155 MBq, $A_{31.12.2004}$ 141.3 MBq	a long needle (RS)
^{137}Cs	$A_{INIT.\ 31.12.2000}$ 121MBq, $A_{31.12.2004}$ 110.3 MBq	a long needle (RS)
^{137}Cs	$A_{INIT.\ 31.12.2000}$ 55.5 MBq, $A_{31.12.2004}$ 50.6 MBq	a long needle (RS)
^{137}Cs	$A_{INIT.\ 31.12.2000}$ 92.5 MBq, $A_{31.12.2004}$ 84.3 MBq	a long needle (RS)
^{137}Cs	$A_{INIT.\ 31.12.2000}$ 60.7 MBq, $A_{31.12.2004}$ 55.4 MBq	a short needle (RS)

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source serial no.:1204-5-89
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source serial no.:1210-5-89
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source serial no.:1206-5-89
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source serial no.:1202-5-89
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source, serial no.:1205-5-89
^{137}Cs	$A_{INIT.}$ 1325 MBq, $A_{31.12.2004}$1285.6 MBq	a sealed source, serial no.:1207-5-89

Table IV. ^{226}Ra sources

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{226}Ra	32 sources, total activity: 5.35 GBq	needles + tubes
^{226}Ra	204 sources, total activity: 23.86 GBq	needles + tubes
^{226}Ra	58 sources, total activity: 17.61 GBq	needles + tubes
^{226}Ra	4 sources, total activity: 370 MBq	needles
^{226}Ra	37.0 MBq	soil
^{226}Ra	unknown activity	Siemens, E25 P8-090
^{226}Ra	unknown activity	luminescent paint (speedometer scale)
^{226}Ra	unknown activity , B.D. up to 100 μSv/h	a hemisphere (signalling device), diameter 5-6 cm

Table V. ^{241}Am, ^{109}Cd, ^{55}Fe, ^{85}Kr, ^{90}Sr and ^{204}Tl sources, uranium acetate and telescope parts

RADIO-NUCLIDE	ACTIVITY (A)	FORM
^{241}Am	$A_{INIT.}$ (22. 02.1972) 1.11 GBq	a sealed source of the form like a flat-iron
^{109}Cd	$A_{INIT.}$ 30 MBq, $A_{31.12.2004}$ 10.42 MBq	a sealed source serial no. 9956 LU
^{109}Cd	$A_{INIT.}$ 525 kBq, $A_{31.12.2004}$ 227 kBq	a sealed source serial no. 8427 LU
^{55}Fe	$A_{INIT.}$ 320 MBq, $A_{31.12.2004}$ 193.5 MBq	a sealed source serial no. 6312 LG
^{85}Kr	unknown activity	a source from a thickness gauge
^{85}Kr	$A_{INIT.}$ 4.172 GBq, $A_{31.12.2004}$ 3.617 GBq	serial no. KR 630, in a welded capsule
^{85}Kr	$A_{INIT.}$ 4.42 GBq, $A_{31.12.2004}$ 3.831 GBq	serial no. KR 606, in a welded capsule
^{90}Sr	$A_{INIT.}$ 18.5 GBq, $A_{31.12.2004}$ 6.28 GBq	
^{90}Sr	6 sources $A_{init.\ per\ source}$ 129 MBq, $A_{31.12.2004}$ 6 x 115.2 MBq	two measuring heads
^{90}Sr	$A_{INIT.}$ 174 MBq, $A_{31.12.2004}$ 104.7 MBq	in a lead container, Ser. no. 169
^{90}Sr	6 sources, unknown activity	without labels and serial numbers; in lead containers
^{204}Tl	5 sources 1. $A_{INIT.}$ 3 x 3.7 MBq, $A_{31.12.2004}$ 0.6 MBq 2. $A_{INIT.}$ 2 x 20.3 MBq, $A_{31.12.2004}$ 3.1 MBq	in working containers; known serial numbers
unknown	3 sources, unknown activity	olive-green cylinders, length 67 cm, diameter 6-8 cm; parts of a telescope
U $_{(NATURAL)}$	unknown	uranium acetate, 205 g; small glass bottles (10 g each)
U $_{(NATURAL)}$	unknown (100 g uranium acetate) unknown (25 g uranium oxide)	uranium acetate, 100 g; uranium oxide, small glass bottles (10g, 100 g each)
U $_{(NATURAL)}$	unknown (50 g uranium-nitrate-6-hydrate) unknown (25 g uranium acetate)	uranium-nitrate-6-hydrate, a small glass bottle (50 g) uranium acetate, a small glass bottle (25 g)

Table VI. Natural sources (Th/U/Ra) found in metal waste

RADIO-NUCLIDE	ACTIVITY (A)	FORM
Th/U/Ra	2 sources, unknown activity, B.D. up to 15 μSv/h	circular and semicircular shape, diameter 70 cm

Table VII. Radioactive smoke detectors with ^{241}Am and ^{226}Ra sources

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	7098 sources of various activities 6 sources (uninstalled 1992) 53 sources (uninstalled 1994) 757 sources (uninstalled 1995) 621 sources (uninstalled 1996) 243 sources (uninstalled 1997) 2390 sources (uninstalled 1998) 448 sources (uninstalled 1999) 42 sources (uninstalled 2000) 818 sources (uninstalled 2001) 1720 sources (uninstalled 2002)	smoke detectors
^{241}Am	24 sources, activity 33 kBq each	smoke detectors, type 301 G SALWICO JD-1
^{241}Am	6 sources, activity 2.66 MBq each	smoke detectors type FES-5B
^{241}Am	6 sources, activity 2.66 MBq each	smoke detectors type FES-5B
^{241}Am	21 sources, activity 2.66 MBq each	smoke detectors type FES-5B
^{241}Am	14 sources, activity 74 kBq each	smoke detectors type JD-1
^{241}Am	346 sources (48 sources, each 74 kBq) (278 sources, each 2.66 MBq) (20 sources each 29.6 kBq)	smoke detectors type FES-5B, type IDD- 801, type NID-28, type JD-1,type F-716 and type IJD-5
^{241}Am	4 sources, activity 59.2 kBq each	smoke detectors type FES-5B
^{241}Am	386 sources 345 sources, activity 2.66 MBq each; 41 sources, unknown activity	smoke detectors type FES-5B and type SV-1 (Vinča)

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	3605 sources 1. 2138 sources, type NIS, activity 74 kBq each 2. 464 "plates" + 116 "cups" from NITTAN, activity 74 kBq each 3. 321 "plates" + 155 "cups", from FES 5B, activity 2.66 MBq each 4. 152 sources, type IJD5, activity 74 kBq each 5. 34 sources, type STATITROL 301G7, activity 33.3 kBq each 6. 225 sources, FES 5B	smoke detectors type NIS and from NITTAN FES 5B, type IJD5, STATITROL 301G7, FES 5B
^{241}Am	34 sources, activity up to 74 kBq each	smoke detectors type IDD 801S
^{241}Am	40 sources, activity up to 2.66 MBq each	smoke detectors type FES-5B
^{241}Am	2 sources, activity up to 74 kBq each	smoke detectors type IDD 801
^{241}Am	8 sources, activity up to 74 kBq each	smoke detectors, 5 sources type IDD 801, 3 sources type JD 5
^{241}Am	7 sources, activity up to 29.6 kBq each	smoke detectors, 7 sources type F-716
^{241}Am	63 sources, activity up to 74 kBq each	smoke detectors, 63 sources type IJD-5,
^{241}Am	24 sources, activity up to 33,3 kBq each	smoke detectors, 24 sources type APOLLO
^{241}Am	28 sources, activity up to 2.66 MBq each	smoke detectors, 28 sources type FES 5B,
^{241}Am	202 sources, activity up to 2.66 MBq each	smoke detectors, 202 sources type FES 5B,
^{241}Am	17 sources, activity up to 2.66 MBq each	smoke detectors, 17 sources type FES 5B,
^{241}Am	237 sources, activity up to 2.66 MBq each	smoke detectors, 237 sources type FES 5B,
^{241}Am	12 sources, activity up to 74 kBq each	smoke detectors, 12 sources type IDD 801,
^{241}Am	49 sources, activity up to 2.66 MBq each	smoke detectors, 49 sources type FES 5B,

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	76 sources, activity up to 2.66 MBq , 74 kBq or 33.3 kBq each	smoke detectors, 40 sources type FES 5B, 12 sources type IDD 801, 11 sources type IJD 5, 13 sources type SATITROL
^{241}Am	19 sources, activity up to 2.66 MBq each	smoke detectors, 19 sources type FES 5B,
^{241}Am	9 sources, activity up to 74 kBq each	smoke detectors, 9 sources type IDD 801,
^{241}Am	61 sources, activity up to 2.66 MBq each	smoke detectors, 61 sources type FES 5B,
^{241}Am	102 sources, activity up to 33 kBq each	smoke detectors, 102 sources type APOLLO ,
^{241}Am	9 sources, activity up to 33 kBq each	smoke detectors, 9 sources type APOLLO series XP 95 ,
^{241}Am	33 sources, activity up to 74 kBq each	smoke detectors, 15 sources IDD 801, 18 sources NITTAN, NID-28
^{241}Am	60 sources, activity up to 74 kBq each	smoke detectors, 60 sources IDD 801,
^{241}Am	83 sources, activity up to 74 kBq each	smoke detectors, 83 sources Nittan Salwico, type NID-28
^{241}Am	176 sources, activity up to 74 kBq each	smoke detectors, 157 sources Nittan Salwico, type JD-1, 10 sources Nittan Salwico, type NID-28, 9 sources IDD 801
^{241}Am	6 sources, activity up to 74 kBq each	smoke detectors, 4 sources JD-1 Salwico, 2 sources IDD 801
^{241}Am	16 sources, activity up to 30 kBq each	smoke detectors, 16 sources I-716
^{241}Am	10 sources, activity do 74 kBq each	smoke detectors, 10 sources type IDD-801

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	10 sources, activity up to 74 kBq each	smoke detectors, 10 sources type: IDD-801
^{241}Am	46 sources, activity up to 74 kBq each	smoke detectors, 46 sources type: IDD-801
^{241}Am	56 sources, activity up to 74 kBq each	smoke detectors, 56 sources type ODD-801"S"
^{241}Am	5 sources, activity up to 74 kBq each	smoke detectors, 5 sources type IJD-5
^{241}Am	70 sources 1. 69 sources activity up to 74 kBq each 2. 1 source, activity less than 555 kBq	smoke detectors, 69 sources type IJD-5 activity up to 74 kBq each 1 source type F600 activity up to 555 kBq each
^{241}Am	22 sources 1. 2 sources, activity up to 74 kBq each 2. 15 sources, activity up to 2.66 MBq 3. 5 sources, activity up to 33.3 kBq each	smoke detectors, 2 sources type IJD-5(ERA) activity up to 74 kBq each; 15 sources type FES 5B activity up to 555 kBq each; 5 sources STATITROL 301G7 activity up to 33.3 kBq each
^{241}Am	47 sources, activity up to 74 kBq each	smoke detectors, 47 sources type: IDD-801
^{241}Am	23 sources, activity up to 74 kBq each	smoke detectors, 2 sources type SALWICO; 2 sources type IDD-801; 3 sources type JD SALWICO 11 sources type IJD-5; 3 sources type IJD-5; 2 sources type IDD 801; 1 source type NID 48F
^{241}Am	17 sources, activity up to 74 kBq each	smoke detectors, 15 sources type IJD-5 2 sources PASTOR-ZAGREB
^{241}Am	5 sources, activity up to 2,66 MBq each	smoke detectors, type FES 5B

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	8 sources, activity do 2,66 MBq each	smoke detectors, type FES 5B
^{241}Am	6 sources, activity up to 74 kBq each	smoke detectors, type IDD 801
^{241}Am	7 sources, activity up to 74 kBq each	smoke detectors, type IDD 801
^{241}Am	35 sources, activity do 74 kBq each	smoke detectors, type IDD 801
^{241}Am	14 sources, activity up to 74 kBq each	smoke detectors, type IOJ-2
^{241}Am	3 sources, activity up to 74 kBq each	smoke detectors, type IDD 801
^{241}Am	176 sources, 42 sources activity up to 74 kBq each 134 sources activity up to 33 kBq each	smoke detectors, 42 sources type IOJ-2 62 sources type STATITROL 72 sources TYPE APOLLO
^{241}Am	6 sources, activity up to 74 kBq each	smoke detectors, type NID-48
^{241}Am	231 sources, activity up to 2.66 MBq each	smoke detectors, type FES 5B
^{241}Am	81 sources, activity up to 29.6 kBq each	smoke detectors, type F-716
^{241}Am	18 sources, activity up to 29.6 kBq each	smoke detectors, type F-716
^{241}Am	7 sources, activity up to 74 kBq each	smoke detectors, 2 sources type IDD-801 5 sources type IJD-5
^{241}Am	50 sources, 42 sources activity up to 74 kBq each 8 sources activity up to 33 kBq each	smoke detectors, 42 sources type IDD-801 8 sources APOLLO XP, ser. 95
^{241}Am	45 sources, activity up to 33 kBq each	smoke detectors, 45 sources APOLLO XP, ser. 95
^{241}Am	160 sources, activity up to 33 kBq each	smoke detectors, 160 sources type IOJ-2 EN
^{241}Am	3 sources, activity up to 74 kBq each	smoke detectors, 2 sources type NID-48, 1 source type: JD-1

RADIO-NUCLIDE	ACTIVITY (A)	FORM/TYPE
^{241}Am	1 source, activity up to 74 kBq	smoke detectors, 1 source type IDD 801
^{241}Am	13 sources, activity up to 74 kBq each	smoke detectors, 13 sources type IDD 801
^{241}Am	71 sources, activity up to 74 kBq each	smoke detectors, 1 source type IDD 802N 8 sources type IDD 801N 62 sources type NID 28
^{241}Am	17 sources, activity up to 74 kBq each	smoke detectors, 8 sources type IDD 801N 9 sources type IDD 801
^{241}Am	13 sources, activity up to 74 kBq each	smoke detectors, 13 sources type IDD 801
^{241}Am	110 sources, 12 sources activity up to 74 kBq each 33 sources activity up to 33 kBq each 40 sources activity up to 29,6 kBq each 25 sources activity up to 2,66 MBq each	smoke detectors, 12 sources, type IDD 801 33 sources, type IOJ-2, IOJ-1 40 sources, type F-716 I 301 G STATITROL 25 sources, type FES 5B
^{241}Am	32 sources, activity up to 74 kBq each	smoke detectors, 32 sources type IDD 801
^{241}Am	63 sources, 54 sources activity up to 74 kBq each 1 sources activity up to 33 kBq each 8 sources activity up to 2,66 MBq each	smoke detectors, 54 sources type IJD 5 1 source type IOJ 3 8 sources APOLLO type XP 95
^{241}Am	7 sources, activity up to 74 kBq each	smoke detectors, type IDD 801N
^{226}Ra	28 sources of different activities	smoke detectors, type CERBERUS
^{226}Ra	147 sources, activity 22 kBq each	smoke detectors, type NITAN NID
^{226}Ra	152 sources, activity 2.22 kBq each	smoke detectors, type ESSER
^{226}Ra	68 sources, activity 2.2 kBq each	smoke detectors, type KLAUSESSER 1052, NW 118/77

Annex III Program of NPP Krško Decommissioning and SF & LILW Disposal

The Program consists of seven modules (chapters). In this Annex only the Executive Summary of the Program is reproduced.

Program of NPP Krško Decommissioning and SF & LILW Disposal

Executive Summary

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Introduction

As required by the paragraph 10 of the Agreement between the governments of Slovenia and Croatia on the status and other legal issues related to investment, exploitation, and decommissioning of Nuclear power plant Krško, Decommissioning program for Nuclear power plant Krško including LILW and spent fuel management was drafted. The Agreement stipulates drafting two programs – one for decommissioning and the other for waste and spent fuel management – but the Intergovernmental body coordinating the implementation of the Agreement (IGB) decided to produce a joint plan since all the decommissioning and waste and spent fuel management activities for Krško NPP are tightly related.

The Intergovernmental body required that the Program should be an extensive revision of the existing program, as one of several iterations to be prepared before the final version will be finished just prior to the end of the useful life of NPP Krško. It was required also that the Program should be based on all known data and international standards as well as the best practice in the field.

Purpose of the Program

The purpose of the joint Program is to estimate the expenses of the future decommissioning, radioactive waste and spent fuel management for Krško NPP. Costing estimation with target sums needed at the beginning of decommissioning will be the basis for establishing special fund in Croatia or correction of the rate for existing decommissioning fund in Slovenia.

Organization of the work

Program development was entrusted to specialized organizations both in Croatia and Slovenia (APO d.o.o. & ARAO) which formed the Project team as the operative body. Also, IGB nominated the Advisory board (alternatively referred to as Project council) with experts form Croatia and Slovenia. The role of the Advisory board was supervising the activities of the Project team and resolving issues raised by the Project team (i.e. setting and interpreting the boundary conditions). NPP Krško was supplying the data needed. Consulting firms from Croatia and Slovenia were involved as well as experts from International Atomic Energy Agency (through short visits to Zagreb and Ljubljana) for specialized fields (e.g. economic aspects of decommissioning, pre-feasibility study for spent fuel repository in crystalline rock, etc.)

Method

Analysis was performed in several steps.

The first step was to develop rational and feasible integral scenarios (strategies) of decommissioning and LILW and spent fuel management on the basis of detailed technical analysis and within defined boundary conditions. Each of the scenarios is a time sequence of interrelated and coordinated jobs on: (a) dismantling of Krško NPP, (b) transport and storage of spent fuel, (c) export or disposal of spent fuel in geological repository, and (d) disposal of LILW in near surface repository. Based on technological data every scenario was attributed with time distribution of expenses for all main activities.

In the second step financial analysis of scenarios was undertaken aiming at estimation of total discounted expense and related annuity (19 installments into a hypothetical joint fund, empty in 2003) for each of the scenarios. It was assumed that this annuity is good financial description of given scenario so that by comparing them financially affordable scenarios could be identified. Furthermore, some of the scenarios were eliminated as being less rational then others or as being temporally inflexible (e.g. sensitive to achieving goals on time).

The third step involves additional analysis of the chosen scenarios aiming at their (technical or financial) improvements even at the price of loosening some of the boundary conditions. Based on such rationalized scenarios, total discounted expense is determined and it's corresponding annuity. Using this abstract annuity Croatia and Slovenia could determine real annuities for their national decommissioning funds. Values of annuities in Croatia and Slovenia could be different due to the existing unsymmetrical situation but accumulated sums in both of the funds in December 2022 should be the same or nearly same and put together sufficient for all the future expenses.

The forth step includes financial comparison of the estimated expenses for the chosen scenario with the available data on decommissioning expenses for similar power plants or LILW and spent fuel repositories. Conclusions and recommendations were formulated.

Contents of the Program

The Program is divided in 7 separate units – modules – where: (a) Previous work on decommissioning and waste or spent fuel management for NPP Krško is described. Boundary conditions are also presented here (modules 1 and 2); (b) Technical solutions for decommissioning, dry storage, spent fuel management and disposal of LILW are explained (modules 3, 4 and 5); (c) Scenarios are formulated respecting boundary conditions. Scenario analysis is done; the optimal scenario is chosen and improved (modules 6 and 7).

Context

Background

a) During the year 2000 NPP Krško undertook a modernization project including exchange of steam generators. Output power was increased to 676 MWe. Replaced steam generators were temporarily stored on location in specially prepared building. In the same time spent fuel pit reracking was successfully finished enabling enough capacity of pool until 2023. Heat exchanger was replaced; the old one was stored in decontamination building. Modernization was aimed at extension of fuel cycle from 12 to 18 months.

b) NPP Krško is having presently 1694 locations in spent fuel pool. 663 places were taken, 603 with fully spent fuel elements and 59 with partially spent fuel elements, at the end of 2002. It is estimated that until 2023, with assumed extension of fuel cycle and increased power output, 1.531±20 spent fuel elements will be produced with total of about 620 tones of metallic uranium.

c) At the end of 2002 in the storage on location of NPP Krško there were 2.208 m3 of operational solid LILW. Most of the waste is short lived with very low content of alpha emitters. With present technology of conditioning and packaging it was estimated that 3.615 m3 of waste will be generated until the end of useful NPP life. If we add up LILW to be generated by decommissioning and replacement of major components, total quantity of LILW is estimated at 17.500 m3. Approximately 1 % of that volume will be the long lived LILW.

Boundary conditions

Establishment of a finite number of rational scenarios (strategies) integrating decommissioning and waste management for NPP Krško requires setting up some assumptions on the processes and their time limitations. These assumptions are here named boundary conditions. Since this iteration of the Program is required to be a limited revision of the NIS study, significant number of the boundary conditions was kept. But some of the boundary conditions were changed according to suggestions formulated at Ljubljana 2000 and Ljubljana 2001 workshops which reviewed the NIS study (e.g. incorporating risk registry). Advisory Board of the project made a revision of the entire set of boundary conditions as well as formulation of some new ones chosen particularly for this iteration of the Program. The most important boundary conditions in this study are:

a) NPP Krško will operate until 2023;

b) Only variations of the SID strategy, which has been originally introduced by the NIS study, will be evaluated, in particular SID-15 option and the original of SID-96 option[6], while SID-30 will be examined within sensitivity analysis;

c) Financial results should be expressed in euros (€2002) as: (1) estimation of nominal and discounted costs; and (2) cash flow of accumulation and expenditure on a time scale;

d) One LILW repository (either in Slovenia or Croatia), subsurface (tunnel type), operational from 2013;

e) One geological repository for spent fuel (either in Slovenia or Croatia), operational from 2030, but permanent export will be analyzed also;

6 SID is short for *Strategy Immediate Dismantling* from NIS study, indicating that decommissioning takes place immediately after shut down; numerical index specifies the period after shut down in which all the activities described in this Program are finished. Dismantling of power plant could be considerably shorter.

f) The Program will address dry storage of spent fuel;
g) Discounting is done with the inflation factor i = 1.0073 and the interest factor k = 1.0429 (with corresponding discounting factor d = 1.035). Annuity for the decommissioning fund is calculated from the total discounted expenses, assuming 19 equal payments into presently empty fund.

Additional assumptions

In addition, the following was assumed:

a) All the expenses are without taxes;
b) Expenses for the repository post-closure institutional control are not taken into account;
c) All the expenses of LILW storage expansion or modification on the location of NPP Krško and all the related expenses (e.g. local incentives) are operational expenses;
d) All the expenses for additional operational LILW waste stabilization and conditioning possibly required by repository (based on waste acceptance criteria) are NPP Krško operational expenses.

Description of technologies and calculation of nominal expenses

The quality of data used for evaluation of decommissioning expenses as well as expenses for waste and spent fuel management is variable:

- LILW management and disposal is well known, based on several detailed feasibility studies.
- Spent fuel management and/or disposal is less known: export expenses are known only as the first and preliminary offers; only one pre-feasibility study was available transposing Swedish disposal technology for spent fuel into local (very different) social and economical circumstances. Calculation of expenses was generic and quite simplified.
- Overall dismantling costs are known with less accuracy than in the NIS study, the reason being additional corrections and recalculations for new circumstances (e.g. US$1996 in €2002, and particularly the work force expenses).

Difference in accuracy was compensated with the addition of extra sums in the form of contingency. Where the accuracy was better (e.g. expenses for establishing LILW repository) 10% was added to the total sum, and where it was lower (e.g. expenses for establishing SF repository) 30% was added to the total sum.

LILW disposal

Based on thorough analysis of different approaches in various countries near surface type of repository was chosen as the most appropriate one. This type of repository could be constructed in the two forms: as a subsurface tunnel and as a surface vault type. This Program

uses primarily analysis for establishing a tunnel type of repository for 17.500 m^3 of NPP Krško LILW which is enough for all the waste generated during operation and decommissioning.
For construction, operation and closure of the repository the estimate of expenses was mostly derived from existing feasibility studies. However some of the expenses were internally assessed with the assistance of IAEA experts. The most of the expenses are related to the construction of repository and needed infrastructure. The construction of the underground objects to be finished from 2011 to 2013 is the biggest single expense.
The methodology used differentiates two periods: the first, development and construction of repository, covers expenses for site selection, negotiation with local community, preparation of requests and obtaining various licenses, construction of repository and infrastructure, disposal technology and safety assessments as well as incentives; the second period starting with 2014 onwards covers the expenses for routine operation of repository, repository closure and incentives for local community.

SF disposal

Disposal in deep geological formations is considered to be the only technically feasible and safe long term solution for spent fuel and high level waste (HLW). Swedish model (developed by Swedish agency for waste management – SKB as KBS-3 concept) was adopted for the evaluation of the expenses related to development and construction of such a repository 500 m underground in hard rock (e.g. granite). This is logical choice since KBS-3 is the most developed disposal concept which is also going to be used in Finland in the first operational repository in Europe. Basic characteristics of the concept are: (a) direct disposal of spent fuel (no reprocessing); (b) capacity for 1531 fuel elements or 620 metric tons of metallic uranium with a small additional volume of HLW (~16 m^3). All the phases of development, operation and closure were studied: (a) research and development; (b) site selection and characterization; (c) design and construction; (d) operation; (e) closure. Swedish methodology for evaluation of expenses was used along with the model.
Referent scenario was analyzed in two versions: (a) beginning of repository operation is 2030 (spent fuel in pool); and (b) beginning of repository operation is 2050 (spent fuel in dry storage).
Since Russian Federation has recently put into force three laws opening the possibility of spent fuel import to Russia for reprocessing and/or permanent disposal, a prospect for export of the NPP Krško spent fuel is opened. The Program analyzes circumstances in which such an export could be conceived. Assuming that social and political conditions for agreement on the issue could be met, export of spent fuel was analyzed as a symmetrical option to disposal in the local repository in scenarios where this was technically possible. According to the data available, the price of SF export is estimated at 1000 - 2000 US$ per kg of metallic uranium. For the costs estimate the mean value of 1500 US$ was adopted.
It could be seen from comparison with other decommissioning programs that fixed expenses are the biggest part in establishing deep geological repository. Because of that the price per

disposed kg of spent fuel will be high where the quantities of spent fuel are comparatively small as is the case with the NPP Krško.

Dismantling

According to boundary conditions the NIS study was used as the only source of data for estimation of dismantling costs. Expenses were "decomposed" on basic activities, their revalorization was done and then they were "composed" in new entities (with some modifications or added activities), and distributed in time accordingly. This was accomplished with the support by the IAEA experts. Analysis of NIS expenses was used to separate expenses for establishing and operation of LILW repository and SF disposal originally integrated in the total NIS price. In particular, work force expenses were scrutinized since the NIS study assumes that work force expenses compose 60% of all the expenses. Furthermore, average salary was set to be based on 16 DEM-95/h, which is rather low. Also, it was assumed that 75% of the total work force expenses are for the NPP personnel and 25% for the local companies.

Based on this, revision of original expenses was done: per hour salary was doubled for all the workers and then a contingency was added (50% for technological expenses and 20% for expenses related to spent fuel transport casks). Recalculated expenses were then converted (DEM-96 into €2002).

Appropriate modifications with different dismantling options were introduced in the SID-96 original technological sequence to be used in integral scenarios which differ from the NIS study approach.

Results

Integral scenarios development and their financial evaluation

By variations of original SID strategy seven rational decommissioning scenarios were formulated respecting boundary conditions and other limitations. Three of them are ending up with local disposal of spent fuel and four of them are assuming permanent SF export.

Original SID-96 scenario could be adapted to new boundary conditions without variations in technology and without changes in sequence of dismantling activities (*SID-96 with disposal*). The same sequence of dismantling activities but with permanent export of spent fuel is a basis for the symmetrical scenario (*SID-96 with export*).

Since it is impossible to dispose spent fuel immediately after the NPP shut down, scenario of prompt decommissioning could not be constructed as simple shortening of the original SID-96, except in the case of permanent export of spent fuel (*SID-15 with export*). For this scenario, and the rest of scenarios considered here (apart from two aforementioned SID-96 scenarios), 80 years of on site storage for the main components and reactor vessel is canceled and technological modifications are introduced to enable their dismantling, cutting and disposal prior to the rest of decommissioning operations.

To achieve fast decommissioning without export of spent fuel, original SID scenario should be modified enabling dismantling while spent fuel is still cooling down in the pool. If wet storage is introduced, the scenario could be finished in less than 15 years even if disposal of spent fuel starts at 2031 (*SID-15WS with disposal*). Spent fuel could be kept in wet storage for the same number of years prior to export in symmetrical scenario (*SID-15WS with export*).

If it would be necessary to store spent fuel for more than 10 years (as is the case with SID-15WS scenarios) dry storage is indicated as better solution since it is cheaper for longer periods than wet storage. Corresponding scenarios lasting approximately 30 years (*SID-30 with disposal* and *SID-30 with export*) were derived from technological operations of the original SID in the similar way it was done for *SID-15 with export.* Location for dry storage was not defined in this Program: it could be on the NPP Krško site or elsewhere.

The set of seven presented scenarios contains all feasible decommissioning options which are respecting boundary conditions.

Each of the seven scenarios was described with temporal distribution of expenses for all of the central activities (dismantling, transport and storage of spent fuel, disposal of LILW and disposal or export of spent fuel). Financial analysis for which all of the needed tools were developed (financial model and computer program) produced discounted total cost for every scenario and corresponding annuity for hypothetical decommissioning fund.

Selection of appropriate scenario

After financial analysis the most expensive scenarios were eliminated (*SID-96 with export, SID-15 with export* and *SID-15WS export*). Among the financially superior scenarios (*SID-96 with disposal, SID-30 with export, SID-30 with disposal* and *SID-15WS with disposal*) some are technically better then others: *SID-96 with disposal* (inherited from the NIS study) is based on rather complicated and expensive solutions, related particularly to SF disposal; *SID-15WS with disposal* was introduced as realistic solution in a response to boundary condition requiring fast decommissioning. Both of them are technologically weak in the same way: they are inflexible to changes in planned operations with SF (e.g. extended site selection process or late approval of licenses, consequently causing considerable expenses for extended wet storage).

Two SID-30 scenarios could be singled out. They are having both of the required properties: low expenses and adaptability to possible changes. In addition, since SID-30 scenarios are based on dry storage of SF, some changes were scrutinized in order to make scenarios more realistic and cheaper. Lower expenses could be accomplished by slight modifications of boundary conditions. Obviously, lowering nominal costs is one possibility and shifting the costs in time is the other, if discounting is considered. In our case, three options are possible: (a) later disposal/export of SF; (b) later opening and shorter lifespan of LILW repository; and (c) surface type of LILW repository. Other optimizations of expenses are also possible, in particular those anticipating further development of nuclear technology. At this early time of Program development they are not considered.

Options (a) and (b) were chosen for our optimization (later disposal/export for SF and shorter lifetime for LILW repository). This was done primarily to make total expenses for export and disposal comparable, and to enable postponement of final decision on the disposal/export for SF.

Introduced extension of the scenario duration (extended dry storage) is formally reflected in the names of new scenarios which we labeled as *SID-45 with disposal* and *SID-45 with export*. For SID-45 scenarios annuities and other financial indicators were calculated. The two scenarios have comparable expenses. A choice on the one to be finally executed is up to the stakeholders deciding on scenario's social acceptability.

A review of most relevant financial characteristics of all scenarios investigated in this Program is presented in Table 1.

Table 1. Review of most significant financial indicators for all investigated scenarios

	million €	LILW disposal		SF transport & storage		SF disposal		NPP dismantling		TOTAL		Needs in 2003	Annuity for initial 0 fund
		nominal	discounted	nominal	discounted	nominal or fixed	discounted	nominal	discounted	nominal or fixed	discounted		
1	**SID-96** export	504,2	131,0	133,8	62,5	982,1	430,9	176,0	61,8	1.796,1	686,2	715,6	**55,8**
2	**SID-96** disposal	504,2	131,0	75,9	26,5	596,4	251,8	243,9	73,3	1.420,4	482,6	503,3	**39,3**
3	**SID-15** export	197,4	107,7	133,8	62,5	982,1	430,9	206,3	80,9	1.519,6	682,0	711,3	**55,5**
4	**SID-30** export	268,5	119,7	175,3	77,0	982,1	146,1	206,3	80,9	1.632,2	423,7	441,9	**34,5**
5	**SID-30** disposal	268,5	119,7	175,3	77,0	509,7	111,4	206,3	80,9	1.159,8	388,9	405,6	**31,6**
6	**SID-15MS** export	193,6	106,8	167,2	63,4	982,1	338,5	208,0	89,2	1.551,0	598,0	623,6	**48,7**
7	**SID-15MS** disposal	201,1	108,6	112,9	43,6	596,4	251,8	208,0	89,2	1.118,5	493,2	514,4	**40,1**
8	**SID-45** export	310,2	107,8	190,3	78,7	982,1	77,8	206,3	80,9	1.689,0	345,3	360,1	**28,1**
9	**SID-45** disposal	186,0	93,9	189,3	78,6	567,7	85,1	206,3	80,9	1.149,3	338,5	350,7	**27,5**

Conclusions and recommendations

Generally, in projects of this kind, technical solutions are most reliable and they could be easily evaluated since they are based on technologies already used or at least well investigated, so they could be compared to similar solutions in projects which are already completed.

The most pronounced unreliability is in estimation of future social or political circumstances in general and in particular of those aspects which could significantly influence the expenses of the project (e.g. political consensus or future attitudes of general public). For so distant view in the future any estimation of such unreliability could not be more than plain guessing. Instead, it is more appropriate to assume that the range of present social and political circumstances surrounding similar projects in other countries is a good measure of probable development of future conditions in Slovenia and Croatia.

To assess suitability of calculations in this project, comparison of estimated decommissioning as well as SF and LILW management expenses was undertaken with estimations or actual expenses for comparable nuclear power plants or spent fuel and waste management in repositories of similar type or size. Such a comparison is complex and even dubious for several reasons (e.g. differences in methodology of estimation; different technical solutions; specific financial models; difficulties in exchange of currencies from one monetary system to another; etc.). However, it could be shown that expenses evaluated by this Program are well within the range of published values: for some segments the expenses are nearer to the average (decommissioning, SF storage, disposal of LILW) and for some on the more expensive side (SF disposal).

The most important conclusions and recommendations of the Program are:

a) Modifications to SID-30, transforming it into SID-45, lead to slightly lower expenses while increasing reliability of the scenario.

b) The two modified scenarios (*SID-45 with disposal and SID-45 with export*) are structurally quite similar with almost identical discounted expenses, enabling simple switching from one scenario to another and back for several decades from now. Furthermore, dry storage which is important part of SID-45 scenarios enables simple adjustment to changes of circumstances on time scale: translation of final solutions for several years (e.g. opening of SF repository several years later than planned or changes in schedule of SF export) will not significantly influence financial plan.

c) Due to specific circumstances several limitations were imposed by TOR to the process of the Program preparation. Next iteration of the Program should be prepared differently, especially its basis: the NIS should be dropped altogether as decommissioning foundation, consequently starting anew decommissioning, dry storage and spent fuel transport programs using new European unified nomenclature of decommissioning jobs. Next iteration should respect the NPP Krško specificities as well as specific solutions for SF and LILW, with as little as possible generic solutions in all four considered program segments. Some of the technical solutions could be based on Slovenian or Croatian industries. Next iteration should be started as soon as possible since two to three years are needed to finish it.

d) This revision of the Program estimated discounted total expenses of decommissioning and SF and LILW management based on the SF dry storage scenarios. Under the circumstances given, it is recommended that in the period from the beginning of 2004 until the next cost estimate in the following revision of the NPP Krško Decommissioning Program, the basis for collecting financial resources into the decommissioning funds in Croatia and Slovenia should be total discounted cost of DP (discounted to the year 2002) in the rounded amount of **350**

million €. The corresponding amount of each of 19 equal yearly installments (deposited from 2004 through 2022) is **28.5 million €**, calculated for one joint fund assumed empty at the beginning of 2004.