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The IAEA Activities in Supporting Long Term Interim Storage and Take-Back Programmes of RR SNF

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ABSTRACT

The IAEA has always striven to give appropriate attention for each stage of the fuel cycle, including back-end management of research reactor (RR) spent nuclear fuel (SNF). Problems associated with RRSNF storage became evident at the beginning of the '90s, when it was clear that many RRs were in a crisis situation due to SNF storage at the reactor site for storage capacity and storage time limits. In view of these concerns, the IAEA initiated a programme to help RR managers to deal with the SNF management problem; and also since the '90's, the IAEA has been providing continuous support to international nuclear non-proliferation activities associated with reduction of utilization of highly enriched uranium (HEU) by eliminating stockpiles of HEU and encouraging eligible countries to convert their research reactors from HEU to low enriched uranium (LEU). The paper gives an overview of IAEA's on-going activities for the collection and dissemination of best practices and lessons learned on long term interim storage as well as on back-end solution of RR SNF. It also presents IAEA's cooperation with take-back programmes made under the auspices of GTRI

1. Introduction

After discharge from the core, the research reactor (RR) spent nuclear fuel (SNF) is usually stored under water for cooling during a period of three to five years, to remove the so called residual decay heat, typically in at reactor (AR) facilities. During this period a decision has to be made about the future of the RRSNF. A management strategy has to be defined based upon the available options, which are: a) send the RRSNF for reprocessing; b) return the fuel to the country where it was originally enriched (transferring the problem to others); c) make a decision to directly dispose the SNF in a national repository, d) transfer it to a dry storage facility or, e) simply keep it in wet storage and or semi-dry storage for a longer period, postponing a final decision [1], [2].

2. IAEA activities in supporting solutions for RRSNF

Problems associated with RRSNF storage have loomed large in the international nuclear community during the last decades. A number of concerns were raised at the beginning of 1993, when it was clear that many RRs were in a crisis or rapidly approaching a crisis situation. In every case, this was due to SNF storage and management problems and the constraints of national laws. It was clear that the capacity for SNF storage had reached or was close to the design limit at many RRs and there were concerns, from a materials science point of view, about ageing materials in ageing storage facilities, and its consequences for the integrity of the fuel elements

In view of these concerns, the IAEA started a programme to help RR managers to deal with the SNF management problem. The activities included Technical Meetings (TM) and Coordinated Research Projects (CRP), which resulted in several publications available for all managers of research reactors and RRSNF storage facilities. The activity involved:

- Exchange of experience in storage options, procedures and practices [3],[4];
- Management of ageing materials in spent fuel storage facilities [5];
- Corrosion and other forms of material ageing leading to the degradation of mechanical and physical properties of RRSNF[6];
- Study of regional solutions for research reactors in Latin America [7];
- Exchange of experience in the two international RRSNF take-back programmes; the USA FRRSNF acceptance programme and the RRRFR programme [8].

Also, in an effort to better quantify the status of RRSNF management and storage worldwide, the IAEA developed the Research Reactor Spent Fuel Database (RRSFDB).

Following the TMs and CRP, it was decided to organise a consultancy meeting with the purpose of (1) assembling operators and managers of research reactors and spent fuel storage facilities, to review their practices and plans for the management of RRSNF; (2) available commercial options for back-end management of RRSNF based on the experiences gained during the accomplishment of shipments under the auspices of back programmes.

2.1. Interim storage of RRSNF

In the preparation of guiding documents for interim storage of RRSNF, the IAEA developed a programme of activities to study and discuss how to safely maintain the integrity of the fuel, and to improve storage conditions until a final decision on the end-point is selected. Within this programme, a Technical Meeting was organized to discuss Good Practices for the Management and Storage of Research Reactor Spent Fuel. The meeting was held during October 2009, in Thurso, Scotland, and was attended by experts representing organizations with experience in handling and storing RRSNF. The information assimilated during the meeting was compiled in a Proceeding to be published to ensure good guidelines on interim storage of RRSNF for managers of research reactors and managers of RRSNF storage facilities [9].

The document will provide an overview on: (1) the review of standards and general criteria for spent fuel management and national programmes; (2) the wet storage practices and experience; (3) the dry storage practices and experience

The IAEA's Publication Committee has approved the manuscript for publication, thus the proceeding will be issued soon.

2.2. Available Commercial Option for Back-end Management of RRSNF

The needs of the nuclear community dictate that the majority of the RRs continue to operate using LEU fuel in order to meet the varied mission objectives. Consequently, inventories of LEU SNF will continue to be created during the life time of a RR with no obvious path to its disposal. Finding appropriate, sustainable and cost effective solutions for the management of the back end of the fuel cycle for these countries are critical to the continued use of RRs in these countries.

A number of industrial entities in several countries offer international SNF management services on a commercial basis. These services may provide the basis for viable SNF management options for RRs, depending on their scope, technical compatibility, cost and accessibility. In order to address this critical issue related to the long term viability of research reactors, the IAEA organized a Consultancy Meeting in Vienna from 3 to 5 May 2011, to discuss the feasibility, scope, acceptance criteria and accessibility of the available SNF management services. The main objective of this consultancy meeting was to: (1) discuss the feasibility of and interest in a publication on Commercial Alternatives for Back-end Management of RRSNF; (2) identify the possible management options and facilities; (3) define a service description template (SD) that would permit comparison of treatment and/or processing options; (4) discuss the potential impact of RR common ventures, including coalitions and other cooperative arrangements (e.g. multiple shipments implementation).

At the meeting it was concluded that it is necessary to develop a document reviewing the status, issues and challenges of commercial solutions for the management of the back-end of the fuel cycle.

3. Support to the Research Reactor Fuel Take Back Programmes

3.1. U.S. Take Back Programme

The US. take back programme was re-started in 1996 under the name of Foreign Research Reactor Spent Nuclear Fuel (FRRSNF) Acceptance Programme [1]. The strategic goal was to remove 1364 kilograms of HEU and LEU to the USA for disposition by 2013. Until now 57 shipments from 30 countries have been completed. The total amount of the removed fuel was 1244 kilogram (91 % of the targeted volume is completed) [10].

The Agency did not ensure a direct support activity in FRRSNF, instead began a number of activities to assist member states eligible to ship spent RR fuels back to the U.S. The IAEA convened experts to develop a document with guidelines for Member States in this regard, which resulted in the "Guidelines Document on Preparatory Work Prior to Return of Spent Fuel of US-Origin from Foreign Research Reactors" [11]. The IAEA TECDOC 1593, "Return of research reactor spent fuel to the country of origin: national experiences and requirements for technical and administrative preparations" contains much about good practices from operators' participation in shipment preparations [12].

3.2. Russian Research Reactor Fuel Return (RRRFR) Programme

The preparation for the Russian Research Reactor Fuel Return (RRRFR) programme started in December 1999 [13], when at the IAEA General Conference in September, the U.S. Energy

Secretary, Bill Richardson announced that the US was prepared to work with Russia and the IAEA to manage and dispose of Russian-origin HEU RR fuel remaining in a number of countries. Then in October 2000 the IAEA's Director General sent a letter to the governments of relevant countries for the elimination of HEU fuel from Soviet RRs. Fourteen out of sixteen responses were favourable, concerning 20 RRs, which led to the launching of the RRRFR programme in 2001.

3.2.1. Shipments accomplished

Since the first shipment made in August 2002, the RRRFR programme successfully completed 46 shipments of more than 1.8 tons of fresh and spent HEU fuel from different countries using Russian fuelled research reactors to the country of origin.

In the case of fresh shipments from 2002 to 2010 under contract agreements by the IAEA, 23 shipments representing a total amount of about 739.1 kilograms of fresh HEU were returned safely to the Russian Federation. The shipments are listed in Table 1 in a chronological order.

Table 1. Fresh RR HEU fuel returned to Russia under IAEA contracts

No.	Country	Facility	Container used	Mode of transport	U-mass [kg]	Actual Finish
1	Serbia	RA, Vinča	TK-S16	Air transport	48.0	2002-08-08
2	Romania	WWR-S Magurela	TK-S16	Air transport	14.0	2003-09-30
3	Bulgaria	IRT-2000, Sofia	TK-S16	Air transport	17.0	2003-12-23
4	Libya	IRT-1 Tajura	TK-S16	Air transport	17.0	2004-03-07
5	Uzbekistan	WWR-SM Tashkent	TK-S16	Air transport	3.0	2004-09-09
6	Czech Republic	LWR-15, Rez	TK-S16	Air transport	6.0	2004-12-21
7	Latvia	IRT-M, Salaspils	TK-S16	Air transport	3.0	2005-05-25
8	Czech Republic	CA, CTU Prague	TK-S16	Air transport	14.0	2005-09-27
9	Libya	IRT-1 Tajura	TK-S16	Air transport	3.0	2006-07-25
10	Poland	MARIA	TK-S16	Air transport	39.8	2006-08-10
11	Czech Republic	Rez	TK-S16	Air transport	0.2	2006-10-15
12	Germany	RRR	TK-S16	Air transport	268.0	2006-12-18
13	Poland	MARIA	TK-S16	Air transport	8.8	2007-08-28
14	Vietnam	Dalat	TK-S16	Air transport	4.0	2007-09-17
15	Romania	Pitesti	TK-S16	Air transport	30.0	2009-06-28
16	Hungary	BRR	TK-S16	Air transport	18.6	2009-07-06
17	Czech Republic	Rez	TK-S16	Air transport	12.2	2010-06-18
18	Belarus	Minsk. Pamir fuel	TK-S16	Air transport	46.7	2010.11.29
19	Ukraine	Sevastopol	TK-S16	Air transport	25.1	2010.12.29
20	Ukraine	KINR	TK-S16	Air transport	9.8	2010.12.29
21	Ukraine	Kharkov 1st	TK-S16	Air transport	15.7	2010.12.29
22	Ukraine	Kharkov 2nd	TK-S16	Air transport	108.6	2012.03.21
23	Poland	MARIA	TK-S16	Air transport	26.8	2012.09.22
Last update: 2012-09-22				**TOTAL**	**739.1**	

Table 2 shows shipments of RRSNF carried out under the RRRFR programme in chronological order. Since 2006, altogether 25 shipments from RR sites to RF were safely and successfully accomplished - a total amount of about 1104.7 kg HEU SNF removal. The first, so called "pilot shipment" was

accomplished in January 2006 followed by three other SNF transports from Uzbekistan. Russian type TUK-19 casks were used for the first four shipments, while later the newly developed Skoda type VPVR/M casks were also used for the shipments.

Table 2. Spent RR HEU fuel returned to Russia

No.	Country	Facility	Container used	Mode of transport	U-mass [kg]	Actual Finish
1	Uzbekistan	WWR-SM Tashkent	TUK-19	RW	10.0	2006-01-10
2	Uzbekistan	WWR-SM Tashkent	TUK-19	RW	13.0	2006-02-14
3	Uzbekistan	WWR-SM Tashkent	TUK-19	RW	14.0	2006-03-20
4	Uzbekistan	WWR-SM Tashkent	TUK-19	RW	26.0	2006-04-15
5(*)	Czech Republic	Rez	VPVR/M	RW	80.0	2007-11-29
6	Latvia	Salaspils	TUK-19	RW	14.4	2008-05-12
7	Bulgaria	Sofia	VPVR/M	RW	6.3	2008-07-04
8	Hungary	BRR	VPVR/M	PR-RW-**SV**-RW	154.5	2008-10-10
9	Kazakhstan	Alatau	TUK-19	RW	17.3	2008-12-25
10	Kazakhstan	Alatau	TUK-19	RW	16.6	2009-03-01
11	Kazakhstan	Alatau	TUK-19	RW	18.8	2009-04-01
12	Kazakhstan	Alatau	TUK-19	RW	21.0	2009-05-01
13	Romania	Magurele	TUK-19	AT	23.7	2009-06-29
14(*)	Poland	EWA	VPVR/M	PR-RW-**SV**-RW	190.1	2009-09-13
15	Libya	Tripoli	TUK-19	AT	5.2	2009-12-21
16(*)	Poland	EWA, MARIA	TUK-19, VPVR/M	PR-RW-**SV**-RW	139.2	2010-03-18
17(*)	Poland	MARIA	TUK-19	PR-RW-**SV**-RW	49.5	2010-05-23
18(*)	Ukraine	KINR	VPVR/M	PR-**RW**	55.9	2010-05-25
19(*)	Poland	MARIA	TUK-19	PR-RW-**SV**-RW	38.6	2010-07-24
20(*)	Poland	MARIA	TUK-19	PR-RW-**SV**-RW	37.5	2010-10-10
21	Belarus	Minsk. Pamir	VPVR/M	RW	42.0	2010-10-24
22(*)	Serbia	Vinča RA	TUK-19, VPVR/M	PR-RW-**SV**-RW	13.2	2010-12-17
23)	Uraine	KINR	VPVR/M	PR-RW-**SV**-RW	19.6	2012-03-25
24)	Uzbekistan	WWR-SM Tashkent	TUK-19	AT	36.4	2012-08-13
25)	Poland	MARIA	VPVR/M	PR-RW-**SV**-RW	61.9	2012-09-15
Last update: 2012-09-22				**TOTAL**	**1104.7**	

(*) = IAEA involvement; PR = Public Road (highway, truck); RW = railway; SV = seagoing vessel; AT = air transport

3.2.2. Programme specific technical cooperation

In general, the IAEA's role in supporting projects like the RRRFR programme is threefold: (1) verification made by Safeguards; (2) standardization ensured by IAEA Safety Standards (e.g. Nuclear Safety, Transport, Emergency preparedness, waste management standards, etc.); and (3) technical cooperation ensuring multidisciplinary backing for MSs throughout technical cooperation mechanisms. The first two supports are a continuous IAEA service for the MSs. From the RRRFR programme's viewpoint, the third group plays a significant role through which programme specific support is provided.

Within the framework of the IAEA's Technical Cooperation projects, two significant subject specific projects were launched: (1) Skoda VPVR/M cask procurement; (2) Vinča (Serbia) SNF return programme.

Skoda VPVR/M cask procurement. Transporting a large quantity of SNF stored at many of Russian origin RRs required to develop suitable new capacity packages for the RRRFR programme to haul all of the stored SNF with one shipment from some facilities (at the beginning 16 pcs. TUK-19 casks were available), and in addition ensure further transport package alternatives with an improved cask loading technology to meet the needs of the different RR site and SNF conditions stored at a facility. To assist in meeting this requirement, the IAEA agreed to use its procurement system to send out a call for bid and procure enough casks to meet the foreseen shipment needs. After the bidding procedure the VPVR/M cask system of Skoda (Czech Republic) was selected from six international cask vendors [14].

The IAEA procured ten high capacity dual purpose (transport/storage) containers under a €4 million contract. The complex procurement and implementation included outlining the technical requirements, evaluation of bids, contracting, quality inspections, evaluation of the results of the so called "dry run" and "wet run" tests [15]. Thus, the programme now has 16 VPVR/M casks and 16 TUK-19 casks.

Vinča (Serbia) SNF return programme. Since 2004 the IAEA, the Nuclear Threat Initiative (NTI), the US-DOE and the European Union have provided funds to cover the Vinča RA Reactor SNF removal. With this financial support, upon the invitation of the IAEA, in May 2005 an international consultancy meeting was held in the Vinča Institute that resulted to issue an international tender for safe removal of Vinca fuel. Following the selection procedure, an RF consortium, Sosny-Mayak-Tenex, was selected and an international tripartite contract between IAEA, Sosny and Vinča Institute was signed in September 2006 for the safe removal of spent nuclear fuel (SNF) from the Vinča RA Research Reactor and return to the Russian Federation.

For the implementation of the tripartite contract, to be consistent with the TC management principle, a special PMO was appointed by the IAEA to coordinate the programme implementation. During the programme performance, 16 technical officers, and two technical experts were assigned to the Project Management Unit at Vinča site. Thus, the IAEA not only contracted, but provided a general coordinative managerial support, including an overall technical backing for the operating organisation and the officers of the regulatory body [16].

The project was completed as planned in December 2010: 8030 SNF was removed representing more than two-and-half tonnes of highly radioactive spent fuel [17]. This transport was the largest single shipment of SNF made under the RRRFR programme, and it became the largest and most complex TC project in the history of the IAEA with a total budget of over US$ 55 million.

3.2.3. Collecting and dissemination practices

Regional lessons learned workshops. As the first shipments were completed, in 2005, the IAEA in cooperation with the US DOE initiated a yearly regional workshop on "RRRFR Programme Lessons Learned". The primary objective was – and still is – to bring together the core players in the preparation and accomplishment of shipments, and sharing experiences on lessons learned so that others may benefit in the future. Table 4 shows the history of the Regional Workshops. Although the meeting indicated in the second row was a workshop on "International

Legal Framework Applicable for Shipment of Russian-origin Research Reactor Spent Fuel to the Russian Federation", it replaced the annual regional workshop in 2007, but its main feature was gathering experience. Thus, altogether six workshops on lessons learned were organised.

Table 4. History of the Regional Workshops on RRRFR programme Lessons Learned"

No	Place	Date	Participants
1	Belgrade, Serbia	October 2006	75 participants from 15 countries
	Poina-Brasov, Romania(1)	April 2007	43 participants from 10 countries and EU
2	Rez, Czech Republic	May 2008	97 participants form 17 countries
3	Varna, Bulgaria	June 2009	88 participants form 17 countries
4	Poina-Brasov, Romania	May 2010	71 participants from 16 countries
5	Jackson, WY-USA	June 2011	95 participants from 17 countries
6	Lake Balaton, Hungary	June 2012	76 participants from 17 countries
7	*Sevastopol, Ukraine*	*Scheduled for 2013*	

(1): It was a Workshop on "International Legal Framework Applicable for Shipment of Russian-origin Research Reactor Spent Fuel to the Russian Federation" organized by the IAEA in cooperation with the European Union.

IAEA-TECDOC booklets issued supporting the RRRFR programme objectives. The IAEA-TECDOC publications mean another effective tool to disseminate practical information and experiences. On the basis of the experience from the RRRFR programme's implementation, the IAEA issued four booklets to support the programme. They are:

- B. Yuldashev and J. Thomas: Technical and Administrative Preparation for Shipment of Russian-origin Research Reactor Spent Fuel to Russian Federation. IAEA Guideline document. Vienna, Austria. February 2007. This guideline document provides key information for the planning and return of Russian-origin SNF or materials containing HEU to the RF.
- IAEA-TECDOC-1593: Return of Research Reactor Spent Fuel to the Country of Origin: Requirements for Technical and Administrative Preparations and National Experiences. July 2008. This IAEA-TECDOC is a proceedings of technical meeting held in Vienna, August 2006 summarising shipment experiences 32 shipment preparation and operation experiences made under the umbrella of USA Foreign Research Reactor Spent Nuclear Fuel (FRRSNF) acceptance programme and RRRFR programme.
- IAEA-TECDOC-1632: Experience of Shipping Russian-origin Research Reactor Spent Fuel to the Russian Federation. November 2009. This IAEA-TECDOC is an extended summary and account of the experience obtained from the completion of international projects on return SNF to the RF from RRs in Uzbekistan, Czech Republic, Latvia, Bulgaria and Hungary;
- Draft of IAEA-TECDOC: Legal Aspects of Spent Nuclear Fuel Repatriation to Russian Federation - Lessons Learned. The need for a multilateral approach to reviewing both national and international legal obligations connected with the international transport of the SNF was first raised in the context of LL workshop held in Belgrade 2006. The TECDOC focuses on the national and international legal aspects of SNF fuel to the RF from RRs located in a number of States in central and Eastern Europe.

Conclusion

The IAEA has been involved for almost 30 years in supporting international nuclear non-proliferation efforts associated with reducing the amount of highly enriched uranium (HEU) in international commerce that includes support of SNF take back programmes. In order to cover the long term interim storage and all aspects of back-end solution of the RRSNF, the IAEA also involved some cases that played an initial role to collect experiences and best practices on interim storage of RRSNF, and available commercial options for back-end management of RRSNF. Regardless of how long the extended interim storage is drawn out; the resolution of the back-end problem will remain, and proliferation, safety and physical security concerns will continue to be a commitment of the RR operating organization/Member State to ensure safe, secure and economic management (especially storage) of its own RRSNF.

It is expected that hundreds of RRs worldwide, both operational and obsolete, but not yet decommissioned, will continue storing RRSNF AR or AFR for a long time. Therefore, the continued safe, secure, reliable and economic handling, management and storage of RRSNF of all types, is a serious issue for almost all Member States with RRs. National strategies for long term storage of the RRSNF will need to be developed.

Thus the IAEA will continue contributing to the international non-proliferation efforts in connection with HEU minimization by supporting RR fuel return programs, and will continue its effort to cover the entire fuel back-end objective thus offering the Member States pertinent technology and best practices. The IAEA offers all mechanisms available through its Regular Agency Programme and Technical Cooperation Programme to assist the Member States in this matter.

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