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Radioactive waste management at WWER type reactors

Report on the Technical Assistance Regional Project on Advice on Waste Management at WWER Type Reactors

First phase

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FOREWORD

This report was prepared within the framework of the Technical Assistance Regional Project on Advice on Waste Management at WWER Type Reactors, which was initiated by the IAEA in 1991. The Regional Project is an integral part of the IAEA's activities directed towards improvement of the safety and reliability of nuclear power plants with WWER type reactors (Soviet designed PWRs). Forty-five WWER type units are currently in operation and twenty-five are under construction in Bulgaria, Czechoslovakia, Finland, Hungary and the former USSR.

The idea of regional collaboration between eastern European countries under the auspices of the IAEA was discussed for the first time during the last meeting of the Council for Mutual Economic Assistance (CMEA) on spent fuel and radioactive waste management, held in Řež, Czechoslovakia, in October 1990. Since then, the CMEA and some of its former Member States have ceased to exist. However, there are many reasons for eastern European countries to continue their regional collaboration at a higher level. The USSR, the designer and supplier of WWER type reactors in eastern European countries, participated in the first phase of the project. The majority of WWER type reactors are situated in States of the former USSR (Russia and Ukraine).

The main results of the first phase of the Regional Project are:

(i) Re-establishment of communication channels among eastern European countries operating WWER type reactors by incorporating the IAEA's technical assistance;

(ii) Identification of common waste management problems (administrative and technical) requiring resolution;

(iii) Familiarization with radioactive waste management systems at nuclear power plants with WWER type reactors – Paks (Hungary), Loviisa (Finland), Jaslovské Bohunice (Czechoslovakia) and Novovoronezh (Russian Federation);

(iv) The present document, which represents the first attempt of the IAEA at analysing the status of radioactive waste management at WWER type reactors. It summarizes information presented at four workshops held in:

- Budapest and Paks NPP, Hungary, 6–10 May 1991,
- Helsinki and Loviisa NPP, Finland, 8–11 October 1991,
- Piestany and Jaslovské Bohunice NPP, Czechoslovakia, 20–24 January 1992,
- Obninsk and Novovoronezh NPP, Russian Federation, 1–10 June 1992.

The first Workshop aimed at identifying difficulties in the management of operational radioactive wastes generated at NPPs in eastern European countries and to plan regional collaboration by incorporating the IAEA's technical assistance.

The second Workshop was held at the Loviisa NPP. This nuclear power plant has been successfully operating since its inception. Participants from other countries operating WWER reactors got acquainted with the Finnish radioactive waste management system.

The third Workshop focused on national radioactive waste management policies and on the structure and responsibilities of regulatory bodies.

The fourth Workshop summarized the first phase of the Regional Project. Participants got acquainted with radioactive waste management at the Novovoronezh NPP and at the Scientific and Industrial Association 'RADON'. As spent fuel management is becoming the key problem of nuclear power, the information presented on aspects of Russian policy in this area was of considerable value.

The IAEA wishes to convey its thanks to all those who took part in the preparation of this document. The IAEA officers responsible for this report were A.F. Tsarenko from the Division of Nuclear Fuel Cycle and Waste Management and W. Zyszkowski from the Division of Technical Co-operation Programmes.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. BACKGROUND

The WWER is a Soviet designed, pressurized water reactor (PWR). WWER stands for water cooled, water moderated, energetic reactor. WWER technology has evolved as indicated by the following reactor types:

WWER-440/230 – the early version, which does not have secondary containment or an emergency core cooling system (ECCS);

WWER-440/213 – the later version, equipped with ECCS and a pressure suppression containment, using bubble condenser;

WWER-1000 – high power PWR, with ECCS and full pressure containment.

In Bulgaria, Czechoslovakia, Finland, Hungary, Poland and the former USSR, there are currently 45 reactor units of the WWER type in operation and 25 under construction. The distribution and status of development of these reactors are shown in Table I.

In Bulgaria, the Kozloduy NPP consists of four WWER-440/230 reactors and two WWER-1000 reactors. The first unit of the WWER-440/230 type was connected to the grid in 1974. Three other units of the same type were connected to the grid in 1975, 1981 and 1984. The first WWER-1000 unit was connected to the grid in 1990 and the second in 1991. Each of the WWER-440 reactors has a net power of 408 MW(e) while the WWER-1000 units have power levels of 953 MW(e).

Eight WWER type reactors are now in operation in Czechoslovakia. Four 440 MW(e) units operate at Jaslovské Bohunice, the first two being of the WWER-440/230 type. They were connected to the grid in 1979, 1981, 1985 and 1986. Four WWER-440/213 type units also operate at Dukovany. They were connected to the grid in 1985, 1986 and 1987. All the WWER-440 units are licensed to a power level of 408 MW(e) net. At present, there are six further units under construction. Four WWER-440/213 type units are being constructed in Mochovce. They will be connected to the grid between 1993 and 1995. Their licensed power level will be 390 MW(e) net. Two units of the WWER-1000 type are being constructed in Temelin. They will be connected to the grid between 1994 and 1997. Their licensed power level will be 890 MW(e) net.

In Finland, there are two NPPs in operation, Loviisa and Olkiluoto, operated by IVO and TVO respectively. Loviisa NPP has two WWER-440/213 type units, while Olkiluoto NPP has two boiling water reactors (BWRs) supplied by ASEA-ATOM. The first unit was connected to the grid in 1977, and the second in 1980. Both units are licensed for gross power levels of 465 MW(e) (445 MW(e) net).

In Hungary, there are four WWER-440/213 type units in operation at the Paks site. The first unit was commissioned in 1982, the second in 1984, the third in 1986 and the fourth in 1987. Their licensed power level is 460 MW(e) (gross) and 415 MW(e) (net).

In Poland, there was a plan to construct a NPP with WWER-440/213 reactors, but this was cancelled in 1989.

TABLE I. WWER REACTOR UNITS

	Under construction	In operation	Construction terminated	Shut down
Bulgaria				
440/230		4		
1000		2	2	
Czechoslovakia				
440/230		2		
440/213	4	6		
1000	2			
Finland				
440/213		2		
Germany				
440/230				4
440/213			3	1
1000			2	
Others				1
Hungary				
440/213		4		
Poland				
440/213			2	
Former USSR				
440/230		4		2
440/213		4		
1000	16[a]	17[b]	1	
Others	3[c]			2[d]

[a] Data may differ, because some NPPs which were being constructed are now temporarily terminated.
[b] Including the fourth unit Balakovo NPP which is almost complete.
[c] Nuclear district heating stations (AST-500) with WWER reactors.
[d] Units 1 and 2 of Novovoronezh NPP (WWER-210 and WWER-365).

In the former USSR, eight units of the WWER-440 type and 17 units of the WWER-1000 type are in operation and 16 units of the WWER-1000 type are under construction. However, construction of some units of this type has now been temporarily terminated. Two units of the WWER-440/230 type at the Armenian NPP and two WWER units of an earlier design at the Novovoronezh NPP have been shut down.

In Germany, six WWER-440 units have been shut down, and construction of other five units (two WWER-1000 and three WWER-440) have been terminated.

Following the political changes in eastern Europe, an intensive re-evaluation of the safety of WWER NPPs is under way. Part of this programme deals with the waste management practices at these NPPs, including waste generation, collection, treatment, storage, conditioning and disposal. Due to differences in design and operating philosophy from those practised in western Europe and in the USA, the waste management systems at the WWERs have to deal with relatively large volumes of waste. This has led to serious public concern, and debate is now taking place over the releases into the environment and the unresolved problems of waste conditioning and disposal.

The ongoing safety evaluation could affect the remaining operational life of some of the older WWER reactors. Any decision to close reactors prematurely will have an impact on the future approaches to their waste management in two ways:

(i) Early decommissioning of some reactors will require the final treatment and disposal routes for all stored wastes to be available much sooner than originally planned;

(ii) The upgrading of the operational waste management systems at the oldest WWERs may no longer be an urgent priority.

1.2. PURPOSE OF THE REGIONAL PROJECT

Most eastern European countries operating WWER type reactors have encountered serious problems with radioactive waste management. After considering the differences in the state of development of waste management systems in the individual countries and the consequences of the breakup of the economic union (CMEA) in eastern Europe, the IAEA initiated in 1991 a regional technical project among affected countries with the following objectives:

- identification of common waste management problems,
- establishment of mechanisms for sharing existing and future experiences,
- recommending processes and activities to improve existing waste management systems,
- re-establishment of communication channels among eastern European waste management institutions and experts that were severed after the breakup of the CMEA structure.

In view of the limited knowledge of the waste management systems and practices in eastern European countries, the goals were qualitatively and broadly defined to allow eventual expansion to areas not identified at the regional project's inception.

1.3. SCOPE OF THE REGIONAL PROJECT

The scope of the Regional Project includes the identification of the major elements of the management systems, cataloguing identified problem areas and providing recommendations for the next phases. A systems engineering approach was used in the execution of the Regional Project. Project system boundaries were defined by: (1) the regulatory bases and requirements in participating countries; (2) waste collection and waste processing systems design requirements and design bases; (3) operating issues; (4) waste form requirements; and (5) temporary waste storage and disposal requirements.

The study was divided into four main areas. The first area included the evaluation of radioactive waste management systems in eastern European countries and the exchange of information on common problems requiring immediate resolution. The second area covered waste treatment at the site and familiarization with the Finnish waste management experience. The third area covered national radioactive management policies and the regulatory requirements governing waste management activities. The Czechoslovakian national waste management policies and regulations were given and examined in detail. The fourth area focused on the safety and reliability of the waste management systems through design changes and implementation of new technologies. The Soviet experience with new technologies, including operating results, and their potential for implementation at other eastern European NPPs were also examined.

1.4. STRUCTURE OF THE REPORT

This report is divided into six sections and one annex. Section 2 discusses the design of waste management systems including waste collection, processing and storage and the development of integrated waste management systems. Section 3 describes modifications made at the original stage to the waste management systems in various countries. Section 4 covers the current situation in individual countries. Section 5 discusses common problems experienced with waste management systems at WWER NPPs, starting with the lack of completeness of the waste management policies, the need for further technical improvements, and plans for future waste treatment and final disposal. Section 6 contains the conclusions and recommendations.

The Annex contains summaries of the workshops held within the framework of this project.

2. ORIGINAL DESIGN OF WASTE MANAGEMENT SYSTEMS FOR WWER TYPE REACTORS

The concept laid down in the late 1960s for the management of wastes at WWERs was to store the wastes on site and to postpone decisions on conditioning and disposal until the decommissioning stage. By this means wastes from operation and dismantling can be handled together. Waste collection and storage systems were developed to accommodate ten years arisings of treated operational wastes with possible extension of storage capacities. The only exceptions were for the very low level solid wastes, where on-site disposal was proposed.

2.1. WASTE SOURCES AND ARISINGS

Early versions of the WWER-440 were designed on the basis of the Soviet guidelines for the following waste sources:

(1) Liquid waste arisings:

– Unintentional leakages of the primary circuit coolant:	0.2 m^3/h (operation); 2.0 m^3/h (outage);
– Decontamination of equipment:	0.1 m^3/h (operation); 0.6 m^3/h (outage);
– Decontamination of building:	1.0 m^3/d (operation); 10.0 m^3/d (outage);
– Hot laboratory drains:	0.25 m^3/h;
– Contaminated samples:	<0.5 m^3/h;
– Laundry and shower effluents were not identified.	

(2) Solid waste sources:

- Low level solid wastes (LLSWs) were assumed to arise mainly from maintenance activities (i.e. textiles, paper, glass, wood, heat insulation, scaffolding wastes);
- Spent aerosol filters and some of the maintenance wastes were considered as intermediate level solid wastes (ILSWs);
- In-core components were classified as high level solid wastes (HLSWs).

2.2. WASTE PROCESSING SYSTEMS

To deal with the liquid waste arisings several special waste treatment systems were envisaged:

Liquid wastes with a specific activity of >10^{-4} Ci/L are processed in multistage evaporators combined with ion exchangers. This class of wastes includes:

- drainage from the primary loop,
- leakage,
- trapped water,
- decontamination solutions.

Low level wastes with a specific activity of <10^{-4} Ci/L are processed in ion exchangers or in single stage evaporating plants. This class of wastes contains:

- blowdown water from the steam generators,
- wastes from special laundries and showers for the personnel.

Radioactive water from the drainage water tanks, after being heated in the heat exchanger, is fed into the evaporator. The concentrate from the evaporator is fed into an 'after-evaporator' facility. The final concentration of impurities can be as high as 40% but, due to the presence of boric acid, problems can be encountered with crystallization at lower concentrations. Radioactive off-gases are fed into the special gas-cleaning system. After cooling, the condensate is pumped into an ion exchange system. Clean condensate is fed into the control tank and later to the clean condensate tanks or is returned for repeated cleaning. The concentrated radioactive wastes after evaporation, as well as used resins from the ion exchangers, are periodically transferred into the liquid waste storage units using compressed air.

The typical design for WWER-440 units does not include any provisions for a conditioning process.

The gaseous waste treatment system for WWER-440s consists of:

- A hydrogen burning system, with two parallel lines, one of which is kept as a reserve;
- A radioactive gas absorption system, consisting of three systems: one for normal operation, the second to occasionally receive high volumes of gases, and the third as a reserve;
- two systems for cleaning the off-gas from the liquid storage tanks, one of which is kept as a reserve.

No special treatment was envisaged for solid wastes in the original design.

2.3. WASTE STORAGE SYSTEMS

Storage of the treated liquid wastes in auxiliary buildings was planned up to the end of life of the plant. Stepwise extension of these stores was allowed when necessary.

On-site storage until final decommissioning was planned for HLSW in the reactor building and for ILSW in the auxiliary building. For LLSW on-site disposal was proposed in concrete vaults.

Typical estimates of the annual waste arisings to be stored at many of the WWER-440 units were:

- spent ion exchange resins — 22.5 m^3/a/unit,
- evaporator bottom (total dissolved solids: 200 g/L) — 300 m^3/a/unit,
- ILSW — 30 m^3/a/unit,
- LLSW — 100 m^3/a/unit.

The waste management technology was not sufficiently developed in the design of the early systems and further treatment of solid wastes and concentrates was anticipated at the decommissioning stage. Sorting and removal of solid wastes from the storage vaults for treatment was not considered. Evaporator concentrates with high salt content could not be treated later because of crystallization of salts in the tanks. In attempts to solve this problem extra capacity was provided in the waste treatment and storage systems. In addition the excessive use of stainless steel in the waste system design has resulted in high costs for waste treatment and storage.

2.4. DEVELOPMENT OF WASTE MANAGEMENT SYSTEMS

Later development of WWER reactors led to the introduction of a boron recovery system, which is used to evaporate boric acid from 'clean' let-down streams, followed by ion exchange purification. No other significant changes to the waste management systems have been implemented.

The current WWER-1000 design incorporates the waste treatment and conditioning facilities (compactor, bituminizer) and on-site storage of conditioned wastes. However, nothing has been done to reduce original waste sources or to improve the anticipated performance of equipment of the overall systems.

3. MODIFICATIONS OF THE ORIGINAL DESIGN

The responses of individual countries to waste management needs differ and were mostly influenced by:

- Existing regulations, requests of the authorities;
- Performance of the plant;
- Previous waste management experience.

Many of the NPPs (or design companies) have changed the original system arrangements or some of its components.

In Czechoslovakia laundry wastes are segregated before evaporation. 'Non-active' (exempted) streams are handled as industrial wastewaters and are released to the environment, while 'active' streams are treated by precipitation and then evaporated if necessary.

In Finland shower and laundry wastes as well as decontamination solutions are segregated from the floor water waste streams; ion exchange resins are not regenerated. Application of high quality equipment (particularly valves) and newly developed instrumentation and control systems have enabled many uncontrolled leakages into the liquid waste collection system to be avoided.

In Hungary separation of laundry and shower waste streams has been built in at the design stage. Later an oxalic acid elimination technology was developed and introduced. The use of thermally resistant, long life ion exchange resins has decreased the amounts of spent resins requiring storage before conditioning.

Solid waste collection and treatment are similar in all WWER reactor systems, although the practice of some NPPs to classify solid wastes in low level and non-active (exempted) categories makes a comparison between various countries difficult. Solid waste treatment systems are usually proposed in the later phase of operations (compaction in Finland, Hungary, Czechoslovakia and the former USSR; incineration in Czechoslovakia and the former USSR; biological degradation has been evaluated in Finland).

4. PRESENT SITUATION IN INDIVIDUAL COUNTRIES

In the late 1980s the scientific, technical and licensing institutions of the participating countries concluded that waste management – including final disposal and decommissioning – was a most important task, if nuclear energy was to be developed further in their country. Most of the operating WWER-440 units were designed in the late 1970s and were based on the Soviet standard regulations valid at that time. It was usual practice to adopt the regulations of the supplier, which resulted in all waste management systems being based on the regulatory requirements of the mid-1970s. As an illustration of the existing situation, the current generation of various operational waste streams is summarized in Table II.

The conclusion can be drawn that evaporator bottoms and solid low level wastes represent the major waste quantities for most of the countries.

There is a lack of knowledge on regeneration practices (frequency, volumes) and decontamination activities (frequency, volumes, chemicals), both of which significantly affect liquid waste compositions and processing possibilities.

There are very considerable differences, which in part reflect their location, in the allowed levels of discharges from individual reactors. In some cases, such as Kozloduy, extremely restrictive release limits are contributing to the high volumes of accumulated liquid wastes. In other cases, such as Loviisa, relatively high release limits result in the reduction of liquid waste to be treated. The importance of release and exemption limits was emphasized in the framework of the Regional Project. Table III presents data available on the release and exemption limits and practices.

The release limits indicated are generally rather low in comparison with the values for US and west European NPPs, e.g. for the corrosion and fission products 185 GBq/a are allowed in the USA and 80–100 GBq/a in western Europe.

The status of waste management systems in the industrial countries can be summarized as follows:

Bulgaria

The very low discharge limit to the River Danube (10 Bq/L) and the lack of any modifications to the original design, together with the poor quality of the equipment, have created a serious situation for waste storage. The liquid waste storage tanks are almost full and the storage capacity for solid wastes will be exhausted in the near future.

TABLE II. AVERAGE ANNUAL GENERATION OF WWER REACTORS OPERATIONAL WASTES (m^3/a/unit)

Waste type	Country/WWER reactor					
	Bulgaria 440	CSFR 440	Finland 440	Hungary 440	Former USSR[b] 400	Former USSR[b] 1000
Liquid wastes:						
- evaporator bottoms	300	170	25	62.5	200	300
- organic wastes				0.5		
Wet solid wastes:						
- spent ion exchange resins	4	6.5	9	0.6	11	20
Dry solid wastes:						
- LLW	90	75	25	25	160	300
- Non-active solids from the controlled area[a]			20	25		
- spent aerosol filters	4.3			2		

[a] can be considered as exempted waste.
[b] data presented by VNIAES.

At Kozloduy immediate action is required to allow the plant to continue operation. Following such action further steps are needed to reduce waste generation. The current waste management practices include collection, treatment and on-site storage. Solidification, storage and final disposal are being planned. No provisions have been made with respect to plant decommissioning, management of decommissioning wastes or the financing of these waste management activities.

Czechoslovakia

At Bohunice and Dukovany the waste collection, segregation and treatment systems are close to the original design. However, several modifications have been made to reduce waste generation, to sort solid wastes and to enable their removal from storage vaults for further treatment and disposal. Two final disposal facilities are being commissioned at Dukovany in Bohemia and Mochovce in Slovakia. The existing collection, treatment and on-site storage practices are being supplemented with solidification of concentrates, incineration, compaction. Steps to develop relevant regulations to provide the necessary financing and to set up organizational responsibilities for waste management have already been initiated.

Finland

The Loviisa NPP represents a good example for all the participating countries of how to very effectively operate and manage a WWER and its waste management system. Well defined goals, policies, schedules, financing schemes and good technical realization characterize the Finnish waste management system. However, their experience with respect to effluent release strategy cannot be fully applied in other countries. The organizational and technological changes introduced by IVO and/or Loviisa NPP could be applied elsewhere as can the results and processes developed through their research activities, e.g. organic wastes caesium removal from evaporator concentrates, microbiological decomposition and waste form characterization.

Hungary

The Paks NPP is a good example of a careful approach to waste management. The waste arisings are almost as low as at Loviisa. Waste management at the plant level incorporates collection, storage and treatment. Conditioning and final disposal are only at the stages of implementation and planning, respectively. No provisions have been made to change Hungary's site specific release and exemption limits or for financing future work. Decommissioning studies are currently being conducted only at the level of literature reviews.

TABLE III. RELEASE AND EXEMPTION LIMITS AND PRACTICES OF NPP

	Aquatic releases		Exemption of solid wastes	
	Authorized limit	NPP's practice	Authorized exemption limit	NPP's practice
BULGARIA, Kozloduy				
- Beta, gamma activity	10 Bq/L	1.1 GBq/a	37.0 Bq/g	n/a
- Alpha activity			3.7 Bq/g	
CZECHOSLOVAKIA, Bohunice V1				
- Corrosion and Fission Products	37 GBq/a	n/a	n/e	1 Bq/g
- Tritium	31 TBq/a	n/a		
Bohunice V2				
- Corrosion and Fission Products	1 GBq/a	n/a		
FINLAND, Loviisa				
- Corrosion and Fission Products	890 GBq/a	20 GBq/a	1 Bq/g[a]	1 Bq/g
- Tritium	160 TBq/a	10 TBq/a		
- Alpha activity			0.1 Bq/g[a]	0.1 Bq/g
HUNGARY, Paks				
- Corrosion and Fission Products	30 GBq/a	n/a	n/e	1 MGy/h
- Tritium	15 TBq/a	n/a		

[a] In materials with a maximum weight of 1000 kg. If weight is less than 1000 kg, authorized exemption limits are 100 kBq of beta, gamma activity and 10 kBq of alpha activity. Contamination of surfaces is allowed less than 4 kBq/m^2 of beta-, gamma activity and less than 400 Bq/m2 of alpha activity.

n/a: Data not available.

n/e: Limits do not exist.

The former USSR

In general, the NPPs in the former USSR seem to be in a similar situation to Kozloduy. No reports were available on their problems, which could be very plant specific.

In the former USSR a multi-stage approach to waste management and environmental protection is applied at NPPs. This includes:

- Collection and segregation;
- On-site temporary storage;
- Conditioning;
- On-site storage of conditioned wastes;
- Transportation of conditioned wastes from the NPP sites to a disposal facility;
- Final disposal of wastes.

Current waste management practice extends to on-site storage of conditioned wastes. Site selection for shallow land and deep geological facilities is going on. Draft laws on the use of nuclear energy and radioactive waste management have been prepared and will probably come into force in the near future.

To reduce waste volumes many NPPs are using evaporation for liquid wastes and incineration and compaction for solid wastes. Bitumen encapsulation equipment was installed at the Kalinin NPP. Research and development is being undertaken with the aim of improving the safety and efficiency of waste management in the plants.

5. COMMON PROBLEMS OF WWER WASTE MANAGEMENT SYSTEMS

Many common problems have been identified during the implementation of the Regional Project and several IAEA waste management advisory missions. These problems can be divided into three main groups:

5.1. INCOMPLETENESS OF THE WASTE MANAGEMENT SYSTEM

The original concept for waste management at WWERs involved the return of spent fuel to the USSR and storage of untreated solid wastes and liquid concentrates with the aim of treating and disposing of them at the decommissioning stage. This concept has had a major influence on the general waste management policy in all the eastern European countries.

Nuclear activities in most of the countries operating WWER reactors are carried out on the basis of nuclear energy acts which deal with all aspects of nuclear activities, but only to the level of defining general principles. Application of these general principles requires a more detailed system of regulations, which are not yet available. In most countries only the period of NPP operation is covered and many of the problems connected with decommissioning and final disposal of all types of wastes, including high level reprocessing wastes or spent fuel, remain to be resolved. Additional problems have resulted from the 'centrally planned economies' in eastern European countries where the funding for any changes had to come from the State and not from the operator directly.

There is, therefore, a need in all eastern European countries to prepare and realize new waste management strategies, covering all of the long term aspects of waste management.

Such a strategy should be based on:

(1) The future nuclear power programme developments in each country;

(2) The remaining lifetime and improvements of the existing units;

(3) Introduction of the systems approach in waste management. This will involve:

- Creation of a long term policy, including regulations and financing arrangements;
- Preparation and introduction of improved technologies for the treatment of wastes from the operation of WWERs;
- Preparation and introduction of technologies for the storage and disposal of the irradiated fuel or HLW;
- Preparation and introduction of technologies for the decommissioning of WWER reactors;
- Preparation and introduction of facilities for the disposal of LLW and ILW from the operation and decommissioning of WWER reactors.

5.2. NEED FOR FURTHER TECHNICAL IMPROVEMENTS

The basic waste management technology applied at the WWER reactors is relatively simple and safe. However, it can be substantially improved in several ways.

5.2.1. Organizational measures and increased responsibility of operators

The following measures were identified as useful ways to reduce waste arisings:

- Re-evaluation of existing operational practices with the aim of limiting the waste streams at the source, segregation of wastes, establishment of exemption limits and clear specification of the responsibilities of the plant operational personnel;

- Reduction of the amount of solid low level wastes by limiting materials allowed to enter into controlled areas (avoiding plastics, application of multiple usable materials), use of marked collection bags (3–4 categories) and limitation of the type of ion exchange resin used to one with an increased lifetime;

- Review and modification of operational instructions with the aim of excluding non-radioactive streams and reducing unwanted and unnecessary flows.

5.2.2. Gradual development of new waste management systems through changes in technology

Technology changes can be introduced as either separate projects or as a part of the safety enhancement programme. The main areas where technical improvements would be beneficial are:

- The quality of valves and equipment to avoid uncontrolled leaks. The quality should be carefully evaluated and improved either by replacement or by appropriate repair during maintenance;

– Segregation of liquid waste streams such as:

  – laundry and shower waters,
  – regeneration solutions,
  – decontamination solutions,
  – boron containing floorwaters;

– Development of waste specific treatment methods.

5.3. PREPARATION FOR FUTURE TREATMENT AND DISPOSAL OF WASTES

As a part of the new waste management strategy the current methods of waste storage should be re-evaluated, taking into account the requirements for future treatment and disposal of all types of wastes. If the reactor site is not to be used for final disposal, then adequate technical solutions need to be available for:

– retrieval of solid wastes from storage areas for future segregation and treatment (i.e. compaction, incineration, biological degradation);

– retrieval of evaporator concentrates and spent ion exchange resins from storage tanks and their solidification;

– site selection, construction and operation of waste repositories.

It is prudent to start developing these solutions during the operational life of the nuclear power plant in order that they will be available on its final shutdown.

6. CONCLUSIONS AND RECOMMENDATIONS

Although many waste management problems are of a general nature, several important, reactor specific features have been recognized and support the need for a specific approach to waste management at WWER NPPs. Typical examples are:

(1) All WWER NPPs were designed and supplied by one vendor with the same philosophy of design and operation.

(2) The general design of WWER reactors and the whole waste management system reflect the features of centrally planned economies, i.e. the role of the State as both the regulatory authority and the operator of NPPs, the neglect of public opinion, etc.

(3) The regulations and standards require re-evaluation to ensure consistency with new regulations issued in eastern European countries.

(4) The storage of untreated wastes during the operational period is not a optimal solution.

(5) Decommissioning and disposal of the wastes were not considered at the design stage of WWER reactors.

(6) The major problems of waste management have been tackled for many years by the Member States of the CEC and OECD through co-ordinated programmes but without any

participation of eastern European countries. Similar programmes existed within the framework of the former CMEA. However, after its breakup practically all contacts in the field were disrupted. Based on the long experience with these programmes, a regional programme for WWER reactors could be considered with participation of some advanced countries to facilitate the transfer of new technology.

The review of waste management practices at WWER reactors has shown that there are at least three major areas where further co-ordination and technical assistance by the IAEA could result in significant improvements.

6.1. FORMULATION OF NATIONAL WASTE MANAGEMENT STRATEGIES

The safe and reliable management of radioactive wastes is only possible within the framework of a clearly defined national waste management system. Although several parts of such systems exist to differing extents in all eastern European countries and in the former USSR, a complete system has not yet been developed.

An urgent task which will influence waste management practices at all NPPs is the development and improvement of legislation and the structure of regulatory bodies in respect of radioactive waste management issues. The new IAEA waste management standards which are now being prepared under the RADWASS programme will help identify the main requirements for a national strategy. These should include:

- A legal framework;
- A clear structure and division of responsibilities between operators and national authorities at all levels;
- Key decisions on the timing and extent of decommissioning activities;
- Key decisions on the type of disposal for low and intermediate level wastes arising from operations and decommissioning;
- Key decisions on solutions for the back end of the fuel cycle (i.e. duration of and technologies for intermediate storage, preparation for geological disposal of spent fuel or high level reprocessing wastes, participation in the development of alternative methods, etc.);
- National regulations or principles for releases of radionuclides into the environment, exemption limits and scope for reuse of construction materials at nuclear installations;
- Long term liabilities, financing and insurances.

6.2. IMPROVEMENT OF SAFETY AND RELIABILITY OF WASTE MANAGEMENT SYSTEMS AT NPPS

Significant improvements in the effectiveness of the waste management systems at some of the NPPs can be obtained by the simple application of waste management practices from other, more efficient NPPs. However, prior to making any change, the available waste treatment and disposal systems should be carefully evaluated. There will be a need to:

- Evaluate the effectiveness of every component of the waste management system and identify all weak parts;
- Rearrange waste streams to give more effective segregation and aid treatment of wastes;
- Redefine waste storage conditions to facilitate future treatment and disposal of wastes;
- Introduce conditioning technologies but with due account being taken of disposal requirements.

Further exchange of experience among operators of NPPs and advisory missions to help apply the best results to remaining WWERs should be promoted.

6.3. CO-ORDINATION OF RESEARCH AND DEVELOPMENT ACTIVITIES

To improve the present state of waste management at WWER power plants, there are a number of research and development projects in progress or proposed by the participating countries. They have the aim to introduce new technologies into the waste management systems of WWER NPPs. Such research and development could be effectively co-ordinated under the auspices of the IAEA. Some topics of common interest are:

- Development of release and exemption limits, based on radiological impact assessments;
- Selective removal of some dominant nuclides (eg. Cs, Sr with a half-life of approximately 30 years) from evaporator bottoms;
- Characterization of WWER wastes with respect to long lived radionuclides (alpha emitters, iodine-129, carbon-14, nickel-58);
- Boron recovery from waste streams;
- Incineration or biodegradation of solid low level wastes;
- Development of more effective conditioning processes for evaporator concentrates and spent ion exchange materials;
- Development of the requirements for the on-site storage of conditioned wastes for intermediate periods;
- Development of decommissioning concepts for WWER NPPs.

Annex

WORKSHOP SUMMARIES

FIRST WORKSHOP

Budapest and Paks NPP, Hungary, 6–10 May 1991

1. INTRODUCTION

The purpose of the workshop was to discuss problems connected with the operational radioactive wastes generated at NPPs, to identify difficulties, to exchange information and to find forms of future regional collaboration for improving the safety and reliability of national radioactive waste management systems for NPPs with WWER type reactors in accordance with the best practice in the world.

Participants agreed on the need for regional co-operation in this area: Bulgaria, Czechoslovakia and Hungary have currently four, eight and four WWER-440 units in operation respectively, with one WWER-1000 unit in Bulgaria. In the USSR eight WWER-440 type units and 16 WWER-1000 type units are operational. In Bulgaria, one WWER-1000 unit is now under construction. Although all these NPPs are of Soviet design, there are many differences between the waste management systems in these countries.

2. STATUS OF THE WASTE PROCESSING SYSTEMS

2.1. Bulgaria

The Kozloduy NPP was put on line in 1974 when Unit 1, with a WWER-440/230, was connected to the grid.

At present, four WWER-440/230s and one WWER-1000 are in operation. The second WWER-1000 unit is being commissioned. In 1990 35.7% of the total electricity in Bulgaria was generated at Kozloduy.

As the capacity at Kozloduy has increased so have the quantities of the radioactive wastes (RWs). Up to now all RWs at Kozloduy have been stored without conditioning in the auxiliary buildings OB-1, OB-2 and OB-3.

Solid radioactive wastes (SRWs)

Management of the SRWs is based on the norms derived from the Soviet documents NRB-76/87, OSP-72/87 and SPAES-79.

The regional project envisaged grading the SRW by physical and radioactive properties and storage in concrete stores consisting of separate cells. The design time for filling one store was ten years. The operational experience with Unit 1 has shown that the current storage capacity for SRW is not sufficient. A small 5 t press was used to reduce the volume of the soft wastes to half, but nevertheless the store in OB-1 was filled in five years. The store in OB-2 could not be used because of flooding as a result of defects in its hydroisolation. A new above ground store, consisting of 40 cells with a total volume of 4800 m^3, has been built.

The approximate quantities of the different types of SRW in the stores are given in Table I.

TABLE I. QUANTITIES OF SOLID RADIOACTIVE WASTE STORED AT THE KOZLODUY SITE

SRW type	OB-1 (m^3)	Separate store (m^3)
1. Compacted wastes	400	200
2. Aerosol filters	200	240
3. Metal	120	1000
4. Ungraded wastes	280	1700
5. Heat insulation		1000
6. Wood		100
7. Soil		100

The radiation level of the bulk of the SRW is below 0.3 mSv/h. For up to a total of 200 m^3 of some of the materials, the level is 0.5–0.8 mSv/h.

The average (rate of) generation of SRW over the whole period of operation was 90 m^3/a/unit of RW for categories I and II and 0.5 m^3/a/unit for category III.

Liquid radioactive wastes (LRWs)

LRWs are stored in tanks in the auxiliary buildings OB-1, OB-2 and OB-3. The existing drainage system does not allow single LRW flows to be separated.

Leakages from the spent fuel pools create additional problems and result in a very high consumption of boric acid. The quantities of spent chemical reagents, sorbents and LRW generated are given in Table II.

The volumes available for storing evaporator bottoms in OB-1 and OB-2 are 5000 m^3 (10 × 500 m^3 tanks) and for storing ion exchange resins 230 m^3. In OB-3 the available volumes are 3600 m^3 and 200 m^3 respectively.

The large quantities of evaporator bottoms generated each year and the limited volumes for their storage resulted in the wrong adoption of the practice of permitting part of the bottoms to crystallize. The quantity of the crystallized solids is estimated to be about 800 m^3 (OB-1 and OB-2).

Measures taken and planned for radioactive waste management

The main tasks for the Kozloduy NPP can be summarized as follows:

(1) Minimization of RW generation;
(2) Segregation of the RW arising from different operations;
(3) Substitution of evaporation as a treatment method for the effluents containing detergents;
(4) Treatment of the stored and newly generated RW;
(5) Revision of the water discharge activity limit (3.10^{-10} Ci/L).

TABLE II. QUANTITIES OF LIQUID RADIOACTIVE WASTE AND SPENT ION EXCHANGE RESINS GENERATED BY KOZLODUY NPP

Quantity	1987	1988	1989	1990
H_3BO_3 (t)	117	119	120	116
HNO_3/45% (t)	86	95	78	50
NaOH/45% (t)	102	113	86	103
KOH (t)	9	4.2	4.6	9.12
Ion exchange resins (t)	16	20	17	3
Drainage waters (m^3)	151 000	153 000	136 000	131 000
Evaporator bottoms (m^3)	2437	2432	2348	2046

To implement these recommendations, a separate unit with responsibility for RW management was set up at Kozloduy. At present, its work is mainly concentrated on the management of the SRW and the implementation of ultrafiltration for LRW containing detergents.

At the government level it was decided to use foreign experience and assistance to solve the problems of RW management. Several companies have offered their services to treat and store the solid and liquid RW.

The work will start with a complete review of the current situation and with the conditioning of the existing liquid wastes by cementation, and treatment of solid wastes by supercompaction.

2.2. Czechoslovakia

The first Czechoslovak NPP, A-1 (150 MW(e) gas cooled, heavy water reactor), started up in 1972 in Jaslovské Bohunice. However, this reactor was shut down in 1977 and is now being decommissioned.

The following programme was based on the use of WWER type reactors. There are eight reactors in operation:

- Four WWER-440 units at Jaslovské Bohunice (in operation since 1978, 1980, 1984 and 1985 respectively);
- Four WWER-440 units at Dukovany (in operation since 1985–1987).

In addition, there are currently six units under construction:

- Four WWER-440 units at Mochovce (planned startup in 1993–1995);
- Two WWER-1000 units at Temelin (planned startup in 1994–1997).

Once in operation, these NPPs will generate about 50% of the country's electricity production.

The main problems are with liquid and solid radioactive waste conditioning and disposal. The original temporary storage facility was designed for a 5–7 year operational period only. An additional storage facility was built later.

At the same time research work into methods for conditioning of evaporator concentrates and the exhausted radioactive sorbents was started. The methods used included bituminization, cementation and calcination.

There are two conditioning lines installed in a special building at Jaslovské Bohunice:

- a bituminization line for ion exchange resins (a calciner is used for drying of ion exchange resins),
- a bituminization line for the evaporator bottoms.

These lines are now being tested.

At the Dukovany NPP a calcination line was installed but testing has been interrupted. In addition, a cementation line (Siemens–KWU with a throughput of 600 L/h) was bought for conditioning the radioactive wastes generated as a result of the accident in Jaslovské Bohunice (Unit A-1) in 1977.

For solid waste treatment a low pressure compactor (0.22 MPa) has been developed. Waste is compacted directly into 200 L drums. These compactors are installed in each unit. In addition, an experimental incinerator was developed. It was intended that the experience gained from this incinerator would be used to produce a new unit.

In Czechoslovakia it was proposed to develop two shallow land repositories for LLW and ILW. At present these repositories are under construction at Dukovany and Mochovce. Containers for transporting the solidified LLW and ILW are also under construction.

Since 1986 an interim spent fuel storage facility has been in operation at Jaslovské Bohunice. A decision has been taken to build a new storage facility at Dukovany.

The main problems related to radioactive waste management at NPPs are:

- minimization of solid and liquid waste arisings,
- proving in routine operation the solidification technology for liquid RW,
- establishment of criteria for a final shallow land repository of LLW and ILW,
- establishment of the exemption limits for wastes from NPPs,
- decision on the back end of the fuel cycle and HLW management,
- development of a project for NPP decommissioning.

2.3. Hungary

Four WWER type reactors have been operating since 1983. They produce approximately 50% of the electricity in Hungary.

The approach to waste management in the original Soviet design was based on on-site storage of liquid wastes and on-site disposal of low level solid wastes. This was not acceptable to the Hungarian authorities. In 1983 a decision was taken to cement the liquid radioactive wastes.

To improve evaporator performance, which was limited by solubility, additional chemical treatment was developed and implemented. New compaction systems were commissioned in 1990.

The waste arisings in the design basis (in brackets) and the operational data for four units are given below:

spent ion exchange resins:	2.5 m^3/a (90 m^3/a),
evaporator bottoms:	200–250 m^3/a (1200 m^3/a),
aerosol filters:	8 m^3/a (120 m^3/a),
solid wastes:	100 m^3/a (400 m^3/a),
sludges:	5 m^3/a.

The activity levels are of the order of 10^5 Bq/L for liquid wastes and 10^6 Bq/kg for solid wastes. These levels have been achieved because of good fuel performance and the absence of Co in structural materials. However, there has been a problem with ^{110m}Ag generation.

These results have been achieved by observing the authorized release limits. In practice gaseous releases have been restricted to 1% of the limit and liquid releases to 10% of the limit.

During the licensing of the final disposal facility, the earlier planned disposal concept and site were not approved due to growing public opposition. This will not create problems until approximately 2000, because the waste arisings are low due to the changes in technology and operational practices already implemented.

The performance of the evaporators is limited from both the source and treatment sides. With the existing technology total evaporator bottoms arisings of 160 m^3 for four units can be achieved. To reduce the quantities of these evaporator bottoms, further studies have been undertaken on:

- separation of the drainage and collection pipeline system,
- boron recovery system (based on membrane separation technology).

By introducing these changes the quantities of evaporator bottoms could be reduced to 100 m^3 for four units, based on the current frequency of decontamination and regeneration. These changes are at the design stage.

Another important area for R&D is the optimization of the operation, regeneration and the change of resin content in the primary circuit water cleanup system.

A solid radioactive waste assaying system is also being developed to measure the activity content of the drums for inventory control purposes. This is based on the Hungarian authorities requirements for waste package evaluation and documentation.

Site selection for a final disposal facility will now have to be repeated. Two possible emplacement technologies will be considered:

- shallow land, trench type disposal in clay or clay–silt formations,
- subsurface disposal in granitic rock in mined cavities.

There is a lack of official policy for NPP waste management. The existing regulations only emphasize the responsibilities of the operator. The financing and long term decommissioning and liabilities are not clear. There is some responsibilities for need to apply the experience of industrialized countries on public acceptance issues.

The degree of contamination of waste streams and final waste forms with long lived nuclides (alpha activity, ^{14}C, ^{129}I, ^{63}Ni) has to be determined and its significance for final disposal options evaluated.

The separation of the dominant nuclides with intermediate half-lives of ~30 years from waste streams has promise as a potential route for further reductions in waste volumes. This could be a topic for regional co-operation.

Decommissioning waste problems have only been studied in Hungary through literature surveys. Setting exemption levels and estimating the quantities of decommissioning wastes need to be considered as existing problems.

3. RECOMMENDATIONS

3.1. Main directions for the improvement of safety and reliability of waste management systems in NPPs with WWER type reactors

Each country or operator of a NPP should have a clear programme for its waste management. If the authorities have not set the requirements, discussions must begin to form them. However, each operator can set up their own programme to help there own work and to initiate discussions with the authorities.

In parallel to this programme, discussions between authorities could be arranged to define the general technical specifications. The operator could then create process specifications for the whole process covering all the steps between collection of the waste and final disposal.

An evaluation of current waste management practices could be arranged for all power plants. With the help of the IAEA and its experts, the operator could formulate a working plan. It is to be recommended that the identification of the current situation should be carried out by the operator. The review of the work and possibly the development of recommendations for a strategy to optimize the waste management can be done by experts. Recommendations and a list of actions for short term and long term improvements should be made.

The list of actions could address:

(a) Liquid waste

- How can different liquid streams be kept separate, if necessary, and their mixing avoided;
- How can the preventive cleaning of tanks and slumps be improved to reduce filtration of wastes;
- How can chemical contamination of resins be minimized.

(b) Maintenance waste

- How should technological wastes be collected, sorted, packaged and documented;
- How can the amount of material entering the controlled area – e.g. wrappings, scaffoldings, protective clothings, etc. – be limited;
- How can contaminated areas be limited – for example by the use of ready made air locks or sometimes with local exhaust fan–filter system.

On an operational level there must be clear answers to the questions:

- Who is responsible for waste management?
- Are all jobs and responsibilities clearly defined?
- What are the objectives of volume reduction?
- Do you have a training programme for waste management?
- Do you have process specifications?
- Do you have operational documents?
- Do you have a quality management system with experience feedback?
- Have you got up to date information on your waste?

3.2. Development of waste management systems in the former USSR

3.2.1. General

The radioactive waste management technology used for NPPs with WWER type reactors was developed in the 1950s–1960s. It was subsequently realized that waste problems were more complex than anticipated. Since the 1970s the USSR has endeavoured to modernize its radioactive waste management systems. Two approaches were pursued:

(1) Reducing the amount of waste which must be treated and stored;
(2) Improvements in the safety of waste storage.

3.2.2. Reducing solid waste

There are two types of incineration plant under development.

The first type has two incineration chambers with a very effective off-gas treatment system and ash immobilization in cement. The second type is a slagging incinerator with an off-gas treatment system and basaltic slag as the residue product. The properties of slag are such that it only requires fixation without further treatment. The USSR has developed technology for melting the ash in an induction furnace of the 'cold crumble' type.

To reduce the volume of compactable waste, a Hungarian compactor, which showed good results at tests carried out at Zaporozhskaya NPP, has been used. In addition, reductions in solid waste volumes are being achieved by proper separation of radioactive and non-radioactive wastes.

3.2.3. Reducing liquid waste

At some NPPs the condensate from evaporation has to be treated by ion exchange. After loading, the resins have to be regenerated by acid and alkaline agents. This results in waste with a salt content which amounts to 50% of the bulk. Reducing this type of waste is one of the primary objectives in the management of liquid wastes.

In the USSR processes for removing ammonia from the condensate of evaporator which use rectification and sorption have been developed. The laboratory trials are at the final stage and technical and economic comparisons of these methods must now be made.

Another activity for the reduction of liquid radioactive waste is the removal of boric acid from concentrates and its return to the reactor primary system. The boron and salt wastes can reach 30% of the liquid waste total. Laboratory and semi-industrial scale tests have shown that it is possible to return up to 70% of the boric acid to the reactor. The USSR is also developing ultrafiltration as a separation process.

Some elements of this technology will be tested at the Kozloduy NPP in Bulgaria.

Improvements in the quality and repair of equipment also offer possibilities for reducing liquid waste volumes.

3.2.4. Improving safety in radioactive waste management

The most important step in improving the safety and reliability of radioactive waste management systems is to solidify the waste. Various types of solidification plants have been developed in the USSR. Installations for bituminization are produced and supplied to practically all NPPs in the USSR. The first example of this equipment was tested at the Kalinin NPP.

Cementation and vitrification processes have also been developed. In addition, the USSR has developed the technology of caesium separation from liquid wastes.

An important part in improving safety is the development of properly engineered systems for the storage and retrieval of raw and conditioned solidified wastes. Some elements of such storage systems have been effected at the NPP with WWER-1000 reactors, where wastes in 200 L drums are stored in concrete wells.

All of the waste treatment facilities mentioned above can be designed or produced in the USSR or in co-operation with other countries.

4. EASTERN EUROPEAN COUNTRIES NOT USING WWER TYPE REACTORS PARTICIPATING IN THE TECHNICAL REGIONAL PROJECT (POLAND, ROMANIA AND YUGOSLAVIA)

Given that the management of waste is a general problem and is not restricted to any particular types of reactor, other countries, i.e. Poland, Romania and Yugoslavia, are also interested in participating in the IAEA project.

Radioactive wastes arise from nuclear activities carried out in research institutes, by isotope users and from research and power reactors.

Some radioactive waste conditioning facilities and intermediate storages are in operation for these wastes. Some difficulties have also arisen in this area concerning the selection of conditioning processes for radioactive wastes due to lack of knowledge of the most appropriate technologies to use.

Participants focused on the following aspects:

- Updating the regulations concerning radioactive waste management with a view to including the most modern world practices;
- Methods for minimizing liquid and solid wastes during NPP operation;
- Technical, economic and safety evaluations of incineration in comparison with compaction for combustible wastes;
- Selection of the most suitable conditioning process for particular classes of radioactive waste, e.g.
  · ion exchange resins,
  · organic liquids,
  · spent filter cartridges;
- Technical design process and safety analyses for final repository.

Participation in this IAEA project will contribute to the improvement of safety, efficiency and reliability of the radioactive waste management systems in NPPs by transferring knowledge gained from different types of reactors constructed and operated in other countries.

5. FUTURE ACTIVITIES

The participants recommended more detailed exchange of information in the fields of policy, regulations and technologies.

During the workshop the following needs were identified:

- It would be worthwhile to conduct a review and evaluation of the existing regulations in countries operating WWER type reactors and to compare these to western European regulations and international standards. Recommendations should then be made to identify the missing areas for a comprehensive set of national regulations. The importance of the IAEA's RADWASS programme was highlighted by the experts in respect of this last item.

- Although Germany does not have any operating WWER type reactor, an invitation to Germany to join the Regional Project was considered important, because of its experience in decommissioning and management of decommissioning wastes.

SECOND WORKSHOP

Helsinki and Loviisa NPP, Finland, 8–11 October 1991

1. INTRODUCTION

The main objective of the workshop was to study the Finnish experience in:

- segregation of different liquid waste streams, either by modifications or by changing existing practices, with the aim of minimizing waste amounts and costs;
- control of materials entering the controlled area;
- collection, sorting, packaging and storing of the technological wastes including development of documentation for waste packages.

Additional relevant information was presented in detail by the Finnish experts on:

- waste management policy;
- authorities, licensing and regulations;
- financing of waste management activities.

A visit to the Loviisa NPP and its waste management facilities was arranged by Imatran Voima Oy (IVO), a Finnish company producing nuclear energy.

Participants reported on the latest developments and waste management problems they have experienced since the first Workshop.

2. SUMMARY OF THE FINNISH ACTIVITIES

2.1. Policy, strategy and regulations

The representative of Finland's Ministry of Trade and Industry gave her presentation entitled "Nuclear Waste Management in Finland; National Policy, Strategy and Legislation".

The responsibilities of the waste producer are laid down in the Nuclear Energy Act and Decree (1988), the Radiation Protection Act (1992), the Nuclear Liability Act (1984), the Decisions of the Council of the State made in 1983 on principles and time schedules and in 1991 on safety principles of final disposal of low level waste. The waste producer is totally responsible for waste management, including its final disposal and all costs involved.

The Ministry of Trade and Industry is the Finnish licensing authority. In addition, there is a special safety authority in Finland, the Finnish Centre of Radiation and Nuclear Safety (STUK). STUK issues the regulations for the safe operation of nuclear facilities.

The representative of STUK gave a presentation entitled "Regulations Related to Nuclear Waste Management".

STUK is supervising the safety of waste management operations, reviewing the plans and safety analysis reports, and preparing guides and regulations for the waste management.

Safety principles for final disposal have been developed. The guide for disposal of reactor waste is now being published, the guide for the exemption of radioactive waste from the regulatory control is in its final stage, and the guide for the treatment and storage of radioactive waste at NPPs is being developed.

2.2. The Finnish nuclear waste management programme and its results

The research and development programme for waste management at the Loviisa NPP was presented in detail. This programme covers all waste categories. The aspects of waste properties, collection, storing, handling, treatment, final disposal as well as safety were included. Short descriptions were also given of spent fuel management and decommissioning.

Finland has been conducting R&D activities on the management of nuclear waste on an annual basis since 1978. Each year, by the end of September, the R&D programme is planned for the following year. The programme as well as the annual report on the activities of the previous year are approved by the relevant authorities.

The R&D programme not only deals with investigations, but also helps to develop plans for implementing waste management including cost estimates. Some 75 million FIM have been spent on investigations. The total cost for waste management is 1103 million FIM. 585 million FIM have already been collected through a fund of the Ministry. The remaining part is covered by insurance.

Under the R&D programme the waste management system is being developed in a systematic way. Sufficient reliable data are being generated for the safety analyses of the different stages of the waste management chain, and especially for the safety analyses of the final disposal of the wastes.

Special emphasis has been laid on minimization of the waste arisings. The generation rate of dry waste from Loviisa has levelled out at the level of 70–80 m^3/a. The generation rate of evaporator bottoms is around 50 m^3/a and that of spent resins between 15 and 20 m^3/a.

As the Loviisa NPP stores its liquid wastes in an unconditioned form, active investigations have been carried out on methods to minimize their volumes before final disposal. For the evaporator bottoms a system has been developed to remove caesium isotopes from the liquid. The research has taken five years. The system will purify the liquid with the decontamination factor of 10 000 giving volume reduction factors of 5000–8000 for the waste. This system is now being commissioned.

Another example has been the microbiological treatment of organic waste. In a pilot scale study a system has been developed by which spent resins could be decomposed to achieve major volume reduction. A full scale system could be constructed as a next step.

Microbiological systems have also been developed for the treatment of dry organic wastes.

A system to separate and collect different kinds of liquids inside Loviisa NPP was presented. Different systems are available for continuous purification of primary circuit water, for boric acid recovery, for drain water purification, for special laboratory effluents, for pond water purification, for steam generator blowdown water purification, for used decontamination solutions, and for storing liquid wastes. In the evaporator system a special modification has been made to enable higher salt contents to be achieved and to minimize the volume of evaporator concentrates.

2.3. Technical visit to the Loviisa NPP

During the technical visit to Loviisa a description of the waste management practices was presented by the representative of the operator. The whole plant was also described in general terms.

The stages of dry waste management were demonstrated, including collection and categorization, radiation monitoring, compaction in the containers, documentation and transport into storage rooms. Plans for final disposal of the NPP waste were presented.

The arrangements for the management of wet wastes were presented, including collection and storage in tanks. Plans for solidification have been prepared. The participants visited the nuclide separation system, which has been constructed and will start active operation on 21 October 1991. The quantity of evaporator concentrates will be reduced markedly. The microbiological pilot plant for decomposing resins was also visited. To date, no decisions have been taken to utilize this system.

3. RESPONSE OF PARTICIPANTS TO FINNISH ACHIEVEMENTS

The systematic and well scheduled handling of questions and problems by the Finnish authorities and companies was highly appreciated by the participants. Questions were primarily oriented towards:

- Liability of various organizations and their responsibilities;
- Financing structure and arrangements for short and long term responsibilities;
- Setting of the exemption levels.

The considerable efforts of IVO and the Loviisa NPP in design, operation and R&D activities were noted, especially in the following areas:

- The Cs removal from evaporator concentrates by inorganic ion exchangers, and the microbiological decomposition of organic wastes, such as paper, plastics and spent resins;
- The characterization of cement based final products, including the development of criteria with respect to treatment, storage and final disposal;
- Effluent release practiced by the Loviisa NPP, although this particular item may not be applicable for other WWER operators,
- Documentation and measurement systems developed for solid low level waste management.

Cost consequences and projections were discussed during the meeting with respect to decision making, although it was appreciated that direct conversion from the Finnish prices cannot be justified.

4. UPDATED INFORMATION FROM PARTICIPANTS SINCE THE FIRST WORKSHOP

Bulgaria

Since the Budapest workshop, a 600 t press has been commissioned at the Kozloduy NPP and it is now in experimental operation for treatment of hard radioactive waste collected in steel drums. The first results are good and a line for sorting, treating and storing of the hard radioactive waste in OB-3 is to be constructed.

A draft of the regulations for radioactive waste management has been developed and presented at the workshop.

The main problem of the Kozloduy NPP, i.e. the low discharge limits to the River Danube, has not been solved. Proposals for its solution are being evaluated. In addition, no decisions have yet been taken on treatment of the backlog of liquid radioactive wastes.

Czechoslovakia

Design changes for the Temelin NPP have been reported, based on national policy decisions. These changes are very similar to those suggested by experts (France, Finland) during the first workshop, i.e. segregation of liquid waste streams.

There is an interest in the investigations on Cs removal from evaporator concentrates, microbiological degradation of organic waste, encapsulation of ion exchange resins in polymers, and ultrafiltration of the primary coolant. The criteria for near surface disposal are also very useful for comparison purposes.

The status of waste management at Bohunice was described in a separate presentation. The main problems are connected with the A-1 decommissioning and waste treatment. Unresolved problems are results of the missing policy guidance.

France

Detailed information on liquid waste management, allowable effluents and costs of waste management, including final disposal, and on ANDRA activities was given by M. Hartmann (EDF). Reduction in waste volumes and discharged activity result from changes in technology and operational measures (culture of operation), such as training, clearly defined responsibilities, and the involvement of all staff.

Hungary

The status of release and waste management regulations was reported. There is a lack of uniformity between the dose limits and environmental concentrations allowed by various authorities. Plant specific exemption limits are now under development. A short overview of the present practice, development work and the recommendations of experts during the first workshop was presented.

Poland

The current waste management practice for institutional wastes and wastes arising from experimental reactors was described. Nuclear power development has been terminated in Poland, but experts expect it to resume in approximately the year 2000. Therefore, the waste management activities cannot be terminated.

Romania

The radioactive waste treatment facility in ICN Pitesti was described. The importance of recommendations on final disposal was highlighted.

Union of Soviet Socialist Republics

Details of design solutions and philosophy for waste management were described together with operational experience. Inadequate equipment quality result in 2-3 times higher quantities of waste than was the design value. The development of the national waste management programme was reported.

5. FUTURE ACTIVITIES

Continuation of the activities under the Regional Project will make an important contribution to the improvement of the national radioactive waste management policy and practice of the participating countries. The transfer of knowledge from the countries with more experience and advanced technologies is recognized as an important positive factor within the regional project.

The experts attending the workshop recommended the continuation of the previously agreed workplan as follows:

(i) First priority should be given to the elaboration of national radioactive waste management policies.

(ii) Direct contact with the Soviet supplier of the plant and more information on their experience is considered important for the transfer of knowledge.

(iii) It is desirable to continue to transfer knowledge from countries having good practice in radioactive waste management. It would be desirable to hold one workshop in France on administrative and organizational measures for minimization of radioactive wastes, including exemption principles.

(iv) Co-operation and joint work on the present report summarizing the status of radioactive waste management in countries operating WWER type reactors should be the target of the Regional Project.

THIRD WORKSHOP

Piestany and Jaslovské Bohunice NPP, Czechoslovakia, 20–24 January 1992

1. INTRODUCTION

The programme of the workshop included:

- Presentations and discussions on national radioactive management policy and practices, experiences and problems mainly relating to this field in Czechoslovakia;
- Presentations and discussions on national radioactive waste management policies, structure and responsibilities of the regulatory bodies, including exchange of information about the latest developments on radioactive waste management in the participating countries;
- Review of the content and structure of the present document;
- Technical visit to the Bohunice NPP.

Information on the subject of the workshop was contributed by the host country, which presented seven papers. Participants from other countries provided information on developments in radioactive waste management in their countries since the last workshop held in Finland in October 1991.

2. HIGHLIGHTS OF THE WORKSHOP

The representative of the Czechoslovak Atomic Energy Commission described the status of the Czechoslovak nuclear energy programme and the principles of the State Energy Policy which was approved by the Federal Government in December 1991. According to this document, the production of electricity and heat in nuclear power plants could be accepted under the provisions of full observance of the internationally recognized safety standards for nuclear energy exploitation. The State Energy Policy Principles have not yet been approved by the Federal Parliament.

The Czechoslovak waste management policy covers three main areas:

(1) Collection, treatment and disposal of radioactive wastes from nuclear research and radionuclide applications;

(2) Treatment and disposal of waste from the operation and decommissioning of nuclear power plants including spent fuel and high level waste;

(3) Treatment and disposal of wastes from the uranium mining and milling industry.

At present the most urgent waste management problems in Czechoslovakia appear to be:

- Decommissioning of the A-1 reactor

  The A-1 reactor (gas cooled, heavy water reactor) decommissioning procedure presents special and complex problems for waste treatment. The activity levels of contaminated surfaces and a number of the damaged fuel assemblies resulting from the A-1 accident in 1977 have been much higher than expected.

– Spent fuel management

  Since 1989 spent fuel has not been transported to the former USSR, because the Russian Federation has refused to accept it without payment. Consequently, an intermediate spent fuel storage facility has to be built on the Dukovany NPP. Both Czech and Slovak Power Companies support the construction of one deep underground repository for high level wastes;

– Financing of radioactive waste management, including final disposal. There is currently no effective system for such financing.

A specific agency or company with responsibility for covering all the radioactive waste management activities, including the safe disposal of radioactive waste, will have to be established. A special fund will be necessary to create a sense of duty among all radioactive waste producers to share the financial expenses for a safe radioactive waste management system. A preliminary proposal suggests that a levy should be paid at the level of 10% of the income from electricity production. At present the legislation covering waste management is a mixture of old regulations which will be invalid in the near future and new regulations which are appearing daily.

The most important document in the field of radioactive waste management is the Waste Management Act No. 238, 1991. The Act defines the basic terms and responsibilities of the activities of the State and waste producers. In accordance with the Act each producer of waste is responsible for its management. A competent authority of the state administration will give permission to manage dangerous wastes. The document, however, does not define the competent authority for the management of radioactive waste. Other important regulations are:

– The Decree of the Czechoslovak Atomic Energy Commission No. 67/1987 on Nuclear Safety Assurance in Radioactive Waste Management;

– Two Decrees on Health Protection against Radiation of the Czech and Slovak Ministries of Health Nos 59/1972 and 65/1972, respectively.

There are two principal research and development institutions in Czechoslovakia:

– the Nuclear Research Institute (NRI) in Řež near Prague;

– the Nuclear Power Plant Research Institute (NPPRI) in Trnava.

The major activities in radioactive waste management conducted at these institutes are:

(i) Volume reduction of solid radioactive waste (including metal fragmentation, compaction, incineration);

(ii) Treatment and conditioning of liquid radioactive waste (laboratory, pilot and full scale bituminization facilities, calcination equipment, vitrification facilities);

(iii) Decommissioning activities relating to the shutdown of the WWER-440/230 reactors in 1995.

During the visit to the Bohunice NPP, the participants were given basic details on the NPP and on the situation at the A-1 reactor which is undergoing decommissioning. The participants were given the opportunity of getting acquainted with the methods of solid and liquid radioactive waste collection, sorting, treatment and temporary storage. Data on the amounts of waste, releases and release limits were given in the course of the discussions. During the technical visit, the participants examined the facility for bituminization of liquid radioactive waste. This full scale facility has completed inactive testing and preparations are underway to start active trial operation.

Participants from Bulgaria, Hungary, Poland, Romania and the Russian Federation reported on national radioactive waste policy practices and the latest developments in radioactive waste management.

Information provided by experts from France and the United Kingdom on radioactive waste management in their own countries was received with great interest by the participants of the workshop.

FOURTH WORKSHOP

Obninsk and Novovoronezh NPP, Russian Federation, 1–10 June 1992

1. INTRODUCTION

The main objectives of the workshop were:

- To collect information on radioactive waste management in the Russian Federation;

- To discuss a draft report of the present document.

The workshop was held in Obninsk (1–6 June 1992) and Novovoronezh (7–9 June 1992). In addition to the presentations given by the participants, three technical visits were included in the programme:

- Scientific and Industrial Association 'Radon' in Sergiev Posad,
- Institute of Physics and Power Engineering in Obninsk,
- Novovoronezh NPP.

Participants from Bulgaria, Hungary, Czechoslovakia and Romania reported on new developments since the previous workshop held in Piestany (Czechoslovakia). The Russian specialists presented papers relating to the development of new processes, equipment and regulations.

2. HIGHLIGHTS OF THE WORKSHOP

2.1. Summary of the Russian specialists' presentations

The principles of Russian policy in nuclear power and, in particular, in radioactive waste management were explained by V. Gubanov, Director of the Department of Nuclear Safety, Environmental Protection and Emergency Situations of the Ministry of Atomic Power. Two high priority areas for the Ministry of Atomic Power are:

(1) Interactions with the public, as it has been recognized that progress in the nuclear power development programme depends on public confidence and acceptance;

(2) The safety of nuclear power plants.

Information on the following points were given by V. Gubanov:

(a) The new structure of the Ministry of Atomic Power after the disbandment of the USSR.

(b) The new distribution of responsibilities among State organizations involved in nuclear power, and status of legislation. The Atomic Power and Radioactive Waste Management Laws are being developed. A special document will also be prepared to regulate relations between the Ministry and the various territories of the country. The package of regulations will be ready for discussion by the end of 1992.

(c) Revival of the nuclear power programme due to the increasing costs of fossil fuels in the country. In this respect the following measures are considered:

- re-starting the construction of five NPP units of a total capacity of 5000 MW which had been 'frozen' earlier,
- the design of a new generation of NPPs with enhanced nuclear safety factors,
- re-consideration of fast breeders to improve their fuel cycle.

(d) Policy on spent fuel management:

- spent fuel from RBMK reactors is temporarily stored at NPP sites. No decision has yet been made as to whether this spent fuel will be reprocessed or directly disposed of,

- spent fuel from WWER-1000 reactors is being accumulated at the site of the new reprocessing plant near Krasnoyarsk, which is under construction,

- spent fuel from WWER-440 reactors is being reprocessed at the reprocessing plant in the Chelyabinsk region (Production Association 'Mayak'). The new environmental protection law forbids the import of wastes to Russia. However, it is expected that special dispensation will be made by the former USSR (the Russian Parliament) to permit both the transportation of spent fuel from countries having NPPs with WWERs and its reprocessing in Russia;

(e) Management of radioactive waste accumulated on the site of the Production Association 'Mayak' has become a national problem. Rehabilitation of the contaminated territory requires expertise and money. More than 2×10^9 Rbls are required at present. The problem had to be discussed by the former USSR by the end of 1992.

The main directions of research work for radioactive waste management in the country were presented by the Russian experts. The papers submitted covered a wide spectrum of issues, such as the selection of radioactive waste management schemes for the new generation of nuclear reactors and the problems of radioactive waste quantification and characterization during the decommissioning of NPPs.

The following is a brief description of the waste management activities presented by the Russian experts:

- Description of the technology and the process flowsheet for the selective absorption of ^{137}Cs from the NPP operational wastes;

- The boric acid recovery method and its subsequent use at NPPs. Preliminary calculations suggest that this technology could reduce by up to 70% the volumes of radioactive waste to be disposed of;

- The principles determining the NPPs liquid effluents discharge limits which are used at all NPPs of the former USSR;

- The research activities aimed at reducing the volume of radioactive wastes, such as reactor coolant and cooling pond water through the use of selective sorbents;

- The development of a filtering element, which is being produced on a semi-industrial scale and shows a better performance than powder filters. Application of these filters will reduce the amounts of regeneration or washout waters;

- The solidification technology for liquid radioactive waste contaminated with organic oils;
- The process for radionuclide fixation in soil. This process allows efficient dust suppression and prevents radionuclide migration into groundwaters in the Chernobyl accident zone;
- The spray pulsation technology for the decontamination of large size components including steam generators;
- The cementation facility using an eddy current mixing process. The facility can be used for the solidification of various liquid streams;
- The vitrification facility for medium level radioactive waste equipped with inductively heated ceramic melter;
- Some technical aspects of the long term storage of spent fuel assemblies. Spent fuel storage in stainless containers filled with lead or lead alloys is being considered in order to increase reliability and safety during storage or final disposal of spent fuel.

The papers presented by the Russian specialists and the discussions which followed showed that a large amount of work had been done and experience gained in the field of waste management. They demonstrated that there is a clear and straightforward need to continue using nuclear energy but with increased levels of safety as well as improvements to the techniques for radioactive waste treatment, conditioning and disposal of all categories of wastes.

2.2. Technical visit to the Scientific and Industrial Association 'Radon' and to the Novovoronezh NPP

During the technical visit to 'Radon', the participants were shown many facilities for treatment, conditioning, storage and disposal of institutional low and intermediate level radioactive wastes.

Good practice in treatment, conditioning and disposal of wastes was presented. Collection, treatment and disposal of institutional wastes have remained free of charge for radionuclide users.

The workshop continued at the Novovoronezh NPP from 7–9 June 1992. There were long and useful discussions with the NPP personnel on radioactive waste management. Techniques being used in Russia, France, Hungary and other participating countries were elucidated. During the technical visit to the NPP, participants were shown the facility for high concentrate evaporation of operational radioactive wastes and the facility for the compaction of dry solid waste.

It was concluded that the radioactive waste management system being used at Novovoronezh does not meet modern requirements. The Director of the Novovoronezh NPP, V. Vikin, took part in the discussions and expressed willingness to collaborate with the IAEA within the framework of the Regional Project.

2.3. Waste management activities reported by participating countries

2.3.1. Bulgaria

In the last two years the regulators and operators in Bulgaria have made a concerted effort to change the negative trends in radioactive waste management. The IAEA assistance in this area has proved to be of crucial importance. The improvements of waste management policies and practices are aimed at reducing the gap between the recommendations and the existing Bulgarian regulations.

The following has been undertaken:

(a) New regulations defining the requirements for waste collection, processing, transport and disposal have been approved. Several plant procedures, based on the new regulations dealing with waste collection and segregation, were developed by Bulgarian institutes;

(b) A new waste processing facility at the Kozloduy site has been developed. A contract with Westinghouse was signed for the waste processing technology development, equipment delivery, assistance in design preparation and overall project management;

(c) The liquid effluent release limits for the Kozloduy NPP were modified in accordance with the ICRP recommendations and IAEA guidelines. Expertise was provided and will be considered by Bulgarian authorities;

(d) Waste disposal site screening and identification of disposal technologies was initiated. These activities are performed by the Bulgarian institutes and completion of work is scheduled for the end of 1992.

The Bulgarian authorities are planning to develop an overall national waste management policy which will systematically cover all aspects of waste management. Special emphasis will be placed on developing criteria for site selection and for the preliminary selection of disposal technologies. The Bulgarian authorities believe that the IAEA's technical assistance will be essential for successful performance of the programme.

2.3.2. Czechoslovakia

The new developments in the NPP programme in Czechoslovakia are:

(a) No construction of new NPPs during the next ten years is expected. The Government has even discussed the possibility of interrupting further construction of one or both units of the Temelin NPP, but a final decision has not been taken yet;

(b) At the Jaslovské Bohunice (Unit V-1) NPP, efforts continue to improve nuclear safety, and a final decision on whether to terminate the operation or to start major reconstruction has not been taken yet;

(c) Regulations for radioactive waste management are under preparation. The principles of the Federal Law on Radioactive Waste were approved at the working level, together with special requirements for the management of radioactive wastes in the national legislation of wastes;

(d) The bituminization plant at Jaslovské Bohunice started active operation and the waste treatment plant at Dukovany is in the final stage of commissioning. The limits for alpha activity in the wastes for the disposal site at Mochovce are still under discussion. It is expected that the low and intermediate level waste from the Jaslovské Bohunice site can be disposed of at the Mochovce disposal site; spent fuel and liquid waste from the A-1 Unit will be stored at the reactor site;

(e) Based on completed research and development work, some new products for waste management are available on the Czechoslovak market, i.e. the biosorbent-M for the purification of waste waters, the decontamination agent DEKONT with increased washing and cleaning effects and the special decontamination vehicle CT-815 for decontamination of large areas.

2.3.3. Hungary

Developments in the waste management programme were reported by the Hungarian participants. The main directions of this programme are:

(a) Development of waste management policy;
(b) Selection of a site for LLW disposal;
(c) Public acceptance programme for disposal sites and facilities;
(d) Selection and design of waste treatment methods incorporating with reasonable levels of volume reduction;
(e) Design of waste disposal facilities.

The waste management policy will include evaluation of waste treatment, storage and disposal options for operational wastes, evaluation of the back end of the fuel cycle (reprocessing or direct disposal) together with the intermediate storage options for spent fuel management, and evaluation of decommissioning wastes. Waste minimization and an immediate solution for LLW disposal to avoid any restriction on the plant operation will also be included. The necessary means of implementation (acts, regulations) and possible financial arrangements will be built into the policy.

Other programme issues will be treated on the basis of the findings and decisions of the waste management policy through commercial proposals.

2.3.4. Romania

The Romanian Authority for Electricity (RENEL) is moving towards settling on its radioactive waste management policy by issuing the principal internal regulation in this field during 1992–1993.

A general scheme for the Cernavoda radioactive waste management has been developed and the conceptual design of the Radioactive Waste Treatment Facility (RWTF) will be ready in 1993. It is proposed to incinerate the combustible low level wastes. The RWTF will contain also a compacting unit, a cementation unit for LLW and another one for ILW (filter cartridges). The organic liquid wastes will also be incinerated. The construction of a temporary store for filter cartridges is under way, as part of the RWTF. Packages containing conditioned radioactive wastes will be kept in a temporary store for 3–5 years after which they will be sent to the final repository. Preliminary studies on repository site selection began this year. The Institute for Power Studies and Designs has been developing improvements to the processes to be used in RWTF, including technical specifications for equipment.

4. PROPOSED FUTURE ACTIVITIES

Evaluation of the waste management practices at WWER type reactors has shown that efficient waste management is only possible within the framework of the national waste management system covering all aspects of the waste management. Although several parts of such systems exist to differing extents in all eastern European countries, complete systems have not been developed yet. It is therefore evident that introduction of an effective waste management system at the WWER type NPPs and further improvement of both operational and long term safety requires the urgent application of a systems engineering approach to all elements of the national waste management system. A further important task is to introduce the IAEA recommendations and a new approach to waste management. It is therefore considered highly advantageous to continue further initiated activities through a programme comprising two main components:

(1) The identification and definition of the main regulatory and licensing principles and requirements for all activities and all phases of radioactive waste management;

(2) The review and in depth analysis of radioactive waste management systems at selected WWER type NPPs in all eastern European countries for the purpose of recommending improvements to the plant waste management systems.

Based on these two components the following tasks are being recommended for the next phase of the regional project:

Task A

Objectives: Assist the participating countries in the development and improvement of legislation and structure of their regulatory bodies.

Scope:

(1) Evaluation of existing legislation, infrastructure and responsibilities of eastern European countries in the light of IAEA recommendations and guidelines. Practices of some industrialized countries, including public acceptance and research and development issues, should be taken into consideration as reference.

(2) Identification of missing elements in the existing regulatory systems of the eastern European countries.

(3) Formulation of recommendations to make the waste management regulatory structure in eastern European countries compatible with IAEA guidelines.

Task B

Objectives: Development of objective criteria for comparative evaluation of the WWER type NPP waste management systems in eastern European countries.

Scope:

(1) Development of a database of performance indicators for the WWER plants waste management.

(2) Evaluation of the waste management design features, operating and administrative procedures on an individual country basis.

(3) Recommendations for improvements to waste management systems of NPPs with WWER.

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Workshops

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