RADIOACTIVE WASTE MANAGEMENT AT THE PAUL SCHERRER INSTITUTE – THE LARGEST SWISS NATIONAL RESEARCH CENTRE

by

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This paper presents the current radioactive waste management practices at the Paul Scherrer Institute (PSI). The PSI contributes to waste related problems in two aspects, namely to the scientific basis of waste management and disposal, and to the practical treatment and storage of radioactive waste. In addition to the tasks of treating on-site generated waste, PSI manages the wastes from medicine, industry, and research throughout Switzerland on behalf of the government. Therefore the Dismantling and Waste Management Section is a part of the Logistics Department at PSI. Proved and accepted methods have to be developed for the safe conditioning and storage of radioactive waste. Various waste treatment facilities exist at PSI. The conditioning facility is dedicated to sorting, compaction by a 120 t press, solidification with special cement, and embedding in concrete. Specialised facilities were constructed for waste from the decommissioning of research reactors. Activated aluminum and its alloys were melted in crucibles and embedded in concrete in a concrete container. After dismantling the structural material of the reactors, it was embedded in concrete in the same manner. For the conditioning of activated reactor graphite, a dedicated method was developed. Graphite was crushed to replace sand in the grout, for embedding radioactive waste in concrete containers.

For accelerator waste, a walk-in hot cell equipped with an electrically driven manipulator is available where the highly activated large components (targets, beam dump) can be cut into pieces and embedded in concrete in containers.

To guarantee the fulfilment of the demands of the regulators, the Dismantling and Waste Management Section applies an accredited quality management system for the safe collection, conditioning, and storage of radioactive waste.

Key words: waste management, dismantling, conditioning, research reactor, "medicine, industry, and research"

INTRODUCTION

The Paul Scherrer Institute (PSI, fig. 1) is the largest national research centre in Switzerland. Its multidisciplinary research is dedicated to natural science and technology, *i. e.* solid state physics and mate-

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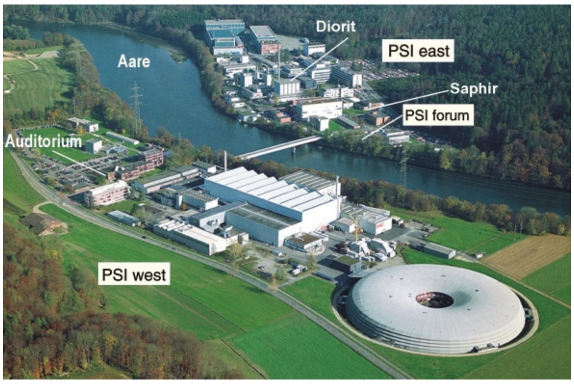

Figure 1. Bird eye view of the PSI with the round structure of the Swiss light source in the foreground

rials sciences, life sciences, elementary particle physics, nuclear and non-nuclear energy research, and energy-related ecology. PSI is the centre of national and international collaboration among universities, industry and other research centres. PSI's priorities lie in the development and operation of complex research installations which are beyond the possibilities of single university departments. As a user laboratory, PSI deals with the design, construction and operation of large, complex research facilities for the national and international scientific community. In close collaboration with universities, PSI contributes to education and training. In partnership with industry, research results are transferred for application to new products and processes. The emphasis of the research has been shifted during the last decade from nuclear energy research and particle physics towards materials sciences, general energy research, life sciences and environmental sciences. With the implementation of the neutron spallation source (SINQ) and the Swiss light source (SLS), a further strong shift to the study of the structure of materials has been undertaken.

PSI contributes in two aspects to waste related problems, namely to the scientific basis of waste management and disposal, and to the practical treatment and storage of radioactive waste [1].

Its scientific work is directed towards the safety analysis of repositories by developing and testing models and by acquiring selected data to support performance assessments of radioactive waste repositories.

PSI operates facilities dedicated to research in nuclear fields and uses nuclear methods in materials and life sciences. These unavoidably produce radioactive wastes which have to be treated, stored and eventually disposed of. In addition to the tasks of treating on-site generated waste, PSI manages the wastes from medicine, industry, and research (MIR) throughout Switzerland on behalf of the government. Therefore, the Waste management section exists including the decommissioning projects for old installations (*i. e.* the DIORIT and the SAPHIR reactors).

Obviously, the shift of research emphasis at PSI away from nuclear energy research generates a certain amount of spent radioactive materials which has to be managed. In addition, new scientific programmes using nuclear methods are considered with respect to future waste production. Proved and accepted methods have to be developed for safe conditioning and storage.

Near PSI, a new interim storage facility, ZWILAG (Zwischenlager Würenlingen AG), a joint effort of the Swiss nuclear power plants, has been constructed. New waste treatment facilities are included in this project. After its completion in 2002, ZWILAG took over waste incineration from PSI [2].

WASTE MANAGEMENT

With respect to its origin, the wastes handled by PSI generally can be divided into *on-site* generated waste, combustible low level waste, and waste from medicine, industry, and research. They differ widely in their nuclide and material composition and will be therefore discussed separately.

On-site generated waste

At PSI there are several main sources of waste.

The reactors to be decommissioned yield several types of fuel, irradiated and non-irradiated, that have to be reprocessed or stored in collaboration with foreign partners. In addition, past and active research activities result in liquid and solid materials containing α-emitters and in the case of post irradiation examinations β/γ-emitters as well [3]. Highly activated material from the accelerator [4] facility, *i. e.* the beam dump, also had to be conditioned.

An overview of this on-site generated material is given in tab. 1.

Whereas the dismantling of the research reactor SAPHIR has already been completed (fig. 2), the research reactor DIORIT (fig. 3) is close to the end of its dismantling [5, 6]. The dismantling of both research reactors [7, 8, 9, 10] has given rise to large quantities of activated or contaminated materials. Depending on the reactor type, the material differs with respect to the composition and extent of activation or contamination. An overview is given in tab. 2.

Table 1. On-site generated waste

Origin	Type of waste	Main nuclides	Material composition
Fuels development	Liquid, solid	Actinides	HNO_3, metals, oxides
Post irradiation examinations (PIE)	Liquid, solid (scrap)	Actinides, activation and fission products	HNO_3, metals, oxides
Accelerator facilities	Beam dump, targets, shieldings	Activation and spallation products	Cu, Al, C, steel, concrete
SINQ	Targets	Activation and spallation products	Pb, zircalloy
Life sciences, teaching activities	Radiation sources, small quantities	^{60}Co, ^{137}Cs, ^{90}Sr, ^{226}Ra, ^{241}Am	Steel, ceramics, glass
Processing waste	Weakly active	Different nuclides	Organics, mixtures

Figure 2. View into the empty reactor hall of SAPHIR after the removal of the reactor

Figure 3. View onto the remaining lower part of the shielding of DIORIT reactor

Radioactive waste from medicine, industry, and research

Responsibilities

The federal government is by law responsible for the collection, treatment, interim and final storage of radioactive waste from medicine, industry, and research. The overall responsibility is delegated to BAG (Bundesamt für Gesundheit), the Swiss Federal Office of Public Health. The government charged PSI with the collection, treatment and interim storage of that waste in accordance with the Swiss legislation on radiological protection and the ordinance on radioactive waste. PSI staff consults with the producers on waste related questions. In collaboration with BAG, waste collection is organised, including the inspection of the waste before shipment and its preparation for shipment according to the ADR/SDR rules. The waste producers have to declare their waste in advance. The waste is conditioned at PSI and, after the final conditioning, waste packages are stored *on-site* in a dedicated interim storage facility (BZL, Bundeszwischenlager). BZL was constructed by PSI with government funding. It is an interim storage facility for finally conditioned waste for which the government is responsible. Documentation of the waste when finally conditioned is done by PSI staff and PSI is also responsible for fee assessment.

General description of the waste management

Each waste collection is an individual task because there is little consistency among wastes with respect to the nuclide and material composition. Waste has to be sorted by the producers into types and classes. Seven types of waste are distinguished based on their radionuclide contents as shown in tab. 3.

In addition, the waste is sorted into classes according to its material properties as shown in tab. 4.

This waste as well as waste from PSI is conditioned in the waste treatment facilities of PSI. Yearly, 30 to 60 producers deliver between 6 and 16 m^3 of waste. The main nuclides are ^{3}H (500 TBq/year), ^{241}Am (400 GBq/year), ^{14}C (60 GBq/year), and ^{137}Cs (30 GBq/year). The largest quantities are delivered by industry and are well defined with respect to their material properties. Smaller quantities, but with complex

Table 2. Radioactive waste from the decommissioning of the research reactors DIORIT and SAPHIR

Origin	Material	Total amount [t]	Treatment
Reasearch reactor DIORIT	Al, -alloys	5.4	Melting, imbedding in concrete
	Steel	250	Imbedding in concrete
	Concrete	120	Imbedding in concrete
	Graphite	45	Interim storage, imbedding in concrete or incineration (not yet decided)
Research reactor SAPHIR	Al, contaminated	1.8	Etching
	Al, activated	0.5	Melting, imbedding in concrete
	Steel, contaminated	1.3	Etching
	Steel, activated	1	Imbedding in concrete
	Concrete	482.3	Imbedding in concrete
	Be/BeO-reflector elements	0.126	Welding in storage cans, MOSAIK cask

Table 3. Types of MIR waste

Type	Description
A	^{226}Ra
B	^{241}Am
C	Other α-emitters
D	^{3}H
E	^{14}C
F	β/γ-emitters with life >60 d including β/γ-sources
G	Neutron-sources

Table 4. Classes of MIR waste

Class	Description
1	Gaseous
2	Liquid organic
3	Liquid aqueous
4	Solid organic
5	Metallic
6	Solid non-metallic (mineral)
7	Solid mixed
8	Sludge
9	Bulky goods
10	Biologic (infectious, rotting, *etc.*)
11	Sealed sources

material properties, are passed from the universities to PSI. In total, the waste contains over 15 different nuclides.

It must be stressed that technically intact sources from hospitals and industry are not included in this total because they are recycled. Recycling allows reduction in the final conditioned waste volume and therefore saves interim and final storage capacity. In addition, recycling appears as an intelligent management of resources and should be further developed for other waste forms.

Conditioning procedures

Based on the waste declaration of the producers and the results of an inspection, the waste is sorted at PSI into groups for further treatment.

Industrial producers, regularly shipping large and uniform quantities of waste, precondition the waste into a safe form. Normally, that waste is welded in steel cylinders after compaction or solidification.

In the same way, research units at PSI precondition their regular waste streams using their knowledge of the waste properties and hazards.

After being sorted or preconditioned, the waste is treated in the waste management facilities when needed.

Homogeneously miscible waste is solidified with cement. Irregular solid waste and pellets of compacted waste are imbedded in concrete. Burnable waste without α-emitters is incinerated. In the case of volatile nuclides such as ^{3}H, ^{14}C, and ^{226}Ra (^{222}Rn), waste is put into in steel cylinders that are welded gas-tight before being imbedded in concrete.

In general, 200 l drums are used as waste packages for finally conditioned waste but concrete containers with a capacity of 20 t are also available. The latter are mainly used to condition dismantling waste from research reactors and for larger components from the accelerator.

In general, the surface dose rate of a final conditioned waste package is limited to 2 mSv/h.

The relation by volume between the different sources of waste is as follows: 94.3% of the waste to be conditioned comes from PSI and only 5.7% from medicine, industry, and research. It is interesting that the administrative effort is in the opposite ratio.

Waste management facilities

The conditioning facility, finished in 1970, is dedicated to sorting (fig. 4), compaction with a 120 t press, solidification with special cement and imbedding in concrete. Specialised facilities were constructed for the waste from the decommissioning of research reactors. Activated aluminum and its alloys, after being cut into pieces, will be melted in crucibles by an inductively coupled furnace. Afterwards, the aluminum reguli within the crucibles will be imbedded in concrete in a concrete container. After dismantling the structural material of the reactors, *i.e.* the thermal and biological shielding, the activated material will be imbedded in concrete in the same manner.

For accelerator waste, a walk-in hot cell equipped with an electrically driven manipulator is available where the highly activated large components

Figure 4. Waste sorting in the walk in cell

(targets, beam dump) can be cut into pieces and imbedded in concrete in containers.

Decay storage

In the Swiss Radiation Protection Act, as well as in the Nuclear Energy Act, the minimisation of radioactive waste is demanded. For that purpose the Nuclear Energy Ordinance demands decay storage for 30 years if the radioactive material has an activation which will decay in that time span below the recent limits of clearance. The PSI fulfils this demand by operating two decay storage facilities, one for accelerator material and one for material stemming from the dismantling of the two research reactors. In addition, the time span for decay storage has been expanded to 75 years.

Measurement for free release

Measurement for free release is an important means to reduce the amount of radioactive waste. The Federal Nuclear Safety Inspectorate issued a guideline R-13 to regulate the measurement for free release and the consequently following clearance of the material. Large amounts of homogenous materials are measured [11, 12] by means of a device for measuring material below the exemption limits for free release (RTM 644 LNC, RADOS, fig. 5). Solid material in big blocks is checked by means of hand held instruments. Both means are calibrated in advance and the calibration has to be accepted by the authority.

Quality assurance in waste management

In addition to the operations and tasks introduced above, PSI is subjected to the regulatory procedures established and controlled by the Swiss Nuclear Safety Inspectorate, ENSI (Eidgenössisches Nukleares Sicherheitsinspektorat). Based on guideline B-05 by ENSI, the final conditioned waste has to be described in a so called specification for each package type and subtype. In this specification, the waste composition, with respect to nuclides, materials, and origin of the waste, has to be described in detail. In the same manner, a description of the production procedure and the construction of the final waste package is included. The corresponding data are managed by the program and data base ISRAM (Informationssystem für radioaktive Materialien) which is used co-operatively by the nuclear power plants, PSI and NAGRA (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle) to assure the uniform handling of the waste related data. The preparation of the specification is done in close collaboration between PSI and NAGRA. After a detailed analysis of the specification, NAGRA issues a certificate for final storage. This certificate, together with the specification, is the basis on which ENSI issues permission to apply the conditioning process.

An important contribution to assuring the quality of waste treatment is the organisation of these tasks at PSI. The waste treatment, together with the two decommissioning projects DIORIT and SAPHIR, is organised as a section. This section is responsible to the logistics department of PSI. The Dismantling and Waste management section consists of three groups: the permits/documentation group, the cement chemistry group, and the facilities group, and the two dismantling projects: SAPHIR and DIORIT.

This section is charged with the planning and coordination of the waste treatment at PSI. It defines the acceptance criteria for radioactive waste and manages the interim storage facility (fig. 6), as well as the facility to stack rough waste before conditioning. Finally, this section organises the collaboration with ZWILAG and the authorities. In addition, each large waste pro-

Figure 5. Free release measurement facility

Figure 6. View into the interim radioactive waste storage facility

ducer at PSI has a person responsible for the waste related tasks of their division. This person collaborates closely with the Dismantling and Waste Management Section.

Quality management in waste management

To fulfil the above described tasks, the Dismantling and Waste Management Section operates a quality management system according to ISO/IEC 17020 and EN/ISO 9001. Since January 2008, this Section has been accredited as an inspection office for radioactive waste.

SUMMARY

Because of its experience in handling radioactive materials, including waste generated on-site, PSI has been charged with managing the treatment and interim storage of the radioactive waste from medicine, industry, and research in Switzerland. Because of the decommissioning of old facilities provoked by the change in the research priorities at PSI, temporarily, an additional amount of waste is released on-site to be treated. PSI possesses the facilities and the organisational structure to fulfil the tasks it has been charged with.

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Ханс-Фридер БЕР

УПРАВЉАЊЕ РАДИОАКТИВНИМ ОТПАДОМ У ИНСТИТУТУ ПАУЛ ШЕРЕР – НАЈВЕЋЕМ ШВАЈЦАРСКОМ ИСТРАЖИВАЧКОМ ЦЕНТРУ

У раду су приказани послови управљања радиоактивним отпадом који су у току у Паул Шерер институту. Институт доприноси на два начина решавању проблема отпада: научној основи управљања и одлагања отпада и практичним поступцима и смештају радиоактивног отпада. Поред обавеза да се бави отпадом насталим на самој локацији, Институт са државним овлашћењима управља медицинским, индустријским и истраживачким отпадом свуда у Швајцарској. Отуда је Сектор за уклањање и управљање отпадом један део Одсека за логистику Института. Ради сигурног кондиционирања и смештаја радиоактивног отпада, морају се развити проверени и прихватљиви поступци. У Институту постоје различита постројења за рад са отпадом. Постројење за кондиционирање бави се сортирањем отпада, сабијањем пресом од 120 тона, очвршћавањем посебним цементом и заливањем у бетон. Посебна постројења изграђена су за отпад настао декомисијом истраживачких реактора. Активирани алуминијум и његове легуре мељу се и улажу у бетон бетонских контејнера. На исти начин, по расходовању реакторске структуре материјала се заливају у бетон. Ради кондиционирања активираног реакторског графита развијен је посебан поступак. Графит се дроби и употребљава да замени песак у цементном тесту при затапању радиоактивног отпада у бетонске контејнере. За акцелераторски отпад располаже се пространом врућом ћелијом опремљеном електричним манипулатором, у којој се високо активирани крупни делови (мете и материјали који су били изложени сноповима честица) секу на комаде и уграђују у бетонске контејнере.

Ради осигурања испуњености захтева регулаторних органа, Сектор за уклањање и управљање отпадом примењује акредитовани систем квалитета у управљању сигурним прикупљањем, кондиционирањем и смештајем радиоактивног отпада.

Кључне речи: управљање отпадом, расходовање, кондиционирање, истраживачки реактор, медицина, индустрија и истраживање