INVESTIGATIONS ON THE RECONDITIONING OF RADIOACTIVE WASTE AND WASTE PRODUCTS FOR LONG-TERM INTERIM STORAGE IN GERMAN FEDERAL STATES (LÄNDER)

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ABSTRACT

As required by federal law, the German Länder run collection sites for radioactive waste resulting from activities in industry, research and medicine. Because most of the main waste producers run their own licensed intermediate storage sites, the remaining amount of radioactive waste is relatively small.

Due to the origin of the waste from minor producers varying amounts are collected. Some Länder have very small amounts of radioactive waste whereas others have a significant amount of low-level radioactive waste. The total amounts are still small in comparison to the major waste producers.

There is a lack of an operating final repository in Germany. The former repository sites of Asse Research Mine (test site) and Morsleben (former final repository of GDR) are closed. It is now anticipated that no final repository for low-, intermediate- and high-level waste will be available in Germany before 2030. The federal government of Germany has the responsibility to provide a final repository site.

The Länder have taken over the responsibility for disposing of the collected waste in a federal final repository subject to the charging of a fee for acceptance of the waste.

Therefore, the remaining radioactive waste and waste products have to be conditioned for interim storage for 30 years or more. Some radioactive waste has already been stored for 15 years or more under a range of conditions.

The paper will present the present status, problems, present (re-)conditioning and some reflections for achieving safe interim storage of low-level radioactive waste at the federal collection sites in Germany.

INTRODUCTION

A final repository for all types of radioactive waste in a deep geological underground site is anticipated for the year 2030 in Germany. Therefore, an extended long-term interim storage of at least 30 years for all types of radioactive waste, existing or presently being generated, is expected in Germany. A safe near-surface storage must be designed for radiological protection of people and the environment.

The conditions at the long-term interim storage site are likely to be significantly different from the conditions at any final repository and may influence the integrity of the waste packages. Internal processing of the waste packages may also influence their integrity. The integrity of the waste packages is important for the safety of long-term interim storage, enclosure of activity, handling, transportation and subsequent final disposal.

Adequate conditioning is required for long-term interim storage. Therefore, specifications for conditioning, storage, guidelines and documentation have to be determined and defined.

These specifications cannot directly be deduced from existing acceptance criteria of interim storage sites, of the Morsleben (ERAM) final repository for radioactive waste 1 or the planned Konrad final repository 2.

The specifications have to include the requirements induced by the long-term interim storage, the technical limitations of future handling and transportation, as well as the specifications of a final repository.

General requirements for long-term interim storage have been compiled by the German Reactor Safety Commission 3.

As required by federal law, the German Länder run collection sites for radioactive waste resulting from activities in industry, research and medicine not related to nuclear industry. Such waste is low level radioactive waste in general. The amount of radioactive waste is relatively small but heterogeneous.

The possibilities of reconditioning of waste packages in long-term interim storage, suggestions for ensuring the confinement of radioactivity and criteria for decision-making are discussed in the following paragraphs.

SAFETY REQUIREMENTS

The general safety requirements for long-term interim storage are outlined in 3. They concern:

- Confinement of radioactivity by the waste package
- Criticality safety
- Minimization of radiation exposure in operation and environment
- Specification of the storage building for expected operational lifetime
- Technical equipment, operating ability and safety
- Internal and external detrimental effects / events

The technical characteristics of waste and waste packages concerning safety are:

- Activity of the waste package
- Activities of single nuclides
- Dose rate at the surface and at 1 and 2 m distance, respectively
- Surface contamination of the waste package
- Chemical composition of the waste
- Conditioning materials, techniques, products
- Waste container specifications
- Mass
- Matrix
- Water content, moisture
- Thermal performance
- Mechanical stability
- Stacking ability

Alterations of the characteristics of the waste packages due to reactions of the waste container or waste products have to be considered on a longer time-scale for long-term interim storage. Comprehensive documentation of the characteristics of waste, waste packages, waste products and their origin is required.

Therefore, the requirements for long-term interim storage can be more restrictive than for final disposal.

Federal Collection Sites in Germany

Germany has eleven federal collection sites including a military collection site for low level radioactive waste that includes spent sources. Depending on possible sources for radioactive waste within a federal state, their sizes vary from a single container with several tens of cubic meters to storages with a few thousand cubic meters.

Long-Term Interim Storage

Waste Package

The radioactive waste delivered to federal collection sites is generally treated for storage and stored in drums.

Alteration of the waste product may occur to the radioactive waste itself, its matrix and its container. This may increase the mobility of the radioactive nuclides.

The main processes are chemical reactions, microbial degradation, corrosion (metals, concrete) and - to a lesser extent at federal collections sites - radiolysis and radioactive decay.

The most obvious potential for activity release are gas generation by corrosion of metals, microbial degradation of organic matter, and corrosion of the waste container itself. This might result in a loss of integrity of the waste package and transportability.

Pressure build-up and inflation of waste drums has been observed occasionally in the past (Fig. 1). Drying of waste drums slows down the gas generation processes. Installation of a vent with filter for aerosols is recommended if substantial gas generation is expected.

Corrosion of the waste drum is visible to a certain degree. Main causes are insufficient storage conditions or conditions inside of the waste package.

Fig. 1. Pressure build-up in a waste drum

Means of Control at Interim Storage Site

In order to check the integrity of the waste packages and to ensure the confinement of radioactivity, non-destructive means of control are available.

Waste packages may be inspected visually from the outside for alteration. Wiping tests on surfaces may detect radioactivity releases. Dose rate measurements and measurements of gas content may indicate a risk of radioactivity release. Imaging by CT, measurement of α-, and γ-spectrum and ultrasonic testing may reveal information on the waste content.

The storage hall may be monitored for released activity by aerosol measurements, measurements of volatile radionuclides, and wiping tests.

Reconditioning Waste

When the integrity of the waste package is not sufficient for long-term interim storage, measures for reconditioning the waste or waste package are available. These include subsequent redocumentation, super compaction, drying, secondary containers (overpacks), repacking, solidification and, in rare cases, incineration or vitrification.

Criteria

General criteria for reconditioning waste products for long-term interim storage are given in the following Table I in qualitative order of importance.

Table I. Criteria for Reconditioning

Criteria
Storage / Monitoring
Integrity of the waste / waste packages
Documentation (chemical / physical characteristics)
Transportability
Acceptability for final repository

Storage / Monitoring

The conditions of storage are of major importance for the long-term interim storage. Physical-chemical processes may be heavily accelerated or slowed down by storage conditions and influence the confinement of activity, transportability and acceptability for a final repository.

Mechanical aspects, such as stacking, are also important. Twisted skids indicate overload.

Outside storage exposes waste packages to atmospheric conditions and enhances alteration. This storage is not recommended although it has been practiced in the past.

Storage in simple building, which is naturally ventilated, protects the waste packages from direct exposure to the atmosphere. Changing temperatures and humidity levels still may affect the integrity of the waste package. Stacking of the waste packages for visual inspection is important.

An air-conditioned building excludes condensation of humidity on waste packages as well as temperatures below freezing point. The air is monitored for released activity. Alteration of waste containers is minimized, but a continuous energy supply and maintenance is necessary.

Storage of waste packages in a sealed building may be a further alternative. This would be comparable to an oversized secondary waste package. The long-term interim storage would be similar to a surface based repository. In contrast to a final repository, retrieval has to be possible. Monitoring is not possible.

Waste Packages

The condition of the waste packages determines the priority of reconditioning if there is a risk of activity release. In general a visual inspection is sufficient.

Documentation

Documentation allows an assessment of physical-chemical properties for reconditioning. If the documentation is insufficient, it has to be supplemented. The supplementation may be

achieved using existing documents, enquiries, or non-destructive investigation on the waste packages. If the waste package must be opened, reconditioning by drying is recommended.

Transportability

Current und future regulations concerning transportation have to be fulfilled. The transportability has to be ensured for waste packages after long-term interim storage.

Acceptability for Final Repository

The requirements for acceptance at some federal collection sites are identical with the preliminary requirements given in 2. The future acceptability and requirements for a final repository are not yet known. Although it seems rational to apply preliminary requirements for a final repository given in 1 and 2 for acceptance in interim storage, they are not necessarily sufficient to ensure suitability for long-term interim storage.

Presently, site-independent requirements for final disposal are under development in Germany and exist as an internal draft only.

Certifications of process flow and acceptability of waste packages for a final repository are currently issued. These are expected to ensure future acceptability.

Proposed Measures for Activity Confinement

The confinement of activity is based on the documented knowledge of activity and the physical-chemical characteristics of the waste package. If necessary, supplementary documentation may be necessary. Non-destructive technical procedures (e.g. scanning) are available.

The confinement of activity during long-term interim storage has to consider external exposure to humidity, temperature, human activity and internal effects (e.g. corrosion, microbial degradation, radiolysis).

The following measures for activity confinement are therefore proposed:

- External exposure can be minimized by conditions of storage. Protection against atmospheric weathering may be achieved by buildings or underground structures.
- Internal reactions can be minimized by inertization of the waste.
- Backfill materials able to absorb gases such as carbon dioxide, hydrogen and humidity may lower the risk of inflation of the waste packages.
- Backfill materials should not hinder future reconditioning measures.
- The specified tightness of waste packages should be balanced against pressure build up.
- Corrosion can be minimized by drying and using high quality coatings.
- Monitoring of the building (air) and waste packages (visual) ensure early detection of activity release. Knowledge of activity release is essential when compliance with legal limits has to be demonstrated.
- Improvements in waste drums for corrosion protection.
- Improvements in sealing materials.
- Improvements in backfill materials.

Pressure Build-Up and Activity Confinement

The confinement of activity requires a tight waste package whereas the prevention of pressure build-up requires vents. This is a conflict of objectives.

A balanced decision has to be made depending on waste characteristics and allowable limits for activity release in the long-term interim storage of volatile radionuclides.

When a tight waste package is required, its tightness has to be ensured for the duration of the long-term interim storage. This may be achieved by

- waste drying
- combustion (if possible)
- high quality surface coatings for corrosion protection
- long-lasting seals
- wall thickness of the container
- choice of container material

In addition there have to be measures to detect leakages and to perform maintenance.

The application of overpacks is a possible immediate measure in case of leakage. Additional reconditioning should be considered for long-term interim storage.

The requirements of waste transport and of the final repository to avoid a pressure build-up has to be balanced against the confinement of activity during long-term interim storage.

Costs and Radiation Protection

Costs

The costs for interim storage have been assessed within an order of magnitude using experience and price lists of federal collection sites given in Table II. Generally, the costs of interim storage decrease with increasing size. The costs of reconditioning vary greatly because of the heterogeneity of the waste, requirements of radiation protection, and different sizes of the federal collection sites.

Therefore, a qualitative comparison of costs of reconditioning measures is given in Table III, with repacking and vitrification being the most expensive.

Improvements in the coatings, seals and bases of waste drums relative to current standards are possible. High quality coatings will enhance corrosion protection. Special welding and more stable T irons will extend the durability of the drum bases. Metal seals instead of rubber will increase thermal stability and extend the duration of gas tightness.

It can be seen from Table IV that improvements in the coating and sealing of the waste drums may double their cost.

Table II. Estimated Costs of Interim Storage and Reconditioning for Different Federal Collection Sites

Size of collection site	Interim storage	Reconditioning
1. 77 000 m^3	30 € a^{-1} $drum^{-1}$	1 000 € $drum^{-1}$

Size of collection site	Interim storage	Reconditioning
2. < 1000 m^3	no data	1 100 € $drum^{-1}$
3. < 1000 m^3	120 € a^{-1} $drum^{-1}$	11 700 € $drum^{-1}$
4. < 1000 m^3	350 € a^{-1} $drum^{-1}$	420 € $drum^{-1}$
5. < 1000 m^3	70 € a^{-1} $drum^{-1}$	no data

Table III. Qualitative Comparison of Costs of (Re-)Conditioning

Measure	Waste (old)	Waste (new)
Super compaction	+	+
Drying	++	+
Repacking	+++	-
Overpacks	+	-
Concrete	++	+
Incineration	+++	++
Vitrification	++++	+++

+ = low, ++ medium, +++ = high, ++++ = very high, - = not applicable

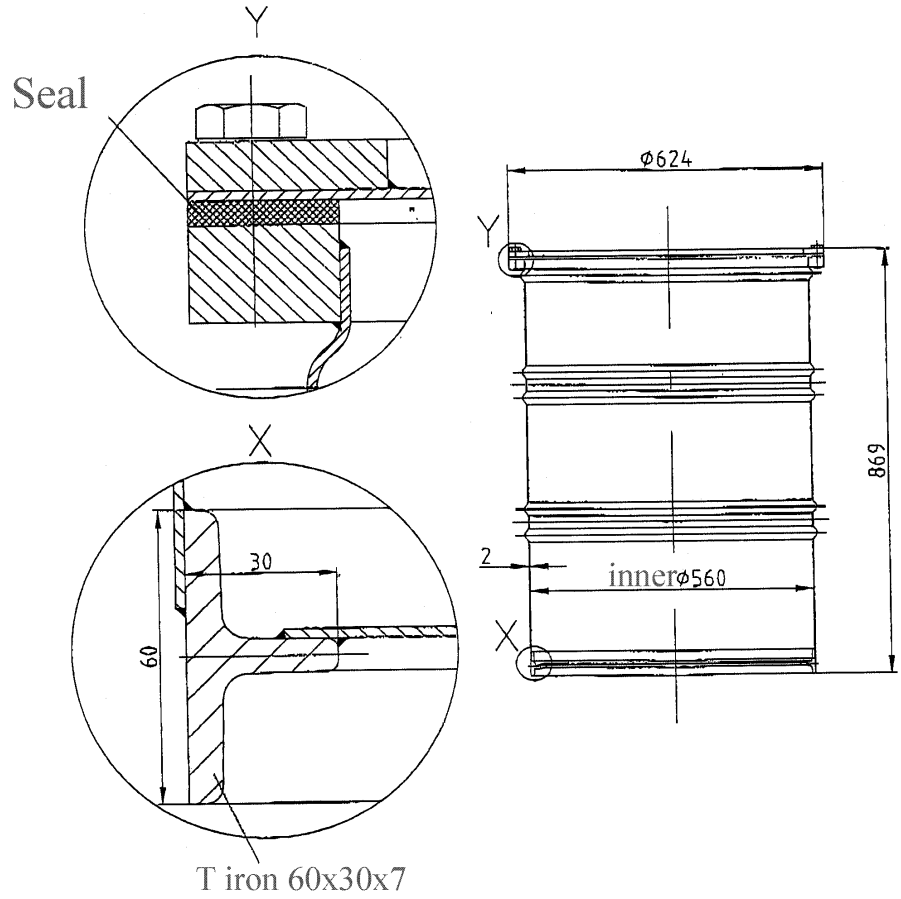

Fig. 2. Improvement of sealing and bottom of waste drums

Table IV. Quoted Prices of Drums as of 2004

Type	200 l (drum)	280 l (drum as overpack)
Standard (firm 1)	175 € per pc	280 € per pc
Standard (firm 2)	185 € per pc	232 € per pc
Improved bottom (firm 2)	222 € per pc	No data
Improved coating and seal (firm 2)	315 € per pc	No data

Radiation Protection

The handling of the waste packages during interim storage, transportation and in the final repository results in radiation exposure, which cannot be represented in financial terms. The exposure to radiation increases when the interim storage work is extended due to monitoring and reconditioning. Table V gives an assessment of additional radiation exposure due to long-term interim storage 4. Long-term interim storage increases radiation exposure by approximately 10 times.

Table V. Estimated additional radiation exposure due to monitoring, reconditioning and documentation of waste packages in interim storage 4

Activity	**Radiation exposure [µSv/package]**
Monitoring	2.5
Reconditioning	2.5
Documentation	1.5
Overpacks	1
Improvement in coatings (including preparation, visual checking, sanding, priming, revarnishing)	Up to 75

Recommentations

The decision on reconditioning measures depends on the conditions of interim storage and waste packages. Therefore the following schematics are suggested if long-term interim storage is necessary.

A system for monitoring released activity should be installed.

The conditions of interim storage have to be constant. This concerns mainly temperature and humidity. If these are not within reasonable limits, technical support is necessary.

If the waste packages are beyond specifications / requirements, then reconditioning is necessary.

The documentation concerning physical-chemical characteristics of the waste packages should be checked. If the documentation is insufficient, an update is necessary.

Using the documentation, it can be checked whether corrosion or gas generation can be expected. Gas sampling and measurements should be used for the decision if reconditioning must be applied.

If gas generation, corrosion, alteration or activity release is detected during interim storage, subsequent reconditioning becomes necessary.

SUMMARY AND CONCLUSION

Long-term interim storage requires monitoring to detect possible activity release.

Reconditioning and updating of documentation, if insufficient, becomes compulsory if the waste packages are beyond specifications / requirements. The documentation should also comply with current regulations for water and groundwater protection.

Storage conditions need to minimize atmospheric contact.

Heterogeneous waste may require reconditioning in batches to minimize costs and radiation exposure.

Waste packages, according to preliminary requirements of a final repository, may not automatically be suitable for long-term interim storage, since handling, storage space and monitoring will be constrained.

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