The Application of LSA/SCO-Regulations to Low- and Intermediate-Level Waste Shipments to Final Disposal Sites in Germany

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INTRODUCTION

According to the German disposal concept, all radioactive waste has to be emplaced in repositories constructed and operated in deep geological formations. As liquid and gaseous wastes are excluded from disposal in such a mine, only solid or solidified radioactive waste is accepted.

The waste arises from nuclear power plant operation, decommissioning, nuclear fuel cycle industry and applications of radioisotopes in medicine, industry, and research.

Two sites are presently considered for disposal of low and intermediate level waste:

- In the abandoned Konrad iron ore mine in Lower Saxony it is planned to dispose of radioactive waste with negligible heat generation

- The emplacement of waste in the former Morsleben salt mine in Saxony-Anhalt, which was operated as a repository for short lived low and intermediate level waste with low alpha emitter concentrations, has been resumed in mid-January 1994.

The shipments of low/intermediate level waste to these sites have to be performed in compliance with the LSA/SCO requirements of the IAEA-Transport Regulations, Safety Series No.6 (IAEA 1990), but waste packages have also to meet specific waste acceptance requirements of the planned Konrad - or operating Morsleben - repository. It is necessary to pay attention to both transport and disposal requirements to derive appropriate waste package criteria for a safe waste management system as well as to obtain a consistent regulatory framework.

By comparing both transport and disposal requirements for typical waste shipments, the resulting consequences for waste package limitations will be discussed concerning mainly criteria for waste form, radionuclide inventory, and packaging. Shipments to the planned Konrad as well as to the operating Morsleben-repository are considered, taking into account the different concepts of lost packagings (Konrad) and reusable packagings (Morsleben). The range of applicability of LSA/SCO-regulations will be considered in particular also to waste which is radioactive itself as well as surface contaminated.

KONRAD DISPOSAL REQUIREMENTS ON WASTE PACKAGES

The preliminary waste acceptance requirements for the planned Konrad repository result from a site -specific safety assessment comprising the undisturbed performance of the planned facility, assumed incidents, the thermal influence upon the host rock, the nuclear criticality safety and the radiological long-term effects in the post-closure phase (Brennecke 1994). They represent a flexible system of requirements and provide several alternatives and different options for waste package qualification depending mainly on criteria concerning radionuclide inventory, waste form, and packaging.

The permissible radionuclide inventory per waste package is specified

- for various waste forms and packaging tightness levels resulting from the safety assessment of normal operation,
- for various waste form groups and packaging integrity levels (waste container classes I and II) resulting from the safety assessment of incidents,
- for various packaging types to limit the heat output resulting from the safety assessment of the decay heat influence upon host rock, and
- for various packaging types to guarantee nuclear criticality safety in case of fissile contents resulting from the criticality safety assessment.

These limits are independent of one another and the most restrictive one has to be applied (Brennecke 1994). The requirements of a uniform activity distribution in case of cemented/concreted waste and the limitation of fissile material concentration to 50 g per 0.1 m^3 of waste volume are of special relevance to transport issues.

There are various types of cylindrical concrete packagings, cylindrical cast iron packagings, and container type packagings, which are standardized according to the operational requirements of the Konrad repository (Brennecke et al. 1987).

The waste packagings can be assigned to two waste container classes I and II having different integrity levels concerning their mechanical and thermal stability under incident conditions in addition to the basic requirements they have to meet (Brennecke 1994).

Finally each waste package must not exceed the following dose rate and contamination limits:

Dose rate limits:

• at surface - maximum value	: 10	mSv/h
• at surface - mean value	: 2	mSv/h
• at 1 m distance from cylindrical packages	: 0.1	mSv/h
• at 2 m distance from containers	: 0.1	mSv/h

The nonfixed surface contamination is limited to

• 0.5 Bq/cm^2	for alpha emitters having an exemption limit (according to the German Radiation Protection Ordinance) of 5 x 10^3 Bq
• 50 Bq/cm^2	for beta emitters and electron capture nuclides having an exemption limit of 5 x 10^6 Bq
• 5 Bq/cm^2	for other radionuclides

MORSLEBEN DISPOSAL REQUIREMENTS ON WASTE PACKAGES

The waste acceptance requirements for the Morsleben repository result from

- specifications given in the license of the repository, and
- additional safety assessments of the operational and post-closure phase of the repository similar to the Konrad facility.

According to the license, only solid radioactive waste with a maximum α-activity concentration of 0.4 GBq/m³ or spent sealed radiation sources are accepted. These wastes are classified by special radiation protection groups, as shown in Table 1, which limit the radioactive contents of the waste by dose, β/γ-activity concentration or activity per source.

Table 1. Classification of wastes for Morsleben Repository (Kugel et al. 1993)

Radiation Protection Group	Solid Wastes		Sealed Sources
	Dose rate [1)2)] mSv/h	β/γ-activity concentration [2)] GBq/m³	Activity per source GBq
S1	< 2	< 4	< 0.2
S2	2 - 10	4 - 40	0.2 - 2
S3	10 - 100	40 - 400	2 - 20
S4	100 - 500	400 - 4000	20 - 200
S5	500 - 1000	4000 - 40000	

[1)] at 0.1 m distance from the unshielded surface
[2)] in case of inconsistency the higher Radiation Protection Group has to be used

There are additional radionuclide-specific limitations of the activity concentration of the waste resulting from the above mentioned safety assessments. All these limits are independent of one another and the most restrictive one has to be applied. They were derived from safety assessments of the post-closure phase of the repository as well as of the undisturbed operation, incidents and the nuclear criticality safety taking into account the properties of different waste products and waste packagings (Kugel et al. 1993).

The waste product must meet basic requirements and must be assigned to one of six quality levels (Kugel et al. 1993). The quality level 1 meets the basic requirements. With increasing quality level an increasing mechanical and thermal stability of the waste product is required. Quality level 6 products, e.g. ,are cemented/concreted wastes with a uniform activity distribution.

Finally from the criticality safety assessment results the limitation of fissile material concentration of U-235 to 15 g per 200 l of waste volume (Kugel et al. 1993).

Besides the well-known 200 l and 400 l drums there are various standardized packagings of the types primary container (PC) and drum container (FC) for the Morsleben Repository (Kugel et al. 1993). The 2 types of PC have a net volume of 0.75 m^3 (PC 18) and 1.1 m^3 (PC 84). The 5 FC-types (FC 40, 50, 70, 75, 100) are designed to contain a 200 l drum. They provide different shielding capability.

All types of PC and FC are reusable which is different from the „lost" packagings for the Konrad repository. They are of cylindrical shape and made from steel. In case of FC 40, FC 70, and FC 100 there is a sandwich shielding wall design of steel-lead-steel. The appropriate packaging has to be used depending on the radiation protection group and the quality level of the waste.
Finally, each waste package must not exceed the following dose rate and surface contamination limits (Kugel et al. 1993):

• dose rate at 0.1 m distance from the surface		: 2	mSv/h
• nonfixed surface contamination	for α-emitters	: 0.5	Bq/cm²
	for β/γ-emitters	: 5	Bq/cm²

There are also five types of standardized reusable packagings for sealed sources up to a maximum activity of 200 GBq for Co-60 (Kugel et al. 1993).

TRANSPORT REQUIREMENTS ON WASTE PACKAGES

The radioactive waste in Germany has to be shipped according to the GGVS (GGVS 1995) on road and the GGVE (GGVE 1993) on rail, which are based on the IAEA Transport Regulations (IAEA 1990), Safety Series No. 6 (SS6).

The regulations for low specific activity material (LSA) of SS6 are mainly applied in case of waste shipments, which leads to the following requirements for the relevant waste packages.

The waste form has a limited specific activity and can be assigned to LSA-II or LSA-III category according to para 131 (b) or (c) of SS6.

In the case of LSA-II, the activity is distributed throughout the waste form and the estimated average specific activity does not exceed 10^{-4} A_2/g (A_2-radionuclide specific limit defined in SS6).

In the case of LSA-III, it is required that

- The radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, etc.);
- The radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble matrix, so that, even under loss of packaging, the loss of radioactive material per package by leaching when placed in water for 7 days would not exceed 0.1 A_2; and
- the estimated average specific activity of the solid, excluding any shielding material, does not exceed 2 x 10^{-3} A_2/g.

LSA-II and LSA-III material has to be shipped in industrial packagings Type 2 and 3 (IP-2, IP-3) according to para 426 of SS6. They must meet the general design requirements (para 505-514) and, in addition, in case of IP-2 the free drop test (para 622) and the stacking test (para 623), and in case of IP-3 all Type A design requirements and Type A tests for solids. By these tests it is demonstrated that the package can withstand normal conditions of transport. Alternatively freight containers may also be used as IP-2 or IP-3 provided they meet the general design requirements and the ISO 1496/1-1978 requirements ("Series 1 Freight containers - Specifications and Testing - Part 1: General Cargo Containers") according to para 523.

The total quantity of LSA material in a single IP-2 or IP-3 package shall be so restricted that the external radiation level at 3 m from the unshielded material does not exceed 10 mSv/h (para 422). In addition, in case of combustible solid LSA-waste in IP-2 or IP-3 the total activity per conveyance is limited to 100 A_2 (para 427).

IP-2 or IP-3 waste packages must not exceed the following external radiation and contaminations limits:

Dose rate limits:

	non-exclusive use	exclusive use
- at the package surface	: 2 mSv/h	10 mSv/h
- at 1 m from the package surface	: 0.1 mSv/h	
- at the external surface of the conveyance	: 2 mSv/h	2 mSv/h
- at 2 m from the external surface of the conveyance	: 0.1 mSv/h	0.1 mSv/h

The nonfixed surface contamination is limited to

- 4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters, and
- 0.4 Bq/cm^2 for all other alpha emitters

If radioactive waste materials can be classified as surface contaminated object SCO-II according to para 144 of IAEA Regulations than also IP-2 packagings have to be used with the requirements as described above for LSA-material.

COMPARISON BETWEEN DISPOSAL AND TRANSPORT REQUIREMENTS ON WASTE PACKAGES

A waste package has to meet both transport and disposal requirements. In comparing both the determining waste package criteria can be derived. Based on such a comparison of the transport requirements with the Konrad and Morsleben disposal requirements the following conclusions can be drawn:

External Radiation and Surface Contamination

These criteria are limited in a similar way, so that in most cases compliance with transport requirements results also in compliance with disposal needs for the Konrad as well as Morsleben repository.

Waste Form

Basically each waste form may be categorized as LSA-material provided that compliance with the described definition can be demonstrated. The main criterion besides the limited leachability of LSA III is the sufficient activity distribution throughout the waste product. This criterion, for example, is already met by disposal needs in case of the waste form group 05 (Konrad) or waste of quality level 6 (Morsleben). In the other cases, this has to be checked in addition to the disposal requirements for the waste form.

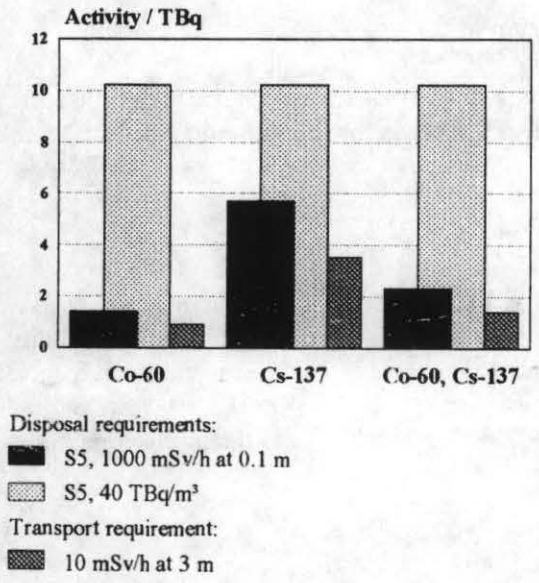
Activity Inventory

The permissible activity inventory of the waste package is determined by the most restrictive limit resulting from the described disposal and transport requirements. For transport these limits have to be derived from the requirements for specific activity, unshielded dose rate at 3 m distance and total activity per conveyance depending on the radionuclide mixture, the material, and the volume of the waste.

For the Konrad repository the described disposal limits concerning normal operation, incidents, decay heat and criticality have to be considered and compared with the transport limits. The resulting permissible activity inventory of the waste package is obtained depending on the radionuclides, the form and packaging group of the waste. In case of Co-60 and Cs-137 as relevant radionuclides of waste originating from nuclear power plant operation, for example, the total activity of the waste package is mainly restricted by the unshielded dose rate limit of 10 mSv/h from transport and by decay heat limits from disposal (Nitsche and Collin 1994). In principle, compliance with this 10 mSv/h criteria is to be expected for waste shipments to the Konrad repository by meeting the external radiation limits of the package, because the standardized Konrad packagings have a limited shielding capability (Nitsche and Collin 1994).

For the Morsleben repository the following conclusions can be drawn. Solid wastes of the radiation groups S1 to S4 will also meet transport requirements due to their very limited α-activity concentration and the limited doses rates and β/γ-activity concentrations. In the upper range of S5-wastes the activity inventory for γ-emitting radionuclides will be restricted by the unshielded dose rate of 10 mSv/h at 3 m distance from transport. A concreted 200-l drum (ρ= 2,35 g/cm^3) containing Co-60 with the maximum S5 dose rate for example exceeds the 10 mSv/h criterion by a factor of 1.6. If the maximum S5-γ-activity concentration is assumed, this criterion will be exceeded even by a factor of about 12, as shown in Figure 1.

Figure 1. Activity limitations of a concreted 200 litre drum package containing Co-60 and Cs-137 according to transport and disposal requirements for the Morsleben repository.



Fissile Material Contents

Due to the disposal limitation of fissile material concentration to 50 g per 0.1 m^3 for the Konrad repository, which is in compliance with the transport requirement of fissile exempted material (para 560 (d), IAEA 1990), such a waste package is excepted from the special transport requirements for packages containing fissile material, provided the activity is uniformly distributed. The same conclusion can be drawn with respect to the Morsleben repository.

Packaging

For the Konrad repository the IP-2 or IP-3 qualification of the package according to transport requirements gives high credit to meet the basic package requirements from disposal. In particular, it meets the mechanical integrity requirement under impact velocity condition of 4 m/s for waste container class I up to a package mass of 10 metric tons. In addition to transport packaging requirements, for waste container class I qualification for disposal, the package behavior under fire conditions (800 °C, 1 h) has to be taken into account as well as for class II qualification together with the 5-m drop test. For the Morsleben repository the required qualification of the reusable packagings according to the transport requirements is also sufficient for disposal needs.

SPECIAL APPLICATION ASPECTS OF LSA/SCO-REGULATIONS TO WASTE SHIPMENTS

Concerning the range of applicability of LSA/SCO-Regulations to waste shipments, it can be expected that in case of the planned Konrad repository more than 95 % and for the Morsleben site almost all solid wastes can be shipped on the basis of LSA/SCO-transport requirements. It has to be taken into account however that in case of γ-emitting waste products the external radiation limit from the unshielded material can become the limiting factor for the permissible contents of a waste package as long as LSA- or SCO-Regulations are applied. If the reusable Morsleben packagings with high shielding capability are used this restriction specially has to be considered, because the compliance with the external radiation limits of the package, which has to be demonstrated for each shipment, does not guarantee compliance with the external radiation limit from the unshielded contents. In such a case appropriate restriction on the activity contents of the waste package is necessary.

The application of LSA/SCO-Regulations seems to be difficult if the waste itself is radioactive and also surface contaminated (activated and contaminated product). In such cases, the waste shipment has to meet both LSA as well as SCO requirements. Subjecting the waste product to LSA, as well as to SCO - Regulations, leads to the conclusion, that the same criteria have to be met, except that for non-combustible solid LSA-II and LSA-III-Material higher conveyance activity limits are allowed compared to SCO. Therefore, a waste product which has a specific activity according to LSA-II or LSA-III-definition and a surface contamination level according to SCO-definition can be shipped according to LSA-Regulations but with the additional requirement, that the conveyance activity limits of 100 A_2 or 10 A_2 for SCO according to Table VI of IAEA Transport Regulations, Safety Series No. 6, has to be applied.

CONCLUSIONS

For radioactive waste intended for disposal in the planned Konrad repository or in the existing Morsleben repository, both transport and disposal requirements have been taken into account in the qualification of the waste package. In particular, requirements on waste form, radionuclide

inventory, and packaging have to be examined to derive the limiting parameter for the waste package design. Depending on the criteria considered credit can be taken from transport as well as from disposal requirements. Such considerations seem to be helpful to optimize waste-management processes from the conditioning to the disposal including transport.

For the shipment of low/intermediate level waste to the repositories it, can be expected that in case of the planned Konrad repository more than 95 % and for the Morsleben repository almost all solid wastes comply with LSA-transport requirements of IAEA-Regulations, Safety Series No.6. Special attention should be paid to the external dose rate limit of 10 mSv/h at 3 m distance from the unshielded waste product if packagings with high-shielding capability are used to ship γ-emitting waste products. The LSA-Regulations are also applicable to activated and surface contaminated waste products, if in addition the SCO-conveyance activity limits are met.

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