Implementation of Requirements on Non-Radioactive Waste Package Constituents – 10449 rev.

Peter Brennecke* / Karin Kugel* / Stefan Steyer*
Wilma Boetsch** / Detlef Gruendler** / Claudia Haider**
* Bundesamt für Strahlenschutz, Salzgitter, Germany
** Institut für Sicherheitstechnologie, Cologne, Germany

ABSTRACT

In radioactive waste disposal, attention must be paid not only to radiological impacts but also to impacts of chemotoxic waste package constituents. Thus, in order to demonstrate the safety of a geological repository in the post-closure phase, the possible releases of non-radioactive organic and inorganic substances via the water pathway are to be investigated. Within the licensing procedure for the Konrad repository it was shown that such constituents may or may not reach the near-surface groundwater in a quantity so small as to obviate the danger of its harmful pollution or a detrimental change of its characteristics. Based on those findings, the licensing authority issued the permitted levels of water-related properties as Annex 4 to the Konrad license. This included, in particular, quantitative limitations on maximum masses of 94 non-radioactive substances (waste package constituents). The determination of these limits and their implementation into practicable measures for the waste generators and conditioners, as well as for Bundesamt für Strahlenschutz (BfS - Federal Office for Radiation Protection), being the licensee and operator of the Konrad repository, is one of the most important challenges currently faced. Principal results are included in an amendment (draft) of the Konrad waste acceptance requirements as of October 2009.

INTRODUCTION

The safety of a repository - being a near-surface facility or a disposal mine in deep geological formations - is generally demonstrated by performing a site-specific safety assessment comprising, inter alia, the normal operation, assumed incidents and not excludable releases of radionuclides in the post-closure phase. Such a safety assessment commonly addresses radiological aspects and, depending on the site-specific circumstances, particularly the calculation and limitation of radiation exposures to the staff and the environment of the repository.

Waste packages to be disposed of mainly consist of non-radioactive organic and inorganic substances including, e.g., chemotoxic constituents such as cadmium, lead or mercury. The chemical composition of such substances is of importance from a groundwater pollution perspective. Thus, attention must additionally be paid to the chemical composition of the radioactive waste, the immobilization material (if used) and the waste containers/packagings. In the past insufficient attention had been paid to harmful waste package constituents and their possible impact on human health and the environment. On the other hand, such issues raised especially in the long-term management of uranium mill tailings and tails originating from uranium enrichment plants.

INTERNATIONAL ISSUES

Regulations and experiences with respect to non-radioactive substances and their assessment in radioactive waste disposal are rather limited. Existing regulations on the protection of groundwater (e.g.,

European Communities' Council Directive 80/68/EEC) are addressing the non-nuclear area and, in the lack of respective radioactive waste disposal related regulations, may alternatively be applied. Experiences on the chemical characterisation of waste packages, for instance regarding certain harmful substances, are only available for a few repositories (e.g., Centre de l'Aube, France) or repository projects (e.g., Wellenberg, Switzerland).

European Communities' Council Directive 80/68/EEC

About thirty years ago the European Communities issued the "Council Directive of 17 December 1979 on the Protection of Groundwater against Pollution Caused by certain Dangerous Substances (80/68/EEC)" [1].The purpose of this directive is to prevent the pollution of groundwater by substances given in its annex and as far as possible to check or eliminate the consequences of pollution which has already occurred. The annex contains in two lists numerous organic and inorganic harmful substances (elements and compounds) the discharge of which into the groundwater is to be prevented or to be limited in order to ensure its effective protection. These substances may be referred to when investigating the chemical composition of waste packages to be disposed of and assessing the potential impact of such constituents on the near-surface groundwater.

Centre de l'Aube Repository, France

In France, the Centre de l'Aube repository in the near of Soulaines-Dhuys, Departement Aube/Haute-Marne, started its operation on January 13, 1992. This near-surface facility is designed to accept up to 1,000,000 m³ short-lived low-level waste (LLW) and intermediate-level waste (ILW).

Radioactive waste disposed of in Centre de l'Aube might contain toxic chemical elements or toxic material the quantity of which must be limited [2]. Such elements and material are

- lead, boron, nickel, chromium (including Cr VI), arsenic, antimony, selenium, cadmium, mercury, beryllium, cyanides (CN^-), uranium, and asbestos.

The occurrence and the possible impact of these 13 substances were part of the Centre de l'Aube long-term impact assessment being based on French and European regulations on the quality of drinking water and the disposal of hazardous waste. With respect to their release via the water and air pathways, the same scenarios as for radionuclides were applied.

GERMAN SITUATION

The Konrad Repository

In the Federal Republic of Germany, solid or solidified radioactive waste with negligible heat generation (i.e., LLW and ILW) containing short-lived and long-lived radionuclides will be disposed of in the Konrad repository at an emplacement depth of approximately 800 m. This facility is located in the northern part of Germany near Salzgitter-Bleckenstedt, federal state of Lower Saxony. The Konrad repository is under construction since May 2007. Its start of operation is envisaged for 2014.

The fundamental safety principle of radioactive waste disposal, i.e., the protection of man and the environment, has been reflected in the licensing prerequisites for the Konrad repository, too. Thus, as part of the post-closure safety assessment, the radiological long-term effects (radionuclide-specific radiation exposures) as well as the potential pollution of the near-surface groundwater by non-radioactive organic and inorganic waste package constituents were investigated and evaluated. The latter particularly took

into account the principle of concern of section 34 “Reinhaltung” (Keeping Pure) of the Wasserhaushaltsgesetz (WHG - Water Resources Management Act).

Legal Regulations Relating To Water

According to Section 34 of WHG, substances may only be stored or disposed of in such a way that a harmful pollution of the groundwater or another detrimental modification of its characteristics is not to be feared [3]. This principle of concern is put in more concrete terms in the Grundwasserverordnung (Groundwater Ordinance) of March 18, 1997 [4] implementing the above-mentioned Council Directive 80/68/EEC [1] into German law. This ordinance mainly serves for clarification or interpretation of the WHG skeleton regulations on the protection of groundwater.

The investigation and evaluation of a potential pollution of the near-surface groundwater was performed within the Konrad licensing procedure. The results served as basis for the requisite allowance according to water law. Procedures and selected results of this investigation of concern are given in [5].

Konrad Water Law Permit

The allowance according to water law is given in Annex 4 to the Konrad license issued on May 22, 2002. It quantitatively stipulates the maximum masses of 94 non-radioactive harmful substances (elements and organic/inorganic compounds) to be disposed of in the Konrad repository. These masses are indicated in comprehensive tables classified by

- substances referring to the lists I and II in the annex of the Groundwater Ordinance [4], and
- other substances which may cause a potential pollution of the groundwater in terms of Section 137 of the Niedersächsisches Wassergesetz (NWG - Water Act of Lower Saxony) [6].

Emplacement of such substances in addition to the radiological inventory (i.e., maximum allowable activities according to the Konrad waste acceptance requirements [7]) is only admissible if explicitely mentioned in the permit, and if the maximum masses are not exceeded. In Table I an extract from those tables being included in the allowance according to water law is given.

Table I : Extract of the List of Harmful Substances (Konrad Water Law Permit).

Substance	Maximum Allowable Mass [kg]	Substance	Maximum Allowable Mass [kg]
Iron	632,000,000	Gold	1,470
Calcium	180,000,000	...	
Lead	33,400,000	Oxalic Acid	741
Aluminum	32,000,000	...	

Table I : Extract of the List of Harmful Substances (Konrad Water Law Permit). (ctd.)

Substance	Maximum Allowable Mass [kg]	Substance	Maximum Allowable Mass [kg]
Titanium	18,400,000	Mercury	43.7
Magnesium	7,650,000	Beryllium	24.5
Sodium	5,860,000	...	
Nickel	5,530,000	Platinum	10.3×10^{-3}
Potassium	3,480,000	...	
...		Biphenyles	1.72×10^{-3}

It must be pointed out that the maximum masses of all 94 harmful substances as imposed by the competent licensing authority in Annex 4 to the Konrad license (allowance according to water law) result from an inquiry into the chemical composition of radioactive waste intended for disposal in the Konrad repository. The data supplied by the waste generators and conditioners were used as input data for the safety-related investigations performed within the licensing procedure [5]. Thus, the maximum masses specified in the permit (cf. Table I) do not represent results of those investigations. From a safety point of view much higher masses could be accepted without any fear of a harmful pollution of the near-surface groundwater or a detrimental change of its characteristics.

In addition to the maximum masses of harmful substances, the Konrad allowance according to water law comprises further requirements to be dealt with. The permit states that BfS shall monitor radioactive waste intended for disposal with respect to its chemical composition. The actually emplaced radionuclides as well as the emplaced non-radioactive harmful substances must continuously be registered and balanced. The substances contained in already existing conditioned waste (i.e., previously generated waste) shall be estimated.

These requirements are defined more precisely in the permit:

- A chemical analysis of the waste package contents is not required for monitoring, registering and balancing the harmful substances.

- Trace impurities may be left unconsidered for the determination of the amounts and balance of harmful substances. Trace impurities may include substances mentioned in the permit as well as other substances whose amounts cannot be quantified. Trace impurities must only occur in such amounts not causing detrimental changes to the near-surface groundwater.

- A quantitative registration is impossible for already existing conditioned waste. From radiation protection perspective it is unadvisable to open waste containers and analyse their content. In these cases, an estimation of the mass of harmful substances must be a sufficient basis.

IMPLEMENTATION OF THE KONRAD WATER LAW REQUIREMENTS

Basic Concept

The transfer of the requirements imposed in the Konrad allowance according to water law should preferably be carried out in a way offering procedures and measures being practicable for both the waste generators and the BfS as operator of the Konrad repository. Thus, as basic concept, the development and introduction of so-called material vectors was pursued [8]. The concept is based on the idea that, in general, all waste packages intended for disposal in the Konrad repository must chemically only once be characterized. For this purpose data on non-radioactive harmful substances contained in a waste stream (e.g., ion exchange resins), waste form, waste container, waste package or charge of waste packages including, if applicable, immobilization material and material used to fill up residual voids, are to be compiled in a comprehensive materials list. In addition, data on waste containers/packagings including interior linings are to be described and quantified in the containers list. Thus, the materials list and the containers list being available, it is sufficient to refer to those data being applicable when radioactive waste is registered for disposal in the Konrad facility. On the basis of these data, BfS will easily register and balance the masses of non-radioactive harmful substances.

Description of the Radioactive Waste Composition

Following the basic concept, the non-radioactive harmful substances which are contained in radioactive waste with negligible heat generation must be registered and described according to their type and amount [9]. The waste generators are responsible for supplying the information and data needed. To this end, all waste package constituents exceeding the relevant description threshold values have to be indicated. These values describe the fraction of a non-radioactive harmful substance contained, e.g., in a waste form, waste container, waste package or charge of waste packages, which must be indicated with respect to the chemical composition. The description threshold value thus defines how accurately non-radioactive substances must be described. It is to be noted that newly generated waste (i.e., radioactive waste generated subsequent to the validity of the water law permit in March 2007) is subject to a description threshold value of 1 % of the gross waste package mass, while previously generated waste (legacy waste) existing prior to that validity date is subject to a threshold value of 5 % of the gross waste package mass. The appointment of the 1 % and 5 % values resulted from an expert meeting dealing, inter alia, with the possibilities and accuracies to specify harmful waste package constituents. In this meeting representatives of the nuclear power plants and the nuclear research establishments were included.

For the description usually common material names such as concrete or glass according to the materials list shall be used. The precision of the description of each material is specified through the description threshold values. While the waste generator has to describe harmful waste portions only above the description threshold value, BfS operating the Konrad repository has to declare harmful waste portions arising above the declaration threshold value. The declaration threshold value defines the percentage mass fraction of a harmful substance which, if exceeded, must be balanced. Both the description threshold values and the declaration threshold values are included in the materials list as well as in the October 2009 draft of the Konrad waste acceptance requirements [7]. If the description threshold values are exceeded, detailed information on the non-radioactive harmful substances is required. If the declaration threshold values are exceeded, respective masses are balanced. BfS will balance the masses of harmful constituents during the complete operational lifetime of the Konrad repository as well as for each year of operation. Masses of harmful substances not exceeding the threshold values are neither to be indicated nor to be balanced (trace impurities).

Materials List

The materials list contains information and data of numerous non-radioactive materials relevant for radioactive wastes [10]. Up to now, the material list consists of more than 700 items, which can be subdivided to three basic groups:

- Group 1 contains the 94 substances listed in the Konrad water law permit together with their relevant compounds. For example, mercury is listed in the permit. However, mercury(I)-chloride, mercurysulfide, mercury(II)-nitrate etc. have to be taken in consideration, too. By this, approximately 300 substances belong to group 1.

- Group 2 considers common basic material appearing in radioactive waste such as concrete, glass or textiles. Group 2 includes approximately 100 items.

- In group 3 waste generator-specific data are compiled. Examples for group 3 items are evaporator concentrates or core components of an individual nuclear power plant as well as miscellaneous waste originating from smaller waste generators (e.g., universities, industry and hospitals).

Thus, by using the items of the materials list supplied by the waste generators, BfS has all information on radioactive waste composition available. The hazards of the respective substances, being also part of the material list, determine whether the respective substance has to be registered and balanced.

Containers List

In supplement to the materials list, there is the containers list containing information and data on all waste containers and packagings used for the disposal of radioactive waste in the Konrad repository. By choosing just an item from this list for a required description all information on the respective container is provided for registering and balancing.

Validation of the Implementation

The implementation of the Konrad water law permit as described so far represents a tool easily to be applied by both the waste generators and conditioners, as well as by the operator of the Konrad repository. However, prior to application, the procedure has to be validated with respect to demonstrate that the protection goal of water law is met [10]. The criteria for this validation are stated in the allowance. Accordingly, the concentration in the near-surface groundwater must not exceed maximum allowable concentrations. Such concentrations are stated in applicable regulations due to the water law. They are part of the Konrad water law permit, too. In principle, the validation is rather simple. The maximum allowable concentration in the deep groundwater is the product of the maximum allowed concentration in the near-surface groundwater and the dilution factor, which is set to 10^4 in the water law permit.

$$c_{\max,i,dgw} \leq c_{\max,i,nsgw} \times f \qquad (1)$$

with

$c_{\max,i,dgw}$ maximum concentration in the deep groundwater of substance i,

$c_{\max,i,nsgw}$ maximum concentration in the near-surface groundwater of substance i, and

f dilution factor (10^4).

If the concentration in the deep groundwater, resulting from the declaration threshold value and the solubility of the substance, do not exceed the maximum value from eq. (1), the requirement of the water law permit is met.

For substances with a higher solubility in the deep groundwater a declaration threshold value has to be determined that fulfills relation (2):

$$c_{\max,i,dgw} \leq \frac{D_i \times m_{tot.}}{V_{dgw}} \qquad (2)$$

with

$c_{\max,i,dgw}$ maximum concentration in deep groundwater of substance i,

D_i declaration threshold value of material i,

$m_{tot.}$ total waste package mass in the Konrad repository (600,000 Mg), and

V_{dgw} volume of the deep groundwater (1,000,000 m^3).

For most of the substances in the Konrad water law permit the harmlessness can be verified. However, there are substances, in particular harmful materials with a high solubility, in the case of which a special analysis has to be carried out taking into consideration the realistic appearance in the radioactive wastes and the percentage of the compounds to the respective material groups. These extended investigations are much more complicated, especially with respect to the appearance of such substances in the radioactive waste and the assessment of the respective chemical compounds. Nevertheless, respective calculations and examinations resulted in a confirmation of the approach pursued by BfS.

Unfortunately, the waste generators and conditioners only supplied very few comments on the items compiled in the material and container lists. As a consequence, when performing those calculations and examinations, assumptions and model data must be used. Thus, it was decided to revise the approach and to use model items (material vectors) and include them into the materials and containers lists. These items should be supplemented in a step-by-step procedure with waste generator-specific data on individual (real) waste streams. This procedure is in progress. It is assumed that it will result in well-defined, examined and confirmed items (waste streams) which may be used in future when the disposal of radioactive waste in the Konrad repository is applied for.

MATERIAL WASTE PACKAGE QUALITY CONTROL

According to the Konrad water law permit the material waste package quality control is to be prepared and implemented in addition to the existing radiological waste package quality control. These quality control measures serve to demonstrate the compliance of waste packages to be disposed of with the Konrad waste acceptance requirements.

The approach of the material waste package quality control is, inter alia, based on the following principles [10]:

- Investigations into specific harmful substances or material with low declaration threshold values have only to be performed in case of reasonable suspicion.

- Complete analyses for the determination of material data are not demanded.

- Principles of radiation protection must be considered.

To minimize efforts and radiation exposures, the control measures on non-radioactive waste package constituents are embedded in the well-established and successfully performed radiological waste package quality control. Thus, adequate protection of the near-surface groundwater can be assured by appropriate control measures to be performed in parallel to the radiological control measures. According to this procedure, there are no new quality control principles to be introduced. The existing options process qualification, sampling and waste container examination are appropriately to be extended and enlarged due to the aspects being of relevance for non-radioactive harmful substances. Nevertheless, this approach offers the opportunity to use existing information on the chemical composition, e. g., results of analyses being performed within the scope of the radiological waste package quality control, thus reducing additional expenditures and proofs. Table II illustrates the additional measures that have to be performed during process qualification due to the requirements originating from the Konrad water law permit.

Table II : Basic Steps of a Process Qualification.

Previous Procedure	Additional Measures Required
Application for process qualification	
Submission of a process control quality plan with the necessary steps for the production of waste packages in compliance with the waste acceptance requirements	Inclusion of additional steps for the characterization and checking of the material composition
Submission of documents on the quality and quantity of the waste	Assignment of entries from the list of compositions for the description of the material composition
Assessment of the process and identification of the required control measures	Assessment of the procedure for the declaration of the material composition (evaluation of the applicability of material vectors)
Approval of the process control quality plan by BfS	Not applicable
Treatment of the waste according to the process control quality plan under accompanying control by independent experts	Comparison of the waste and the containers with the assigned entries from the list of compositions
Documentation of the results of the accompanying control measures in an inspection report by the independent expert	Additional aspects with respect to the material composition
Compilation of a documentation of the radioactive waste package	Description of the material composition
Evaluation of the documentation by an independend expert on behalf of BfSs	Verification of the plausibility of the description of the material composition
Approval of the compliance with the waste acceptance requirements by BfS	Not applicable

The additional measures do not comprise comprehensive and/or detailed checks and examinations.

CONCLUSION

The Konrad allowance according to the water law addresses new safety-related aspects in radioactive waste disposal which, up to now, have rather insufficiently been considered. Thus, BfS has faced the challenge to develop and to implement practicable measures for the transfer of the limitations and requirements given in this permission. Main topics such as the development and introduction of the material vectors, the treatment of uncertainties regarding a proper chemical characterization and suggestions how to deal with rather small allowable masses for certain waste package constituents have often been presented and discussed with the waste generators and conditioners. Although the final implementation of the concept is still pending, more and more waste generators and producers of waste containers are submitting information and data on selected waste streams and packagings for testing purposes and for gaining experience in the application of the system developed by BfS. According to the current status, an implementation including the revised Konrad waste acceptance requirements and the measures for waste package quality control may be expected by mid-2010.

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