Experience with the Quality Control of Radioactive Waste Packages for the German Repository Konrad - 16493

Fabienne Anton, Anne Glindkamp, Elke.-D. Kohlgarth, Daniel Schaper, Tobias Wels, Ralf Ohlhof
TÜV NORD EnSys Hannover GmbH & Co. KG

ABSTRACT

The German repository Konrad for radioactive waste with negligible heat generation is designed to accept 303,000 m^3 of waste packages in total. Based on the Konrad licensing conditions, any treatment and conditioning of radioactive waste should be planned and carried out in accordance with the waste acceptance requirements of the repository Konrad in order to produce waste packages suitable for disposal. The qualification of the waste treatment processes and the resulting products are achieved by interaction of different parties involved. On behalf of the Federal Office for Radiation Protection – the competent German authority for disposal of radioactive waste - TÜV NORD EnSys Hannover GmbH & Co. KG acts as one of the independent expert organizations for more than twenty years in the field of qualification of waste treatment campaigns and review of waste packages documentations.

The permitted amount of nuclide activity in the radioactive waste packages depends on the characteristics of the radioactive waste products. Projecting a suitable strategy for loading the waste containers contributes to determine in advance, what requirements the radioactive waste products have to fulfill as well as what properties of the waste products need to be verified and documented during conditioning or treatment process. On the basis of various examples, it is being demonstrated how appropriate advance process planning can ensure that radioactive waste packages are generated to comply with the waste acceptance requirements. In consequence, technical measures due to requalification can be avoided even in case of unpredictable difficulties.

INTRODUCTION

Due to the operation, decommissioning and/or dismantling of nuclear facilities, e.g. nuclear power plants, nuclear industry, reprocessing facilities, research and development establishments, the amount of radioactive waste continuously increases. Consequently, it entails the necessity for an appropriate disposal of radioactive waste.

In Germany, radioactive waste disposal is a federal task. The Atomic Energy Act (AEA) assigned the responsibility for radioactive waste disposal to the Federal Government with the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB - Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit) as competent ministry. The legally responsible authority for performing this task is the Federal Office for Radiation Protection (BfS - Bundesamt für Strahlenschutz).

All radioactive waste in Germany has to be disposed - based on a government decision - in deep geological formations within the country. According to this decision only solid and solidified radioactive waste is accepted for disposal. Liquid and gaseous radioactive waste is excluded from disposal and therefore need to be appropriately processed. This presupposes the necessity of pre-treatment, conditioning and packaging processes of the radioactive waste in order to produce waste packages suitable for emplacement in a repository. Thus, a safe management procedure applicable for different measures, procedures, documentations of waste characteristics regarding the conditioning and quality assurance process for the disposal of radioactive waste is required.

According to the German approach, radioactive waste is basically subdivided into waste with negligible heat generation (i.e., low-level waste (LLW) and intermediate-level waste (ILW)) and heat-generating waste (i.e., high-level waste (HLW) and spent nuclear fuel (SNF)). About 90 % of the radioactive waste accruing in Germany is classified as waste with negligible heat generation.

It is intended to dispose of radioactive waste with negligible heat generation in the repository Konrad.

THE KONRAD REPOSITORY

In 1982 a plan approval (licensing) procedure for the German repository Konrad was started. The abandoned iron ore mine (see Fig. 1) located in the Federal State of Lower Saxony (Niedersachsen) was investigated for the disposal of short-lived and long-lived radioactive waste with negligible heat generation originating from electricity generation using nuclear energy and application of radioactive substances for medical, industrial, research and commercial purposes in Germany.

The license was issued on May 22, 2002 by Lower Saxonian Ministry for the Environment [1], for the emplacement of waste packages of 303,000 m^3 at maximum in 800 m to 1,300 m below ground level. After public complaints were dismissed by the Federal Administrative Court on March 26, 2007, a legal and unappeasable licensing decision for the Konrad repository was fixed.

The emplacement operation of the repository is expected to last for 30 or 40 years.

Up to now the repository Konrad is in the phase of construction and installation of technical equipment. The estimated start of operation will be in 2022 [2].

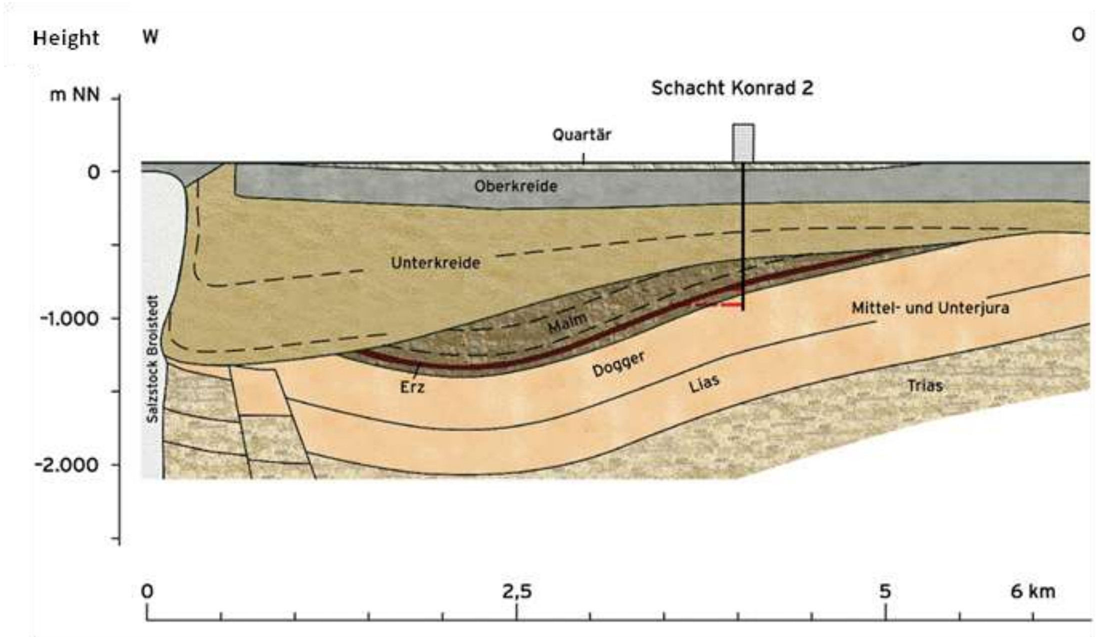

Fig. 1: Geological formations near the Konrad mine. The repository is marked in red and is situated in a layer of iron ore between two layers of clay stone [3].

According to German Radiation Protection Ordinance any treatment and conditioning process leading to waste packages for the disposal in the repository Konrad must be assessed by the BfS. This task is conducted on the basis of the Konrad waste acceptance requirements and the waste package quality control and assurance process - established by the BfS - published in 1995 for Konrad and endorsed during the licensing procedure for this facility. By now, treatment and conditioning of radioactive waste is carried out based on the waste acceptance requirements in order to ensure that sufficient amounts of waste packages are ready for disposal when the repository is ready for operation.

In addition to the actual construction work further requirements imposed by the licensing authority in the Konrad license had to be realized and implemented (e.g. declaration and limitation of the mass of nonradioactive harmful substances, limitation and regulations with regard to fissile material). Revised waste acceptance requirements were published in 2010 in which the licensing conditions were implemented [4], [5]. No major changes of the requirements, except some formal aspects, are expected in further revisions.

Waste Acceptance Requirements (Status 2010)

The waste acceptance requirements specify various requirements for radioactive waste with negligible heat generation. These are developed on the basis of site-specific safety assessments results with regard to normal operation, accident safety, thermal influencing of the host rock, criticality safety and radiologic long-term effects.

The requirements are subdivided in:

- general requirements concerning the waste package itself (like dose rate, contamination, overpressure)
- requirements arising from the waste form (e.g. solid, flammable, meltable, cemented, super compacted)
- requirements to the waste packing due to geometry, stability and leak tightness
- requirements to the limitations of the activity of individual radionuclides and the total activity as well as on the mass and activity of fissile materials
- requirements to nonradioactive harmful substances in the waste packages

Based on the performed safety analyses individual restrictions for the activity of radioactive nuclides were deduced according to the waste form and packing. In general, these requirements based on the different analyses have to be fulfilled by the waste packages. The allowed activity of the content increases with the stability of the waste product in regard to mechanical and thermal impact of an accident.

With respect to the pollution of near-surface groundwater the license for the repository Konrad also contains regulations on the declaration and limitation of the mass of nonradioactive harmful substances in the waste packages. A special methodology was developed to describe and control the material composition of radioactive waste packages [7], [8], [9]. The resulting criteria for the description of nonradioactive substances in waste packages are also part of the waste acceptance requirements [4], [6].

In order to verify the compliance with the waste acceptance requirements important characteristics of waste packages provided for disposal, need to be checked prior to the approval. Among these characteristics are radiological, chemical and physical properties e.g. total activity, activity of safety-relevant radionuclides, dose rate, surface contamination, composition of the waste, quality of the matrix, quality of the waste container, mass ratio, mass of waste package, waste product condition, residual moisture content, possible gas generation resulted from a possible chemical/ biochemical reaction, concentration and distribution of fissible material per volume, chemo toxic organic and inorganic compounds.

QUALITY CONTROL OF WASTE PACKAGES

The BfS as the competent authority in Germany in terms of construction and operation of Konrad facility and disposal of radioactive waste is responsible for the quality control of radioactive waste packages in compliance with the waste acceptance requirements.

The necessity of technical measures for waste package quality control and assurance leads to organizational and administrative regulation achieved by interaction of different parties involved (see Fig. 2).

Involved Parties

The waste owner is responsible for waste treatment and disposal in compliance with waste acceptance requirements. The waste owner also has to ensure these compliances if service companies for waste conditioning are involved. It is his duty to verify all relevant aspects of their waste products (e.g. radiological and chemical characteristics) in order to prove compliancy with the waste acceptance requirements. Thus, the waste treatment needs to be documented in agreement with the acceptance requirements.

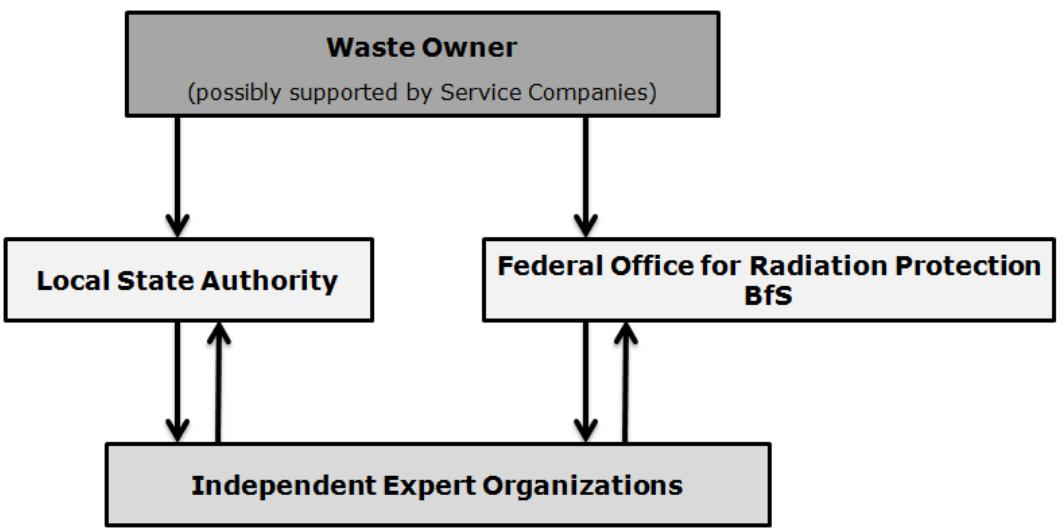

Fig. 2: Parties involved in quality control and assurance.

Based on the provision for the respective nuclear facility – established by the competent Federal State Authorities - the competent Local State Authority supervises the waste owner with regard to requirements which need to be fulfilled within the license for operation of the facility, for the interim storage of waste packages or for operation of conditioning facilities with regard to inspection on site. The Federal Office for Radiation Protection is responsible for the quality control of radioactive waste packages in compliance with the waste acceptance requirements. Among other duties the BfS defines appropriate control measures and the extent of documentation, approves applied and qualified conditioning methods as well as standardized container types and approves and releases waste packages for final storage.

In order to fulfill their tasks of waste package quality control and assurance the Local State Authorities as well as the BfS are contracting independent expert organizations. These expert organizations are responsible for the examination of application documents, qualification and inspection on site of conditioning procedures with regard to waste package quality, examination of the container intended for application or inspection of nuclear facilities and waste treatment processes.

Qualification of Waste Treatment and Waste Packages

With the aim of producing a waste package (conditioned radioactive waste) suitable for disposal in the repository Konrad various qualification strategies are implemented in order to prove compliancy with the waste acceptance requirements. This can be done by standardized qualification of the conditioning and treatment process of the radioactive waste (process control).

The main approach to access a treatment and conditioning process of individual waste streams is the campaign-specific qualification. This covers the assigned quality assurances process for a certain amount of waste within a certain time. The responsibility for the approval of the applied conditioning process lies with the BfS. The aim of the campaign-specific qualification is to ensure - according to the present state of knowledge - that (1) all relevant administrative issues are met, (2) all relevant measures during a conditioning process are carried out and (3) all repository relevant data are documented in order to verify the compliance with the waste acceptance requirements at the end of a conditioning process. Thus, a campaign-specific qualification enables it to ensure the implementation of a suitable strategy for waste treatment and packaging in advance and additional technical measures can be avoided.

The main steps of a campaign-specific qualification (see Fig. 3) can be described as follows:

(1) Announcement of a waste campaign by the waste owner/ service company
(2) Qualification and evaluation of the specific campaign (process control quality plan) by BfS experts under consideration of disposal-relevant aspects
(3) Approval of the campaign-specific procedure by the BfS
(4) Conditioning of the waste by its owner or a service company according to the qualified and approved process inspected by independent experts
(5) Compilation of all disposal-relevant data by the waste owner/ service company

according to the approved procedure
(6) Review of the documentation by BfS experts
(7) Approval of the waste package by the BfS relating to final storage

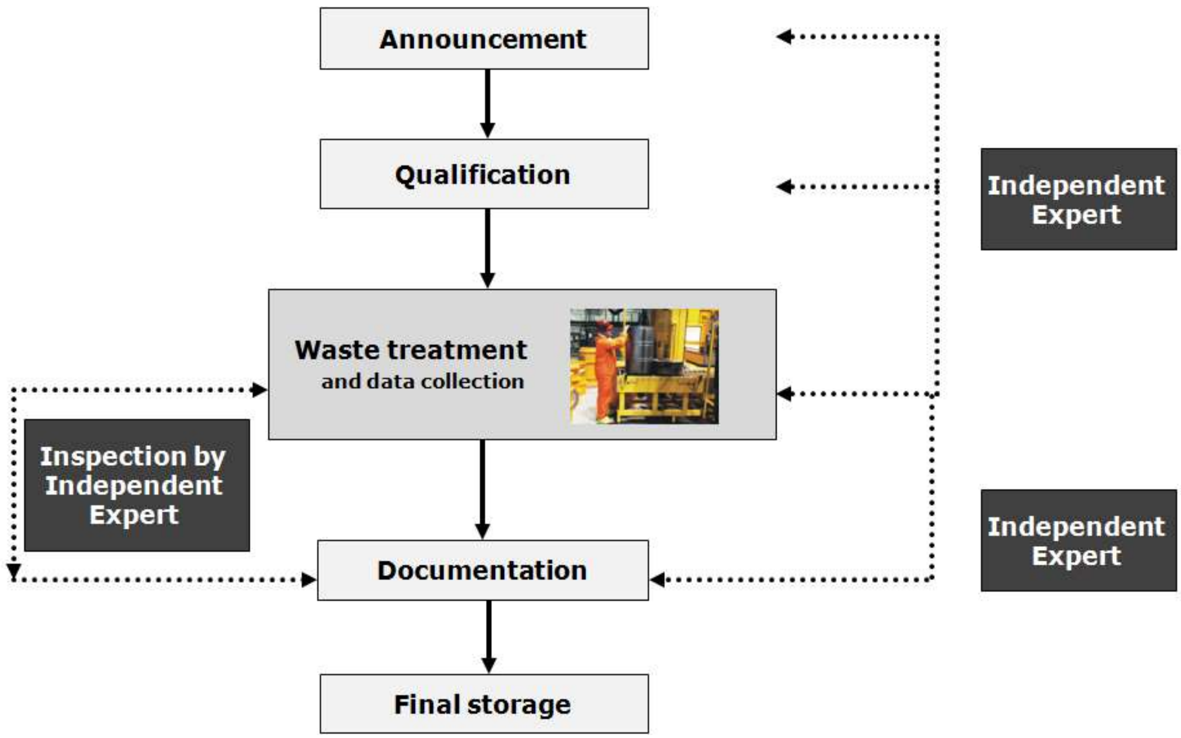

Fig. 3: Campaign-specific qualification.

TÜV NORD EnSys Hannover GmbH & Co. KG (TÜV NORD) acts as one of the independent expert organization on behalf of the BfS for more than twenty years in the field of quality control of waste treatment process and radioactive waste packages. During this time more than 1,200 campaign specific qualifications were announced - evaluated and reviewed by TÜV NORD on behalf of the BfS - and approved by the BfS. Based on a long-lived experience as independent expert in the field of qualification procedure for waste treatment it became obvious that the more precise and elaborate the procedure at the beginning of a campaign is, the easier is the qualification of the process and the lower are the expenditures and costs which possibly arise at the end of a campaign.

The following information should be delivered with regard to the qualification of a campaign:

- information about the waste (type, form, activity, amount)
- a detailed campaign-specific process control quality plan for the treatment and

conditioning process showing all relevant administrative and formal steps regarding the conditioning strategy
- information about the treatment method and the documentation of process relevant data

Based on such detailed information a campaign specific evaluation and qualification of the main procedure can be performed by the BfS supported by independent experts.

Due to inspections on site by independent experts during the conditioning process the correct execution of the agreed commitments can be verified. At the end of the process the waste products and/or waste packages produced are examined and evaluated on the basis of the documentation. Based on the agreements within the campaign specific qualification disposal-relevant data are compiled and recorded in a qualified way. An assessment report prepared by independent experts on behalf of the BfS is used as basis for the BfS to make a statement relating to the proof of compliance with the waste acceptance requirements and consequently for release for final storage. This process ensures control for quality measures.

PRACTICAL EXPERIENCE WITH PLANNING STRATEGIES FOR QUALITIY CONTROL OF RADIOACTIVE WASTE PACKAGES

The following examples show how the compliance with the waste acceptance requirements without further technical measures due to requalification can be achieved. Therefore a suitable process planning beforehand ensures that all disposal-relevant data are compiled and verified.

Example A

The considered campaign covers the dismantling of a reactor pressure vessel (RPV) from a light water reactor with its peripheral components. The objective was the packing of the reactor parts in containers which meet the requirements of the repository Konrad. Each waste package had to fulfill requirements regarding to its total mass, the nuclide-inventory, the amount of nonradioactive harmful substances and the ambient dose rate. Therefore detailed planning had to be done.

The RPV and its peripheral components cover a total mass of about 290 t and a volume of about 80 m³. A 3D model of the reactor was used as basis to meet the mass requirements and to optimize the utilization of space in the containers. It enabled a precise simulation of the cutting process which had to be undertaken in order to dismantle the reactor [10], [11].

In addition, the nuclide-inventory of the reactor parts had to be determined. The three dimensional model was used to calculate mass, volume and surface of the components. Furthermore an overall understanding of the composition of chemical elements in the materials and the performance history of the reactor were well known. Based on this information, activation and burn-up calculations could be performed in order to get the nuclide-inventory of the desired cutting parts. The calculations were supported by sampling of the real RPV. Both, the activity caused by activation and the activity caused by contamination of the components were determined. Sampling of the RPV-cover was performed to calculate the nuclide-inventory of the crud. All these efforts led to a very precise knowledge of the activity derived from activation and corrosion processes and enabled an optimal packing of the containers [11].

Furthermore the chemical compositions of the waste and the containers as well as the geometrical data of the 3D model were used to describe the waste packages by means of the amount of nonradioactive harmful substances. Based on the deduced cutting-strategy a dismantling procedure could be implemented.

The dismantling-campaign was announced at the BfS for a campaign-specific qualification. A comprehensive documentation of the projected process was provided including information about the waste (radiological and chemical composition/ characteristics), the estimated nuclide-inventory of the components, the intended packing strategy based on the nuclide-inventory and the virtual deduced cutting parts and as well the planned procedure for the verification of the nuclide-inventory (sampling plan) of the expected waste packages. Additionally, the specific process quality control plan containing all necessary steps regarding waste treatment and the documentation process (operating procedures/ protocols) of relevant data to ensure the verification of the compliance with the waste acceptance requirements, was submitted [10]. This detailed documentation allows an efficient evaluation and approval of the campaign by the BfS with support by TÜV NORD as independent expert organization.

Up to now the conditioning process takes place partially inspected by independent experts. As a result of an elaborate planning beforehand the documentation (compiled batch-wise) of the final waste packages are continuously submitted for assessment and verification one by one. The documentation of the first batch is already approved by the BfS and further batches of waste packages will follow.

Example B

From 1969 to 1991, plutonium has been processed into MOX-fuel assemblies in a German MOX-plant [12], [13]. Simultaneously with the final phase of plant operation, the initial decommissioning activities began in mid-1999, and decommissioning techniques were tested on inactive components. The large-scale decommissioning started in the autumn of 2001.

Due to regulations by the International Atomic Energy Agency (IAEA) and the Radiation Protection Regulation issued in Germany in the year 1976 fissile materials shall be documented.

Since 1984 an own processing equipment for creating waste drums was implemented in the fuel element plant. The procedure was the following: The equipment which was considered as waste was dismantled e.g. by cutting the different items into pieces of different sizes. The plutonium-content of each package was determined using special equipment. The evaluation included the determination of all plutonium nuclides as well as the determination of Am-241 and uranium. Inorganic waste was filled into 200-l-drums; these were connected to the cementation system. The organic waste was shredded and homogenously mixed with cement and water. This mixture was then poured into the drums. Liquid waste was added as a substitute for part of the water. All measured values as well as other properties of the waste like the material composition were documented.

With the knowledge of the plutonium-content of all waste items, the optimum composition for the cemented drums was evaluated to meet the limit per drum in order to minimize the volume for disposal. As the distribution of plutonium within the drum is not homogenous, the limit of fissile material per drum was conservatively set to – up to the year 1995 - the value of about 15 g/drum, after the year 1995 to 50 g/drum to meet limitations defined in the license of the Konrad repository. The procedure was described in a process control quality plan in 1997 and granted by the BfS.

The drums had been stored at the MOX-fuel-plant-site. Since the emplacement of 200-l-drums in the repository Konrad is not intended it was planned to concrete a package of 10 to 14 of these drums into containers for storage in Konrad. For these waste packages several limitations considering the content of fissile materials had to be observed. This could be evaluated easily from the documented data of the drums.

Also, the criteria for the limitation of the mass of nonradioactive harmful substances in the waste packages could be fulfilled. For this purpose, a check of the documentation regarding the cemented drums was sufficient to prove the compliance with the acceptance criteria for the repository Konrad [14].

Through the joint effort of all the involved parties the decommissioning for the resulting waste packages of the MOX-facility was accomplished within four years only. This was also based on accurate and comprehensive documentation produced by the owner of the waste. The conditioning of the final waste packages began in 2001 and was completed in July 2005 with the end of the decommissioning of the MOX-plant. More than 1,100 containers have been produced and are now stored in an interim storage facility until the repository Konrad will be opened [13].

For some of these waste packages – treated within other campaigns– the final approval for disposal in the repository Konrad is yet not achieved. As the radiological qualification for all waste packages is already granted by the BfS, the review of the documentation regarding the nonradioactive harmful substances has to be performed. Since the documentation of these waste products is similar to the documentation of the cemented drums, it is assumed to be an easy procedure.

This experience shows that based on detailed knowledge of the waste and accurate and comprehensive documentation an elaborated strategy can be achieved, which allows the maximum exhaustion of the limitations. A good traceability is also reached whereby it is possible to prove in retrospect the meeting of limitations, which were not defined when the waste treatment started.

Example C

This example regards to a German interim storage facility where 200-l-drums in addition to other types of waste packages are stored. When the contained radioactive waste was treated in the 90s, the waste packages were foreseen to be disposed of at the Morsleben site which was closed in 1998. Therefore the waste acceptance criteria of the repository Konrad where not considered. Now, these 200-l-drum need to be packed in containers which meet the waste acceptance requirements. Different strategies are conceivable for this task.

It is possible to describe the packing process based on the data which were already measured and documented during the treatment process. These data do not concern all requirements for the repository Konrad – e.g. there is a difference in the declaration requirements of nuclide activities. As a result the packing strategy is based on partially non reliable data. Hence, when trying to achieve maximum exhaustion of the limitations, for the waste owner there is a risk of exceeding of these limitations. This may lead to necessity of waste repacking.

Another possible way is to up-grade the old documentation of waste packages in order to qualify the 200-l-drums concerning the characteristics and the activity of the contained waste products for the repository Konrad. Nuclide activities that were not considered beforehand can be correlated on the basis of the existing data. The new documentation is submitted to the BfS beforehand of the packing process. Thus, the documented data can be checked on behalf of the BfS by an independent expert and the BfS approves the declared nuclide inventory and the documented characteristics of the radioactive waste. Based on this verified data, a packing strategy can be elaborated, which permitted the maximum exhaustion of the limitations allowed by the waste acceptance requirements of the repository Konrad. This procedure offers a high reliability for the packaging process to the waste owners.

CONCLUSION

The generation of waste packages for storage in the Konrad repository is associated with high requirements that must be met and verified. To meet this challenge, a good planning in advance is essential. The qualification of specific campaigns offers a good opportunity of purposeful waste treatment.

With regard to the verification of the waste acceptance requirements, not only a good knowledge of the waste and a farsighted planning beforehand, but also an optimal strategy planning based on the waste acceptance requirements for the intended verification is crucial. This not only facilitates the qualification process prior to the conditioning but also the subsequent approval process, which is performed on the basis of the documentation verification. Furthermore, a subsequent qualification of waste without additional technical steps is possible through proper analyses and a comprehensive documentation of the waste.

The better the campaign planning in advance, the easier is the qualification process and the more target-oriented the way to an unrestricted approval of waste packages for disposal in the Konrad repository.

REFERENCES

[1] Niedersächsisches Umweltministerium, „Planfeststellungsbeschluß für die Errichtung und den Betrieb des Bergwerks Konrad in Salzgitter als Anlage zur Endlagerung fester und verfestigter radioaktiver Abfälle mit vernachlässigbarer Wärmeentwicklung", 22. Mai 2002.

[2] Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, „Flasbarth: Schacht Konrad muss so schnell wie möglich in Betrieb genommen werden", Nr. 067/15, Berlin 26.03.2015, http://www.bmub.bund.de/presse/pressemitteilungen/pm/artikel/flasbarth-schacht-konrad-muss-so-schnell-wie-moeglich-in-betrieb-genommen-werden/, 17.11.2015, 15:30 Uhr.

[3] Bundesamt für Strahlenschutz (BfS), website: http://www.endlager-konrad.de/Konrad/EN/themen/einlagerung/Planungen/planungen, 19.11.2015; 15:30 Uhr.

[4] P. Brennecke, „Anforderung an endzulagernde radioaktive Abfälle (Endlagerungsbedigungen, Stand: Oktober 2010) - Endlager Konrad - ", Bundesamt für Strahlenschutz.

[5] S. Steyer, „Produktkontrolle radioaktiver Abfälle, radiologische Aspekte – Endlager Konrad – Stand: Oktober 2010", Bundesamt für Strahlenschutz.

[6] S. Steyer, „Produktkontrolle radioaktiver Abfälle, stoffliche Aspekte – Endlager Konrad – Stand: Oktober 2010", Bundesamt für Strahlenschutz.

[7] P. Brennecke, K. Kugel, S. Steyer, W. Boetsch, D. Gruendler, and C. Haider, "Implementation of Requirements on Non-radioactive Waste Package Constituents", 10449, WM2010 Conference, March 7 - 11, 2010, Phoenix, AZ.

[8] H. G. Jung and C. Scupin, "Water Law specific Regulation of the German Repository Konrad", 11474, WM2011 Conference, February 27 – March 3, 2011, Phoenix, AZ.

[9] S. Steyer, K. Kugel, P. Brennecke, W. Boetsch, D. Gruendler, and C. Haider, "Implementation of Control Measures for Radioactive Waste Packages with Respect to the Material Composition", 12365, WM2012 Conference, February 26 – March 1, 2012, Phoenix, Arizona, USA.

[10] R. Borchardt, „Erfahrungen mit der kampagnenspezifischen Verfahrensqualifikation für das Endlager Konrad am Beispiel des Abbaus des Reaktors im Kernkraftwerk Obrigheim", TÜV NORD Akademie – GmbH & Co. KG, Symposium Endlagerung radioaktiver Abfälle – Fortschritte bei der Vorbereitung auf die Endlagerung in Deutschland und internationale Entwicklungen, 08. – 09. Oktober, 2014, Hannover, Germany.

[11] R. Borchardt, "Dismantling of the Obrigheim NPP Reactor and Waste Management", 14500, WM2014 Conference, March 2 – 6, 2014, Phoenix, Arizona, USA.

[12] W. Koenig, R. Baumann, "Release and Disposal of Materials During Decommissioning of Siemens MOX Fuel Fabrication Plant at Hanau, Germany", ICEM2007-7205, 11th International Conference on Environmental Remediation and Radioactive Waste Management, ICEM2007, September 2 – 6, 2007, Brügge, Belgium.

[13] R. Baumann, G. Grondey, I. Hanel, E.-D. Kohlgarth, Decommissioning of a MOX Facility in Germany: Applied Techniques for Minimisation and Optimisation of Loading Containers with Nuclear Grade Waste for Final Repository", ICEM2003-4995, 9th International Conference on Radioactive Waste Management and Environmental Remediation, ICEM2003, September 21 – 25, 2003, Oxford, Great Britain.

[14] K. Kugel, P. Brennecke, S. Steyer, D. Gruendler, W. Boetsch, C. Haider, „Characterisation of Radioactive Waste with Respect to Harmful Materials", ICEM2013-96134, 15th International Conference on Environmental Remediation and Radioactive Waste Management, ICEM2013, September 8 – 12, 2013, Brüssel, Belgium.