

Knowledge Management in Nuclear Waste Disposal: Approaches and Challenges in Germany

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Abstract: Knowledge management (KM) in the field of nuclear waste disposal in Germany was largely neglected in all predecessor organisations and existed mostly within a loose framework of a substandard data archiving system. A reliable KM structure was only established since 2019. The KM team has gradually established various KM methods and tools to meet the current and future needs of colleagues. KM work is, and continues to be, marked by multitude challenges such as an ongoing major company reorganisation for the last years. Reduced KM workforce, loosening interest on KM and the longtime awaited, still missing implementation of Artificial Intelligence (AI) are making the work increasingly difficult.

Keywords: Radioactive waste disposal, Germany, Knowledge management tools, External and internal challenges, Upcoming AI support

1. A Short History of Radioactive Waste Disposal in Germany

The final storage of nuclear waste has been an important issue in Germany for over six decades.

The first trials began in the late 1960s at the Asse II mine, which served as a research facility and later became a final repository for around 126,000 drums of low- and medium-level radioactive material.

Further initiatives regarding nuclear waste disposal in Germany took place in the 1970s with the construction of the exploratory mine in Gorleben (no storage of radioactive material).

From the 1970s to the 1990s, around 37,000 cubic metres of low- and intermediate-level radioactive waste were stored at the Morsleben mine.

Currently the Konrad repository is under construction to store existing and future low- and intermediate-level radioactive material. The Morsleben repository is being decommissioned, with the radioactive waste remaining in the mine. The Gorleben exploration mine will be backfilled and subsequently sealed. The radioactive waste from the Asse II mine is to be retrieved and the mine subsequently sealed.

Since 2017, the Federal Company for Radioactive Waste Disposal (BGE) has been involved in the site selection process and is searching for a final repository for the high-level radioactive waste from nuclear power plants currently held in interim storage facilities.

The last nuclear power station in Germany was decommissioned in 2023, meaning that no new high-level radioactive waste is currently being generated.

2. Knowledge Management in the Past

A look at the history of knowledge management in the field of nuclear waste disposal in Germany reveals a mixed picture. Due to the large number of organisations and institutions (predominantly state-run, but also partly private) that have been responsible for nuclear waste management over the last 60 years, there has been neither a uniform nor a shared approach to knowledge management. This is also because there was no understanding of the importance of preserving and passing on knowledge in the past.

The topic of knowledge management was first discussed in the 2000s. Initially, this referred only to the systematic documentation of existing analogue information. However, even so-called inventory lists of stored waste were, at that time, inadequately recorded and, in some cases, vague.

Considerations regarding knowledge management in line with today's understanding of information preservation, accessibility and knowledge transfer were first recorded in commissioned research projects in the 2010s. However, these approaches and ideas were not implemented. Consequently, every institution responsible for final disposal, whether administratively or operationally, pursued its own uncoordinated, individual approach. Even these individual approaches to knowledge management were, for the most part, little more than documentation organised to a greater or lesser extent within the various organisations' existing, non-standardised systems. Isolated attempts to offer optional information formats, such as a specific internal system modelled on Wikipedia, were discontinued due to low usage and a lack of regular updates.

Furthermore, apart from the mere storage of documents, knowledge management was viewed exclusively as an internal tool for specialist training and the professional development of new staff.

A review of the history of knowledge management in the field of nuclear waste disposal in Germany shows that, prior to the establishment of the Federal Company for the Disposal of Radioactive Waste (BGE) in 2017, there were neither coherent and structured nor standardised knowledge management systems in place within the predecessor organisations.

It was only as part of the process of reorganising responsibilities for radioactive waste disposal in Germany and merging the various competent administrative and operational bodies into a single organisation in 2019 that it became possible to introduce a knowledge management system, which, in its initial phase, was based on the guidelines of the International Atomic Energy Agency (IAEA) (IAEA 2011, 2016, 2022a, 2022b) and the relevant standard literature (Nonaka & Takeuchi, 1995).

3. Establishing a Knowledge Management System - The Portfolio

The wide range of knowledge management tools currently offered by BGE is, on the one hand, the result of planned initiatives based on concept papers, but on the other hand, it is also the result of a gradual development driven by the desire to offer potential customers a broader range of services.

3.1 Digital Information Base (DIB)

The DIB fulfils the purpose of a centralised collection of documents containing information on all aspects of final disposal including all searchable scientific and technical works on the topics of the above-mentioned mining sites, as well as on general issues relating to the final disposal of radioactive waste in Germany, drawn from internal and external sources. The database consists primarily of internal reports, series of publications, presentations and dissertations. It is intended to make the entire body of documented knowledge on all aspects of final disposal available within the BGE and to serve as a source of information for answering current and future questions on this subject area. It is continuously expanded and updated. By today it consists over 25.000 documents, wherein at least one third had to be digitized. Many of the documents were retrieved from former hidden and not available sources.

3.2 Intelligent Search Engine (iFinder)

As part of the development and maintenance of the “Digital Information Base”, the BGE decided to use an intelligent search engine to provide users with an optimised search experience tailored to their specific needs. It is designed to deliver more relevant search results based on the user’s context and profile, with the aim of improving the efficiency of knowledge and information retrieval.

Therefore, we use the “iFinder5elastic” tool (iFinder for short), a proprietary software, as an intelligent search engine to index document content and facilitate efficient research. The iFinder combines enterprise search, artificial intelligence such as machine learning, and linguistic methods such as ‘semantic search’, a search method that focuses on the contextual meaning of a search query. The advantages for the users are the visualisation of knowledge content or hidden knowledge (e.g. via facets), the integration of subject-specific knowledge (glossaries, abbreviations, acronyms, dictionaries), the ability to search for ‘similar documents’ as well as the ability to access information and knowledge from various sources to be made accessible. It provides a central platform that allows users to access a wide range of data internal and external connected sources and quickly find relevant information.

3.3 Interactive Knowledge Maps

Knowledge maps visually represent knowledge within organisations and enable the externalisation of internal knowledge.

The aim of our knowledge maps is to provide clarity regarding internal and/or external knowledge assets. Such a transparent and clear representation of knowledge in knowledge maps is intended to ensure that existing knowledge is visible to and can be effectively utilised by all stakeholders. This information may include, for example, details about knowledge holders, existing knowledge, knowledge sources or the development of knowledge. Knowledge maps serve less as a direct repository for embedded knowledge and more as a reference to relevant information, experts, structures, or documents and records.

Our purpose designed knowledge maps are also intended to support the rapid documentation of both explicit (conscious and accessible) and implicit (less conscious and intuitive) knowledge, and to facilitate and accelerate

access to the knowledge required. This promotes knowledge exchange, collaboration and the shared use of resources. Our various knowledge maps range from project specific information to the support of new colleagues offering a knowledge map for the onboarding process and further questions.

3.4 Lessons Learned (LL)

Before the knowledge management department was established, there were no lessons learned at BGE. The introduction of lessons learned was implemented solely on our initiative. The purpose is that the LL serve to continuously improve the BGE as a learning organisation and, with their implicit, positive culture of error, contribute to a sustainable transformation of the organisational culture.

The systematic approach to capturing, documenting and organising lessons learnt within the framework of knowledge management is:

Selective capture of experiential knowledge using tools such as:

1. Expert debriefing or project debriefing
2. Post-project reviews and debriefings
3. Surveys and questionnaires
4. Analysis of project documentation
5. Experience reports or case studies
6. Data analysis
7. Workshops and brainstorming sessions

as well as

Regular evaluation and systematic analysis of lessons learnt

Active communication and dissemination of lessons learnt

Integration of lessons learnt into existing business processes

and finally, the

Promotion of an open culture of error-acceptance

as well as a culture of knowledge-sharing, a willingness to learn and openness to change

Experience shows that, after some initial hesitation, there is considerable interest in this approach. The KM department supports the interested organisational units, organising, accompany and moderate the initial workshops and brainstorming sessions, and support them units within the framework of the systematic approach with the goal that the resulting reports contain a collection of recommendations on best practice and lessons learnt, which are intended to help avoid or minimise past mistakes and risks in the future.

3.5 Knowledge Café (KC)

The Knowledge Café serves to disseminate and transfer knowledge across our organisational units. It is an informal and interactive event where employees from all departments come together in a relaxed setting to share information on various relevant topics. Furthermore, this setting is intended to provide an opportunity for a free and intensive exchange of thoughts and ideas with the participants. The KC is run as flexibly as possible and tailored to specific needs and the organisational culture. It aims to raise awareness of knowledge management and to promote knowledge sharing and collaboration across departmental boundaries.

The KC is a regular event that takes place every 4–6 weeks and is announced in advance on the intranet. To reach as many staff members as possible, the KC is held exclusively online. It lasts around half an hour and takes place before the lunch break. The session is divided into a 15-minute presentation and 15 minutes for questions and answers; it concludes with a preview of future Knowledge Cafés and their topics. Among other things, the KC aims to act as a catalyst to promote the exchange of knowledge.

3.6 Knowledge Circle (KC²)

The Knowledge Circle is an extended version of the Knowledge Café.

It is meant to be within a closed expert or working group. This group meets regularly to exchange knowledge on a specific topic. The KC² is intended to take place in an informal setting, so that committed colleagues can further

develop their area of interest or expertise together. However, it can also be organised more formally, for example as a working group.

The knowledge circle offers members the opportunity to learn from one another, share their experiences and work together to find better solutions in their respective fields. Through the regular exchange of experiences and the discussion of best practices, existing knowledge is shared, new insights are gained and applied across the relevant areas.

3.7 Interviews

Interviews are one of the most important and fundamental components of knowledge management. They serve to capture and make available the personal knowledge of an individual or group (tacit or implicit knowledge). This individual knowledge can be utilised by groups of people and reassessed as and when necessary. The advantage is that it minimises knowledge loss caused by staff leaving the company, whilst also disseminating expert knowledge to individuals or the entire group. At BGE, three different types of interviews are currently being conducted, each focusing on a distinct area:

Expert Debriefing

- Interviews with experts who are still active on highly topical or specific subjects

Offboarding Interviews

- Interviews with colleagues who are due to leave the company shortly and who have been identified as key knowledge holders, without whom a significant information gap would arise if their tacit knowledge were not passed on

Contemporary Witness Interviews

- Interviews with eyewitnesses are conducted with both colleagues and external stakeholders in order to capture their motivations, goals and views.
- Furthermore, the aim is to tap into hidden or implicit knowledge in order to record authentic
- assessments from the perspective of the respective stakeholders at specific points in time.

3.8 Internal DokuWiki

The internal DokuWiki contains various types of information that we believe are currently best shared in this way. The DokuWiki is operated as a simplified version of Wikipedia, with editing privileges reserved exclusively for the administration.

The DokuWikis operated by the KM Department are:

Knowledge Management Methods Catalog

- Here, all methods currently used by the Knowledge Management Department are explained in detail

Uniform Glossary

- An attempt to create the company's first standardized glossary. Currently, only a fraction (approx. 400) of the identified necessary terms (>3,000) have been included.

Modeling Software

- An overview of all software programs for numerical modeling and simulation, including their location within the company, availability, and experiences with the respective software.

3.9 Community of Practice (CoP)

For BGE, a company newly established in 2019 with a new structure and hierarchy spread across various locations, CoPs are an essential component. Isolated CoPs already existed before the KM department offered support, for example as a neutral body that asked various questions to keep the process moving. In other instances, we saw an opportunity to offer our support or were asked to help initiate CoPs. Today, Knowledge Management initiates, supports, accompanies and promotes all types of Communities of Practice at BGE.

3.10 Cooperations

The Knowledge Management team is involved in various national and international collaborations.

We exchange ideas with sister organisations such as the French ANDRA and the Swiss NAGRA.

We participate in European programmes such as EURAD and are invited to act as consultants and guest speakers (Hoefer, Feuker & Wellmann, 2023); (Hoefer, Wanka & Wellmann, 2022).

We present our KM approach at national and international conferences such as the, SafeND (Hoefer, Wanka & Wellmann, 2021), the ICKM (Abbasova et al, 2022) or the IAEA (Hoefer & Wellmann, 2026).

We are involved in the OECD/NEA's IDKM and EGKM programme areas.

Since 2024/2025, we have been a member of the German working and knowledge initiatives

the Radiation Protection Qualification Network and the Nuclear Safety Qualification Network, within which we have established a Community of Practice.

And our latest collaboration began in 2026 with an exchange with Airbus.

We see cooperation and exchange as absolutely essential and as the best opportunity to critically examine our work, share our knowledge and experience, and, above all, learn from and with others.

4. New Tools for a Better Knowledge Management?

We will shortly be introducing two new methods and tools, which we expect will lead to significant improvements that will benefit our colleagues. Firstly, this involves the introduction of an

4.1 Expert Compass (EC)

The "Expert Compass" is designed as an intelligent network of employees for the future.

The EC will function as a database on a digital platform where information about the skills, experience and knowledge of an organisation's employees is stored. It enables employees to find expert contacts for various specialist topics or with specific skills and to seek their advice or support. Data protection guidelines ensure the security and confidentiality of the data.

This EC serves to map the pool of specialist skills within the organisation, thereby facilitating the identification of competent contacts depending on the required field of expertise. This is intended to promote and strengthen communication, networking and knowledge transfer between employees.

This increases transparency regarding existing knowledge and enables networking across sites and organisational units.

It also supports effective skills management within the organisation, enabling the full potential of employees' existing knowledge and skills to be realised.

The aim is to provide the HR department with additional information and for the system to serve as a company-wide yet personalised tool for skills management and HR. We hope this will result in improved efficiency in project and staff planning.

4.2 Artificial Intelligence (AI)

The introduction and use of artificial intelligence (AI) within the company is long overdue. The Knowledge Management Department was the first organisational unit to call for the use of AI. The implementation of a generative AI called 'iAssistent' will build on the aforementioned intelligent enterprise search tool, 'iFinder'. We expect better and more precise context-based answers, as well as results with a significantly shorter response time compared to the current system (iFinder).

We therefore anticipate that the search results will be more efficient for staff and will function as a dialogue-driven staff information system.

Our first step following the implementation of iAssistent will be to run a test system to evaluate the performance of large language models (LLMs). This will be trained using our in-house content. To ensure the reliability of the results, we will have the trained version tested by groups of employees. From experts to beginners, from long-serving employees with diverse project experience to new colleagues with varied professional backgrounds, from older to younger staff. In this way, we aim to ensure the highest possible level of reliability. Following this test phase and the final implementation, we envisage numerous use cases, such as the onboarding process, tools for skills development, and knowledge sharing such as knowledge maps, etc. We see the potential for

communities of practice to be elevated to a new level, as well as the option for a chat with final storage expertise. The possibilities are diverse and will be positive.

Nevertheless, the foundation for AI-generated results is knowledge management, which encompasses the continuous maintenance of data and the evaluation of the results delivered by the AI.

5. Challenges that Affected and Still Affect Knowledge Management

In recent years, there have been a number of challenges and difficult, sometimes ongoing, situations that have undermined the concept and practice of effective knowledge management, in some cases quite significantly.

5.1 Concept

When the KM Department first began its work, only a few of the team members had prior knowledge or a basic understanding of knowledge management. As a result, we all started from virtually scratch, without having a predefined overall concept for knowledge management. Before we began, there was only a concept for the digital capture and analysis of historical documents, which served as the basis for the DIB. Subsequently, the concept for the “Introduction to Knowledge Management in the Learning Organization” was developed later; however, this is a theoretical concept with an extremely limited practical approach to capturing implicit and tacit knowledge. It was not until three years after the department was founded that a concept for capturing explicit knowledge in a digital information database was developed, which provided a practical approach to using a search engine for the dissemination of explicit knowledge.

As shown, there was no overarching guiding principle as a starting point before we began working on knowledge management.

5.2 Survey

A survey based on a questionnaire that took staff needs into account was not introduced until 2022. As a result, the KM team worked for three years with great dedication and a firm belief that they were doing the right thing for their colleagues, without having received any feedback prior to the aforementioned survey.

5.3 Methods

Experience over the years has shown that, whilst some of the methods introduced by the knowledge management department were frequently used initially, they were almost completely forgotten and fell out of use after a year or several years. A good example of this is the Knowledge Circles and ‘Lessons Learned’ mentioned above. After a while, interest in the Knowledge Circles was so low that they were discontinued. Demand for ‘Lessons Learned’ is now so low that they hardly exist or are requested anymore.

Both methods and the cause of the lack of demand must be investigated.

5.4 Continuous Reinvention

A key insight from work in the field of knowledge management is the ongoing development and optimisation of existing tools, as well as the introduction of new techniques and methods. The life cycle in knowledge management encompasses the introduction of a method, its dissemination, its acceptance, its use (to a greater or lesser extent), a decline in frequency of use, further development, optimisation or discontinuation, and the introduction of an improved version or a new tool.

5.5 Key Performance Indicators (KPI)

One of the problems in knowledge management is the lack of reliable key performance indicators (KPIs). To a certain extent, it is possible to determine the usage figures for certain tools or the attendance figures for various events. However, when it comes to hard facts in the form of KPIs, as demanded by senior management to justify the existence of KM, these are unfortunately lacking, particularly as access figures or attendance figures vary greatly depending on the topic (35 people versus 200 people).

5.6 Reorganisation

The main problem for practical knowledge management and the very existence of a KM department is the ongoing and repeated restructuring of the company over months and years. Taking a smaller organisational unit as an example, the previously independent KM department is transferred to the HR department, with new additional tasks being added, key components being removed, and the workforce being reduced by a quarter at

the same time. Within just over a year, the KM department within the HR department is moved to another sub-division with different additional tasks, whilst the workforce is reduced by a third in total.

The same situation arises in most departments across the entire company.

The impact and consequences of this type of restructuring are immense and severe for the KM department. All new and newly established departments (most of which officially carry out the same work under a different name) require a considerable amount of time (1–2 years) to develop a consistent structure and identify their needs. During this period, there are few or no demands placed on knowledge management. These measures deliberately push knowledge management to the sidelines.

6. Key Insights and Considerations for Successful Knowledge Management – in Brief

In our experience, what are the key considerations and prerequisites for successful KM?

6.1 Support

First, the unconditional support from senior management. Without this, all attempts to introduce a KM system and ensure its successful implementation. This is also a prerequisite for the next stage.

6.2 Attitude

A positive or at least neutral attitude towards knowledge management, which implies acceptance and therefore does not hinder the dissemination of KM ideas.

6.3 Concept

Development of a concept that is also practicable before work on KM begins. Individual concepts can always be developed subsequently. The consequences of an overly theoretical approach and a basic concept developed too late only become apparent in the medium term, but they are clear.

6.4 Customer Focus

Given these prerequisites, it is absolutely essential to take into account and ascertain colleagues' expectations and wishes regarding KM. They should be regarded as customers to whom a service is being offered. Consequently, all tools and methods introduced subsequently are always linked to the success of persuasion.

6.5 Constant Communication

It is absolutely essential to keep the topic in the conversation or in people's minds. This can be achieved through various initiatives, new projects or so-called KM ambassadors within organisational units.

It is important that KM is viewed as positive, relevant and necessary.

6.6 Parallel Systems

It is equally essential that no independent parallel KM systems are created within the organisation that compete with one another and have a negative impact on each other.

Should a variety of KM approaches exist within the organisation, they should all operate under the same high-quality and mutually agreed regulations. Ideally, there should be a coordinating, overarching knowledge management system in place.

7. Recent Developments

Whilst this paper is being drafted, the BGE's Knowledge Management Department is independently launching a comprehensive review process. The new strategy will need to reflect the impact of the company's current restructuring and ongoing reorientation, including the loss of a third of the department's staff.

One outcome that is already certain is, that there will be a significant reduction in the portfolio including the transfer of nearly fully developed projects, such as the abovementioned Expert Compass, to other departments. This is necessitated by the reduced workforce and the reorientation of content as part of the HR strategy and development department.

The changes to content and staffing intended by the company's management will determine the future direction and future of the knowledge management department.

However, as long as we have a dedicated team and the department remains in place, we will continue our work in the field of knowledge management.

For us, knowledge management is not only an absolute professional necessity, but also a passion that we live and breathe, guided by our philosophy of knowledge management:

Approach – Combination – Dissemination – Reflection ... and back to the beginning.

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