Note:
This is a translation of the recommendation entitled “Leitlinie zur Einordnung von Entwicklungen in Wahrscheinlichkeitsklassen”.
In case of discrepancies between the English translation and the German original, the original shall prevail.

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RECOMMENDATION of the Nuclear Waste Management Commission (ESK)

Guideline on the classification of evolutions according to probability categories

Contents

1 Introduction and regulatory requirements

1.1 Introduction

Chapter 6 "Protection from damage caused by ionising radiation" of the "Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste" (as at 30 September 2010) [1] sets out the assessment criteria for the indicator "dose" for the post-closure safety case. Based on the uncertainty regarding the evolution [*Translator's note: In the English translation of the "Sicherheitsanforderungen an die Endlagerung wärmeentwickelnder radioaktiver Abfälle", i. e. the "Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste", referred to as "development"*] of the repository system after closure, the potential system evolutions are classified according to the categories probable, less probable and improbable evolutions. Furthermore, it is required in Chapter 7.2.2 (Long-term radiological statement) that for probable or less probable evolutions evidence must be provided that the criteria specified in Chapters 6.2 and 6.3 have been met.

1.2 Evolutions and scenarios

The "Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste" of the BMU [1] include specifications both on how to interpret the term scenario and on the classification of evolutions made according to their probability. In the Safety Requirements, the terms scenario and evolution are largely used synonymously. Within this guideline, distinction is drawn between the two terms as follows:

Potential evolutions of the repository system are clearly characterised by the starting situation and by the interaction of features, events and processes (collectively referred to as FEPs) in specifically defined forms. Such an evolution is either already a scenario when considered alone, or, if appropriate for the safety analysis, several evolutions may also be combined into one scenario. Based on specific scenarios, assessment cases are then derived for the analysis of consequences.

2 Approach to the classification of evolutions and scenarios

2.1 Boundary conditions

In [1], the evolutions are allocated to probability categories. Since for some evolutions it is difficult to determine quantitative occurrence probabilities, the classification is usually performed verbally argumentative. If quantification of occurrence probabilities is possible, the following conditions can be derived from the Safety Requirements for their allocation to probability categories:

Probable evolutions

The occurrence probability (p) of a probable evolution is set at $p \geq 0.1$ over a period of 10^6 years.

Less probable evolutions

The occurrence probability of a less probable evolution is set at $0.01 \leq p < 0.1$ over a period of 10^6 years.

Improbable evolutions

This group comprises evolutions,

a whose occurrence probability is to be set at $p < 0.01$, or
b whose occurrence within the assessment period is to be ruled out in all probability..

2.2 Approach

2.2.1 Assumptions

The underlying methodology of this guideline for the classification of scenarios as to their probability of occurrence is based on the following assumptions:

1 The evolutions are derived – following international practice – systematically on the basis of site- and repository-specific features, events and processes (FEPs). According to [2], FEPs are defined as follows:

- features: conditions or circumstances that characterise a particular system or part thereof at a particular time,
- events: processes and changes that occur over a very short period in comparison to the assessment period, i. e. short-term phenomena, and
- processes: processes and changes that take place over a significant period of time in comparison to the assessment period, i. e long-term phenomena.

2 The basis of the probability classification of systematically derived evolutions is the probability classification of the FEPs defining them.

3 The classification of evolutions according to probability categories outlined in this guideline refers to a systematic derivation of evolutions of the repository system. Since human activities cannot be dealt with systematically over the entire assessment period, their classification is not addressed in this regulation. The handling of scenarios that are based on human activities is regulated by a separate guideline [3].

4 The following considerations do not include evolutions where the primary consequences of the initiating event exceed the secondary consequences due to the repository by far. An example for this would be the impact of a large meteorite above the repository whose mechanical and thermal effects reach down to the isolating rock zone of the repository system (i. e down to a depth of several 100 m).

5 Evolutions are either already scenarios in themselves, or, if appropriate, are combined into one scenario.

2.2.2 Probability classification of the FEPs

The occurrence probability of an evolution is determined by the occurrence probability of the FEPs defining the evolution (Section 2.2.1, Assumption 2). For the assessment of an evolution, it is necessary to identify the relevant FEPs. "Relevant" means that there have to be features, events and processes in the assessment period of a quality and with characteristics that are necessary for the evolution so that evolution can occur.

Due to the different importance for the relevance, hereinafter, a distinction must be drawn between features on the one hand, and events and processes on the other hand. For events and processes, it is necessary to distinguish whether the cause is due to waste- and repository-induced phenomena or due to natural phenomena. Figure 1 schematically shows the mentioned distinctions.

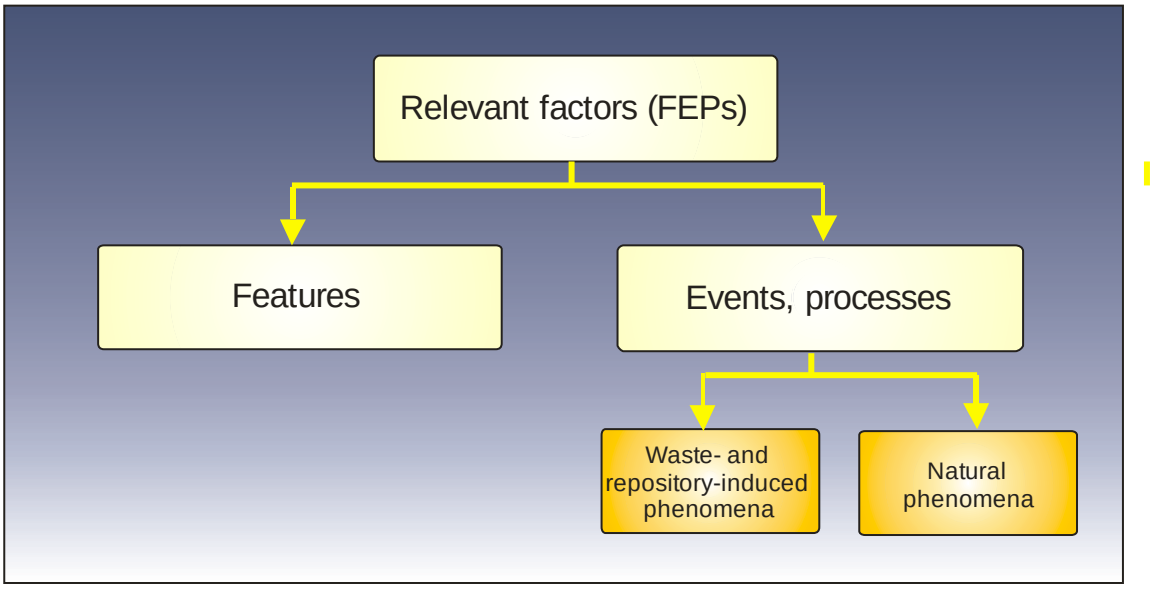

Figure 1: Differentiation of the FEPs for the classification of their occurrence probability

2.2.2.1 Probability classification of features

For the classification of features according to probability categories, the following approach is to be adopted:

- If at present the feature does not exist at the site under assessment and if its occurrence can also be ruled out in the future in all probability, the feature is to be regarded as improbable.

- Features already identified on the basis of the site characterisation and the system description or reliably derived for the future (i.e. verified, existing features or surely occurring in the future) are to be assigned to the category "probable".

- If occurrence of a feature is not certain, it is necessary to check whether a statistically verifiable, quantitative occurrence probability (p) for the existence of this feature can be derived.

- If a statistically verifiable, quantitative occurrence probability (p) for the existence of a feature can be derived (e. g. by taking into account statistics on manufacturing defects of containers or other system components or the validity of geophysical/geological findings), the following classification criteria shall apply in accordance with the corresponding statements in [1]:

    - If the derived occurrence probability (p) is in the range of $p \geq 0.1$, the feature is to be assigned to the category "probable".
    - If the derived occurrence probability (p) is in the range of $0.01 \leq p < 0.1$, the feature is to be assigned to the category "less probable".
    - If the derived occurrence probability (p) is in the range of $p < 0.01$, the feature is to be assigned to the category "improbable".

If quantification of the probability is not possible, the following assignment is to be derived on the basis of substantiated and clearly documented expert judgement:

- If there is reasonable expectation that the feature will occur within the assessment period it is to be classified as probable.
- If a feature is not to be expected for the site, but cannot be ruled out it is to be classified as less probable.
- If a feature can be ruled for the site in all probability it is to be classified as improbable.

Figure 2 shows schematically in a decision tree the described approach to the classification of features according to probability categories.

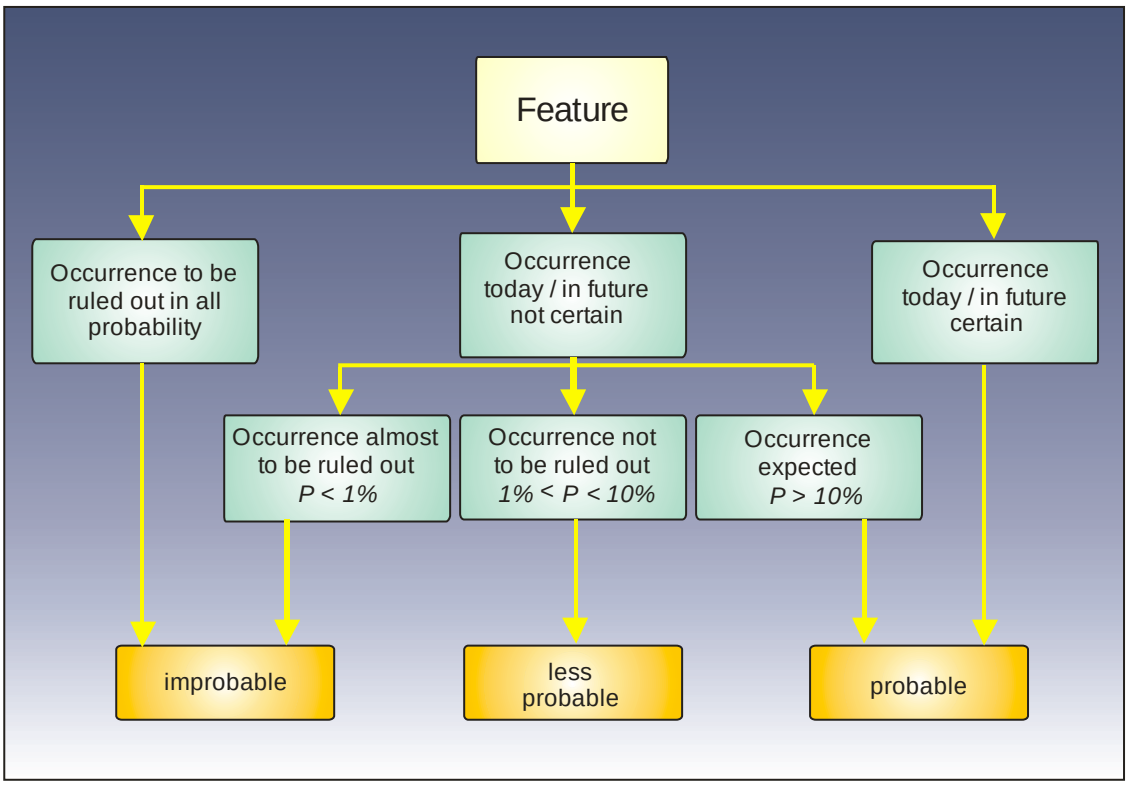

Figure 2: Classification scheme of the relevant factor “feature”

The classification scheme in Figure 2 clearly shows that two criteria that are based on qualitative assessments cannot be applied through comparison with actually existing facts or features. These are, on the one hand, the initial criterion according to which it is determined whether the occurrence of a particular feature can be ruled out in all probability and, on the other hand, the criteria within the classification scheme for which an assignment is made by experts. Thus, the assignment for this type of criteria is not free from subjective influences. The reasons for each assignment are to be shown in the documentation in a detailed and comprehensible manner by the applicant.

2.2.2.2 Probability classification of the events and processes

Events and processes have to be further differentiated in terms of the source or cause of the particular event or process:

a waste- and repository-induced phenomena, and
b natural phenomena.

Events and processes due to waste- and repository-induced phenomena

If events and processes are waste- and repository-induced phenomena, the following case distinctions are to be made (see Figure 3):

1 If occurrence of an event or a process is to be ruled out in all probability, it is to be assigned to the category "improbable" (example: the emplaced backfill material withstands the natural rock pressure so that the development of the permeability of the backfill structure, as provided by design, is prevented).

2 If occurrence of an event or a process is certain since the event/the process has already been taking place since emplacement, or if occurrence in future is unavoidable, it is to be assigned to the category "probable" (example: radioactive decay, heat generation by emplaced irradiated fuel assemblies).

3 If occurrence of an event or a process is not certain, another case distinction is to be made on the basis of substantiated and clearly documented expert judgement.

4 If occurrence of an event or a process is plausible for the repository system under assessment (although not entirely certain) and has the FEP initiating[1] the process or event been classified as probable, it is to be assigned to the category "probable" (example: development of the permeability of sealing structures as provided by design).

[1] Should FEPs initiate subsequent events and processes, the probability of the initiated events and processes will be assigned to the same category as that of the initiating FEP.

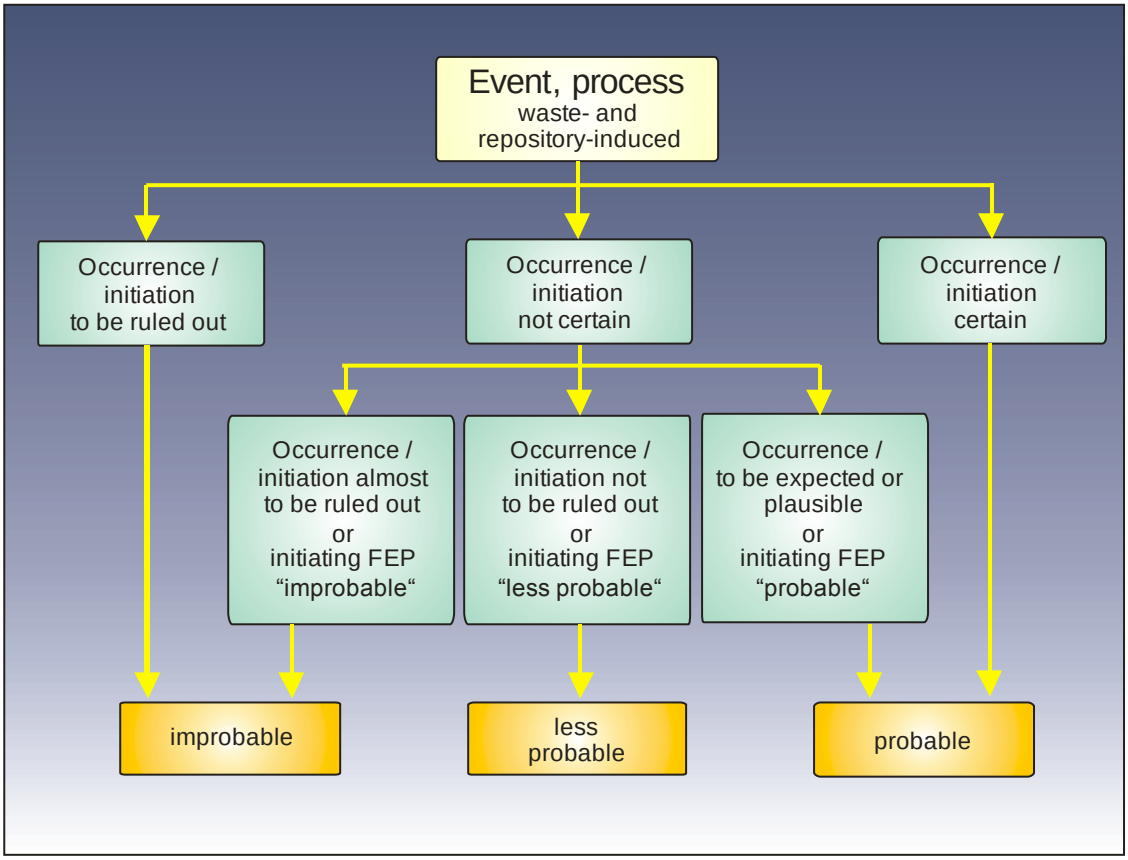

Figure 3: Classification scheme of the relevant factors “events and processes” in the context of waste- and repository-induced phenomena

5 If occurrence of an event or a process is not to be expected for the repository system under assessment but cannot be ruled out, or if the initiating FEP has been classified as less probable, it is to be assigned to the category “less probable” (example: development of the permeability of specific sealing structures not as provided by design).

6 If occurrence of an event or a process can virtually be ruled out for the repository system under assessment as far as predictable, or if the initiating event has been classified as improbable, it is to be assigned to the category “improbable” (example: complete failure of a sealing structure consisting of several components).

The classification scheme allows taking a decision on the basis of qualitative assessments according to the three screening criteria. The expert judgements on which the classification of the corresponding events/processes is based have to be documented in a detailed and comprehensible manner.

Events and processes due to natural phenomena

The statements below relate to events and processes of natural origin (see Figure 4):

1 If occurrence of the event/process under consideration is to be ruled out in all probability, it is to be assigned to the category “improbable”.

Prior to the classification of all other phenomena, an assessment is to be performed as to whether still ongoing and/or recurring events and processes are concerned. The evolutions and events are to be examined to determine whether they will continue presently and in the assessment period or whether their occurrence is also to be expected in the assessment period due to their cyclic nature in the past (e. g changes between warm and cold periods).

2 If it is a recent event or process (e. g. subsidence processes) and/or occurs cyclically and if the next cycle period is within the assessment period (e. g. continental glaciations), it is to be assigned to the category “probable”.

3 If the event or process does not show such recent and/or cyclic features, it is to be determined through investigation of the geological evolution of the site, whether the corresponding phenomenon has already occurred before in the last 10 million years (e. g. volcanism).

- If the investigation of the evolution to date provides evidence that in the past 10 million years[2] the event under consideration or the corresponding process has occurred at the site and recurrence is possible in the next 1 million years, it is to be assigned to the category “probable”.

- In the absence of indications from the past in the past 10 million years is to be determined whether an occurrence of the event/process in the next 1 million years can be ruled out on scientific grounds. If this is not the case, assignment to the category “less probable” is to be made (e. g. inland ice advances reaching farther south than all other ice advances in the past).

Figure 4 shows schematically in a decision tree the described approach to the classification of features according to probability categories.

[2] The chosen period of 10 million years is significantly longer than the assessment period (1 million years). From a geological point of view, it is also a period over which reliable statements can be made on the evolutions in the deep underground for a geologically stable area.

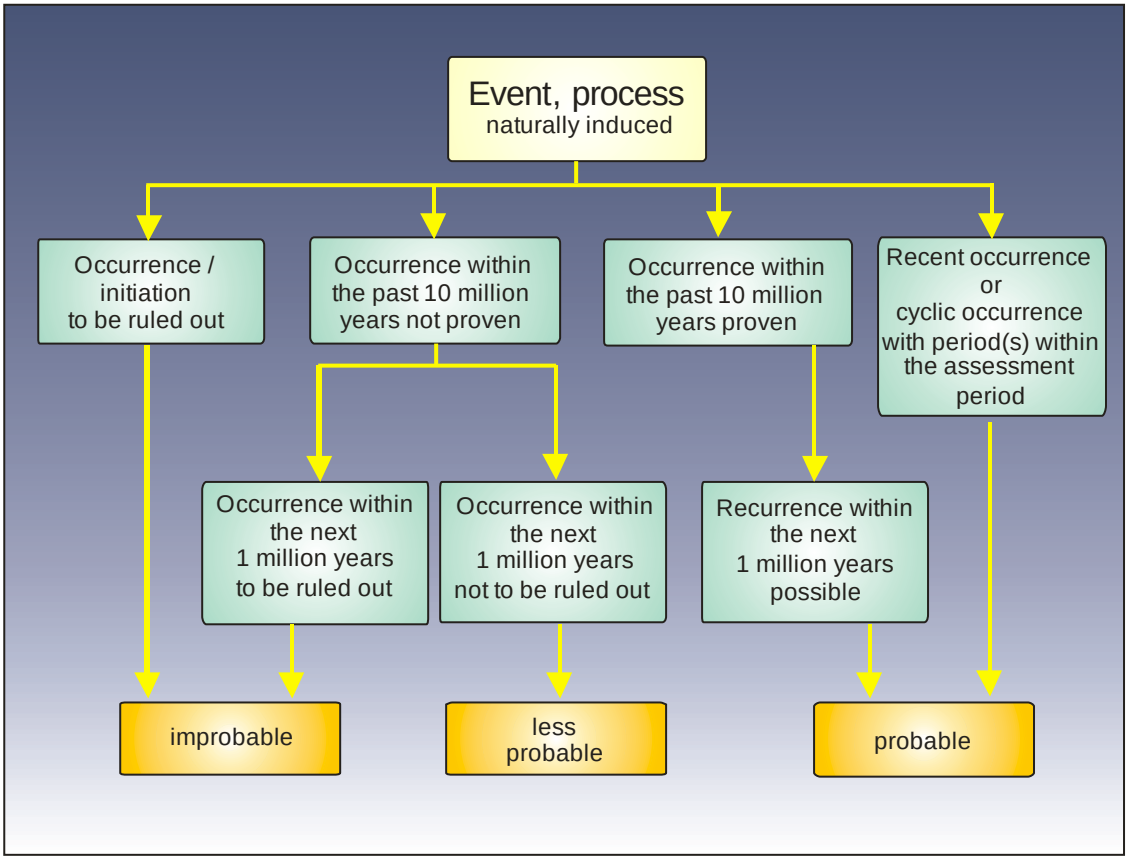

Figure 4: Classification scheme of the relevant factors “events and processes” in the context of natural phenomena

2.2.3 Classification of evolutions and scenarios

The applicant has to derive the evolutions of the repository system on a step-by-step basis and to document this in a clear manner. Here, in particular, the following documentation must be provided:

- compilation of a universal list (FEP catalogue) of features, events and processes (FEPs) which may occur at the repository site,
- identification of relevant FEPs to describe potential evolutions of the repository system (FEP screening),
- probability classification of the relevant FEPs and their intensities/characteristics, respectively,
- derivation of the evolutions on which the safety case is to be based by defining the initial situation and the interaction of features, processes and events and the corresponding intensities/characteristics,
- assignment of evolutions to probability categories.

For the assignment of evolutions to probability categories, the following generally applies:

a The relevant FEPs with their intensities/characteristics with the lowest probabilities determine the occurrence probabilities of the evolutions, as far as the FEPs are mutually independent.[3]

b The combination of evolutions into scenarios may only take place within a probability category. The resulting scenario is assigned to the same probability category.

When combining several less probable mutually independent FEPs, the applicant has to explain why the resulting evolution is considered improbable.

For evolutions for which a definitive assignment is not possible, assignment has to be performed, in due consideration of the protection goal, to the category with the higher probability, i. e. with the stricter protection goal requirement.

[3] Since concurrent occurrence of all relevant FEPs with the corresponding intensities/characteristics is necessary for the evolution ("and" operation), i. e. the evolution under consideration will not be initiated in case of non-occurrence of only one relevant FEP with its intensity/characteristics, this requirement is justified.

3 References

[1] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU): Sicherheitsanforderungen an die Endlagerung wärmeentwickelnder radioaktiver Abfälle – Stand 30. September 2010 (Endfassung).
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU):
Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste – as at 30 September 2010 (final version).

[2] Buhmann, D., Mönig, J., Wolf, J., Keller, S., Mrugalla, S. Weber, J.R., Krone, J., Lommerzeheim, A.: FEP-Katalog für einen HAW-Standort im Wirtsgestein Salz. Überprüfung und Bewertung des Instrumentariums für eine sicherheitliche Bewertung von Endlagern für HAW (Projekt ISIBEL), Gemeinsamer Bericht von DBE TECHNOLOGY GMBH, BGR und GRS. DBE TECHNOLOGY GMBH Peine, April 2010.
Buhmann, D., Mönig, J., Wolf, J., Keller, S., Mrugalla, S. Weber, J.R., Krone, J., Lommerzeheim, A.: FEP catalogue for an HLW site in salt host rock.
Evaluation of safety assessment tools for HLW repositories in rock salt (ISIBEL project), joint report of DBE TECHNOLOGY GMBH, BGR and GRS. DBE TECHNOLOGY GMBH
Peine, April 2010.

[3] Empfehlung der Entsorgungskommission vom 26.04.2012:
Leitlinie zum menschlichen Eindringen in ein Endlager für radioaktive Abfälle.
Anlage zum Ergebnisprotokoll der 26. ESK-Sitzung am 26.04.2012.
Recommendation of the Nuclear Waste Management Commission (ESK) of 26.04.2012:
Guideline on human intrusion into a repository for radioactive waste.
Appendix to the minutes of the 26th ESK meeting on 26.04.2012.