Development and Application of Post-Closure Safety Assessment

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Topics

- Safety Case and Safety Assessment
- Types of Assessment
- Safety Assessment Methodology
- Generic Safety Assessment for Borehole Disposal of DSRS
  - Generic Safety Assessment for Borehole Disposal of DSRS (Results)
  - Generic Safety Assessment for Borehole Disposal of DSRS (Use of Results)

Safety Case and Safety Assessment

- Safety Case
  - Comprises the collection of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in safety, of a radioactive waste disposal facility
  - Essential input into all the important decisions and authorizations that concern the facility
  - Provides the arguments as to why the facility is considered to be safe and includes the safety assessment and other analyses explaining the relevance of the various arguments and their strengths and weaknesses

Safety Case and Safety Assessment

- Safety Case
  - A ‘living document’ that is developed in parallel with the development programme for the waste disposal facility
  - Regardless of the stage that the programme has reached, a safety case submitted for regulatory scrutiny should cover the complete programme so that the regulatory body can put the licence application into its correct context
  - Overall aim is to demonstrate, with an appropriate level of confidence given the programme stage, that the complete programme is feasible

Safety Case and Safety Assessment

- Safety Assessment
  - Essential part of any radioactive waste disposal facility development process
  - Provides inputs to ongoing decision making in relation to e.g.:
    - Selection of conceptual designs
    - Guidance of research
    - Site selection and characterization
    - Development of assessment capability
    - Allocation of resources
    - Development of waste acceptance criteria

Safety Case and Safety Assessment

- Safety Assessment
  - Identify key safety relevant processes and contribute to develop an understanding of safety through the life-cycle of the facility
  - Provides the basis for safety arguments presented in a safety case
  - For small scale borehole disposal facility, where the small inventory results in the calculated dose falling well below the regulatory constraint, it is likely that the safety assessment and the associated investigations would be relatively simple

Types of Safety Assessment

- Generic Safety Assessment
  - Generic (i.e. non-site specific) safety assessment is a tool that can be used in many aspects of a waste disposal programme
  - At the concept development stage and in support of site screening, generic safety assessment can be used to help:
    - Identify radionuclide inventories suitable for disposal
    - Determine suitable levels of engineering;
    - Determine suitable site characteristics;
    - Determine the need for, and duration of, an institutional control period

Types of Safety Assessment

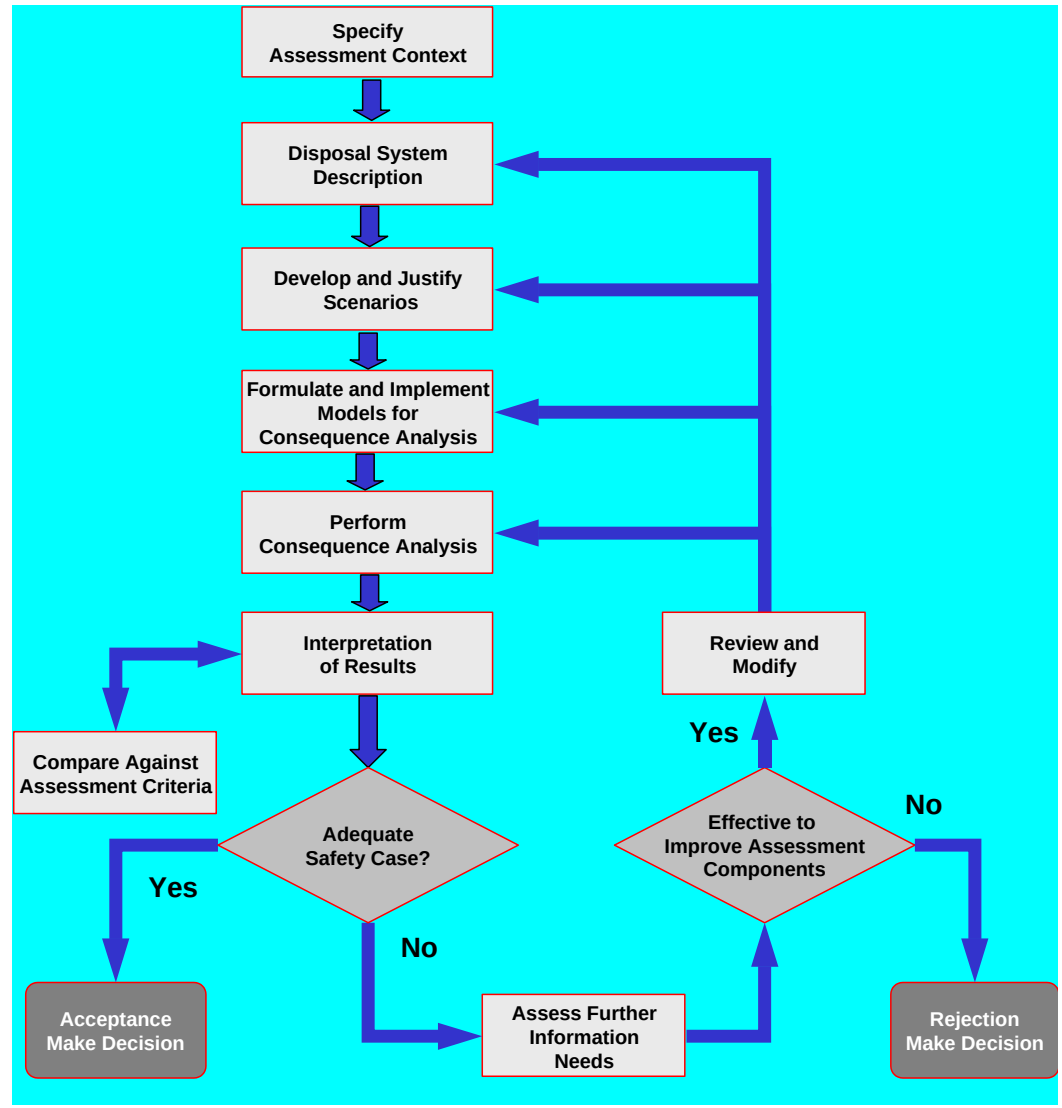
- Generic Safety Assessment
  - Even when a site has been chosen for investigation, generic safety assessment may help in:
    - Identifying the key parameters that need to be characterized for a site specific assessment and the extent of site characterization require
    - Providing basis for any site specific assessment that might be undertaken and helping to build confidence in that site specific assessment
  - Could be sufficient to undertake site specific investigations to confirm that site conditions, design and inventories fall within the generic safety assessment's envelope of assumptions and data

Types of Safety Assessment

- Site-specific Safety Assessment
  - By replacing generic information contained in safety case with site specific information, site specific safety assessment covering all aspects of safety can be developed with the aim of determining whether disposal facilities constructed at a site would be capable of meeting the regulatory requirements
  - Site specific safety assessment will be an important component of the site-specific safety case
  - Where a generic safety assessment has been performed, it may be possible to simplify the site specific assessment by limiting it to a confirmation that, in all important respects, the safety of the proposed facility is adequately described by the generic safety assessment

Safety Assessment Methodology

- ISAM Safety Assessment Methodology developed under an IAEA Co-ordinated Research Project
- Now applied in a wide range of countries



Generic Safety Assessment for Borehole Disposal of DSRS

- Developed as part of an AFRA Project for the management of DSRS in Africa
- Went through 2 iterations thus far to improve the assessment
- Numerous review cycles
  - March 2004
  - September 2004
  - November 2004
  - April 2005
  - May 2005 Peer Review
  - July 2005 TM
  - October 2005 CS
  - November 2007 TM

Generic Safety Assessment for Borehole Disposal of DSRS

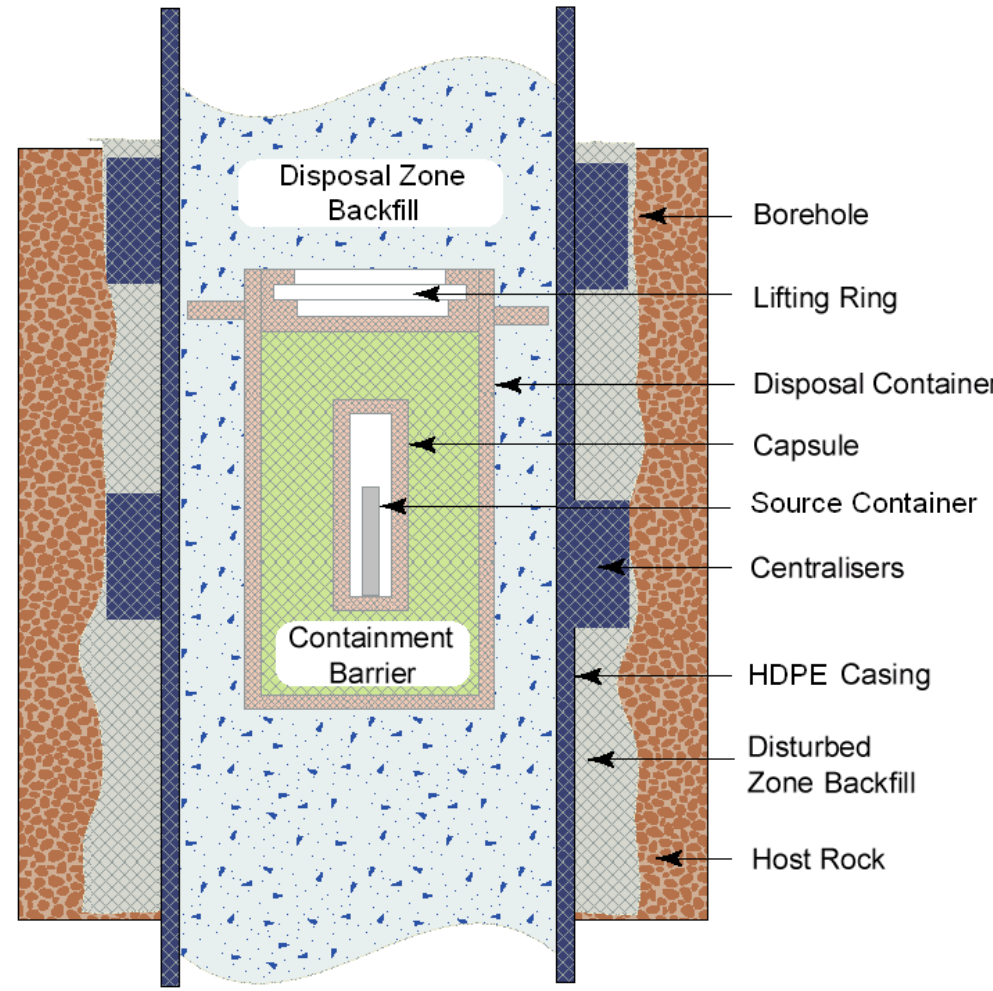
- Initial objectives of the generic safety assessment
  - Provide a basis for any site-specific assessment that might be required
  - Identify the key parameters that need to be characterised for a site-specific assessment and the extent of characterisation required
- Evolved objectives of the generic safety assessment
  - Serve as the primary safety assessment for specific disposal sites that are within the envelope of modelled conditions
  - Detailed supporting level near field models of the engineered barriers

Generic Safety Assessment for Borehole Disposal of DSRS

- Near Field: Waste
  - 11 representative radionuclides
    - H-3, Co-60, Kr-85, Sr-90, Cs-137, Pb-210 (100 d $< t_{1/2} <$ 30 y)
    - Ni-63, Ra-226, Pu-238, Pu-239, Am-241, ($t_{1/2} >$ 30 years)
  - Unit inventory of 1 TBq of each radionuclide per package
  - 50 packages per borehole
  - One borehole considered in reference calculations

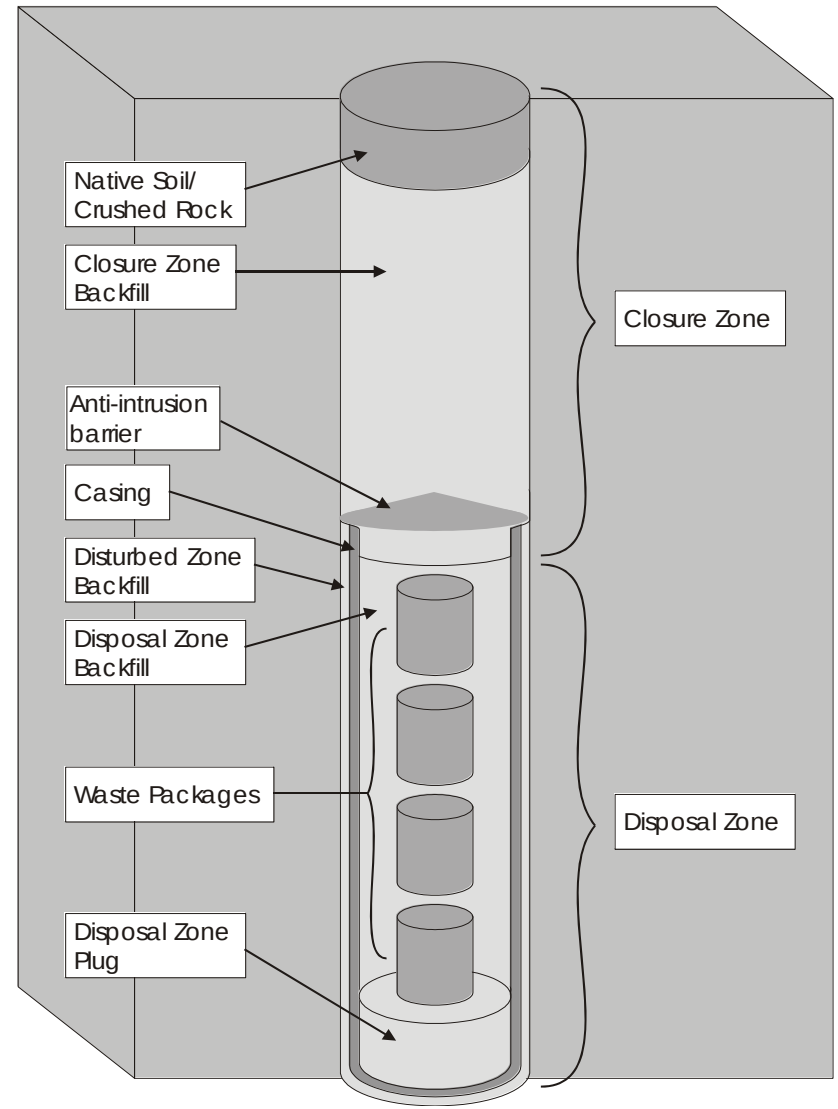
Generic Safety Assessment for Borehole Disposal of DSRS

- Near Field: Waste Packages
  - Source container
  - Capsule (stainless steel Type 304) (3 mm thick, Ø 21 mm)
  - Containment barrier (cement grout) (41 mm thick)
  - Disposal container (stainless steel Type 316 L) (6 mm thick, Ø 115 mm)



Generic Safety Assessment for Borehole Disposal of DSRS

- Near Field: Borehole Repository
  - Disturbed zone - space between borehole and HDPE casing (50 mm thick)
  - Disposal zone - area within which waste is emplaced (50 m thickness)
  - Closure zone - remainder of borehole following waste emplacement operations (at least 30 m thickness)



Generic Safety Assessment for Borehole Disposal of DSRS

- Near Field: Hydrology and Chemistry
  - Disposal in either unsaturated or saturated conditions
  - Unsaturated: oxidising
  - Saturated: oxidising or reducing

Generic Safety Assessment for Borehole Disposal of DSRS

- Geosphere – “synthesised” characteristics
  - Geological, hydrogeological and geochemical conditions considered have been selected to represent a broad spectrum of site conditions
  - Unsaturated (for disposal in unsaturated zone only):
    - 10 m thick below base of borehole
    - 10 y travel time for conservative tracer
    - Oxidising
    - Low or high K_d (consistent with saturated geosphere)
  - Saturated (for disposal in unsaturated or saturated zone):
    - High flow rate, porous or fractured, low Kd, oxidising
    - Medium flow rate, porous, low or high Kd, oxidising or reducing
    - Low flow rate, porous, high Kd, reducing

Generic Safety Assessment for Borehole Disposal of DSRS

- Biosphere – “synthesised” characteristics
  - Synthesised” - representative of real biosphere conditions but *not* site-specific
  - Simplified to abstract water from a borehole (well) for domestic and agricultural purposes

Generic Safety Assessment for Borehole Disposal of DSRS (Results)

- Can serve as the primary post-closure safety assessment for specific disposal sites that lie within the envelope of conditions assessed in the assessment

- Corrosion behaviour of the stainless steel containers is dominated by the alkaline near-field pH and the redox conditions. If the near-field pH remains in the alkaline range (pH >12), the vessels will undergo general corrosion at a rate that is estimated to range from 0.01 to 0.2 $\mu m \cdot y^{-1}$ depending upon the salinity and redox potential of the surrounding environment

- Estimated waste capsule lifetimes are in excess of 10E+4 y and as high as 7 x 10E+5 y for fresh, anaerobic groundwaters

Generic Safety Assessment for Borehole Disposal of DSRS (Results)

- Derived generic reference activity values could be used as a benchmark against which to compare values derived from the site-specific assessment.
- Results show that with a suitable combination of inventory, near-field design and geological environment, the borehole disposal concept is capable of providing a safe solution for the disposal of both long-lived and short-lived radionuclides.
- Deterministic sensitivity analysis (e.g. different near-field dimensions, corrosion rates, geosphere travel times, water uses)
- Consideration of uncertainties

Comparison of inventories for disposal and calculated activity limits

Radionuclide	Maximum Inventory for Disposal in a Country (Bq)	Calculated Activity Limit (Bq)	Maximum Number of Sources in a Country
H-3	2.8E+14	>1E+18	303
Co-60	2.9E+15	>1E+18	158
Ni-63	2.1E+10	>1E+18	-(2)
Kr-85	6.3E+11	>1E+18	21
Sr-90	5.3E+11	>1E+18	135
Cs-137	7.5E+14	>1E+18	1500
Pb-210	1.0E+07	>1E+18	-(2)
Po-210	1.0E+10	>1E+18	4
Ra-226	2.6E+13	>1E+18	912
Pu-238	2.0E+10	2E+12	44
Pu-239	6.7E+11	5E+11	12918
Am-241	1.2E+13	3E+12	2274

Generic Safety Assessment for Borehole Disposal of DSRS (Results)

- For most radionuclides, including longer-lived radionuclides such as Ra-226, post-closure safety places no limit on the radionuclide inventory that could be disposed of using the borehole disposal concept

- Even for radionuclides such as Pu-238, Pu-239 and Am-241 with exceedingly long daughters (i.e. half-lives in excess of 100,000 years), the concept has the potential to dispose around 1 TBq in a single borehole

Generic Safety Assessment for Borehole Disposal of DSRS (Use of Results)

- Site-generic level
  - Start to develop the envelope of suitable conditions in terms of:
    - key parameters (e.g. geochemical, hydrogeological conditions)
    - key assumptions
- Site-specific level
  - Identify key parameters that need to be characterised and associated extent of characterisation
  - Provide a basis for site-specific confirmation

Generic Safety Assessment for Borehole Disposal of DSRS (Use of Results)

The site-specific confirmation process:

1. Collect and review site specific information, especially relating to the key parameters identified in the GSA (e.g. travel times, groundwater chemistry)

2. Compare site with the synthesised sites from the GSA:
   - ✓ if the site is outside the envelope of assumptions and conditions considered in the GSA => site-specific assessment required
   - ✓ if the site is inside the envelope of assumptions and conditions considered in the GSA => move to Step 3

Generic Safety Assessment for Borehole Disposal of DSRS (Use of Results)

The site-specific confirmation process:

3. Collate information concerning the sealed sources to be disposed

4. Compare site-specific inventory with relevant GSA activity limits:
   - ✓ if no exceedence => qualitative/semi-quantitative confirmation required
   - ✓ if exceedence => site-specific assessment required

Thank You for Your Attention!