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Titolo

The International Intercomparison and Harmonisation Project on Demonstrating the Safety of Gological Disposal (GEOSAF)

Descrittori:

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Collocazione contrattuale: Accordo di programma ENEA-MSE: tema di ricerca "Nuovo nucleare da fissione"

Argomenti trattati: Trattamento e stoccaggio dei rifiuti radioattivi

Sommario

Il documento presenta una presentazione del progetto GEOSAF sullo smaltimento geologico dei rifiuti radioattivi, sviluppato in ambito IAEA. Sono riportate inoltre alcune considerazioni di base e i documenti, sebbene ancora a livello di bozza, predisposti durante il progetto.

Note: Lavoro svolto in esecuzione della linea progettuale LP4 dell'Accordo di Programma ENEA-MSE, PAR 2008-09, obiettivo D.

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Premessa

La presente attività è stata svolta nell'ambito della Linea Progettuale 4, Obiettivo D - "Indagini conoscitive relative alle problematiche inerenti lo smaltimento definitivo dei rifiuti radioattivi ad alta attività e lunga vita".

I destinatari del rapporto, considerata la consistenza e la rilevanza dei contenuti tecnici e socio-politici, sono i rappresentanti del governo e dell'industria: responsabili politici di alto livello, regolatori e gestori di impianti ed i loro esperti tecnici.

1. Introduzione

Il progetto GEOSAF, nato in ambito IAEA nel giugno 2008, ha come obiettivo il confronto tra i partner sulle *performances* di sicurezza di un deposito geologico per lo smaltimento di rifiuti radioattivi ad alta attività e lunga vita, nonché l'armonizzazione degli obiettivi di studio e dei progetti condotti in ambito internazionale.

Lo scopo del progetto, quindi, è quello di elaborare una posizione tecnica comune ed un approccio condiviso nella gestione delle tematiche relative alle valutazioni di sicurezza di un deposito geologico, con particolare enfasi alla fase di esercizio del deposito stesso. Più specificatamente, con il progetto si intende sviluppare un approccio comune sull'analisi di sicurezza e sulle modalità di conduzione della stessa e di presentazione dei risultati alle autorità competenti.

Per quanto riguarda i contenuti, i partners hanno convenuto che il progetto, per la sua completezza, debba riguardare sia la fase di esercizio che quella post-chiusura, tenendo conto oltre al rischio radiologico anche quelli di tipo convenzionali ed includere una valutazione della solidità ingegneristica dell'infrastruttura e delle relative *performances*, una valutazione degli impatti sulla salute umana e sull'ambiente ed una valutazione del sistema di gestione del deposito.

Il progetto coinvolge numerosi paesi, in particolare tutti quelli che occupano un ruolo di primo piano internazionale nello sviluppo e sfruttamento dell'energia nucleare, tra cui Francia, Regno Unito, USA e Canada. L'Italia, tramite l'ENEA, ha seguito ultimamente alcuni sviluppi di queste attività, ma non è partner ufficiale del progetto.

GEOSAF ha avuto una prima fase di durata triennale, anche se il lavoro svolto fino ad ora non può essere considerato conclusivo, ma solo propedeutico ai successivi ed ulteriori sviluppi, che dovrebbero essere indirizzati maggiormente alle implicazioni pratiche nella realizzazione di un'analisi di sicurezza e che costituiranno uno specifico TECDOC dell'Agenzia Internazionale per l'Energia Atomica (IAEA) .

L'ultimo meeting, che ha coinvolto i partecipanti diretti e indiretti, tra cui l'ENEA, si è tenuto a Vienna tra il 16 e il 20 maggio 2011, presso la IAEA. In quest'ultimo incontro sono stati definiti nel dettaglio i documenti in emissione, chiariti i risultati del lavoro svolto e sono state poste le basi per le loro future implementazioni (§ 2).

La nascita del progetto, comunque, è riconducibile all'evidenza, nonché necessità, che il personale tecnico e quello coinvolto a diverso titolo nelle attività legate allo smaltimento geologico dei rifiuti radioattivi hanno notato e sollevato da tempo: *nonostante l'impegno di alcuni paesi nella promozione di attività di ricerca e sviluppo in questo settore, i risultati ottenuti a livello internazionale non fornivano una visione comune e una posizione tecnica sufficientemente condivisa ed armonizzata per questa tipologia di smaltimento, con particolare riferimento all'approccio per le valutazioni delle performances di sicurezza del deposito.*

I partner hanno deciso, quindi, di concentrare il lavoro anche sulla fase di esercizio del deposito che, oltre a quella realizzativa, rappresenta una fase molto critica per le future *performances* dell'opera. Inoltre, l'approccio internazionale comune è inevitabilmente partito dalla definizione di una corretta terminologia, per quanto possibile condivisa tra tutti i partecipanti, al di là della cultura e delle conoscenze specifiche.

La base documentale per lo sviluppo delle argomentazioni di progetto è rappresentata dal Safety Requirements SSR-5 della IAEA, cioè le linee guida generali per lo smaltimento geologico dei rifiuti ad alta attività e lunga vita. Il documento analizza i diversi stadi di sviluppo del processo di realizzazione del deposito, in modo integrale, dalle prime fasi progettuali, fino all'esercizio e alla sua definitiva chiusura, con particolare riferimento alle *performances* di sicurezza, che devono essere adottate in ciascuno stadio di sviluppo.

Anche per quanto riguarda gli aspetti tecnico-ingegneristici dell'opera, il progetto GEOSAF ha fatto riferimento diretto a questo documento. Uno dei criteri tecnici fondamentali adottati direttamente dal SSR-5 riguarda l'approccio modulare, *step-by-step*, per l'analisi di sicurezza da attuarsi durante le differenti fasi di sviluppo, così da affrontarne singolarmente gli aspetti più critici. Allo stesso modo, ogni aspetto o decisione tecnica può essere poi rifinita durante lo sviluppo o adattata a particolari esigenze contingenti, sulla base di un processo iterativo di continuo affinamento.

Uno degli aspetti salienti che si è concretizzato nei tre anni di lavoro consiste nella possibilità delle autorità nazionali, degli organi di controllo e di tutte le realtà coinvolte nel processo di licensing, di maturare in altri paesi parte delle competenze necessarie per interagire con i tecnici legati all'analisi di sicurezza e di poter trasferire il know-how acquisito nel proprio paese. Infatti, in questo modo, si è dato vita ad una piattaforma efficace per il trasferimento delle conoscenze e delle competenze maturate in ambito scientifico, sfruttando quelle già maturate dai singoli partner.

Questo può avere un indiscusso risvolto positivo anche nel nostro ambito nazionale, dove i soggetti addetti alle procedure decisionali o coinvolti a qualsiasi titolo nel processo di *licensing* delle future infrastrutture di smaltimento, potrebbero fare tesoro delle conoscenze e delle competenze maturate in questo ambito in paesi esteri, grazie ad un sistema di formazione che potrebbe avviarsi proprio tramite l'esperienza ENEA in GEOSAF.

La partecipazione e confronto in ambito GEOSAF, inoltre, possono migliorare anche la collaborazione tra le singole realtà nazionali coinvolte in queste attività che spesso risultano poco indirizzate verso percorsi di reciproca collaborazione e confronto o volti a condividere le proprie esperienze; un fattore, questo, estremamente necessario per la risoluzione di un problema annoso e di rilievo nazionale.

Dal punto di vista organizzativo, sono stati creati differenti gruppi di lavoro, su specifiche tematiche, quale ad esempio, l'identificazione delle principali problematiche nella realizzazione delle opere sotterranee. Aspetto che ha già trovato risposte tecnico scientifiche più che soddisfacenti in ambito minerario e nell'industria convenzionale.

Per tale ragione i tecnici coinvolti in questo particolare argomento hanno effettuato delle visite mirate ad importanti infrastrutture sotterranee, in cui poter prendere atto delle esperienze maturate. In particolare sono state visitate le miniere Moab Khotsong, in Sud Africa, Mc Arthur River, in Canada e il deposito Waste Isolation Pilot Plant (WIPP) nel New Mexico (USA).

Nella miniera canadese, in cui la società CAMECO estrae principalmente uranio, è stato anche possibile affrontare aspetti operativi di sicurezza radiologica, oltre che convenzionale. Proprio i tecnici del GEOSAF Working Group on Operational Safety, coinvolti in queste visite, hanno convenuto sulla necessità di procedere nella realizzazione di un futuro impianto pilota a livello internazionale per affrontare e dirimere le questioni principali su queste tematiche, magari sfruttando uno degli *Underground Research Laboratory* già esistenti. GEOSAF ha anche fatto tesoro dell'enorme lavoro svolto in Francia per l'individuazione del contesto geologico più favorevole per lo smaltimento dei rifiuti ad alta attività. Infatti i tecnici ANDRA hanno svolto in parallelo due campagne di studio: una sulla formazione argillosa Meuse/Haute-Marne di età Calloviana/Oxfordiana e una sulle formazioni granitiche dei massicci francesi.

L'esperienza d'oltralpe ha dimostrato a tutti gli effetti la solidità del progetto di smaltimento nelle formazioni argillose ed ha rappresentato in un certo senso il progetto pilota ulteriormente implementato in ambito GEOSAF.

Un ulteriore filone che andrebbe sviluppato nelle future eventuali attività che discenderanno da GEOSAF, riguarda l'estensione del progetto pilota della formazione argillose di Meuse/Haute-Marne, al contesto delle formazioni cristalline, che rappresentano la soluzione geologica adottata dai paesi del nord Europa. Il differente contesto geologico e le differenti caratteristiche e capacità di confinamento delle rocce ospiti impongono pesanti differenze in materia di valutazione delle *performances* di sicurezza del deposito. Per tale ragione andrebbe anche inclusa nel progetto l'esperienza pratica del deposito WIPP, situato all'interno delle formazioni saline del New Mexico, le cui competenze potrebbero essere utilmente trasmesse agli altri partner.

L'attività condotta dall'ENEA, che ha seguito lo sviluppo finale del progetto, è stata utile per poter condividere il know-how di conoscenze che si sono accumulate in questo ambito. Il bagaglio di competenze maturate potrebbe ad esempio essere utile agli organi regolatori e decisori che dovranno acquisire conoscenze e competenze nella specifica materia.

L'Italia, che ha maturato ritardi notevoli nel settore dello smaltimento dei rifiuti radioattivi e che non dispone di un laboratorio per ricerche sotterranee, solo partecipando a consessi internazionali di questo tipo può fare proprie le esperienze maturate ed accorciare la distanza che la separa dagli altri paesi in termini di R&S per lo smaltimento geologico.

Le importanti attività di ricerca condotte dall'ENEA, inoltre, potrebbero trovare rinnovato slancio proprio partendo dall'interazione con partner europei (quali la Francia) che hanno sviluppato e attuato un mirabile progetto di ricerca su tali tematiche. Per questo gli ulteriori sviluppi di GEOSAF dovrebbero essere seguiti dall'ENEA con rinnovato interesse e fattiva partecipazione, grazie anche alla disponibilità di specifiche competenze tecniche.

2. Attività in ambito IAEA

L'Agenzia Internazionale per l'Energia Atomica (IAEA) ha organizzato un *Technical Meeting* (Vienna 16-20 maggio 2011), i cui risultati sono riportati nel presente documento, con lo scopo principale di rivedere il lavoro svolto da uno specifico gruppo tecnico, condividere i risultati del progetto ed elaborare ulteriorori specifiche tematiche inerenti lo smaltimento geologico.

Inoltre, l'incontro ha avuto l'obiettivo di analizzare e discutere i primi risultati del gruppo sulla sicurezza operativa degli impianti di smaltimento geologico, stabilito nel corso del progetto.

L'incontro era rivolto a un ampio spettro di discipline professionali, compresa la gestione dei rifiuti radioattivi, la protezione dalle radiazioni, ingegneria ambientale, ingegneria meccanica e civile, e la valutazione radiologica.

Nei paragrafi successivi è riportata una sintesi dei risultati dei lavori effettuati durante il *Technical Meeting* in oggetto, condivisi da tutti i partecipanti, compreso uno degli autori della presente relazione (Francesco Troiani).

2.1 Saluti di benvenuto e note di apertura

Gerard Bruno è il nuovo capo dell'*Unità rifiuti radioattivi e gestione del combustibile*, nonché segretario tecnico di GEOSAF, in seguito del pensionamento di Phil Metcalf. Magnus Vesterlind, capo della *Sezione Rifiuti e Sicurezza Ambientale*, ha aperto la riunione plenaria, sottolineando il fatto che la partecipazione attiva degli Stati membri è un requisito indispensabile per il perseguimento dei progetti IAEA come GEOSAF, sviluppato per favorire l'applicazione delle norme di sicurezza. Ha anche evidenziato l'importanza dell'attività sulla valutazione operativa della sicurezza, svolta in ambito GEOSAF; cioè un argomento ancora in pieno sviluppo nei programmi di smaltimento geologico, come testimoniato dai casi svedese, finlandese o francese.

2.2 Stato del progetto GEOSAF (risultati in corso di completamento, obiettivi da finalizzare, …)

Christophe Serres, responsabile del progetto GEOSAF, ha presentato la relazione sull'attività svolta nell'ambito del progetto dall'ultima riunione plenaria (tenutasi tra il 8 e 12 Marzo 2010) e con inizio nel 2011. Il responsabile ha ricordato che l'attuale riunione plenaria avrebbe chiuso ufficialmente i tre anni del progetto GEOSAF. Sono attualmente in preparazione due relazioni: un report principale dedicato alla presentazione delle attività realizzate nei 3 anni di lavoro e in particolare il questionario sviluppato per le specifiche del documento SSR5; un report secondario, in allegato, come risultato del lavoro intrapreso dal Gruppo Operativo per la Sicurezza (sottogruppo di GEOSAF).

Lo scopo della riunione plenaria è stato quello di rivedere i due report predisponendo un certo numero di azioni da svolgere velocemente al termine della sessione stessa, per emettere ufficialmente i rapporti e chiudere il progetto. E' stato anche richiesto al gruppo di trarre delle conclusioni da GEOSAF e di proporre delle prospettive per il futuro, al fine di stimolare la IAEA sulla necessità di un nuovo progetto nel 2012.

2.3 Informazioni generali

I recenti sviluppi in ambito IAEA (feedback sulle norme di sicurezza, stato dei progetti internazionali sull'armonizzazione tra cui PRISM e SADRWMS, ecc.).

E' stato fornito un resoconto sullo sviluppo degli standard di sicurezza nelle aree di smaltimento e pre-smaltimento. Per quanto riguarda lo smaltimento, nel marzo 2011 è stato pubblicato il documento *SSR-5 Safety Requirements on Disposal of Radioactive Waste*. E' in corso di pubblicazione la guida di sicurezza per lo smaltimento geologico dei rifiuti radioattivi, mentre è ancora in fase di sviluppo la guida di sicurezza per lo smaltimento sub-superficiale. Inoltre la guida di sicurezza DS355 sul *safety case* e sulla valutazione di sicurezza per lo smaltimento dei rifiuti radioattivi sarà presentata al CSS alla fine di maggio, per l'autorizzazione alla pubblicazione. E' stata anche presentata una breve panoramica sullo sviluppo degli standard di sicurezza per le attività di propedeutiche allo smaltimento dei rifiuti radioattivi.

Per quanto riguarda i progetti internazionali sull'armonizzazione, è stata fornita un'informativa sul progetto PRISM (*Practical Illustration and use of the Safety Case concept in the management of Near-Surface Disposal*) e SADRWMS (*Safety Assessment Driving Radioactive Waste Management Solutions*). PRISM è in corso di sviluppo; la prossima riunione plenaria è prevista dal 31 ottobre al 4 novembre 2011 a Vienna per evidenziare i progressi sui 4 filoni di attività. Il progetto SADRWMS è terminato nel 2010 e l'applicazione della metodologia sviluppata come parte del progetto (definita *CRAFT, Complementary Safety reports, Development and Application to Waste Management Facilities*, nell'ambito del secondo anno di progetto) è stata avviata la settimana antecedente la riunione plenaria GEOSAF.

Sono state anche fornite alcune informazioni sul recente progetto internazionale Integrated Transport and Storage Safety case for Dual Purpose Casks for Spent Nuclear Fuel.

Lo stato di avanzamento del progetto pilota europeo

Si propone di sviluppare, tra i soggetti regolatori europei, posizioni comuni per l'approccio alla sicurezza dello smaltimento geologico dei rifiuti radioattivi. In particolare si è concentrato sul contenuto di un *safety case* di un deposito geologico e le modalità con cui questo dovrebbe essere esaminato dalle autorità. Nel processo di aggiornamento e completamento del EPS (versione 2010), i redattori hanno tenuto in considerazione le osservazioni espresse sulla revisione 2007 del EPS svolta in ambito GEOSAF.

Nel 2010, l’argomento sull’accettabilità dei rifiuti radioattivi in un impianto di smaltimento è stato scelto per un esame più dettagliato nell’ambito dello studio pilota, per comprendere il grado di condivisione delle posizioni espresse dai paesi partecipanti, le loro differenze e per rafforzare e sviluppare basi comuni per successivi orientamenti.

Lo scopo non è quello di fornire prescrizioni tecniche dettagliate o criteri di accettabilità dei rifiuti (WAC), ma piuttosto lavorare ad una metodologia generale per la loro definizione, all’organizzazione dei soggetti che possono essere coinvolti e alle possibili disposizioni tecnico-organizzative per assicurare che tali criteri siano rispettati. Nel presente studio l’idea è quella di coprire tutti i tipi di impianti di smaltimento; nonostante l'esperienza acquisita in un tipo di impianto possa essere di aiuto per altre tipologie, è importante però tenerne presenti le differenze.

<u>I recenti sviluppi in seno alla Commissione europea: il progetto SITEX presentato nell’ambito della “call FP7: Fission-2011-1.1.2”: Supporto per le funzioni di regolamentazione in materia di smaltimento geologico.</u>

Nel quadro di questa *call*, la Commissione Europea ha annunciato che sarà fornito un sostegno alle autorità di regolamentazione, NSA e/o i TSO debitamente nominati; questo per facilitare la comprensione e l’approccio comune a problemi relativi alle richieste di licensing da parte dei soggetti attuatori, nel processo di implementazione dello smaltimento geologico. Un certo numero di organizzazioni europee e la canadese CNSC (12 organizzazioni in totale) ha deciso di coordinare gli sforzi e presentare il progetto SITEX nell'ambito della stessa *call*.

Lo scopo di SITEX è quello di definire i mezzi più efficaci, da sviluppare mediante la realizzazione di una rete di competenze europee, che permettano di:

? giungere ad una comprensione reciproca tra i vari organismi di regolamentazione, GST e organizzazioni di gestione dei rifiuti (*Waste Management Organisations*, WMOs) su
   i. le esigenze di regolamentazione
   ii. come gli aspetti tecnico-scientifici definiti dai WMOs possano soddisfare tali esigenze;

   in questa prospettiva, saranno affrontate le esigenze di chiarimento delle attuali guide normative o di quelle in via di sviluppo. Saranno anche favorite le eventuali interazioni con il progetto IGD-TP su tali tematiche. Infine sarà anche affrontato il ruolo della funzione di expertise e le esigenze per il suo miglioramento

? definire, in coordinamento o a complemento del programma di ricerca WMO, il porgramma di R&S in ambito TSO, che garantisca autonome capacità di revisione di un *safety case* e permetta di valutare le argomentazioni scientifiche fornite dalle WMOs. Il programma di ricerca e sviluppo del TSO e le relative priorità saranno affrontate favorendo una stretta interazione con il progetto IGD-TP, cercando attività comuni di ricerca nell’ambito delle WMOs per favorire un'interpretazione comune degli aspetti tecnici più importanti nell’ambito della sicurezza, evitando indebite duplicazioni

? garantire lo sviluppo di competenze per gli esperti incaricati delle revisioni tecniche e del trasferimento di conoscenza sulla sicurezza dei rifiuti e sulla protezione dalle radiazioni; saranno anche affrontate le esigenze di sviluppo di linee guida per armonizzare le attività previste nell'ambito della revisione tecnica stessa

? ove necessario, condividere con i vari portatori di interesse l'approccio di expertise, in modo più integrato rispetto ai casi in cui è solo prevista una forma di comunicazione o diffusione delle informazioni. Saranno anche discusse la raccolta e l'organizzazione delle azioni svolte in passato nonchè le modalità di coinvolgimento dei portatori di interesse nel processo di revisione tecnica.

2.4 Working group sul questionario per la sicurezza a lungo termine

Lo scopo di questo lavoro è stato quello di revisionare il questionario elaborato nel 2010, sulla base dei requisiti e delle specifiche di sicurezza sullo smaltimento dei rifiuti radioattivi (sviluppato come documento DS354 e pubblicato come documento SSR-5).

Il questionario è già stato esaminato in occasione dell'ultima sessione plenaria del 2010. E' uno strumento che agevola la verifica degli argomenti relativi alla sicurezza, perché siano contenuti nel documento relativo al *safety case* e ne soddisfino i requisiti. Dall'ultima plenaria del 2010, un certo numero di osservazioni sono state aggiunte a complemento dei requisiti. Queste sintetizzano le discussioni e le esigenze di chiarimento sorte in occasione della revisione effettuata dal gruppo GEOSAF nel 2010. Questi commenti sono anche legati alle argomentazioni emerse dalle revisioni del EPS e del documento DS355 svolte in ambito GEOSAF nel 2009.

I risultati e le raccomandazioni emersi nell'ambito dei gruppi di lavoro per finalizzare il questionario sono i seguenti:

? Raccomandazioni che possono essere implementate "facilmente" per concludere il questionario:
  - ✍ indicare che questo è solo dedicato allo smaltimento geologico profondo;
  - ✍ indicare che il numero di domande per ogni requisito non è proporzionale all'importanza del requisito stesso;
  - ✍ c'è l'esigenza di riformulare alcune frasi, chiarire concetti, controllare la terminologia, cancellare…: lo SC (*Steering Commitee)* ritiene sia necessario ritornare ai commenti sviluppati nell'ambito del documento SSR5, che illustrano i requisiti per verificare se le raccomandazioni GEOSAF siano o non siano appropriate;
  - ✍ completare alcune domande: ad esempio sui laboratori URL;
  - ✍ spostare i commenti in appendice: anche se questi sono ritenuti appropriati e utili per chiarire o evidenziare la complessità di alcuni argomenti che ancora rimangono in discussione, i gruppi di lavoro preferiscono spostarli al di fuori del questionario, per semplificazione. Lo SC prenderà in considerazione questa raccomandazione caso per caso, al fine di mantenere una realzione tra le esigenze e le diverse argomentazioni discusse dai membri GEOSAF e informare il lettore che, anche se i

requisiti sono ufficialmente convalidati dagli stati membri, gli esperti hanno dibattuto la loro applicazione pratica e in alcuni casi non c'è stata una visione univoca della questione;
  - ✍ altri commenti e suggerimenti sono indicati nella bozza del report.
- ? Azioni complementari che richiederebbero più tempo e che risultano di difficile realizzazione nel report finale di GEOSAF:
  - ✍ alcuni partecipanti ritengono che certi commenti sul questionario siano più istruttivi delle relative domande e suggeriscono la loro trasformazione in altrettante domande. Nel processo di autovalutazione IAEA, lo SC ha proposto di studiare la possibilità di sviluppare domande aggiuntive che completino l'insieme di quelle già esistenti;
  - ✍ migliorare la coerenza tra i requisiti 10 e 21;
  - ✍ qual è l'affidabilità di specifiche dettagliate per azioni da svolgere nel lontano futuro? Le risposte alle domande sono affidabili viste le incertezze associate?
  - ✍ nel questionario, considerare ulterioriormente la gestione di attività condotte nello stesso intervallo di tempo (costruzione, trasferimento dei rifiuti, chiusura tunnel, ...);
  - ✍ esaminare meglio le questioni relative alla sicurezza, in riferimento ad azioni terroristiche o criminali;
  - ✍ valutare meglio il rapporto tra sistema di gestione e difesa in profondità (aggiuntivo al 25.17).

Lo SC ritiene che tali osservazioni e suggerimenti, atti a migliorare il questionario e la comprensione reciproca dei requisiti (obiettivi e limiti), potrebbero essere scopo di successivi sviluppi del progetto GEOSAF.

2.5 Gruppi di lavoro sullo studio pilota della sicurezza in fase operativa (OPS)

L'obiettivo dei gruppi di lavoro era duplice: (1) rivedere la bozza di manuale sulla metodologia di valutazione della sicurezza in fase operativa (2) sviluppare lo studio pilota sulla valutazione del rischio d'incendio.

Questo manuale è stato emesso dal gruppo OPS: i contenuti sono stati stabiliti durante la riunione del gruppo per la sicurezza in fase operativa tenutasi a Fontenay Aux Roses, (Francia, IRSN) il 18-19 novembre 2010, e sono stati sviluppati dal 11 al 15 Aprile 2011 a Carlsbad (Stati Uniti, USDOE).

Il manuale integra l'esperienza acquisita dall'interazione con personale proveniente dal settore minerario, così come da relazioni già esistenti con personale WIPP o sviluppati nell'ambito di programmi nazionali (Francia, Svezia, Finlandia). Questa iniziativa, avviata recentemente, è ancora in fase preliminare, ma le osservazioni da parte dei gruppi di lavoro è di grande importanza al fine di:

- ? verificare se il contenuto del documento riflette correttamente i diversi argomenti e i vari step che nello studio sono stati identificati come termini di riferimento dal gruppo OPS;

? identificare quali capitoli dovrebbero essere ulteriormente ampliati;
? identificare le esigenze di ulteriori chiarimenti;
? individuare eventuali mancanze nell'approccio per la valutazione della sicurezza o problemi/domande chiave non ancora affrontate e meritorie di essere ulteriormente sviluppate nei successivi sviluppi del progetto GEOSAF (prospettive per il futuro).

I gruppi di lavoro concordano sul fatto che la bozza di manuale sulla metodologia di valutazione OPS sia di buona qualità e contempli un buon numero di importanti argomentazioni. Hanno identificato un certo numero di azioni:

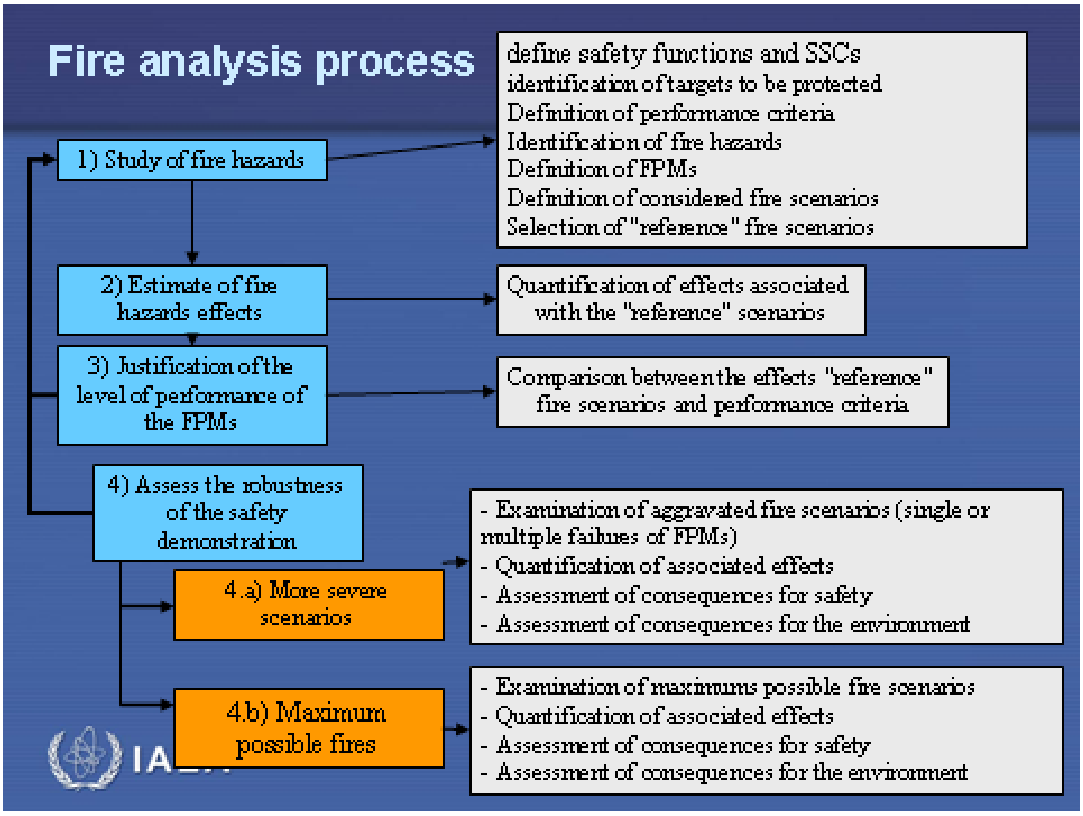
? relative alla struttura e alla chiarezza della bozza di report in corso di sviluppo
  ✍ per verificare la coerenza della terminologia nel documento (*long term* rispetto a *post closure*, *geological repository* e *geological disposal facility*, *assessment* rispetto a *evaluation*,...) e in riferimento al documento SSR-5;
  ✍ per chiarire se l'approccio è limitato solo alle strutture in sotterraneo o applicabile anche alle strutture di superficie;
  ✍ per chiarire il termine *minimizzazione dei controlli* (III.5.4);
  ✍ per espandere il testo per spiegare meglio le tabelle 1 e 2;
  ✍ per introdurre un elenco delle abbreviazioni;
? relative al miglioramento del contenuto dello studio corrente
  ✍ per sviluppare una sezione relativa allo stato dell'arte (valutazioni di sicurezza disponibili e già effettuate da alcune organizzazioni);
  ✍ per aggiungere una sezione sulla specificità di un deposito geologico, in che modo questo sia differente dalle miniere convenzionali e/o dagli impianti nucleari di superficie;
  ✍ per meglio collegare le problematiche di sicurezza post chiusura con quelle di sicurezza operativa, sviluppandone i relativi argomenti (III.7);
  ✍ per considerare le plausibili combinazioni di eventi (III.5.3);
? relative alle prospettive di lavoro futuro
  ✍ per introdurre raccomandazioni per le attività future;
  ✍ per meglio sviluppare l'identificazione dei rischi;
  ✍ per indirizzare le caratteristiche degli strumenti - Modellazione;
  ✍ per affrontare la normale operatività (non solo in casi incidentali);
  ✍ per valutare l'influenza della reversibilità/recuperabilità;
  ✍ per far fronte a rischi specifici collegati a cause esterne (costruzione, operatività, chiusura, ...);
  ✍ per stabilire l'insieme di requisiti (per un successivo questionario).

Inoltre, nella relazione dei gruppi di lavoro sono presentati una serie di suggerimenti per migliorare la versione attuale della bozza di manuale.

I membri del gruppo di lavoro OPS prenderanno in considerazione queste raccomandazioni e proporranno una pubblicazione della bozza di manuale. Le seguenti decisioni sono state concordate con lo SC:

? aggiungere un capitolo nella bozza, relativo alle lezioni apprese dal gruppo di lavoro e alla visione maturata in questa fase;
? adattare meglio i capitoli alle conclusioni e viceversa, magari con piccoli aggiustamenti dove necessario, ma senza ulteriori azioni in questa fase, onde permettere la finalizzazione del rapporto;
? elaborare un documento esplicativo (2 pagine): oltre alla finalizzazione del manuale, questo documento esplicativo sulla valutazione della sicurezza nella fase operativa riassumerà le lezioni apprese in questa fase e le principali prospettive per i futuri sviluppi dello studio. Questo documento sarà indirizzato alla IAEA e rappresenterà la posizione comune del gruppo GEOSAF sul lavoro svolto, evidenziando la necessità di continuare il lavoro in un prossimo futuro. Più in particolare, questo documento dovrebbe evidenziare gli argomenti da sviluppare ulteriormente per le specificità di un'infrastruttura nucleare sotterranea.

Per quanto riguarda lo sviluppo dello studio pilota sulla valutazione del pericolo di incendio, il gruppo ha elaborato un quadro di riferimento sulla metodologia di valutazione, in base alla bozza di linea guida elaborata da IRSN (relativa alla valutazione della sicurezza antincendio) presentata durante la riunione plenaria. Questo studio pilota è una derivazione pratica della metodologia generale sviluppata nel manuale sul rischio specifico (incendio). La rispondenza all'approccio generale è stata controllata e la specificità per il processo di analisi del rischio di incendio è stata identificata come segue:



Lo studio pilota sarà aggiunto alla bozza di report come allegato.

2.6 Conclusioni e prospettive per il futuro

Finalizzazione del report principale

- ? Bozza da finalizzare a cura del Presidente + Segreteria dell'IAEA (Fine Luglio 2011);
- ? aggiungere conclusioni e prospettive;
- ? bozza da inviare ai membri per osservazioni entro 2 settimane.

Manuale e documento esplicativo

Manuale da finalizzare a cura di M. Tichauer, B. Hedberg, J. Hainonen, J. Mertens (fine luglio 2011):

- ? da inviare ai membri per le osservazioni entro 2 settimane.

Pagina speciale sul sito IAEA con una raccolta di risultati GEOSAF:

- ? disponibile da fine luglio 2011 (segreteria IAEA).

Suggerimenti per le attività future

Il gruppo di lavoro è del parere che GEOSAF sia stato un punto di incontro utile per sviluppare una migliore comprensione delle attuali esigenze e dei nuovi approcci alla sicurezza, che sono in via di sviluppo, per valutare i diversi rischi durante le operazioni di smaltimento. Sono state identificati gli argomenti ancora in sospeso connessi agli aspetti di sicurezza e agli approcci da trattare in futuro (per facilitare l'applicazione delle norme e delle linee guida in via di sviluppo) per giustificare la continuazione del lavoro svolto. Il gruppo raccomanda che IAEA attivi un nuovo progetto il prossimo anno.

Il segretario IAEA (G. Bruno) concorda sul lancio di un nuovo progetto come sviluppo futuro di GEOSAF e ha sottolineato che la IAEA prenderà in considerazione la possibilità di pianificare un incontro il prossimo anno (2012) per la definizione dei termini di riferimento (T*erms of Reference*, TOR) del nuovo progetto. La bozza contenente i TOR dovrà essere predisposta in anticipo sulla base delle conclusioni della relazione principale (dal questionario LT) e sulle prospettive del documento OPS (da pianificare a cura della segreteria IAEA).

Infine, il responsabile ha espresso al gruppo la sua soddisfazione per aver presieduto GEOSAF per tre anni e ha ringraziato tutti per il lavoro svolto. In particolare ha apprezzato di aver potuto lavorare a stretto contatto con i colleghi dei gruppi di lavoro SC e OPS e li ha ringraziati per il loro impegno nel progetto e per il prezioso contributo al successo di GEOSAF; le interazioni con i rappresentanti generali degli Stati membri hanno costituito un'esperienza unica, viste la differente formazione, professionalità e le diverse attitudini di pensiero, tutte di grande importanza per sviluppare una migliore comprensione reciproca dei problemi di sicurezza, fondamentali per lo sviluppo dello smaltimento geologico, su come questi debbano essere affrontati nel *safety case* e su come questo debba essere analizzato.

Il questionario sviluppato e gli elementi che provengono dagli scambi sul EPS, sui documenti SSR5 e DS355, sul banco di prova francese (Andra Dossier 2005, IRSN) rappresentano esempi pratici dei progressi compiuti nell'armonizzazione delle prassi e nell'identificazione delle questioni in sospeso o dei problemi che devono essere sviluppati ulteriormente. Il lavoro sviluppato in merito al OPS risponde ad una forte richiesta proveniente dai programmi nazionali in corso in Europa e sarà utile per la comunità internazionale. La sua prosecuzione è di primaria importanza per consentire lo sviluppo di un approccio armonizzato alla sicurezza durante il funzionamento normale, ma anche accidentale, di un deposito geologico.

Una lezione importante risultante dalle attività condotte in GEOSAF è che, dopo la convalida delle norme da parte degli Stati membri, la loro applicazione pratica nel quadro dei programmi e delle politiche nazionali richiederà un forum specifico come GEOSAF per la condivisione delle pratiche e per sviluppare la comprensione reciproca sul modo di applicarle e soddisfarne i requisiti.

Il responsabile del progetto e la totalità dei gruppi di lavoro che hanno partecipato alla riunione plenaria finale di GEOSAF lanciano l'idea di un nuovo progetto per il 2012, sugli sviluppi di GEOSAF, e richiedono alla segreteria IAEA di prendere in considerazione questa opportunità.

3. Partecipanti e working groups

GEOSAF questionnaire

Group 1 (Meeting room M6)	Group 2 (Meeting room MOE67)	Group 3 (Meeting room MOE68)
Son Nguyen (Canada) (leader)	Kazumasa Hioki (Japan) (leader)	Jin-yong Park (Rep. of Korea) (leader)
Mourad Khelifa (Algeria)	Nour-el-hayet Kamel (Algeria)	Christophe Depaus (Belgium)
Sona Konopaskova (Czech Republic)	Jeroen Mertens (Belgium)	Francesco Troiani (Italy)
Abdel Ghani Said (Egypt)	Weiming Chen (China)	Ahmed Manar (Morocco)
Jussi Heinonen (Finland)	Jean de Meredieu (France)	Borut Petkovsek (Slovenia)
Christophe Serres (France)	Sung-bok Lee (Rep. of Korea)	Don Beckman (USA)
Michael Tichauer (France)	Bengt Hedberg (Sweden)	Gunnar Buckau (EC)
Shigeyuki Saito (Japan)		

Operational phase safety

Group 1 (Meeting room M6)	Group 2 (Meeting room MOE67)	Group 3 (Meeting room MOE68)
Yannick Ormières (France)	Kazumasa Hioki (Japan)	Jin-yong Park (Rep. of Korea)
Mourad Khelifa (Algeria)	Nour-el-hayet Kamel (Algeria)	Christophe Depaus (Belgium)
Sona Konopaskova (Czech Republic)	Son Nguyen (Canada)	Francesco Troiani (Italy)
Abdel Ghani Said (Egypt)	Weiming Chen (China)	Ahmed Manar (Morocco)
Jussi Heinonen (Finland) (leader)	Borut Petkovsek (Slovenia)	Don Beckman (USA)
Christophe Serres (France)	Sung-bok Lee (Rep. of Korea)	Gunnar Buckau (EC)
Shigeyuki Saito (Japan)	Bengt Hedberg (Sweden) (leader)	Michael Tichauer (France)
Gérard Bruno (IAEA)	Sylvie Voinis (France)	Jeroen Mertens (Belgium) (leader)

4. Allegati

Per completezza di informazione sono riportati in allegato i seguenti documenti che, allo stato attuale, sono da considerare a livello di BOZZA:

ALLEGATO 1 - GEOSAF: The International Intercomparison and Harmonisation Project on DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL;

ALLEGATO 2 - GEOSAF: Geological Disposal Safety Case explained to my mom; 'OPERATIONAL SAFETY' COMPANION REPORT - CARLSBAD EFFORT

INTERNATIONAL ATOMIC ENERGY AGENCY

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GEOSAF

The International Intercomparison and Harmonisation Project

on

DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL

1 Scope of the project

The IAEA has convened a number of **international intercomparison and harmonization projects** on the safety of radioactive waste management; in particular on the issues related to safety assessment, carried out in support of safety demonstration for radioactive waste management facilities and activities, decommissioning projects and radioactive waste disposal facilities.
International Intercomparison and harmonization projects are one of the mechanisms developed by the IAEA for examining the application and use of safety standards, with a view to ensuring their effectiveness and working towards harmonization of approaches to the safety of radioactive waste management.

The GEOSAF project complements the experience gained in a number of similar international projects undertaken by the IAEA relating to safety demonstration. These include: the project Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities for Radioactive Waste (ISAM), which was completed in 2000, and the project Application of Safety Assessment Methodologies for Near-Surface Radioactive Waste Disposal Facilities (ASAM); the international project Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities (DeSa); the international project Safety Assessment Driven Radioactive Waste Management Solutions (SADRWMS); and the international project on Environmental Modelling for Radiation Safety (EMRAS).

GEOSAF has been established to work towards harmonization in approaches to demonstrating the safety of geological disposal with a special emphasis on the expectations from the regulatory authorities engaged in the licensing process with respect to the development of the safety case. GEOSAF provided a forum to exchange ideas and experience in developing and reviewing the safety case.
It also aimed at providing a platform for knowledge transfer. With more countries contemplating embarking on nuclear power and existing producers seeking to define national policies and strategies aiming at covering all elements of the fuel cycle, such a platform is considered apposite. The need exists also to maintain existing knowledge bases.

The project focused on the Safety Case, a concept that has gained in recent years considerable prominence in the waste management area and is addressed in several international Safety Standards [ref].
GEOSAF gave particular attention to the evolution of the safety case with the development of a disposal project and particularly to the regulatory expectations on the development of the safety case in order to enable decisions to be made as part of the licensing process. Whilst the project addressed the elements of the safety case necessary for safety demonstration and the work necessary to support the various safety arguments, it also considered the process of reviewing and evaluating the safety case by regulatory authorities or technical safety organizations (TSOs) and the needed resources for conducting this technical review. That is the reason why the project involved regulatory authorities, technical safety organizations and waste management organizations responsible for the development and operation of geological disposal facilities.

GEOSAF addressed geological disposal defined in SSR5 [ref] as a "facility constructed in tunnels, vaults or silos in a particular geological formation (e.g. in terms of its long term stability and its hydrogeological properties) at least a few hundred metres below ground level. Such a facility could be designed to accept high level radioactive waste (HLW), including spent fuel if it is to be treated as waste. However, with appropriate design a geological disposal facility could receive radioactive waste of all types [ref]".

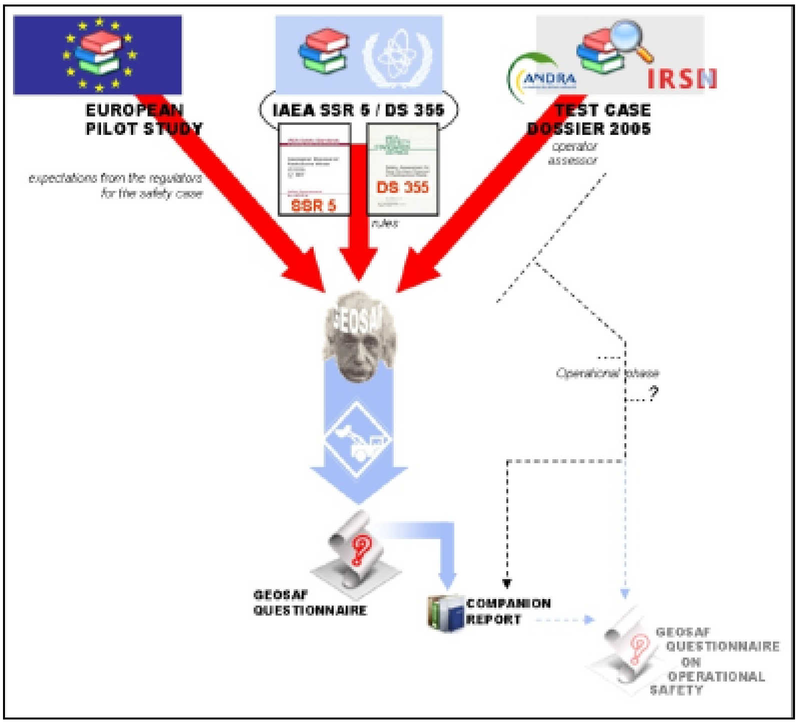
2 Main outcomes

In order to foster harmonization and common understanding of key issues for demonstrating safety and reviewing it, GEOSAF worked towards the development of a questionnaire devoted to review the Safety Case that would structure a foreseen IAEA review procedure.

Noting that, after decades of long term safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase of a geological disposal, GEOSAF decided to launch a specific programme of work on the safety of the operational phase. The outcomes of this pilot study are documented in a companion report attached to this main project report. It is expected from that pilot study that it will serve as a basis of a potential further work.

3 Working methodology

In practice GEOSAF has developed its own work on the ground of the work of the European Pilot Study [ref] on the Regulatory Review of a Safety Case for Geological Disposal of Radioactive Waste (French Nuclear Safety Authority initiative) and on two IAEA safety standards: (i) the Specific Safety Requirements No. SSR-5 (former DS354) on Disposal of Radioactive Waste, (ii) the Draft Safety Guide No.DS355 on the Safety Case and Safety Assessment for Radioactive Waste Disposal.
In addition, with the view to contributing to the development of the questionnaire, GEOSAF will carry out an exercise on the development and technical review of a real national case, namely the French Safety Case presented in the *"Dossier 2005 Argile"* [ref] by the French WMO (ANDRA), for demonstrating the feasibility of a geological disposal in a clay formation. The *"Dossier 2005 Argile"* was technically reviewed by the IRSN, the French Radiation Protection and Nuclear Safety Institute in order to advise the French Nuclear Safety Authority (ASN). The technical opinion of IRSN was published on its website [ref].



4 Main achievements

4.1 European Pilot Study review

Add objectives of this review? Suggestions:

The *European Pilot Study* develops how a regulator should review a safety case and the expected content of the SC at each stage of the development of a geological disposal. It was therefore considered useful for the GEOSAF project both to get familiar to this already harmonized vision at a European level and to review this document and provide inputs to the group in charge of updating the EPS with the objectives of improvement and clarification.

In order to perform the review of the *European Pilot Study* two working groups were created for crossing views from regulators and operators: (i) WG1 aiming at reviewing the *European Pilot Study* framework with a focus on the content of the safety case and its evolution, (ii) WG2 aiming at reviewing the *European Pilot Study* with a focus on the regulatory and technical reviewing process, considering the necessary organization and resources to be developed by the regulator or the technical safety organization. The groups elaborated a number of recommendations that were discussed with the EPS group and gave rise to particular emphasize in the follow up of the EPS work. Main issues concerned:

4.1.1 Organizational aspects for the regulatory body or TSO

- Elaborating guidance : some guidance should be provided on the preparatory activities to be undertaken by the assessors to be ready for the technical and regulatory review (e.g. Review of key reports and technical publications from proponents, Development of Guidance documents (for example as in Canada, France, etc.)…). GEOSAF discussed the issue of the appropriate time for setting (regulatory) requirements but did not reach a consensus: Early definition of requirements provides security in that the stakeholders know the "rules of the game" from the beginning. On the other hand, an early definition increases the likelihood of very generic and unspecific requirements while a later definition would allow accounting for the evolving knowledge

- Being involved in the project at the earliest :
    - Assessors should be involved in review activity early before a Safety Case is actually submitted to any licensing process.
    - Periodic meetings with proponents to give feedback, either in the form of formal review reports and/or informal discussion
    - However the reviewers should be careful oft not being involved into the choices that are of the responsibility of the implementer and to avoid co-development of the safety case.

- Develop competences and structure the review process :
    - Perform independent research externally and in-house on key safety aspects by expertise organizations or expertise units from the authorities, on areas which are complex and need better understanding, development of modelling capabilities in order to perform independent calculations and assessment, etc
    - Seek expert input with external independent experts
    - Establish a team of reviewers. It is anticipated that in early stages, activities are focused on geoscientific disciplines (geology, hydrogeology, geomechanics, geochemistry…). At later times before submission of the safety case, other experts should be involved (fire protection, criticality, ventilation, transportation, radiation protection, biosphere modelling, dose calculation, etc.)
    - the regulatory and expertise activities in preparation for the licensing review of the safety case should focus on key aspects that are relevant to safety, in order to identify gaps and provide feedback to the proponents before they finalize their safety case.
    - Adequate resources should be allocated to the expertise body,
- Participation in international activities(such as GEOSAF and IGSC)
- Organisational factors (such maintaining competencies) are a crucial issue WRT the evolution of a project lasting over decades and should be more explicitly accounted for.

4.1.2 Improvement for more detailed guidance

- GEOSAF generally agreed with the stages proposed in the EPS: conceptualization, siting, design, construction, operation, closure. However, because jurisdictions differ between countries, a license, permit or approval is not always required at the end of each stage
- GEOSAF generally agreed that the safety case provided by the proponent at the end of each stage should be reviewed by the regulators, even if it is not formally submitted in support of some kind of license, permit or approval. Decision points, however, might be taken either by a policy-maker or by the implementer / operator. The issue is all the more important because the Safety Case has to inform these decisions and consequently has to be tailored accordingly
- GEOSAF generally agreed with the detailed regulatory expectations provided by the EPS for the conceptualization, siting and design stages but emphasized

in particular the need for clarifying the fact that the requirement for multiple lines of arguments / confidence building (e.g. by means of natural analogues or by using different indicators than dose) should be made more explicit in the report rather than focusing on radiological impact assessment in order to clarify that safety assessment is much broader than just a set of dose calculations

There should be some guidance on the need for site-specific information that would require some degree of field investigations, versus published data for each stage. In general site-specific data become more important in later stages (e.g. design versus conceptualization, etc.).

- to address the siting strategy or approaches that could be used for siting
- the question of selection of time frame for impact assessment should be discussed
- The importance of natural analogues and paleohydrogeology as strong safety arguments in support of the safety case should be more emphasized in the EPS.
- The question of optimization in site selection, facility design should be discussed
- It should also be noted that at the siting stage, not only the host rock characteristics (geology, hydrogeology, geochemistry, geomechanics, thermal, etc.) should be determined but also the characteristics of the surrounding environment that might impact on the performance of the repository

Other guidance may be developed :

- There should be some guidance on at what stage an Underground Research Laboratory may be needed
- For the design stage, there should be some more guidance :
    - o on what to expect from the proponent for their proposed monitoring program. What, where and when do they measure?
    - o How to address rules, regulations, codes, and standards (including those from outside the nuclear regulation, e.g. engineering design standards) to be accounted for during the design step
- For preparing for the operational phase, the guidance should develop
    - o How to address evolution from preliminary to definitive waste acceptance criteria during the design and construction phases
    - o allowance for analyzing and managing incidents and accidents
    - o operational rules to handle unexpected conditions (e.g.when is an unexpected condition "fatal"?)
    - o commissioning and testing services as an identified activity/step; operations would not be licensed until all (control and) safety systems are checked and proven;
- For the closure and post closure phase GEOSAF recommends accounting more explicitly in the guidance:
    - o for the necessity to address issues linked to the closure of the facility and its safety in relationship to the closure concept already in early development phases
    - o forthe possibility of a post-operational open phase including monitoring issues and to addressthem

- In addition GEOSAF considers that the relationship of the Safety Case to Environmental Impact Assessment activities should be addressed

The guidance should also account for the need to present the overall safety strategy in the Safety Case. The evolution of the safety strategy over the project's duration should be addressed.

4.1.3 Overlaping/interactions between stages

The GEOSAF recommends to better account for overlap and interplay between activities during different stages of disposal development. For example, site characterisation results will have an influence on the repository layout, and it is conceivable if not likely that layout modifications will take place even during construction and emplacement. Furthermore, construction, emplacement, and closure might or will go on in parallel: While some emplacement fields are already sealed, in others emplacement will go on while a third part is under construction. This interplay is not very well visible in the 2007 document but the group believes that using decision points will help resolving this issue.

It should also be noted that even if the design was developed for construction purposes, there still should be flexibility for this design to be modified during construction and in later stages if the need arises.

4.2 Review of the *Draft Safety Guide No. DS355 on The Safety Case and Safety Assessment for Radioactive Waste Disposal*

Regarding the review of the *Draft Safety Guide No. DS355 on The Safety Case and Safety Assessment for Radioactive Waste Disposal* comments were received from Belgium, Canada, France, Germany, Japan, Slovakia and USA considered in the drafting process of the *DS355*. Comments could be classified in following categories:

- clarity and consistency of definitions of main principles
- DS355 seems to focus mainly on post-closure safety of deep geological disposal. More or separate guidance should be provided on pre-closure safety; and on surface facilities (mainly for LLW, NORM and Mine wastes)
- Time frames
- Intrusion
- Institutional Control
- Stakeholders involvement
- Regulatory Process
- Integration of safety and security
- Important principles should be defined clearly upfront; For example, Safety Case and Safety Assessment. It was acknowledge that definitions could vary between different States, however principles remain the same.
- Other examples of clear definitions that were required concerned the issues of containment and isolation, the graded approach, the safety strategy, the defence-in-depth vs multiple barrier, etc.
- More guidance on institutional control, long term care and maintenance, to protect against intrusion and natural processes.

Those outcomes are detailed and integrated in the section related to the description of the questionnaire in the present report.

4.3 Questionnaire development

Based on the requirements of *the Specific Safety Requirements No. SSR-5 (former DS354)*, the IAEA Secretariat prepared a series of questions that the participants assessed by looking at a real-life situation where a deep geological repository is planned, and for which a safety case has been prepared (*"Dossier 2005 Argile"* and the associated technical review). Questions were developed with the view to allowing:

- ? assessing whether the safety issues addressed and the key arguments provided by the operator comply with IAEA safety standards;
- ? guiding the review process performed by the regulator and/or the TSO ;

Besides that, the work undertaken for developing the questionnaire and reviewing the standards contributed to identify areas where requirements and the way of complying with deserved more attention and better mutual understanding.

4.3.1 Briefing session on French case "Dossier 2005":

A presentation of the structure and main results of the "Dossier 2005 Argile" was given by Andra. The purpose of the dossier was to demonstrate the feasibility of the deep geological disposal in the Callovo-Oxfordian clay formation investigated with the Bure URL. Andra explained how was developed the comprehensive understanding of the disposal evolution with time in an integrated approach called "APSS". The needs for multi-disciplinary skills, simulations/experiments capabilities, and traceability were discussed. Necessity to either simplify or complexify modelling was addressed depending of calculation times and being less conservative and more realistic. Andra also presented indicators different from dose as mass rate decay, delay or molar flow…

Then IRSN presented the approached followed since 1997 to review the SC developed by Andra. Key aspects of IRSN regulatory review concerned the inventory, the knowledge of the site, the performances of the engineered components, the disturbances and interactions caused by the repository, the necessity to develop in situ demonstration tests to support safety demonstration as well as the safety assessment methodology and the accounting for uncertainties. The close follow-up of Andra work by IRSN and the nuclear safety authority (ASN) since the conceptualization phase, the legal framework (2 acts in 1991 and 2006 framed the development of deep geological disposal as reference solution for managing HLW and assigned clear responsibilities and means to the WMO Andra) as well as independent research carried out by IRSN to support regulatory review were judged favorable conditions by French actors to progress in the way of deep geological disposal creation.

4.3.2 Working methodology

GEOSAF members were separated into 3 subgroups considering 3 different sets of questions. The 1st group illustrated the applicability of the questions WRT existing real case (French Dossier 2005); the 2 others groups tested the relevance of the questions and started improvement including consideration of DS 355. All groups observed some inconsistencies in the questions and the need for improvement and clarification. Some aspects worth to be part of the reviewing structure were missing.

The questionnaire and the remaining open issues coming from the different reviews are detailed in the next section describing the questionnaire.

4.4 The operational safety working group

Volunteers developed the working methodology devoted to this specific group and based as far as possible their work on exchanges with mining industry that a priori faces hazards possibly to occur in an underground nuclear facility. It is expected from this group that it identifies a first approach for developing safety demonstration of the operational phase. This approach shall take into account constraints that come from a geological disposal facility, which combines safety issues derived, on the one hand from classic nuclear facilities and on the other hand from construction and operation of an underground nuclear installation.

During the course of the project, GEOSAF members have noted that, after decades of long term safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase. It is the reason why GEOSAF decided to launch a programme of work on this topic. This programme included amongst other visits of underground facilities including mines. The programme of work of a dedicated working group on operational phase safety (OPS Working Group) tackled the following issues:

a. Explore hazards associated with the underground facility operation with a view to integration of them into the Safety Case
b. In addition to hazards, consider the activities undertaken in parallel, e.g. emplacement, construction, monitoring, safeguards, maintenance and closure.
c. Long-term safety implications of the operational activities
d. Quality assurance activities in the operational safety
e. Cultural difference between miners and nuclear industry
f. Explore the implications of working in different rock types
g. Explore computer aids to assessing underground hazards
h. Explore the implications of restrictions on damage to the host rock
i. Implications of handling heavy items
j. Implications of operating in an underground nuclear licensed environment – Synergies and conflicts with conventional mining regulation
k. Practical application of controls over life time of the facility

The overall objective of the group is :

- to develop an assessment methodology based on a questionnaire on operational safety in a similar manner as the questionnaire developed for reviewing long term safety;
- to test the questionnaire against existing or ongoing development documents or approaches

In December 2009, as a preparatory work for this group, GEOSAF visited the Klerksdorp Moab Khotsong mine. The mine focuses on gold exploration up to more than 3000 m deep. The visit gave access to a depth of 3108 m in addition to a meeting with the mine management board during which exchanges on safety issues took place i.e. eliminating unsafe acts 96%, role clarification, risk assessment for surface area, shaft barrel and underground, prevention escape procedures and controls flammable gas, fires, ventilation. Regarding radiation and fire risks, preliminary thoughts from the GEOSAF group about main differences between conventional mines and « classic » nuclear facilities were:

- Higher air flow rates / renewal rates
- Higher temperatures
- Higher hygrometry
- New pollutants and more dust (gases?, silica…)

New issues for the geological disposal arised concerning:

- co-activity : conventional and nuclear activities
  - Static and dynamic confinement
- A specific issue for the nuclear ventilation : HEPA filters' deteriorations
  - classical deterioration due to temperature, moist air, high flow rates, clogging, etc.
  - Unknown deterioration due to new pollutants
  - Need of new air purification equipments ?
    - For dust
    - For new pollutants
  - Need of air conditioning ?

This OPS Working Group met **20-22 July 2010** at the **Canadian Nuclear Safety Commission (CNSC) premises in Saskatoon-Canada** and organised the visit of the **Mc Arthur River uranium mine** followed by discussions with staff **from CAMECO** (mine operator) on the radiological and operational safety issues. Because the remaining time was limited before the end of GEOSAF project (June 2011), and the scope of the operational phase safety group very large, the group argued that a "**pilot study**" should be initiated at this time with the view to validating the working methodology on one safety topic of interest for the operational phase.
As a 1st step, the group supported its discussion for selecting the hazards and events to be dealt with in the pilot study based on the the WIPP Operational safety report that have been put at the disposal of the group and on the hazard/eventmatrix of the WIPP.

I. The **questionnaire** and the operational safety **assessment methodology** could be derived from the following issues (preliminary discussion):

- Identify hazards/enveloppe scenarios and their relationship on operational safety and long term safety
- Which ones are specific to nuclear facilities ? To underground facilities? To standard industrial facilities … ?
- Identify regulations or standards, for industrial and nuclear facilities for protection against the hazards.
  - Do such standards exist ?
  - Are they adequate for a deep geological disposal? if not recommend development of new regulations
- Describe the facility, its safety functions, its systems and operational processes. Determine which systems could be integrated in the design and operational procedure to deal with the hazards
- Develop controls to prevent/mitigate the hazards and their impact on operational & long term safety
- Continuous feedback and improvement. Operators / member states may need to build [regulatory] requirements!
- …

II. **Validation of the pilot study** :

Hazard/event selected for the pilot study was related to **Fire**

Different items were discussed:

- WIPP methodology as illustration of existing approach regarding the selected hazard/event
- Existing code: e.g. in Canada Fire Protection code, part of National Building Code, provincial mining code. No specific code for fire protection for underground facility. No code or standard, guidance for deep geological disposal
- Systems and design to tackle fire: limit fire size, ventilation system, fire suppression system, specific administrative control, vehicle barriers, grading and sloping, etc…
- Impact of fire accidents during operation on degradation of geological and engineered barriers, effects on criticality (???)…
- Systems to mitigate fire hazard, like the ventilation shafts, influence long term safety, by being potentially preferential contaminant pathways
- …

It was decided that the Pilot study should be issued as a GEOSAF companion report.

Development of the Draft questionnaire

Requirement 1: Government responsibilities

The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities are clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility.

1.1 What is the legal and regulatory framework and how does it provide the basis for the development of a radioactive waste disposal facility and its associated safety case?

1.2 What roles and responsibilities are identified within the legal and regulatory framework associated with the derivation of regulatory requirements?

1.3 What arrangements are in place and how is it demonstrated that adequate funding is available to conduct research for development of the safety case and for the development of the radioactive waste disposal facility?

There should be some guidance on at what stage an Underground Research Laboratory may be needed.

Organisational factors and characteristics are a crucial issue in the evolution of a project lasting over decades

Requirement 2: Responsibilities of the regulatory body

The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.

2.1 What are the legal and regulatory requirements imposed upon the facility and its associated safety case?

2.2 What is the licensing process in terms of the communications between the regulator(s) and the operator during the development of the safety case?

2.3 What regulatory guidance has been developed to clarify regulatory requirements on radioactive waste disposal and the associated safety case?

The Group discussed the issue of the appropriate time for setting (regulatory) requirements but did not reach a consensus: Early definition of requirements provides security in that the stakeholders know the "rules of the game" from the beginning. On the other hand, an early definition increases the likelihood of very generic and unspecific requirements while a later definition would allow accounting for the evolving knowledge.

Regulators and/or TSOs should be involved early before a safety case is actually submitted. Some guidance could be provided on the activities by the regulators and/or TSOs to prepare for that review that could include:

? *Review of key reports, technical publications from proponents*
? *Development of Guidance documents (for example Canada, France, etc.) for proponents to develop safety case*
? *Independent research performed externally and in-house on key safety aspects , on areas which are complex and need better understanding, development of modelling capabilities in order to perform independent calculations and assessment, etc. (see Appendix on TSOs research capacities)*
? *Participation in international activities(such as GEOSAF and IGSC)*
? *Seeking expert input with external independent experts*
? *Periodic meetings with proponents to give feedback, either in the form of formal review reports and/or informal discussion (see Appendix on French study case)*

The regulators' resources can not match the operators'. The regulatory activities in preparation for the review of the safety case should then focus on key aspects that are relevant to safety, in order to identify gaps and provide feedback to the proponents before they finalize their safety case. Adequate resources should be allocated, and responsibilities should be defined. A team of reviewers *should be established. It is anticipated that in early stages, activities are focused on geoscientific disciplines (geology, hydrogeology, geomechanics, geochemistry…). At later times before submission of the safety case, other experts should be involved (fire protection, criticality, ventilation, transportation, radiation protection, biosphere modelling, dose calculation, etc.)*

2.4 What system is required to document the procedures used to evaluate the safety of facilities and activities proposed for licensing?

2.5 What procedures are in place to inform and direct the operator in respect of the regulatory process for different steps in the development and licensing of a radioactive waste disposal facility?

2.6 What guidance is provided on the procedures that will be applied to assess compliance of the licence application with safety requirements?

W*G1 notices that the perception of independence can vary between States, depending on the socio-political situation. In practice, a regulator, although independent, must however interact with the proponents. What degree of interaction is acceptable and tolerable before independence is perceived to be affected is a question every country should ask itself.*

Requirement 3: The responsibilities of the operator

The operator of a disposal facility shall be responsible for its safety. The operator shall carry out safety assessment and develop a safety case, and shall carry out all the necessary activities for siting, design, construction, operation, closure and, if necessary post closure surveys, according to national strategy, in compliance with the regulatory requirements and within the national legal infrastructure.

3.1 What process is in place to develop a safety case? How is this process envisaged to change with the steps in the development of a disposal facility?

3.2 What human resources are assigned to different waste management functions? How are staff competence levels established and maintained?

3.3 What processes are in place to engage in dialogue with waste producers, the disposal facility operators and other interested parties?

3.4 How does the safety case demonstrate that processes are in place to ensure the operator organization is executing its responsibility for the safety of a radioactive waste disposal facility?

3.5 What programme of research and development is carried out or envisaged in support of safety during siting, design, construction, operation, closure of the facility?

3.6 What process is used to establish all the technical specifications used for controlling activities and processes relevant to safety throughout the development of a disposal facility?

3.7 What process is used to identify and retain all the information relevant to the safety case?

The group discussed the issue to present the overall safety strategy approach to the project in the Safety Case. The evolution of the safety strategy over the project's duration should be addressed.

Requirement 4: Importance of safety in the development process

Throughout the development of a disposal facility, an appropriate understanding of the relevance and implications for safety of the available options shall be developed by the operator, for achieving the ultimate goal of providing an optimized level of operational and post-closure safety.

4.1 What process is in place to ensure that the implications for safety are taken into consideration before key decisions are taken?

4.2 How is the optimization of safety taken into consideration in the decision-making process?

4.3 What measures are taken to ensure that there is an adequate level of confidence in safety before decisions are made?

4.4 How is it determined that before construction activities are commenced that there is sufficient evidence for the feasibility and effectiveness of design features important to safety to perform their design functions over the intended timeframes?

4.5 How is it demonstrated that before construction activities commence there will be sufficient evidence that the performance of the backfilling, sealing and capping will function as intended to fulfil design requirements?

4.6 What approach is used to determine that an adequate level of characterization has been carried out before construction commences?

Requirement 5: Passive means for the safety of the disposal facility

The operator shall evaluate the site and shall design, construct, operate and close the disposal facility in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the

facility is minimized.

5.1 What processes are in place to assure that the passive design features are evaluated and optimized throughout siting, design, construction, operation, and closure of the facility?

5.2 What active control measures are in place or envisaged for the radioactive waste disposal facility?

5.3 To the extent that some active measures are adopted, what process is put in place to ensure these are minimized?

Requirement 6: Understanding and confidence in safety

The operator of a disposal facility shall develop an adequate understanding of the facility and its host environment and the factors that influence its post-closure safety over suitably long time periods, so that a sufficient level of confidence in safety is achieved.

6.1 What features of the facility and its host environment are important to safety and how are they identified?

6.2 How have factors been identified that might be detrimental to safety?

6.3 In respect to 6.1 and 6.2 how is it demonstrated that these features and factors are sufficiently well characterized and understood?

6.4 How is confidence in the margin of safety enhanced by factors that are less quantifiable, and what are those factors?

6.5 How is it demonstrated that the knowledge base related to the performance of the disposal system has been developed and contributed to an increased level of confidence over time?

6.6 In respect to 6.5, how is this knowledge base used to demonstrate the reliability or robustness of design features important to safety?

6.7 How is it demonstrated that the appropriate range of possible disturbing events and processes is taken into consideration in the safety case?

6.8 In regards to 6.7, how is it determined to what extent safety functions may be degraded by these disturbing events?

6.9 What processes are in place to address uncertainties including their identification, characterization and management?

6.10 Regarding post closure, how is the range of possible developments affecting the disposal system performance determined, including those of low probability?

Requirement 7: Multiple safety functions

The host environment shall be selected, the engineered barriers of the disposal facility shall be designed and the facility shall be operated to ensure that safety is provided by means of multiple safety functions. Containment and isolation of the waste shall be provided by means of a number of physical barriers of the disposal system. The performance of these physical barriers is achieved by means of diverse physical and chemical processes together with various operational controls. The capability of the individual barriers and controls together with that of the overall disposal system to perform as assumed in the safety case shall be demonstrated. The overall performance of the disposal system shall not be unduly dependent on a single safety function.

7.1 What safety functions are associated with the various engineered and natural features of the disposal facility? During what timeframe are the functions intended to be effective?

7.2 What safety functions, if any, are provided by active as opposed to passive means?

7.3 How is it demonstrated that safety functions have sufficient defence in depth to provide assurance that the margin of safety is not reduced if a particular safety function does not perform as intended?

7.4 How is it determined that safety functions, if any, are complementary (dependent upon one another)?

7.5 How is overall adequacy of the multiple safety functions evaluated and what approach is taken to demonstrating that safety is not unduly dependent on any single safety function?

Requirement 8: Containment of radioactive waste

The engineered barriers, including the waste form and packaging, shall be designed, and the host environment shall be selected, so as to provide containment of the radionuclides associated with the waste. Containment shall be provided until radioactive decay has significantly reduced the hazard posed by the waste. In the case of heat generating waste, containment shall be provided while the waste is still producing heat energy in amounts that could adversely affect the performance of the disposal system.

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*How is **containment** defined ?*

RADIOACTIVE WASTE MANAGEMENT GLOSSARY 2003 Edition. Methods or physical structures designed to prevent the dispersion of radioactive substances. Although approximately synonymous with confinement, containment

is normally used to refer to methods or structures that prevent radioactive substances being dispersed in the environment if confinement fails.
DS 354 section 3.39. The containment of radioactive waste implies designing the disposal facility to avoid or to minimize the release of radionuclides.
There is a difference between the above two definitions. The glossary seems to define containment as 0% of release of radionuclides from the barrier; DS 354 however assumes that 0% release might not be possible and introduces the notion that the barrier should alternatively minimize that release.

H *ow is* ***isolation*** *defined ?*

There is no definition for isolation in the Radioactive Waste Management Glossary.
DS 354 section 3.44 Isolation means design to keep the waste and its associated hazard apart from the accessible biosphere. It also means design to minimize the influence of factors that could reduce the integrity of the disposal facility. Sites and locations with higher hydraulic conductivities have to be avoided. Access to waste has to be made difficult without, for example, violation of institutional controls for near surface disposal. Isolation also means providing for a very slow mobility of radionuclides for migration from disposal facilities.
GEOSAF group is of the opinion that the definitions of containment and isolation are neither clear nor consistent between the glossary, DS354 and between themselves (requirements 8 and 9).

G*EOSAF group reviewed the requirement and the explanatory clauses that follow the requirement. The group considers that this requirement should explicitly mention both normal evolution and alternate evolution scenarios. However, the participants noticed that DS-355 provided more detailed guidance on scenario definitions. Concerning clauses 3.40 and 3.42, the group considers that the guidance provided related to container integrity is not always practicable or necessary in order to have safe containment. Some concepts do not rely on container integrity. For example, in the dry salt concept, containers might fail earlier due to mechanical impact, but due to dry conditions, radionuclide migration is controlled and minimized.*

The degree of containment for different engineered and natural barriers is calculated in the Dossier 2005 for different radionuclides and several scenarios. For Iodine 129 originating from spent fuel, in the normal evolution scenario, the Safety Assesment results showed (Figure 2):
Total containment in the containers during the first 200 years; total failure of the containers at 10,000 y. The peak release of I-129 from the containers into the repository occur shortly after 10,000 y.
The flux into the Callovo-Oxfordian (COX) starts at approximately 220years, peaks at approximately 10,000 yr.
The flux out of the COX into the overlying formation starts at 300yr and peaks at 200,000 yrs.
The flux into the shaft is only 0.0008% of the total release from the wastes. Only 3x10-5 of the total release exits the shaft at more than 100,000yr.

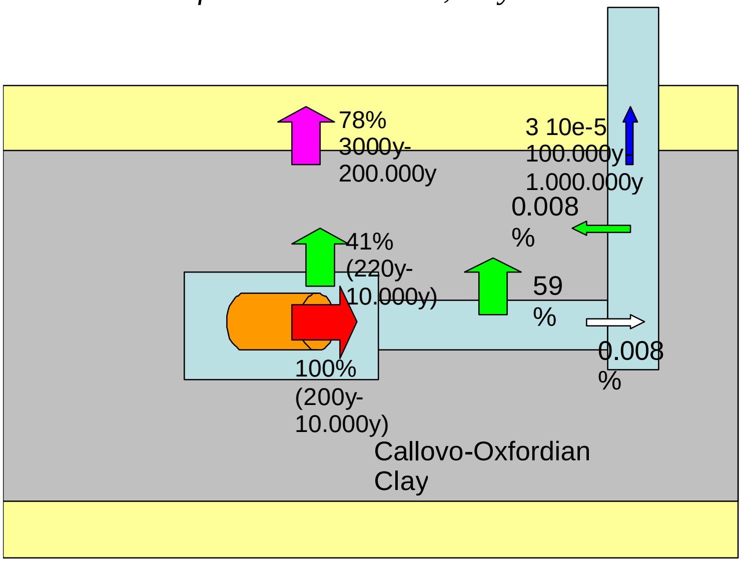


Figure 1. Illustration of the containment provided for I-129 in the normal evolution scenario in Dosssier 2005. The % of flux, the starting time, and the time to peak, are shown for different compartments.

8.1 What degree of containment is claimed for the components of the waste disposal system including the waste form, packaging, and other engineered and natural features?

8.2 How is it demonstrated that the major part of activity will decay in situ within the designed containment configuration?

8.3 What is the intended design lifetime of the containment configuration and how is this deemed to be adequate?

8.4 How is it established that the migration of radionuclides outside of the disposal system will only occur after the heat produced by radioactive decay within the waste has substantially decreased?

8.5 What particular consideration is given to assuring the integrity of containment features over timeframes commensurate with the hazard presented by the waste for mining and minerals processing waste?

8.6 In cases where human intrusion events could give rise to the radiation dose criteria for intrusion being exceeded, how were alternative design options considered before deciding on the final design?

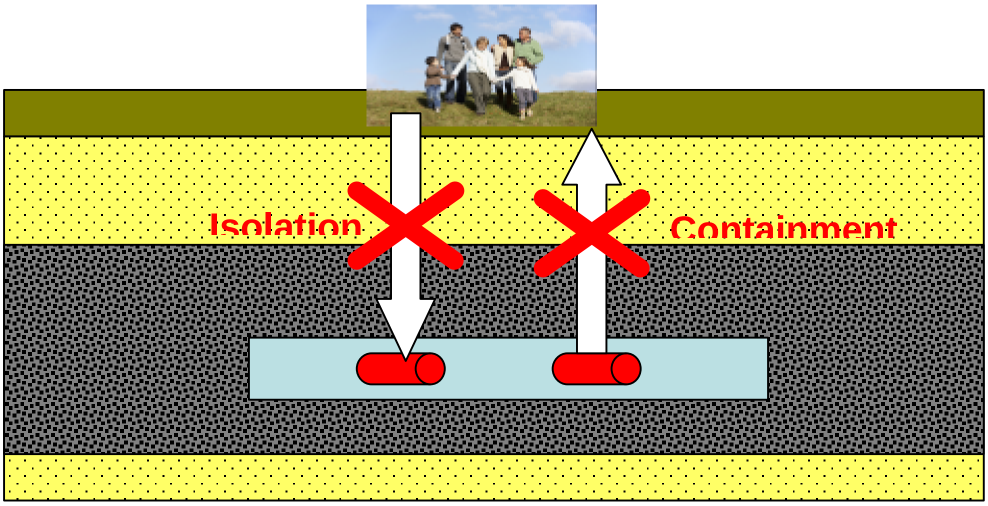
8.7 How is the release of any gaseous or airborne radioactive material from the waste form or waste packages demonstrated to be acceptable?

Requirement 9: Isolation of radioactive waste

The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short lived waste and at least several thousand years for intermediate and high level waste. In so doing, consideration shall be given to both the natural evolution of the disposal system and events causing disturbance of the facility.

The definition of Isolation given in DS354 (as cited in the first sentence above) is applicable for waste, but not the radionuclides. However, in the last three sentences, hydraulic conductivities of the host media and slow mobility of radionuclides were invoked. The group is of the opinion that these characteristics are rather related to containment of radionuclides and not isolation of the wastes. It suggests, and adopted the following definition to carry on with the workshop:

From GEOSAF understanding, isolation means spatial separation of the wastes from the biosphere; while containment means prevention and/or minimization of migration of radionuclides through the different barriers of the disposal system.
The following figure schematically shows this understanding:



9.1 How is it demonstrated that the facility provides for isolation of the waste from the accessible biosphere?

9.2 What is the technical basis for the intended design lifetime of the features providing isolation?

9.3 What is the anticipated duration of any administrative controls providing for isolation and how is it derived?

9.4 What factors have been identified that could reduce the integrity of the disposal facility and what measures have or will be taken to minimize the influence of these factors?

9.5 How is it demonstrated that the facility has been located in a suitable host geology that will allow the disposal system to provide adequate isolation of radioactive waste?

9.6 How is it demonstrated that the regulatory system safety criteria have been met over the stipulated timeframes?

9.7 How has uncertainty been accounted for and managed in assessing radiological impacts?

9.8 Are indicators of safety other than radiation dose made use of and how is this done?

Requirement 10: Surveillance and control of passive safety features

An appropriate level of surveillance and control shall be applied to protect and preserve the passive safety features, to the extent that this is necessary, so that they can fulfil the functions that they are assigned in the safety case for safety after closure.

10.1 How is it demonstrated that the passive safety features will be robust enough to ensure that repair or upgrading will not be required within their design lifetime?

10.2 What is the basis for the programme of surveillance and monitoring of passive safety features and how is the adequacy of the programme addressed in the safety case for each different step of the facility lifecycle?

10.3 What monitoring and surveillance will be carried out at the different steps of the facility development, operation, closure and post closure to ensure that passive safety features are or will fulfil their assigned safety function after closure?

Requirement 11: Step by step development and evaluation of disposal facilities

Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system.

11.1 What are the major steps that have been identified for design, operating, and regulatory decisions during the life cycle of the facility?

11.2 What iterative evaluations have been conducted of the performance and safety of the disposal system in each step identified below?

- ? siting
- ? design
- ? operations
- ? closure
- ? post closure

The GEOSAF group generally agrees with the stages proposed in the EPS (see annex) but noted differences in approaches between steps defined in SSR5, Req.3 and the phases taken into consideration by the EPS group. The identified phases defined in the EPS present in particular a first phase called "conceptualization phase" prior to the siting phase as well as specific regulatory milestones regarding authorization for construction, operation and closure as stated below.

The ***conceptualisation*** *phase, during which an implementer considers potential sites and design options, establishes the safety strategy and carries out preliminary assessments. Regulatory review of the work at this stage should guide the implementer on the likelihood of achieving the necessary* *demonstration of safety.*

The ***siting*** *phase, during which the implementer identifies potentially suitable sites that are compatible with the design concept and characterises these sites to the extent that a decision can be made on the preferred site.*

The ***reference design*** *(and application for construction) phase, during which the implementer adapts the conceptual design to the site properties, finalises and validates the design of the disposal facility, and develops the safety assessment, to support the implementer's application to construct the facility. This is used by the regulator to decide whether to grant a licence for the implementer to construct the facility and is the crucial milestone in the development of a repository.*

The ***construction*** *(and application for operation) phase, during which the implementer demonstrates that it has built the facility in accordance with the terms of the construction licence. In preparing for operation, the implementer will need to demonstrate safety during operation and radiation protection of workers and members of the public. The regulator would decide whether to grant a separate licence before emplacement of waste in the facility.*

The ***operational*** *phase, during which the implementer emplaces waste packages in the disposal facility, may build new disposal units, backfill and possibly seal, either temporarily or permanently, parts of the disposal facility where waste emplacement has been completed ; develops its application to close and seal the facility, and prepares a draft plan for post-closure institutional controls, monitoring and surveillance. Towards the end of this phase the regulator will decide whether to grant a license for the implementer to close and seal the facility.*

The ***post-closure*** *phase : the implementer will demonstrate that it has closed the disposal facility in accordance with safety requirements and present a firm plan for institutional controls and continuing monitoring and surveillance. At this stage the regulator will confirm what controls, monitoring and surveillance are required and for how long.*

However, because jurisdictions differ between countries, a license, permit or approval is not always required at the end of each stage. We also generally agree that the safety case provided by the proponent at the end of *each stage should be reviewed by the regulators, even if it is not formally submitted in support of some kind of license, permit or approval. Decision points, however, might be taken either by a policy-maker or by the implementer / operator. The issue is all the more important because the Safety Case has to inform these decisions and consequently has to be tailored accordingly.*

11.3 What role does the safety case play in supporting the decisions to be taken to move to subsequent steps?

Different authorizations are required at different steps in repository development in different national programmes. The table attached in annex summarizes the authorizations needed in various Member States for the realization of a radioactive waste disposal repository and identifies the stage of repository development in each national programme. This information is of use when attempting to harmonize different aspects of national programmes through comparing and contrasting country-specific information such as review methods, regulatory resources and available guidance documents. The compilation is based on a brief survey that was conducted during the March 2009 GEOSAF Workshop, Vienna

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Four types of authorizations are identified (licences, permits, approvals and decisions). The definitions of these authorizations are presented in the table footnotes. The definitions are adopted from the following information to have specific application to HLW/SNF disposal programmes.

Licence

*1. "A legal document issued by the regulatory body granting authorization to perform specified activities related to a facility or activity." [**IAEA Safety Glossary, Terminology Used In Nuclear Safety And Radiation Protection, 2007 Edition**]*

*2. Any authorization granted by the regulatory body to the applicant to have the responsibility for the siting, design, construction, commissioning, operation or decommissioning of a nuclear installation. [**Convention on Nuclear Safety, INFCIRC/449, IAEA, Vienna (1994),** cited in IAEA Safety Glossary*

3. Any authorization, permission or certification granted by a regulatory body to carry out any activity related to *management of spent fuel or of radioactive waste. [**Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546, IAEA,*** **Vienna (1997)**, cited in IAEA Safety Glossary.]

A licence often specifies conditions, responsibilities for reporting to the issuing authority and compliance oversight by the issuing authority.

Permit

*(n) written order giving permission to act, (v) to give consent or opportunity (for) [**Concise Oxford Dictionary, Seventh Edition, 1982**]*

A permit may specify conditions, but typically does not specify reporting or compliance oversight.

Approval

*1. The granting of consent by a regulatory body. [**IAEA Safety Glossary**]*

*2. The act of pronouncing or considering (that something is) good or satisfactory (from **approval**: act of approving, sanction; and **approve**: pronounce or consider good or satisfactory [**Concise Oxford Dictionary, Seventh Edition, 1982**])*

Decision

*settlement (of question, etc.), conclusion, formal judgement, making up one's mind, resolve [**Concise Oxford Dictionary, Seventh Edition, 1982***

Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility

A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step.

12.1 What safety objectives and safety principles have been indentified as a basis for the safety case?

12.2 How is each element of the safety case addressed and enhanced at each step of the facility life cycle?

? siting
? design
? operations
? closure
? post closure

12.3 How are design and safety studies integrated in the process and what measures are in place to ensure adequate confidence in the safety of the facility at each of the major decision steps?

12.4 How is the adequacy of the scientific basis for safety studies and the various supporting analyses evaluated?

12.5 What process is in place to ensure the access of interested parties to the safety case and all supporting assessments and analysis?

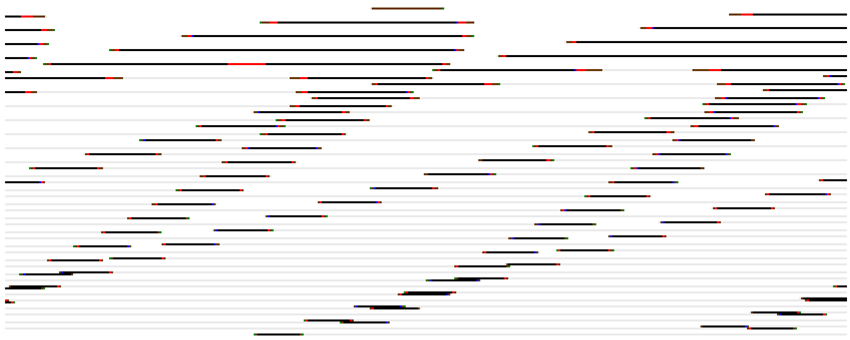
12.6 What process of independent technical review has been adopted? What is the process of regulatory review associated with the different steps?

12.7 What approach has been used to demonstrate that all safety requirements have been met when deciding to move to the next step?

12.8 What arrangements are in place to undertake periodic safety reviews during the operational period?

Requirement 13: Scope of the safety case and safety assessment

The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility, and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met.



FigureXX: Posiva's safety case port-folio

The relation between the Safety Case and the Environmental Impact Assessment activities should be addressed

Safety requirements and related explanations are given in the SSR5 as well as in DS355 but a number of member states questioned themselves on the real significance of safety case as well as safety assessment, the linkage and differences between both concepts. Generally, it appears that terminology used for Safety Case differs from country to country : for example, where it is called "XXXX", it is called in France "Dossier de Sûreté" that means "Safety File" and, in practice, is a collection of different reports related to the DGR project (including the documentation related to the basic data (geology, hydrogeology, chemistry, waste inventory…), the design, the safety approach, the evolution scenarios…). This collection of different reports aims at compiling all arguments in a structured way that contributes to demonstrate the safety of the DGR whatever the level state of the project. This is the definition that is endorsed by the NEA. Even in the early phases of the development of a project, it is necessary for the operator to develop a Safety Case as basis for internal decisions (research and development, site selection and evaluation, design conceptualisation…..), as well as basis for dialogue with *the regulator.*

The safety assessment of a repository aims at evaluating the soundness of the safety strategy on one hand and at verifying that the repository performs such as adequate levels of protection of man and environment are reached on the other hand. It is during this step that the « global » performance of the repository is evaluated against plausible situations (scenarios). This requires a policy for scenario definition and development and for integrating all pertinent information into a sound modelling. In return, safety assessments provide an input for the treatment of uncertainties and contribute to provide a hierarchy of the studies deserving particular attention and that should be implemented in the next stage of project development. It should also provide input for modifying or complementing the strategy, and confirm, in advanced stages of development, that the application of specified parameters lead to adequate levels of protection. The realisation of safety assessments requires:

- *to assemble all qualitative and quantitative information obtained in particular during the phase of implementation of the safety strategy in order to determine a plausible set of scenarios of repository evolution,*
- *to test the reliability of the safety functions against these scenarios through performance assessments using in particular the "process/subsystem" modelling that has been possibly validated during the phase of implementation of the strategy,*
- *to use integrated performance assessment (and sensitivity analysis), enabling to evaluate the fluxes and concentrations of radionuclides released in the various parts of the repository, for various time frames and for the set of scenarios determined previously, so as to evaluate quantitatively the pros and cons of the proposed safety strategy, and highlight the various roles played by the barriers in time with regard to radionuclides releases and migration,*
- *to use also integrated performance assessment to verify that the protection standards can be satisfied.*

Safety Assessment *is a specific activity carried out by the operator in order to assess a number of aspects as described in the Figure … As explained in the draft DS355, safety assessment relies to qualitative and quantitative assessment of elements relevant for the safety of the development, operation and closure of the disposal facility.*

Regarding the quantitative aspects of the safety assessment, member states often consider that safety assessment refers to dose calculations. As safety assessment is part of the safety case, radiological impact calculation is a component of the safety assessment. But, safety assessment not only covers the quantitative assessment of the radiological impact but also the evaluation of the qualitative and quantitative performances of the DGR. It takes into account the data (for example experimental results, site characterisations…), the design and evolution scenarios that are described in the Safety Case for performing different types of calculations (see for example the scheme proposed by STUK for illustrating quantitative assessment on Figure XX below).

These calculations are related to the modeling of processes that occur in the repository and aim at building confidence in the well understanding of the DGR behaviour all along its lifetime (more specifically on the long term) considering the influence of remaining uncertainties. For example, calculations should address:

- *the verification of the favourable behaviour of the disposal components when no interactions are expected, individually and globally;*
- *the evaluation of the disturbances caused by the interactions between the different disposal components and the assessment of the consequences of those disturbances on safety functions;*
- *the modeling of the future behaviour of the repository for specific scenarios;*
- *and finally, checking that individual exposure is acceptable.*

Those results could be presented in terms of various indicators of the confinement performances of the DGR as activity fluxes, concentrations, ratios, or doses if needed. This was illustrated by the Safety Case presented by Andra with the "Dossier 2005 argile" that considered, besides radiological impact calculations, a number of quantitative *evaluations of radionuclides migration from the disposal tunnels up to the top of the host formation.*

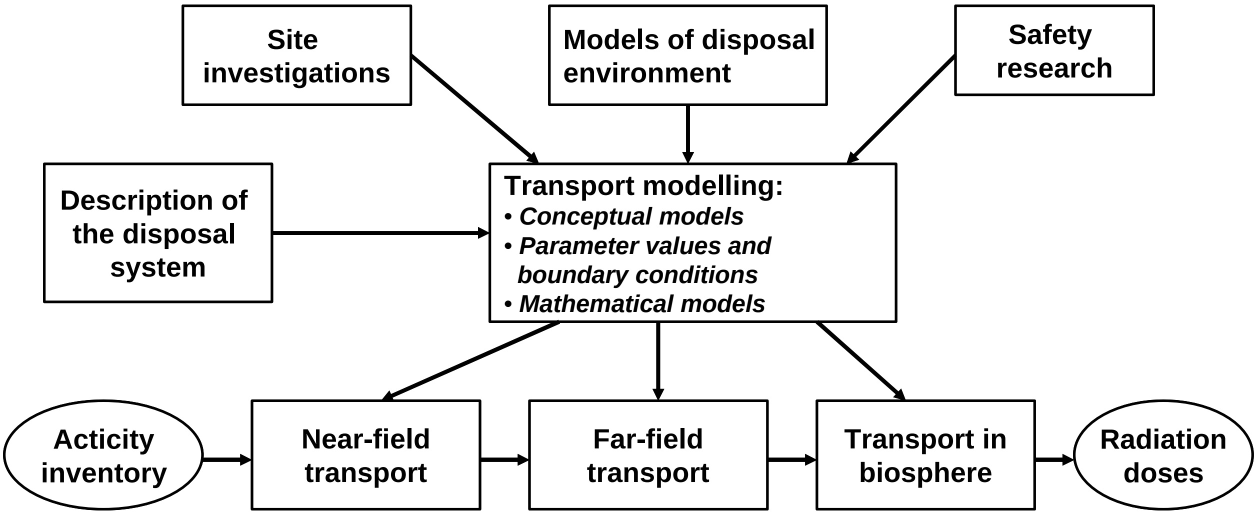


Figure XX from STUK

13.1 How is the adequacy of design and operational features evaluated?

13.2 How is the safety case structured to address both operation and post closure safety?

13.3 How is it demonstrated that the feasibility of implementing the design is addressed?

13.4 How do the safety case and the supporting assessments demonstrate adequate defence in depth provisions?

13.5 How does the safety assessment process demonstrate that all relevant accident or disturbing event scenarios have been analyzed, including those of lesser frequency?

13.6 How does the safety case address occupational exposure and public exposure arising from normal operation and unanticipated occurrences during the facility lifetime, and on what basis?

13.7 What approach is adopted to consider the consequences of unexpected events and processes that test the robustness of the disposal system?

13.8 What approach is taken to develop a reasonable level of assurance that all the relevant safety requirements will be complied with and that radiation protection has been optimized?

13.9 What sensitivity analyses and uncertainty analyses have or will be undertaken to obtain an understanding of the performance of the disposal system and its components under the range of normal evolutions and potentially disturbing events?

Requirement 14: Documentation of the safety case and safety assessment

The safety case and supporting safety assessment for a disposal facility shall be documented to a level of detail and quality sufficient to inform and support the decision to be made at each step and to allow for independent review of the safety case and supporting safety assessment.

14.1 What is the scope and structure of the documentation which makes up the safety case and supporting safety assessment for the different steps of the project?

14.2 What is the process used to develop and maintain the safety case and supporting safety assessments documentation to assure justification, traceability and transparency?

14.3 How are assumptions and decisions that play a role in the development of the safety case and associated safety assessments documented and recorded?

Requirement 15: Site characterization for a disposal facility

The site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time. This shall include its present condition, its probable natural evolution, and possible natural events and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility.

15.1 What is the planning basis for the site characterization program?

15.2 What is the appropriate site characterization program for the different phases of disposal facility development?

15.3 What general approach is taken to iterate the site characterization work with the safety case and supporting assessment?

15.4 What approach is taken to characterize the environmental aspects including natural aspects such as :

- hydrology,
- meteorology,
- flora and fauna,
- anthropogenic activities in the site environs relating to normal residential patterns,
- industrial and agricultural activity,
- natural background radiation, and
- the radionuclide content in soil, groundwater and other media

15.5 What approach is taken to investigate the following:

- long term stability,
- faulting and the extent of host rock fracturing;
- seismicity;
- volcanism;
- confirmation of the volume of rock suitable for the construction of disposal zones;
- geotechnical parameters relevant to the design;
- groundwater flow regimes;
- geochemical conditions;
- mineralogy
- surface processes

15.6 What approach is taken to identify the features, events and processes that could have an impact on safety and which are to be addressed in the safety case and supporting safety assessment?

15.7 What approach is adopted to develop understanding of the site to support the conceptual models used in the safety assessment?

15.8 What general approach is taken to determine the extent of characterization necessary for different parameters?

It should also be noted that at the siting stage, not only the host rock characteristics (geology, hydrogeology, geochemistry, geomechanics, thermal , etc.) should be determined but also the characteristics of the surrounding environment that might impact on the performance of the repository.
There should be some guidance on the need for site-specific information that would require for each stage some degree of field investigations, versus published data. In general site-specific data become more important in later stages (e.g. design versus conceptualization, etc.).
Address the siting strategy or approaches that could be used for siting

Requirement 16: Design of a disposal facility

The disposal facility and its engineered barriers shall be designed to contain the waste with its associated hazard, to be physically and chemically compatible with the host geological formation and/or surface environment, and to provide safety features after closure that complement those features afforded by the host environment. The facility and its engineered barriers shall be designed to provide safety during the operational period.

16.1 What is the basic design and how is it demonstrated that it is complementary with the host environment?

16.2 How is it demonstrated that optimal use has been made of the safety features offered by the host environment?

16.3 What measures have been taken to ensure that the layout is designed so that waste is emplaced in an appropriate location in consistency with the safety case?

16.4 How has the feasibility of fabrication of waste containers and of the construction of engineered barriers been demonstrated?

16.5 How is it demonstrated that appropriate materials are used in the facility design?

16.6 What design considerations address the long-time performance requirements of the disposal facility?

16.7 If design features are incorporated to facilitate retrievability, how is it demonstrated that safety is not compromised?

16.8 How is it demonstrated that sufficient flexibility exists in the design to allow for variations such as in rock conditions or groundwater conditions in underground facilities?

16.9 How does the design ensure that in the event that fissile materials are present in the waste a sub-critical configuration will be maintained?

The section should address rules, regulations, codes, and standards (including those from outside the nuclear regulation, e.g. engineering design standards) to be accounted for during the design step.
It should also be noted that even if the design was developed for construction purposes, there still should be flexibility for this design to be modified during construction and in later stages if the need arises.
For the design stage, there should be some more guidance on what to expect from the proponent for their proposed monitoring program. What, where and when do they measure?

Requirement 17: Construction of a disposal facility

The disposal facility shall be constructed in accordance with the design as described in the approved safety case and supporting safety assessment. It shall be constructed in such a way as to preserve the safety functions of the host environment that have been shown by the safety case to be important for safety after closure. Construction activities shall be carried out in such a way as to ensure safety during the operational period.

17.1 What construction techniques have been decided upon and how have they been demonstrated to be compatible with the various safety functions described in the safety case?

17.2 How have the construction techniques been deemed to be feasible in particular in an underground environment and what evidence is provided of their adequacy?

17.3 How has it been demonstrated that excavation and construction activities will be carried out in such a way as to avoid unnecessary disturbance of the host environment?

17.4 How is it demonstrated that sufficient flexibility exists in the construction techniques to allow for variations such as in rock conditions or groundwater conditions in underground facilities?

17.5 What plans have been developed to ensure that ongoing excavation and construction does not compromise either operational or post-closure safety?

Requirement 18: Operation of a disposal facility

The disposal facility shall be operated in accordance with the conditions of the licence and the relevant regulatory requirements so as to maintain safety during the operational period, and in such a manner as to preserve the safety functions assumed in the safety case that are important to safety after closure.

18.1 How is it demonstrated that all operations and activities important to safety are subjected to limitations and controls?

18.2 How does the safety case address and justify the operational management arrangements which are used to ensure that the safety objectives and criteria are met?

18.3 If the facility remains unsealed following emplacement of waste, what provisions are in place pertaining to maintaining active controls for safety?

18.4 What approach has been used to ensure that when fissile material is disposed of in the facility it will be managed and emplaced in a configuration that will remain sub-critical?

18.5 What approach has been used to assess the possible evolution of the nuclear criticality hazard after waste emplacement, including in the post-closure period?

18.6 How is it demonstrated that configuration management processes are adequate and effective?

18.7 How is it demonstrated that the safety documentation is managed, updated, and preserved, especially with plant modifications, to assure safety?

18.8 What system(s) are used to ensure that all documentation associated with operations such as operating procedures, specifications and plans are controlled?

18.9 What processes and plans are in place to address abnormal operations and emergency situations?

The safety case should define clearly the operating envelope inside of which the facility should be operated. Thresholds and margins should be described, in order to qualify unexpected or expected events, such as :

? *abnormal (incidents): the components relevant to safety and procedures allows the operator to get back to normal operation without damaging safety,*

? *unauthorized (accidents, emergency situations): the facility is out of its operating envelope, and emergency systems and procedures have to be mobilized to protect workers, the population and the environment and mitigate consequences of such an event.*

Therefore the safety case should describe the methods and means for analyzing and managing incidents and accidents :
- operational rules to handle unexpected events (e.g. when does an unexpected condition have a significant impact on long term? safety?),
- commissioning and testing services as an identified activity/step; operations would not be licensed until all (control and) safety systems are checked and proven.

The GEOSAF group is of the opinion that there is a need to address how incidents and/or accidents during the operational phase can be anticipated and avoided. If not, elements should be provided on the way the consequences of those incidents and/or accidents can be mitigated and how to adopt measures to mitigate their consequences both on operational and long term safety and allowance for analyzing and managing incidents and accidents

GEOSAF recommends to better account for overlap and interplay between activities during different stages. For example, site characterisation results will have an influence on the repository layout, and it is conceivable if not likely that layout modifications will take place even during construction and emplacement. Furthermore, construction, *emplacement, and closure might or will go on in parallel: While some emplacement fields are already sealed, in others, emplacement of waste will go on while a third part of the disposal is under construction. This interplay is not very well visible in the 2007 document but the group believes that the EPG approach of using decision points will help resolving this issue.*

Requirement 19: Closure of a disposal facility

A disposal facility shall be closed in a way that provides for those safety functions that have been shown by the safety case to be important after closure. Plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.

The group recommends to consider explicitly addressing as early as possible in the development phases, safety issues related to the closure of the facility (plans for closure). In any case, at least one closure solution should be presented as part of the licensing process for the creation of the disposal. But the level of detail requested for this demonstration remains an open question.

19.1 What are the elements of the closure plan and how do they relate to the initial design of the facility?

19.2 What arrangements have been made to ensure the availability of the necessary technical and financial resources to achieve closure?

19.3 What plans are in place for closure and seal or capping designs and how are they updated as the design of the facility is developed?

19.4 What arrangements are in place to ensure that the disposal facility will be closed in accordance with the conditions set for closure by the regulatory body in the facility’s authorization (e.g. license or certification), with particular consideration given to any changes in responsibility that may occur at this stage?

19.5 What particular considerations have been given to the implications of closure operations being performed in parallel with waste emplacement operations?

19.6 How would a delay in backfilling, the placing of seals or capping for a period after the completion of waste emplacement be evaluated with respect to operational and post-closure safety?

Requirement 20: Waste acceptance in a disposal facility

Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with and are derived from

***the safety case for the disposal facility in operation and after closure*.**

20.1 What approach is used to derive the waste acceptance criteria (WAC) and verify that they will allow for safe disposal with regard to both operational and long term safety?

20.2 How is the WAC demonstrated to be compatible with the safety case?

20.3 What measures are taken to ensure that the quality control of waste packages is based on records (primarily), appropriate characterization of waste (validated methods), preconditioning testing (e.g. of containers) and control of the conditioning process?

20.4 How will it be demonstrated that the WAC will ensure the fulfilment of the safety functions of the waste form and waste packaging with regard to long term safety (e.g. R&D programs to assess performances of waste matrix and package)?

20.5 How are responsibilities with regard to waste and waste package compliance with the WAC clearly and correctly defined?

20.6 How does the WAC take into account the need for handling of waste packages in a manner that will not cause damage to the packages?

20.7 What plans are in place to deal with non-compliant waste packages and to prevent recurrence?

20.8 How was uncertainty in system-level model results dealt with in establishing the WACs? Are the WACs a reflection of an expected case mean outcome, an expected case extreme outcome, or a low-likelihood disturbed case mean or extreme outcome?

20.9 What arrangements/agreements are or will be in place to ensure and verify that waste intended for disposal is characterized to provide sufficient information to ensure compliance with the WAC?

20.10 How doe the corrective action program ensure that deviation from the WAC will not have a detrimental effect on long term performance?

20.11 What processes are in place to deal with new waste forms that may arise?

The group recommends that the uncertainties associated to the accurate consideration of the waste inventory be anticipated in the development of the disposal project. Indeed as the disposal project will be developed over several decades, uncertainties on the planned inventory have to be taken into account in the design of the facility and in the demonstration of safety (for example taking margins in the volume and inventory of waste when designing the facility and making the safety assessment).

The compatibility between the waste acceptance criteria and the evolution of the disposal concept (selection of site, characterization of pore water, geometry and dimension of the disposal layout, knowledge of the inventory…) must be ensured.

Requirement 21: Monitoring programmes at a disposal facility

A programme of monitoring shall be carried out prior to and during the construction and operation of a disposal facility, and after its closure, if this is part of the safety case.

This programme shall be designed to collect and update information necessary for the purposes of protection and safety. Information shall be obtained to confirm the conditions necessary for the safety of workers and members of the public and protection of the environment during the period of operation of the facility. Monitoring shall also be carried out to confirm the absence of any conditions that could affect the safety of the facility after closure.

21.1 What are the objectives, components and reference criteria for the monitoring programme and on what basis are they determined?

21.2 What data collection and monitoring is planned to be carried out during siting , construction, operation and final closure of the disposal facility and how is this justified by the safety case?

21.3 How do the monitoring programmes consider:

- providing information for safety assessment,
- the assurance of operational safety, and operability of the facility, and
- confirmation that actual conditions are not inconsistent with those assumed in post-closure safety assessments?

21.4 How are deviations from the reference criteria managed?

21.5 How is it demonstrated that monitoring programmes are designed and implemented so as not to reduce the overall level of post-closure safety of the facility?

21.6 What degree of flexibility has been included in the monitoring programme to enable revision and updating during the development and operation of the facility?

21.7 How are the resources available to undertake the monitoring programme shown to be adequate?

21.8 What actions are proposed if post-closure monitoring identifies conditions or behaviour not accounted for in the safety case?

21.9 How has experience in monitoring existing closed near-surface disposal facilities been brought into the consideration of monitoring activities?

21.10 How have actual or proposed monitoring programmes for other facilities of a similar nature been taken into consideration?

Requirement 22: The period after closure and institutional controls

Plans shall be prepared for the period after closure to address institutional control and the arrangements for maintaining the availability of information on the disposal facility. These plans shall be consistent with passive safety features and shall form part of the safety case on which authorization to close the facility is granted

22.1 What are the plans for institutional controls for a deep repository and how are they consistent with the approach for post- closure safety in the safety case?

- ? how are local land use controls/site restrictions considered?
- ? what are the plans and the organisation defined to ensure that local, national and international records are preserved and for how long?
- ? what use is to be made of surface and/or subsurface markers and what regulatory or other basis defines the requirements for these markers?

22.2 What are the responsibilities for the developer, regulator, and government during the period of institutional controls?

22.3 If no institutional controls are required beyond closure, has this been justified in the safety case and what reasons have been provided?

22.4 After the period of institutional controls, what status is envisaged for the facility?

22.5 What are the plans for institutional controls for intermediate to near surface disposal and how are they consistent with the approach for post-closure safety in the safety case and how do they address the following?

- ? site protection and access restrictions for both people and animals,
- ? inspection of physical condition and retaining appropriate maintenance capabilities,
- ? surveillance and monitoring as a method of checking performance as specified (i.e. check of degradation)
- ? local land use controls;
- ? site restrictions or surveillance and monitoring;
- ? local, national and international records;
- ? the use of durable surface and/or subsurface markers

22.6 How has it been demonstrated that undue reliance is not taken for institutional controls?

22.7 How has it been demonstrated that the passive safety barriers are sufficiently robust and are unlikely to need repair or upgrading?

22.8 How does the post-closure plan address and justify the method and time period the system will be monitored?

22.9 For near surface disposal of mining and minerals processing waste containing very long lived radionuclides, how have activity concentrations been limited so that safety does not rely on ongoing active institutional control?

22.10 For existing disposal of mining and mineral processing waste what provisions have been taken to assure the long term functioning of the disposal facility (e.g. stability and cover integrity)?

22.11 How is flexibility of implementation maintained over long institutional control periods (e.g., 100 years)?

22.12 What arrangements assure the ability to pass on information about the disposal facility and its contents to future generations to enable them to make any future decisions on the disposal facility and its safety?

22.13 How will institutional controls be integrated with other activities that may be occurring in parallel?

? safeguards activities
? environmental activities

22.14 If monitoring is part of institutional controls, how will monitoring information be used to judge whether or not the added information conforms with, or demands an update to, the safety case?

The group raised issues on the role of inadvertent human intrusion in the safety case for deep geological disposal.

In relation with isolation requirement, the purpose of a deep geological disposal is to reduce the possibility of any human intrusion in the waste disposal tunnels as long as potential hazards linked to the waste activity could cause unacceptable radiological impact. The depth and the absence of valuable natural resources close to the disposal location are specific conditions that contribute to minimize the likelihood of such an intrusion.

Nevertheless, intrusion in the disposal may be accounted for with the view to guiding conception of the disposal with respect to optimization strategy of the design and to assessing the robustness of the disposal. As an example, in the Dossier 2005 Argile, Andra assessed the consequences of a drilling borehole through components of the disposal.

This could result in a potential contamination of aquifers due to the connection between disposal tunnels and geological surroundings. Lessons learnt from this scenario were that the modular architecture of the disposal facility and the low hydraulic characteristics (permeability, hydraulic gradients…) of the host rock and of surrounding formations allowed for a strong limitation of the radionuclide release and transfer through the borehole to the aquifers. These results completed the set of arguments gathered by Andra in favour of the robustness of the disposal concept but didn't aim at assessing the consequences of a plausible situation.

Regarding the compliance with radiological criteria, SSR5 introduces updated recommendations in accordance with ICRP103 for the case of inadvertent human intrusion in the disposal. However, since the likelihood of inadvertent intrusion is low, the associated risk is likely to be outweighed by the higher level of protection and safety afforded by the disposal of waste in comparison with other strategies.

The group also raised issues on the need and duration of institutional control including surveillance and monitoring (SSR5 does not accept to rely on ongoing (perpetual) control as a safety measure, although this is common practice for example when managing mining waste)

SSR5, 5.11 states that "The status of a disposal facility beyond the period of active institutional control differs from the release of a nuclear installation site from regulatory control after decommissioning inasmuch as release of the site of a disposal facility for unrestricted use is generally not contemplated. […]". As a matter of fact, the radioactive source term of a geological disposal will remain in place after closure and dismantling of surface facilities (such an installation is designed for that purpose!). As a consequence, even if the long term safety demonstration does not rely on perpetual institutional control and is based on passive features linked to the characteristics of the disposal:

- *it should be stated that there is no a priori desire to abandon the disposal site after post-closure phase,*
- *it shouldn't be stated that the disposal site after post-closure phase will be abandoned,*
- *record keeping of the site should be envisaged on a time frame in accordance with the duration of the hazards caused by the activity of the waste.*

Requirement 23: Consideration of the State system of accounting for and control of nuclear material

In the design and operation of disposal facilities subject to agreements on accounting for and control of nuclear material, consideration shall be given to ensuring that safety is not compromised by the measures required under the system of accounting for and control of nuclear material.

23.1 What nuclear safeguards plans are envisaged?

23.2 What considerations have been given to nuclear safeguards being achieved by remote means (e.g. satellite monitoring, aerial photography, micro seismic surveillance and administrative arrangements)?

23.3 How will safeguards monitoring be integrated/coordinated with other monitoring and surveillance activities?

23.4 What consideration has been given to the interface issues between the system of accounting for and control of nuclear material (nuclear safeguards) and the safety of the facility?

23.5 How will the continuity of knowledge important to safeguarding the system be maintained and controlled for use by only those identified entities who have a need to know?

? as drifts are backfilled and closed
? over the long operational periods and beyond closure to the extent necessary

23.6 What measures have been taken to ensure that safeguards related activities will not compromise post-closure safety?

23.7 What procedures are set up to integrate monitoring and safeguards activities in respect of?

? exchange of information and measurement data
? coordination of changes in testing and measurement techniques
? worker safety monitoring

23.8 The continuation of safeguards and monitoring after closure may be beneficial to improving confidence in post-closure safety – what consideration has been given to this factor and how is it integrated with post-closure institutional controls?

Requirement 24: Requirements in respect of nuclear security measures

Measures shall be implemented to ensure an integrated approach to safety measures and nuclear security measures in the disposal of radioactive waste.

24.1 What measures are planned to prevent the unauthorized access of individuals and the unauthorized removal of radioactive material?

24.2 What plans are in place that can demonstrate that safety and security are approached in an integrated manner?

24.3 How is it planned that security measures (e.g., access control program) will be coordinated during parallel activities (e.g., construction, waste emplacement, and closure and sealing of rooms, galleries, boreholes, shafts or drifts)?

24.4 What approach is planned to ensure that the level of security required is commensurate with the level of radiological hazard and the nature of the waste?

24.6 Is consideration given to ensure that an emergency response to one part of the system will not lead to security vulnerability in another part of the system?

24.7 If security is required in the post-closure period, what are the security plans?

- ? do the security plans describe what level of security is required?
- ? do the security plans describe how long security is to be applied and do they provide a technical basis for the timeframe**?**

Requirement 25: Management systems

Management systems to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety.

25.1 What are the elements and structures of the management system?

25.2 How does the management system define the roles, responsibilities, authorities and organizational structure for implementing processes to ensure an adequate level of quality in all safety related activities and functions?

25.3 How does the management system accommodate the evolution of the facility from siting through final closure?

25.4 What is done to ensure and document that the level of attention assigned to decisions is commensurate with their importance to safety?

25.5 How does the management system consider uncertainty in the information used in making decisions?

25.6 How is it demonstrated that the management system will comply with international standards on management systems?

25.7 What is the process for identification of safety related issues and assuring that corrective actions are taken at an appropriate level, verified and documented?

25.8 How is the continued adequacy and effectiveness of the management system assured?

25.9 How is it assured that the relevant activities, systems and components are identified and evaluated?

25.10 How does the management system provide for the production and retention of documentary evidence to illustrate?

- ? that the necessary quality of data has been achieved;
- ? that safety related components have been supplied and used in accordance with the relevant specifications;
- ? that safety related activities have been performed in accordance with the relevant specifications;
- ? that the requirements for waste acceptance have been met and that waste has been properly emplaced in the disposal facility.

25.11 How are resources ensured for retention of records over the necessary time period?

25.12 What provisions are in place to accommodate changes in information technology?

25.13 How does the management system assure identification and preservation of that portion of the information important to safety and any reassessment of the facility in the future?

25.14 How is a “knowledge management” system implemented to support changes in management and key personnel?

25.15 How does the management system promote a safety and security culture? What measures are in place?

25.16 How do the management systems provide assurance of quality in the design and operational features addressed in the safety case?

Annex EPS

The pilot study aims at developing, amongst European regulators common positions on the safety approach to geological disposal of radioactive waste. More specifically the approach focuses on the content of a safety case for a geological disposal and the way this safety case should be reviewed by the authorities. Some flexibility in the process of submitting and reviewing a safety case is included in the EPS to take into account the different existing regulatory regimes and administrative procedures existing amongst various countries.

In the process of up-dating and completing the EPS (version 2010), the redactors have taken into account the comments of the review by GEOSAF of version 2007 of the EPS and above all the necessity for flexibility. Other comments have been integrated in the document.

According to the EPS, and in accordance with international standards and recommendations, a disposal facility and its safety case should be developed in a step-by-step manner with well-defined decision points. Safety arguments must be continuously refined and supporting safety assessments must be undertaken iteratively as the disposal facility is developed. The structure of the assessments is expected to be consistent throughout for more efficient regulatory review. It is acknowledged that the degree to which a step-by-step process is legally implemented in regulations varies from country to country, and the responsibilities of the regulator at decision points may also vary. However, it is recommended that the regulator should be involved from the earliest stages in the development of a disposal facility, even if initially the role is less formal and decisions or opinions of the regulator may not be legally enforceable.

The safety case can be presented in various formats, but its content should be a collection of documented arguments and evidence supporting the safety of the disposal facility to allow for key decisions relating to progressing to the next phase of development of the disposal to be made. A safety strategy, which sets out the high-level approach for achieving safe disposal needs to be established from the beginning of the project. Elements of the safety assessments supporting the safety case are those related to: assessment of the robustness and performance of the site and engineering of the facility; assessments of impacts to people and the environment, assessments of the management system. The safety case must include an integrated assessment of the overall arguments. The manner and extent to which these elements are assessed during the process of developing and implementing the facility will vary with the phase reached.

Version 2010 develops new expectations for the safety case : the safety case should cover both the operational phase and post closure phase and demonstrate operational safety together with long term safety. It is considered that in the process of optimization, long term implications should be emphasized for the choice of the best option. It is acknowledged that depending on national regulations, operational and long-term aspects may be addressed under separate regulations and reviewed by different licensing bodies.

The assessment of the impact of the repository should also cover the non radiological impact, however, in this domain and, depending on the national context, different licensing bodies may be concerned and the emphasis given to non-radiological impacts may vary with the licensing body.

The safety case must set out clearly information on the design, construction and operational options considered and the key features on which safety relies. The safety case will need to acknowledge and accommodate uncertainties. It should include a program of work to acquire enough knowledge to demonstrate confidence in the safety of the disposal system. Assessing the soundness of the proposed options is essential to enable the project to move forward from one step to the next.

Actual version of EPS (2010) covers all the phases of the development of a repository which describe broadly the progressive development of a repository (and its safety case). The EPS identifies when certain information would generally be foreseen, but it is expected that national programs may have different requirements. Regulatory decisions will govern the progression through the stepwise process. In nearly all programs, formal decisions are expected at least from the point of repository construction and, in some countries regulatory decisions will also be needed in earlier phases (conceptual and siting phases). Political decisions may also be required in addition to regulatory actions.

Annex National programmes

Regulatory Approvals and HLW/SNF Disposal Programme Structure and Status

L : licence[1]   P : permit[2]   A : approval[3]   D : decision[4]   * : HLW/SNF Disposal Programme status

Authorization for:	Belgium	Bulgaria	Canada	China	Czech Republic	Finland	France	Germany	Hungary	India	Indonesia	Japan	Korea	Pakistan	Portugal	Saudi Arabia	Slovenia	South Africa	Ukraine
Conceptualization / generic design		D	*				L[8]	*	*	*	A				[16]	L		D	A
Site identification / screening	D	A		*	*		L[8]			[12]	A	*A		*		L		D	L
Site selection		A		[6]	P[7]						A	A				L	L	D	
Site detailed characterisation		D	A[5]			*D	* A[8]		A		P	A[13]							L
Detailed design									P		L	L					L	D	L
Site preparation			L					L	DL		P					[17]	L	L	L
Construction		A	L		P	L	L[8]	A[9]	L[10]		L	A	L	L					
Commissioning	L	L							L		L	A	P	L			L		L
Operation			L	[6]	P	L			L	[12]	L	A	L					L	
Decommissioning	L	L	L						L		L		P	P			L		[18]
Closure / sealing	L	L			P[7]	L		A[9]			L	A	P	A				L	
Post-closure	L								[11]		P	A[14]	D				L		[18]
Abandonment	L		L			A					P	[15]							

Footnotes

[1] Licence: a legal document issued by the regulatory body granting authorization to perform specified activities related to a facility or activity (in the context of this document, related to management of spent fuel or of radioactive waste), typically specifying conditions on those activities, responsibilities for reporting by the licensee, and compliance oversight by the issuing authority

[2] Permit: written order giving permission to act (may specify conditions on those actions)

[3] Approval: formal pronouncement that something is good or satisfactory

[4] Decision: formal judgement (of question, etc.)

[5] Approval from federal Minister of Environment based on an Environmental Assessment. The subsequent licensing decisions are by the nuclear regulator (CNSC).

[6] Internal decision made by a team of experts in China Atomic Energy Agency (CAEA); regulations that address the procedure of site selection and the type of authorization for each step in the procedure are not formalized yet

[7] Also an EIS submitted to Ministry of Environment for approval

[8] In France the programmes are defined by Law (see the Additional Notes for explanation) and 'site selection' and 'site detailed characterisation' refer to the disposal area in the vicinity of the URL at Bure. It is undecided if operation will be authorized by a licence or by an approval to commence.

[9] Approval of German Mining Authority for underground works

[10] Environmental Licence based on EIA

[11] At least 50 years of Institutional Controls

[12] Internal decision by team of scientist/engineers in National Agencies; regulatory aspects not formalized yet in India

[13] Siting is divided into 3 phases (Literature Survey, Preliminary Investigation, Detailed Investigation) with approval of Minister of METI at end of each phase. Site Investigations, Design and Safety Assessment are performed iteratively by NUMO within each phase.

[14] In the Japanese programme, Closure (of the underground repository) is before Decommissioning (of the surface facility)

[15] Disbandment of NUMO will be separately laid down by law.

[16] Portugal has no HLW , and no legislation relating to HLW

[17] On-going programme is for storage of unused radioactive sources – licensed up to site selection, following steps to operation are on-going

[18] Regulation after operations is not yet defined

Additional Notes

Belgium
- Decision in Principle on concept by Minister of Interior Affairs, leading to site identification and screening
- Approval of site selection by communities and government ministers
- Environmental Impact Report also required following detailed design
- Remaining licensing steps specified in FANC note 007-020-N Rev. 1, will be translated to a Royal Decree in the future:.
- Licence for construction and operation
- Licence for completion of activities and start of surveillance and monitoring (following operations)
- Licence for closure (may be combined with Licence for completion of activities and start of surveillance and monitoring)
- Licence for confirmation of closure and short period of post-closure activities (continued surveillance)
- Licence for retieival of regulatory control

Bulgaria
- Decision by Council of the Ministry and Permission by the nuclear regulator (BNRA) on the conceptualization and generic design
- Decision on site characterization needed before Order to Design by BNRA
- Construction requires Order and permission by BNRA
- Subsequent licences issued by BNRA
- Need for authorizations for post-closure and abandonment not yet known

Canada
- Licences are for a fixed period (typically 3-5 years) and must then be renewed
- Environmental Assessment is re-visited and updated as needed at each licence application

China
- Although the law of the People's Republic of China on Prevention and Control of Radioactive Pollution addressed that the HLW should be disposed in deep geological formation, regulations addressing the siting and operation of a disposal facility (including defining the steps in facility development and the authorizations needed at each step) are not formalized yet in China
- Safety assessment and engineering is in the conceptualization and generic design stage
- Management system is in the conceptualization and generic design stage
- Siting is in the site identification / screening stage

Czech Republic
- Authorizations are needed under the Construction Law and Atomic Act
- Permit for Site Confirmation (at site selection) requires Introductory Safety Report / Safety Case and EIA submitted to Minister of Environment
- Permit for Construction requires Preliminary Safety Report

- Permit for Operation (planned for 2065) requires a pre-operational Safety Report / Safety Case, including Waste Acceptance Criteria
- Permit for Closure requires a Final Safety Report / Safety Case and EIA submitted to Minister of Environment

Finland
- Decision in Principle on selected site includes: the community accepts, the government (STUK) approves and Parliament ratifies
- Construction Licence (expected in 2012), Operating Licence and Closure Licence require government (STUK) approval
- STUK inspects operations, and there are periodic renewals of the Operating Licence
- Abandonment is with government (STUK) approval

France
- Site selection for creation of Underground Research Labs (URLs) was licensed by the regulator under the Law of 1991
- Feasibility of geological disposal in clay investigated by the means of the Bure URL was approved by the regulator in 2006 and a new Law of June 2006 established the new programme for the creation (site preparation and construction) application to be submitted in 2015.
- Selection of a disposal site in the vicinity of the URL, additional characterization if needed for the purpose of confirmation and reference design is expected to lead to a construction licence by 2016 (+ a new law on reversibility) and an operating licence or approval for starting operations by 2025
- Further licensing steps are not yet defined

Germany
- Entries in the table reflect the present situation, applied to LILW facilities; a finer breakdown for SNF/HLW is under discussion
- Licensing decision (plan approval) at the detailed design / site preparation stage includes EIA

Hungary
- Approval of a Geological Research Plan for site characterization is not prescribed legally
- Permit based on a final report of site investigations justifying the site suitability
- Preliminary Decision in Principle of the Parliament and an Environmental Licence based on an EIA required prior to site preparation
- Construction Licence is based on architecture design
- Commissioning Licence is based on a pre-commissioning safety case; Operating Licence is based on a pre-operational safety case
- Closure Licence is based on a “final” safety case

India
- Regulatory aspects of the disposal of HLW are not yet finalised, however all developments regarding conceptual design, generic sites and R&D programme are informally communicated to the regulatory body

- Conceptualization, site identification/screening, site selection and site characterization are subject to an internal decision by a team of scientists and engineers and National Agencies

Japan

- Siting divided into 3 phases (Literature Survey, Preliminary Investigation, Detailed Investigation) with approval by METI at end of each
- Site investigations, Design and Safety Assessment are performed iteratively within each phase
- Nuclear Safety Commission's requirements specify exclusion of sites with unsuitable geologic conditions
- Siting Approvals: Selection of Preliminary Investigation Areas (at end of Literature Survey phase), Selection of Detailed Investigation Areas (at end of Preliminary Investigation phase), Selection of Final Repository Site (at end of Detailed Investigation phase)
- License for radioactive waste management in detailed design phase
- Authorization for commissioning, operation and post-operation after licensing requires: Confirmation for Wasteform and Measures for Safety Operation, Approval for the Design and the Construction Methods of Repository; Pre-operational Inspection; Inspection of Welding Methods; Pepriodic Inspection of Facilities; Notification of Commencement, Cessation or Restart of the Management; Recording and Record Keeping; Approval for Operational Safety Programme and Operational Safety Inspection; Approval for Physical Protection Programme and Physical Protection Inspection; Approval for Closure Plan and Confirmation of Closure in Each Process; and Approval for Decommissioning Plan and Confirmaion of Completion of Decommissioning.
- Closure of the underground repository precedes Decommissioning of the surface facility
- The licensee shall perform dose assessment at most every 20 years after licensing.
- All types of authorizations are relevant to the Minister of METI.

Pakistan

- Dry storage is under consideration for spent fuel
- DGNR is in the process of siting disposal facilities, with first priority being near-surface disposal. Potential formations have been identified.
- If spent fuel is declared a waste, then siting process for deep geological repository must be started.
- Regulator is involved with site characterization, detailed design and site preparation prior to licensing construction.
- Operations are under stringent regulatory control

Portugal

- The Directorate General for Energy is responsible for licensing of all installations of th enuclear fuel cycle, including the Portugese Research Reactor. (RPI) at ITN premises. DG also authorizes the transfer of spent fuel from RPI to the USA as per exisiting return agreement.
- The Independent Commission on Radiological Protection and Nuclear Safety (CIPRSN) verifies and evaluates the conditions of application of the legislation

regulating licensing of all installations and activities that produce radioactive waste
- Currently Portugal doesnot have HLW to manage, and there is no plan or specific legislation for HLW in Portugal.
- ITN, besides being a research institute, has th elegal ability to authorize transfer of radioactive waste between Portugal and other Member States, to evaluate radwaste transport safety and collects, segregates, conditions and temporarily stores the treated waste (cement drums) at a storage facility.
- There is nothing in Portugese legislation concerning radwaste storage or disposal in terms of installations characteristics.
- ITN and the producers of radwaste follow international good practices (IAEA, etc.)

Kingdom of Saudi Arabia
- Table entries are based on a project to develop a facility to store non-used Radioactive Sources.

South Africa
- Decision on site selection will be based on an EIA
- Construction Licence will include “cold” commissioning, Operating Licence will include “hot” commissioning
- Not yet in the conceptualization stage; at the first step of establishing a science strategy and reaching agreement with the regulators on the development steps and approvals process.

Ukraine
- Site Screening and Site Selection requires a Licence and a Decision under a special law
- Licensing requirements after operations have not been defined, but they will likely include a decommssioning licence

Annex

Example from the French case and the role of TSOs in developing expertise functions

Independent research activities for performing the technical review process and ensuring the necessary support to the regulatory body

close follow up of the scientific knowledge gained by the WMOs when developing the disposal project and reported in the safety case for external review

In the field of radioactive waste safety, IRSN develops a pluri-annual research programme so as to develop IRSN staff skills and anticipate the needs for new knowledge necessary to perform comprehensive safety reviews of high quality. This research programme, launched initially to support IRSN assessment of Andra's file on the "feasibility of reversible geological disposal in clay" issued in December 2005, is now structured upon the new main steps related to the development until 2015 of the high-level and long-lived intermediate-level waste repository project as prescribed by the French Planning Act of 28 June 2006 on the sustainable management of radioactive materials and waste. This act plans a licence application to be submitted in 2015 for the creation of a deep geological repository. IRSN research programme is annually updated and periodically reviewed by a scientific committee and organised along 4 types of research activities devoted to addressing several "key safety issues" defined by IRSN as follows.

Taking into consideration the feedback and main conclusions drawn from the regulatory review of the "feasibility of reversible geological disposal in clay" in 2005, IRSN has identified a number of important issues, grouped hereafter in " key safety issues", on which researches should be carried out with priority from 2006 to 2015. The issues presented hereafter, which relate only to the Meuse/Haute-Marne site, do not anticipate on the possible emergence of other issues of importance for establishing the safety demonstration during further steps of project development. However at this stage of the project, IRSN gives priority for examining:

- the confinement capabilities of the sedimentary host rock and the identification of possible fracturing in the host formation and the geological layers surrounding it,
- the perturbations due to excavation or due to the interactions between different components,
- the waste degradation,
- the uncertainties on corrosion rates of metallic components, due particularly to a lack of knowledge on transient environment conditions and their duration,
- the dimensioning hypotheses for the various repository components, with the aim at constructing containment barriers that are as effective as is reasonably possible,
- the construction/operational safety (accounting for reversibility) particularly with respect to the risk of explosion relevant to hydrogen produced by radiolysis in waste cells, the ability to remedy a situation caused by a package fall in cells and the possibility of retrieving waste,
- the sealing capabilities with the view to assessing the likely performances of a sealing engineered structure, taking into account the effects of potential disturbances over time or difficulties for emplacing seals at industrial scale,
- the long term performances of the repository with emphasis on hydrogeological modelling, integrated transfer of radionuclides and biosphere modelling. It is

particularly important to be able to rule on whether or not localised preferential transfers exist and to assess their influence on the general flow patterns.

Definition of safety research activities

The above mentioned "key" scientific and technical topics should also be of prime concern for the implementer since they relate to "key" safety issues for demonstrating the overall safety of the repository, and the level of funding that the implementer should afford to research activities of concern for safety should be naturally much higher than those of the regulator and technical safety organisation (TSO). This is fully justified by the different respective roles played by both entities but it is of assessor's duty to be able to cover all the safety case issues with care to make appropriate balance between topics that must be addressed by R&D programme or topics that do not require specific R&D development. In this last case, the regulator or TSO should be able to explain why it is not necessary to develop its own research capabilities. In this respect, some aspects are not addressed by IRSN R&D programme because either they relate to conception/construction demonstration tests that are of implementer responsibility or because IRSN considers that the scientific knowledge is sufficiently shared by different stakeholders and well managed by the operator. Considering the elements that justify IRSN R&D programme, 4 categories of major questions are addressed: the adequacy between experimental methods and data foreseen, the knowledge of complex coupled phenomena, the identification and confidence in components performances and the ability of the components to practically meet in-situ the level of performances required. Addressing these questions requires the research programme to be developed along the following lines:

- test the adequacy of experimental methods for which feedback is not sufficient. The assessment of their validity allows addressing the consistency and degree of confidence of the data produced,

- develop basic scientific knowledge in the fields where there is a need for better understanding the complex phenomena and interactions occurring all along the life of the repository and their influence on nuclear safety, so as to preserve an independent evaluation capability in these matters,

- develop and use numerical modelling tools to support studies on complex phenomena and interactions so as to allow IRSN assessing orders of magnitudes of components performances and physico-chemical perturbations but independently than specified and estimated by implementers,

- perform specific experimental tests aiming at assessing the key parameters that may warrant the performances of the different components of the repository. Such experiments are designed in particular to simulate the behaviour of components in altered conditions and allow IRSN delivering appraisal on the specifications of construction that are to be proposed by implementers.

These studies are carried out by the mean of experiments performed either in IRSN surface laboratories, or in the Tournemire Experimental Station (TES) operated by IRSN in the south-east of France. The TES is a former railway tunnel crossing a 150m meters thick Toarcian argillite formation and has been intensively used for some 20 years to perform in-situ experiments devoted to better understanding:

- the diffusion mechanisms in stiff clay (origin of over-pressures and influence of pore size on water-rock interactions…). Many characterization methods (devoted to characterise movement of natural tracers…) have been tested,
- the hydraulic role of faults/joints : survey methods (seismic survey analysis combined with others methods…) used to identify fractures in clay and their potential as water pathway have been tested,

- the differential fracturing phenomenon in clay and its high damping potential,

- the EDZ development: characterisation methods and modelling have been used and developed taking advantages of, on the one hand the 100 years passed since tunnel construction, and, on the other hand the observation of new drifts recently drilled,

- the clayey materials evolution due to cement-clay / iron-clay interactions by characterisation and modelling of 10-year old in situ experiments (using a coupled transport/chemistry code Hytec developed by Ecole des Mines de Paris),

- the chemical conditions during transient processes and the specific effects of the presence of micro-organisms or of redox conditions (characterisation of processes upon Tournemire data) on the waste or engineered components degradation over time,

- the parameters that will have to be specified and controlled in situ to warrant the performance of seals and concrete liners; a dedicated *in-situ* mock-up is under development and will be implemented in TES to study altered evolution of seals,

Besides the Tournemire Experimental Station, specific studies are in progress in complementary scientific fields with the view to:

- better knowing, on the one hand of the physical and chemical properties of the concretes in their initial and altered state and, on the other hand, of the influence of industrial implementation conditions on their performances,

- better understanding the transient phenomena and in particular the behaviour of hydrogen generated by corrosion and radiolysis and its influence on water flow; these studies are addressed by experimental, theoretical and modelling developments,

- better knowing of the waste performances,

- better knowing of the transfer properties of radionuclides and chemical elements under repository conditions (data base review),

- modelling flow and transport of radionuclides by developing computer models simulating the underground flow patterns at various scales in the vicinity of the Bure site as well as radionuclide migration from the waste packages to the biosphere (3D computer code MELODIE),

- modelling the biospheres of interest for the Bure site (existing and possible in future).

In addition, the safety researches to be possibly undertaken related to operational safety and reversibility issues are in a preliminary phase devoted to the definition of targeted actions.

Organisational aspects

Because of the complexity and large scope of issues to be addressed, IRSN promotes a multi-disciplinary approach integrating experimentalists, modellers and experts of safety who work together on each of the topics of interest for safety. This synergy between research engineers and experts in safety assessment is a valuable tool to ensure consistency and quality of technical assessment. Scientific partnerships with research facilities and universities is the preferred strategy of IRSN in order to be able to take benefit of high level scientific skills in different specialities and for a duration compatible with the planned time frames of the assessment process (several decades).

Part of IRSN research programme is integrated in the EURATOM Framework Programme related to radioactive waste management research. IRSN is involved in 6th and 7th Framework Programmes which offer a valuable framework for achieving results and for sharing experience among countries involved in waste safety. IRSN supports also international research programmes as the Mont Terri project as well as bilateral cooperation with homologous organisations in foreign countries.

Quality and independency of research programme carried out by IRSN allow building and improving a set of scientific knowledge and technical skills that serves the public mission of delivering technical appraisal and advice. In particular they contribute in improving the decisional process by making possible scientific dialogue with stakeholders independently from regulator or implementer.

Conclusion

Because of time constraints, it is of crucial importance to be able to anticipate the development of knowledge and resources required to assess risks posed by nuclear facilities in the future, and in particular waste management safety. It is the reason why IRSN has identified very early in the French geological repository project development the scientific issues that had to be addressed in priority. This enabled IRSN to optimise the resources allocated to research. These resources are periodically assessed with respect of the progress made in studies, the new issues to be taken into account and duly planned, as well as the regulatory review agenda that requires to swap research and assessment activities.

The research activities carried out by IRSN are developed in consistency with conclusions drawn from the stepwise regulatory process that allows periodically addressing the remaining issues that must be dealt with to improve the safety demonstration. The expected outcomes of IRSN R&D programme are clearly identified with respect to the safety review approach, paying in particular a specific attention on which phenomena that must be studied by the TSO so as to ensure appropriate independent judgement of the level of safety that the repository may reach. It is also a duty for TSO to be able to deliver opinion on the consistency and degree of confidence of the data produced as well as on the ability of the implementer to realise, at industrial scale, components that will perform “as designed”.

But the efficiency of the research carried out by the regulator or the TSO does not rely only on technical skills but also on its ability to promote synergy between experts in charge of assessment and researchers. This contributes highly in guiding research efforts that must be made for the purpose of maintaining the quality of the regulatory review. In complement, high scientific skills ensure efficient technical dialogue between the implementer and the evaluator which is also a necessary condition to achieve valuable assessments.

Illustration of the organisation of the technical dialogue between the different actors (WMO, TSO and authority)

Interaction between ASN (the authority), IRSN (the TSO) and Andra (the WMO) was undertaken in order to come to a common understanding that the regulatory requirements and expectations are met. The ASN performed regular inspections of the Meuse Haute-Marne URL, and published in 2006 its official opinion on Dossier 2005. The IRSN established a constant dialogue with ANDRA and ASN all along the development of the project, whatever it was formally requested by law (license application, decree…) or not. IRSN carried out periodic technical expertise of the progress of the safety case (from 1997 to 2005). This agreement between all the parties allowed defining periodic meeting points for important steps. These steps were in particular related to key safety questions that were ought to be dealt with by Andra: the structural characteristics of the site, the hydrogeological settings, the geochemical containment characteristics of the host rock, the main perturbations and their influence on the properties of the disposal components, the technical feasibility of the seals and the influence of the operation phase and retrievability conditions on the disposal concepts. IRSN opinion about the feasibility of a deep geological disposal in the callovo-oxfordian clay investigated by Andra with the Bure URL was published in 2006 as well as the ASN opinion.

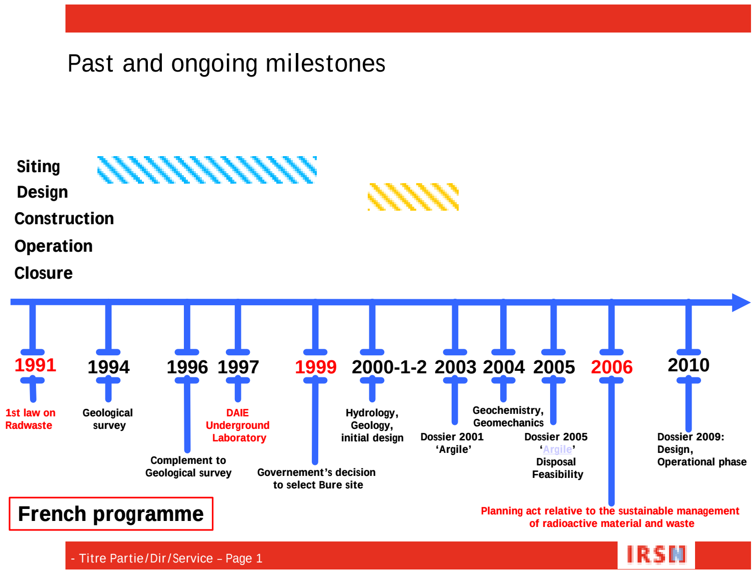
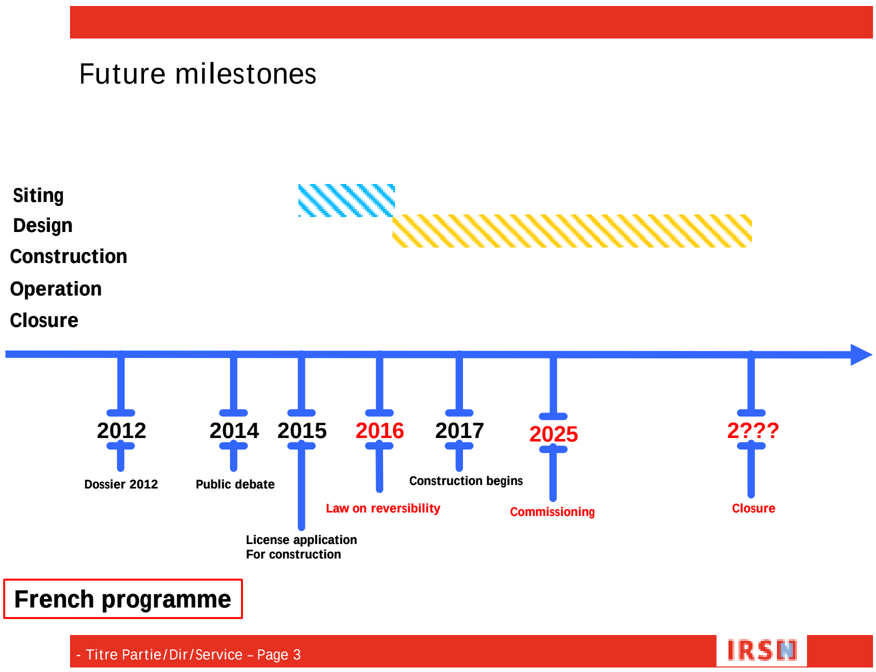


Illustration of the close technical follow up by TSO of the scientific development of the content of the safety case



Example from the French case: staged development of the safety case by Andra

The 30 December 1991 Waste Act initiated a research process into different methods for managing high-level,long-lived waste. In this framework, Andra has conducted work to investigate the possibility of a deepgeological waste repository, considering two rocks of differing nature, clay and granite. Some conclusions may be highlighted in the case of the clay medium studied at the Meuse/Haute-Marne site.

Fifteen years of considerable progress in research

Deep geological disposal has been investigated since the sixties in various western countries. *However, theperiod 1991-2005 in France was marked by acceleration in the progress of research. From this point of view,the 30 December 1991 Waste Act was a catalyst*. The schedule set by this Act led to bringing together skillsand concentrating energy to produce a dossier in 2005 based on solid scientific and technical knowledge.
A significant step forward in knowledge
Assessing the feasibility of a repository requires acquiring knowledge and investigating various fields: wasteand material behaviour, history and properties of the geological medium, architectural design, understandingthe phenomena occurring within a repository, modelling interactions, assessing safety. *An extremely richharvest of results was reaped about all these topics. Fifteen years of research have laid down the foundationsof a solid corpus of scientific and technical knowledge, providing an accurate view of the major issues andproperties of all the repository components.* Now, is available, for example, a historical view of the argillite layer studied at the Meuse/Haute-Marne site,from its deposition 155 million years ago. The Callovo-Oxfordianargillites have been surveyed extremelycarefully, both though samples and *in situ*, providing an intimate knowledge of their properties. In this field,their mature degree reached by these investigations places them at the forefront of our knowledge of thegeology of the Paris Basin.

The advantage of the Meuse/Haute-Marne site where a wide range of measuring and investigativetechniques have been used

In the case of the clay medium study, a decisive contribution of the period was the possibility of carrying outvery thorough investigations on a specific site, the Meuse/Haute-Marne one. Andra has been exploring the siteand its environment since 1994 and thus has acquired a thorough knowledge of the actual conditions of thegeological medium.

With its two shafts and over 300 m of drifts, *the Meuse/Haute-Marne Underground Laboratory is currentlya leading-edge scientific facility, comparable to similar international ones*. An important experimentalprogramme is carried out and notably concerns: rock permeability with its chemical and diffusion properties,rock mechanical characteristics with its behaviour when excavated. It has produced very significant data, butalso constitutes a valuable asset for future years. If so wished, it will be capable of supporting a study anddetailed design approach through the production of measurement records over long periods, thus completingthe results already acquired.

To investigate the Meuse/Haute-Marne site, Andra set out to gather together the widest possible range ofmeasuring tools and survey technologies. Exploring the clay geological medium is a complex undertaking,requiring very specialized technologies, for example for measuring the permeability of a rather imperviousmedium or characterizing water that is present only in a very small quantity in the rock, which makes itsextraction difficult.

From the start of the research programme, Andra built very strong ties with all its foreign counterparts so asto transpose, elaborate or validate the investigation technologies it needed. This preparatory work then enabledit to be immediately operational on the Meuse/Haute-Marne site.

The last fifteen years have therefore witnessed the development and improvement of a wide array ofmeasuring and characterization technologies brought to their best level. For example, oil explorationtechnologies have been adapted and improved for meticulous geological exploration. All possible facets ofinvestigatory means were used: surface observations (e.g. with the seismic survey), measurements onsamples, testing and sampling in vertical or practically horizontal directional boreholes, characterizations inshafts and drifts. *The diversity of the experimental tools used provides complementarity and redundancybetween measurements, which increases confidence in the results obtained.*

Confirmation by foreign underground laboratories

In parallel with the programme carried out in France, foreign underground laboratories have played a veryimportant part through their methodological and theoretical contribution, in particular those of Mol in Belgiumand Mont Terri in Switzerland. The Mol laboratory has seen the development of measurement technologies forappraising all the phenomena present in clay. The Mont Terri laboratory has been used to prepare experimentsconducted at Bure by offering the possibility of full-scale repetition. In addition, the similar nature of the two clays(Opalinus clay in Switzerland and Callovo-Oxfordianargillites) led to establishing an essential point: *at Mont Terri,it was shown that the results found on samples were also representative of large-scale tests*. This constitutes aweighty support for the work carried out at Bure. Furthermore, the models prepared based on the samplesextracted at Bure were corroborated *in situ* at Mont Terri.

Foreign laboratories thus provided methodological and theoretical validation for the analytical approachconducted in France.

Mobilization of a high-level scientific community and integration of research at the international level

Another basic asset of the research programme carried out since 1991 lies in the mobilization of the scientificcommunity. At the launch of the process, the research remained relatively restricted to a circle of specialistsor to a small number of bodies responsible for the work. Andra strived to involve the widest possible scientificcommunity in its work. In other words, rather than keeping the investigations and research in-house ordeveloping its own special skills, it always preferred to use the best laboratories in France or internationally foreach topic. This meant a great deal of effort in arousing scientists' interest and familiarizing them with theproblems involved.

In the end, this policy proved successful. It enabled nearly a hundred laboratories at the national and internationallevel to be brought together around the theme of geological disposal. With their different perspectivesthese laboratories could pool their expertise, and develop cooperation and interdisciplinary outlooks. This is allthe more important in that the originality of the research on disposal entails the need to muster together veryvaried scientific fields in order to achieve an overall understanding. At the same time, Andra instituted supportfor research training, in the form of thesis grants, which meant having active scientific resources readilyavailable; about fifty or so young researchers over five years, were specifically dedicated to Andra researchtopics.

Mobilizing the scientific community ensured that the production of results was conducted and discussedaccording to the current standard of the academic world and within a framework of excellence.The scientific initiative was not limited to mobilizing the French scientific community. *Andra has specificallyextended its activity within an international framework*, by developing close partnerships with both itscounterpart agencies in Europe and international research establishments. As an illustration, the Meuse/Haute-Marne underground laboratory has regularly hosted scientists from international organizations who have usedtheir expertise in experimental work. The research has thus benefited from the best international skills.*Thus, after fifteen years, the French research programme is well-placed internationally and enjoys therecognition of its foreign counterparts.*

Regular external assessment

Finally, a programme of this scope would not be complete without assessments. *Andra regularly uses externalexperts and reviewers for comparing its study programmes, research and results with the best internationalpractice*. An international review of its programmes was carried out in 2002 / 2003 and was very encouragingregarding the work conducted. In the spirit of progress driving the research, the recommendations of thisreview were integrated into the documents produced for 2005.

Andra strived to encourage the publication of its results in the best international scientific journals, at a rate ofsome forty articles a year over the last three years. Critical examination of the results obtained is mandatoryfor publication, which is also a guarantee of work quality.

The research programme therefore was provided with the tools needed for producing quality scientific data,within a framework characterized by stringency and concerned for scientific excellence.

The basic feasibility of geological disposalin a clay formation has now been established

Assessing the basic feasibility of geological disposal consists mainly in obtaining an overall perspective of thedata collected on each research topic in order to build up an overview of the disposal system and assesswhether it can protect man and the environment from the radioactive waste that would be emplaced there. Allthe elements gathered to date support its basic feasibility, for several reasons.

The Meuse/Haute-Marne site offers favourable geological conditions

The Callovo-Oxfordian layer combines some very useful properties, matching those expected for the design ofa repository in a clay medium.

Firstly, the layer is of considerable thickness (130 metres) and is broadly unaffected by faults. Its geologicalhistory is well-known. Since its deposition this history has been very quiet, which is a major argument forconfirming its homogeneity and its extreme stability. It is almost not subject to earthquake and seismicphenomena.

The layer contains very little water, which movement is extremely slow, due to its very low permeability.Physical and chemical characterizations further show that it has a strong ability to retain and trap most of thechemical elements and radionuclides present in the waste.

It is suited to excavation by mining techniques and building structures within it only causes moderatedisturbances, which are not in principle capable of creating preferential flow pathways.There is a wide zone of more than 200 km2 within which, *a priori*, these properties are met (the so-calledtransposition zone).

Finally, putting the collected data together has provided a model of the overall geology of the sector, includingthe formations above and below the Callovo-Oxfordian. *The geological medium therefore intrinsically offersfavourable characteristics making it suitable for hosting a repository*.

Architectures have been designed to make the most of the favourable geological conditions

It is not just a matter of having a geological medium with the right qualities; it is necessary to make the mostof it appropriately. Engineering studies have defined simple and robust disposal concepts suited to thecharacteristics of the argillaceous layer, taking the utmost advantage of its qualities.

These concepts include cautious choices providing therefore design margins. The work has not been pursuedup to the optimization stage, but has established that the proposed architectures were realistic, capable ofbeing constructed and used to host the waste without any special difficulty. These architectures includenumerous features promoting overall safety, such as module separation, which compartmentalizes therepository zones, or its general lay-out, which limits the possibilities of water circulation. *In-depth design andengineering work thus supports the favourable natural properties of the medium and helps make the mosteffective use of them. In addition, studies relating to operational and nuclear safety, based on feedback fromother mining or nuclear facilities, demonstrate the possibility of safe operation without any impact on theenvironment.*

Reversibility at the heart of the investigation approach and translated in

concrete practical terms

The architectures drawn up for the repository were selected according to their ability to allow for reversibility.The requirement of reversibility involves a cautious approach to waste management in an uncertain universe.It refers closely to the precaution principle. It also meets a legitimate requirement for modesty on the part ofthe scientist. When evolutions have to be forecast over very long periods and complex phenomena have to bemanaged, reversing the process must be possible.

Andra has developed a concrete approach to reversible disposal that is more than just the technologicalpossibility of retrieving packages. It may be defined as a possibility for progressive, flexible, stepwisemanagement of the repository. The objective is to allow future generations freedom of decision in wastemanagement. Consequently, Andra has opted not to set a predetermined duration for reversibility. This involvesoffering as great a flexibility as possible in the management of each stage, allowing for the possibility ofmaintaining the status quo before deciding on the next stage or going backwards. The repository design (modular architecture, simplified operation, dimensioning and choice of durable materials, etc.) aims at allowingthe widest possible choices.

Reversible disposal can thus serve two purposes. It can be managed as a storage facility with emplacementof waste and, if so desired, its retrieval by simple reversal of the disposal process. Obviously, maintaining thisreversibility assumes human intervention, without, however, causing excessive workloads. But what basicallydistinguishes it from simple storage is that *it includes the possibility of being progressively closed, so as to beable to subsequently evolve safely and passively without human intervention*.

Investigations have shown *that a repository installation was reversible for a period of two to three centuries,with no intervention other than standard* maintenance and monitoring *operations*. Beyond this period, it wouldbe necessary to carry out more extensive interventions, which remain technically possible.

The argillaceous geological medium and the concepts developed by Andra meet the reversibility requirementand make it a flexible tool in radioactive waste management. Reversibility also enables progressive confidence buildingin the repository safety demonstration, while leaving always open the ultimate possibility of evolutionindependently of human intervention.

A safety overview that demonstrates the absence of significant environmental impact

Would the choice be made to close the repository, a detailed assessment has been made of its behaviour overtime and its possible impact on man and the environment.Based on the scientific data obtained and the proposed repository architecture, an analysis has been made ofthe repository post-closure evolution.This consisted in reviewing all the phenomena that will occur in it, examining their interactions, modelling theeffects of possible disturbances so as to, *in fine*, predict waste behaviour and appraise the mechanisms capableof leading to a release of radioactivity. *A major achievement of the research is to have built up a history of* *therepository over the next few hundred thousand years which provides an understanding of the system evolution*,key parameters, risks and corresponding uncertainties.

Based on this very detailed view of the repository and its components, the safety studies aimed to give asimplified and cautious representation for assessing its performances.The evolution of the repository under normal conditions has been represented and modelled using computationaltools integrating recent advances in digital simulation (ALLIANCES platform). The objective was to examine therepository safety functions efficiency. These functions translate the expectations from a disposal facility,expectations which themselves justify the utility of this technical system. By means of various indicators,analysis has shown that the three safety functions ("preventing water circulation", "limiting radionuclidesrelease and immobilizing them", "delaying and reducing radionuclide migration") were achieved by the proposedsystem. The cautious, or even pessimistic choices made provide significant safety margins. Thus, all the assessmentsdisplay a high degree of robustness.The analysis showed that these conclusions were not only fulfilled only under normal conditions, representativeof the most probable evolutions, but also in altered configurations, clearly more penalising: a failure inrepository components or an intrusion by drilling a borehole into the repository should not prevent the latterfrom fulfilling its functions, effectively protecting man and the environment from the disposed radioactivewaste.

Overall, performance analysis shows that safety does not depend on a single element, but is based on defencein-depth which involves multiple and redundant components. The presence of several elements that can takeover from one another in case of failure thus constitutes a considerable added value of the current repositorydesign and ensures the robustness of the disposal system.Following the calculations performed within the framework of the safety model under normal evolution, therepository performances meet the dose compliance recommended by the basic safety rule RFS III.2.f, withsignificant margins. The impacts caused by vitrified high-level waste (C waste) and long-lived intermediate-levelwaste (B waste) are several orders of magnitude below the reference standard set at a quarter of the permissibledose for the public (i.e. 0.25 mSv per year).The situation of great degradation of all the repository components, the geological medium included, wasstudied as well. It also led to an impact compatible with the references in terms of dose.In conclusion, the safety approach underpins the repository feasibility study. In the light of current knowledgeand by adopting cautious hypotheses, the consequences for man and the environment that a possiblerepository could entail, appear to comply with the standards and recommendations in force. This conclusionhas been reached with significant safety margins.

Research that could be carried out with a view tosite qualification and technological development

The research programme conducted over the past fifteen years included the necessary material to answer thebasic feasibility issue. We may assume that this is confirmed with reasonable confidence. However, this is onlybasic feasibility (in its principle) and uncertainties do remain. There could be no question at this stage of anindustrial approach or a complete performance and safety assessment, which would be essential for formallyfiling a licence application.

Without anticipating any decisions that the Parliament may consider appropriate, a few elements are necessaryto clarify the current state of the investigations and identify the prospects that they may open up, whereappropriate.

Four elements must be taken into account:

- although most of the parameters needed for assessing safety have been obtained in conjunction with theunderground laboratory, experiments have only been carried out over short periods. Without calling intoquestion the previous conclusions, a reasonable caution involves obtaining a series of data over longerperiods, allowing experiments to carry on acquiring knowledge over subsequent years. This work, to beperformed at the same time as other developments, will reinforce the overall approach;
- repository architecture has been assessed from on basic studies and feedback from other facilities. At thisstage no full-scale technological testing of repository structures has been carried out. This would appearpremature for establishing basic feasibility. In order to progress beyond this, it would be useful to constructdemonstrators of disposal cells *in situ* and to actually test the possibilities of implementing the solutionsinvestigated in an underground environment. Consolidating and optimizing the engineering would also beuseful to reach industrial objectives, if required.
- research aimed at mainly characterizing the zone in the immediate vicinity of the underground laboratory.Studies at larger scale and with a wider mesh were conducted over a transposition zone of 200 km2. However,the fine, detailed characterization of this zone has not been carried out. This means in particular that the issueof siting a possible repository within this zone cannot be achieved at present and calls for additional qualificationwork;
- finally, some elements of the repository system are currently represented using simplified and pessimisticmodels. This obviously adds safety margins, since effects favourable to repository safety are neglected.However, as part of a more exhaustive approach, it would be useful to quantify these margins and reduce theresidual uncertainties at the same time. We should then be in a position to appraise, even more accurately,the level of confidence attributable to the safety assessments.These various elements help clarify the main guidelines of the possible work programme beyond 2006, shouldthe evaluators and reviewers confirm the relevance of Andra conclusions and should the Parliament decide topursue work on deep geological disposal.

For the period beyond 2006, with all the reserves already made, Andra has tried to construct a developmentscheme aiming at producing a safety report with a dateline of a decade.Initially, we should pass from the current phase of basic feasibility to a phase of development, optimization anddetailed studies. This phase could extend over a period of approximately five years. It would first answer anypossible questions raised by the evaluators in 2006 and focus increasingly on technological aspectsand industrial implementation, while seeking to optimize the current proposed design. This would allow aprogressive transition from a scientific to an industrial situation:

- firstly, the necessary information would have to be gathered for siting a possible repository installation.Accordingly, the transposition zone should be better defined based on additional information to that used todate, then a zone matching the footprint of a possible repository could be characterized in further detail inorder to qualify it. This overall reconnaissance would especially include a large-scale seismic survey taking upthe most of previous results on the analysis methods and their representativeness.

- from a scientific point of view, the research would basically relate to two major issues: changes of scale (toconfirm the detailed validity of data obtained over limited intervals of time and space) and validating theunderstanding of phenomena and their couplings (full-scale and in situ) while accurately assessing safetymargins. From a technological viewpoint, the issues to be tackled would relate to study the construction ofrepository infrastructures, together with handling or monitoring operations. As part of this, the Meuse/Haute-Marne laboratory is a tool for acquiring data and performing technological experiments directly withinthe concerned medium. These experiments would have two objectives: at first, full scale testing of theconstruction processes with their associated techniques and tools. Secondly, full scale validation (i.e. in arepresentative structure) of the scientific knowledge acquired from samples or at intermediate scale (forinstance, experimental results obtained in drifts with regard to geomechanics). These tests would completethe progressive approach of scale change, in conjunction with design iterations.

This phase of development, optimization and detailed studies could be concluded with an overall technicalassessment, an intermediate milestone before possible transition to a subsequent development phase.Beyond this phase, assuming that the various scientific results and techniques are deemed favourable, it wouldbe possible to pass on to an industrial development stage. In order to provide an order of magnitudes, such anapproach might lead to an industrial installation by 2025.

Therefore, an analysis was conducted to specify the conceivable stages for pursuing research beyond 2006,if such were the conclusion of the Parliament. It offers an initial development scheme taking stock of thesignificant findings of the 1991-2005 period.

- GEOSAF -

Geological Disposal Safety Case explained to my mom

'*OPERATIONAL SAFETY'* COMPANION REPORT CARLSBAD EFFORT

Draft, April 20, 2011

TABLE of Contents

I. INTRODUCTION

I.1 Origins

During the course of the GEOSAF project, members have noted that, after decades of post-closure safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase of a geological disposal (GD). Thus GEOSAF decided to launch a programme of work on this topic at the plenary meeting held on March 2010 and a subgroup on operational safety was established. During the course of work the subgroup on operational safety decided to focus efforts on:

- Identification of hazards/safety issues
- How hazards/safety issues are addressed by conventional mining industry: uranium mines and others), conventional nuclear facilities and existing radioactive waste disposal facilities (for long term safety issues)
- Which of hazards/safety issues are specific to an underground nuclear facility? Which of them need to be addressed by developing a specific safety approach?
- What recommendations need to be developed with regard to the development and review of the safety case dealing with the operational phase?

I.2 Scope and Objectives

This companion report aims at presenting the outcome of the efforts of the GEOSAF working group on Operational Safety of geological disposal of radioactive waste, as well as to identify the need – if any – for continued work in this area.

I.3 Modus operandi

The work programme developed by the group involved visits to three underground facilities of different character to collect information on experience in the field of operational management with special emphasis on management of hazards and/or risks;

- a conventional mine (the Moab Khotsong gold mine in South Africa,
- a high uranium mine (Mc Arthur River, Canada), and
- a disposal facility for transuranic waste (Waste isolation Pilot Plant, WIOPP, US). A workshop was arranged in conjunction with the WIPP-visit in April 2011, to analyse and compile the conclusion drawn.

A summary of the main conclusions from the visits are found in appendix I.

I.4 Common Terminology

It was found valuable by the group to start on common grounds with a terminology that fits with everyone's culture and practice. The following definitions are based on the two IAEA glossaries that are currently in use [B, C]:

Hazard: A hazard is something (e.g. an object, a property of a substance, a phenomenon or an activity) that can cause adverse effects

Hazard assessment: Hazard assessment is the *process* of analysing systematically the hazards associated with *facilities*, *activities* or *sources* in order to identify:

(a) Those *events* and the associated areas for which *protective actions* may be *required*;

(b) The actions that would be effective in mitigating the consequences of such *events*.

Event: An event is any occurrence unintended by the operator, including operating error, equipment failure or other mishap, and deliberate action on the part of others, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

Initiating event: An initiating event is an identified event that leads to anticipated operational occurrences or accident conditions.

Risk: Risk is a multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual or *potential exposures.* It relates to quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences.

Scenario: A scenario is a postulated or assumed set of conditions and/or events.

II. Background

The IAEA Safety Requirements SSR-5 [A] contains basic requirements for disposal of radioactive waste in a specially designed disposal facility. It covers the whole life cycle of the facility, i.e. from early preparatory activities up and until the disposal facility has been properly decommissioned (closed and sealed).

The SSR-5 concludes that disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal facility and systems. Throughout this process, an understanding of the relevance and the implications for safety shall be developed with the purpose of providing an optimized level of safety both in the operational stage and after closure.

A safety case and supporting safety assessment shall be prepared and updated, as necessary, at each step in the development of a disposal facility. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input and for informing the decisions necessary at each step.

The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design, operation and closure of the facility. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment. The safety case shall demonstrate those hazards and other radiation risks to workers and members of the public under conditions of normal operation and anticipated operational occurrences have been reduced as low as reasonably achievable. It shall provide assurance that safety requirements during all stages of development of the facility will be met. Ensuring safety both in the operational stage and after closure is the overriding factor at each decision point.

During the course of the GEOSAF project, the need to develop a better understanding of implications on post-closure safety for a geological disposal facility from activities performed during the operational phase and, more specifically, to which extent accidents during the operational phase may have a negative impact on post-closure safety. This document, therefore, focuses on safety assessment of operational hazards and their management and, where applicable, their possible impact on to post-closure safety.

In a first approach, no major difficulty is identified for the operation of the surface facilities associated to underground repository with an appropriate level of safety, given the important experience feedback from all of the nuclear industry regarding the conception, construction and operation of such surface facilities. Thus, the present project focuses on the operation of the underground part of the facilities (including shafts and ramps).

III ASSESSMENT METHODOLOGY

III.1 General Context for the Methodology

Post-closure safety for a repository depends on isolation and/or containment of the disposed waste/material. Post-closure safety of the repository is therefore dependent on proper performance of technical barriers and of the host rock environment. Thus, proper design of the facility, the construction of the technical barriers as well as proper construction and safe operations, is of special importance as it may affect the post-closure safety. Special emphases should therefore be put on identification of risks associated with the (construction and) operation of the repository.

As it is the case for any nuclear facilities and especially for the demonstration of post-closure safety of geological disposal, Defense-in- depth (DiD) is one of the main principle to rely on when demonstrating the operational safety. Safety must be demonstrated for all the operational states of the facility, including the stand-by ones, considering the limiting conditions of operation. The safety approach should be based on verifying the compliance with technical performances of the protection provisions against all concerned hazards, derived from the hazard analysis. In this regard, safety functions and associated technical requirements have to be defined. The quantitative assessment of radiological consequence from any postulated hazards is only considered as a mean of verification. Both deterministic and probabilistic approach may be implemented for operational safety assessment; however a prudent approach could consider that probabilistic analyses complement the deterministic approach.

Hazard assessment require identifying and analysing i) plausible hazards (alea) and ii) elements or “targets” to be protected regarding nuclear safety (radioactive materials, containment systems of these materials, evacuation pathways and access to equipments to handle the hazard and thus maintain the facility in a safe status…). The provisions adopted on the basis of this analysis, organized in successive and independent levels according to DiD, aim at :

- preventing the hazards or limiting their number and intensity (development), in time and space,
- maintaining the technical safety requirements and mitigating the potential radiological consequences of the hazards (to protect the targets from the alea and limit the consequences).

An approach on how to address risks to post-closure safety associated with operation of the facility is described below, and schematically illustrated in figure 1.

Operational Safety Context

Flow chart

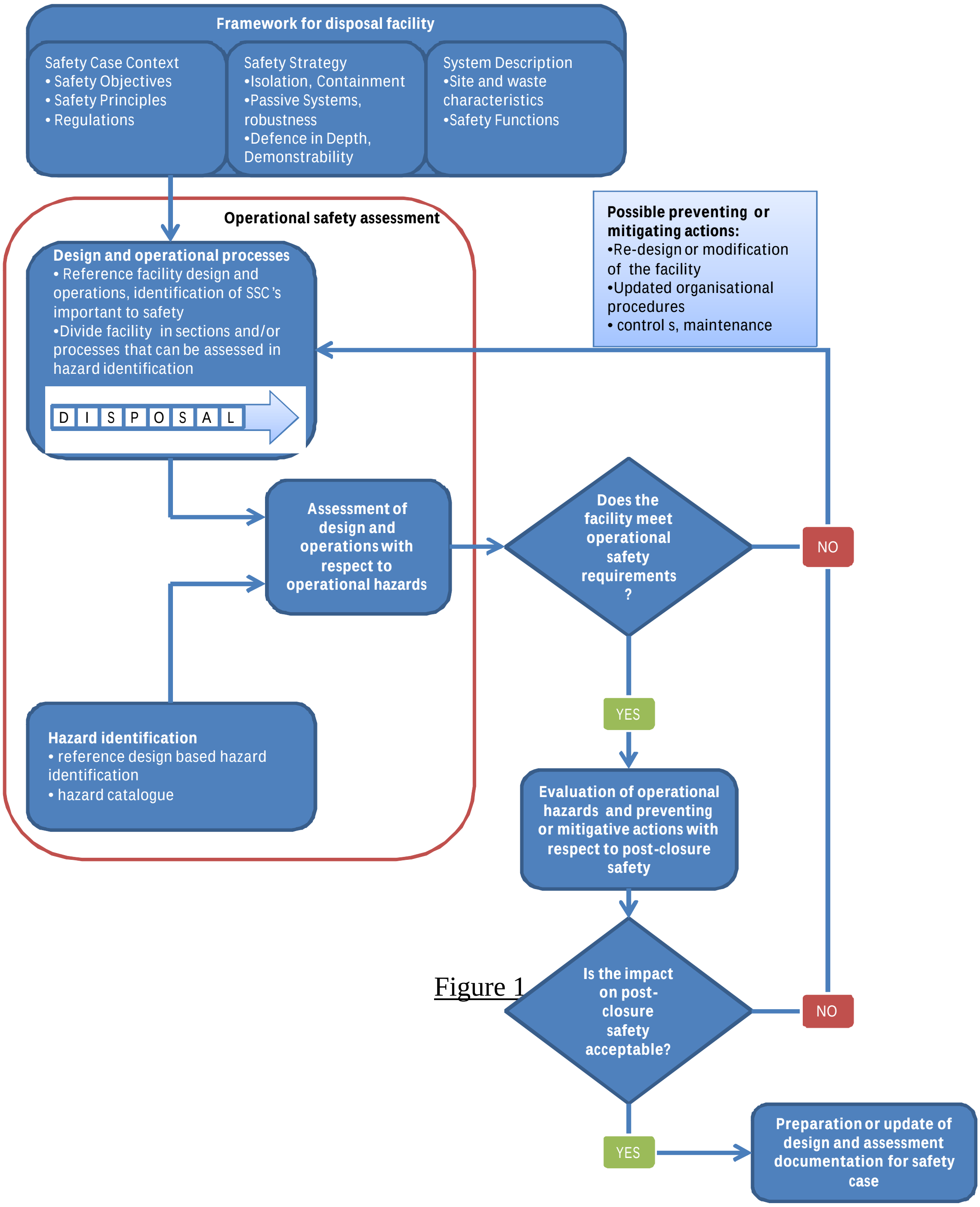


Figure 1

Description of the flow chart process :

In a first step, **the framework for the disposal facility** (**I**) will guide the initial design of the facility, which might take into account already some standard hazards that are defined through regulatory requirements – all or not nuclear – or through a preliminary analysis of hazards. In order to perform the hazard assessment, the reference **design and operational processes (II)** should be described, and divided into assessible sections and/or phases or periods. Based on this and maybe on other sources such as hazard catalogue or matrices, the **hazards (III)** of the facility are **identified**.

The identified hazards are put against the design and operational procedures and an **assessment of design and procedures** is made **with respect to operational hazards (IV)** identified to show that preventive and mitigation features present are effective.

Design and operational processes, hazard identification and hazard assessment form a operational safety assessment based on a judgement of whether these features are acceptable in terms of consequences or risk can be made.

- If **not acceptable**, adaptations should be made of the preventive and mitigation features, which could be on the level of design (re-design or modification) or operational procedures. Facility re-design or design modification (II) requires iteration of hazard identification (III) and assessment (IV) with regard to updated features.
- If **acceptable**, an evaluation is made on the impact of hazards and the preventive and mitigation features on the **post-closure safety (V)**.

Regarding post-closure safety a judgement is made if identified hazards or taken actions have impact and whether this is acceptable in terms of consequences or risk. Balance should also be made here between consequences of interventions after accidents or loss of a part of the facility and the efforts needed for preventing or mitigating the hazard.

- If **not acceptable**, adaptations should be made of the preventive and mitigation features, which could be on the level of design (re-design or modification) or operational procedures. Facility re-design or design modification (II) requires iteration of hazard identification (III) and assessment (IV) with regard to updated features.
- If **acceptable**, the design and operational processes and the preventive and mitigation features can be finalised or updated, together with the final documented operational safety assessment.

III.2 Operational Safety - Context

There is no major difference in the safety case concept whether it is dedicated to a disposal or another nuclear facility. Assessment of operational safety is an integral part of the process described in SSR-5, i.e. assessment of operational hazards should be integrated in the safety case development for a disposal facility. Thus, operational hazards should not be treated separately from the overall development process for a disposal facility. However, the way member-states carry out safety assessments, as part of the safety case, may vary, even if the goal of such a step is a well approved common feature: to provide a demonstration (or an evaluation of this demonstration in the case of the regulatory review of the safety case) that measures taken by the operator to manage hazards are adequate to ensure the safety of the facility (following the defence-in-depth principle).

III.3 Design and Operational Processes

In the safety case, the design phase consists of selecting the reference layout and design for systems and components relevant for safety. The reference design needs to be consistent with all those regulatory requirements and constrains coming from disposal constrains, referred to in the previous section, and checked against the facility's safety functions and ability to ensure safety during the operational *and* the post-closure phases.

In the design of disposal facility it is necessary to identify all regulations and requirements that all relevant for disposal system in mind. The identified requirements for the disposal facility can be compiled as design basis that can also involve constrains coming for example from construction and disposal practices. Design basis can be used as a tool for the regulator to review that all the relevant regulatory requirements have been addressed. Design basis also forms the premises/ safety envelope for the designers to work on.

Beyond architecture and underground layout, facility design includes systems, controls, maintenance, and a feedback system on the selected hazards or items relevant to safety.

For the purposes of hazard identification and evaluation, it may be necessary to break out the overall facility operational process into various operational sections based on for example waste handling areas and the activities performed in those areas. For instance, in the WIPP safety case, the facility is broken out into different sections where hazards are (i) identified, (ii) recorded and (iii) screened, and analyzed. Once the analysis is complete, then controls are established to ensure safe operational parameters.

In case that the designed facility does not meet operational safety requirements (assessment described later) there is a need to introduce preventing or mitigative actions such as re-design or modification of facility systems, structures or components, organizational procedures or other controls. These actions are described in more detailed in section III.5.4 of this reports.

At some point during the operational phase of a geologic repository, it may become necessary to perform a modification to permit a new process, change to a procedure that is safety related, or a reconfiguration of the underground environment. Prior to performing these modifications it is necessary to develop and execute a procedural process that permits a comprehensive evaluation of impacts to the facility, operation, or process and assess the impacts to safe operations and post-closure safety. A change to the facility could have a negative impact to the post-closure safety (disturbance of geologic media) or operational safety envelope (impairment to a safety related system, structure or component) for the facility. A process that executes the methodology mentioned above should be implemented to ensure post-closure performance requirements of the facility are not challenged or jeopardized and that the modification can be imposed with little impact. If impacts are noted that effect safety, then the facility may not meet operational safety requirements and the operational assessment (that may lead to a re-design of the modification) must be executed (refer to flow chart).

The design of an underground disposal facility needs to meet requirements coming from nuclear facility operational safety, post-closure safety and, depending on national approach, also the ones coming from mining safety. Post-closure safety can set constrains that are contradictory for operational safety and design needs to optimized to fulfill these. For example it can be beneficial for post-closure safety to have only few surface connections (access ramps, shafts) and small cross-section tunnels to avoid disturbance on site properties. Whereas for operational safety and emergency purposes a design should avoid dead-end tunnels and be in favor of safe exit. Other examples of specific features for underground disposal facility are possibly aggressive environment and long operational lifetime (aging management, maintenance), procedures concerning underground operations, interfaces between mining activities and nuclear disposal operations and that the detailed knowledge of host rock properties will develop during on-going mining activities. Examples of these kind of design constraining issues are given in Appendix 2.

III.4 Hazard Identification

The identification of hazards inherent in waste activities is necessary to provide a sound basis for identifying potential accident events and performing a hazard evaluation in order to define the preventive and mitigative controls.

Hazard identification is a comprehensive, systematic process by which known hazards associated with the facility in question are identified, recorded, and screened by a team of individuals. This process must be conducted in accordance with regulation and/or requirement processes for hazard identification and selection of accidents.

Hazards are primarily identified through the development of lists of known hazardous energy and material sources and identifying hazardous locations. Information for identifying hazards and determining their applicability to the facility in question may be obtained, as applicable, from the following sources:

- Existing project, safety, and environmental documents

- Design drawings and reviews
- Test plans and studies
- Process walk downs and equipment data
- Consultations with facility, system, and process experts
- Pre-defined lists of hazards, such as hazard matrices in appendix II

One approach to the hazard identification process could be to perform three steps by the integrated team:
1. Division of the facility into facility "sections."
2. Information gathering to identify hazards.
3. Screening out of standard industrial hazards.

The hazards defined can be of different nature and amongst others result from:

- aspects of the facility waste handling process,
- natural Phenomena (e.g., earthquakes, lightning, tornadoes, snow/hail buildup and high wind impacts),
- human induced external events (e.g., aircraft and vehicular impact), or
- nuclear criticality
- …

The hazards will in the next step be represented by an envelope or typical initiating event.

III.5 Hazard Evaluation

III.5.1 Scope of the Hazard evaluation

The hazard evaluation is the process of analysing systematically the hazards associated with the facility in order to identify the events that would need protective or mitigatory controls. It focuses attention on those hazards that pose the greatest risk or have the greatest potential consequences to/for the public and the workers during the operational period. Hazard categorization, identification of event cause(s), assignment of event frequency and unmitigated consequence levels, and finally the identification of necessary preventive and mitigative features are tasks performed during the hazard assessment process.
The final goal of this process is to be able to operate the facility in line with operational safety requirements, in spite of the hazards that might drive the facility into abnormal or accidental conditions and due to this pose a risk to the public and the workers. The demonstration of this capacity of safe operation in all conditions, as well normal as abnormal or accidental is the main mission of the operational safety assessment (see section III.6) that needs to be developed in the Safety Case or Safety Evaluation Report.

The next sections will develop the different steps that are undertaken when performing a hazard evaluation. Such process is not unique for a geological disposal, compared to other nuclear installations. The unique character lies in The unique character lies in the fact that the assessment is performed in the frame of an underground installation, which has its own particular set of hazards that differ from the ones one encounters in surface facilities. This underground environment also set some particular boundary conditions to the way one can cope with these hazards. Another aspect, but one that is common with surface disposal facilities, is the necessity to consider also the effect of hazards and their preventive and mitigative controls on the post-closure safety of the facility.

III.5.2 Event Description

The hazard evaluation includes a brief description of a postulated hazard evaluation event, which is an initiating event that is representative or envelope for the type of hazard considered. The event description includes a hazardous condition being postulated, general location of the event, the release mechanism (e.g. fire, pressurized release, spill) or other consequence mechanism (e.g. direct exposure), and the affected hazardous material, including the material at risk that may be affected by the event. Using the event scenarios are developed wherever a potential exists for a release of hazardous energy and/or material.

III.5.3 Consequence evaluation and risk ranking

Consequence evaluation

In order to assess further the postulated events through scenarios or to be able to risk rank the hazards, it is necessary to assess the consequences of an initiating event resulting out of the hazard in an unmitigated way. This means that no credit is given to neither preventive, nor mitigatory controls that might be implemented. Also, margins should be taken in the hypotheses considered for the evaluation, and uncertainties should be identified.
The consequences can be categorised according to different predefined consequence levels, or they can be further used as such.
It might be necessary to also consider plausible combinations of events.
It is common to evaluate consequences at the following receptor locations to assess effects associated with the postulated event, although other approaches can be acceptable:

- Qualitative evaluation for those workers in the immediate area of the hazard
- A semi-quantitative evaluation for those workers in the same area who may not be aware of the hazardous condition.
- A pure quantitative evaluation for the public and the environment.
- A pure quantitative evaluation is also appropriate for personnel outside the site boundary, at a prescribed or predetermined distance (site boundary).

These consequences will be used to identify the preventive and mitigatory actions such as developed in some of the sections further in this report. Some countries adopting a risk based approach which will rank the hazards further according to the risk they pose and according to the methodology developed in the next section. Other countries do not adopt this risk ranking and define the preventive and mitigatory controls purely based on the consequence analysis, while postulating the initial event and developing scenarios that put the facility at its worst state it can reach given the initiating event.

Risk Ranking

Some countries that adopt a risk based approach, will rank the identified hazards with respect to the risk they pose. This risk that poses a hazard is the combination of the unmitigated consequence levels of the hazard with the levels of frequency of its appearance. The objective of risk ranking is to focus attention on those events that pose the greatest risk to the public and workers. In this process of qualitative ranking (qualitative due to the fact that it works with levels rather than absolute values), events with an unacceptable risk ranking or marginally acceptable risk ranking are analyzed to provide appropriate features of prevention or mitigation.

III.5.4 Determination and evaluation of controls

In order to cope with hazards that have unacceptable consequences or pose an unacceptable or high risk, the next step consists of identifying and selecting controls to be put in place in order to prevent hazards or mitigate their consequences. This should lead to the reduction of the frequency of the hazard or the exclusion of its appearance in case of preventive controls, or the reduction of its consequences in case of mitigative controls. The controls can be a combination of both. The two types of controls are further developed hereunder. The goal of the definition of the controls is to reduce the risk posed by the hazard, or in the case no risk based approach is adopted, to exclude the appearance of events or to reduce their consequences to an acceptable level.
Efforts should also be made to keep the identified set of controls to a minimum but try as much as possible to focus on controls that will be applicable to multiple events.

The controls are then evaluated for completeness by evaluating their effectiveness to reduce the likelihood or consequences of any representative events that also had an unacceptable risk rank or a public high consequence level. If the controls are determined to be inadequate to reduce the risk of the representative events, additional controls are selected to reduce the risk rank of the events to an acceptable level.

Care should however be taken as to always prevent as much as possible the appearance of hazards or to keep the risk as low as reasonably achievable.

Preventive Features

Preventive features are features expected to reduce the frequency of a hazardous event. The identification of such features is made without regard to any possible pedigree of the feature such as procurement level or current classification. These might include engineered features (Structures, Systems and Components, etc.), Administrative Controls (procedures, policies, programs, etc.), natural phenomena (ambient conditions, buoyancy, gravity, etc.), or inherent features (physical or chemical properties, location, elevation, etc.) operating individually or in combination. Preventive features constitute a significant portion of Defense in Depth and worker safety and provide essential input to the control selection task. Therefore, the identification effort captures essentially all of the possible features that could be counted on to prevent a hazardous event. The preventive features are a listing of some of the potential measures that the Accident Analysis and mitigatory control selection process may later credit. These features represent a potential set of controls that could offer reduction in event frequency, but whose appropriateness must be demonstrated throughout the development preventative measures.

Mitigative Features

Mitigative features are any features expected to reduce the consequences of a hazardous event. The identification of such features is made without regard to any possible pedigree of the feature such as procurement level or current classification. Mitigative features must be capable of withstanding the environment of the event. These might include engineered features (e.g., Structures, Systems and Components), Administrative Controls (e.g., procedures, policies, programs), natural phenomena (e.g., ambient conditions, buoyancy, gravity), or inherent features (e.g., physical or chemical properties, location, elevation) operating individually or in combination. Mitigative features should be listed in a hazard evaluation table in a manner that a distinction is made between administrative controls and active or passive engineered controls.

Mitigative features constitute a significant portion of Defense in Depth and worker safety and they provide essential input to the functional classification task. Therefore, the identification effort captures essentially all of the possible features that could be counted on to reduce the consequences of a hazardous event. The mitigative features are a listing of the potential controls that the accident analysis and control selection process may later credit. None of the mitigative features are credited in the unmitigated hazards analysis. These features represent a potential set of controls that could offer reduction in event consequence, but whose appropriateness must be demonstrated through the control selection process.

III.6 Operational Safety Assessment Basis

The goal of operational safety assessment is to assess the safety of the facility during the operational phase and to identify normal operation of the facility, as well as abnormal and accidental conditions that might be the result of initiating events based on hazards and the means put in place to cope with these conditions, in line with the safety principles such as defence in depth and optimization.

When it comes specifically to hazards, the operational safety assessment demonstrates that in the first place, sufficient effort is done to reduce the probability, or to prevent the appearance of hazards that might impact operational safety. For hazards that are plausible, operational safety assessment demonstrates that, possibly for different initial conditions, the consequences of the initiating events based on these hazards are mitigated through system design or procedures such that they do not give rise to unacceptable radiological consequences or pose an unacceptable risk. It is demonstrated that if the postulated initiating events associated to hazards give rise to abnormal conditions, than the controls in place are able to put the facility back into its normal operation envelope, and it is also demonstrated that if postulated initiating events associated to hazards give rise to accidental conditions, than controls are put in place in order to keep the facility in a safe state.

The assessment can be done in a deterministic way, through the postulation of events, all or not categorised according to their frequency and the development of a propagating scenario of of this event into an incident or accident. This scenario is than assessed in terms of acceptability of controls with respect to the potential consequences of the event and, all or not, its frequency. In these scenarios, the facility is usually put at its most penalising state and conservative assumptions are made. For instance, the Dossier 2009 regulatory review underlined the likelihood of a fire on a handling system (within an emplacement cell dedicated to the disposal of waste packages that are sensitive to a certain elevation of temperature) which would not be extinguished by the selected countermeasures developed by the designer/operator. As a matter of fact, the regulatory reviewers considered that this event could lead to unacceptable consequences (a fire impossible to extinguish once it has started), even if the probability of occurrence of such an event is considered as particularly low (common failure scenario). This resulted neither in a risk ranking, nor in a calculation, but led to a recommendation underlining the need for a strengthening of this type of control, thus a redesign.

It can also be done in a more risk based way, i.e. the evaluation of the risk of the hazard, taking into account the probability or frequency of the event and its potential unmitigated consequences, and the assessment of the acceptability of design and procedural preventive and mitigation controls in view of the reduction of this risk.

III.7 Influence on Post-closure Safety

As described above, the operational safety assessment process should verify that the provisions for preventing or mitigating risks and their consequences are sufficient to meet the requirements of regulators for operational phase or accepted industrial standards/practices. However, it has to be considered that measures to ensure operational safety by either preventing or mitigating risks may have consequences on post-closure safety.
Therefore it has to be verified that these provisions are such that:

- They do not have an unacceptable adverse effect on the performances of the disposal system with respect to post-closure safety
- The consequences of the postulated incident or accident may not deteriorate in an unacceptable way the post-closure safety functions.

If necessary, the provisions should be reconsidered and the risk assessment should be reevaluated.
Post-closure safety can set constraints for example on use of foreign materials or other actions that can change the desired geological properties. In the underground facility this can mean restrictions on use of construction materials, amount or type of rock reinforcement or grouts, ventilation, fire protection, etc.

IV CONCLUSION

During the course of the project, GEOSAF members have noted that, after decades of post-closure safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase of a geological disposal. The *IAEA Draft Safety Requirements No. SSR-5* provides guidance pertaining to safety in all aspects of geologic disposal as to expectations and was a catalyst for the GEOSAF Operational Safety Working Group to engage their work predicated on the following statement from SSR-5:

> *Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal facility and systems. Throughout this process, an understanding of the relevance and the implications for safety shall be developed with the purpose of providing an optimized level of safety both in the operational stage and after closure.*

SSR-5 requires the preparation of a safety case and a supporting safety assessment for each step in the development of a disposal facility. It must be technically sound to ensure informed decision making is executed at each step. Moreover, SSR-5 requires that the safety case and safety assessments are prepared and updated at each step.

The relationship between operational safety and the safety case are truly seen in the fact that SSR-5 requires that the safety case for a disposal facility describe all safety relevant aspects of the site, the design, *operation* and closure of the facility and that the safety case and supporting safety assessment demonstrate the level of protection of people and the environment. SSR-5 also specifies that the safety case demonstrate those hazards and other radiation risks to workers and members of the public under conditions of normal operation and anticipated operational occurrences have been reduced as low as reasonably achievable. It shall provide assurance that safety requirements during all stages of development of the facility will be met. Ensuring safety both in the operational stage and after closure is the overriding factor at each decision point.

During the course of the GEOSAF project, the need to develop a better understanding of implications on post-closure safety for a geological disposal facility from activities performed during the operational phase and, more specifically, to which extent accidents during the operational phase may have a negative impact on post-closure safety. This document, therefore, focuses on safety assessment of operational hazards and their management and, where applicable, their possible impact on to post-closure safety.

In its essence, IAEA-SSR-5 was a catalyst for the GEOSAF to engage the GEOSAF Operational Working Group to begin investigations to research the areas of operational safety and impacts to the safety case and post-closure performance of a repository and acknowledge that work in this area of knowledge has still to be seeded and harvested, because experience feedback is limited at the moment.

To that extent, the GEOSAF Operational Working Group was compelled to address three areas that could assist other member states in designing an approach to identifying, evaluating, and assuring operational safety providing an example of a fire in the underground as a common event scenario. To achieve this activity is was decided to provide the following three steps:

1. A methodology for assessing the OPS, which is designed to help building or evaluating the safety case of a geologic disposal
2. Identify the common features and differences between national approaches to assess the safe operations of a geologic repository
3. A pilot study designed to test the methodology against a specific hazard chosen by the group

After visiting several facilities in various countries, the team met in Carlsbad, New Mexico to assimilate information and formulate this report that will be attached as a complimentary report to the overall final report of GEOSAF to the IAEA.

This complimentary report identified strengths and weaknesses in various geologic disposal programs concerning operational knowledge and experience and urges further work in this area to ensure the post-closure performance of a geologic repository meets the safety case and post-closure design. The GEOSAF Working Group on Operational Safety recommends using a pilot study that targets common events in mining and geologic disposal that associates an operational event to the impacts of post-closure activities or the safety case in general. It is also suggested that the GEOSAF design and adapt a questionnaire developed specifically for reviewing processes that ensure safe operations and impacts to the post-closure performance and safety case of a repository. The questionnaire should focus on the operational phase.

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APPENDICES

I Observations from other mining and geologic repositories
II General Hazards Matrix
III Generic example of the process of hazards identification, evaluation, and control application pertaining to a fire in the underground part of WIPP (US)

APPENDIX I: Observations from other underground facilities

McArthur River facility, Canada and the Moab Khotsong, South Africa
In particular, the group had the opportunity:

1. To tackle ventilation issues with operators (both during the Saskatoon and South African meetings), including maintenance and dimensioning of ventilation systems. The operators underlined the absence of limitation in terms of air flow, however the maximum capacity of the air intake and outflow have to be determined at the shaft design, prior to the construction of the first drifts. In fact, the dimensions and number of shaft can be impacted by such constraints, and the ventilation systems have to be dimensioned to allow for the extension of the underground areas. They also stressed the functions that can be assigned to the ventilation systems, such as radon rate control, and the way these functions can be implemented in the mine. For example, at the McArthur River facility, every underground area has to be ventilated to allow for works, therefore specific doors equipped with radon sensors prevent ventilated areas to be mixed with un-ventilated areas.

2. To gain experience in the Canadian approach to Uranium mining regulation. The Saskatoon meeting underlined the risks related to exposure to radiation, including the radon risk. Both the regulator and the operator explained the importance of sensible tele-operated mechanical devices for the mining operations: the extraction process itself is designed to prevent human presence in the vicinity of the uranium ore, and the lorries and skips are equipped with radio controlled systems in order to prevent workers from operating close to the extracted ore.
   At every step of the process, the regulator underlined the need to either design barriers or allow enough distance between the sources of radiation and the workers. The exposure time factor had to be taken into account in the least possible cases in the underground areas, thus the safety case had to provide sufficient controls with regard to radiation screening or distance from sources. Radon risk was controlled mainly by ventilation systems and security measures (locked doors…).

3. To stress the need for adequate fire protection systems. The South African meeting and the discussions between the group and the gold mine operator put light onto the way such a hazard might be taken into account in underground works. The gold mine operator introduced the group to the method developed by his fire protection experts, in order to prevent fires to lead to unacceptable consequences. This method mainly relies on an occurrence/gravity matrix that is often used in reliability management, for instance. The group was interested to discover the whole set of constraints that the

operator includes in this matrix: security, but also environmental issues, social issues, etc. For instance, a fire leading to human casualties has consequences on the production, but also on the population acceptance of the operator in the area of the facility, or on the stock price of the parent company. All these variables are taken into account in the fire hazard analysis provided by the operator.

Waste Isolation Pilot Plant, Carlsbad, New Mexico – USA

To be elaborated! Gary – can you help?

APPENDIX II: General Hazards Matrix

Hazards & safety issues are identified through various sources relevant to a GD: industrial facilities, underground facilities such as mines or tunnels, and nuclear facilities. The OPS working group worked extensively to identify those hazards.

For instance, the group consolidated the following matrix after gaining feedback from mine operators (AngloGold Ashanti from RSA and Cameco from Canada) and a regulatory body (CSNC from Canada):

Hazards	Conventional Mines (e.g. Moab Khotsong)	High grade Uranium Mines (e.g. Mc Arthur River)	Control and mitigation measure in Mines	Nuclear facilities (waste management)	Relevance to Deep Geological Repositories
Radiation	Not applicable	Sources: radon, dust, gamma exposures	Ventilation, mining methods, shielding, freezing,	Waste packages Spent fuel ✍ shieding and ventilation ✍ procedures	Handling of used fuel containers towards emplacement constitutes radiation hazard
Criticality				Package design Facility design Administrative controls	Package design Facility design Administrative controls
Stability of shafts and galleries	Yes. Ore bodies are usually associated with fractured rocks with relatively high in-situ stress	Yes. Ore bodies are usually associated with fractured rocks with relatively high in-situ stress	Ground control measures: bolting, meshing, arches, shotcreting Monitoring for rock deformation	Not relevant	Ground instability would be less of a problem. DGR are usually associated with competent and sparsely fractured rocks. However, there is a need to control damage zones induced by excavation, and subsequent heat loss. For LT safety : optimize use of foreign materials for reinforcement✍ balance operational safety and LT safety
Internal Flooding	Yes in general, since ores are associated with fractured rocks. However at Moab Khotsong, not an issue, since the rock is not saturated .	Yes. High water inflows rates associated with fractured rock.	Pumping capacity; freezing; grouting.	Breach on circuit Fire extinction	Less of a hazard. Most of DGR are located in low permeability rocks but non controlled inflow can cause flooding (granite site)
External flooding				Depending on site ✍ siting, site protections (fences, dams)	Need to be addressed in selecting site or in designing the accesses to disposal (shafts or acces ramp)
Fire	Yes. Sources: flammable gas, blasting operations, electrical and fuel sources,	Yes but not as significant. Sources: burning vehicles, electric cables.	Refuges; ventilation; personal equipment, sectioning with fire resistant walls, fire extinguishers, good housekeeping, use of low toxicity and fire retardant cables, more than one shaft for escape, emergency drills, etc…	flammable gas, electrical and fuel sources. (risk handled through : Iimitation of burning load + fire detection system+ fire fighting systems + fire compartments)	Fire hazard could be as relevant to DGR. Sources could be comparable to UG mines. Same protection and mitigation measures as UG mines could be applied. Optimization between Operational Safety and post-closure safety wrt number and location of accesses to surface

Explosion	Blasting operations,	Blasting operations,	Blast resistant walls, strict procedures for handling explosives,	Gazes from waste (control of materials in WP)	If excavated in phases, proper procedures for separation of disposal and excavation activities Natural flamable gases + gazes generated by waste
Earthquake	Mining at great depths in high in-situ stress environment can trigger movements of faults, that generate earthquakes. Also, if mine is located in seismic zones, earthquakes can also occur naturally and affect mine stability.	Not as relevant, since depths are less important, and rock is less brittle. For Mc Arthur, the mine is located in a low seismic zone.	Control the mining rates; try to configure the tunnels so that mining does not get too near a fault,… Depending on the epicentral distance, usually underground structures are less vulnerable to seismic activity.	Siting, system and structure design	Excavation induced seismicity would be relevant for granite compared to sedimentary rocks. Depth of a repository should be chosen with due considerations of isolation and containment functions versus magnitude of in-situ stress . In most countries, repositories would be sited in low seismic zones. Design repository to resist earthquakes.
Hoisting equipment failure / elevator blocking	Yes, potential hazard	Yes, potential hazard	Prevention: Handling procedures, single failure proof hoisting machinery; maintenance/good housekeeping.	Prevention : : Handling procedures, single failure proof hoisting machinery; maintenance/good housekeeping. And mitigation : ventilation	Yes, both conventional and radiological in case WP is handled. In this case: mitigation: ventilation/procedures/section closure, refuges…
Ageing	Yes, long operation, infrastructure degrades as function of time	Yes, long operation, infrastructure degrades as function of time	Maintenance, inspection, repair/replacement	Maintenance, inspection, repair/replacement	Yes, operation for possibly more than century. Should be addressed
Decomissioning and impact of operational activities (including e.g. utility infrastructure) on post-closure safety	Reduce impact of mining activity on environment, so decommissioning is relevant	Reduce impact of mining activity on environment, so decommissioning is relevant	Surface infrastructures should be dismantled; mine wastes should be managed with consideration of post-closure environmental impact; underground openings should be backfilled to reduce likelihood of surface subsidence,etc.		Yes, all related to post-closure safety. Mining technique, ventilation,… has impact on post-closure safety. Backfill/buffer. Dismantle operational infrastructure and impact of remains on post-closure safety. Should be addressed in Safety assessment.
Breach of security	Arson, sabotage, theft of valuable materials and equipments,…	Arson, sabotage, theft of valuable materials and equipments,…	controlled access; security screening of workers and visitors		Arson, sabotage, theft of valuable materials and equipments, … are all relevant. In addition, needs security and safeguards measures wrt radioactive materials. Sabotage of LT term site properties

APPENDIX III: A generic example from WIPP (US)

GENERIC EXAMPLE OF THE WIPP PROCESS OF HAZARDS IDENTIFICATION, EVALUATION, AND CONTROL APPLICATION PERTAINING TO A FIRE IN THE UNDERGROUND

Methodology

At the Waste Isolation Pilot Plant located near Carlsbad, New Mexico – USA, fires in the underground have been identified as one of many hazards. Standard Industrial Hazards are identified also, however particular to the operation of a deep geologic repository, waste is emplaced for disposal by diesel powered equiement that requires combustible fuel. One event postulated is a fuel pool fire as a result of of several accident scenarios and is the topic of this writing.

Table 1, below identifies hazards commonly expected for waste operations for deep geologic repositories and surface waste preparation facilities. The fire event described in this writing has a hazard source and material group identified in the first 7 groups under fires in the Hazard Sources and Potential Events in Table 1.

The listing in the table below represents major hazard sources and material groups that *could* be potential initiators for specific accident events to be discussed in the safety report. Wherever these hazards are present in a given waste operation an analysis must evaluate the applicability of the corresponding accident event(s). It is important to note that hazards identified in above table do not always result in accidental release of radiological materials or hazardous chemicals. Depending on the location and specific characteristics of the hazard, it may be considered a Standard Industrial Hazard. Standard Industrial Hazards can be defined as a hazard that is:

> *. . . routinely encountered in general industry and construction, and for which national consensus codes and/or standards exist to guide safe design and operationwithout the need for special analysis to design safe design and/or operational parameters/*

It is not the intention of the safety report to provide analysis of SIH type of hazards. Rather, hazards in the table above are evaluated to the extent that they act as initiators and contributors to accidents that result in a radiological or chemical release. Applying appropriate levels of hazard screening during the hazard identification process can be helpful in distinguishing between SIH and those that must be evaluated by the safety report.

Now that the source is identified, the hazard identification process progresses to a particular mode of operation that involves a diesel powered vehicle such as a transport vehicle, forklift, etc. that is involved in an accident that results in a spillage of fuel from the fuel tank and that fuel pools under the vehicle or can spread to the material at risk (waste). Once the event is identified and a comprehensive identification of all known hazardous material and energy sources coupled with diesel powered equipment operated in the underground is completed, the hazard evaluation process and accident analysis can be performed. This effort includes the event categorization, identification of event cause(s), assignment of event frequency and unmitigated consequence level, and identification of potential mitigative and preventive features.

Table 1

Hazard Sources and Potential Events

Hazard Source and Material Groups	Potential Accidents
Electrical	Fires - In combination with combustible/flammable material Explosions
Thermal	Fires - In combination with combustible/flammable material Explosions In combination with explosive material. Criticality Increased concentration
Pyrophoric Material	Fires - Pyrophoric fire; may serve as ignition source for larger fires and explosions when in combination with explosive material
Spontaneous Combustion	Fires - May serve as ignition source for larger fires Explosions - In combination with explosive material
Open Flame	Fires - In combination with combustible/flammable material Explosions (Events 5-8) - In combination with explosive material
Flammables	Fires - In combination with ignition source
Combustibles	Fires - In combination with ignition source
Kinetic Energy (Linear and Rotational)	Loss of Confinement/Containment - Impacts, acceleration/deceleration, missiles Criticality - Loss of configuration or spacing
Potential Energy (Pressure)	Loss of Confinement/Containment - Impacts, missiles Criticality - Loss of configuration or spacing
Potential Energy (Height/Mass)	Loss of Confinement/Containment - Impacts (falling objects), dropping Criticality - Loss of configuration or spacing
Internal Flooding Sources	Loss of Confinement/Containment - Ground/surface water runoff Criticality - Increased moderation
Physical	Loss of Confinement/Containment - Puncture, dropping
Radiological Material	All Events - Potentially releasable material
Hazardous Material	All Events - Potentially releasable material
Ionizing Radiation	Direct Exposure - Direct exposure to worker
Non-Ionizing Radiation	Direct Exposure - Direct exposure to worker Other - May interfere with equipment operation
Fissile Material	Criticality
Non-facility Events	External Initiated Event
Vehicles in Motion (external to facility)	External Initiated Event
Natural Phenomena	Natural Phenomenon Hazard (NPH) Events

However, before beginning the evaluation, the *initial conditions* for the facility in question are postulated. Initial conditions are specific conditions that are a part of facility operations or parameters used in the analysis. Initial conditions may include assumptions, inventory information and specific passive features (i.e., no mechanical or human involvement) such as the facility construction.

Once the initial condions are known, a hazard evaluation process begins by investigating the *unmitigated* results and then *mitigated* (controls). The scope of the hazard evaluation in this scenario includes the following:

- Performed in an *unmitigated* manner to determine the risks (frequencies and/or consequences) involved with the facility and its associated operations without regard for any safety controls or programs. *Unmitigated refers to the determination of the frequency and consequences without credit given for preventive or mitigative features other than the specified initial conditions and assumptions regarding facility inventory*.

During the hazard evaluation process the material at risk reflects the available hazardous inventory that can be acted upon during the postulated event and no credit is taken for any controls; however, the laws of physics are applied.

This particular hazard evaluation and accident analysis identified several additional events that were similiar to the primary pool fire event, and thus are added to the evaluation and analysis. The identified hazardous events are then binned into like events using the minimum set of events using Table 2 below as a guide. The hazard evaluation with the highest risk ranking from each event bin is selected as the ***bounding*** event for the event bin and is assigned a unique alpha-numeric designator and as the HE event scenario. The other events were retained as representative events for the event bin. When the event required further analysis and possible control selection, the bounding hazardous event is evaluated first for further evaluation and control selection.

Now we select our controls to mitigate the event. The controls are then evaluated for completeness by evaluating their effectiveness to reduce the likelihood or consequences of any representative events in the bin that also had an unacceptable risk rank or a public high consequence level. If the controls are determined to be inadequate to reduce the risk of the representative events, additional controls are selected to reduce the risk rank of the events to an acceptable level.

The hazard analysis and hazard evaluation of events are collected and organized into a single hazard evaluation table that represents both the waste handling processes as well as other facility process areas. For these events the following are included:

- **Event number** is a unique identification number provided for tracking the event through analysis and also for easily identifying the event when in reference to a specific accident scenario under consideration.
- **Event description** includes a brief description of a postulated HE event
- **Initiating frequency level** is a qualitative or semi-quantitative process that involves assigning a frequency level to each event in the HE table

- **Unmitigated consequence level** are evaluated at the following receptor locations to assess health effects associated with the postulated event
- **Preventive features** are features expected to *reduce the frequency* of a hazardous event
- **Mitigative features** are any features expected to *reduce the consequences* of a hazardous event

Table 2
Minimum Waste Activity/Hazard Evaluation Event Matrix

Hazard Evaluation Event[1]	Character- Container ization Handling[2]		venting &/or Abating/ Purging	Staging and Storage	Retrieval and Repack-aging	Waste Excavation	Container Loading/ Unloading
Fire Events							
Fuel Pool Fire		X		X	X		X
Small Fire	X	X	X	X	X	X	X
Enclosure Fire	X		X			X	
Large Fire	X	X	X	X	X	X	X
Explosion Events							
Ignition of Fumes Results in an Deflagration/Detonation (external to containe		X			X	X	X
Waste Container Deflagration)	X	X	X	X	X		
Multiple Waste Container Deflagration	X	X	X	X	X		
Enclosure Deflagration	X		X			X	
Loss of Confinement/Containment							
Vehicle/Equipment Impacts Waste/Waste Containers		X	X	X	X	X	X
Drop/Impact/Spill Due to Improperly Handled Container,		X			X	X	X
Collapse of Stacked Containers		X	X	X			
Waste Container Over-Pressurization	X	X	X	X	X		
Direct Exposure to Radiation Events	X	X	X	X	X	X	X
Criticality Events	X	X	X	X	X	X	
Externally Initiated Events							
Aircraft Impact with Fire	X	X	X	X	X	X	X
External Vehicle Accident	X	X	X	X	X	X	X
External Vehicle Accident with Fire (Combustible or Pool)	X	X	X	X	X	X	X
External Explosion	X	X	X	X	X	X	X
External Fire	X	X	X	X	X	X	X
NPH Initiated Events							
Lightning	X	X	X	X	X	X	X
High Wind	X	X	X	X	X	X	X
Tornado	X	X	X	X	X	X	X
Snow/lce/Volcanic Ash Build-up (Event 23)	X	X	X	X	X	X	X
Seismic Event (Impact Only)	X	X	X	X	X	X	X
Seismic Event with Fire	X	X	X	X	X	X	X

The result of this effort is a table such as Table 3 below which descibes the event and associated events. In this case, we identified three possible accident scenarios that involve a fire in teh underground.

1. Fuel Pool Fire (Event 1)
2. External vehicle accident with fire (combustible or fuel pool) (Event 17)
3. If vehicle impact is the initiator of this event, controls from vehicle/equipment impacts with waste/waste containers (Event 9) must be added.

Minimum control functions are determined and listed. Three minimum control functions are identified: 1) limit the fire size, 2) separate the material at risk from the fuel, and 3) minimize releases. The preferred control to limit the fire size (item 1) is to ensure an automatic fire suppression systemsais in place OR limit the amount of fuel permitted in the vehicle. The material at risk can be separated fromthefuel bu grading and sloping berms in the underground or providing vehicle barriers (stop vehicles from close proximity to the material at risk). Item 3 minimizing releases can be addressed by ensuring an operational confinement ventilation system.

However, althernative controls are also identified and recommended. In this case, alternative fire protection controls, which are approved by a qualified fire protection engineer, are implemented to reduce the fire size such as limiting flammables and combustibles. Also, to separate the material at risk from the fire, rerouting vehicles, creating a stand off distance, and establishing refueling locations away from the material at risk. Spacing and fire breaks are used to minimize releases and also limiting of the fuel and material at risk.

The final area that needs addressed is to provide reference to relevant criteria and discussionsuch as; regulatory requirements, standards, national safety codes, and a discussion if necessary concerning systems for clarification.

General Example of Methodology concerning a Fire Event in the Underground

Accident	Minimum Control Functions	Preferred Controls	Alternative Controls	Relevant Criteria/Discussion
Fuel Pool Fire (Event 1) External Vehicle Accident with Fire (Combustible or Pool) (Event 17) If vehicle impact is the initiator of this event, controls from Vehicle/Equipment Impacts Waste/Waste Containers (Event 9) must be added	Limit fire size (P)	Automatic Fire Suppression System (FSS) OR Vehicle Fuel limit	Alternate fire protection controls approved by qualified fire protection engineer (e.g., flammables and combustibles limit)	DOE O 420.1B Note 1: FSS is not applicable to outside pool fires. Facilities with potential for indoor pool fires should consider both Preferred Controls. Note 2: These controls are expected to be supplemented by the overall Fire Protection Program suite of controls to prevent or mitigate accidents (e.g., flammable and combustible limits).
	Separate the MAR from fuel (P)	Grading and sloping; berms; vehicle barriers	Control vehicle route; stand off distance; establish refueling location;	
	Minimize releases (M)	Non-combustible containers AND	Spacing, fire breaks	
		Confinement Ventilation System (CVS)	MAR limit and/or vehicle fuel limit	CVS defined in DNFSB 2004-2 (Indoor activities only)

PROGETTO INTERNAZIONALE DI CONFRONTO ED ARMONIZZAZIONE DEI CRITERI PER DIMOSTRARE LA SICUREZZA DELLO SMALTIMENTO GEOLOGICO (GEOSAF)

R. Levizzari, F. Troiani, ENEA

Settembre 2011

Report Ricerca di Sistema Elettrico
Accordo di Programma Ministero dello Sviluppo Economico – ENEA
Area: Governo, Gestione e sviluppo del sistema elettrico nazionale
Progetto: Nuovo nucleare da fissione: collaborazioni internazionali e sviluppo competenze in materia nucleare

Responsabile Progetto: Paride Meloni, ENEA