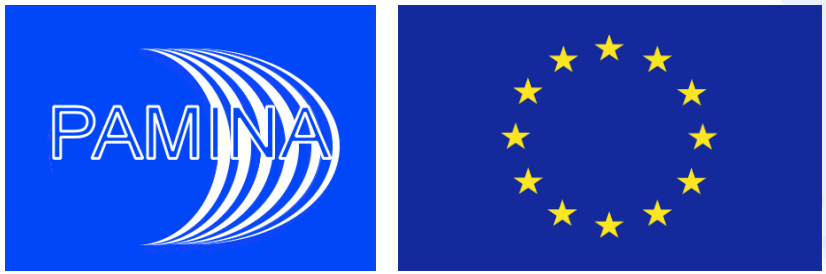
PAMINA



The Treatment of Uncertainty in PA and the Safety Case

EURADWASTE, Luxembourg, October 2008

Daniel GALSON

Galson Sciences Ltd

PAMINA RTDC2 Objectives

- **To allow development of a common understanding of different approaches to the treatment of uncertainty in performance assessment (PA)**
- **To provide guidance on – and examples of – good practice on how to treat different types of uncertainty in the context of development of a post-closure safety case**

Scale of Effort in RTDC2

- **~15 person years over period Oct 2006 – Sep 2009**
- **2.7 Million Euros**
- **10 countries, ~20 partners, + inputs from beyond EU**

PAMINA RTDC2 Work Programme

Three phases:

1. ***Oct 2006 – Mar 2007***
   - **Initial state-of-the-art review**
2. ***Apr 2007 – May 2009 (RTDC2 core work programme)***
   - **Methodological research for treating uncertainties (4 tasks)**
   - **Testing methods for treating uncertainties (5 tasks)**
3. ***June 2009 – Sep 2009***
   - **Comprehensive review and guidance document**

Most core work still ongoing

- **Regulatory compliance task - completed**

Some Key Features of a Safety Case

Multi-barrier

Multiple lines of reasoning

Safety functions

- Containment in waste canister
- Waste form, packaging
- Backfill barrier
- Geological barrier

Safety arguments

- Natural analogue studies
- **Numerical modelling**
- Demonstration experiments
- Complementary indicators

Intrinsic safety

Safety assurance

Regulatory dialogue

Safety Case

Communication

Initial Review of Treatment of Uncertainty

Review aims:

- **Establish a picture of current practice for management of uncertainties in PA and the safety case across programmes**
- **Promote discussion of 'best practice'**
- **Identify gaps in understanding and application of methods**
  - **Provide a spring board for rest of PAMINA RTDC2 programme**
  - **Facilitate workshop in Brussels March 2007**

Questionnaire-based approach

Completed 2007

PAMINA Partners Organisations

Waste Management Organisations (9)

Belgium

Czech Republic

Finland

France

Germany

Netherlands

Spain

Switzerland

United Kingdom

Regulators (2)

Belgium

France

Other Participating Organisations

Waste Management Organisations (5)

Canada

Japan

Sweden

United States

- **Waste Isolation Pilot Plant**
- **Yucca Mountain Project**

Status of Programmes

Review covers 16 programmes in 13 countries:

- **4 programmes at conceptual development/feasibility stage**
- **7 programmes at site selection/characterisation stage**
- **2 programmes at licensing stage**
- **1 programme at construction stage**
- **1 programme at operational stage**
- **1 programme at decommissioning/closure**

Different waste types considered (LLW, ILW, HLW, TRU, SF)

Regulatory Approaches to Treatment of Uncertainty

- **Treatment of uncertainty in PA impacts regulatory compliance**

  … and regulation can influence the PA approach

- **Regulation**
  - **Prescriptive vs non-prescriptive**
  - **Regulations under development / revision**
  - **Concept of the safety case and need for both *quantitative* and *qualitative* approaches**
- **Subsequent (2008) workshop on regulatory compliance**

Types of Uncertainty in PA

- **High level of consensus about types and nature of uncertainty in PA**
  - **… sometimes masked by differences in terminology**
- **Need for common language and definitions**
  - **… at least within a single project or programme**
- **System based on *classification* and *nature* of uncertainties in PA**

Classes of Uncertainty in PA

- ***Classes* of uncertainty are a convenient way to summarise how uncertainties have been treated in PA, and say nothing about their *nature***

THREE CLASSES IN PA:	"THE RISK TRIPLET"
Scenario uncertainty	What will happen?
Model uncertainty	How likely is it to happen?
Parameter uncertainty	What are the consequences?

There is variation in how particular uncertainties are classified

… reflects differing views on structuring of calculations, and how best to communicate what has been done

Fundamental *Nature* of Uncertainty

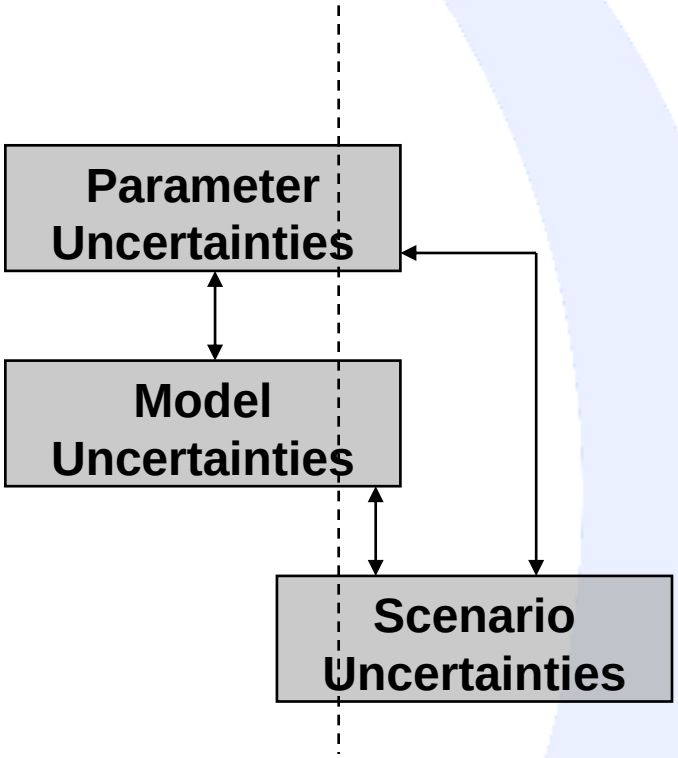
- **Epistemic uncertainty**
  - **Knowledge-based, reducible**
- **Aleatory uncertainty**
  - **Random, irreducible**
- **All three classes of uncertainty can contain elements that are epistemic and aleatory**

  Example: Parameter uncertainties arise because:
  - **Parameter values have not been determined exactly**
  - **Model runs use single (or spatially averaged) values derived from measurements at discrete locations (and times)**

Class and Nature of Uncertainties in PA: Summary

Epistemic Uncertainties
Knowledge-based, reducible

What are the consequences?



Aleatory Uncertainties
Random, irreducible

What will happen? How likely is it?

Treating Uncertainty in PA: Parameter Uncertainties

- **Several well-explored methods available**
  - **Setting Probability Density Functions (PDFs) which are sampled in probabilistic PA**
  - **Repeat deterministic calculations employing alternative sets of likely or possible parameter values**
  - **Use of deliberately pessimistic parameter values, usually to demonstrate compliance with regulations**
- **Approaches often used in tandem**
  - **The probabilistic / deterministic dialectic has moved on …**

Treating Uncertainty in PA: Model Uncertainties

- **Includes uncertainty in conceptual models, mathematical models, and computer models**
- **Uncertainties associated with alternative *conceptual models* – least well covered in PA**
  - **Use expert judgement to widen parameter PDFs (probabilistic)**
  - **Use alternative model conceptualisations (deterministic, probabilistic)**
  - **Not always explicitly treated**

Model complexity and geometry focus of PAMINA RTDC4

Treating Uncertainty in PA: Scenario Uncertainties

- **Two main approaches**
  - **A pure probabilistic approach in which scenario properties and/or timing are sampled from PDFs**
  - **Use of a limited number of deterministically defined scenarios – limited variations in scenario characteristics**
    - **Reference or normal evolution scenario**
    - **Altered evolution scenarios – more unlikely future conditions**
    - **"Stylised" scenarios where there are large aleatory uncertainties**
- **Increasing use of safety functions concepts to identify and define scenarios (in terms of function impairment or failure)**

Other Aspects of Treating Uncertainty

- **Use of sensitivity/uncertainty analyses to manage uncertainty in iterative assessment approach**
  - ➢ **NEXT PRESENTATION**
- **Qualitative arguments to manage uncertainties**
  - ➢ **QA, robust engineering, qualitative assessment methods**
- **Key uncertainties in PA**
- **Communication of uncertainties**

THE INITIAL REVIEW WAS NOT COMPREHENSIVE -

… spatial variability, upscaling, sensitivity analysis, formal expert judgement, "hybrid" approaches (fuzzy mathematics)

Review Summary

- **Wide range of progress toward implementation among participating countries**
  - **Not necessarily mirrored in state of advancement of PA tools**
- **Different regulatory approaches exist – regulations evolving**
- **High level of consensus on nature and classification of uncertainties**
- **Two main approaches to system PA – deterministic / probabilistic – often used together**
- **Conceptual model uncertainties least well treated in PA**
- **Great variety with respect to key uncertainties**
- **Few programmes have addressed issue of communicating**
- **Good support for choice for tasks in PAMINA programme!**

PAMINA WP2.1: Methodological Research for Treating Uncertainties

- **PAMINA has one year to run**
- **Detailed work for the treatment of uncertainty in the following areas:**
  - **Regulatory compliance (Task 2.1A) - COMPLETED**
  - **Communication of uncertainty (Task 2.1B) – Discussed Monday – One Deliverable available**
  - **Approaches to system PA (Task 2.1C) - EXAMPLE**
  - **Sensitivity analyses (Task 2.1D) – NEXT PRESENTATION**

PAMINA WP2.2: Testing Approaches for Treating Uncertainties

- **Parameter uncertainty (Task 2.2A)**
  - **Recommendations for derivation of PDFs, expert judgement**
- **Conceptual model uncertainty (Task 2.2B) – Two Deliverables – Gas pathway and U transport**
- **Scenario uncertainty (Task 2.2C)**
  - **Probability determination, expert judgement**
- **Spatial variability / upscaling (Task 2.2D) - reviews**
- **Total probabilistic modelling approach (Task 2.2E)**

PAMINA WP2.3: Synthesis and Integration

PAMINA RTDC2 Final Deliverable

- Guidance on approaches for treatment of uncertainty in PA and safety case development
- Illustrative examples – from initial review and RTDC2 work programme
- Communication of uncertainty
- Approaches to prioritisation and screening of uncertainties – uncertainty management

Conclusion

- **Only a few deliverables currently available**
  - **Workshop on communication of uncertainty (GSL/NDA)**
  - **Workshop on regulatory compliance (GSL/SSM)**
  - **Model uncertainty – gas calculations (NDA)**
  - **Model uncertainty – K_d vs reactive transport calculations (VTT)**
- **We are in an intensive phase of the core work programme – initial review sets framework**
- **Many more tasks will be completed from early 2009 onwards (final guidance document in September)**
- **http://www.ip-pamina.eu**

Where Next? …a personal view

- **Increasing databank of site-specific SAFETY CASES**
  - **We know how to do PA calculations – good methods exist … 20 years since initial generic EC studies (PAGIS)**
  - **We know about the sources of uncertainty – and their management in PA**
  - **We know that expert judgement runs through all steps**
- **What is driving refinements?**
  - **How best to communicate about safety?**
  - **How best to manage the work (System Integration)?**
    - **Use of PA as a tool for optimisation as move closer to implementation**
    - **Use of PA as a tool to manage site and R&D investigations**
    - **Integration into the Safety Case**

Task 2.1.A Regulatory Compliance

- **The safety case for a disposal concept, design or facility will include several components to support a conclusion on safety, including…**
  - **Performance assessment – dose and risk calculations**
  - **Alternative lines of reasoning that build confidence in safety**
- **The safety case must include arguments for safety over different timescales and hence with different levels of uncertainty**
- **The regulator must make judgements on the strength of the arguments and assess whether uncertainties are adequately managed**

Task 2.1.A Regulatory Compliance

- **Facilitated workshop to explore regulatory role in the treatment of uncertainties**
- **Stockholm, 10-11 June 2008**
- **14 participants representing**
  - **Sweden**
  - **UK**
  - **Belgium**
  - **Japan**
  - **France**
  - **Finland**
  - **Switzerland**
  - **NEA**

  most outside PAMINA

Role of Regulator

- **Most regulators want to match the level of scientific understanding and knowledge of the developer**
  - **Allows meaningful reviews of research, development and demonstration (RD&D) programmes, safety cases and licence applications**
- **Most regulators have taken steps to have modelling capabilities independent of developers**
  - **Allows verification of results from developer's assessment, and investigation of alternative conceptual or physical models**

Safety Case

- **Less emphasis than before on traditional comparison between safety assessment calculation results and regulatory dose/risk criteria**
  - **Optimisation and safety functions are increasingly used as alternative safety indicators or additional arguments**
  - **Additional arguments support demonstration of compliance with dose/risk criteria and build confidence in long-term safety**
- **Requires additional expertise from regulator**

Dialogue

- **Close dialogue between a regulator and a developer is beneficial to the development of a safety case and a licence application**
  - **Dialogue must be controlled and documented and not lead to a compromise of a regulator's freedom to make decisions**
- **International harmonisation of dose and risk constraints would be ideal for public communication - unlikely in practice**

Task 2.1.C Approaches to System PA

- **Participants: CEA, Facilia, GSL, NRI and VTT**
- **Research into different approaches to the quantification of uncertainty in system-wide PA calculations – four topics**
  1. **The treatment of uncertainty using probability (GSL, Facilia, VTT)**
  2. **Level of conservatism and realism in PA (GSL, Facilia)**
  3. **Hybrid stochastic-subjective approaches to treating uncertainty (NRI)**
  4. **Alternative approaches to presenting the results of probabilistic assessments (CEA)**

Conservatism and Safety Functions

- **Study aims to determine**
  - **Whether use of a safety functions approach to organise a PA can provide a demonstrably conservative approach; and**
  - **(Conversely) whether the use of safety functions can introduce additional, potentially unrecognised, conservatisms to a PA**
- **Questionnaire & telephone interviews**

Belgium

Sweden (developer)

US (Yucca Mountain Project)

two outside PAMINA

Switzerland

Sweden (regulator)

UK

Conservatism

- **Using safety functions does not inherently bias the safety case towards conservatism or realism**
- **Mechanisms identified that have the potential to introduce *unintended conservatism***
  - **Requiring several limits on safety function performance to be satisfied independently**
    - **e.g., where safety function is provided by several barriers**
  - **Applying inappropriate limits to sub-system performance**
    - **Generic regulatory requirements**
    - **Indicators not related to overall performance measures**
  - **Concentrating on failure of safety functions rather than degradation – unintended optimism**
    - **can miss more likely scenarios related to gradual degradation**

Safety Functions & Optimisation

- **A safety functions approach is a valuable tool that can be used in various ways to support the analysis of the repository design/concept, and development of the safety case**
- **However, using safety functions quantitatively is limited by the need to identify *meaningful* limits or criteria on safety function performance**

Avoiding Unintended Conservatism

- **Unintended conservatisms in a safety functions approach can be avoided by:**
  - **Accounting for any inter-dependence of safety functions and safety function indicators**
  - **Relating performance limits for individual safety functions to overall system performance limits**
  - **Avoiding regulatory limits on individual safety functions indicators**
  - **Making use of additional methods for scenario development to achieve comprehensiveness (avoiding optimistic bias)**