Frédéric Coulon
Simon J.T. Pollard

Sustainable Systems Department
School of Applied Sciences

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The Implications of Uncertainty in Contaminated Land Risk Assessment

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Risk Assessment concepts applied for decades:

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- Health Assessment
- Environmental Assessment

- Systematic risk-based strategy
- Comprehensive & integrative framework

Contaminated Land Risk Assessment - 5 components

Step 1	Step 2	Step 3	Step 4	Step 5
Problem formulation	Hazard identification	Exposure Assessment	Risk Estimation	Risk characterisation

Environment Agency Tiered Approach
(Generic)

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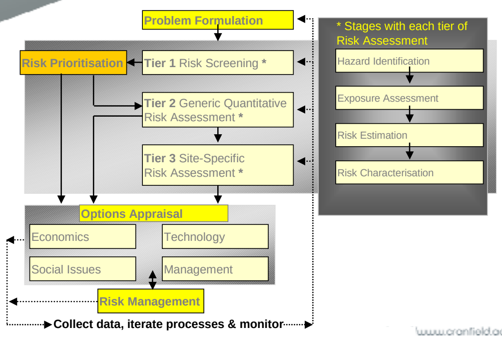

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Risk-Based approaches are necessary because:

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- It's a huge potential problem - very many activities have the potential to affect soil and groundwater and many places are already polluted;
- We do not have the resources (money or people) to deal with everything at once;
- There is <u>huge technical and scientific uncertainty</u> about the sub-surface environment;
- In addressing the need for, and scale of, action to be taken the text in UK legislation refers to:
  - "the significant possibility of significant harm";
  - "take account of sustainability and cost benefit".

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Benefits of Risk Assessment Approach

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- Allows more projects to proceed to redevelopment
  - Reduced cost
  - Clarified residual risk/liability
- Another tool to manage overall project risk - balance cost versus benefit among options
  - Further site assessment
  - Remediation to more stringent standards
  - Risk management measures and restrictions on property use
- Public is assured of a consistent level of protection

HOWEVER

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Measuring risk is scientific.
Judging the acceptability of risk is a value judgment

Risk assessment is always clouded in uncertainty

Jayjock, et al

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Risk assessment is not an objective scientific process; facts and values frequently merge when we deal with issues of high uncertainty; cultural factors affect the way people assess risk.

Sheila Jasanoff

Uncertainty

- Knowable
  - Reducible
  - Irreducible
- Unknowable

Affects our **confidence** in the assessment

Types of uncertainty

Scientific
- Insufficient data
- Variability
- Extrapolations across time, space, environmental compartments
- Modelling
- Analytical
- Hierarchy of scale
- Causal

Institutional and policy
- Design-critical uncertainty
- Organisational infrastructure
- Regulatory obligations
- Changes to default policies
- Timeframe for decision relative to speed of ecosystem response

Types of uncertainty in environmental fate, exposure and effect modeling

Parameter uncertainty
Variability and uncertainty of each model input parameter

Model uncertainty
Uncertainty of the model itself

Scenario uncertainty
Uncertainty in the application / use of models

Overall uncertainty
of the model result

Overwhelming uncertainty results in paralysis of any remediation/restoration effort

Classifying Uncertainty

Table 1. A simple typology of uncertainties

Type	Indicative examples of sources	Typical approaches or considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

Guidance notes for lead authors of the IPCC Fourth Assessment report on addressing uncertainties (July 2005)

Hierarchy of Uncertainty Analysis

Tier 0: Default assumptions – single value of result

Tier 1: Qualitative but systematic identification and characterisation of uncertainty

Tier 2: Quantitative evaluation of uncertainty making use of bounding values, interval analysis and sensitivity analysis

Tier 3: Probabilistic assessment with single or multiple outcome distributions reflecting uncertainty and variability

IPCS 2006

International Programme on Chemical Safety. 2006. Draft Guidance Document on Characterizing and Communicating Uncertainty of Exposure Assessment. World Health Organization

Other Uncertainty approaches

- Define relative importance of causal pathways
  - Sensitivity analysis
  - Scenario-consequence analysis
  - Most important decision-making uncertainties tied to most important pathways
  - Use of models to define range of condition or relative importance of conditions

Sensitivity vs Uncertainty

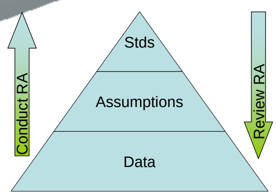
Sensitivity analysis: identification of input parameters with significant influence on the final model result

Uncertainty analysis: identification of major sources of uncertainty of the model result and quantification of its overall uncertainty

Combining both: identification and eventually reduction of dominating uncertainties

Uncertainty	Sensitivity	Importance of parameters for overall uncertainty
high	low	Low to negligible
low	high	Medium to high
low	low	negligible
high	high	high

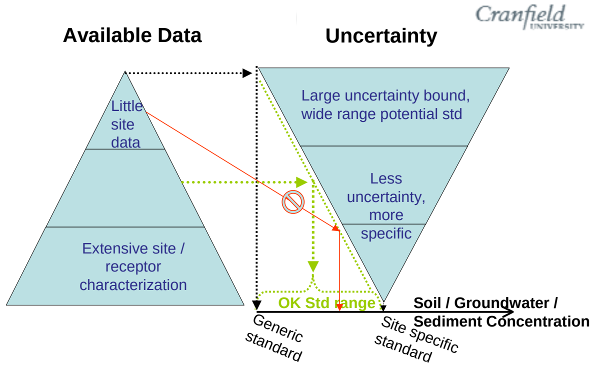
Understanding the risk assessment review process

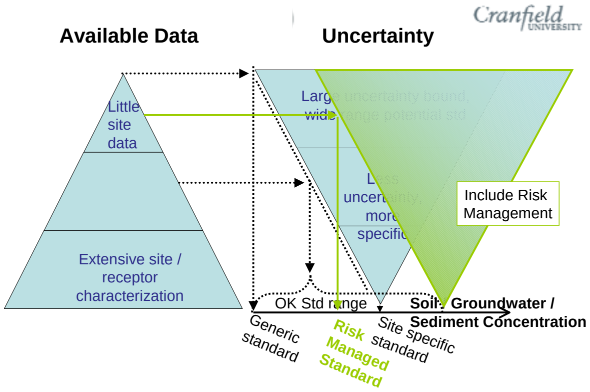


- What standards are proposed?
- What assumptions / concepts do the standards rely on to be acceptable?
- Is there sufficient data or conservatism to support assumptions (and therefore to support the standards)?

Understanding the risk assessment review process

- A standard is accepted if the site data and toxicology support it;
  - Lack of site data creates uncertainty
  - Conservative model assumptions can compensate for uncertainty, but result in low concentrations as standards (more stringent to meet)
- A standard may be developed through repeated collection of data and refinement of the exposure models according to the needs of the project.





Recommendations

- *… encourage risk assessments to characterize and communicate uncertainty and variability in all key computational steps of risk assessment" (p. 7)*
- *"uncertainty and variability analysis should be planned and managed to reflect the needs for comparative evaluation of the risk management options." (p. 7)*

National Research Council (2008) Science and Decisions: Advancing Risk Assessment. http://www.nap.edu/catalog/12209.html

Take Home Points

- We need to be more quantitative and systematic in our approach to exposure assessments
- We need to acknowledge and manage uncertainty in our assessments
- We can do both of the above and improve the efficient use of limited resources by adopting an iterative approach to our decision making

The UK approach is:

- A tiered/staged approach to risk assessment based on "fit for current use";
- Focus on critical issues; conceptual models are key;
- Encourages the appropriate use of quantitative risk assessment; no generic clean-up standards.
- Requires justification of approach & content; assessments should be transparent and accessible to other audiences

Some questions:

- How sensitive are COCs risk assessments to bioavailability, given other uncertainties?
- How meaningful are *in vitro* bioavailability methods? Can they replicate *in vivo* behaviour?
- How are bioavailability predictions affected by mixtures and authentic conditions?
- What is the long-term fate and behaviour of COC residuals in soils?
- Does a critical load concept apply?

Future needs

- Develop guidance to determine the appropriate level of detail needed in uncertainty and variability analyses to support decision-making and should provide clear definitions and methods for identifying and addressing different sources of uncertainty and variability

National Research Council (2008) Science and Decisions: Advancing Risk Assessment. http://www.nap.edu/catalog/12209.html

Multiple line of evidence

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- Risk-based effort uses multiple-lines-of-evidence:
  e.g., One line has uncertainty; other lines evidence

Significantly reduce overall interpretation of uncertainty
Directionality (e.g., consistent; converging; diverging)

- This component of risk assessment enhances confidence

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Synthesis of key message

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Systematic risk-based strategy for uncertainty helps:

- identify relative importance of uncertainties to decision-making process
- assess whether sources can be reduced, controlled, or mitigated, or have to be accepted
- assess whether the reduction of some uncertainties significantly improve the assessment/remediation process
- accommodates uncertainties that contribute to Type II errors in decision making

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