

Groundwater Chemotoxic Screening for Radioactive Waste Disposal

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Workshop on Safe Storage and Disposal of Redundant Mercury

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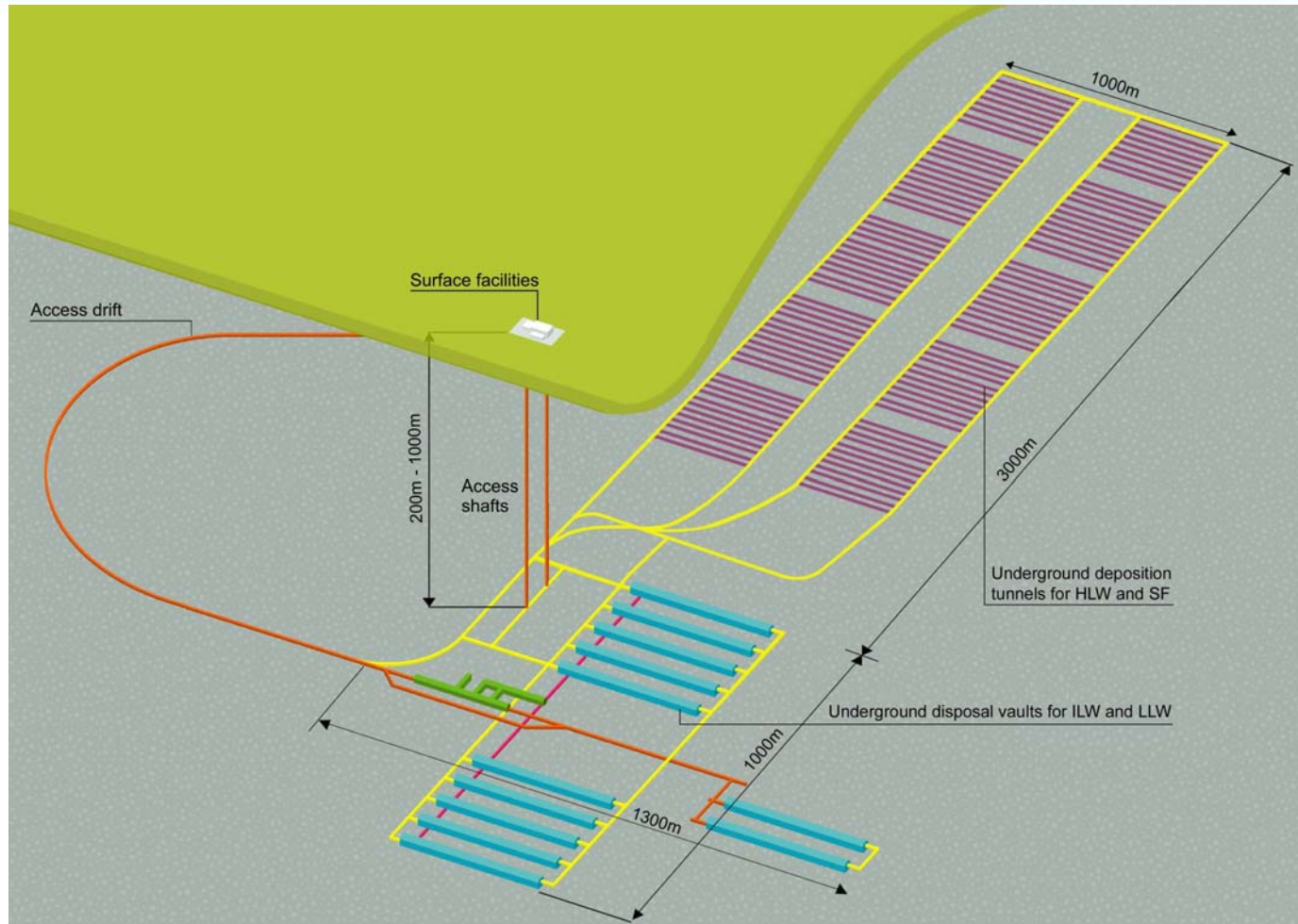
13-14 October 2009



Introduction

- Long-term management of higher activity radioactive waste in the UK
- Government policy is geological disposal preceded by safe, secure storage, supported by R&D (2008 MRWS White Paper)
- NDA to plan and implement
- Site selection led by Government based on voluntarism and partnership approach
- Generic research and assessment at present
- Detailed assessment methodologies for impact of radionuclides
- Requirement to consider chemotoxic materials
- Approach developed in the context of ILW in UK
- Groundwater pathway

Geological disposal



Simulant 500 litre ILW packages



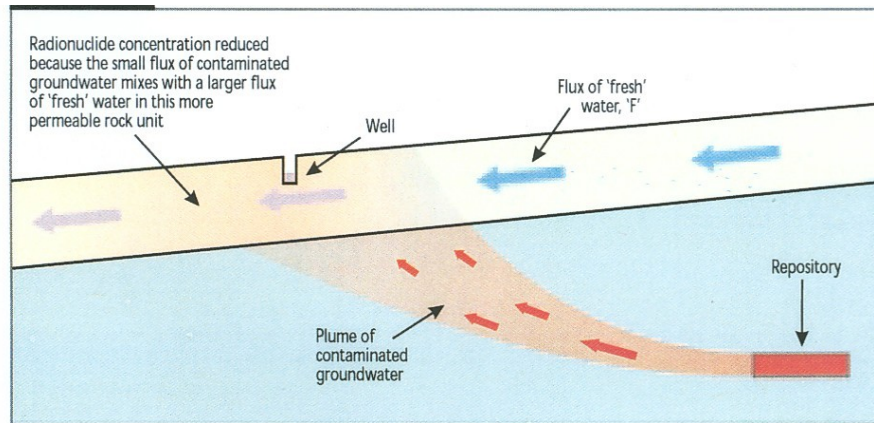
Typical chemotoxics in packaged ILW

Material	Inventory/t	Material	Inventory/t
Be	136	U	2020
Cr	24,900	F	105
As	44	NO ₃ ⁻	1560
Cd	35	Benzene*	2.9
Hg	23	Phenol*	3.4
Pb	1000	* = model degradation products	

Screening assessment of chemotoxic materials

- Assessment at a level commensurate with potential detriment
- Initial assessment of substances using simpler quantitative models than applied to radionuclides
- Fewer initial chemical parameter requirements
- Stepwise screening based on quantitative analysis to identify species for more detailed consideration
- Impact compared with limiting values (assessment criteria)

Simple model of groundwater pathway



- Q - the flux of groundwater (m^3yr^{-1}) from the host rock through the engineered barrier system of the repository
- T - the groundwater travel time (years) for a 'particle' of groundwater to travel from the repository to the surface
- F - the groundwater mixing flux (m^3yr^{-1}) - the flux of groundwater in the near-surface rock unit into which the plume of contaminated groundwater, originating from the repository, passes as it moves to the surface

Screening steps

- Step 1- simple plume dilution and dispersion
 - No chemistry considered
 - Compare concentrations in near-surface groundwater with drinking water limit
- Step 2 – add source-term chemistry
 - Source-term concentrations estimated on basis of equilibrium sorption & solubility arguments
- Step 3 – consider persistence of organics
 - Represent by using, for example, reactivity half-life in the environment

Example application of screening process

Spreadsheet application of screening methodology

- $Q = 300 \text{ m}^3\text{y}^{-1}$
- $T = 100,000 \text{ y}$
- $F = 300,000 \text{ m}^3\text{y}^{-1}$
- Half life for persistence of organic compounds = 10,000 y
- Screening Criteria
 - $<0.1 \text{ DWL}$ (green)
 - $<0.1 - 1\text{DWL}$ (yellow/orange)

Example results

Table 16 Results of Base Case Screening Calculation with Central Groundwater Flow
Parameters ($Q = 300 \text{ m}^3 \text{ y}^{-1}$, $T = 100,000 \text{ y}$, $F = 300,000 \text{ m}^3 \text{ y}^{-1}$)

Material	Drinking water limit (mg dm ⁻³)	Near-surface conc. (no chem) (mg dm ⁻³) (Step 1)	Best-estimate repository conc. (mg dm ⁻³) (Step 2)	Near-surface conc. (chem) (mg dm ⁻³)	Near-surface conc. (persistence) (mg dm ⁻³) (Step 3)
Arsenic	1 10 ⁻²	9.91 10 ⁻⁴			
Antimony	5 10 ⁻³	1.63 10 ⁻³	8.24 10 ²	1.63 10 ⁻³	
Vanadium	3 10 ⁻²	1.72 10 ⁻³			
Beryllium	1 10 ⁻⁴	3.03 10 ⁻³	5.65 10 ²	3.03 10 ⁻³	
Magnesium	5 10 ¹	2.86 10 ⁻¹			
Aluminium	2 10 ¹	2.24 10 ⁻²	1.31 10 ⁴	2.24 10 ⁻²	
Chromium	5 10 ⁻²	5.57 10 ⁻¹	3.60 10 ⁴	5.57 10 ⁻¹	
Manganese	5 10 ⁻²	5.40 10 ⁻²	3.74 10 ²	5.35 10 ⁻²	
Iron	2 10 ¹	3.34 10 ⁰	2.47 10 ⁴	3.31 10 ⁰	
Nickel	2 10 ⁻²	3.41 10 ⁻¹	3.39 10 ⁰	3.53 10 ⁻³	
Copper	2 10 ⁰	8.66 10 ⁻³			
Zinc	5 10 ⁰	1.05 10 ⁻³			
Zirconium	2.1 10 ⁰	3.23 10 ⁻²			
Molybdenum	5 10 ⁻³	2.74 10 ⁻²	9.11 10 ⁻¹	9.47 10 ⁻⁴	
Tin	2 10 ⁰	3.36 10 ⁻⁴			
Cadmium	5 10 ⁻³	7.88 10 ⁻⁴	4.97 10 ¹	7.88 10 ⁻⁴	
Mercury	1 10 ⁻³	5.13 10 ⁻⁴	7.16 10 ⁻²	7.36 10 ⁻²	
Lead	1 10 ⁻²	2.35 10 ⁻²	1.38 10 ⁴	2.35 10 ⁻²	
Fluoride	1.5 10 ⁰	2.35 10 ⁻³			
Nitrate	5 10 ¹	3.49 10 ⁻²			
Phosphate	6 10 ⁻¹	2.62 10 ⁻³			
Sulphate	2.5 10 ²	6.84 10 ⁻²			
Selenium	1 10 ⁻²	5.57 10 ⁻⁵			
Boron	1 10 ⁰	3.02 10 ⁻⁴			
Nitrite	5 10 ⁻³	2.44 10 ⁻⁴			
Caesium	5 10 ⁻³	6.86 10 ⁻⁶			
Uranium	3 10 ⁻¹	4.52 10 ⁻²	7.27 10 ²	4.51 10 ⁻²	
Cobalt	1.5 10 ⁻¹	3.18 10 ⁻³			
Yttrium	8 10 ⁻³	1.86 10 ⁻¹⁰			
Ruthenium	1.15 10 ⁵	1.35 10 ⁻⁵			
Acetic acid	1.75 10 ⁴	6.57 10 ⁻⁴			
ISA	4.75 10 ⁴	3.28 10 ⁻²			
Benzene	1 10 ⁻³	6.48 10 ⁻⁵			
Phenol	5 10 ⁻⁴	7.69 10 ⁻⁵	4.52 10 ¹	7.69 10 ⁻⁵	7.51 10 ^{-5*}
VCM	5 10 ⁻⁴	3.21 10 ⁻⁵			
Cyanide	5 10 ⁻²	8.33 10 ⁻⁷			
TBP/OK	2.97 10 ⁴	1.73 10 ⁻⁴			

* = assuming 10,000 year half-life for degradation

VCM = vinyl chloride monomer, ISA = Isosaccharinic acid, TBP/OK = tributylphosphate /odourless kerosene

Green = below screening level ($<0.1 \times$ drinking water limit)

Yellow = above screening level but less than drinking water limit

No background colour = above drinking water limit

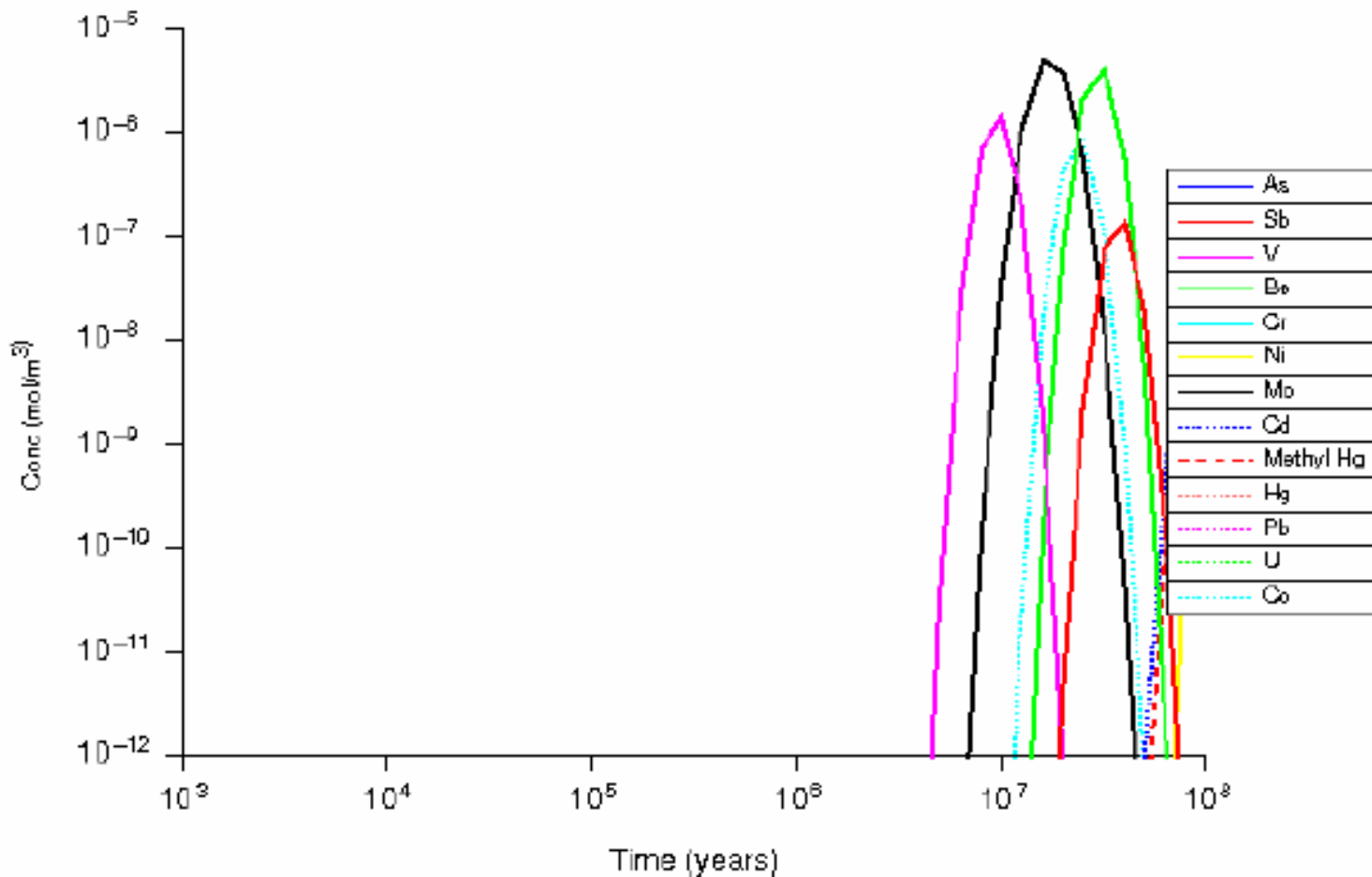
Selected results

Material	DWL/ppm	Step 1 Near surface conc/ppm	Step 2 Near surface conc/ppm	Step 3 Near surface conc/ppm
Be	0.0001	0.003	0.003	-
Cr	0.05	0.6	0.6	-
As	0.01	0.001	-	-
Cd	0.005	0.0008	0.0008	-
Hg	0.001	0.0005	0.00007	-
Phenol	0.0005	0.00008	0.00008	0.00000008

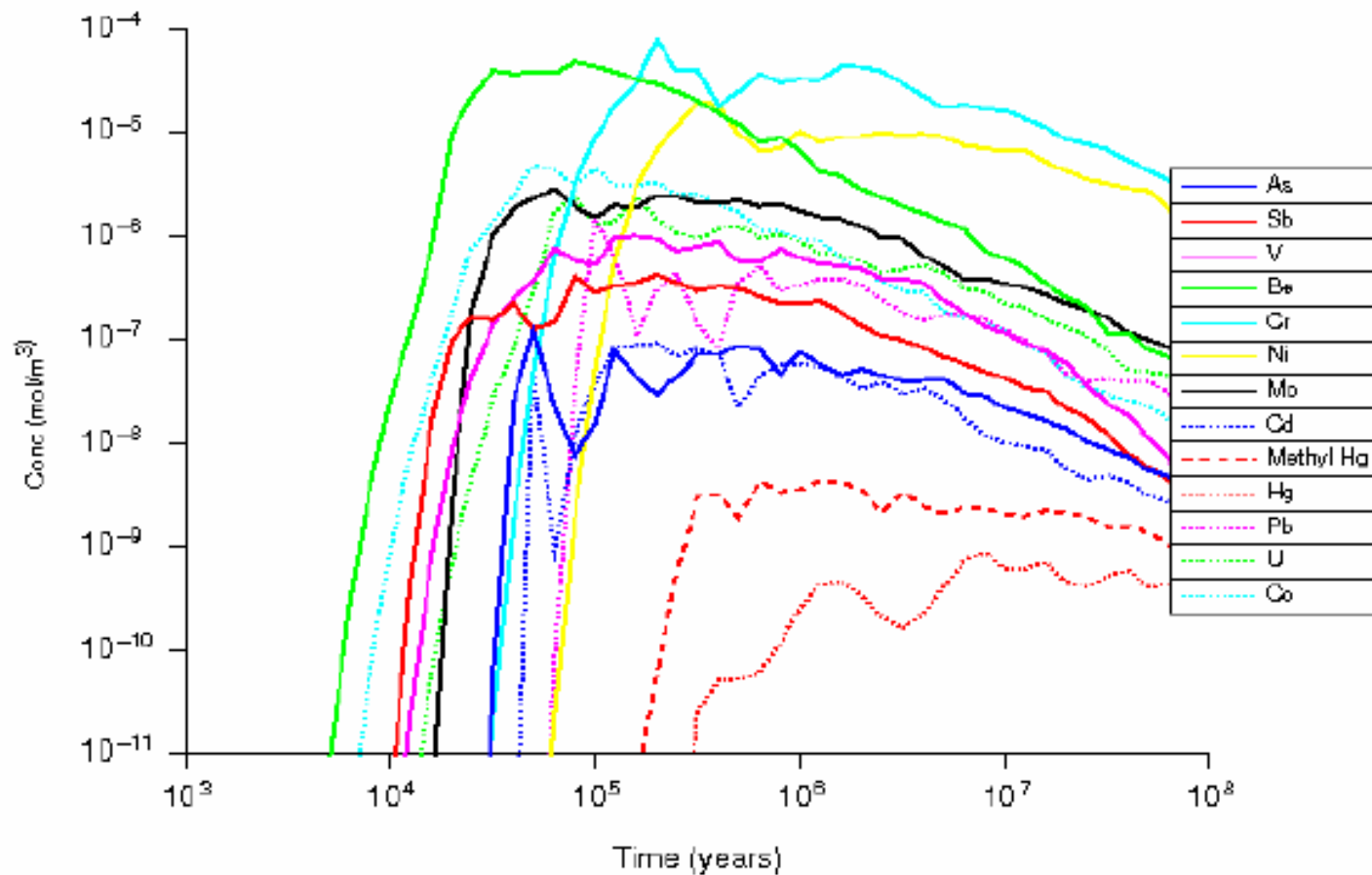
Detailed modelling of groundwater pathway

- Example using MASCOT program for performance assessment
- Requires parameters for migration through the host geology
- Deterministic and probabilistic treatment

Deterministic calculation results



Probabilistic calculation results



Selected results

Material	DWL/ppm	Deterministic peak conc/ppm	Probabilistic peak conc/ppm
Be	0.0001	0.000004	0.0004
Cr	0.05	-	0.004
As	0.01	3E-17	0.0000009
Cd	0.005	0.0000003	0.000001
Hg	0.001	-	0.00000002
Pb	0.01	-	0.0003

Summary

- Simple screening model reduces input data requirements and identifies species requiring more detailed consideration
- More detailed groundwater modelling with greater data requirements focused on fewer species
- From the example presented beryllium was identified as needing further detailed consideration
- For further information see 'Development of a Groundwater Toxicity Assessment for Key Stable Elements in the Nirex PGRC' SA/ENV-0943,
(can be requested from NDA-RWMD bibliography on NDA website)