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The challenges of nuclear waste management from a life cycle perspective

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The challenges of Nuclear Waste Management from a Life Cycle perspective

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Presentation outline

- Introduction
  - Nuclear industry in the UK
- Project objectives
- Radiological Impact Assessment framework
  - Critical Group methodology
  - Compartment-type methodology
  - Qualitative comparison
- LCA scenario
- Conclusions and future work

Nuclear Industry in the UK

Share of electricity generation:

- ❑ 20% at 2013 → 40-50% by 2050

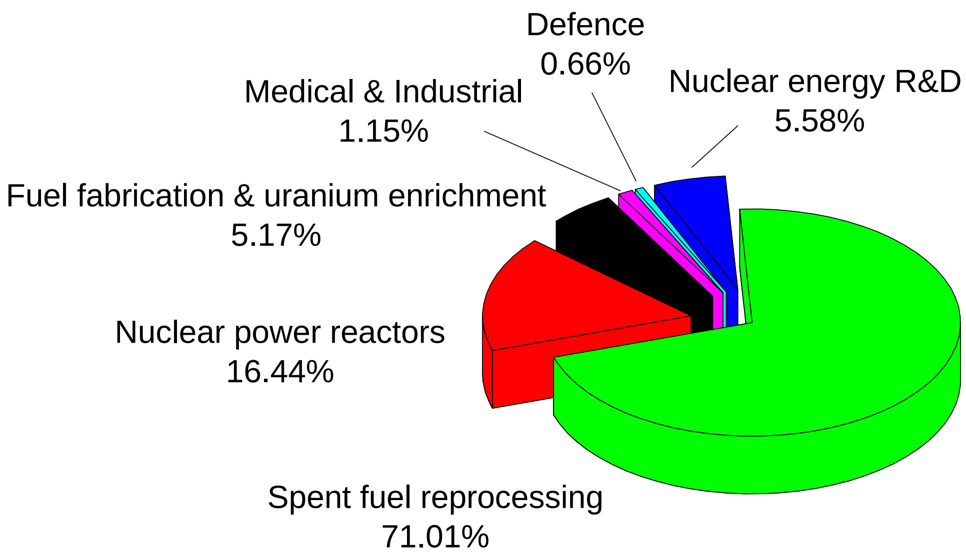
Some numbers:

- ❑ 8 Operating Power Plants (9.5 TWe)
- ❑ 5 Planned Power Plants (15.6 TWe)
- ❑ 11 Power Plants Under Decommissioning
- ❑ 2 Operating Reprocessing Plants (***due to be closed by 2018/20***)

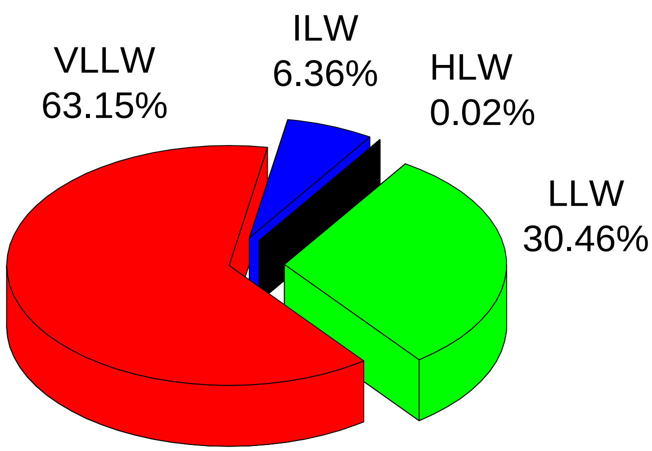
UK nuclear power generation reactors' map

Nuclear Waste in the UK

Waste proportion by activity



Waste proportion by type



Key questions:

- *How to deal with Spent Nuclear Fuel: Direct Disposal or Reprocessing?*
- *What to do with the end-process Solid Nuclear Waste? How to dispose of it?*

Life Cycle Assessment

The issue….

Standard impact categories	Unit Equivalent
Abiotic Depletion	Kg Sb / MJ
Acidification Potential	Kg SO_2
Eutrophication Potential	Kg PO_4
Freshwater Aquatic Toxicity	Kg DCB
Global Warming Potential	Kg CO_2
Human Toxicity Potential	Kg DCB
Ozone Layer Depletion Potential	Kg R11 eq
Photochemical Ozone Creation Potential	Kg Ethene
Terrestric Ecotoxicity Potential	Kg DCB

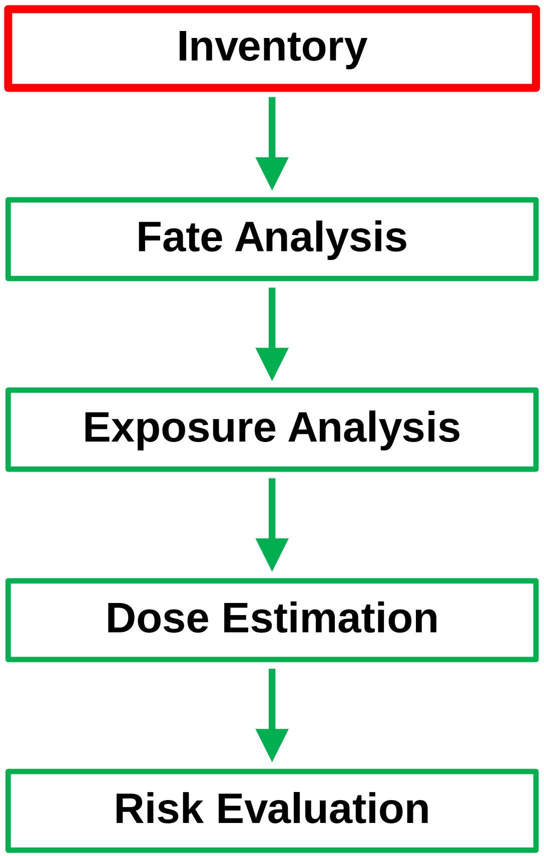
Where are radionuclides included?

Nowhere!

Project objectives

- Develop a high-level Life Cycle Assessment approach for assessing the **environmental impact performance** of radioactive releases and nuclear waste.
- Develop a **Life Cycle Assessment scenario** to demonstrate the approach.
- Analyse **alternative strategic options** for nuclear waste management.

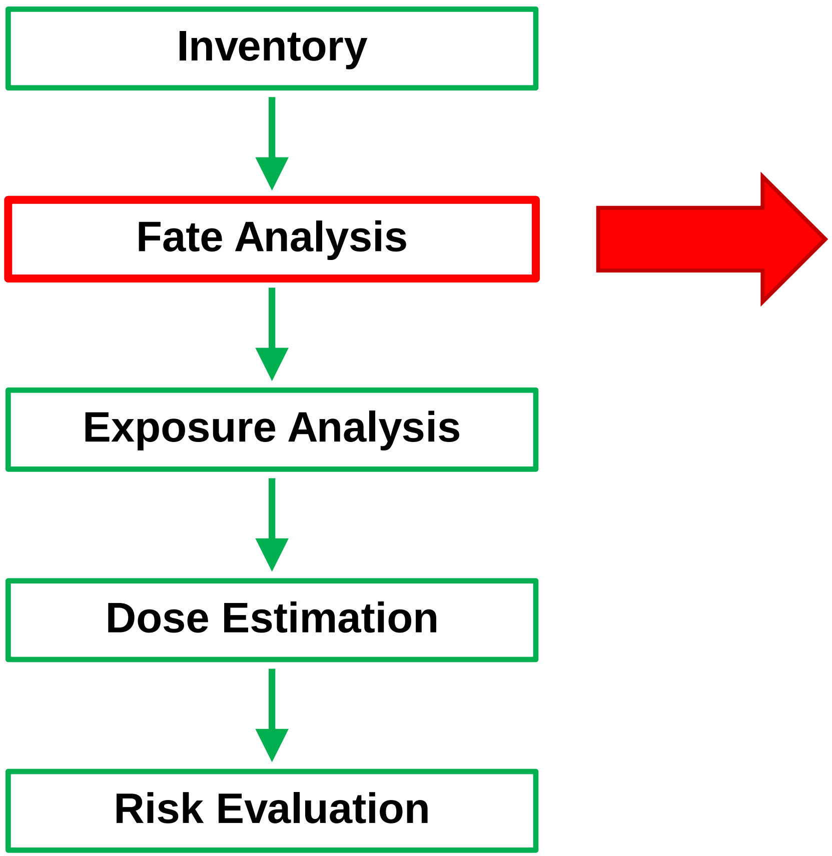
General framework



Radionuclide	Source	Emission	Unit	Amount
Am241	Central off Gas - THORP	Air	Bq/y	[redacted]
Am241	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
C14	Central off Gas - THORP	Air	Bq/y	[redacted]
C14	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Ce144	Central off Gas - THORP	Air	Bq/y	[redacted]
Ce144	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Cm244	Central off Gas - THORP	Air	Bq/y	[redacted]
Co60	Central off Gas - THORP	Air	Bq/y	[redacted]
Co60	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Cs134	Central off Gas - THORP	Air	Bq/y	[redacted]
Cs134	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Cs137	Central off Gas - THORP	Air	Bq/y	[redacted]
Cs37	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
H3	Central off Gas - THORP	Air	Bq/y	[redacted]
H3	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
I129	Central off Gas - THORP	Air	Bq/y	[redacted]
I129	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Kr85	Central off Gas - THORP	Air	Bq/y	[redacted]
Mn54	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Np237	Central off Gas - THORP	Air	Bq/y	[redacted]
Pm147	Central off Gas - THORP	Air	Bq/y	[redacted]
Pu241	Central off Gas - THORP	Air	Bq/y	[redacted]
Ru106	Central off Gas - THORP	Air	Bq/y	[redacted]
Ru106	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Sr90	Central off Gas - THORP	Air	Bq/y	[redacted]
Sr90	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Tc99	Central off Gas - THORP	Air	Bq/y	[redacted]
Tc99	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]
Zr95	Low Active Effluent - THORP	Sea water	Bq/y	[redacted]

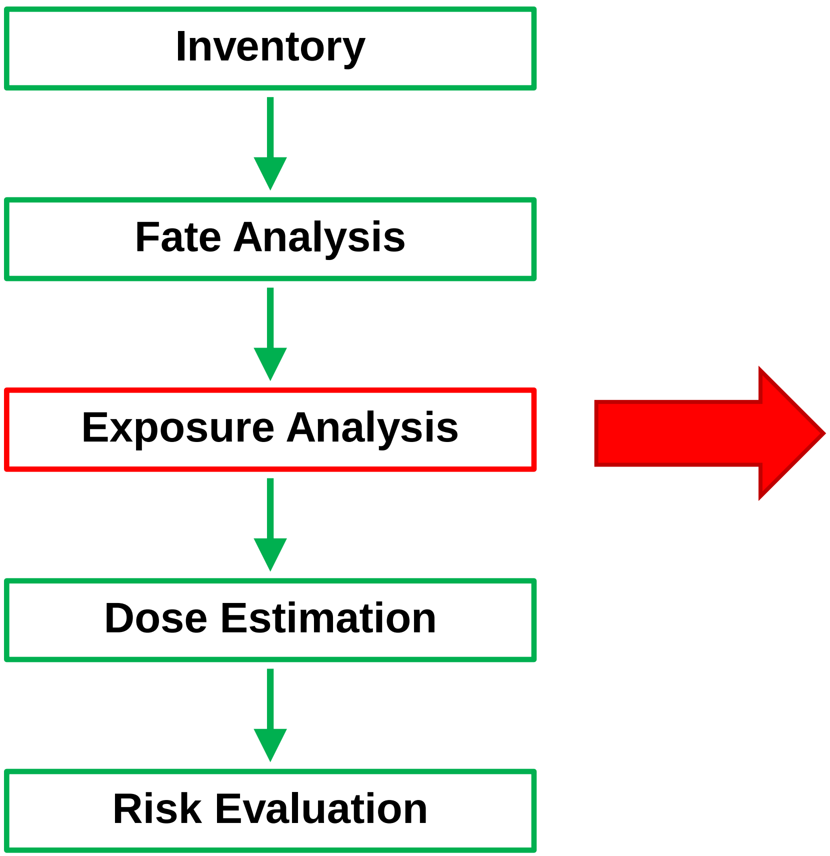
UCL

General framework



- ➢ Environmental concentration
  - *E.g. Air, freshwater, Sea water, Soil*
- ➢ Models
  1. Numerical
  2. Analytical
  3. Compartment-type

General framework



- Human exposure to radionuclides and ionising radiation
- Pathways
  - *Inhalation*
  - *Ingestion*
  - *Plume immersion*
  - *Ground deposition*

General framework

Inventory

↓

Fate Analysis

↓

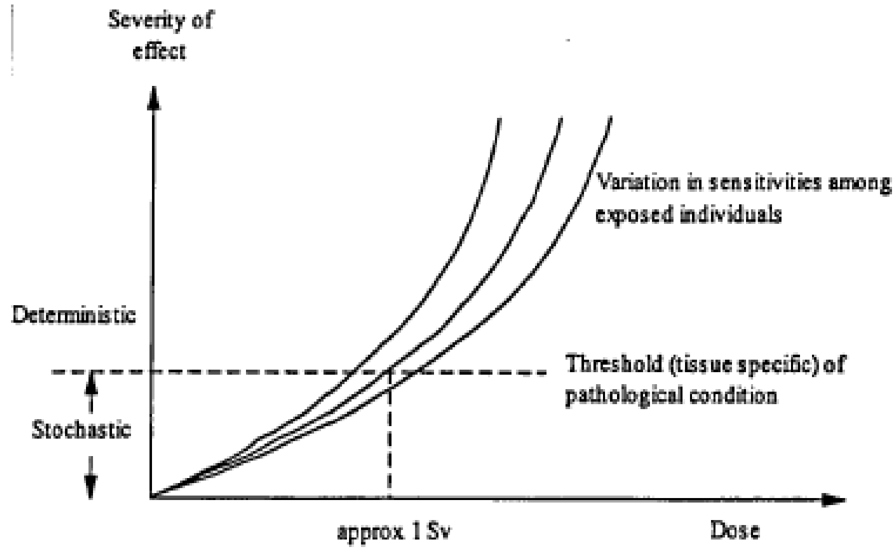
Exposure Analysis

↓

Dose Estimation

↓

Risk Evaluation



- Effective dose
- Stochastic effects

General framework

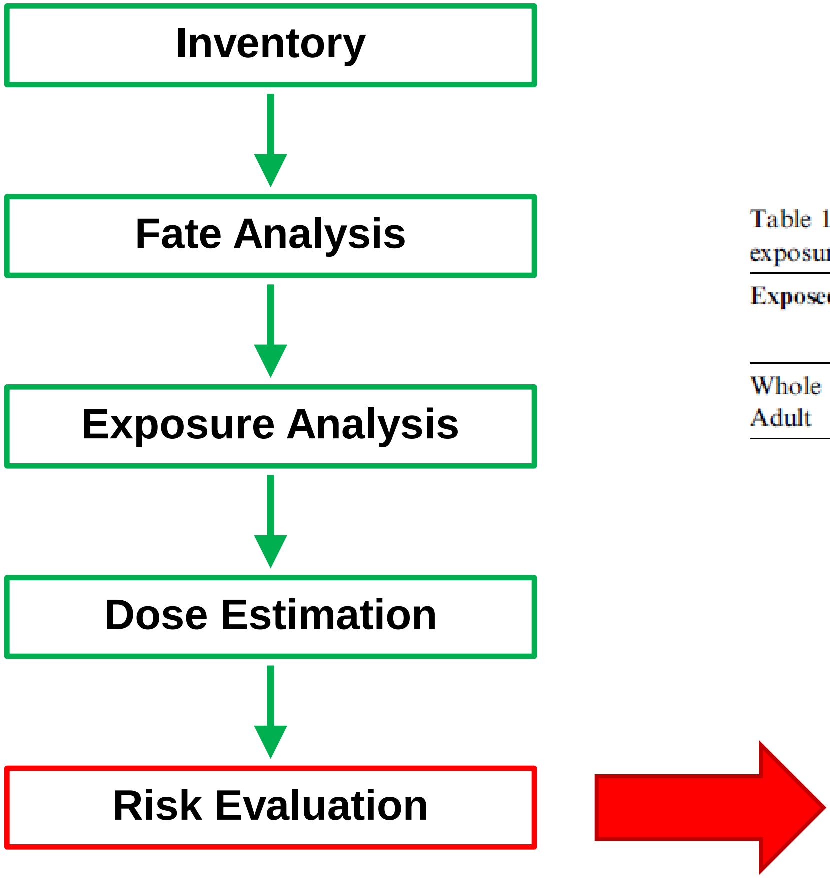
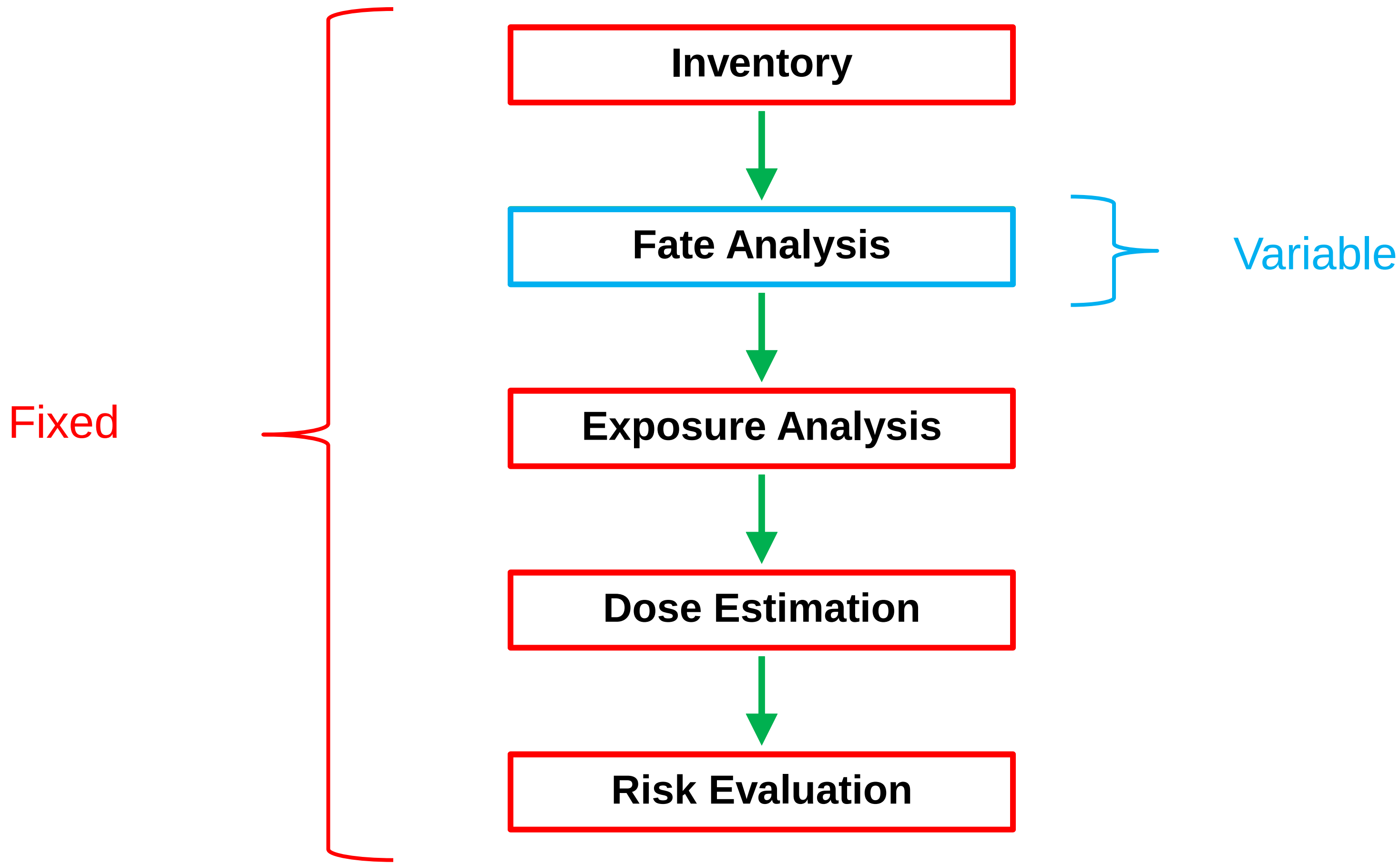


Table 1. Detriment-adjusted nominal risk coefficients (10^{-2} Sv^{-1}) for stochastic effects after exposure to radiation at low dose rate.

Exposed population	Cancer		Heritable effects		Total	
	Present[1]	*Publ. 60*	Present[1]	*Publ. 60*	Present[1]	*Publ. 60*
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

- Risk of detrimental effect (i.e. cancer)

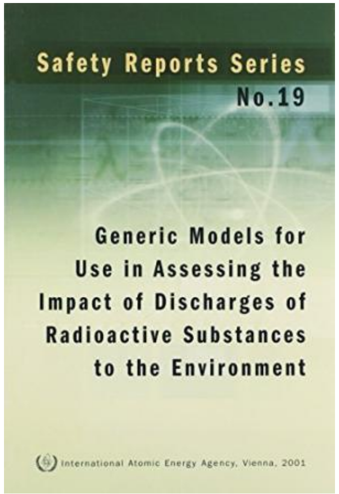
General framework



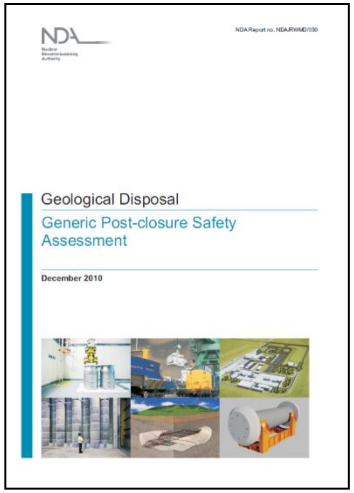
Critical Group methodology

Direct discharges | *Solid waste*

IAEA Generic models… (2002)



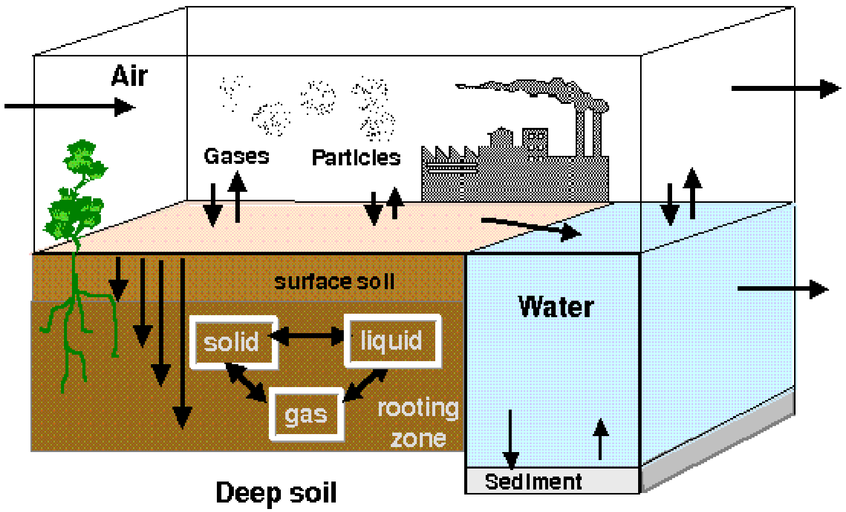
RWM Ltd. Post-Closure Safety Assessment (2010)



Compartment-type methodology

Key features

- USErad
- Level III Mackay models
  - Fugacity concept for material transfers
  - Homogenously mixed compartments
  - Steady-state conditions



Picture taken from CalTox website

- 8 compartments
  - Air, fresh and sea water, natural and agricultural soil
  - Freshwater and marine sediments, and groundwater (under development)
- 2 Spatial scales
  - Continental and global
- Only element/radionuclide-specific parameters are used (no predictive equation)

Qualitative discussion

Critical Group methodology

Risk per Bq released		
	Air	Sea water
I129	2.16E-07	2.10E-14

- \+ Results accuracy
- \+ Largely established in the nuclear industry

- \- Worst case scenario
- \- Location-dependent results
- \- Poor knowledge on GDF behaviour

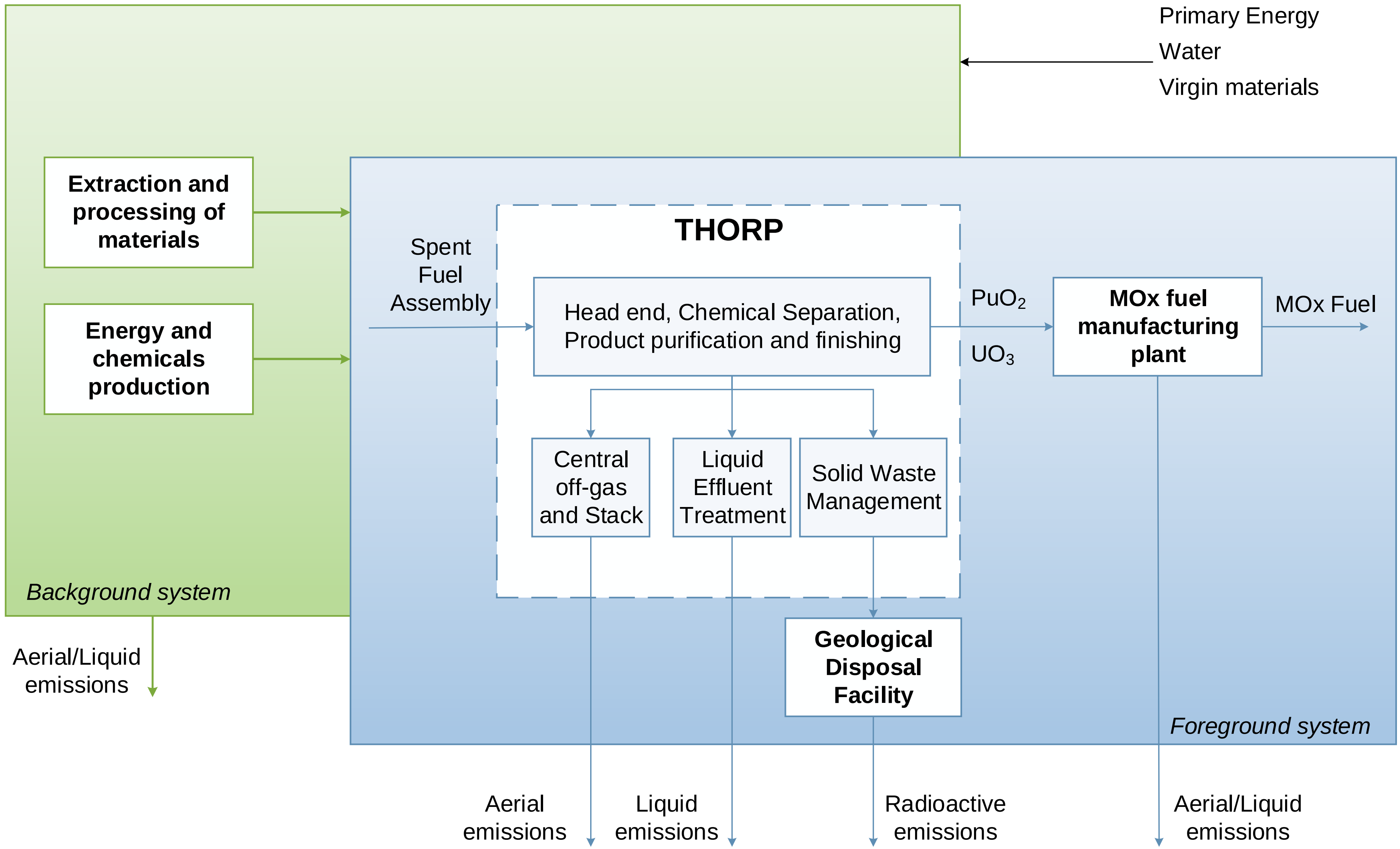
Compartment-type methodology

Risk per Bq released		
	Air	Sea water
I129	1.35E-19	1.34E-10

- \+ Average impact
- \+ Consistent with toxicity potential methodologies

- \- Results accuracy
- \- Partition factors
- \- Poor knowledge on GDF behaviour

Scenario – UK approach for the management of SNFs



Functional unit: Amount of AGR spent fuels that produced 1 TJ of electricity

Conclusions

- ➢ There is a need to develop a standard framework for assessing radionuclide impact.
- ➢ A new framework has been developed, and two methodologies have been derived.
- ➢ A qualitative comparison has been presented.

Current challenges

- Complete the groundwater compartment in the compartmental model.
- Compare quantitatively the two developed methodologies.
- Time factor (solid waste vs direct discharges).

Future work

- Real-data collection on site (Sellafield).
- Apply the LCA to the reference scenario (UK approach to Nuclear Waste Management).

Acknowledgements

NDA
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DISTINCTIVE

NATIONAL NUCLEAR LABORATORY

Sellafield Ltd

Thanks