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Supplement of

The ^{14}C dose assessment model chain – ^{14}C source term definition and uncertainty quantification

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THE ^{14}C DOSE ASSESSMENT MODEL CHAIN –
^{14}C SOURCE TERM DEFINITION AND UNCERTAINTY QUANTIFICATION

SafeND, Berlin, 14.09.2023

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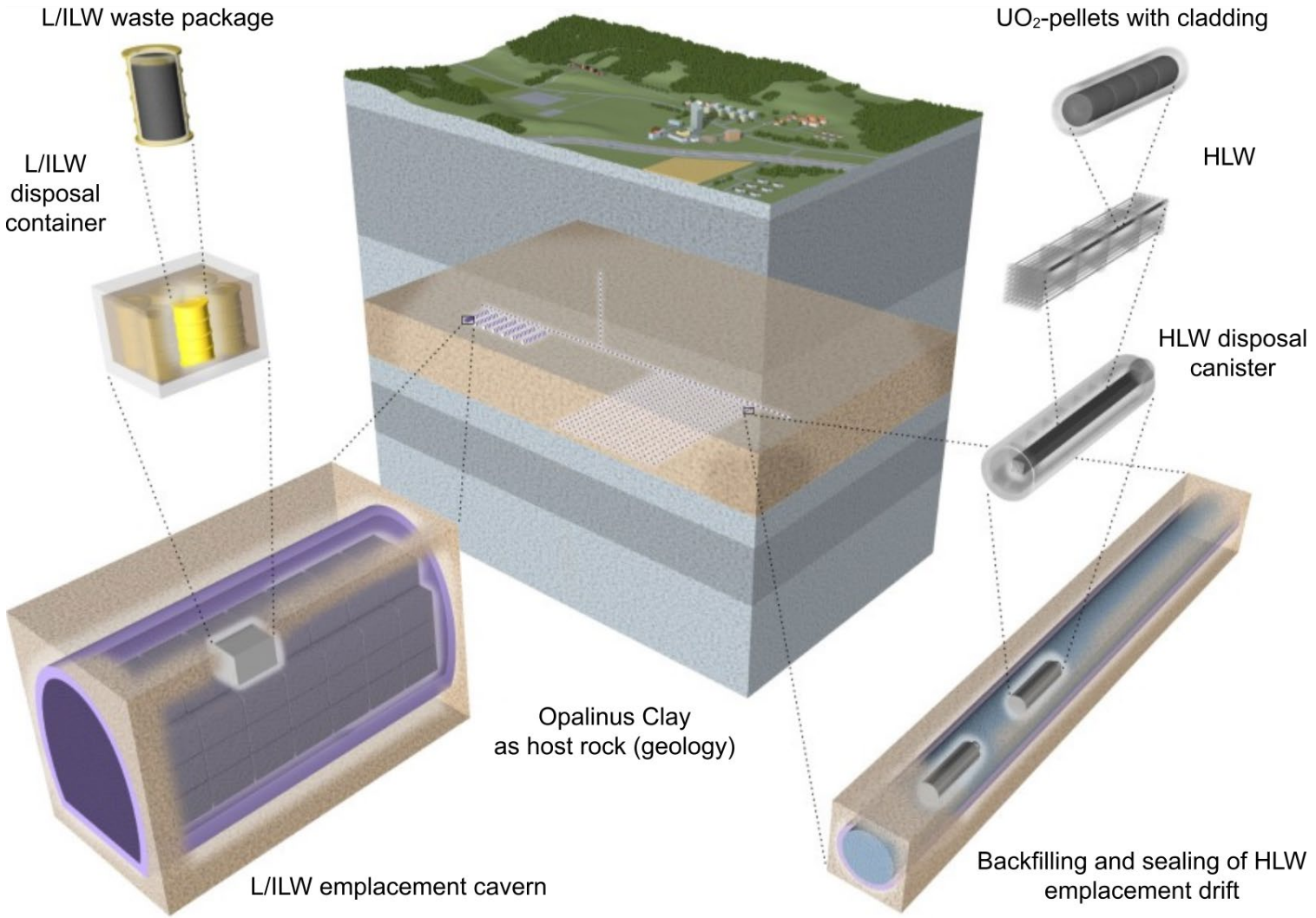
nagra.

SWISS REPOSITORY CONCEPT



IMPORTANCE OF ^{14}C

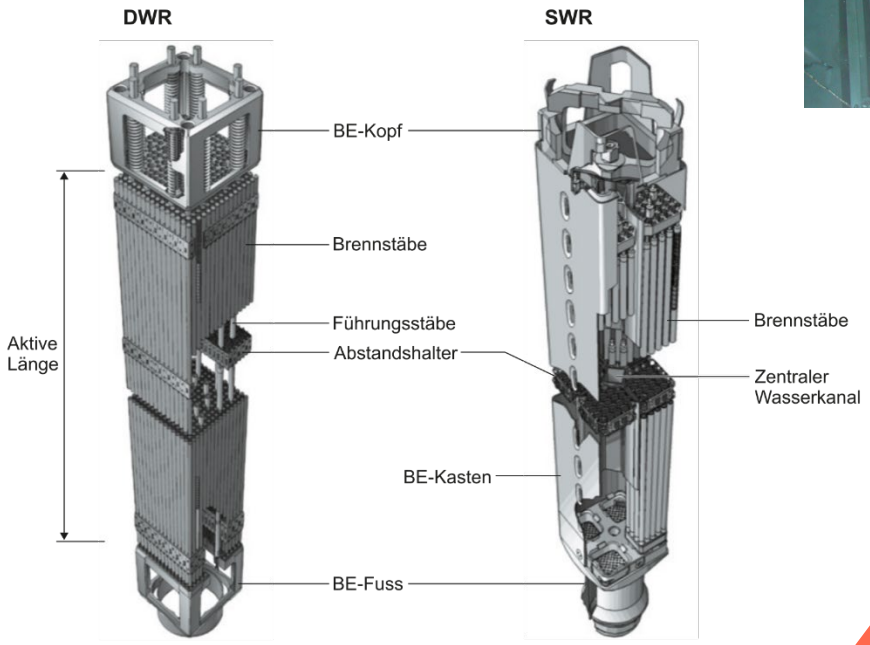
- Just a small number of nuclides are relevant for long term post closure dose
  - Focus today: ^{14}C
    → release from waste into fluid and gas phase → high mobility within geosphere
    → half life of ca. 5700 a,
    → C relevant as building block within biosphere
- Probabilistic dose assessments
  - Realistic modeling enables assessment of systems's robustness
  - Requires realistic input and parameter setting for models to
  - **Goal** troughout ^{14}C model chain: **best estimate + uncertainty**

^{14}C MODEL CHAIN

Reactor waste,
NPP Gösgen

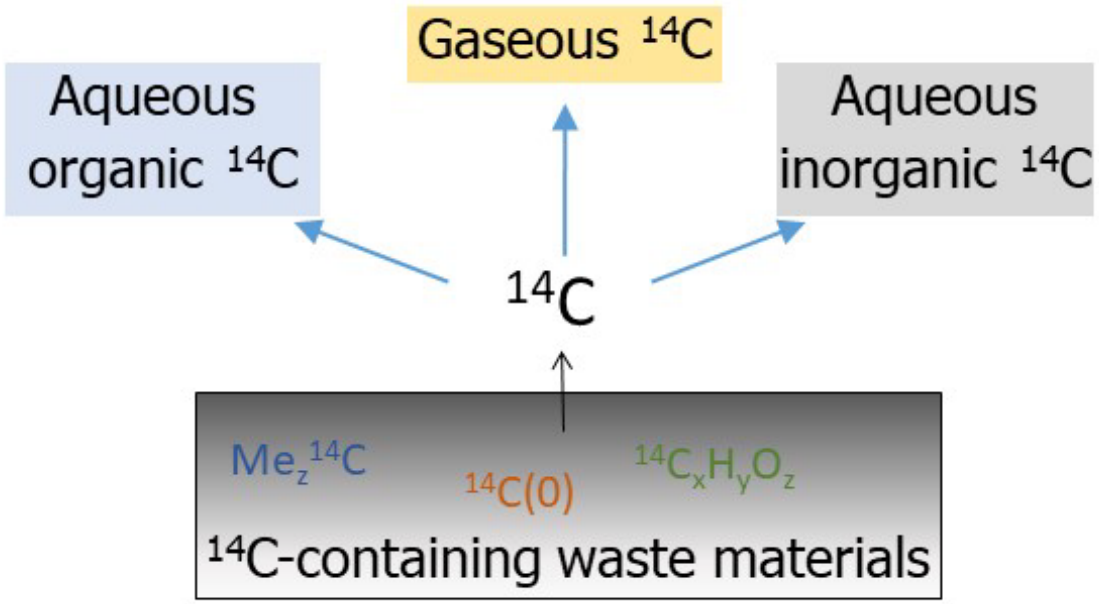
Reprocessing coquille

Model of a concrete container



^{14}C inventory

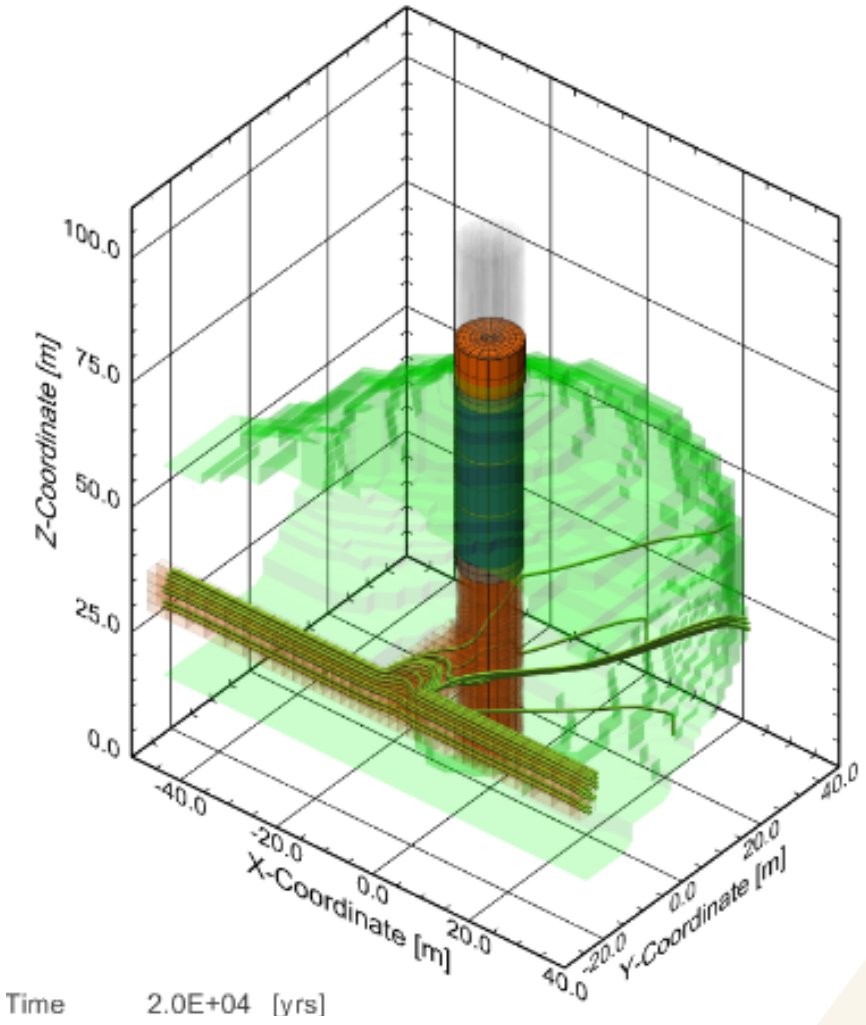
^{14}C MODEL CHAIN



Release & Speciation from each material

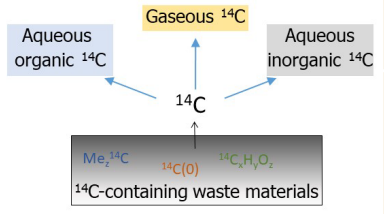
^{14}C inventory

^{14}C MODEL CHAIN



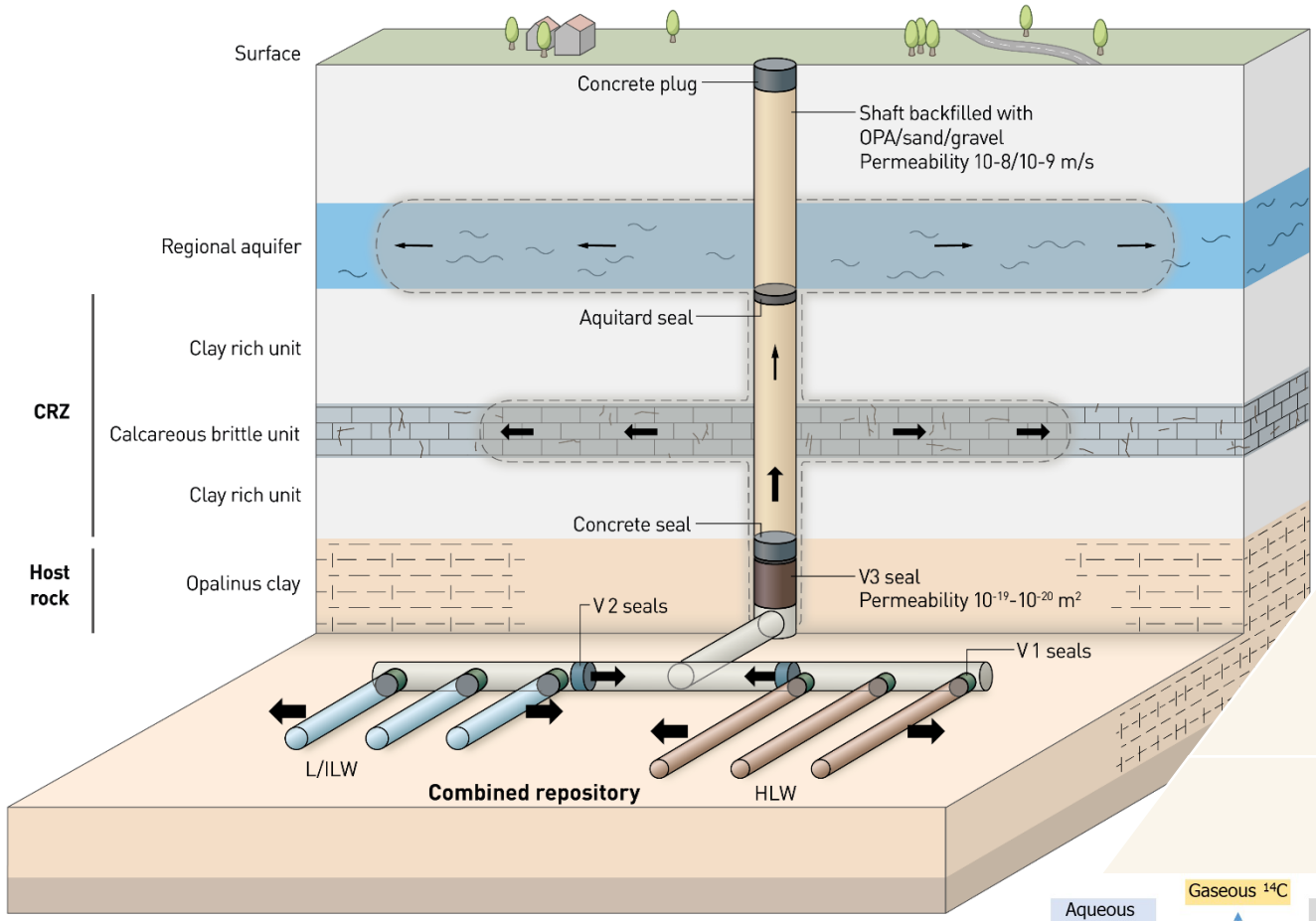
Transport within repository

Release & Speciation from each material

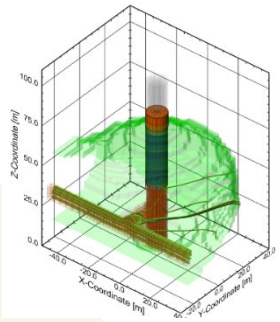


^{14}C inventory

^{14}C MODEL CHAIN

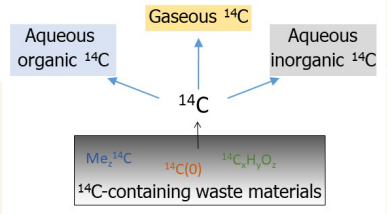


Transport to biosphere



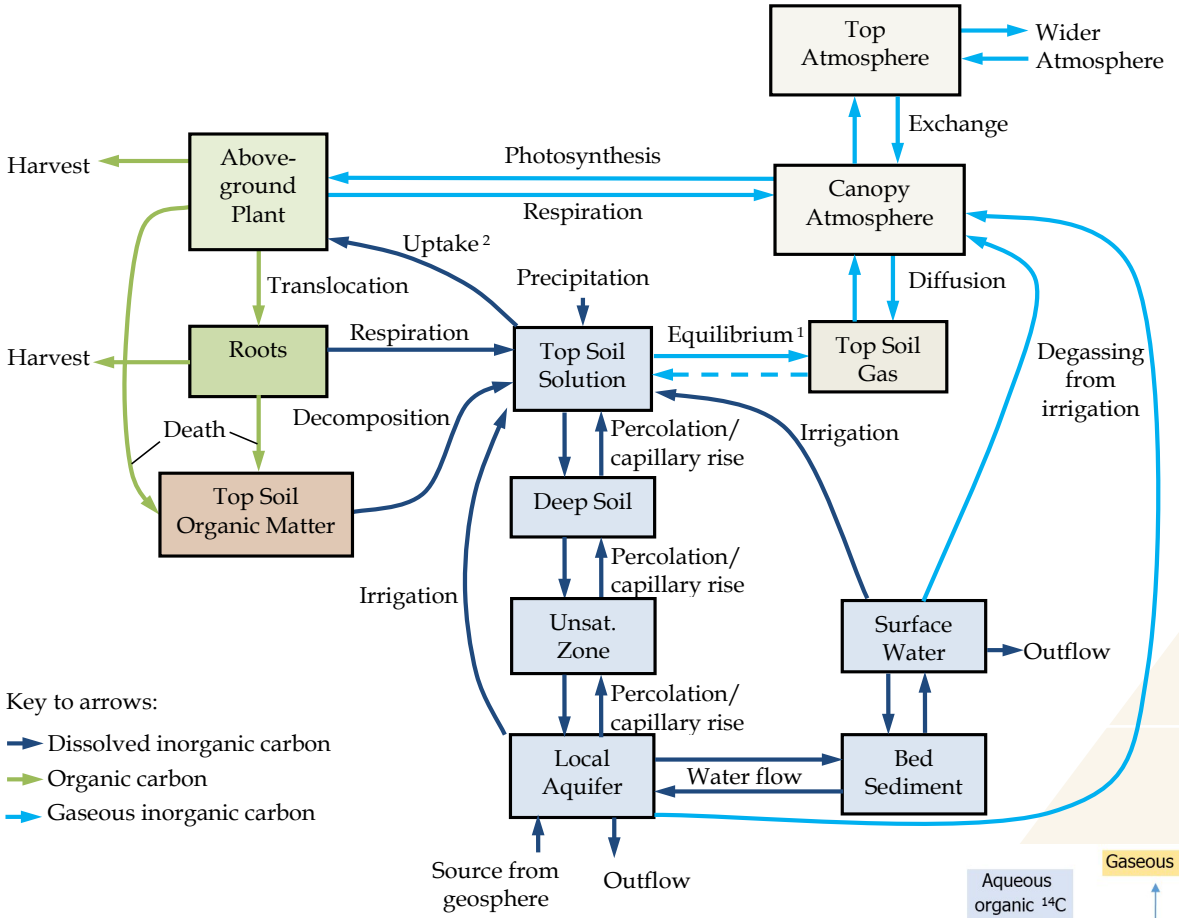
Transport within repository

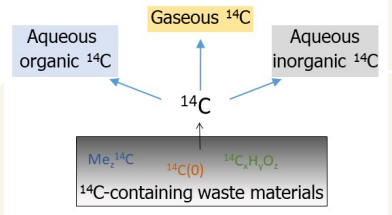
Release & Speciation from each material



^{14}C inventory

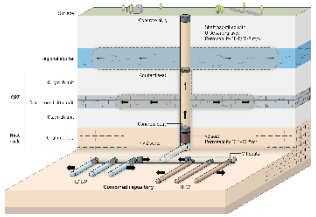
^{14}C MODEL CHAIN



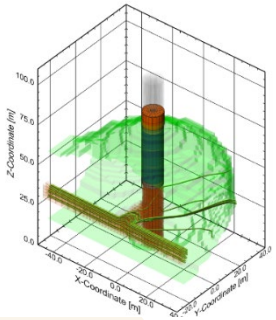


Transport within biosphere

Transport to biosphere



Transport within repository



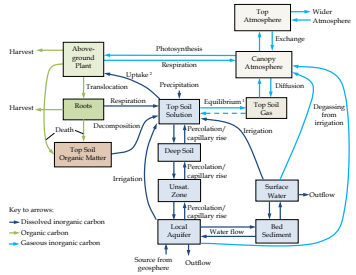
Release & Speciation from each material

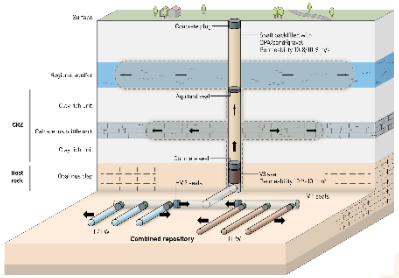
^{14}C inventory

^{14}C MODEL CHAIN

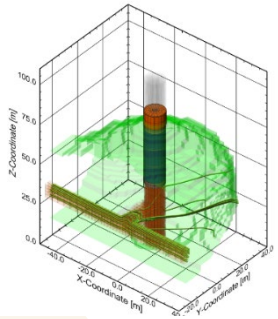
^{14}C dose

Transport within biosphere

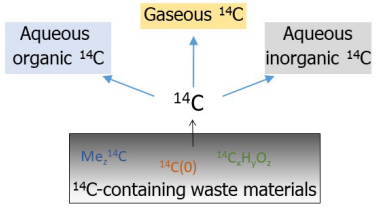




Transport to biosphere



Transport within repository



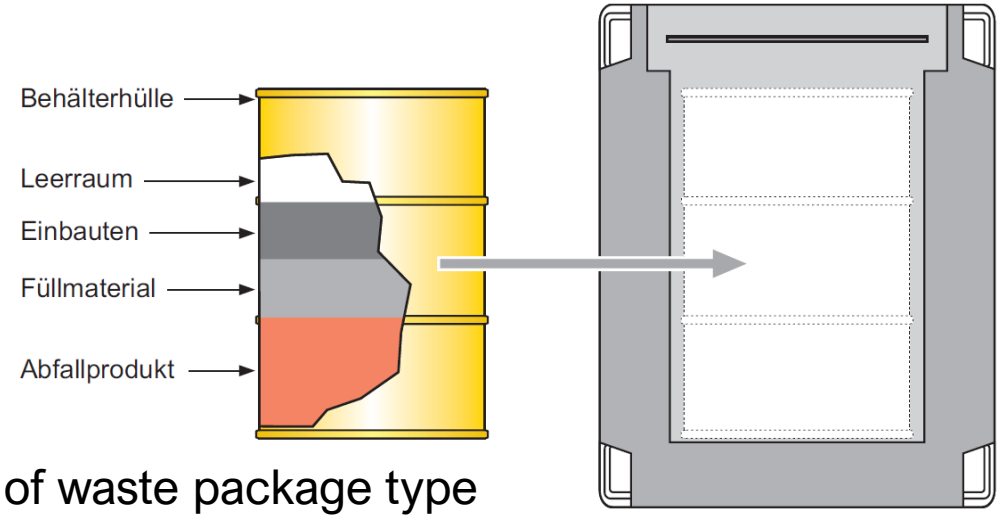
Release & Speciation from each material

^{14}C inventory

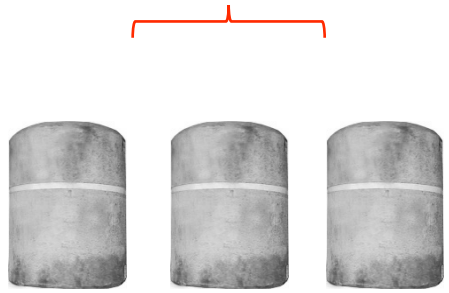
MIRAM-RBG – MODEL INVENTORY

MIRAM (**M**odel **I**nventory of **Ra**dioactive **M**aterials)

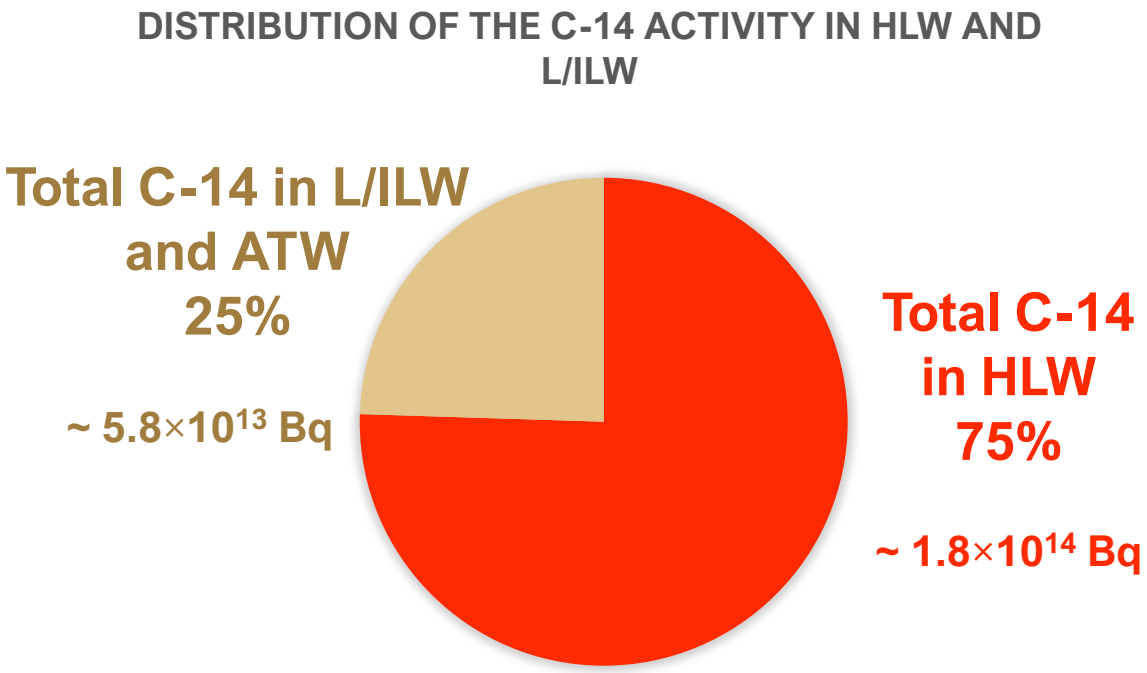
- Basis for **long-term safety analyses**
- Detailed **average properties** of reference package **at time of production**
  → **waste package type = AGT**
  - ➢ nuclide and material inventory, metal geometries and waste properties
- Based on **ISRAM**: database of existing waste packages + model types for future waste
  - ➢ used by all waste producers in CH and Nagra for radioactive material management.



Example of waste package type

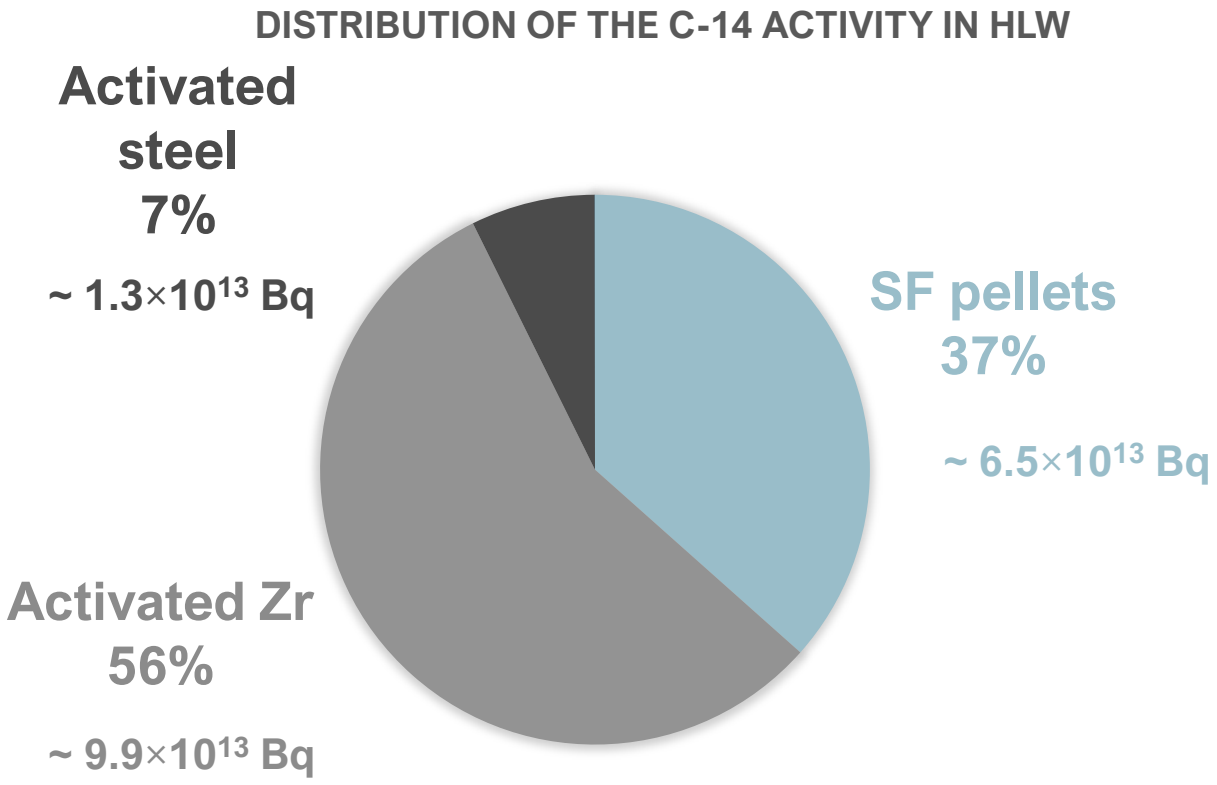


^{14}C – INVENTORY



- 87% of total ^{14}C-activity in 10 AGTs (waste package types)
  - 76% of total ^{14}C-activity in HLW → 6 AGTs describing SFA

^{14}C – HLW-INVENTORY



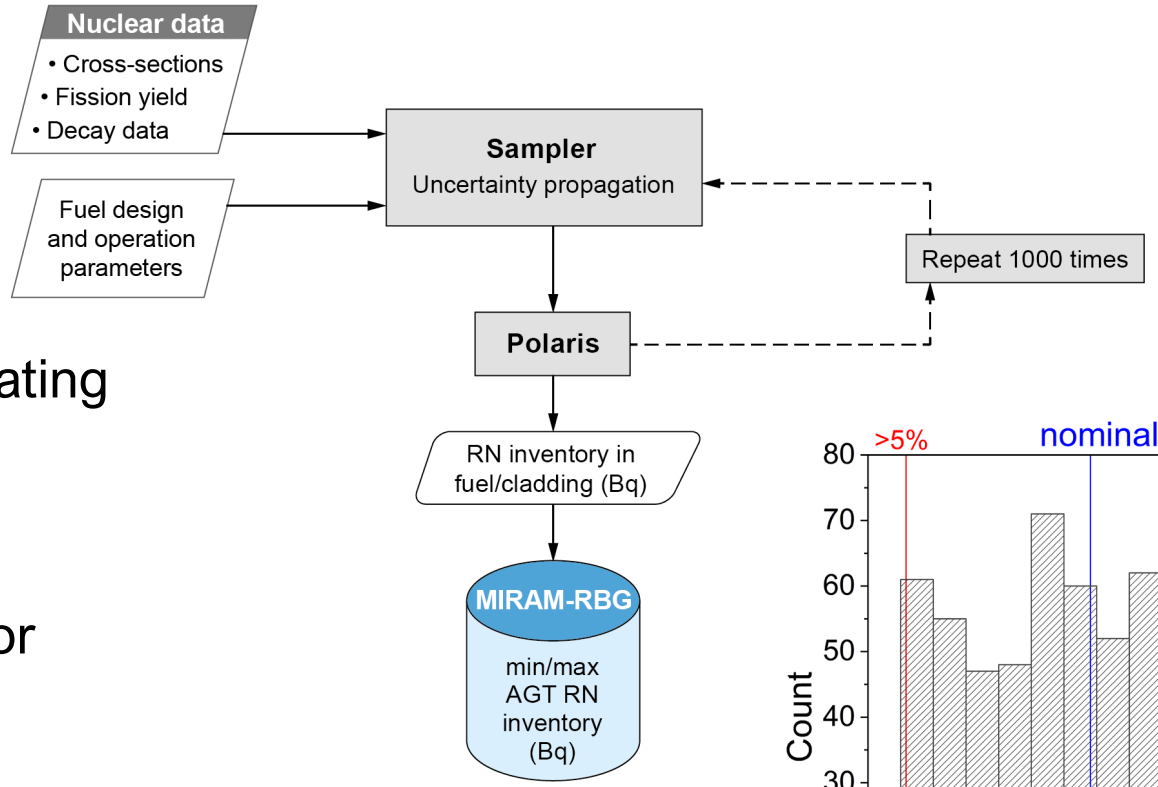
- Inventory based on single SFA-calculations
  - ➢ emphasis on full repository inventory best estimate
    → nominal AGT inventory
- Inventory given for
  - Fuel itself
  - Active-length structural parts (e.g. cladding)
  - Additional structural parts (e.g. top and bottom end-pieces)
  - ➢ Allows material specific attribution of ^{14}C-activity

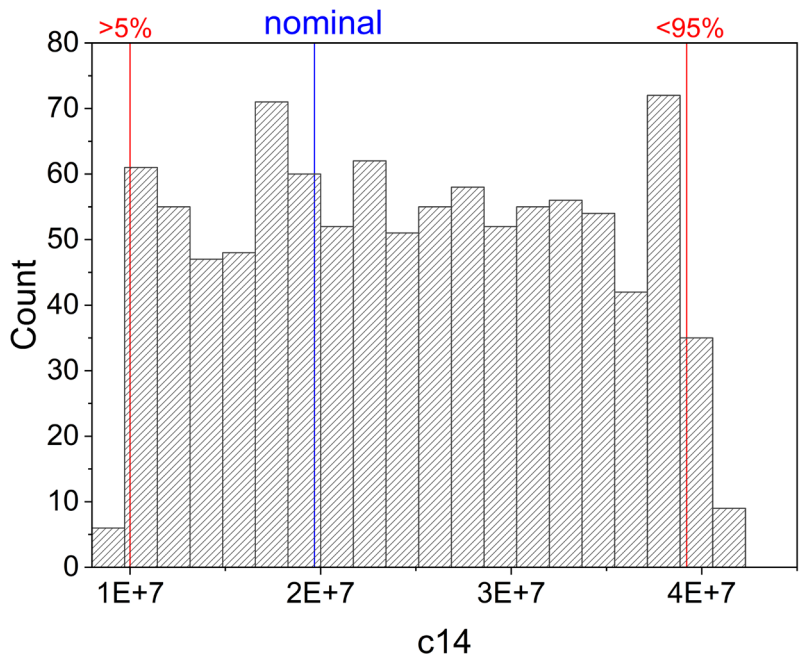
^{14}C – HLW – UNCERTAINTY QUANTIFICATION

- Sources considered
  - Nuclear Data
  - Material impurities
  - Design parameters, operating parameters and history

- Perturbation calculations for representative SFA

➢ Distribution of activity

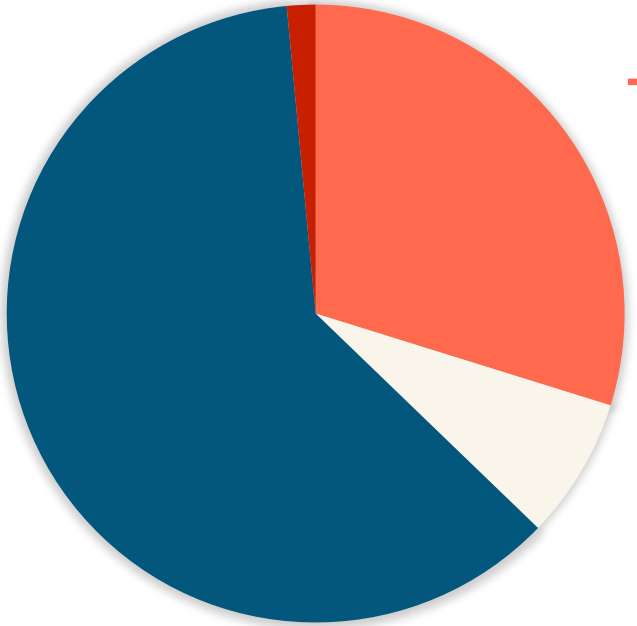




^{14}C – L/ILW-INVENTORY

DISTRIBUTION OF C-14 IN L/ILW
BY WASTE ORIGIN
WA – REPROCESSING
SA – DECOMMISSIONING
BA – OPERATIONAL
RA – REACTOR WASTE

Total C14 in WA
2%
~ 8.6×10^{11} Bq



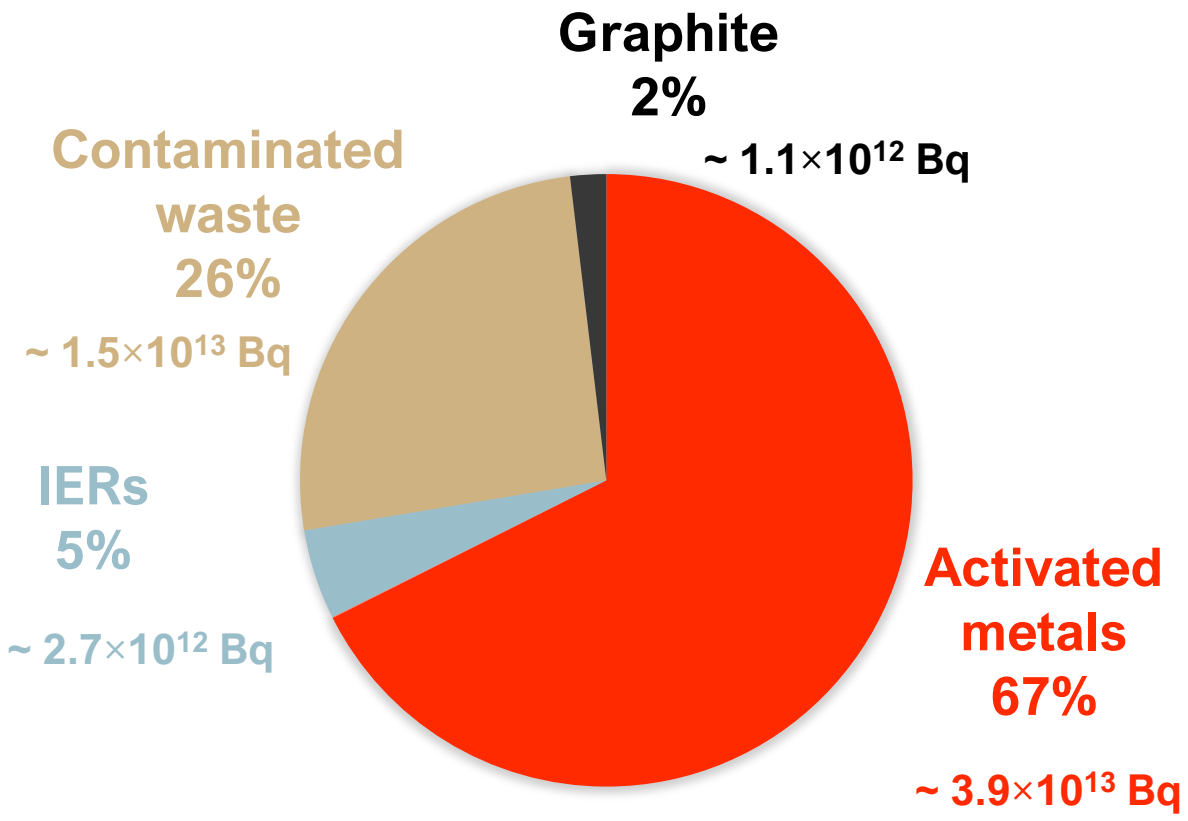
Total C14 in BA
30%
~ 1.7×10^{13} Bq

Total C14 in SA
61%
~ 3.5×10^{13} Bq

Total C14 in RA
7%
~ 4.3×10^{12} Bq

^{14}C – L/ILW-INVENTORY

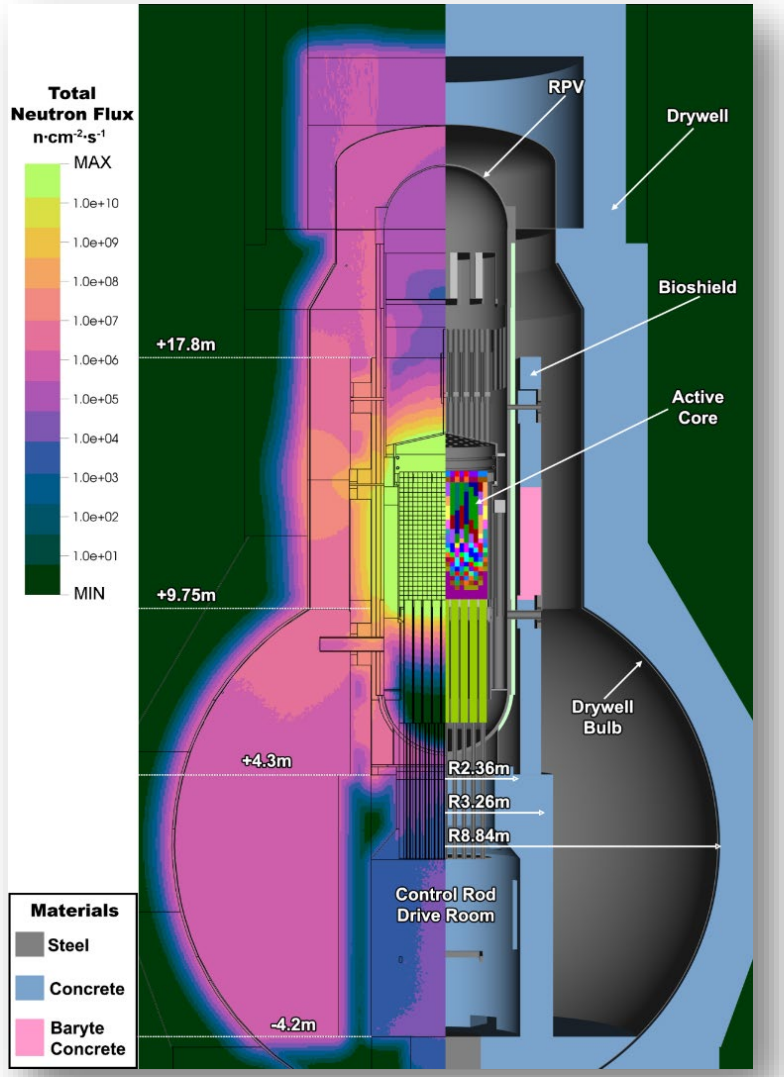
Distribution of ^{14}C by material – activated metals



^{14}C is primarly formed by the activation of ^{14}N impurities present in metals, mainly steel.

Precursor isotope	Nuclear reaction	Isotopic abundance (%)
^{14}N	$^{14}N(n,p)^{14}C$	99.632
^{17}O	$^{17}O(n,\alpha)^{14}C$	0.038
^{13}C	$^{13}C(n,\gamma)^{14}C$	1.07

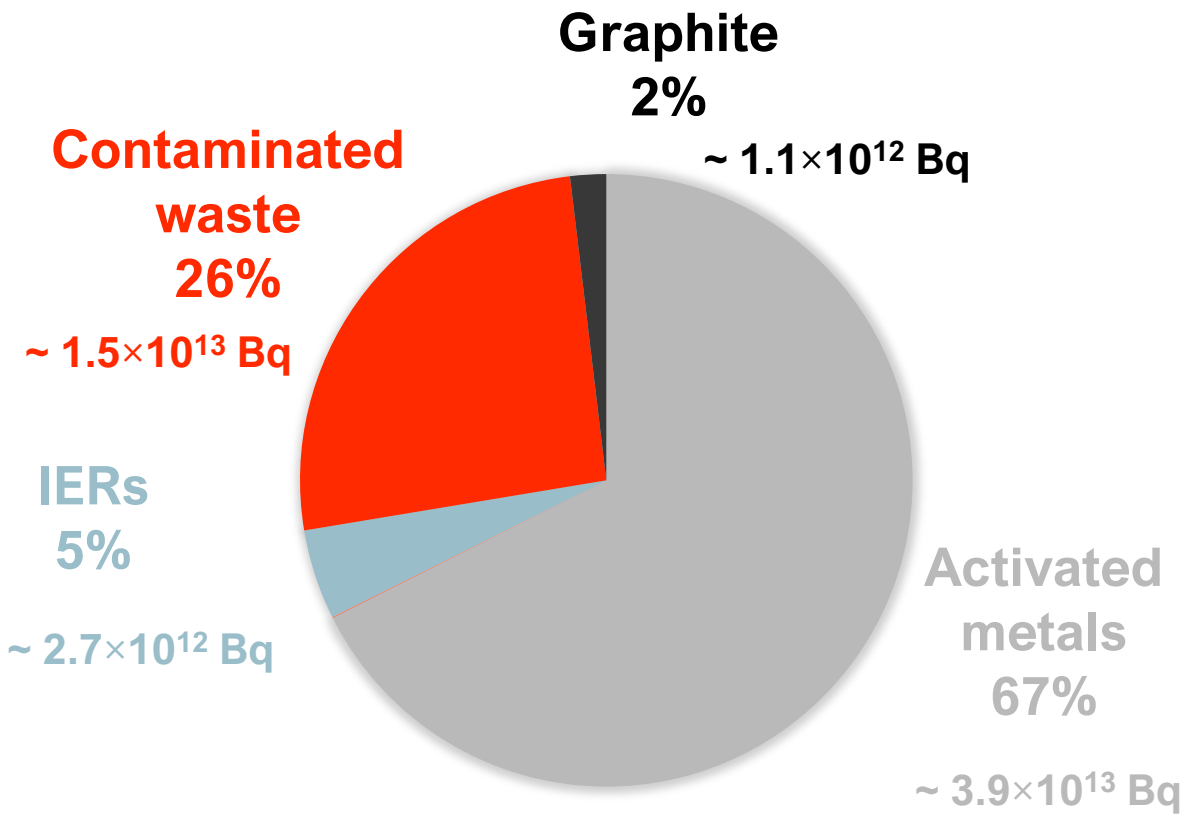
^{14}C – ACTIVATED METALS - INVENTORY FROM NPPS

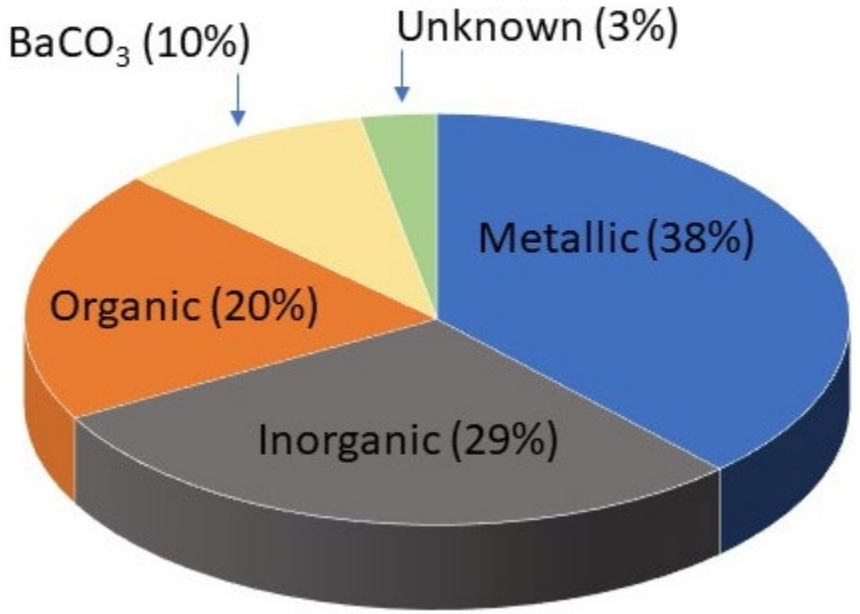


- Detailed activation calculations by Nagra
- Main source of ^{14}C – Core Internals
- Main source of uncertainties
  - Material composition = N-impurities
  - Approach for ^{14}C:
    - **Best estimate** based on measurements where available, literature review and estimates based on expert knowledge
    - **Upper confidence limit** based on expert knowledge → «highest known» N-impurity

^{14}C – L/ILW-INVENTORY

Distribution of ^{14}C by material – contaminated waste





^{14}C – CONTAMINATED WASTE - INVENTORY FROM MIR

- Detailed inquiry into
  - → ^{14}C-waste producers
  - → ^{14}C-waste properties
  - → **Estimations of future waste production and expected ^{14}C-activities**
    - → main source of uncertainty → best-estimate * («expert knowledge based» factor)

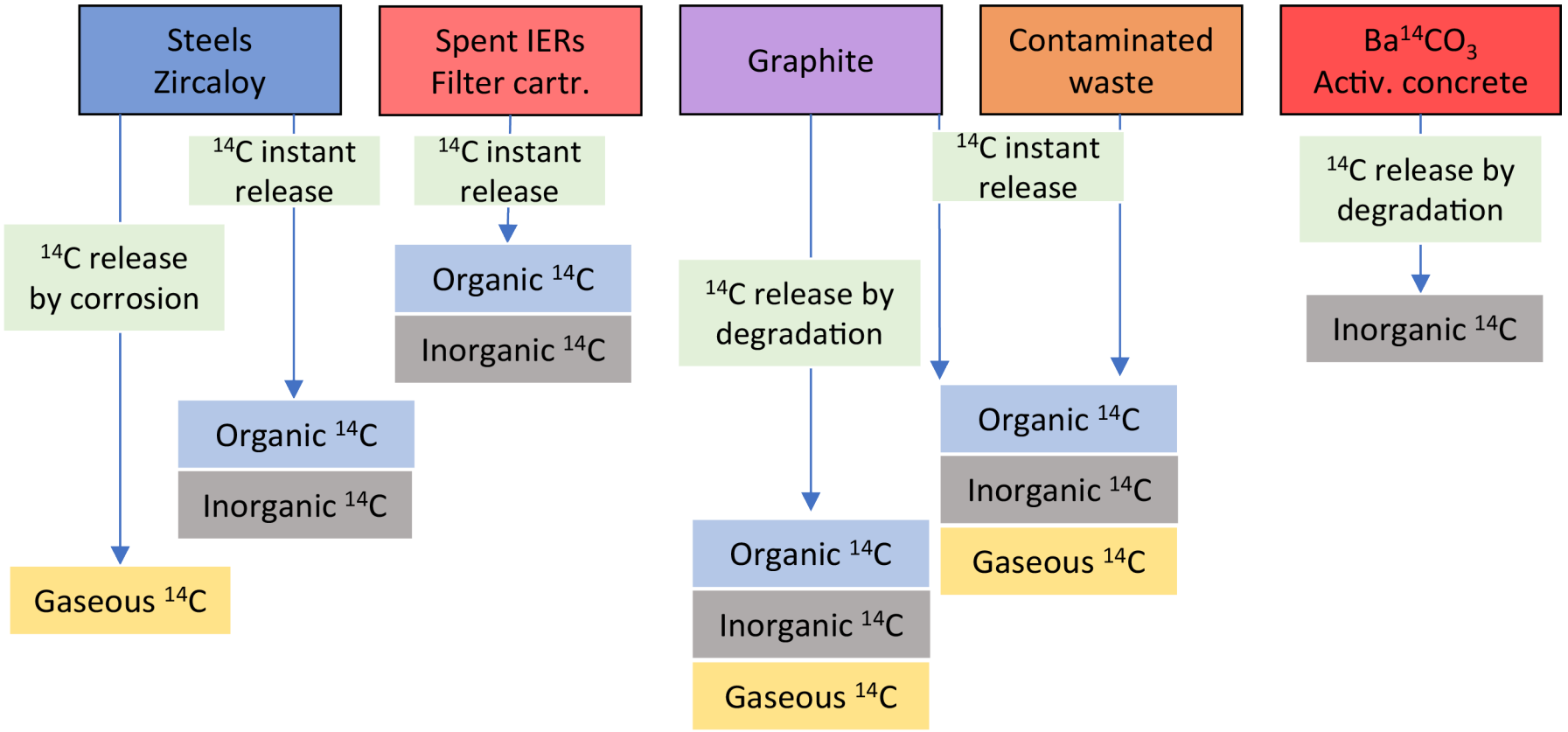
  - Spent fuel research
    → contaminated metallic, inorganic and organic waste
  - Medicinal research → ^{14}C-labeling
    → contaminated organic waste
    → use in rapid decline (^{3}H-labeling as main alternative)
  - Military equipment – luminiscing paints/colours
    → $BaCO_3$
    → existing old equipment amount reassessed → replaced nowadays by ^{3}H and alternatives

^{14}C SOURCE TERM

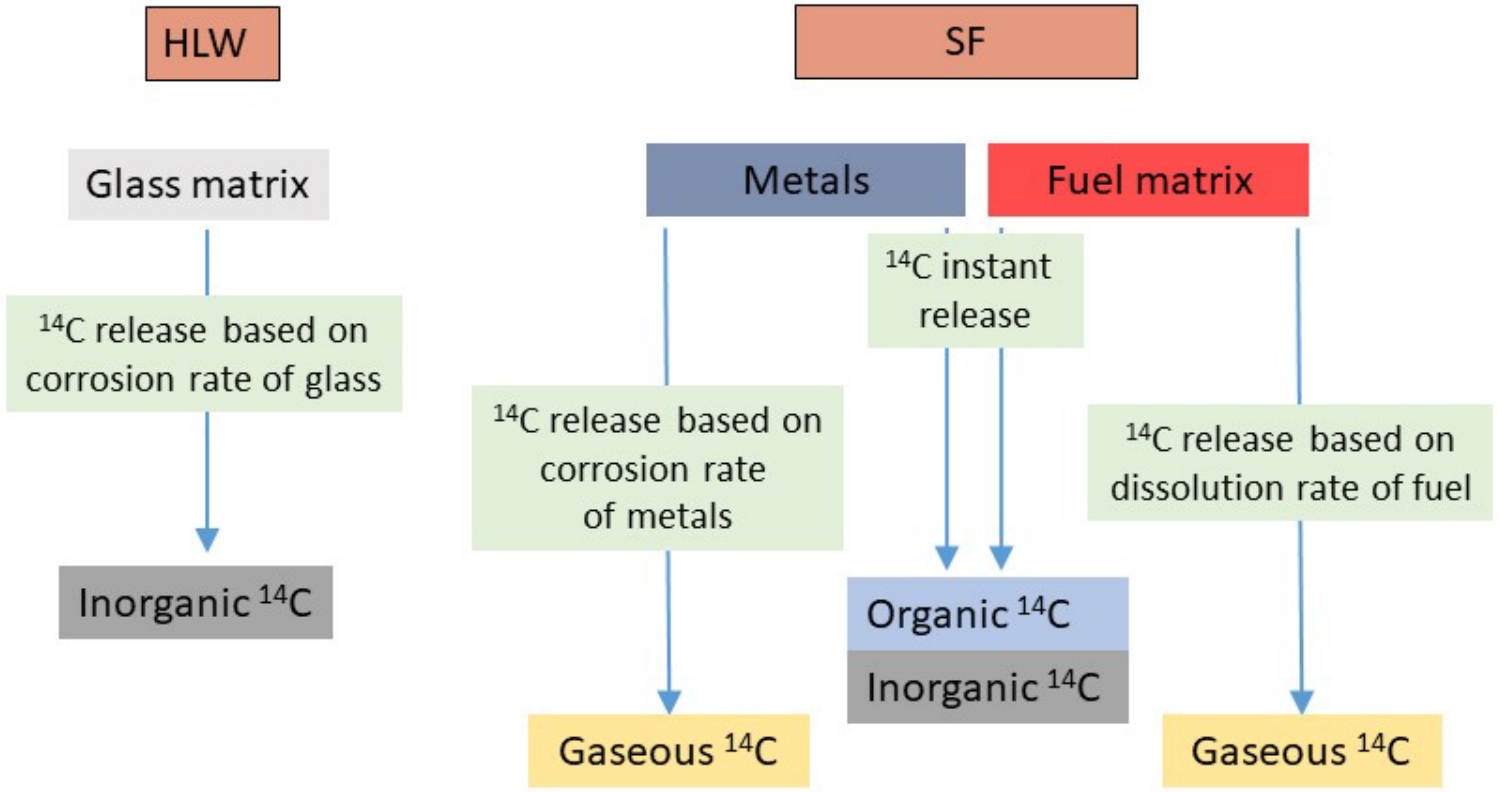
- from inventory to transport model source term
  - Release rate
  - Released species
  - Dependent on ^{14}C-containing material in repository conditions

- CAST-Project → basis of international state of knowledge
- IGD-TP LOMIR → Long term monitoring of ^{14}C compounds released during corrosion of irradiated steel
  - (new) Partners welcome!

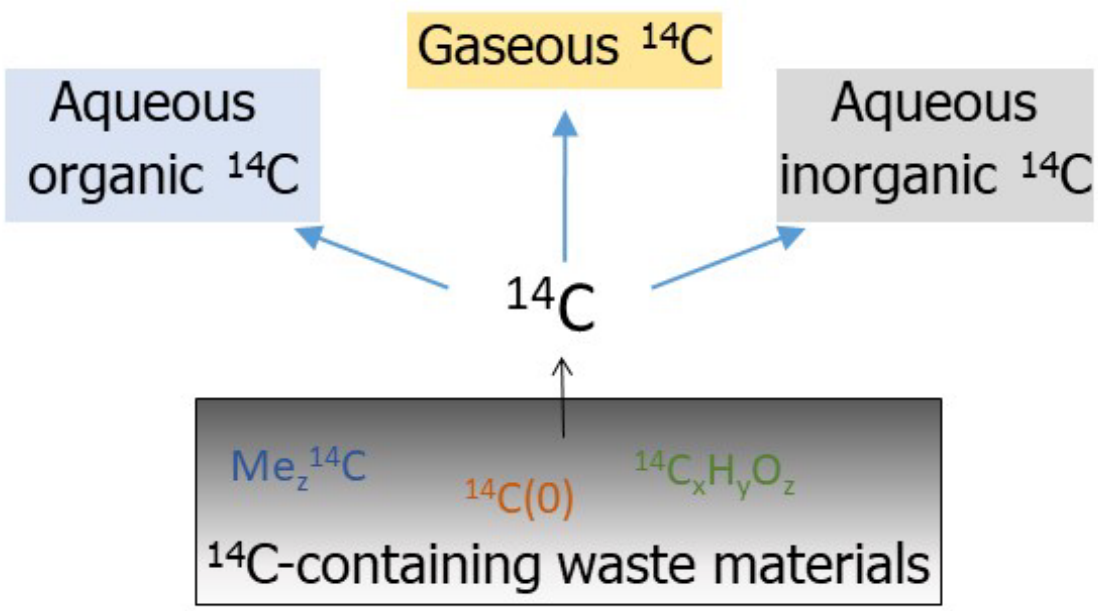
SPECIATION AND RELEASE OF ^{14}C FROM L/ILW



SPECIATION AND RELEASE OF ^{14}C FROM HLW



SUMMARY - ^{14}C SOURCE TERM QUANTIFICATION



Goal → realistic assessment base
→ Best estimate + uncertainty

- Assumptions of ^{14}C speciation and release are based on material
- ^{14}C inventory (best estimate + unc.) captured in model inventory per waste type
- For each waste type ^{14}C was assigned to one main ^{14}C-bearing material

➢ **Comprehensive source term of ^{14}C-species** and activities for the dose assessment model chain

THANK YOU FOR YOUR ATTENTION

QUESTIONS?

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