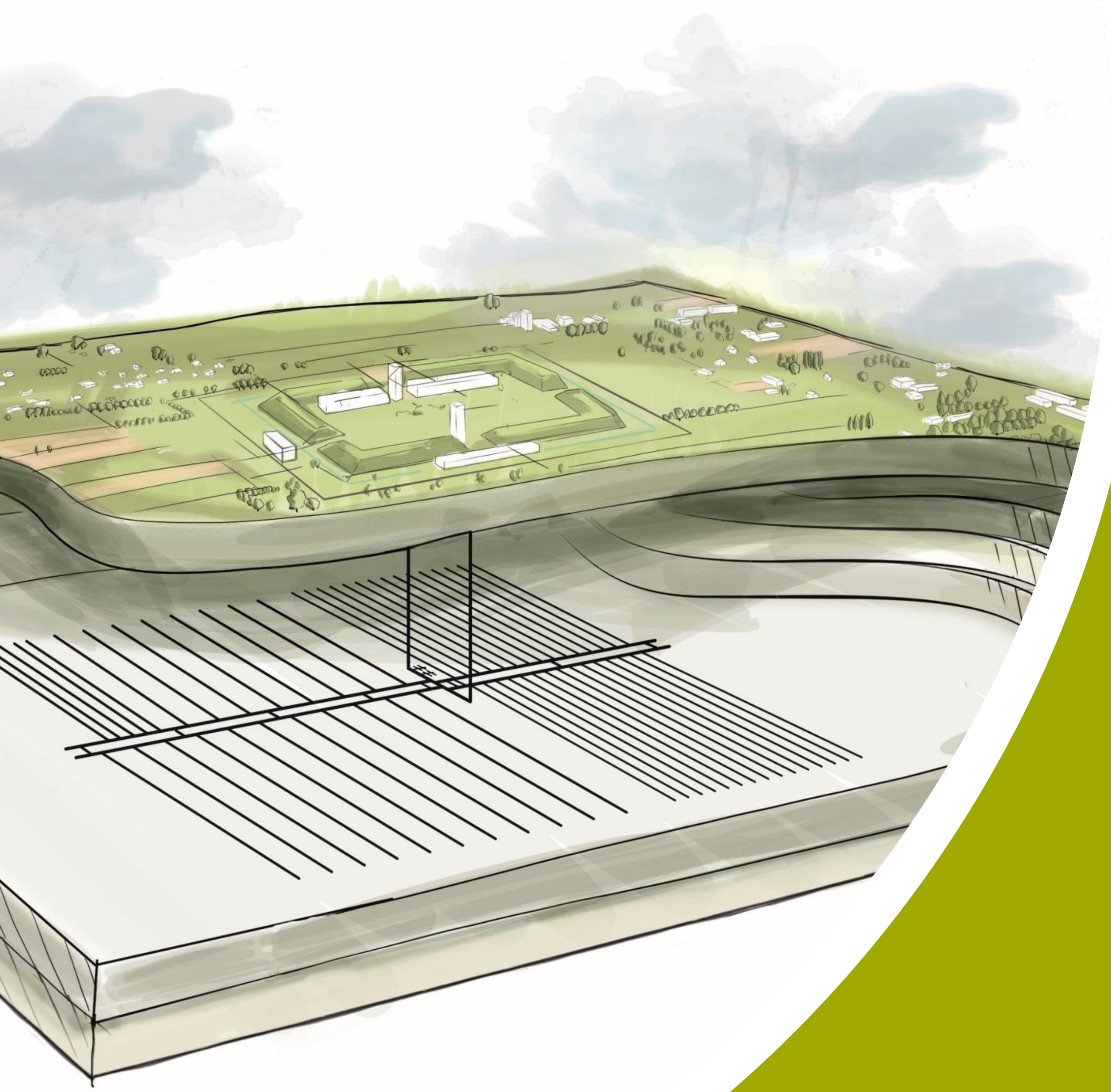

Synatom ONDRAF/NIRAS

Management of spent nuclear fuel data: the Belgian case

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IAEA TM on the Management and Preservation of Spent Fuel Data
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Contents

SPENT FUEL DATA COLLECTION AND MANAGEMENT IN BELGIUM

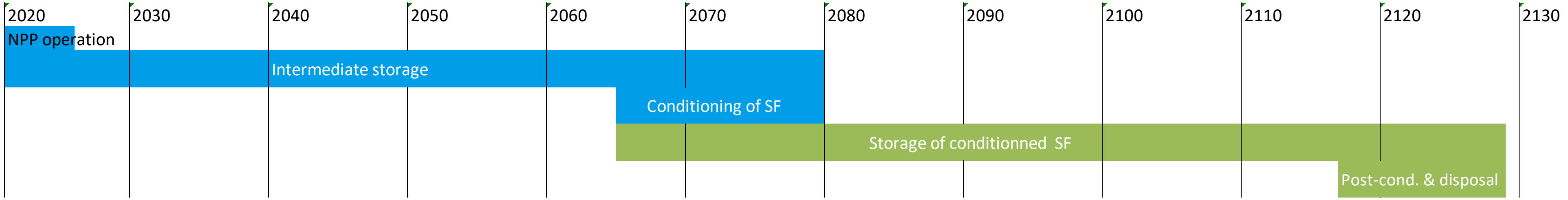
PLAN

- Actors
- Timeline
- Fuel characteristics
- Storage
- Use & data
- Fuel characteristics on long term
- Conclusion

ACTORS

- SYNATOM : owner of the nuclear fuel in Belgium, in charge of its management before and after the irradiation in reactor
- ELECTRABEL : subsidiary of French group ENGIE, utility operating 2 NPP
  - Doel : 4 PWR
  - Tihange 3 PWR
- ONDRAF/NIRAS : responsible for the safe management of radioactive waste in Belgium

TIMELINE



The transfer of information from SYNATOM to ONDRAF/NIRAS will take place around 2065, ONDRAF/NIRAS will ensure the subsequent conservation.

FUEL CHARACTERISTICS

	Doel				Tihange		
Units	D1	D2	D3	D4	Ti1	Ti2	Ti3
Array	14x14	14x14	17x17	17x17	15x15	17x17	17x17
Length	8’	8’	12’	14’	12’	12’	14’
Fuel	UNE	UNE	UNE	UNE	UNE	UNE	UNE
	URE		MOX			MOX	

STORAGE

- DOEL :
  - Dry storage - SCG
    - Building for 165 casks
    - 120 heavy metallic casks are stored, at end 2021
  - Dry storage – SF2
    - Building for maximum 97 casks - construction is in progress
- TIHANGE :
  - Wet storage - DE
    - Centralised pool for about 3,700 assemblies
    - 3,275 assemblies are stored , at end 2021
  - Dry storage – SF2
    - Building for maximum 108 casks - construction is in progress

USE & DATA

- Data bases are built to meet identified needs for reprocessing (if any), storage, disposal
- Major contents
  - Fabrication data
    - Fuel Assembly identification, enrichment, cladding type,…
  - Irradiation data
    - Burnup, U and Pu content after irradiation,…
  - Storage data
    - Location

LONG TERM

- Computer code using Excel sheets
- Determine the content in critical isotopes and in chemio-toxic elements
- Input data
  - Fabrication data, enrichment, burnup, cooling time
- Output data
  - Activity of 56 isotopes, residual power (at cooling time), content in 56 chemio-toxic elements (conservative value)

CONCLUSION

- Data available related to
  - Fabrication
  - Irradiation
  - Storage
- Determination of fuel characteristics on long term
  - Activity
  - Residual power
  - Chemio-toxicity

ONDRAF/NIRAS

Why do we need spent fuel characterisation?

For RD&D, design & costing of GDF

Future inventories of spent fuel and reprocessing waste

- For safety studies and design & costing of the GDF, O/N has to estimate future waste inventories and characteristics
  - ⇨ Current need for ONDRAF/NIRAS

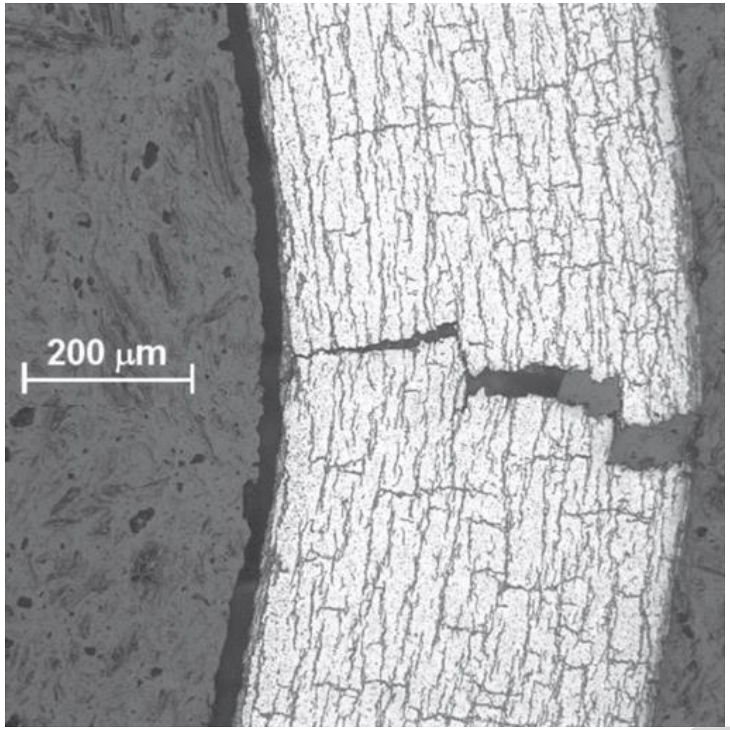
- 2 possible scenarios are currently considered for SF mngmt:
  - no further reprocessing: direct disposal of SF inventory
  - partial reprocessing: disposal of reprocessing waste + part of SF
    - Inventory of reprocessing waste is derived from inventory of the to be reprocessed spent fuel

GDF = geological disposal facility

For operational safety

State of spent fuel assemblies after interim storage

- Spent fuel will be stored during several decades before disposal
- Fuel assembly and cladding should retain structural integrity (handling, heat removal, containment of radionuclides & gases,…)
- Aging mechanisms are dependent on:
  - Storage type
  - Characteristics of the fuel
- Aging mechanisms are driven by:
  - Fuel temperature
  - Internal pressure induced stresses
  - Environment/events during storage + transport



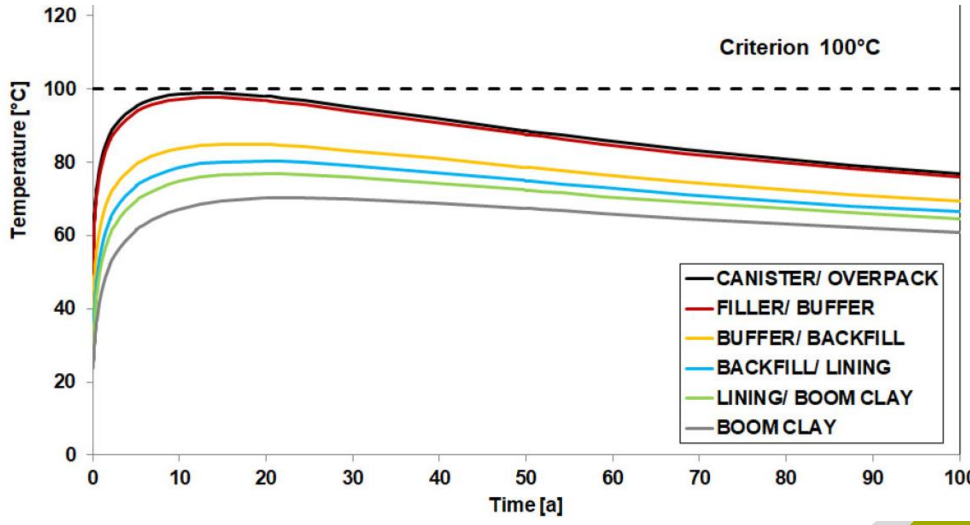
For long-term safety

Thermal impact

- Temperature constraint on supercontainer due to:
  - possible impact on the integrity of the concrete buffer
  - possible impact on corrosion rate of the carbon steel overpack
- Temperature constraint on host rock:
  - limit pore water overpressures which could damage host rock
- Temperature constraint on aquifer:
  - regulatory temperature limit for groundwater

⇨Leads to several requirements, a.o.:

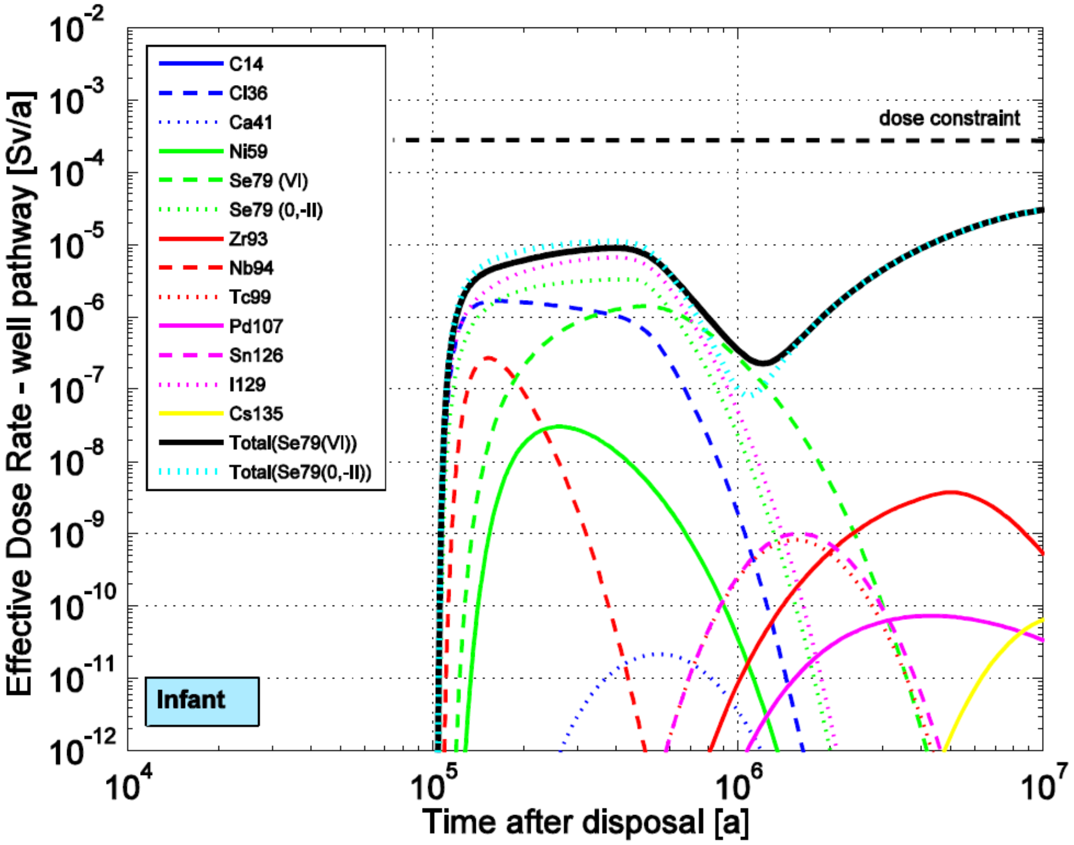
- sufficient cooling time
- total power of supercontainer should be governed (depending on GDF depth)
- design, materials,…



For long-term safety

Long term evolution of the disposal system

- Eventually, radionuclides will be released into the aquifer system and the biosphere



- up to 1 million years:
  - fission and activation products
  - most impacting: I-129, Se-79, Cl-36
    ! all difficult to measure RN
    ! Cl impurity at fabrication
- after 1 million years:
  - actinides & decay products (not on figure)
  - most impacting: Ra-226, Th-229

For long-term safety

Long term criticality

- during thermal phase: containment is guaranteed
  - no water in overpack $\Rightarrow$ no criticality risk (by design)

- after thermal phase: water ingress in overpack is possible
  - in-package scenarios (altered geometry):
    - no criticality risk for fuel with BU>35GWd/t_{HM} in any studied situation
    - different WMOs found minimal BUC requirement to be around 30-35 GWd/t_{HM}
  - very long term:
    - dissolution of spent fuel and migration of radionuclides
    - possible reconcentration of U isotopes by precipitation in EBS/host rock

WMO=Waste Management Organisation; BUC = Burn-Up Credit

For safeguards

- Separate database with specific information requested by IAEA and Euratom
- Need for consistency with other databases?
- Verification via measurements could be required at time of (post-)conditioning by IAEA and Euratom

SF Knowledge management

Future needs

- 3 aspects with future need for data on Spent Nuclear Fuel:
  - Safeguards
  - Operational safety
  - Long term safety

  All three should be coherent, though level of detail, need, uncertainties, etc. can differ

- Complete characterization of the fuel assumes following input:
  - Calculation codes
  - Nuclear Data
  - Fuel and operational data

How to handle this aspect?

1. Perform complete characterization as soon as possible so that data and codes become obsolete: REX surface disposal project (see next section)
2. Central database with at least all necessary information to perform characterization of the fuel

ONDRAF/NIRAS

Experiences from the surface disposal project

Brief history of the cAt project

cAt project = surface disposal project in Belgium

“category A” waste = low/medium level short-lived waste

- 1984: ONDRAF/NIRAS received the mission to find a sustainable solution for the low and intermediate level short-lived waste
- 1994-2006: siting based on local participation
- 2006: selection of a site
- 2006-2013: pre-licensing
- 2013: first license application
- 2013-2017: review of first license application
- 2017: second license application

Evolution of radiological WACs for cAt

Radionuclides to characterise

until 1994

- no defined list of nuclides to characterise; only total activity and “principal” RN

1994 – 2007 (start siting -> beginning of pre-licensing)

- Determination of critical nuclides based on common radionuclides in lists of other countries.

  => list of 20 critical radionuclides for long term safety

from 2007

- Determination of critical nuclides based on the inventory

  => 39 nuclides “important for long term safety”,
  of which 28 are critical *(10 new compared to 1994)*

WACs=Waste Acceptance Criteria

Evolution of radiological WACs for cAt

Radiological limitations

until 1994

- some (operational) limitations for some nuclides

1994 - 2017 (start siting -> end of review 1st license application)

- Radiological criteria use a weighted sum of activity levels
- <15g fissile material

from 2017 (from 2nd license application)

- Absolute activity limits on 28 critical nuclides
- <50g fissile material if enrichment <5%

Physical-chemical WACs related to cAt long term safety

- Specifications in the 90s:
  - Toxic waste & lead to be packaged separately
  - Aluminium: <10kg/conditioned waste package
  - No putrescible materials
  - Complexing/chelating agents to be identified & quantified
  - No free liquids

  - Some criteria on quality of cementitious matrix
  - No interactions between waste & matrix (e.g. no direct contact with Al)
  - Leachability: indicative test

Physical-chemical WACs related to cAt long term safety

- WACs ~1999

  Additional:
  - Cellulose < 10kg/conditioned waste package
  - Composition of waste+matrix to be given
  - <20% free space in conditioned waste package

- WACs >2017

  Major change:
  - Cellulose: < **200g**/conditioned waste package

  Additional:
  - Chlorides: <0,4wt% of mass of cement in conditioned waste package
  - Water soluble sulfates: < 12g/kg wasteform
  - ASR/DEF: both cementitious waste and matrix should be insensitive
  - Mass of hardened concrete > 10wt% of mass of conditioned waste package
  - Conditioning matrix should fill 85% of free space around waste

Evolution of the cAt project - conclusions

- Surface disposal project experienced a lot of changes over a timespan of ~30 years, with still major changes after 1st license application.
- Changes are related to all aspects of the project:
  - Siting
  - Societal support
  - Safety file: evolution scenarios, methodology & hypotheses
  - Radiological and physical/chemical criteria ⇒ need for detailed characterisation
- Changes were driven by:
  - Society & government
  - Regulator
  - Evolution of scientific knowledge
  - Strategic choices by ONDRAF/NIRAS

SF Knowledge management

Status political decision for long term management

- 28/10/2022: political **decision** on '**deep disposal**' for the long-term management of high level and long-lived radioactive waste.
- No decision on the modalities: nor the 'how', the 'where' and the 'when' is decided.

➔Timings and research remain **generic**

➔**Impossible** today to **define acceptance criteria** with respect to the disposal of spent fuel

SF Knowledge management

Future needs

- 3 aspects with future need for data on Spent Nuclear Fuel:
  - Safeguards
  - Operational safety
  - Long term safety

  All three should be coherent, though level of detail, need, uncertainties, etc. can differ

- Complete characterization of the fuel assumes following input:
  - Calculation codes
  - Nuclear Data
  - Fuel and operational data

How to handle this aspect?

1. Perform complete characterization as soon as possible so that data and codes become obsolete: REX surface disposal project
2. Central database with at least all necessary information to perform characterization of the fuel = preferred solution

ONDRAF/NIRAS

REX from other countries

SF knowledge management

COMMON APPROACH

1. Storing and preserving SNF data:
   - Characteristics of the SNF and operation details
2. Coupling with calculation codes
3. Implementation of measurement and inspection results for validation of characteristics
4. Assure complete workflow of SNF for storage and disposal

Spain

US

Sweden

Finland

➔ Status depends on the progress of the national program

Synatom ONDRAF/NIRAS

Conclusions and difficulties

SF knowledge management

Conclusions

- 3 aspects with future need for data on Spent Nuclear Fuel:
  - Safeguards
  - Operational safety
  - Long term safety

  All three should be coherent, though level of detail, need, uncertainties, etc. can differ

- Complete characterization of the fuel assumes following input:
  - Calculation codes: **on an international level**
  - Nuclear Data: **on an international level**
  - Fuel and operational data: **on national level (operators, WMO, government)**

- **Consensus on the need of a central database**
- **Next step is identification of data types needed and level of detail**

SF knowledge management

Difficulties in constructing a centralized database

- Uncertainties on future needs:
  - Very long timeframes:
    - Conditioning between 2066 – 2080
    - Acceptation by ONDRAF/NIRAS not before 2066
  - A lot of changes to be expected over such a timespan
  - Changes can be driven by external stakeholders

- Uncertain nuclear situation

SF knowledge management

Difficulties in constructing a centralized database

- Available data and format of data evolved over time
- How much/which data should be stored?
  → 'As much as possible' vs 'what is reasonable'
- How to treat certain existing data
  - *e.g., is BU primary data or calculated?*
- Should calculation codes be coupled? And if yes, how to keep them up-to-date?
- Should the data be validated?