Radioactive waste management in France, safety demonstration fundamentals

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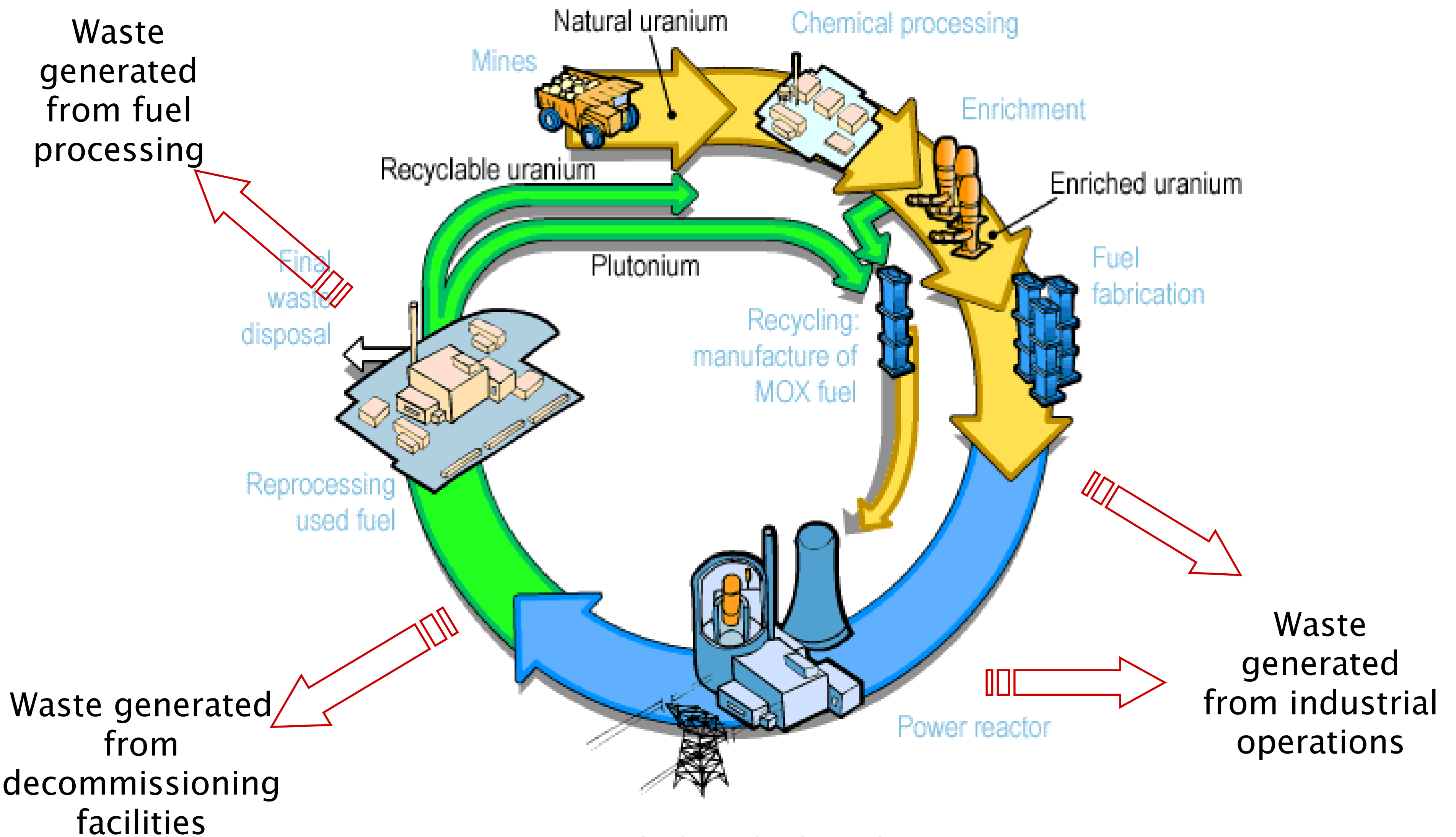
The nuclear fuel cycle



The French classification

Short-lived waste
Period ≤ 31 years

Long-lived waste
Period > 31 years

Very low level

Low level

Intermediate level

High level

Waste from dismantling operations (CSTFA in France since 2003)

Graphite, radium-bearing waste
(Studies stage in France)

Waste mainly from day-to-day operation of NPPs
(CSFMA in France since 1992)

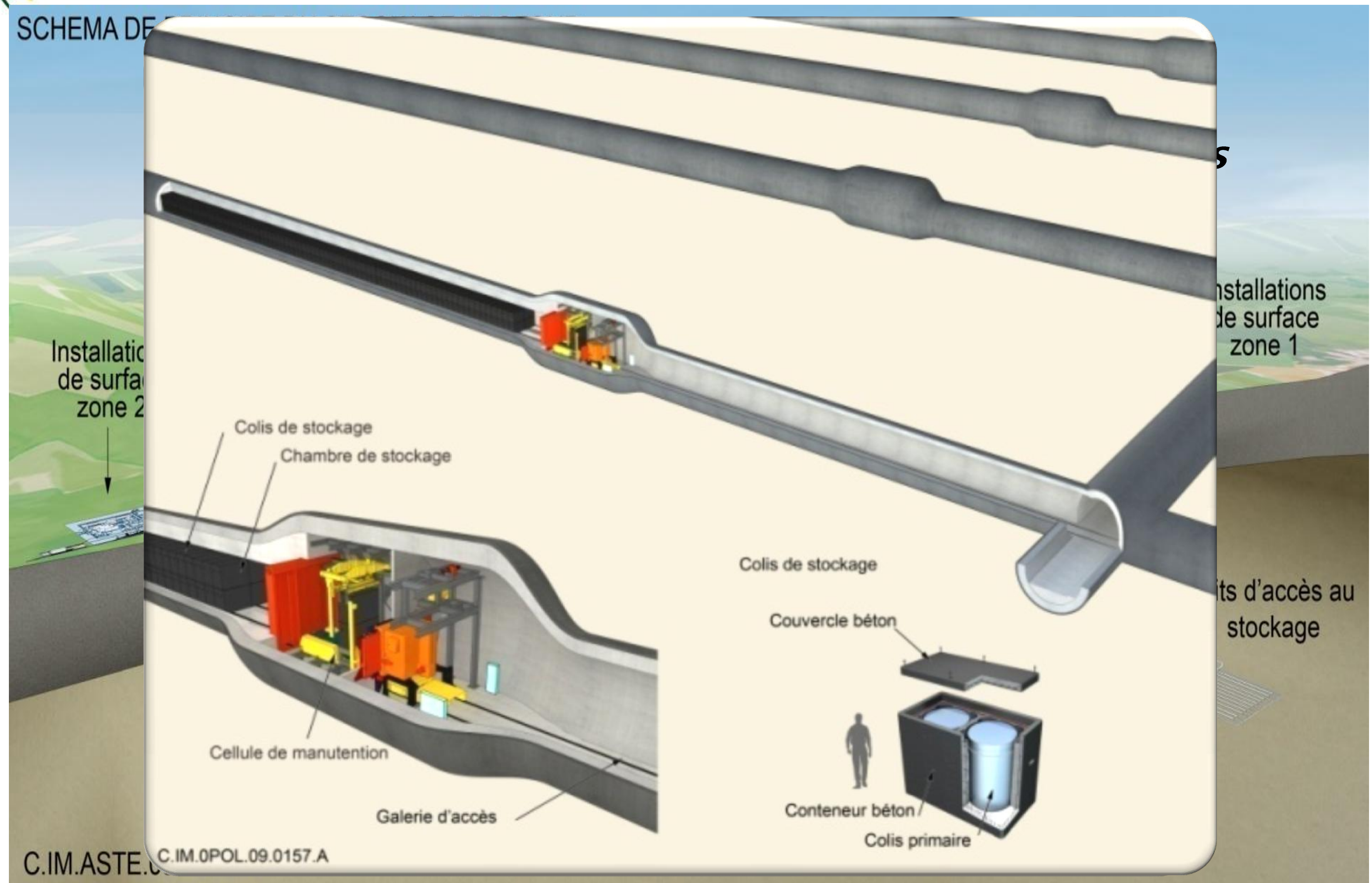
Waste from SF reprocessing plants
(Geological disposal facility in France to be commissioned in 2025)

HL vitrified waste : after reprocessing & cooling,

Centre de stockage de l’Aube, LIL-SL waste

ANDRA
La maîtrise des déchets radioactifs

The Cigéo Project
(*Centre industriel de stockage géologique*)

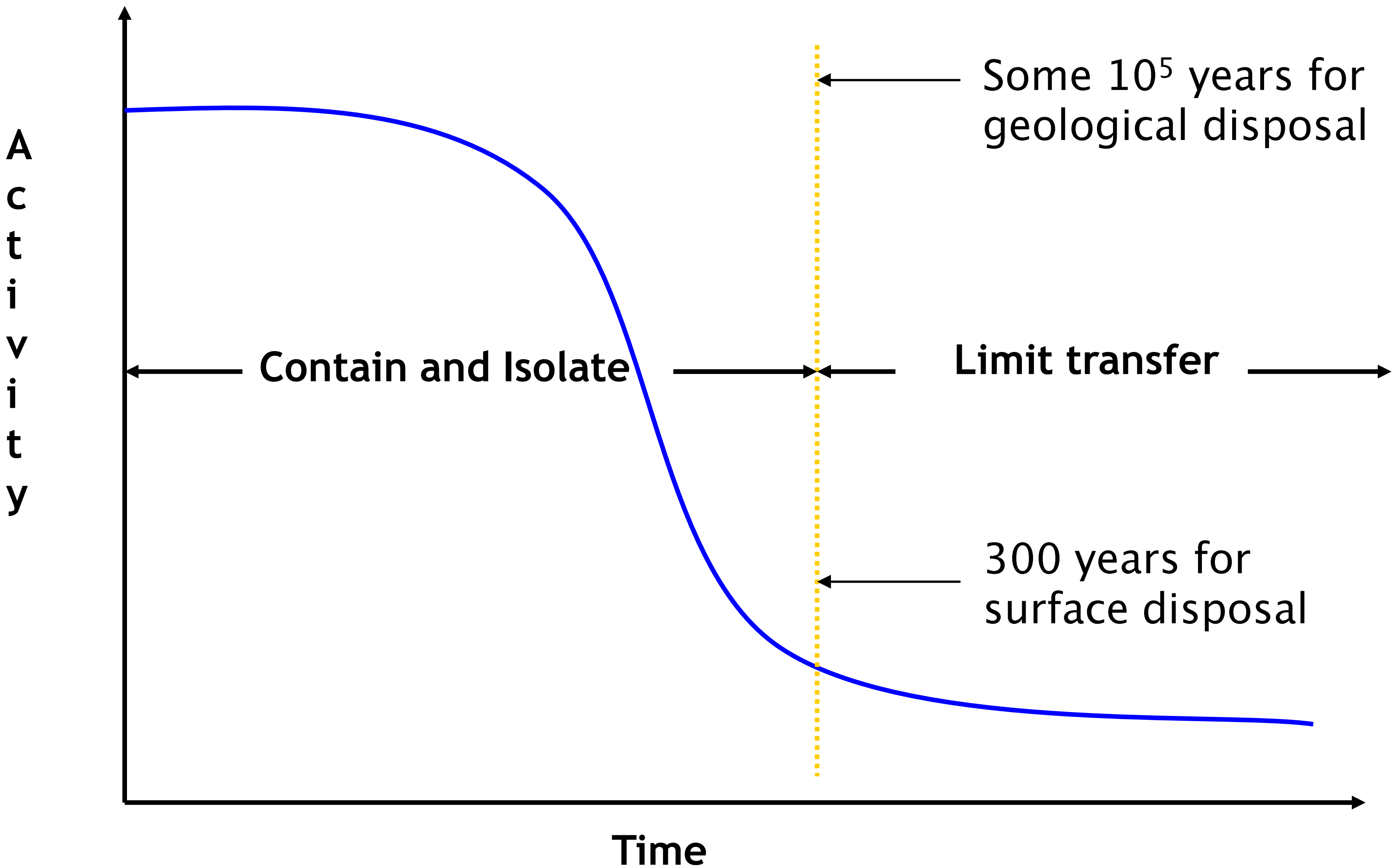


A common concern

- **Protection of human beings and the environment**

- **Immediate and long term protection**

Strategy for management



Specificities of disposal safety cases

- No feedback or reference from already existing experience for long-term radioprotection concerns
- Timescales to be considered which extend beyond human experience
- Consider the different life phases of a repository in a coordinated and consistent way (i.e. operation, and post-closure)
- Integrate in a consistent framework all the available information, including waste characteristics, technical design, site data and scientific knowledge to perform safety assessments
- Manage THMCR uncertainties especially for the post-closure phase

Long timescales

Main challenge for the development of the Post-closure safety case

- All physical processes likely to occur over time can be described, modelised and analysed
  - *Waste characteristics evolution*
    - » heat generation, dose generation, activity decrease..
  - *Engineered components degradation*
    - » Long term behaviour
  - *Geodynamic evolution in known conditions*
    - » erosion, climate change, seismic..
  - *Radionuclides release and migration…*

- Many events may however occur, especially when dealing with very long periods
  - + *Human intrusion*
  - + *Climate change and consequences on geodynamic evolution*

↳ High standard of reliability in the safety case

↳ Understanding and description of the sequence of events and processes likely to occur over the lifetime of the repository

Safety: two main Objectives for All Disposal Facilities

- **Protection of human beings and the environment**
  - assessment of the radiological and chemical impact of the disposal facility
  - monitoring of facilities and of the environment

- **Immediate and long term protection**
  - notion of present and future with timescales consistent with the lifetime of radionuclides
  - Impacts assessed over a longer or shorter timescale depending on the nature of the waste involved and, consequently, on the related disposal facility

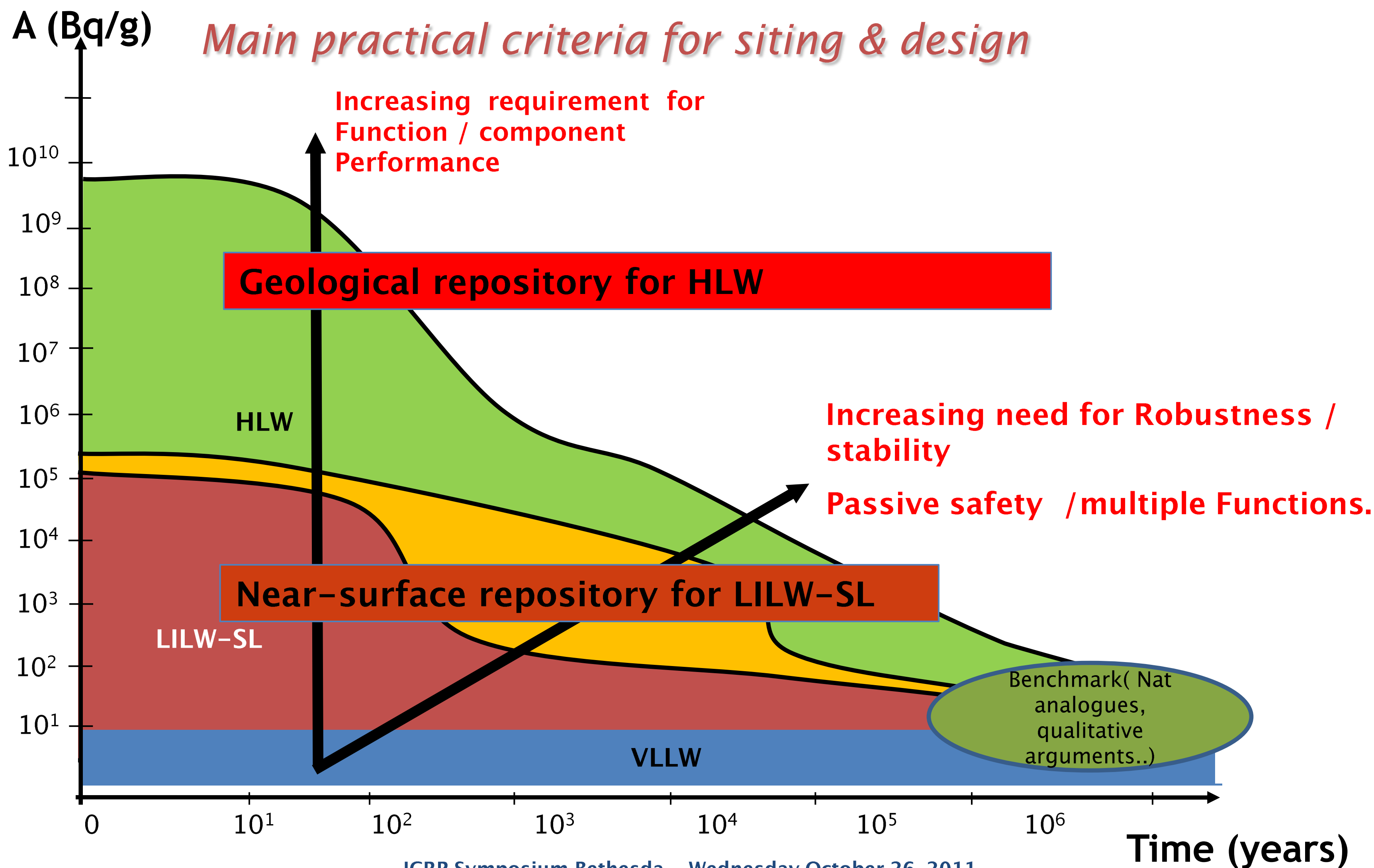
General objective of the disposal design

The repository is designed according to the site and wastes characteristics

- suitability to accommodate with the radioactive and the toxic inventories
- designed to meet requirements defined according to the type of waste
- allowing the decay of the activity contained in the disposed waste packages in order to reach a residual level that may potentially cause acceptable exposures to humans and the environment
  - Whatever the scenario envisaged

Disposal solutions suited to residual radioactivity

Will depend on the radioactive inventory and thus on the involved timescale



Basic principles

- Post-closure: « Passive Safety »
- Robustness of the disposal concept
- Demonstrability

→ Best possible usage of multiple arguments (qualitative reasoning, safety calculations, analogies, experiments, technical demonstrators)

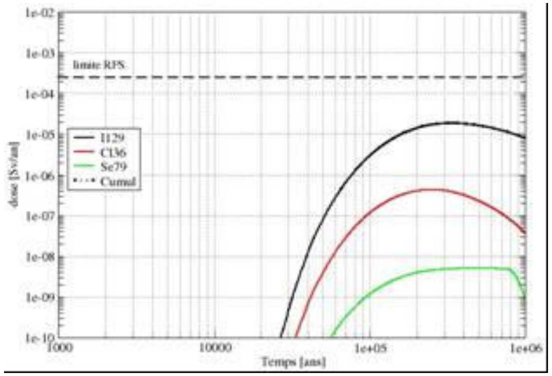
Protection of human beings and the environment understood, above all, as a protection against the specific risk linked to radioactive waste:

- Radioactivity and its induced effects
- Normal situation: equity between generations
  - ☐ 0.25 mSv/year as a fraction of dose limit for the repository's operating and closure periods
- Altered situations
  - ☐ No fixed constrained value, calculated impact according to
    - » likelihood of the events (intrusion..) ,
    - » chronic or timely character of the exposures,
    - » degree of pessimism of the calculation assumptions

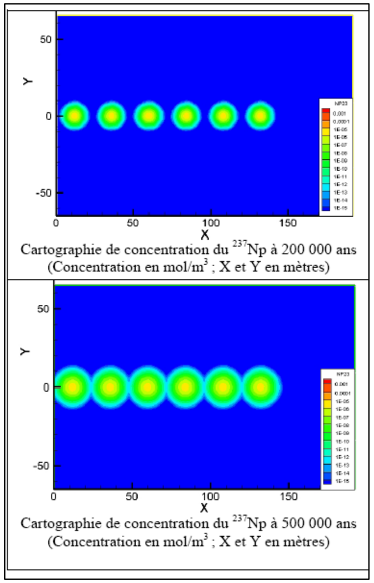
According to regulatory safety guidance 2008, the first 10,000 years will be the subject of a special attention (since the stability of the site must be demonstrated); the 0.25-mSv/y threshold constitutes a reference.

Compliance with Protection objectives

- **Radiological impact assessments :**
  - to verify compliance with dose constraints



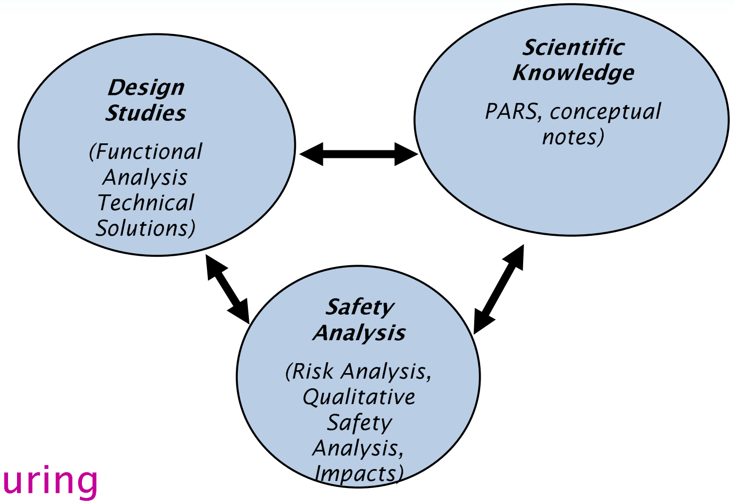
- **But safety verified with complementary indicators assessments.**
  - to verify performance (concentration, RN fluxes, water flows, ….)



Cartographie de concentration du ^{237}Np à 200 000 ans (Concentration en mol/m^3 ; X et Y en mètres)

Cartographie de concentration du ^{237}Np à 500 000 ans (Concentration en mol/m^3 ; X et Y en mètres)

A multidisciplinary process with a strong integration need

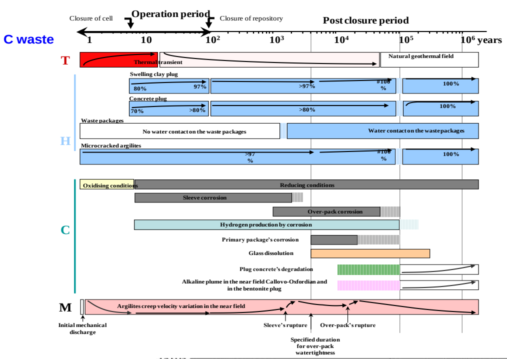


Functional analysis

- Identification of safety functions

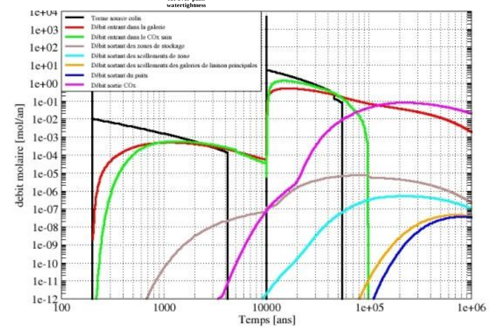
Phenomenological analysis (PARS)

- Phenomenological evolution of a repository during its lifetime
- Identification of uncertainties



Safety analyses

- Handing of uncertainties
- Scenario defined for safety-calculation purposes
- Quantification of indicators *(complementary indicators and dose)*



The importance of scenarios 1/2

- Favour simple representations of processes in order to facilitate the interpretation of results

  - ☐ Normal-evolution scenario corresponds to the likely chronological and spatial evolutions of the repository

  - ☐ Altered evolution scenarios take into account uncertainties on understanding as well as on external events
    - + *Container/over-pack failure*
    - + *Seal failure*
    - + *Intrusive borehole drilled through the repository*
    - + *Heavily degraded operation (all safety functions are set at a more pessimistic level than normally expected, i.e. COX permeability, etc)*

  - ☐ Both type of scenarios include sensitivity cases

BUT

Not to predict the impact
because of uncertainties and envisaged timescales

- To evaluate the repository impact upon conservative assumptions
- To verify the performance of the three safety functions by using relevant indicators (e.g., Péclet number, molar-flow rate, transfer pathways, etc.).
- To evaluate the dose impact, at the end

The place of the biosphere

Constitutes the last step in modelling the transfer of radionuclides and chemical toxins towards “human beings” and to further determine their impact.

- Various links in the food chain are considered for that purpose.
- A common topic in the different safety cases addressed by Andra whether they refer to existing surface waste disposal facilities or future projects.

No safety function given to the biosphere.

The place of the biosphere

- Andra's strategy and approach for description and modelling of the biosphere is based on
  - the BIOMASS project
  - international practices
  - Past Andra exercises (D2005, CSM safety report..) and reviews by the IRSN

- The IAEA BIOMASS was adapted by Andra
  - To be applicable to both surface and deep geological repositories
  - To refine the different steps of selection and conceptualisation
  - To consider the different life phases of a nuclear waste disposal facility,
  - The selection of typical biosphere to be modelled
  - To consider the activities of the potential exposed population groups.

Conclusions

- **Experience is available for low and intermediate-level radioactive waste disposal solutions**
- **There are no reference on geological repositories for high-level and intermediate level long-lived wastes**
- **Safety is build from the general knowledge and the common sense**
  - Tools are specifically developed to integrate all the information and to assess the future behaviour and impact of the disposed of radionuclides
- **Thorough and high quality physics are used to demonstrate how safety can be achieved**
- **Given the timescales to consider, only a full set of approaches may contribute to convince**