Low and Intermediate Level Waste Management

CSA example

Julien Recarte, CSA Safety Department

Scientific seminar in the framework of « Paldiski » project »
CSA, 17/11/2015

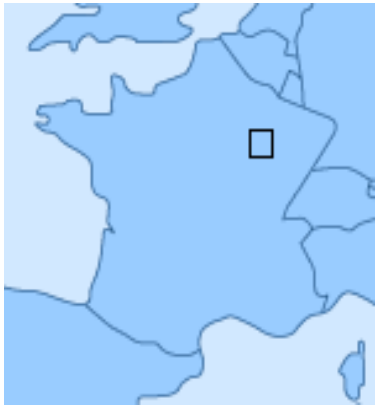
Summary

1. CSA general overview, capacity and characteristics
2. Waste disposal concept
3. Installations of the disposal facility
4. Waste packages
5. Safety cases
6. Waste acceptance criteria
7. Waste package authorisation

1. General overview, capacity and characteristics

1. General overview, capacity and characteristics

- Type of facility: Basic Nuclear Installation
- Area: 95 hectares including 30 reserved for disposal
- Industrial start-up: 1992
- Operational period: 60 to 70 years, then monitoring period of 300 years



1. General overview, capacity and characteristics

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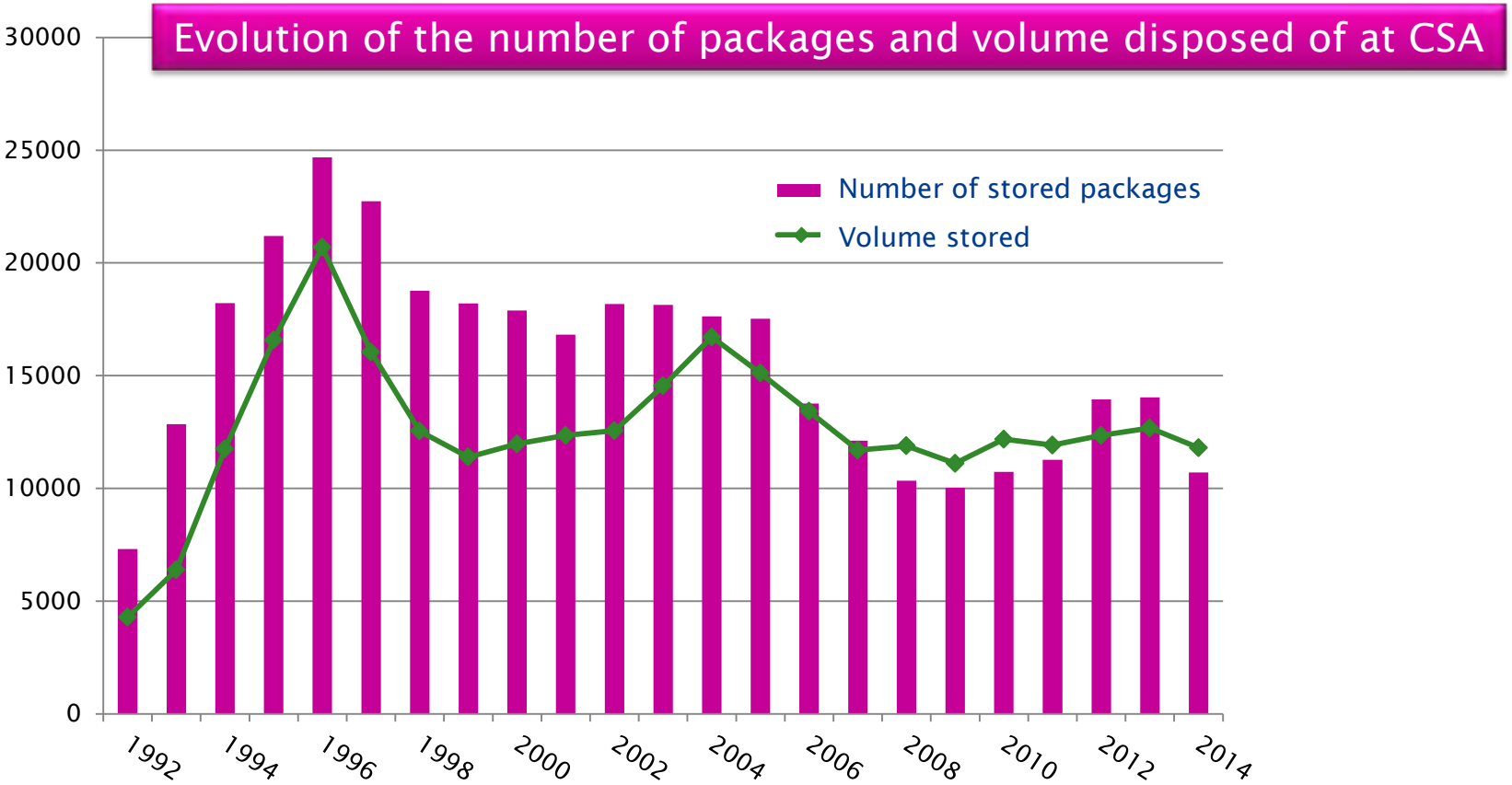
- Disposal capacity: 1,000,000 m^3
- Annual average volume: 12,000 m^3 of waste packages disposed of, or 30,000 waste packages
- About 400 disposal vaults foreseen

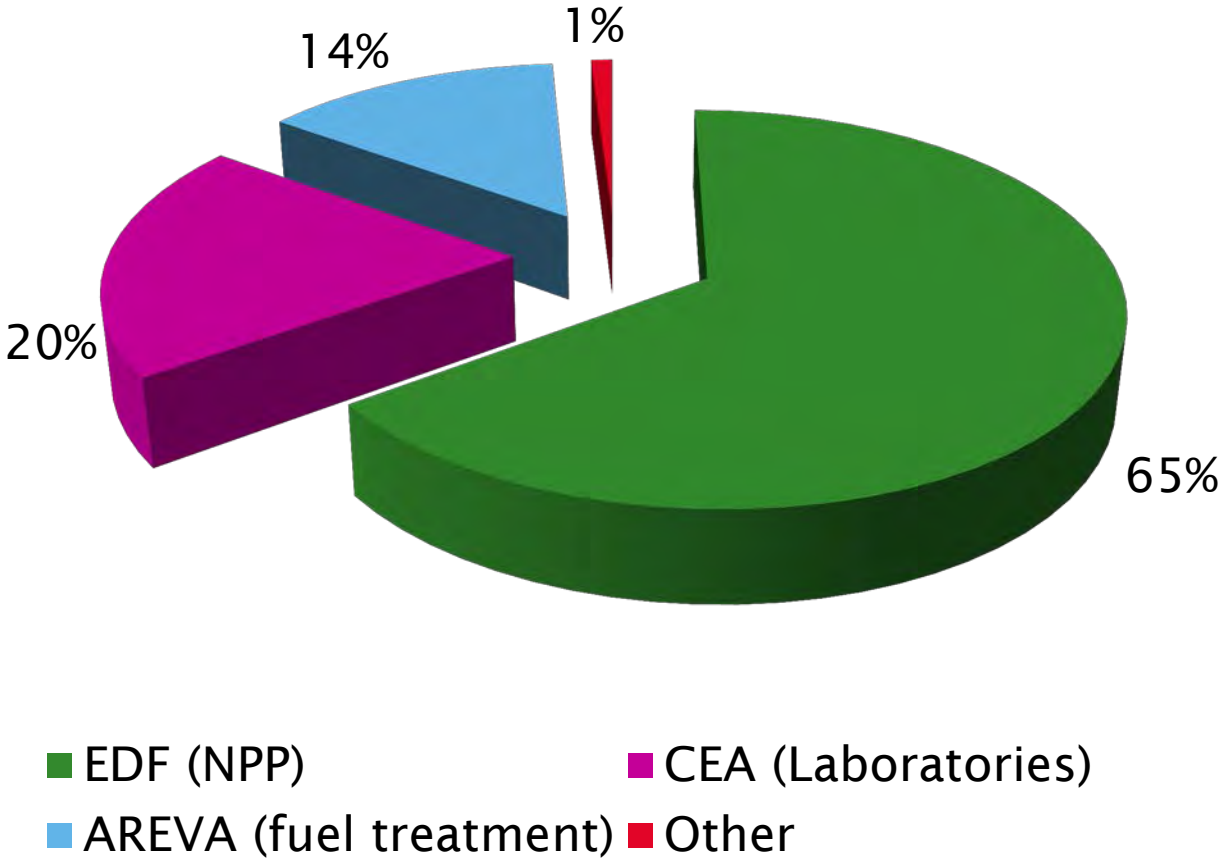
At end of December 2014:

- 291,975 m³ disposed, equivalent to 29,2% of the total capacity



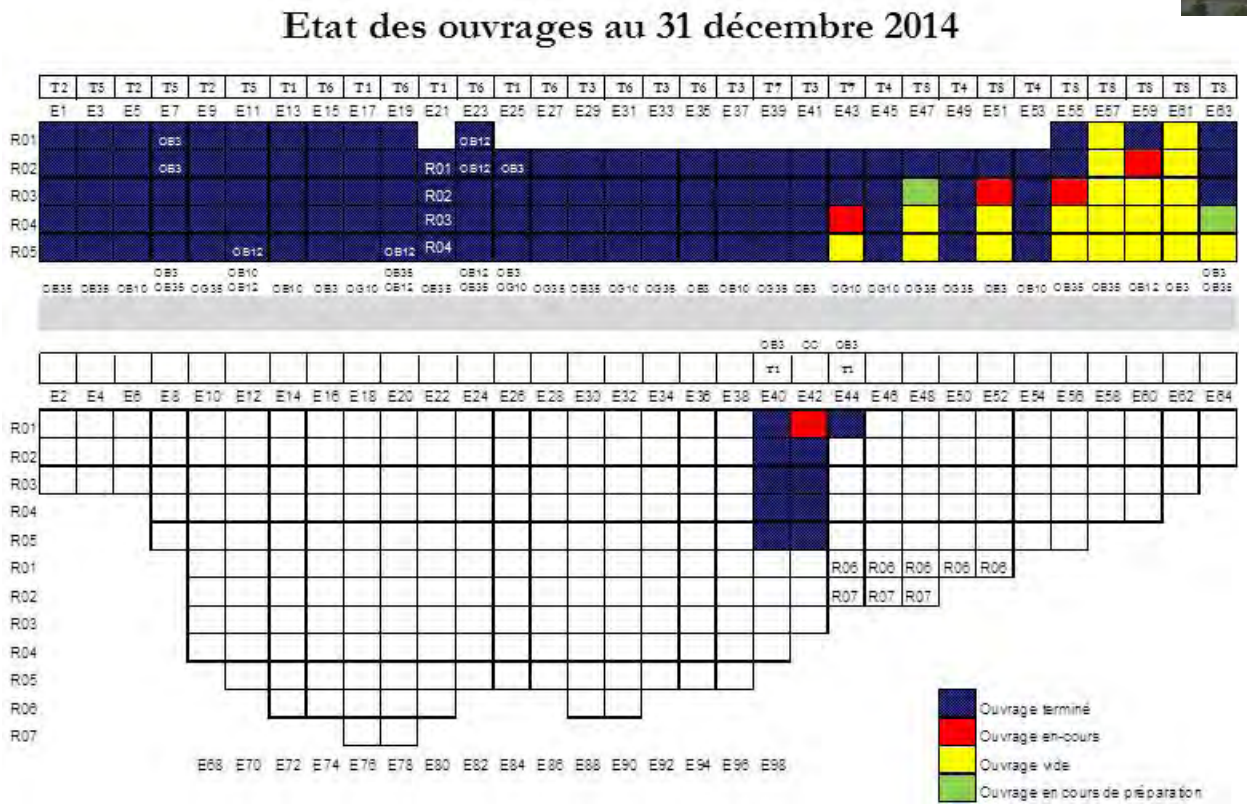
1. General overview, capacity and characteristics

Waste origine in volume (year 2012)



At end of December 2014:

- 127 closed vaults
- 5 operating vaults
- 2 vaults under preparation
- 21 built vaults waiting for operation



2. Waste disposal concept

"Multi-barrier concept"

2. Waste disposal concept

Safety objectives

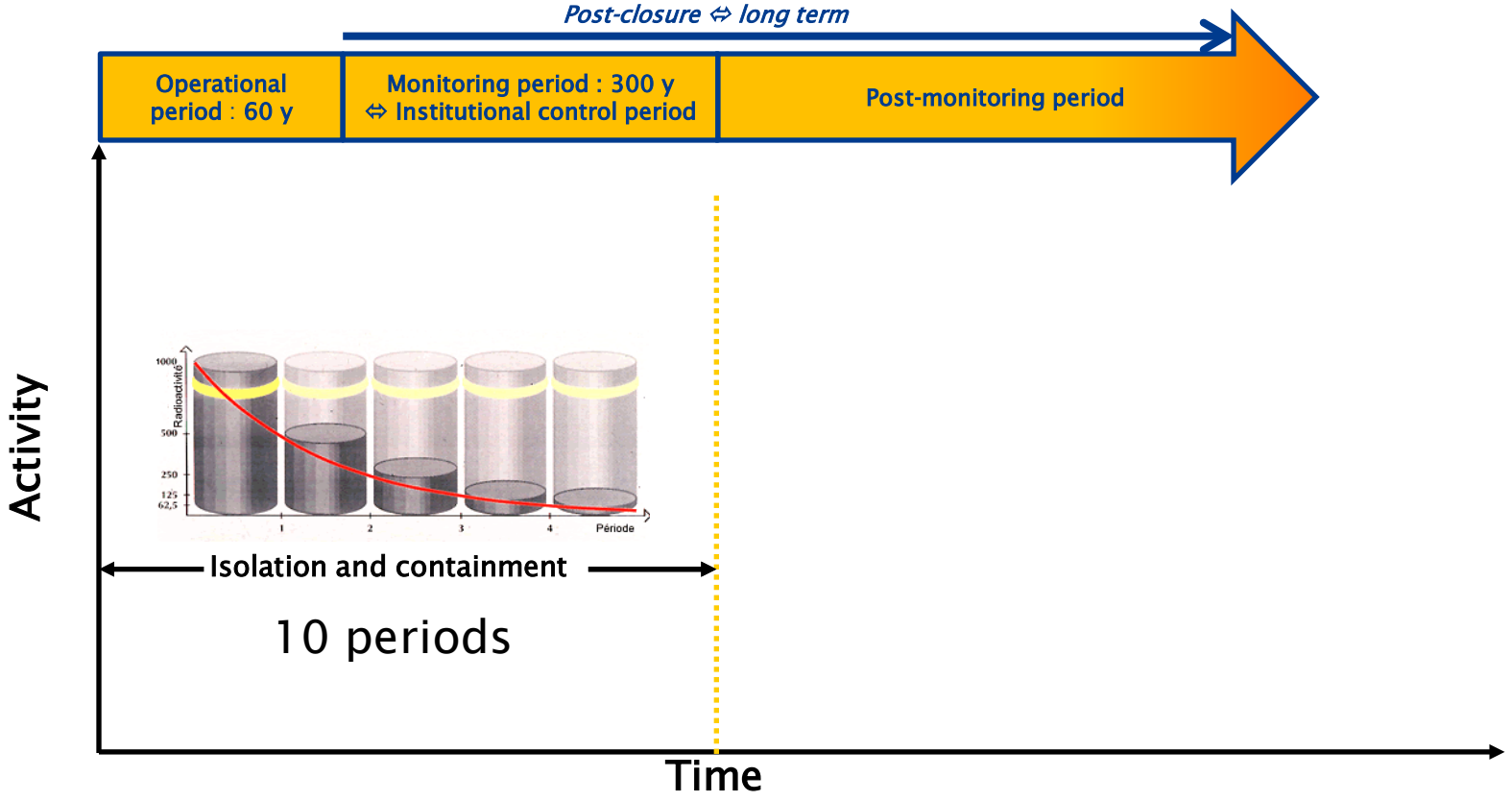
- CSA waste disposal must respect two fundamental safety objectives defined by regulation and applicable to any radioactive waste surface disposal facility. These objectives are:
  - Immediate and deferred protection of the population and the environment
  - Limitation of the required monitoring time to 300 years after delivery of the last waste package

This implies a limitation of long-lived radionuclides to limit the long-term impact to the period of 300 years

2. Waste disposal concept

Limit the spread of radioactive materials into the environment through three containment barriers:

- Waste package
- Disposal vaults
- Geological formation (site geological characteristics are specific)

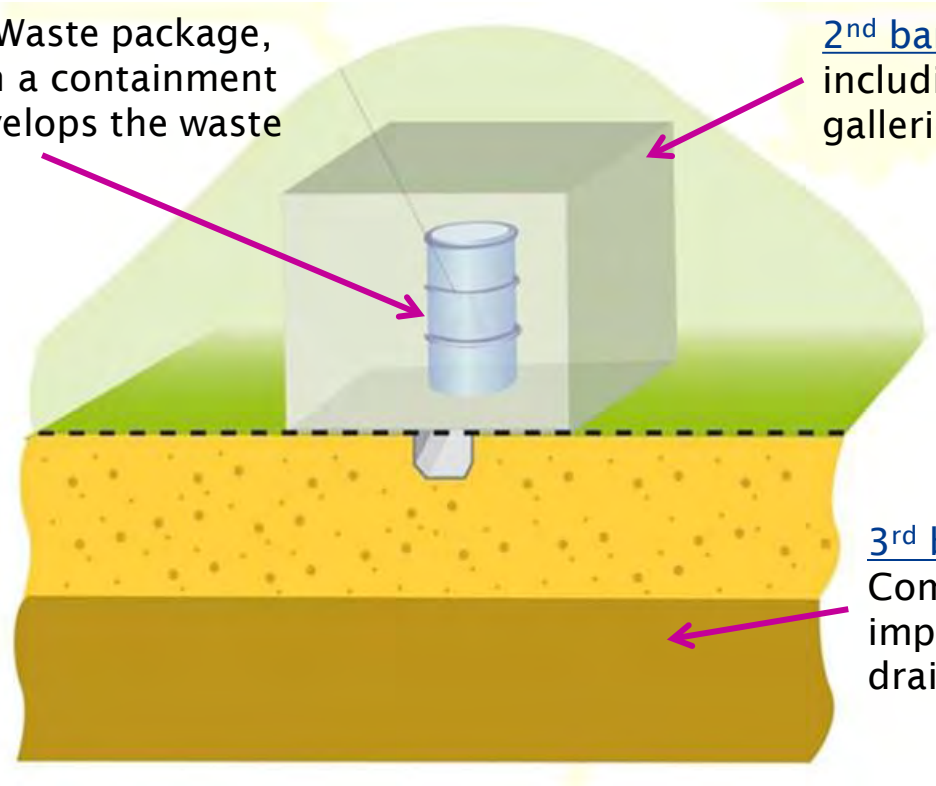


2. Waste disposal concept

The principle of CSA disposal is to confine radioactivity and monitor containment while radioactivity decreases to such a level that there is no more significant radiological risk (after 300 years LILW activity is roughly divided by 1000)

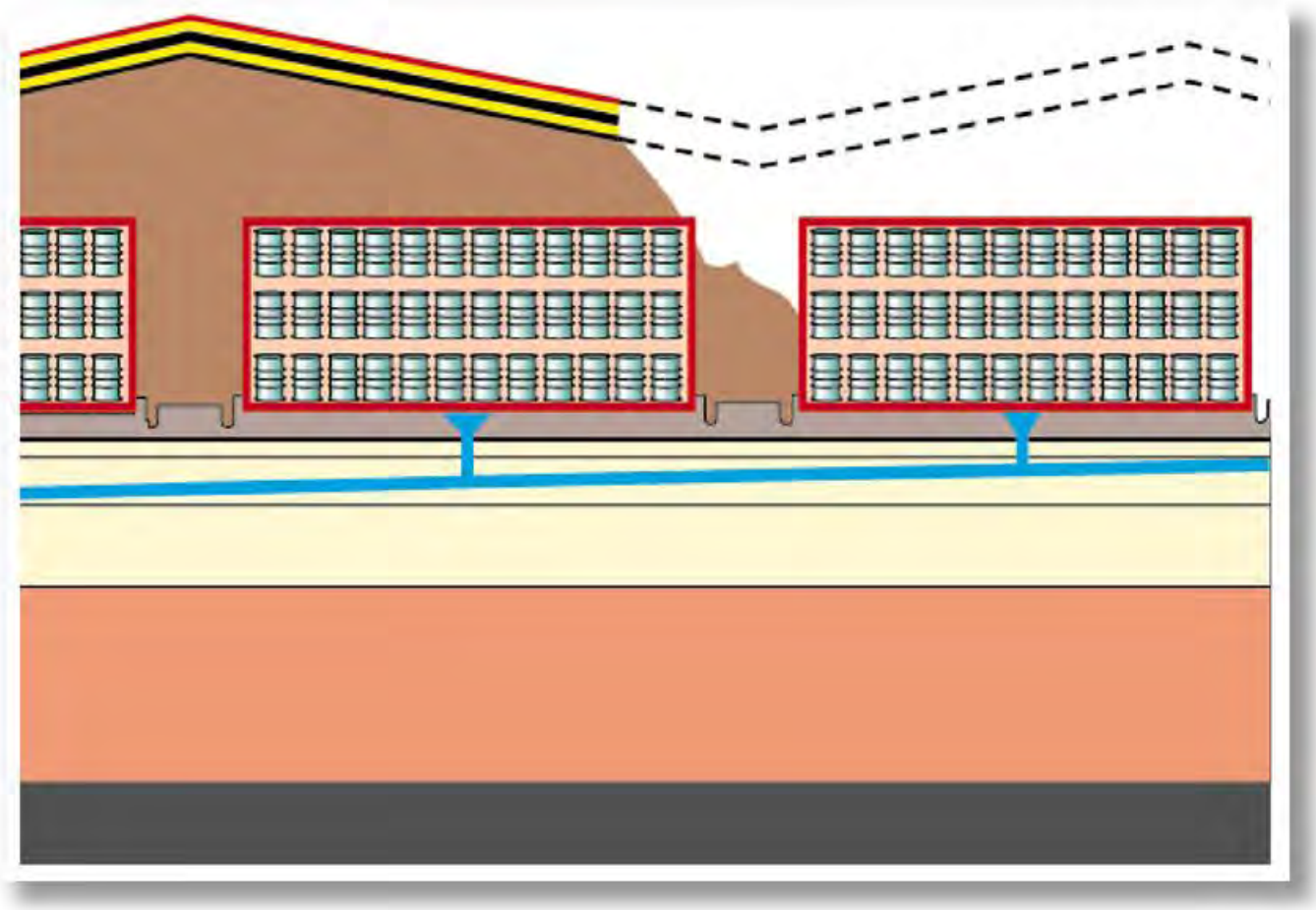
1st barrier : Waste package, within which a containment material envelops the waste

2nd barrier : disposal vault, including the network control galleries (RSGE) and final cover



3rd barrier : The geological environment Composed by a natural barrier of impermeable clay layer topped by a draining sand layer

2. Waste disposal concept



Final cover

Vaults

Underground galleries, water collection network

Draining layer

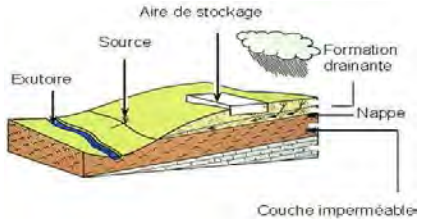
Impermeable layer

Deep layers

2. Waste disposal concept

Geological barrier – 3rd confining barrier

- Protection during operation and monitoring / post-monitoring phase against the effects of water dissemination
  - Geological and hydrogeological features limiting and controling the possible transfers of radioactive materials in the soil
  - Deliver radionuclides to an identified outlet (eg: the Noues d'Amance river)



- Criteria for site implementation
  - Absence of natural hazards (earthquakes, floods, volcanoes, etc.)
  - Absence of natural resources of interest
  - Have certain hydrogeological and geochemical qualities enabling to limit the flow of radionuclides and toxic materials likely to reach the outlet and being transferred to humans

2. Waste disposal concept

Disposal vault – 2nd confining barrier

- Protection against the effects of external radiation exposure
  - Limit the exposure of workers and public
  - Reduce the dose rate in contact with the vault walls

- Protection against the effects of water dissemination
  - Protect waste from rainwater infiltration
  - Isolate waste from telluric water
  - Limit the release of radionuclides through the vaults
  - Direct the water seeping into the vaults to the underground water collection galleries' network

2. Waste disposal concept

Waste package – 1st confining barrier

- Protection against the effects of external radiation exposure
  - Limit the exposure of workers and public
  - Reduce the dose rate in contact with package
- Protection against the effects of water dissemination
  - Protect waste from rain and telluric water
  - Limit the activity likely to be released
    - Limit the initial activity
    - Immobilize waste
- Protection against the effects of air dissemination
  - Limit the risk of waste dispersion (mainly in case of package drop)
  - Limit the gaseous releases

3. Installations of the disposal facility

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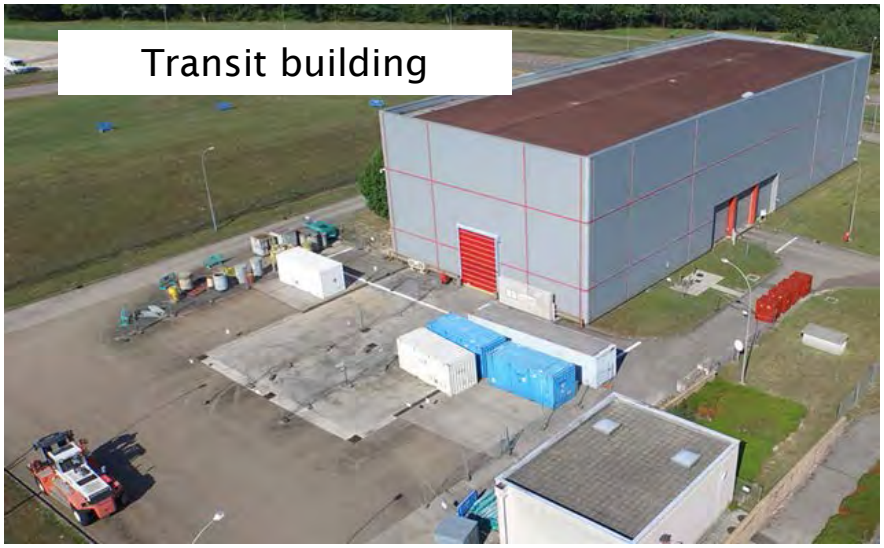
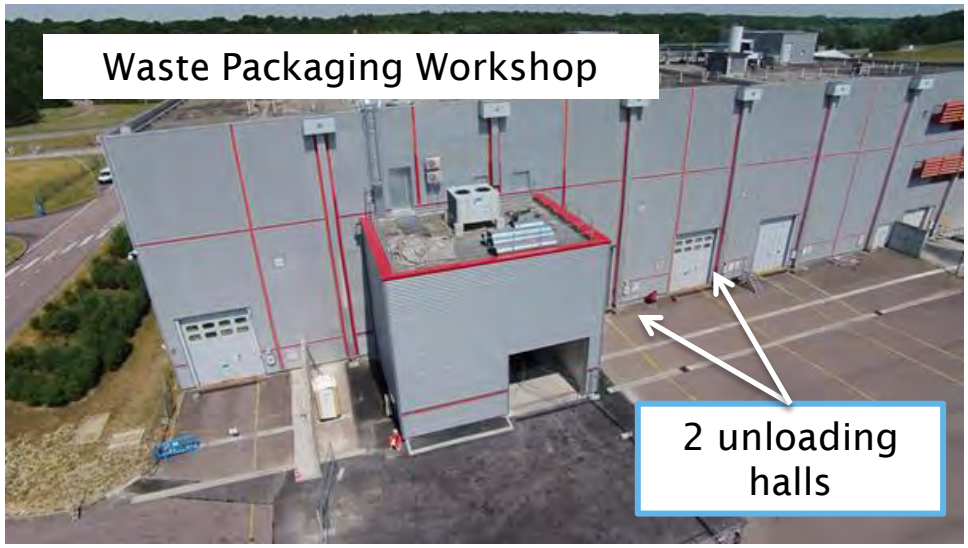
Package delivery by shipping containers or sheeted trailers

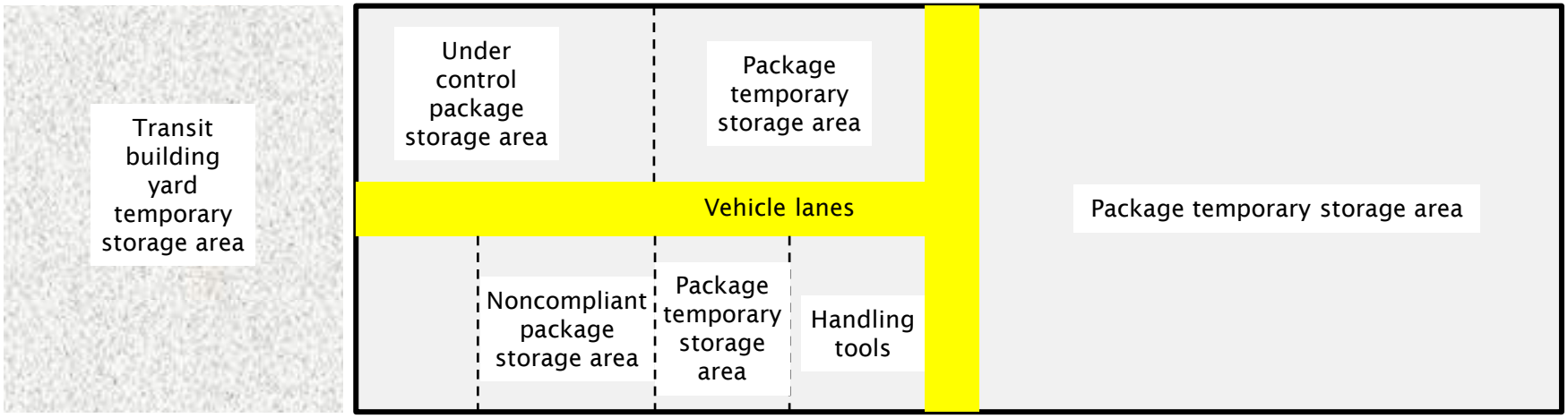
After delivery controls, the waste package can be held in the Transit building yard or unloading at the Waste Packaging Workshop





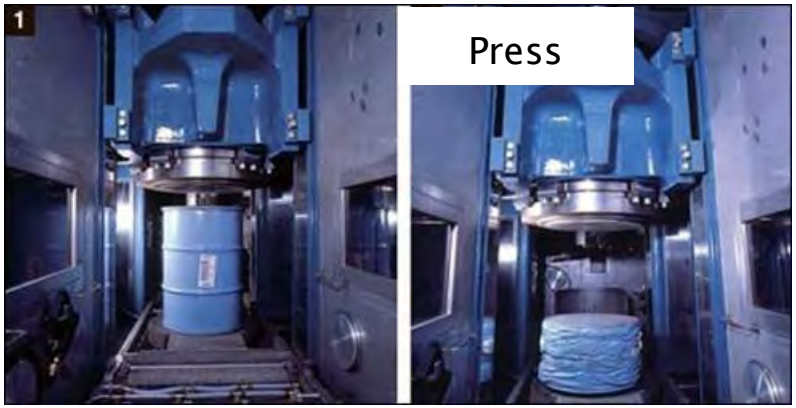
3. Installations of the disposal facility

Transit Building activities & organisation



Waste Packaging Workshop: Compaction area

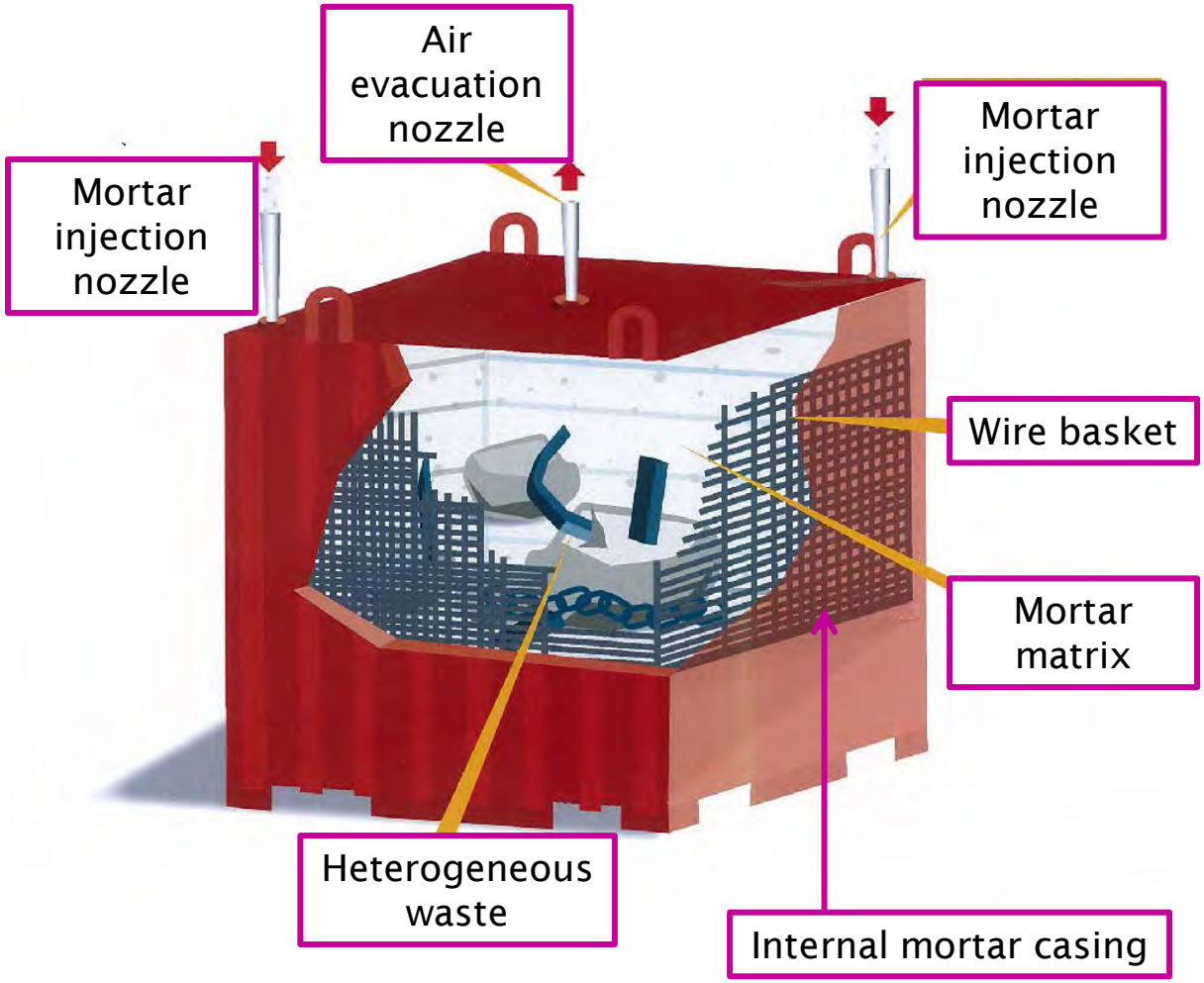
Stacker crane



Drying area

Bridge perch

Waste Packaging Workshop: Injection area



3. Installations of the disposal facility

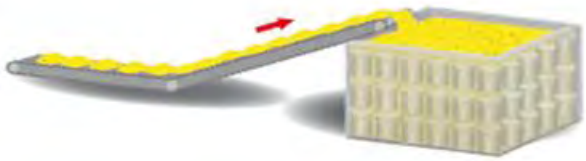
Two type of vaults:

- Concrete filled vaults
- Gravel filled vaults

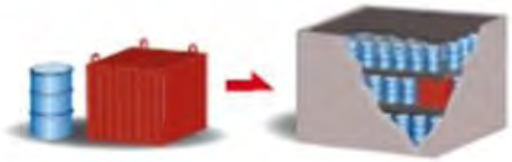
disposal operated away from rain under mobile structures

Gravel-filled vaults (OG) disposal concept

Gravelling when vault completed



Concrete-filled vaults (OB) disposal concept



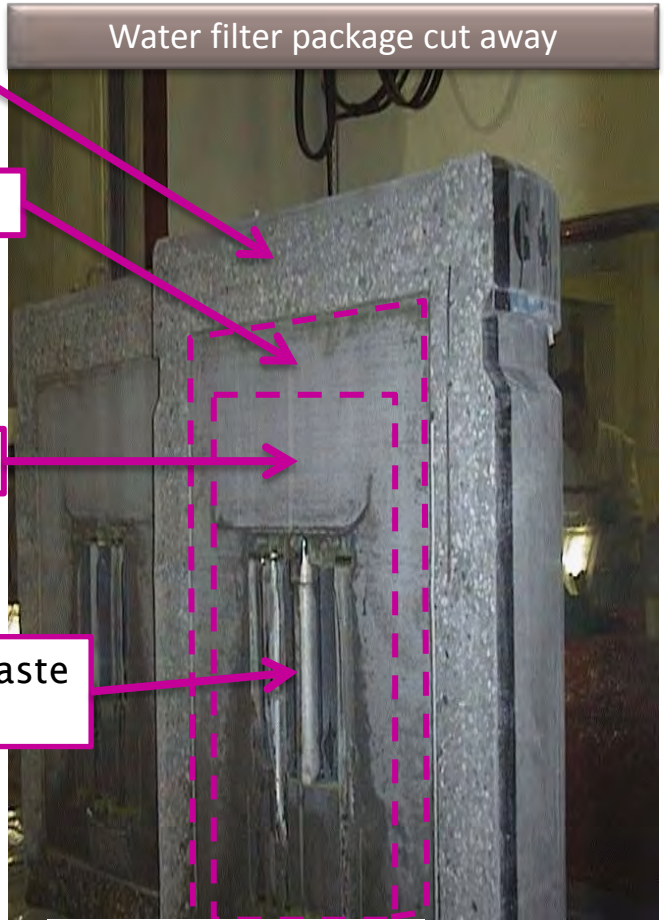
Each layer is completed with concrete when a vault level is completed

4. Waste packages

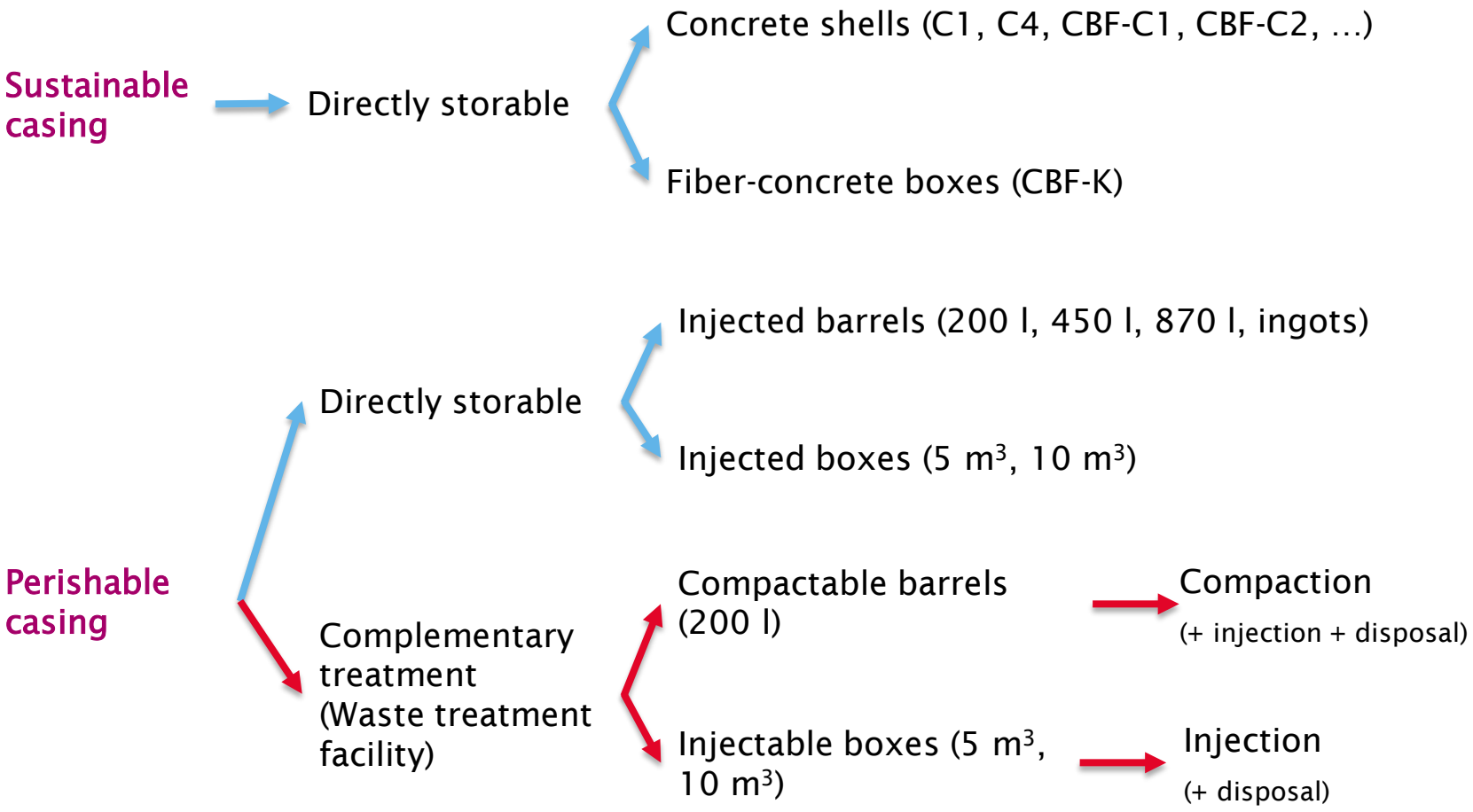
4. Low and intermediate level waste packages

Waste package is composed of the following elements:

- Waste
  - Heterogeneous
  - Homogeneous
- Casing
  - Metallic, considered as perishable
  - Concrete, sustainable and confining
- Eventual internal casing
  - Based generally on hydraulic binder (mortar)
  - Confining properties
- Matrix
  - Based on hydraulic binder, bitumen or polymer
  - Eventual confining properties



4. Low and intermediate level waste packages



4. Low and intermediate level waste packages

Casings	Package code	Pictures	disposal vaults
Metallic drums (for compaction)	12 16 19		OB 3 tons after compaction and conditioning in 450 liters casings
Metallic boxes of 5 m^3 and 10 m^3	31 – 32 71 - 72		OB 12 tons or OB 35 tons
870 L metallic drums	48		OB 3 tons OB 12 tons OB 35 tons

4. Low and intermediate level waste packages

Casings	Package code	Pictures	disposal vaults
450 L metallic drums	49		OB 3 tons
Directly disposable 200 L metallic drums	51		OB 3 tons
Steel ingots	54		OB 3 tons

4. Low and intermediate level waste packages

Casings	Package code	Pictures	disposal vaults
Graphite containing boxes	76		OB 35 tons
CBF-K fiber concrete boxes	78 98		OG 35 tons OB 35 tons
C1 concrete shells	81 91		OG 10/35 tons OB 12/35 tons

4. Low and intermediate level waste packages

Casings	Package code	Pictures	disposal vaults
C4 concrete shells	84 94		OG 10/35 tons OB 12/35 tons
CBF-C1 fiber concrete shells	88		OG 10 tons
CBF-C2 fiber concrete shells	89		OG 35 tons

4. Low and intermediate level waste packages

Unconventional waste packages :

- Reactor vessel heads (example)

Such unconventional waste is not covered by the standard acceptance criteria for disposal at the CSA: specific safety studies shall be done and approved by the French Safety Autority.

Reactor vessel head (removal, disposal and injection)

5. Safety cases

5. Safety cases

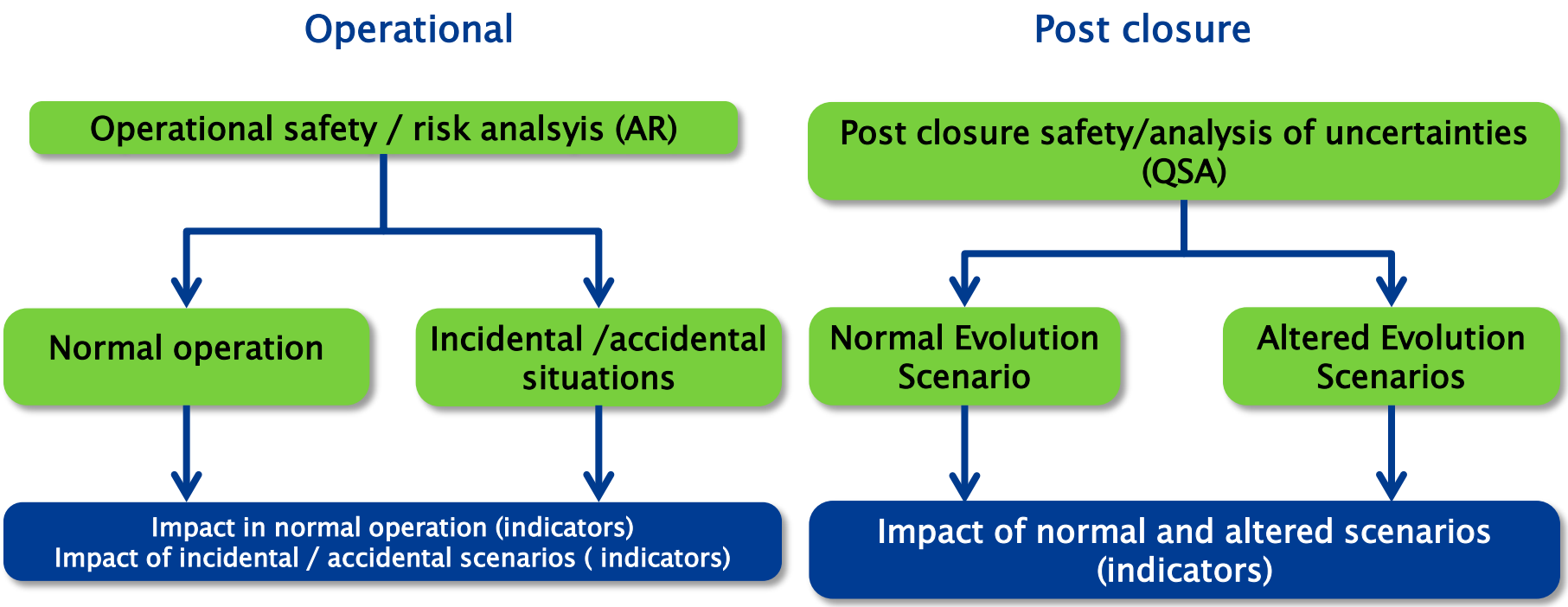
Strategy - Context

- Framework and Safety Strategy
- Regulatory framework/reference guidance

Data input – Assessment basis

- Waste package characteristics
- Site Characteristics
- Technological knowledge
- Scientific knowledge
- Description / design of disposal packages and the facility
- Functions Required (AF)

5. Safety cases



Compliance of the safety level with the objectives to be reached and as a function of the stage of the design development

5. Safety cases

Operational safety

- Step 1: Risk analysis
  - Identification of risk sources and targets
  - Definition of events
- Step 2: Prioritization of events
  - Selection of events
    - Excluded by design
    - Hypothetical
    - Design events (to be studied)
- Step 3: Identification of design situations (conservative assumptions)
  - Classification of design events
    - Operational or degraded events → Defense in depth level 1
    - Incidental events → Defense in depth level 2
    - Accidental events → Defense in depth level 3
  - Selection of penalising scenarios

5. Safety cases

Operational safety

- Step 4: Review of design situations (conservative assumptions)
  - Assessment of radiological and toxic impact
- Step 5: Design situations for internal emergency plan (realistic assumptions) → Defense in depth level 4
  - Assessment of radiological and toxic impact
- Step 6: Extreme situations (i.e. post Fukushima studies) → Defense in depth level 5
  - Identification of events following extreme situations
  - Review of extreme situations

5. Safety cases

Indicators of operational radiological and chemical impacts

- Radiological impact
  - Public
    - compliance with a dose constraint of 0.25 mSv/year in normal operation
    - punctual individual exposure can be considered as acceptable impact with the value of 10 mSv in accidental situation
  - Workers
    - 5 mSv/year in normal operation
    - 10 mSv in accidental situation
    - 100 mSv for public authorities
- Chemical impact :
  - assessment of the “individual excess risk” (ERI) and the “coefficient of danger” (QD), which gives the risk of cancer associated with chronic exposure to a toxic material
  - Constraints: ERI $<10^{-5}$ and QD <1

5. Safety cases

Post closure safety

❑ Qualitative Safety Analysis

- Explore possible uncertainties and dysfunctions of the repository components (waste package defects, seal failures,….)
- Propose design measures
- Identify scenarios to be quantified:
  - Normal Evolution Scenario (NES)
  - Altered Evolution Scenarios (AES)

By design :

- Specific or generic measures

In the definition of scenarios:

- In the normal evolution scenario (including sensitivity studies)
- Or in altered evolution scenarios (and their sensitivity studies)

Scenarios for safety analysis

- Definitions
  - The scenario is a description of a sequence of events leading to the transfer of radionuclides to the biosphere and making a calculation of possible impact .
- Two main types of scenarios
  - Normal evolution scenario (NES)
    - Covers all events considered as sufficiently certain or probable
    - is a verification step in the design and acquisition of knowledge by presenting an integrated view of disposal components with the expected functions
  - Altered evolution scenarios (AES)
    - Describe situations improbable corresponding to:
      - » *Failure of one or more safety functions of disposal*
      - » *Situations of human intrusion*
    - occurrence after monitoring period (> 350 years)

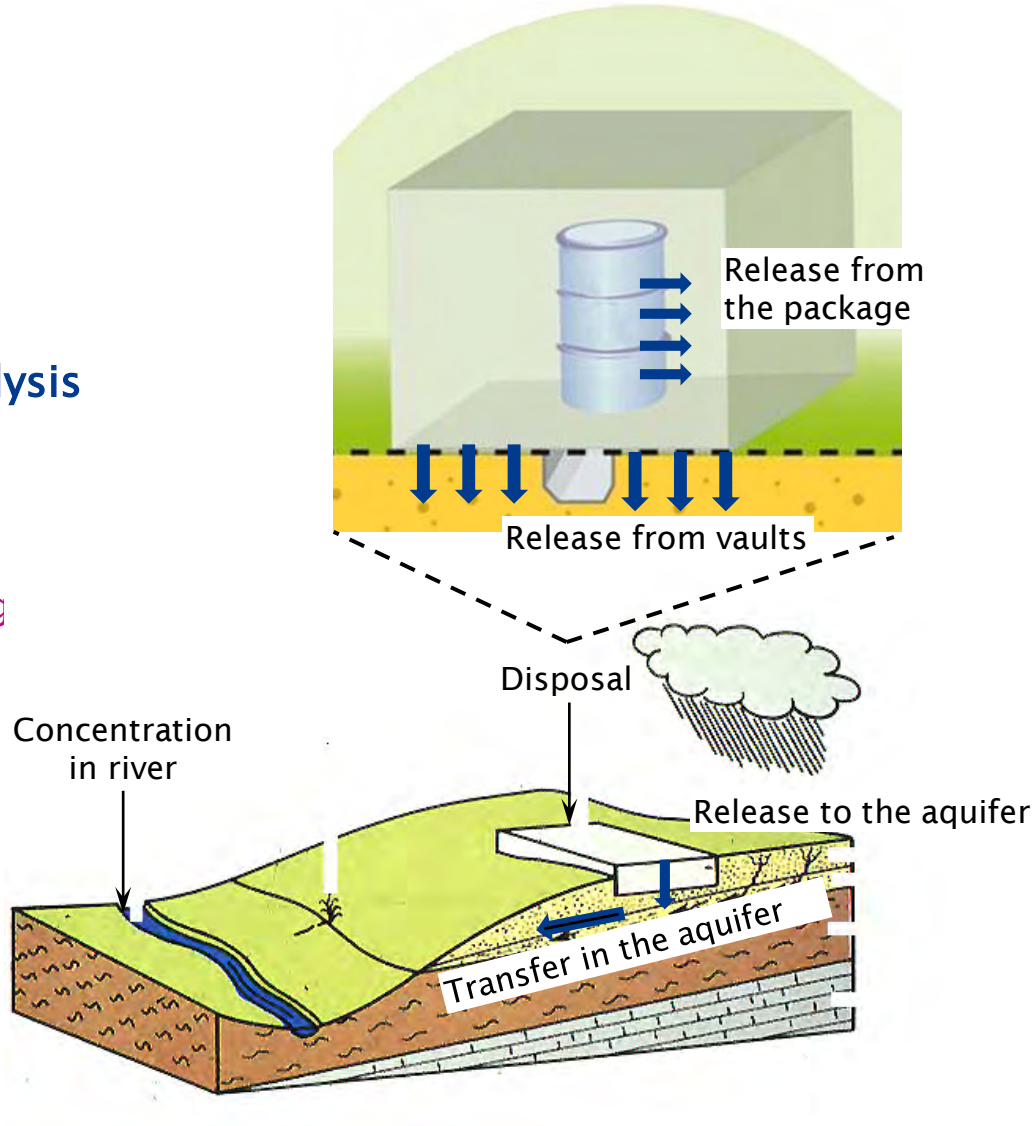
Example for modelling of water transfer pathways in normal evolution scenarios

Final indicator

- concentration of radionuclides and toxic chemicals in river

Intermediate indicators for detailed analysis of disposal behavior

- Annual activity release rate per package
  - Confining performances of each package type
- Annual activity release rate through underg water and collecting network
  - Confining performances of vaults
- Peclet number
  - Convective or diffusive flow regime
- Distribution of concentrations in aquifer
  - Spatial and temporal mapping



5. Safety cases

Altered evolution scenarios during monitoring period, examples:

- « Failure of the cover system »
- « Degradation of waste packages and vaults after implementation of the cover system »
- « Failure of underground gallery »
- « Waste packages containment failure » (cracks)
- « Rise of underground water and vaults degradation »
- « Pumping Well near the facility »

Altered scenarios after monitoring period : Inadvertent intrusions

- “Road Construction trough the site”
- “Well dug trough disposal”
- “Archaeological excavation”,
- “Residential area”,
- “Children playing on excavated material”

5. Safety cases

Indicators of long-term radiological and chemical impacts

- Radiological impact
  - assessment of individual dose engaged for a human being of a hypothetical critical group living close to the disposal
  - compliance with a dose constraint of 0.25 mSv / year in normal evolution scenario,
  - discussion on an individual basis for altered evolution scenarios based on the likelihood of the situations represented.

- Chemical impact :
  - assessment of the “individual excess risk” (ERI) and the “coefficient of danger” (QD), which gives the risk of cancer associated with chronic exposure to a toxic material
  - Constraints: ERI $<10^{-5}$ and QD <1

5. Safety cases

Safety related radionuclides in normal evolution scenario

- Monitoring
  - All disposal components are operating normally:
    - low infiltration rate from coverage
    - Packages and vaults efficient
    - Infiltrated water flow partially headed towards RSGE
    - No intrusion
  - Only uncaptured RN can reach the groundwater and the river
    - H3, Fe55, Tc99, Mo93, I129, CL36
    - Very little impact

- Post-Monitoring
  - Assumptions
    - Infiltration equivalent to the natural recharge of the aquifer
    - Vaults and packages under degraded detrital form
    - RSGE closed, residual RN are released into the groundwater and the river
  - Important criterion
    - sorption in disposal materials (concrete and sands)
    - Radioactive period of the nuclides
  - Radionuclides concerned :
    - ^{135}Cs, ^{59}Ni, ^{107}Pd : captured RN maximum impact after 10 000 years
    - ^{129}I, ^{36}Cl, ^{99}Tc, ^{93}Mo : weakly captured cause a quicker impact
  - Low impact : near $2{,}3.10^{-2}$ mSv/year

Safety related radionuclides in altered evolution scenarios

- Post-Monitoring
  - Some of altered scenarios lead to an increased release of sorbed nuclides (package and vault alteration) but do not change significantly the impact nor the most important nuclides
  - The most important scenario is the implantation of a well directly on the disposal
    - Increase the impact of the nuclides, up to 7,6 mSv/year
    - Reduce the time to reach the maximum impact (hundred years for uncaptured radionuclides compared to 10,000 years)

- Conclusion
  - All long lived or uncaptured nuclides are concerned in these altered scenarios

Safety related radionuclides in intrusion scenarios

- Type of scenario
  - Road construction
  - Residential area
  - Child playing on excavated material
- Ways of exposure
  - Inhalation exposure (road construction, child games)
  - External exposure (residential)
- Radionuclides of interest
  - Alpha emitters (^{241}Am, ^{239}Pu, ^{240}Pu)
  - Gamma emitters (^{137}Cs, ^{94}Nb, ^{108m}Ag)

6. Waste acceptance criteria

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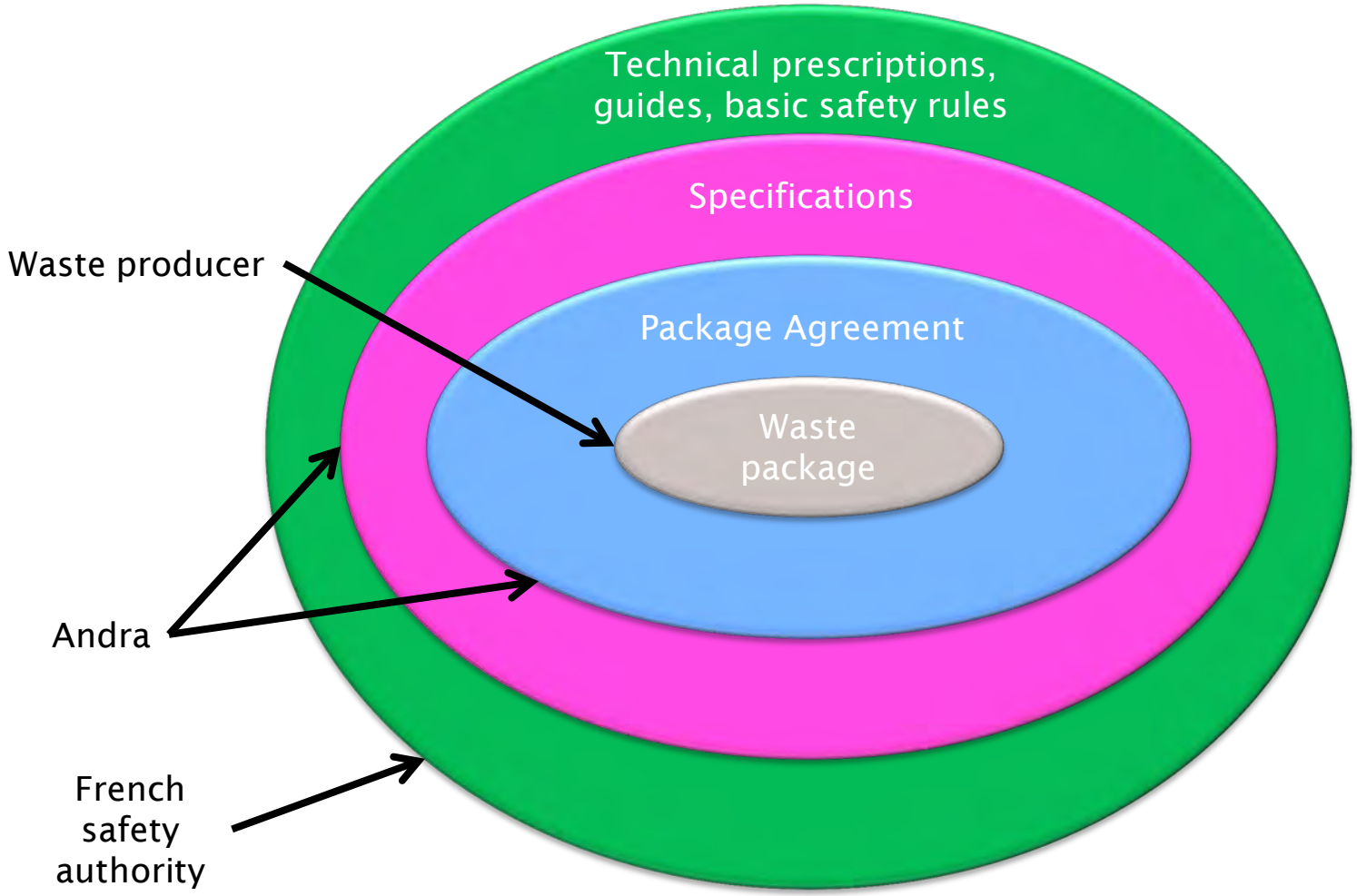
Acceptance criteria for radioactive waste packages and associated specifications are declined from:

- Basic safety rules (RFS) or guides (from French safety authority)
- Technical requirements
- Orders release
- The safety report (i.e. safety cases)
- The general operating rules (RGE)
- The CSA disposal operating constraints

Compliance with the specifications guarantees the safety of the disposal during the operational phase, the monitoring phase and post-closure, the protection of man and his environment from effects of:

- External radiation exposure
- The spread of radionuclides by water
- The dispersion of radionuclides in the air

6. Waste acceptance criteria



6. Waste acceptance criteria

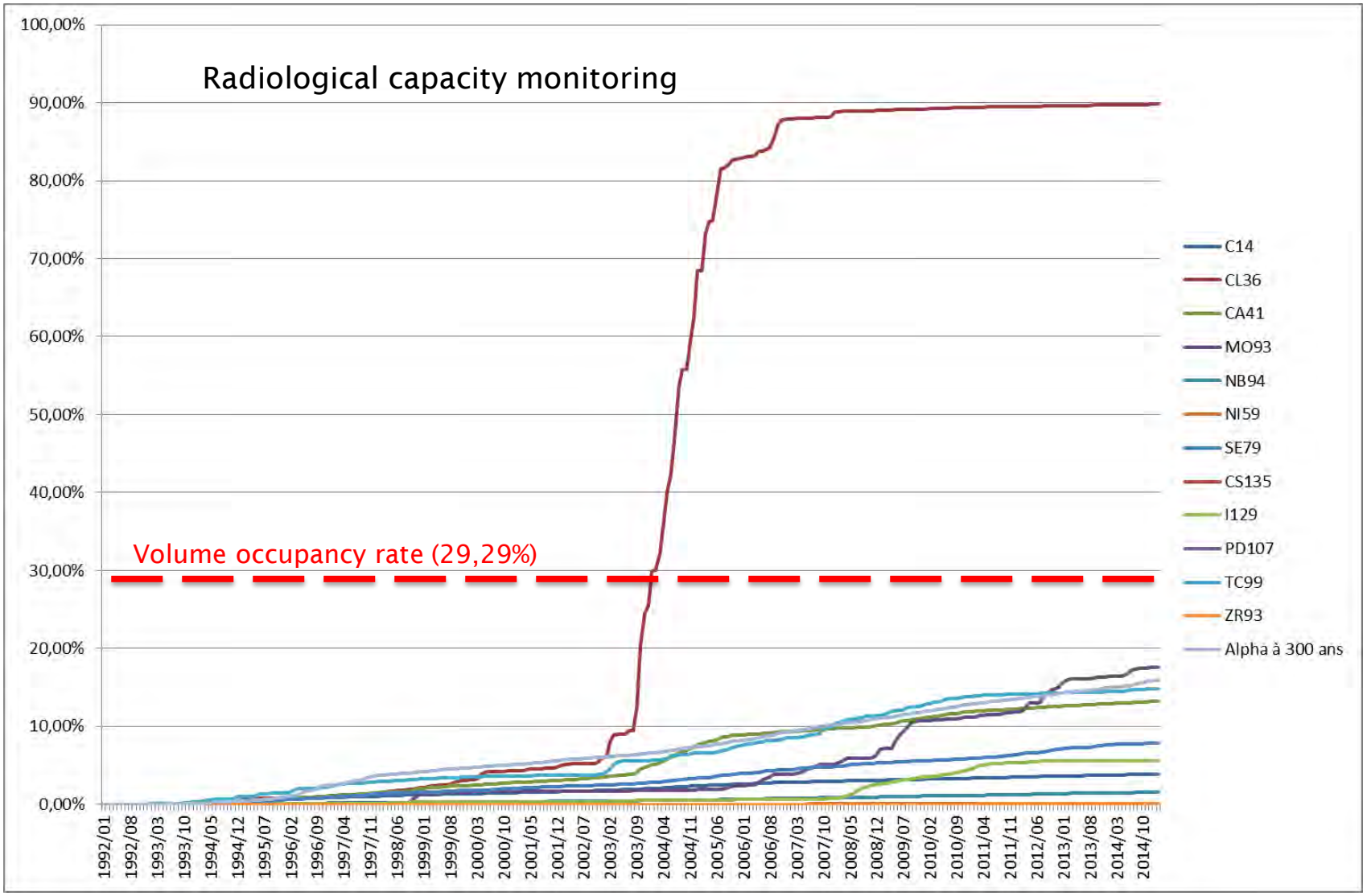
The general technical specifications are applicable to all waste packages :

- ACO.SP.ASRE.98-084: Requirements for the agreement and quality monitoring of the waste package

- ACO.SP.ASRE.99-001: General Technical Requirements
- ACO.SP.ASRE.99-002: Requirements on assessment and declaration of radioactive characteristics

→ **Objective: Capacity monitoring**

6. Waste acceptance criteria

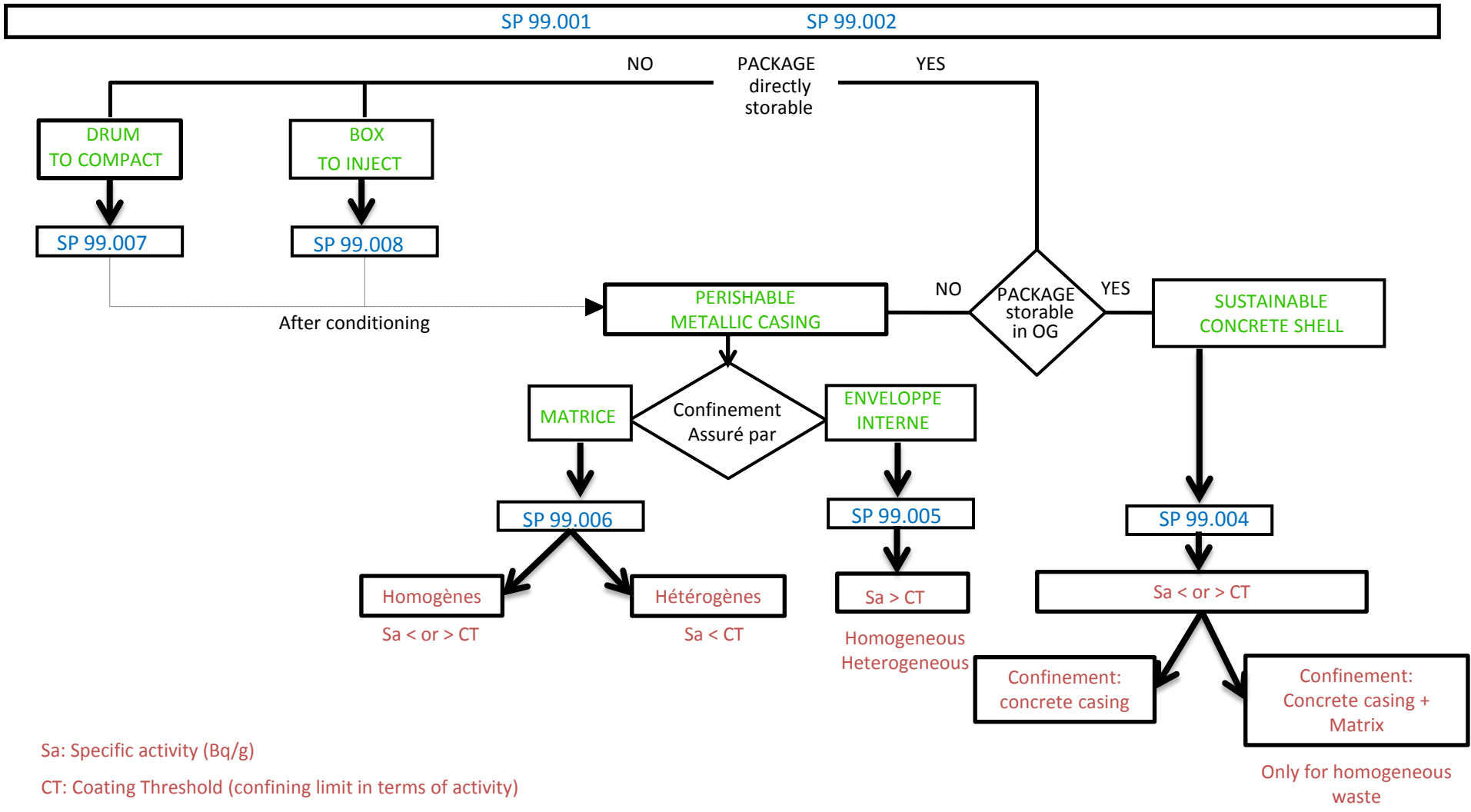


6. Waste acceptance criteria

Specific technical requirements depending on the package type:

- Packages directly disposed
  - ACO.SP.ASRE.99-004: sustainable concrete containers
  - ACO.SP.ASRE.99-005: perishable metallic containers with internal confining casing
  - ACO.SP.ASRE.99-006: perishable metallic containers with confining matrix
- Packages for further processing on CSA before disposal
  - ACO.SP.ASRE.99-007: metallic drums to be compacted
  - ACO.SP.ASRE.99-008: metallic boxes to be injected
- SUR.SP.AMES.06-0002: Requirements for sealed radioactive sources out of use

6. Waste acceptance criteria



Sa: Specific activity (Bq/g)

CT: Coating Threshold (confining limit in terms of activity)

6. Waste acceptance criteria

Technical tests (in addition to the technical specifications)

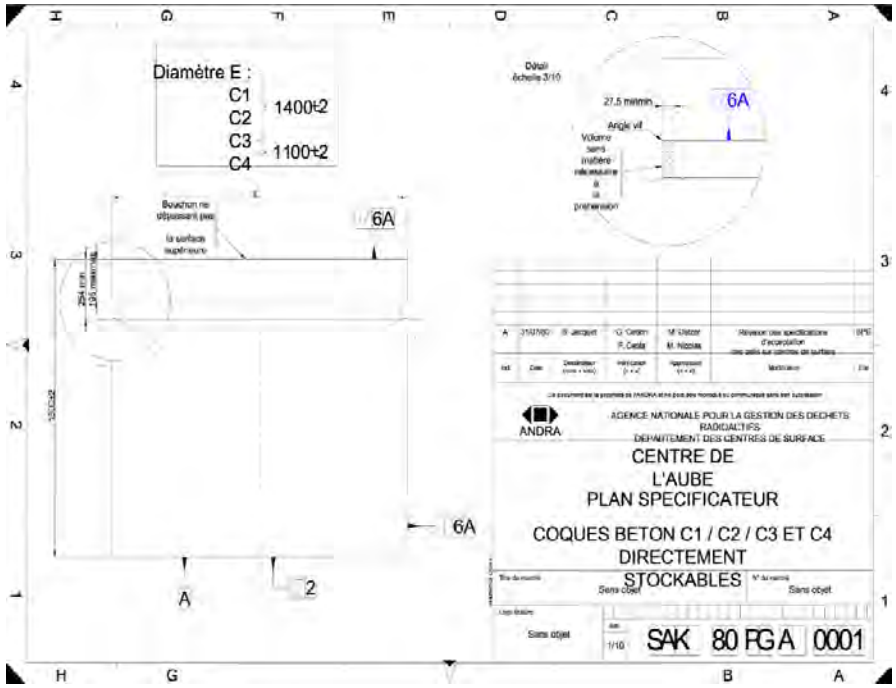
- Technical Tests applicable to all waste packages:
  - TT n°048: Homogeneous waste block homogeneity degree evaluation
  - TT n°050: Waste packages freeze-thaw cycles resistance assessment
  - TT n°054: Waste packages resistance to gamma irradiation assessment
  - TT n°057: Waste packages held under load assessment
  - TT n°058: Waste packages drop resistance assessment
  - TT n°060: Waste packages fire resistance assessment
- Technical Tests applicable to concrete made casing/matrix
  - TT n°049: Homogeneity and continuity of an envelope evaluation
  - TT n°053: Determination of tritiated water effective diffusion coefficient in a hydraulic binder material
  - TT n°062: Assessment of the gas permeability, water accessible porosity and density of a hydraulic binder material
  - TT n°066: Container-plug connection sealing test

6. Waste acceptance criteria

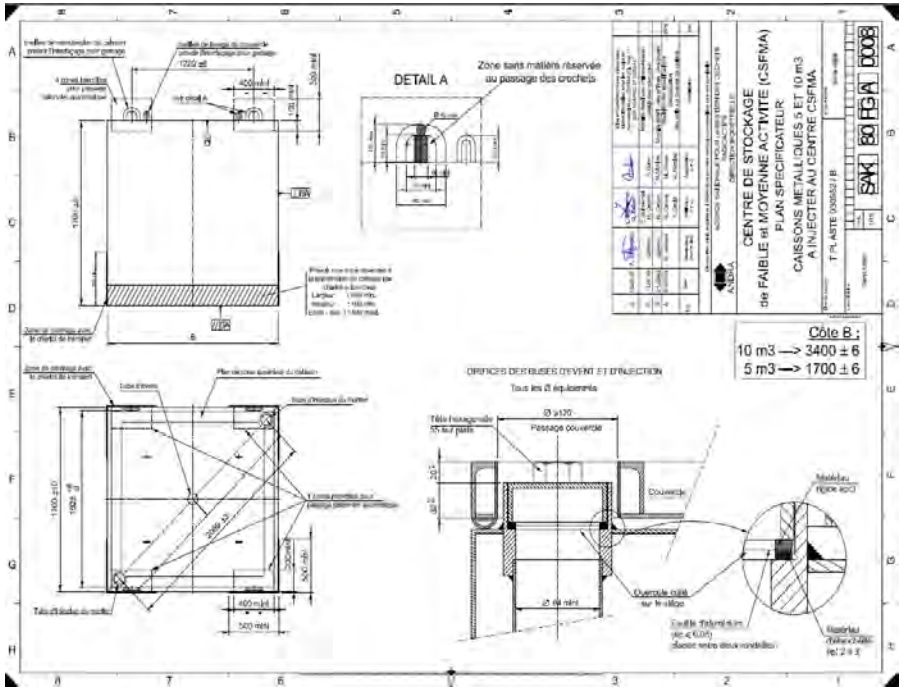
Technical tests (in addition to the technical specifications)

- Other specific Technical Tests:
  - TT n°051: Waste package tritium/carbon 14 release rate assessment
  - TT n°052: Assessment of homogeneous waste block lixiviation resistance
  - TT n°061: Water exudation under compressive force assessment
  - TT n°063: Waste gas production in alkaline environment characterization
  - TT n°064: Evaluation of the mechanical stability of a waste block whose matrix is an alkaline hydraulic binder
  - TT n°065: Evaluation of the aggressive nature of homogeneous waste block against envelope

Casing technical drawing (requirements for handling and processing)

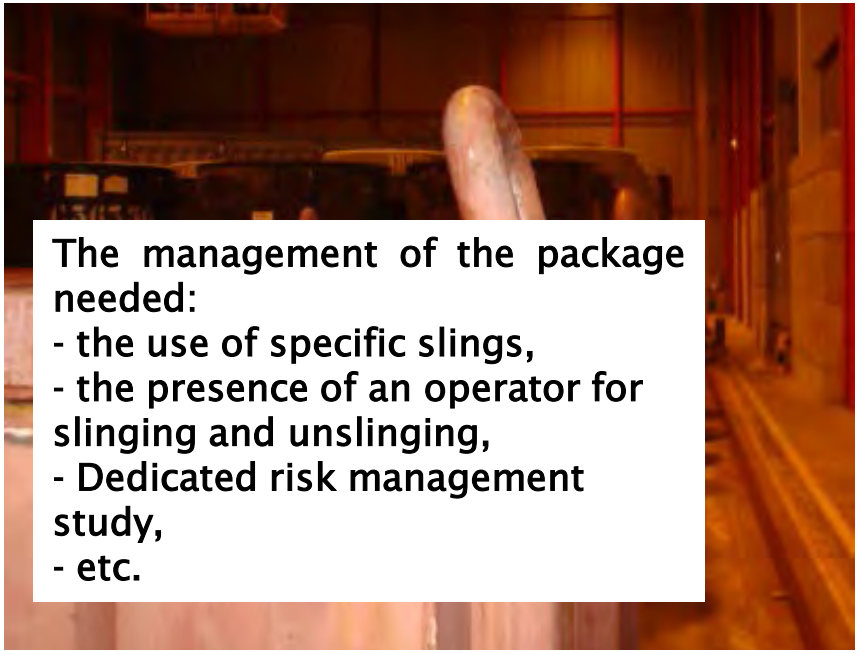


Concrete shells C1, C2, C3 and C4

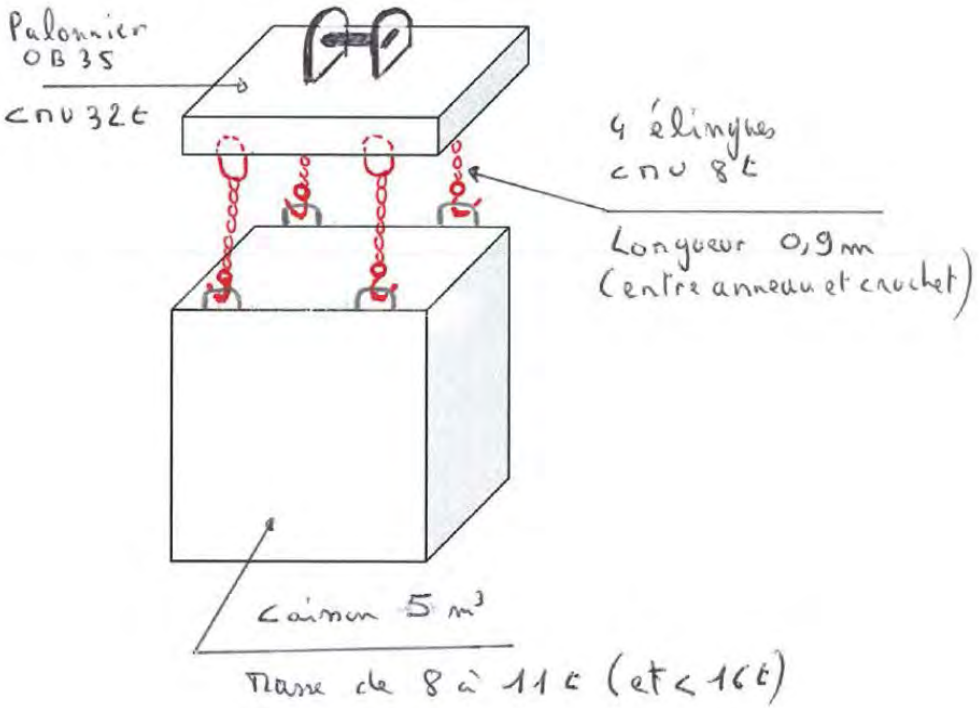


Metallic boxes to be injected on the CSA disposal

Casing technical drawing (example of noncompliance)



Distorted lifting rings, prohibiting the package lifting with appropriate spreader



6. Waste acceptance criteria

General technical requirements (ACO.SP.ASRE.99-001)

- Requirements for raw waste
  - Licensed waste without limitation:
    - plastics and rubber waste, metal waste, rubble, cellulose waste (excluding wood), glassware, water system and ventilation filters, iodine traps, homogeneous waste (sludge, REI, concentrates, etc.)
  - Waste permitted with restrictions:
    - wet waste, wood, powdered materials, paint residues, aerosol cans, batteries, neon lights, sources, asbestos waste, greases, paint residues, reactive metal materials (aluminum), etc.
      - » *Wet: no liquid easily exudable*
      - » *Wood: <10% vol, limited number of packages*
      - » *Paint waste: hardened*
      - » *Aerosols: pierced*
      - » *Etc.*
  - Prohibited waste:
    - inflammables or explosive materials, free aqueous/organic liquid, compostable, infectious materials, pyrophoric or highly reactive metal waste with hydraulic binder (magnesium), friable asbestos.

6. Waste acceptance criteria

Example for reactive metal materials (studies)

- Aluminum alloys
  - Decreasing corrosion in time
  - Corrosion increases if pH and high temperature
  - If coated in cementitious material:
    - Lower corrosion in saturated conditions
    - Very severe corrosion (300 microns/y) in unsaturated conditions

- Magnesium alloys
  - Low corrosion rate at pH near 13 (2 microns / year)
  - Very important localized corrosion in the presence of chlorides (40 microns/y)
  - Corrosion rate increases with temperature (350 microns / year at 50 ° C)
  - If coated in cementitious material: low corrosion in unsaturated conditions

6. Waste acceptance criteria

General technical requirements (ACO.SP.ASRE.99-001)

- Chemical characterization
  - Average composition to be determined
  - Toxic chemicals to identify and quantify:
    - Pb, B, Ni, Cr, As, Sb, Se, Cd, Hg, Be, CN, asbestos, CMR
  - Complexing substances to identify and quantify:
    - chlorides, fluorides, nitrates, sulfates, EDTA, acetates, etc.
- Final waste package characteristics
  - Maximal mass,
  - Fire resistance,
  - Drop resistance,
  - Etc.

6. Waste acceptance criteria

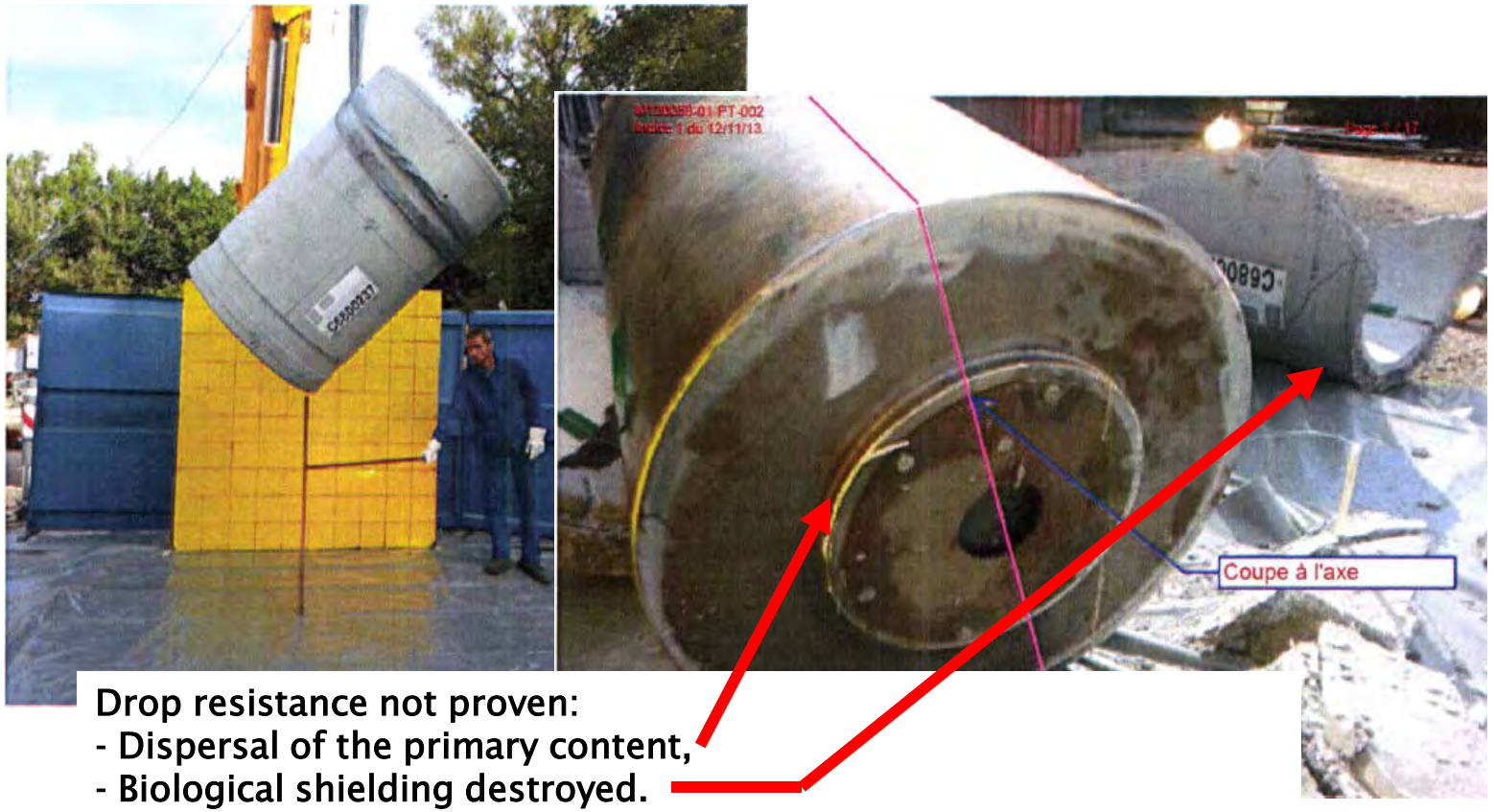
General technical requirements (ACO.SP.ASRE.99-001)

- Chemical characterization
  - Average composition to be determined
  - Toxic chemicals to identify and quantify:
    - Pb, B, Ni, Cr, As, Sb, Se, Cd, Hg, Be, CN, asbestos, CMR
  - Complexing substances to identify and quantify:
    - chlorides, fluorides, nitrates, sulfates, EDTA, acetates, etc.
- Final waste package characteristics
  - Maximal mass,
  - Fire resistance,
  - Drop resistance,
  - Etc.

Drop resistance (Technical test example – C1 concrete package)

Drop resistance proven:
- No dispersal of radioactive material,
- Biological shielding still sufficient.

Drop resistance (Technical test example – CBF-C2)



Drop resistance not proven:
- Dispersal of the primary content,
- Biological shielding destroyed.

6. Waste acceptance criteria

Radioactive requirements (ACO.SP.ASRE.99-002)

- The radiological content must be described for each agreement by an Activity Evaluation File
- This file shall describe:
  - Activities (α, $\beta\gamma$), the type of waste package to measure (box, 200L drum ...) and content (link with the transfer functions),
  - How the radionuclides are measured and reported (method, chain measures and uncertainties on the assessments),
  - In connection with the two points above, the justification of reasonable upper bound nature of the activity evaluation (penalising approach)
- Radionuclides (RN) to be reported
  - RN with half-life > 6 month : if Activity Threshold > Reporting Threshold
  - RN with half-life < 6 month : if Activity > 10% of total package activity

Isotope	*Période (ans) (1)*	*Filiation (2)*	*Seuil de déclaration (Bq/g)*
^{3}H	1.23E+01		10
^{10}Be	1.60E+06		10^{-4}
^{14}C	5.73E+03		10

6. Waste acceptance criteria

Radioactive requirements (ACO.SP.ASRE.99-002)

- Waste package mass to be reported
  - Directly disposable packages: $M_{package} - M_{shield} - M_{metallic\ casing}$
  - Package to be injected or compacted: Max between $M_{package}$ and $M_{standard}$
- Activity limits
  - Coating Threshold (CT):
    - Specific activity threshold upon which the confinement of the package shall be proven ("coated package")
    - It depends on
      - » *The radionuclides type (one RN could have a specific CT),*
      - » *The global α and βγ activity of the package.*
  - Maximal limit of activity
    - Specific activity threshold defined for waste packages to respect the global activity licensed per RN on the CSA
  - Homogeneous distribution of activity
    - Limit the amount of activity per volume unit
    - Prohibit the disposal of Mid or High activity waste at CSA by dilution
- Particular cases
  - radium-bearing waste
  - Gaseous waste
  - Fissile material

6. Waste acceptance criteria

Radioactive requirements (ACO.SP.ASRE.99-002)

- Surface contamination
  - ≤ 4 Bq/cm² for βγ emitters
  - ≤ 0,4 Bq/cm² for α emitters
- Nuclear materials
  - Specific declaration based on the content of Pu and U (natural, depleted, low enriched, highly enriched)
- Dose rate
  - < 2 mSv/h at package contact
  - The use of patch is subject to specific acceptance and shall comply with the following rules :
    - Heterogeneous waste package
    - Sustainable fixing
    - Must not exceed the thickness of the package top edge
    - Preferably made of steel

6. Waste acceptance criteria

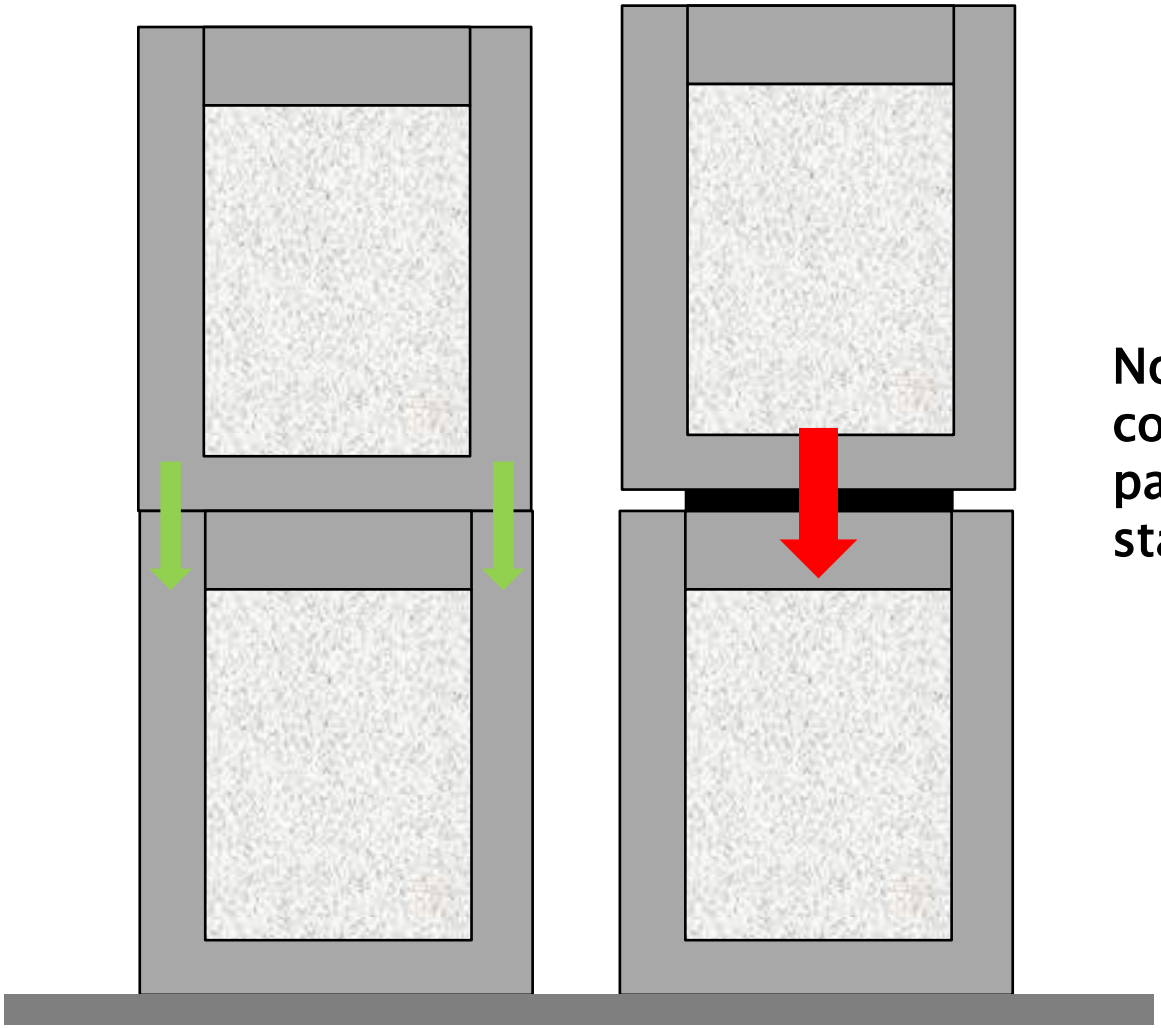
Focus on patch use (consequences)

Management of Toxic (lead declaration)

Thickness of the package top edge exceeded: risk when package stacking

Focus on patch use: risk when package stacking

Optimal package stacking



Non compliant package stacking

6. Waste acceptance criteria

Specific requirements for packaging

- ACO.SP.ASRE.99-004 : Sustainable concrete casing
  - Mechanical hull outfit > 0.35 MPa
  - Containment: casing performance (tritiated water diffusion coefficient)
  - Casing thickness, mechanical strength, homogeneity
  - Requirements for casing material:
    - cement, mixing water, additives, formulation, strength, etc.
  - State of the finished package:
    - Shells are acceptable if they show no defects such as
      - » *nests of aggregates (gravel, sand, fibers),*
      - » *exposed reinforcement,*
      - » *cracks,*
      - » *Bursts.*
- ACO.SP.ASRE.99-005: perishable metallic containers with internal confining casing
  - Containment: internal casing performance (tritiated water diffusion coefficient)
  - Internal casing thickness, mechanical strength, homogeneity

Focus on concrete package state at delivery: cracks

Non-compliances:

- Confining casing degraded
- Non confining package
- Impact on radionuclide transfer

Focus on concrete package state at delivery: burst

Package laid on a wedge stopper corner

Non-compliances:

- Confining casing degraded
- Non confining package
- Impact on radionuclids transfer

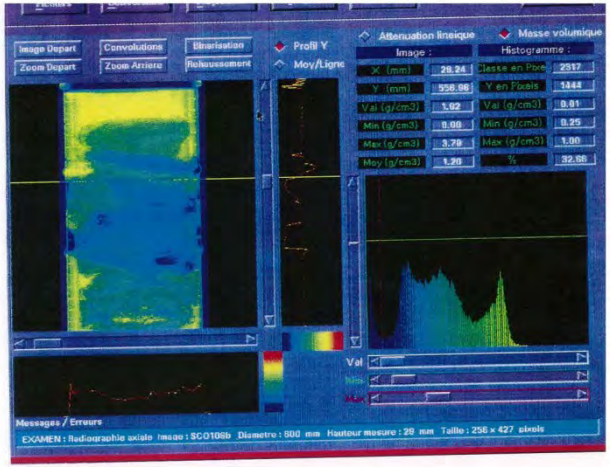
6. Waste acceptance criteria

Specific requirements for packaging

- ACO.SP.ASRE.99-006: perishable metallic containers with confining matrix
  - Containment: matrix performance (block lixiviation resistance)
- Requirements on matrix for all packages
  - Immobilization of homogeneous waste
    - Homogeneity (TT n°048)
    - Water content (TT n°061)
    - Mechanical strength:> 8 MPa
    - Gas permeability, porosity, density (TT n°062)
  - Immobilization of heterogeneous waste.
    - Mechanical strength:> 20 Mpa
    - Mortar penetration quality, tensile strength, shrinkage
  - Filling rate

Focus on filling rate

- The main objective of this requirement is to limit the possible void in the matrix in order to:
  - Fulfill the requirements on mechanical strength,
  - Exclude water penetration into the matrix after disposal (example below)



<u>Consequence:</u>
Performance degradation

6. Waste acceptance criteria

Focus on the confining requirements for waste packages (Specific activity > CT)

- Confining requirements are based
  - For metallic packages
    - On the performance of the waste matrix or,
    - On the performance of the internal mortar casing
  - For concrete packages
    - On the performance of concrete casing (and the eventual internal mortar casing) or,
    - On the performance of concrete casing and the waste Matrix
- Waste matrix performance
  - Lixiviation test

	Tritium	βγ emitter	α emitter
Da (m^2/s)	$< 2{,}10^{-12}$	$< 6{,}3{,}10^{-13}$	$< 3{,}2{,}10^{-17}$

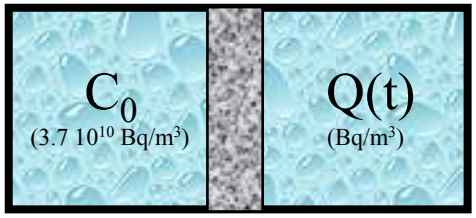
6. Waste acceptance criteria

- Focus on the confining requirements for waste packages (Specific activity > CT)
  - Internal mortar casing performance
    - Tritiated water diffusion coefficient (De) < $1{,}7.10^{-12}$ m^2/s
    - Thickness > 50 mm
  - Concrete casing performance
    - Thickness
      - » $L_{cont}=max(L_{conf}, L_{méca})+L_{deg}$
        - L_{cont} : concrete casing thickness
        - L_{conf} : confining thickness (linked to the tritiated water diffusion coefficient)
        - $L_{méca}$: mechanical thickness (50 mm)
        - L_{deg} : degradation thickness (20 to 40 mm depending on concrete formulation)
    - Tritiated water diffusion coefficient (De) < $1{,}75.10^{-12} \times L_{conf}$
    - With an internal casing : $$\frac{L_{conf}}{De} = \frac{L_{conf,casing}}{De_{casing}} + \frac{L_{internal\ casing}}{De_{internal\ casing}}$$
  - Concrete and Matrix confinement: De < $1{,}1.10^{-11} \times L_{conf}$

De (m^2/s)	50 mm	80 mm	100 mm	150 mm
Casing only	< $8{,}8.10^{-14}$	< $1{,}4.10^{-13}$	< $1{,}7.10^{-13}$	< $2{,}6.10^{-13}$
Casing and Matrix	< $5{,}7.10^{-13}$	< $9{,}1.10^{-13}$	< $1{,}1.10^{-12}$	< $1{,}7.10^{-12}$

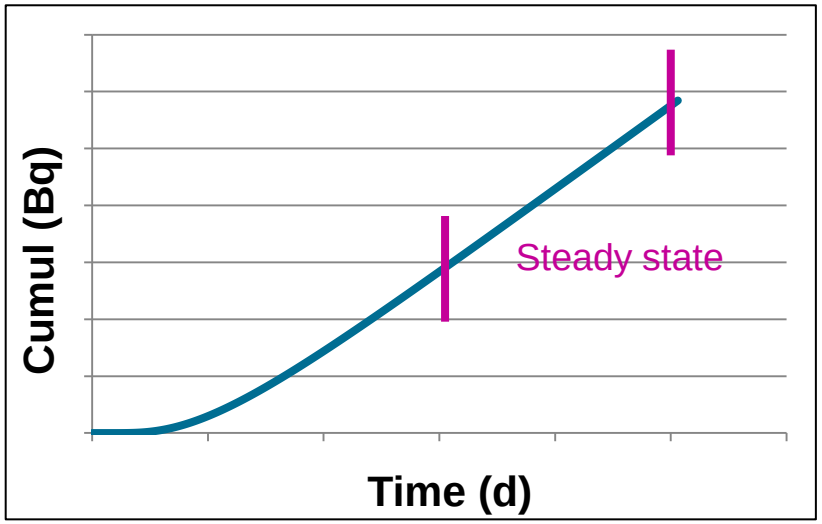
Tritiated water diffusion coefficient measurement (technical test)

Principle : measuring the activity in the downstream compartment versus time (tritium transfer). Upon reaching steady state, determining the diffusion coefficient.



Materials et specimens dimension:

- Cement paste 4 à 8 mm
- Mortar 8 mm
- Concrete 1,6 $Ø_{gran}$ (20 mm max)
- Polymer 4 mm



2 methods proposed in the TT

- Method A
  - 3 specimens
  - Th. 20 mm max
  - Test duration on concrete : 3 to 4 years
- Method A'
  - 15 specimens
  - Th. 16 mm max
  - Test duration on concrete ≈ jusqu'à 2 ans

Main difficulty :
Important duration of test poses problems for the characterization of new concrete or for packages inspection

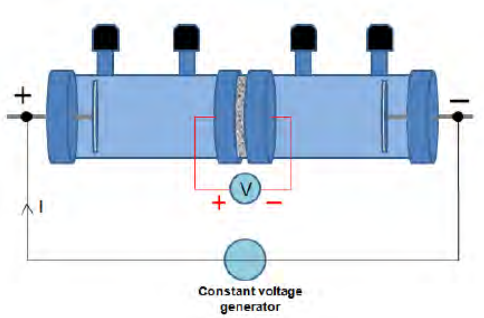
R&D on tritiated water diffusion coefficient (De) measurement

Development of a new and faster method

Measure of *De* under electric field

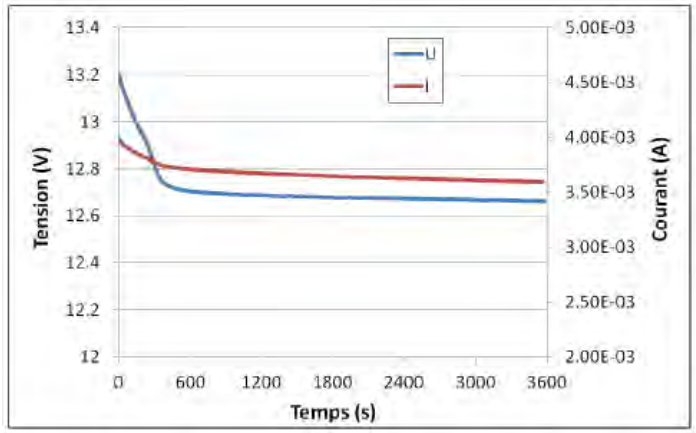
Principle :

- Saturation of the specimen
- Applying an electric field
- Determination of a form factor $F_F = \frac{\Delta U}{I}\frac{SF^2}{RTL}\sum_i z_i^2 c_i D_{0,i}$
- De calculation $D_{e,HTO} = \frac{D_{0,HTO}}{F_F}$



Advantages :

- Duration ≈ 1 hour
- Working in idle



- ❑ Applicable only on materials of which De > 10^{-12} m^2/s (mortars, low confining concrete)
- ❑ Pursuit of R&D for use on materials of which De < 10^{-12} m^2/s

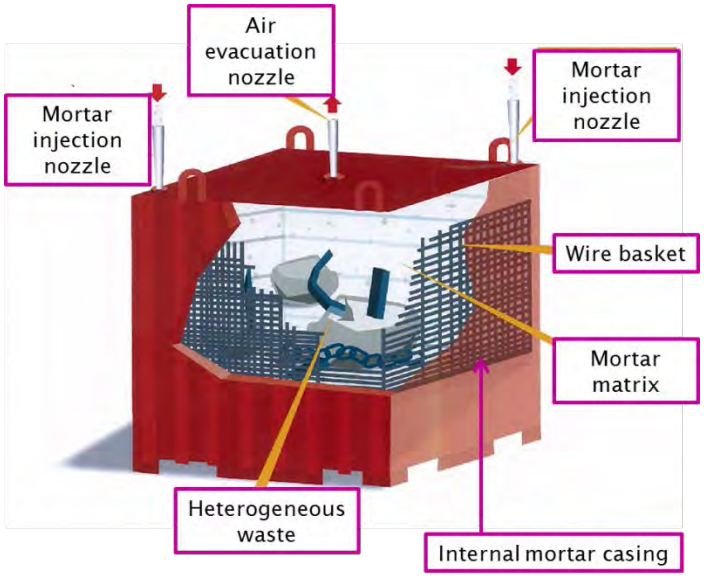
6. Waste acceptance criteria

Specific requirements for processed waste package

- ACO.SP.ASRE.99-007 : compactable drums
  - Raw waste
    - Dispersible powdered waste (decanters pots, etc.): Ac < CT, study of resuspension rates,
    - Prohibited waste: asbestos, Be, solvent, oil and grease, sources, flammable and pyrophoric, lead, little deformable or massive parts,
    - Waste restricted: difficult to compact pieces to place in the bottom half of the barrel.
  - No waste that can release liquid water
    - Absorbent: water = less than 1% of the volume of the drum prior to compaction,
    - Bottles not drained

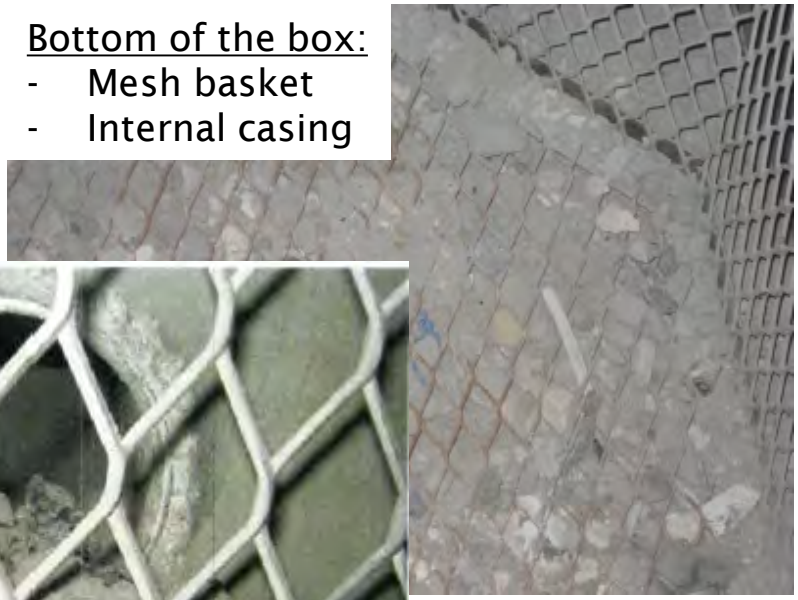
Specific requirements for processed waste package

- ACO.SP.ASRE.99-008 : injectable boxes
  - Raw waste
    - Dispersible powdered waste (decanters pots, etc.): Ac < CT, study of resuspension rates,
    - Dispersible waste (earth, sand, etc.) not locked: <10% vol,
    - Asbestos waste: non-friable, < 40 kg, packaged in a box or vinyl layer,
  - Boxes features and mass limit
  - Resistance to the buoyancy exerted on the lid by the mortar
    - > 50.000 Nm for 5 m^3 boxes,
    - > 100,000 Nm for 10 m^3 boxes .
  - Implantation of the injection ports
  - Features of the injection nozzles
  - Features of the internal mesh basket
  - Inner casing (waste-free space)
    - 70 mm below the lid
    - 50 mm for the other walls
    - Lid nozzles features



Injectable boxes: focus on dispersible material

Bottom of the box:
- Mesh basket
- Internal casing



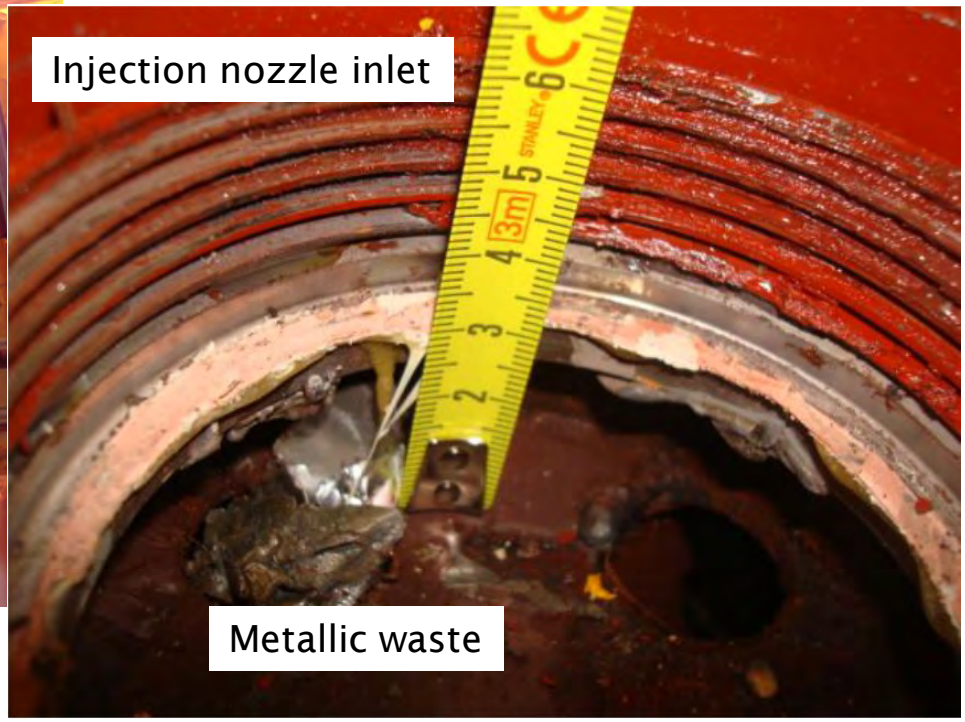
Injection nozzle outlet

Non-compliances:
- Degraded quality of the internal casing
- Unblocked waste matrix
- Injection still possible??

Injectable boxes: focus on mesh basket and nozzles

Potential non-compliances:

- Failure of inner casing establishment
- Waste presence in the inner casing
- Degraded confinement properties



Potential non-compliances:

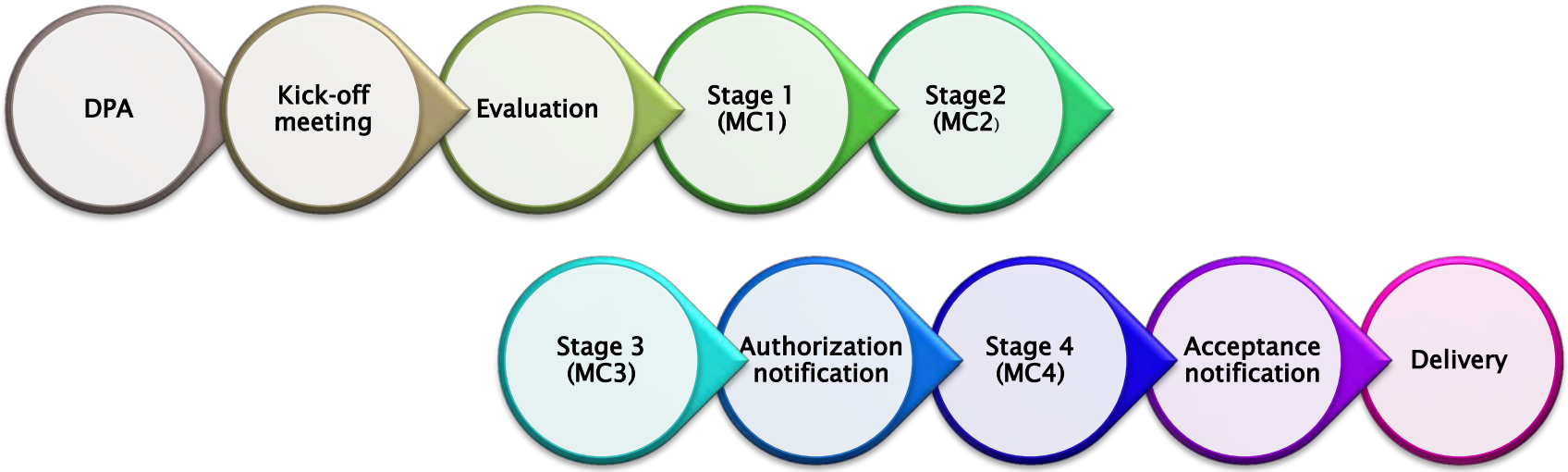
- Injection prohibited

7. Waste package authorisation

Some definitions

- AUTHORISATION: delivered after determination and shared acceptance of operating/technical parameters that will be used in package production
  - "Product" compliance referential : reference used by the manufacturer to determine compliance at the end of production of a package
- ACCEPTANCE of delivery imposed on the basis of implemented quality control requirements that are:
  - Likely to give confidence in the producer's ability to produce packages as approved in operational parameters
  - Auditable (defining who does what, when, how?) and sustainable
- For the processing of agreement and acceptance approval, a tool: COMPLIANCE MATRIX
  - Exhaustive review of Andra specifications requirements,
  - Identification of derogations
  - A key quality recording related to the agreement and acceptance

Authorization/Acceptance process (similar for an authorization revision)



- DPA: Description of agreement project
- MC: Conformity matrix at different filling stages (0, 1, 2, 3 and 4)
- DP: Process description
- DEA: Activity Evaluation description
- DC: characterization file

Compliance Matrix

- Established by Andra (then completed by the producer) from the software “MCAC (Package Authorization Compliance Matrix)“
- Requirements to be met selected according to the following parameters:
  - Package Type
    - Selecting a specification from 99004-99008
  - Specific activity
    - < or > CT
  - Nature of waste
    - Heterogeneous or homogeneous
  - Nature of the matrix
    - Hydraulic binder (LH), polymer (P) or bitumen (B)
  - Containment provided by
    - Envelope (E) or Block (B) or Envelope + Block (E + B)

Filling stages of the compliance matrix

Critères pris en compte : Spécification : 8 Activité massique : <5E, Déchet : Hétérogène, Matrice : Liant Hydraulique, Confinement : Bloc + Enveloppe

Colonne 1				Colonne 2	Colonne 3	Colonne 4	Colonne 5	Colonne 6
EXIGENCES ANDRA				RESPECT DE L'EXIGENCE	REFERENCE DE LA DEROGATION	JUSTIFICATIF DE LA REPONSE FAITE EN COLONNE 2	REFERENTIEL CONFORMITE PRODUIT	DISPOSITIONS D'APPLICATION (Gestes effectués sur le terrain pour respecter l'exigence)	DISPOSITIONS D'ORGANISATION (Références documentaires où sont décrits les gestes effectués sur le terrain)
N°	Spéc.	§	Libellé	Oui Non Sans objet			Oui Non		
1	1	3.1.3.1	Absence de produits ou mélanges présentant des risques d'inflammation ou d'explosion ou de réaction exothermique brutale						
2			nets que e défini 97-1048						
3			des						
4			des organiques						
5	1	3.1.3.1	Absence matières putréscibles t.q. cadavres d'animaux						
6	1	3.1.3.1	Absence de déchets métalliques pyrophoriques ou très fortement réactifs t.q. magnésium finement divisé, sodium et alliage de sodium						
7	1	3.1.3.1	Absence de déchets contenant de l'amiante friable (libre)						
8	1	3.1.3.3.2.1	Absence de récipients contenant des liquides						
9	1	3.1.3.3.2.1	Les déchets humides compactables ne doivent pas contenir de liquide facilement exsudable : absence égoutture suite à pressage manuel						

MCO stage (Andra)

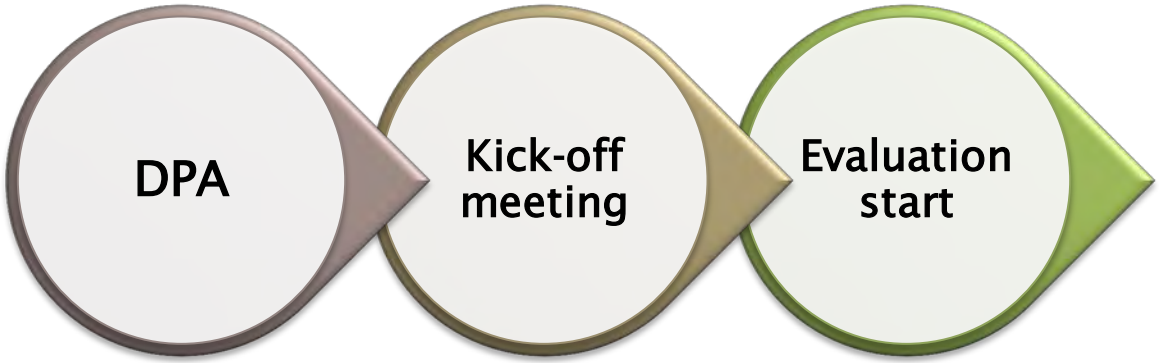
MC1 stage (Producer)

MC2 stage (Producer)

MC3 stage (Producer)

MC4 stage (Producer)

Phase prior to inquiry

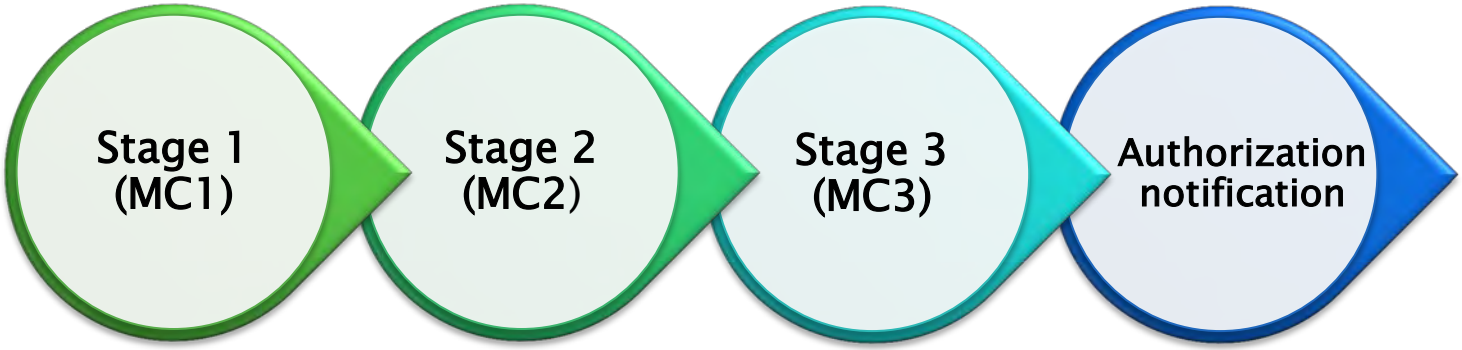


- Transmission of MC0
- Inquiry planning establishment

- Main objective
  - Establish the applicable reference for the package conditioning process
    - List of requirements to be met
- Source
  - General and technical specifications

Instruction of the authorisation application

- Goal
  - Limit the risk of non-compliant package production
  - Ensure the detection of non-compliant package before delivery to the CSA
  - Ensure "stability" of production over time



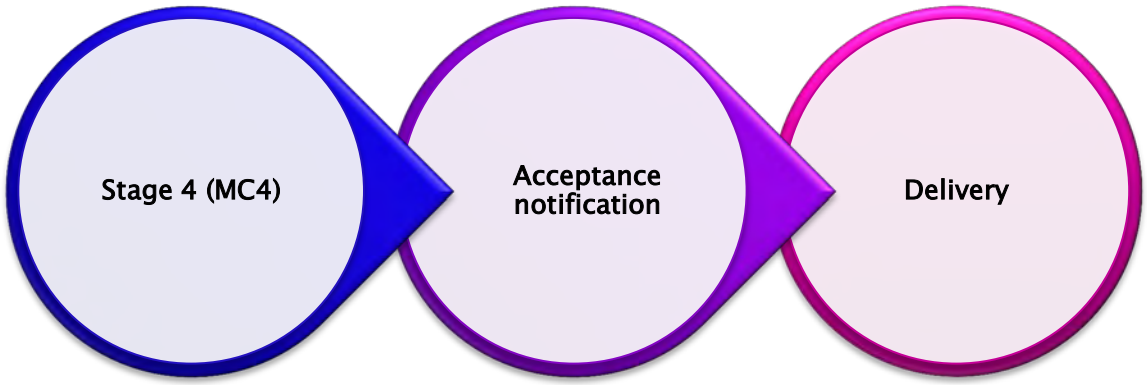
- Fill the 1st column of the matrix (MC1 state) + identification of derogations
- Establishment of the characterization program (Technical Tests / design calculations ...) and its validation process
- Update of inquiry schedule

- Realization of the characterization program + establishment of the characterization file
- Schedule update
- Complement filling column 4 "Justification..." in the matrix (MC2 state)
- Establishment of DP + DEA
- Treatment of derogations

- Definition of product compliance referential and technical provisions + sold of derogation
- Filling the relevant columns of the matrix: Column 5 (MC3 state)

Instruction of the acceptance

- Goal
  - Decline in the production site applicable documentation:
    - The technical provisions (column 5 of the MC)
    - Andra organizational specifications (for example, those related to the provisions to be applied by the production site in case of producing a non-compliant package, or those related to reporting procedures and shipments (PROCOMX))



- Transmission by the producer of the matrix with the last column filled (MC4 state), LDA, procedures
- MC4 analysis by Andra (audit possible)

Break