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Environmental remediation and waste management following a nuclear accident

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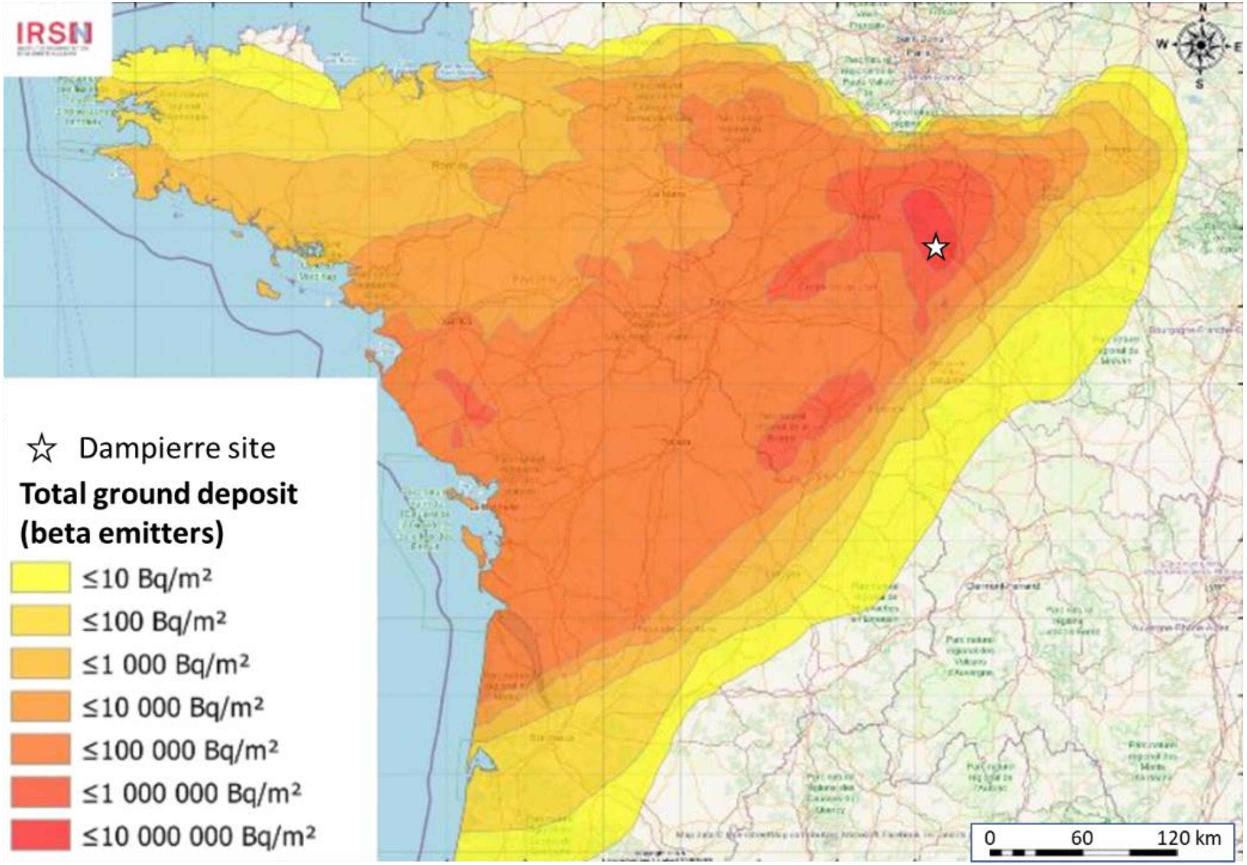
Introduction and context

- Post-accidental doctrine defined by the **Steering committee for the management of post-accidental situation (CODIRPA)**

- "**Contamination reduction and waste management**" working group
  - Studies about environmental remediation strategies and waste management options following a major nuclear accident
  - Aiming at comparing several remediation strategies and providing decision makers with food for thought

- IRSN's work based on a **study case consisting in modeling a major nuclear accident and estimating waste volumes generated by several remediation strategies** in urban and agricultural areas
  - Steps to build the study case
    1. Simulation of atmospheric discharge and ground deposit
    2. Definition of remediation strategies
    3. Estimation of waste volume
  - Waste management options

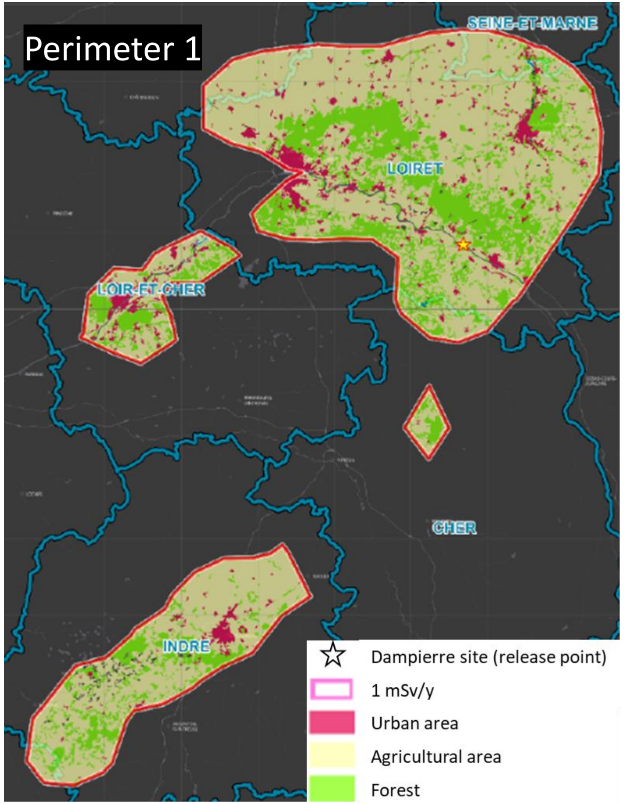
Step 1: simulation of atmospheric discharge and ground deposit

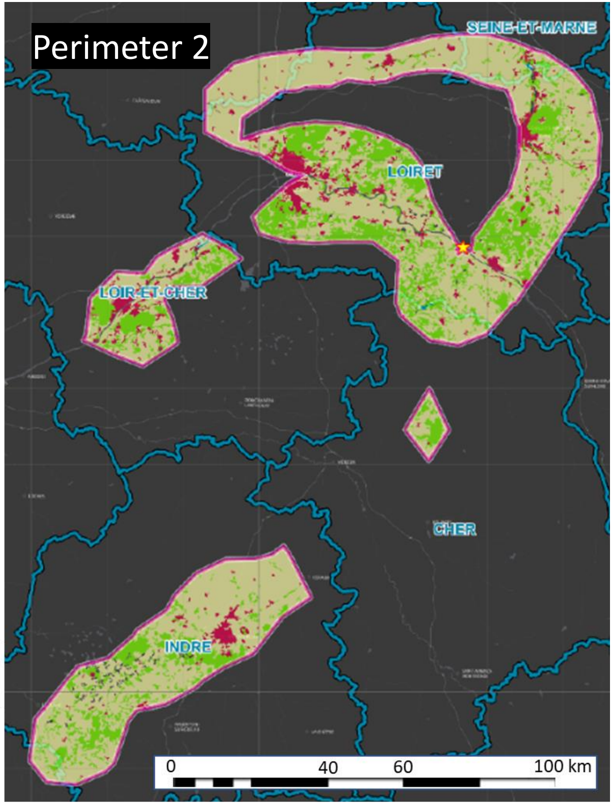


- Nuclear power plant along the Loire River
- Source term: same order of magnitude as Fukushima accident
- Ground deposit computed based on meteorological conditions on the French territory (April 12th - 15th, 2020)

Step 2: definition of remediation strategies

Perimeter *in which remediation actions are implemented*





- Total dose (excluding voluntary ingestion of contaminated food) **≥ 1 mSv/y** (between the 3rd and 15th month following the end of discharge)
    - With (**Perimeter 1**) or without (**Perimeter 2**) the “relocation perimeter” (≥ 20 mSv/y)
- **Perimeter 1** = 7 962 km²
    - 493 km² of urban area
    - 5 350 km² of agricultural area
- **Perimeter 2** = 6 511 km²
    - 429 km² of urban area
    - 4 323 km² of agricultural area

Step 2: definition of remediation strategies

*Sets of **remediation actions***

- Actions based on **feedbacks from remediation actions** in the territories affected by Chornobyl and Fukushima nuclear accidents
  - Related to specific land cover (urban and agricultural areas) and materials (roads, roofs, lawns, etc.)
  - Specific data per processed square meter: waste volume, workforce, efficiency, cost

- Three sets of actions, each including a dozen of remediation actions
  - "**Chornobyl feedback**" and "**Fukushima feedback**":
    - Similarities: **high pressure hosing** (walls, windows, roofs, roads), **removing soil, grass, and plants** (private gardens and public parks) → same actions, but specific data from each feedback
    - Differences in agricultural land:
      - **ploughing** for "Chornobyl feedback"
      - **thin-layer soil stripping** for "Fukushima feedback"

    No reproduction of the strategies actually implemented (but data from those feedbacks)
  - "**Maximum surface dose rate reduction**" designed to maximize the global efficiency of actions to reduce the ambient external dose rate, without considering other factors (waste volume, cost, feasibility at large scale, etc.): e.g., **recovering grass surface with asphalt** (private gardens and public parks) or **skimming and burial ploughing** (agricultural land)

Step 2: definition of remediation strategies

***Time frame** & summary*

Summary : **comparison of six strategies**

Perimeters	Sets of actions	Time frame
Perimeter 1 (≥ 1 mSv/y) Perimeter 2 (without the relocation zone)	Fukushima fb. Chornobyl fb. Max. surface DR reduction	1 year

⚠ Actions are implemented on the whole perimeters disregarding the contamination level

Step 3: estimation of waste volumes
dewaX

- dewaX: numerical tool developed by IRSN to compare remediation strategies in urban and agricultural areas, mainly based on estimated waste volume

- Map of ground deposit
- Strategies
  - Perimeter
  - Set of actions
  - Timeframe

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- Land cover (roads, gardens, etc.)
- Data for each action per processed m² (waste/m², workforce/m², etc.)

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- Waste (volumes and activity)
- Workforce
- Cost
- Efficiency

Step 3: estimation of waste volumes

Results

- Solid waste generated in **perimeter 1** (in 10^6 m^3)

	Soil	Solid incinerable waste	Other solid waste	TOTAL
Chornobyl fb.	12	0.1	0.1	12.2
Fukushima fb.	273	1.3	0.2	274.5
Max. surface DR reduction	0	1.2	6.3	7.5

  - More solid waste generated by “Fukushima fb.” set of actions: mainly due to soil stripping in agricultural lands (disregarding the contamination level)
  - Less solid waste generated by “Max. surface DR reduction” set of actions: use of exposure mitigation practices such as ploughing or surfaces covering
  - For ~95 % of waste, activity <100 Bq/g (VLLW)

- In **perimeter 2** (relocation perimeter not included)
  - Reduction of waste volume in relation with the reduction of treated surfaces
  - Reduction of waste activity since the most contaminated area is not subject to remediation actions

Waste management options (French context)

1. **Storage** (short-term): sites available near the locations of waste production
    - Possible accordingly to the dedicated regulatory framework in France
2. **Waste treatment and volume reduction** especially for incinerable and putrescible waste
    - Capacity of existing radioactive waste incineration facility not sufficient
    - Construction of dedicated incineration facilities or use of existing incineration facilities for conventional waste, after adaptation to the treatment of radioactive waste (or both)
3. **Interim storage and disposal**
    - Volumes exceeding capacities of existing disposal facilities, especially for VLLW
    - Interim storage awaiting the design and construction of a disposal facility adapted to the waste volumes and natures
4. **Conditional clearance** (related to a specific use, a type of materials, etc.), given the large volume of VLLW, even if it is not the usual way to manage VLLW in France
    - Reuse and recycling
    - Disposal in facilities designed for industrial hazardous waste

Conclusion and perspectives

- The study underlines the **impact of remediation strategies on the waste volumes and natures**
- **Other criteria must be considered** in decision-making regarding remediation strategies, in order to find an **adequate balance between safety and sustainability**
  - Such as acceptance, feasibility, adverse effects, impact on living conditions (recovering lawns, removing plants, etc.)
  - Multi-stakeholder and multi-criteria analysis: help answer questions such as “which strategy enables a safe and quick return of population, with living conditions as close to before the accident as possible (maintaining social and economic activity, agriculture, transports, leisure facilities, etc.)?”

  → Integrating such criteria and analysis could enrich the current comparison between the strategies and help future decision-making
- Waste volumes largely exceed the capacities of French treatment and disposal facilities. Sustainable waste management options may consist in:
  - **Reducing waste volumes**, based on an optimized choice of remediation strategies
  - Reflections on some **possible developments in the current radioactive waste management system** to facilitate decision-making, **reserved for the post-accidental context** (defining generic concepts for treatment, storage or disposal facilities; evaluating the possibility to introduce clearance levels, etc.)