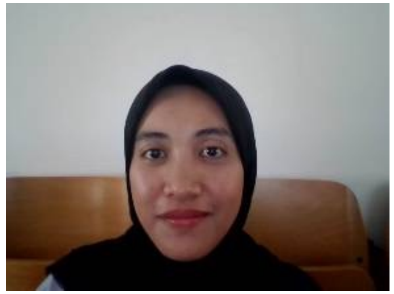

# Radiological impacts of Nuclear Power Plant (NPP) decommissioning through the lens of Life-Cycle Assessment

*Exp. 7*

*European Summer School 2024*

*Radiation Measurements and Radiochemistry in Environment and Decommissioning*

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Under the supervision of Paul Robineau

07/04/2024

# Global context

## 60% of operational reactors > 30 years in 2019

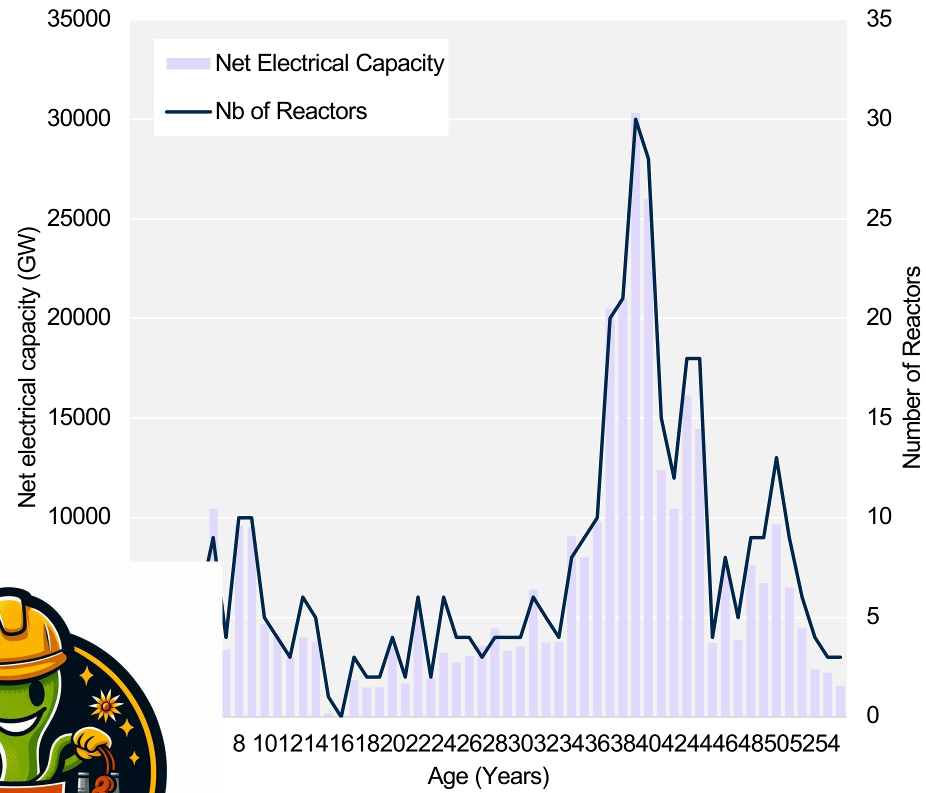
- Expected decommissioning of 75-80 GW during the 2030s

## French situation:

- 56 Pressurized-Water Reactors, high-standardization
  *IAEA 2022 and Grubler 2010*
- Fessenheim NPP shutdown in 2020, decommissioning planned for 2026-2040
- Starting decommissioning of 14 reactors might happen by 2035
  *EDF proposals, last PPE law*

## Few studies on the environmental impact of decommissioning:

- Focus on construction/operation, on climate change impact category
- Only 3 Life cycle assessment studies specific to decommissioning
  *Wallbridge et al. 2013*
  *Seier & Zimmerman 2014*
  *Iguider et al. 2024*




Data from: IAEA 2024. *World statistics: Age distribution*. Power Reactor Information System database. URL.

2.1 *EDF regulatory impact study*

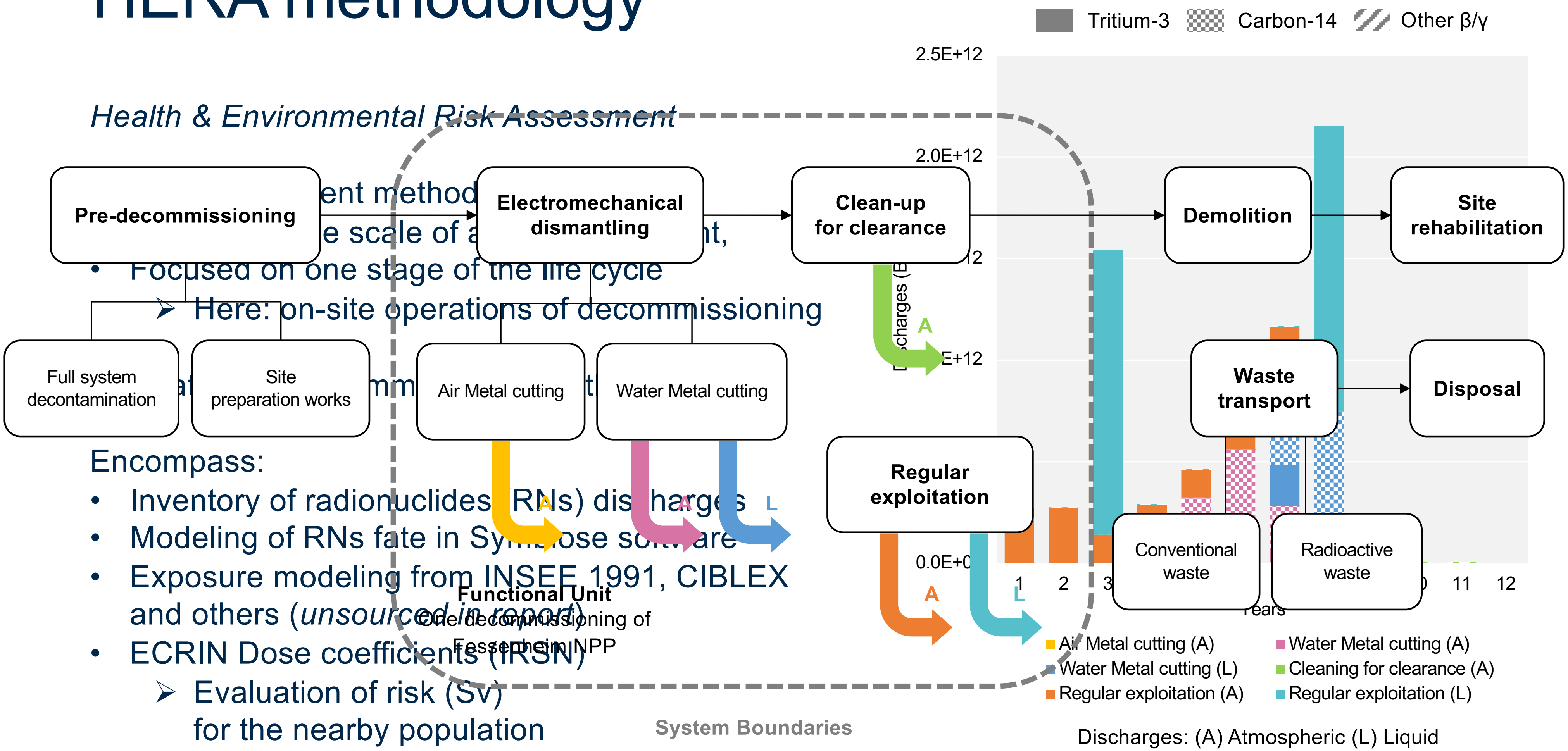
# HERA methodology

*Health & Environmental Risk Assessment*

- ...ent method... e scale of a ... nt,
- Focused on one stage of the life cycle
  - ➢ Here: on-site operations of decommissioning

Encompass:

- Inventory of radionuclides (RNs) discharges
- Modeling of RNs fate in Symbiose software
- Exposure modeling from INSEE 1991, CIBLEX and others (*unsourced in report*)
- ECRIN Dose coefficients (IRSN)
  - ➢ Evaluation of risk (Sv) for the nearby population




Discharges: (A) Atmospheric (L) Liquid

## 2.3 *Radiological LCIA methods*

# UCrad

Paulillo *et al*. 2020. Radiological impacts in Life Cycle Assessment. Part I: General framework and two practical methodologies. Science of The Total Environment 708, 135179. DOI.

## Typical global assessment LCA

- For comparison with USEtox (conventional toxics)

**Inventory**
Radionuclide quantity emitted [Bq]

**Fate module**
Radionuclide distribution [Bq to compartment]

**Environmental Compartment Model**

**Exposure module**
Cumulative dose via internal/external pathways [Sv]

## Primary use: Technology assessment

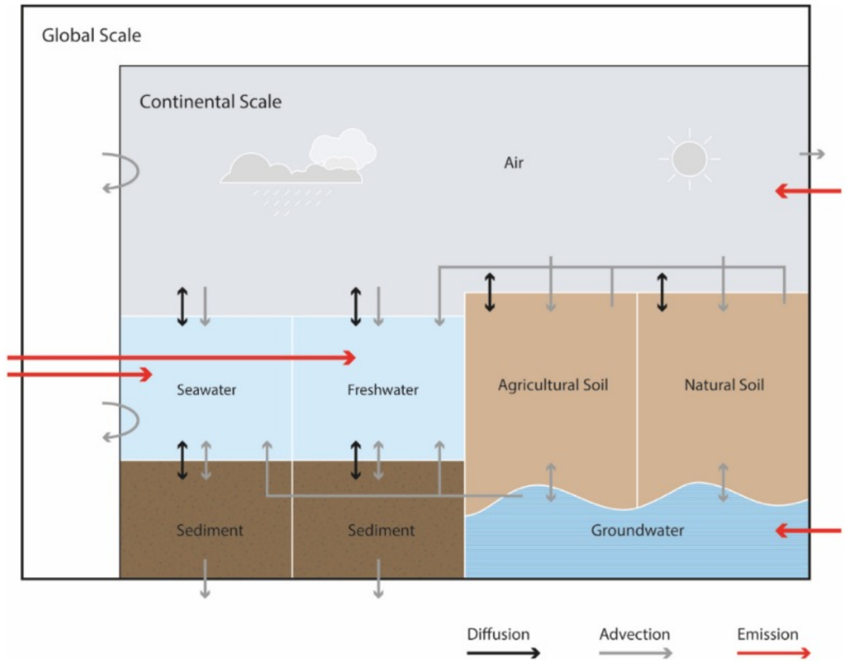



**Fig. 3.** Compartments considered in UCrad fate model.

## 2.3 *Radiological LCIA methods*

# CGM

Paulillo *et al*. 2020. Radiological impacts in Life Cycle Assessment. Part I: General framework and two practical methodologies. Science of The Total Environment 708, 135179. DOI.

## Adapted from Critical Group Methodology

- For comparison with HERA approaches

**Inventory**
Radionuclide quantity emitted [Bq]

**Fate module**
Radionuclide distribution [Bq to compartment]

**Gaussian Plume Model** **(IAEA 2001 + UK data)**

**Exposure module**
Cumulative dose via internal/external pathways [Sv]

## Primary use: Plant-scale assessment

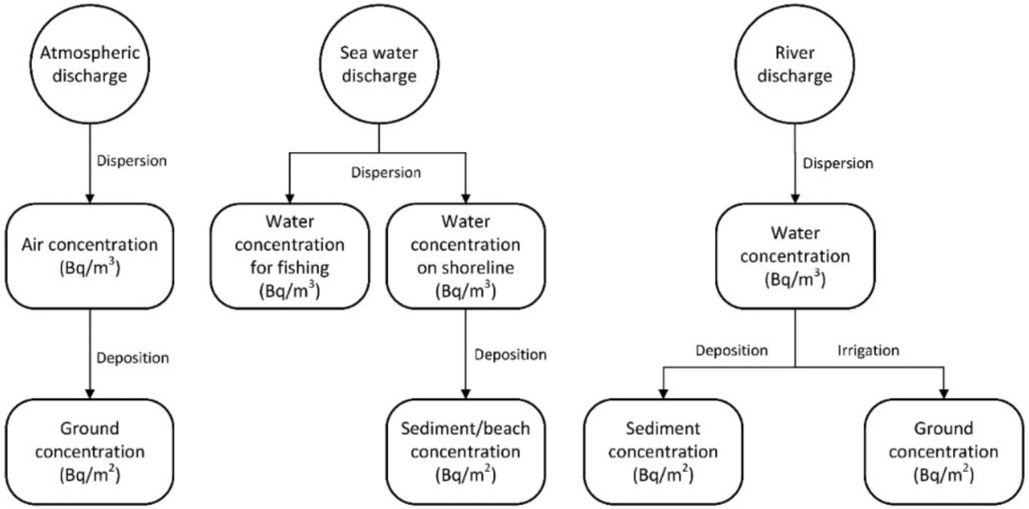



**Fig. 2.** Overview of the CGM Fate Module, adapted from IAEA (2001).

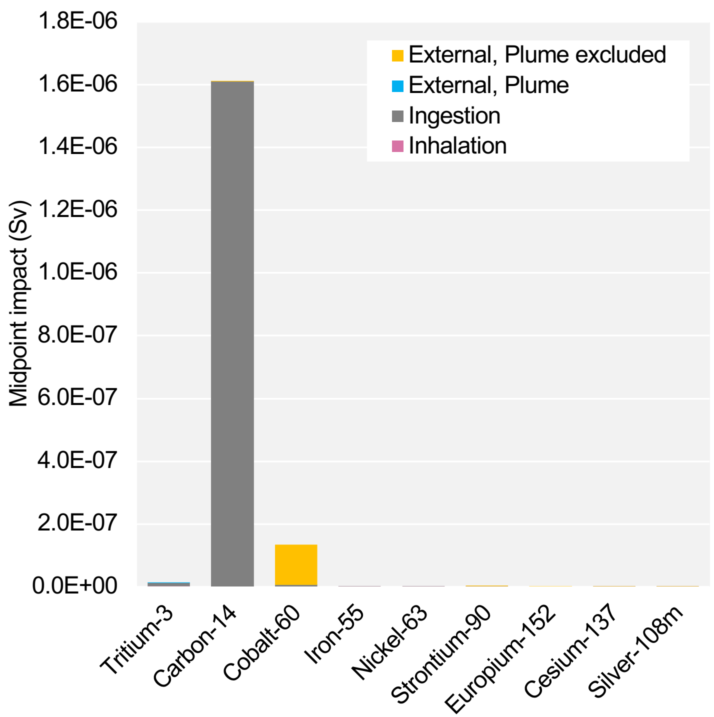
***Critical Group :*** *representative of those expected to receive the highest doses, small enough to be relatively homogenous with respect to age, diet and aspects of behavior that affect the doses received*

**2.1** *UCrad midpoint impact*

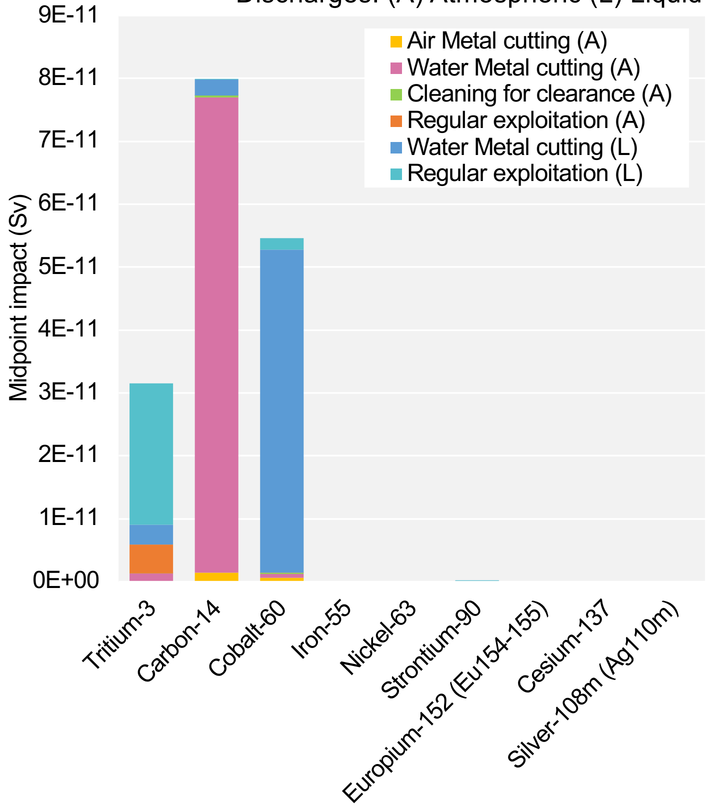
# Impact per radionuclide comparison

Same major RNs: $^{14}C$, $^{60}Co$, but changing relative proportions, and more importance given to $^{3}H$

EDF




Discharges: (A) Atmospheric (L) Liquid



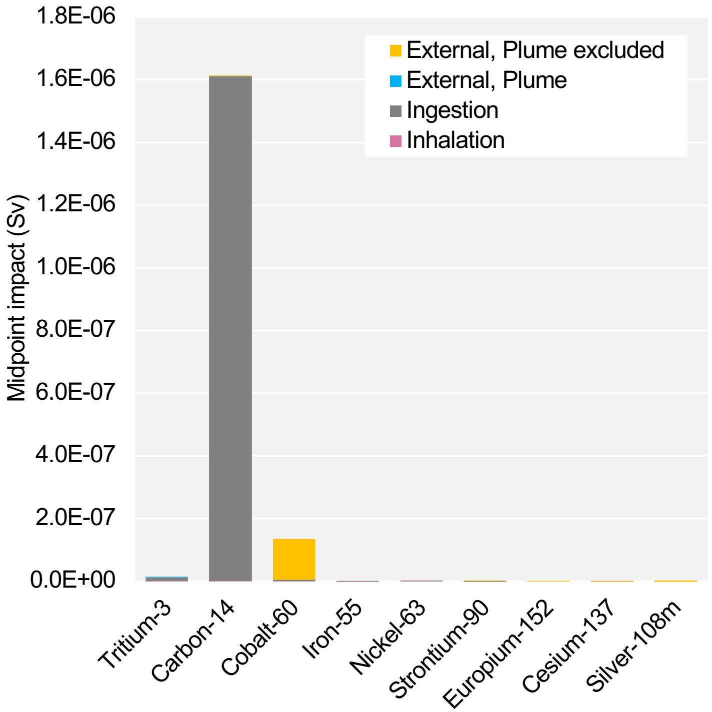

UCrad

3.2 *CGM 1 km midpoint impact*

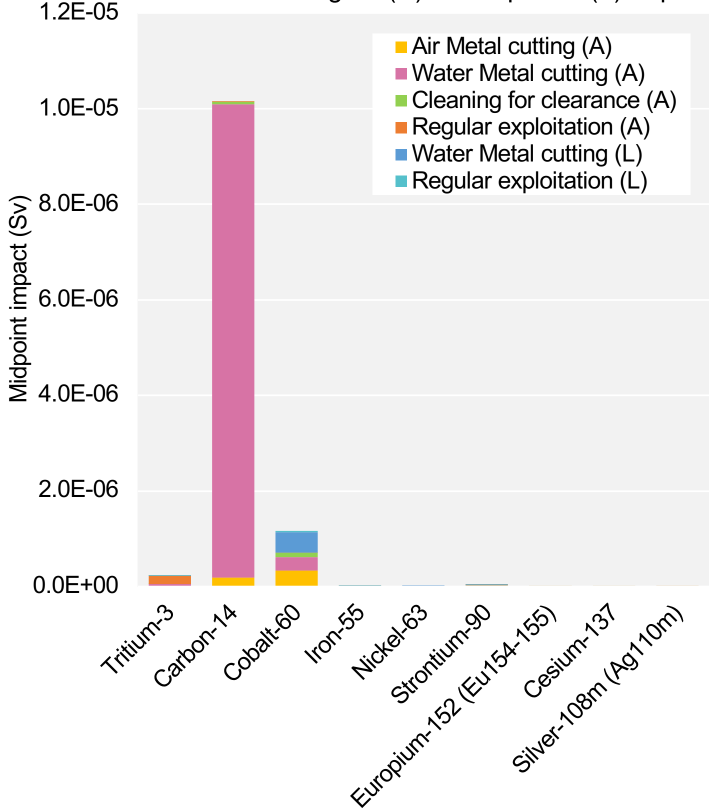
# Impact per radionuclide comparison

Similar relative proportions of major RNs, with CGM 1 km ~ 6,5 x EDF

EDF




Discharges: (A) Atmospheric (L) Liquid




CGM
1 km

3.3 *CGM 1 km control*

# Characterization comparison

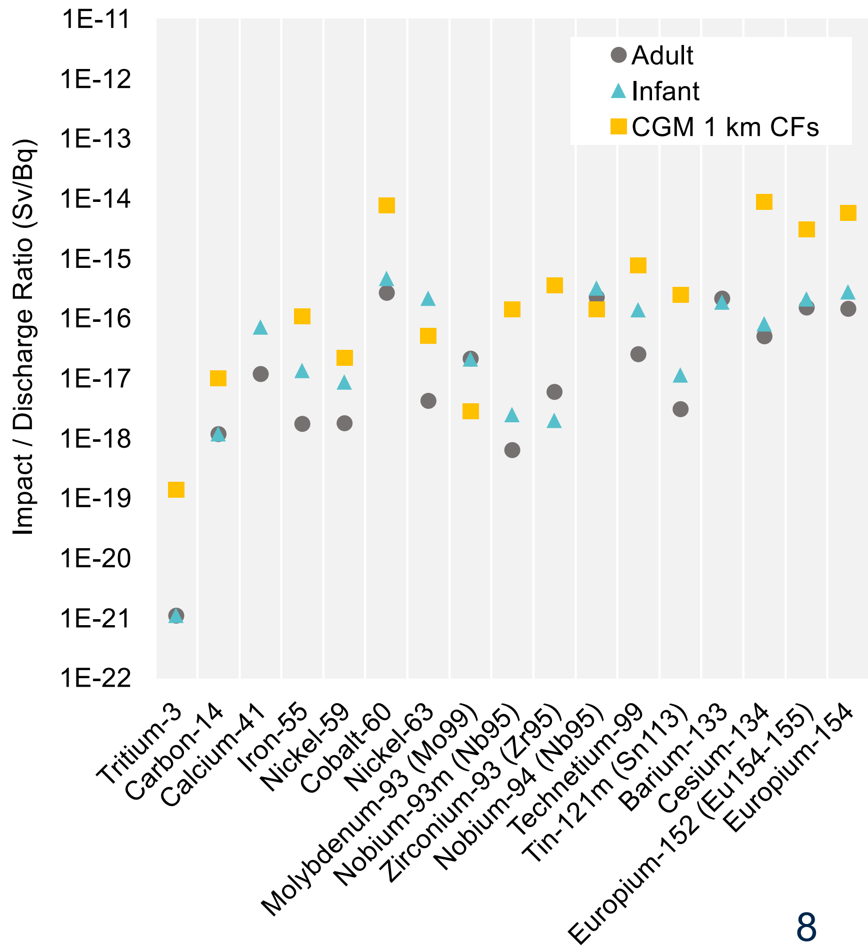
Chitra *et al.* 2020. *Dose assessment for atmospheric discharge for long-lived radionuclides in Nuclear Power Plant decommissioning*. Radiation Protection Dosimetry 190, 139–149. DOI.

## Few studies found in the literature yet

- Simulation example linked to the decommissioning of a Pressurized Heavy Water Reactor in India
  - Discharges of 1 Bq/s during a year for various RNs
  - Fate modeling following HERA approach
  - Exposure modeling from Indian NNMB 2012

- Effective dose results (Sv) normalized by discharges (Bq) to compare with CGM 1 km CFs

➔ CGM 1 km higher by 1-2 orders of magnitude



# Conclusions and Perspectives

## EDF risk assessment study for the Fessenheim NPP decommissioning:

- Provides a lot of data useful for LCA research
- Does not provide sufficient details for fully-fledged comparison
  *Extrapolations necessary*

## UCrad recently developed method:

- Seems appropriate for its purpose, complementary to HERA
  *e.g. global scale assessment, health impact comparison with conventional toxics*
- Allowed to make the first properly detailed radiological impact assessment of NPP decommissioning in the LCA framework
- ➢ Next step: a full life cycle approach

## CGM parallel method:

- Seems to overestimate the impacts due to insufficient regionalization
- ➢ Still needs important developments

Several RNs without any Characterization factor