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Assessment of radiological doses to wildlife due to its exposure to radionuclides in the Rhône River: case studies in link with natural background and actual NPP releases.

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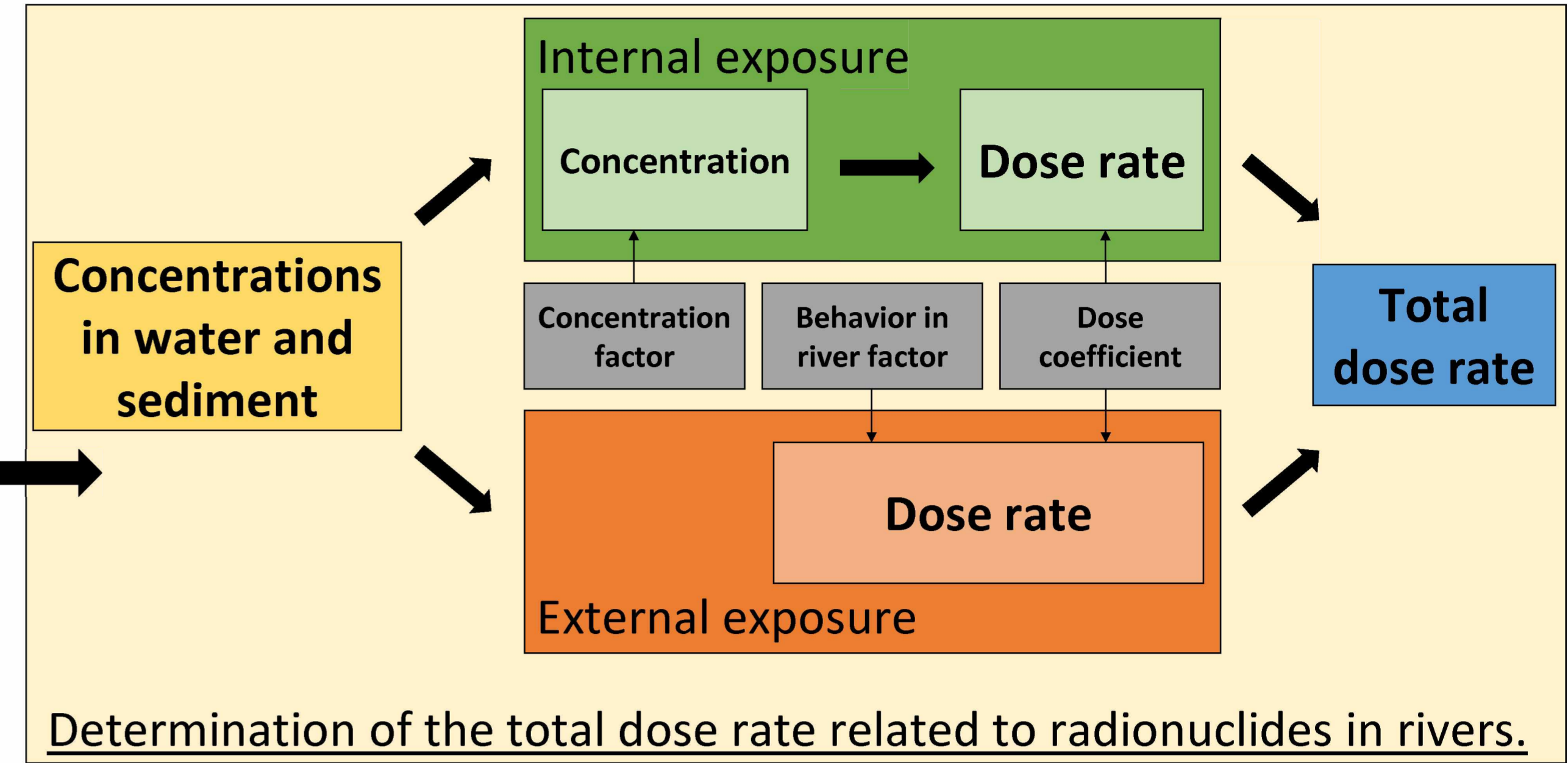
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Ecological impact of radionuclides

Artificial radionuclides are commonly observed in the environment:

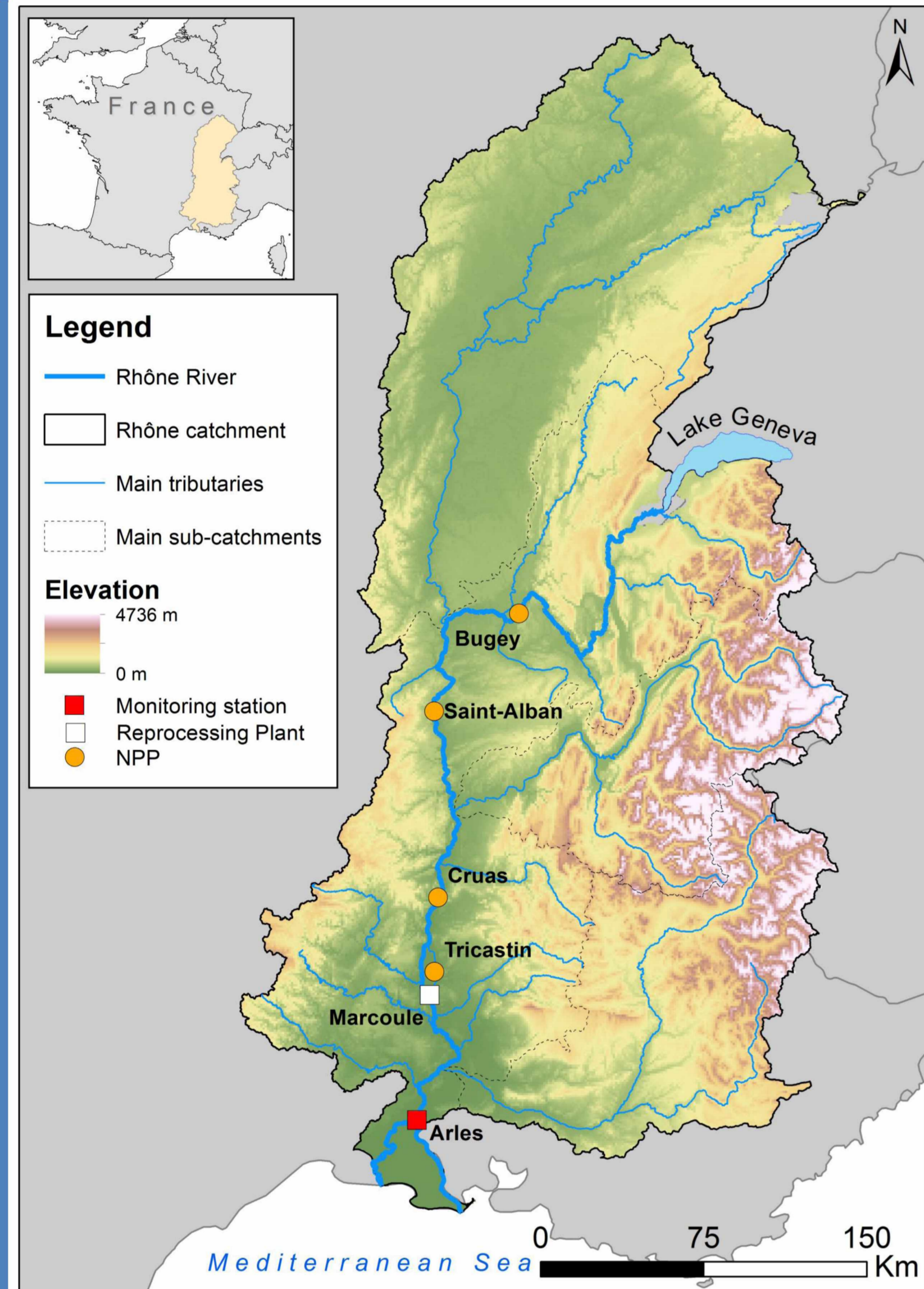
- Authorized releases by nuclear industry (with associated chemical contaminants),
- Atmospheric fallouts from past events (Chernobyl, Fukushima...).
- Wildlife is chronically exposed to the associated ionizing radiation.
 - Evaluation of the level of radiological risk for fauna and flora is needed,
 - Radionuclides emit radiation that will interact with the organisms by internal and external exposure

Investigations were conducted according to the recommendations and guidance provided by the International Commission on Radiological Protection (ICRP) to **characterize ecological impact of the presence of artificial radionuclides in the Rhône River (France)**, one of the most nuclearized river in the world with 14 reactors in 4 Nuclear Power Plants (NPP).



The Rhône River

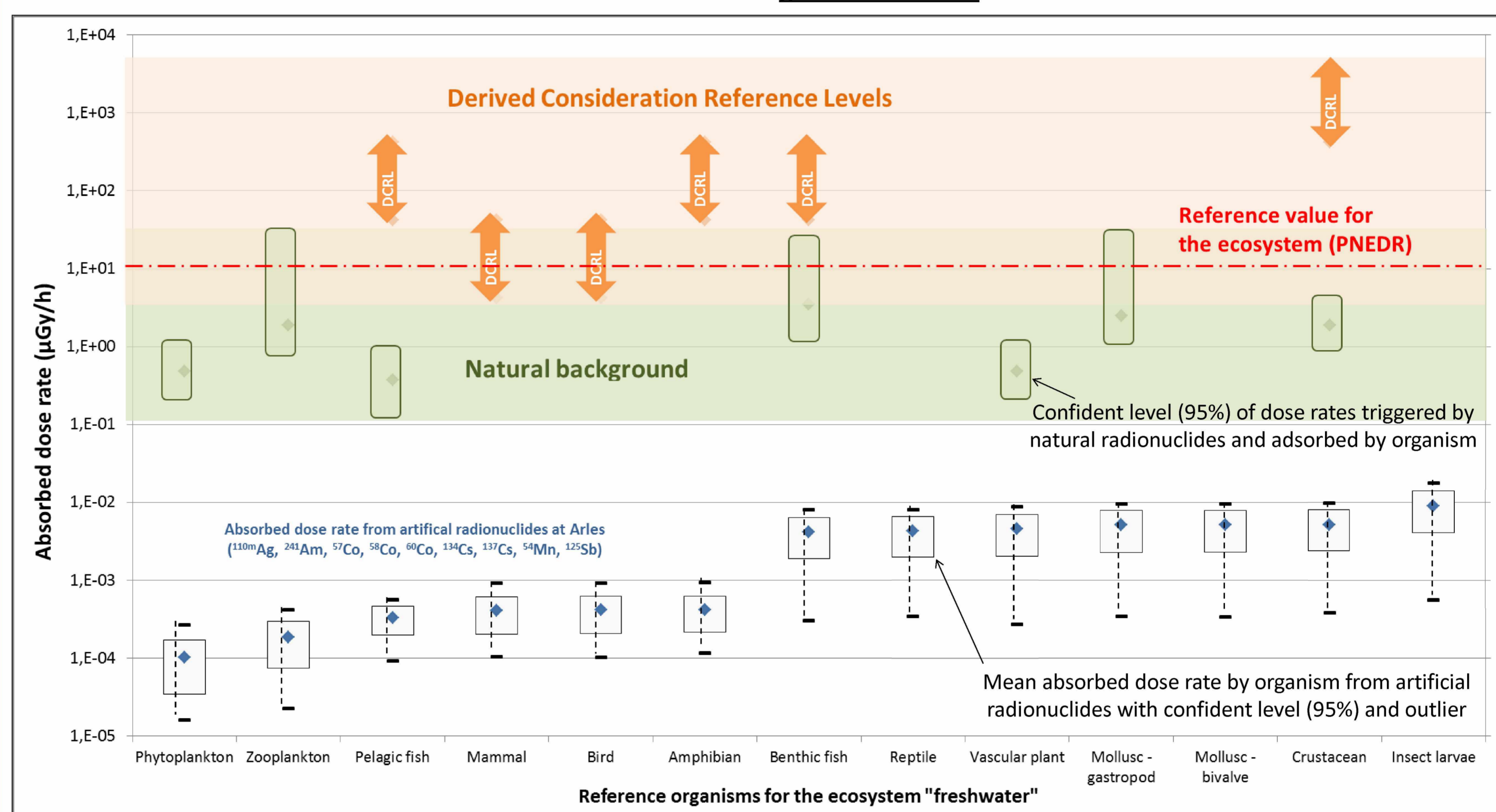
Location of the Nuclear Power Plants (NPP), Marcoule reprocessing plant and the city of Arles



Radionuclides ecological impact at Arles in the Rhône River^a

- Sampling:** suspended sediment and water samples collected at least every month at a Arles (monitoring station) since 2005.
- Origins:** NPPs authorized releases, Marcoule fuel reprocessing plant, fallout of nuclear weapon testing and Chernobyl accident.

Annual mean concentration of 9 artificial radionuclides - gamma emitter - were used to determine the total dose rate with the **ERICA tool^b**.



Conclusion: artificial radionuclides trigger an absorbed dose rate at least **one order of magnitude under natural background**

What about chemical contaminants?
→ See next part.

What about other emitters?
→ See perspective.

Radionuclides and chemical substances ecological impact downstream Nuclear Power Plants of the Rhône River^c

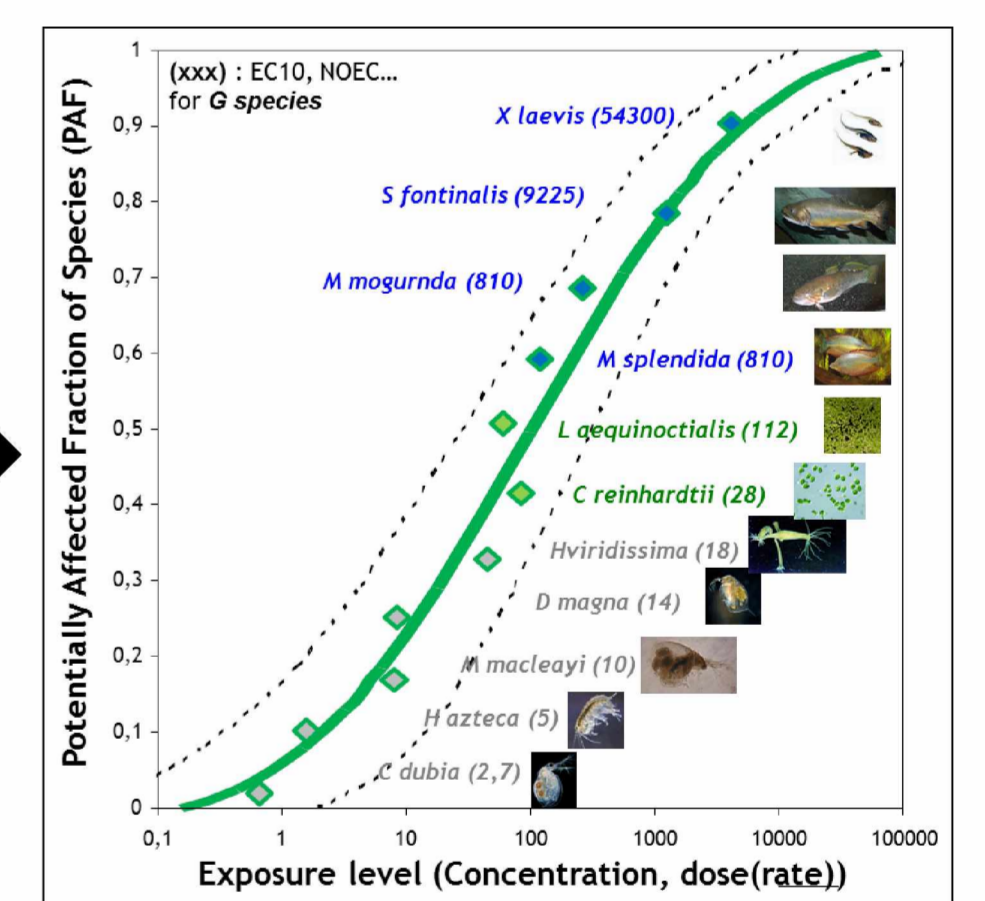
Problematic: several chemical substances released by the nuclear industry with radionuclides

- Risk assessment conducted using annual quantities of contaminants released by the four NPPs in the Rhône River in 2013.

Method:

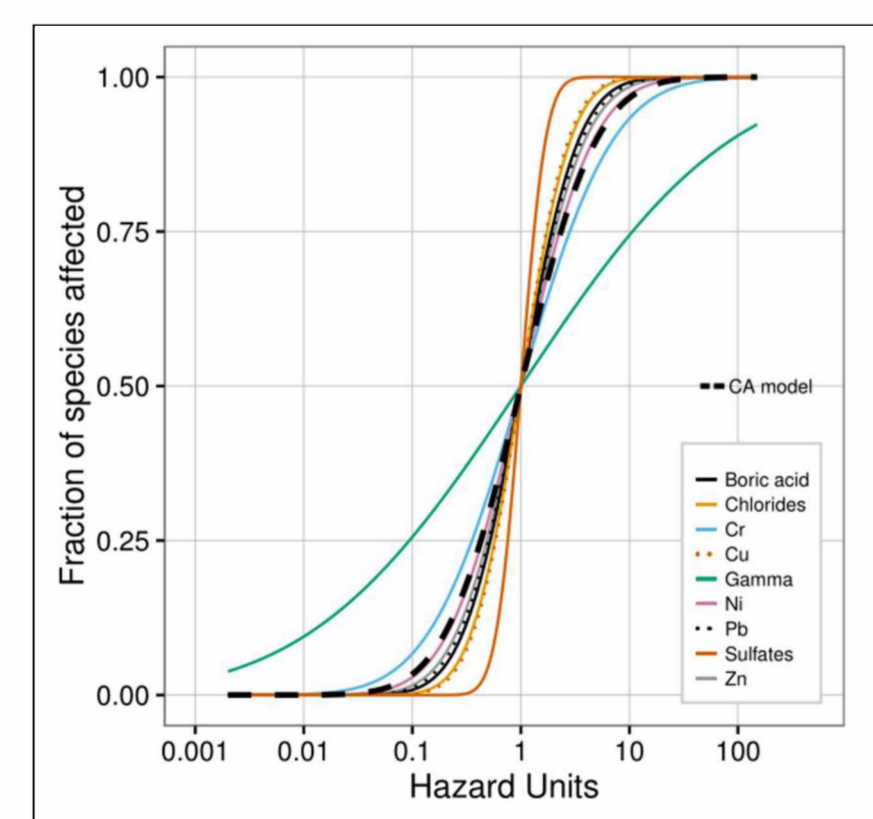
- Determination of radionuclides and chemical substances common factor:
 - Species Sensitivity Distribution (SSD)** used for estimation of the **Fraction of Affected Species (PAF)**.
- Combination by two different mixture models: **Concentration Addition (CA)** and **Independent Addition (IA)**.
 - provide the indicator of ecological risk called **msPAF (fraction of species potentially affected by the mixture)**
 - both models might also be mixed (model CAIA) => CA for substances with similar behavior then IA models is used to estimated the msPAF

SSD →



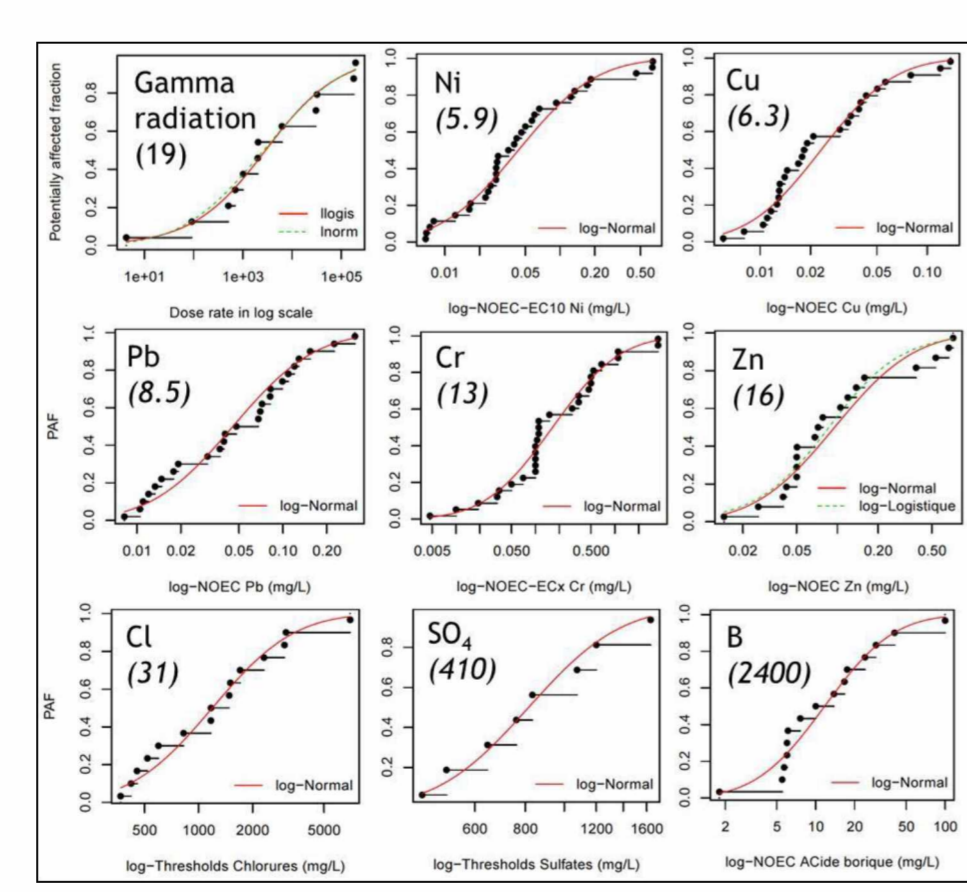
Concentration Addition

- SSDs normalized to their toxic potential (HC_{50})
- Estimated hazard unit (HU) = $\frac{C}{HC_{50}}$
- $msPAF = PAF$ at $\sum(HU)$



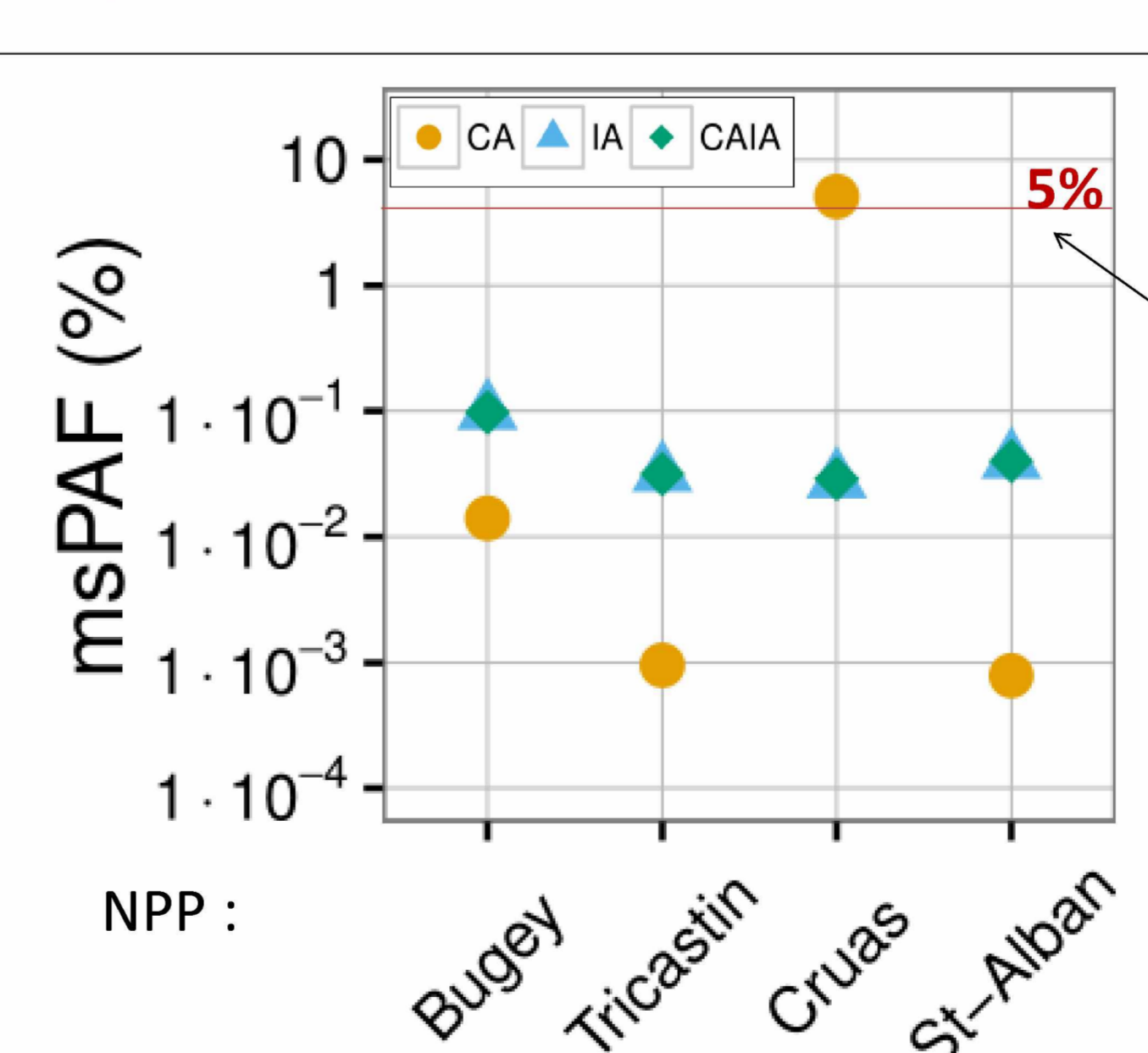
Independent Action

- Estimation of PAF for each substance
- $msPAF = 1 - \prod(1 - PAF_i)$



SSD for radionuclides and chemicals released by the NPPs

msPAF estimated with NPP released radionuclides and chemical substances



Conclusion:

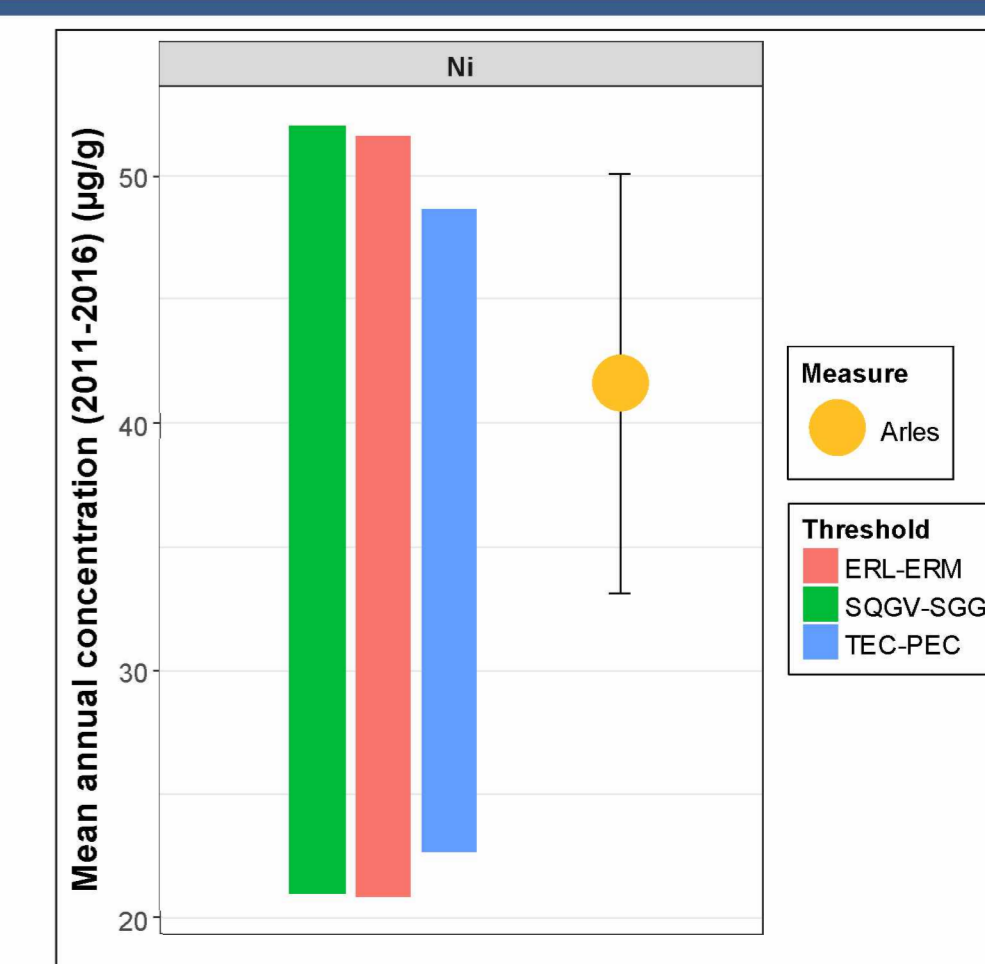
- Negligible overall potential ecological risk
- msPAF exceeding 5% in 1 case (related to high quantities of chemical substances released)
- No difference between CA and CAIA
- Use of both concepts (CA and IA) to provide a **"prediction window"**
- Contrarily to what is generally accepted, **CA was not the most conservative** in all cases due to very different SSD shapes (ionizing radiation vs. stable chemicals)

Perspective^d

Investigation of the ecological impact based on monitoring data (organics, inorganics and radionuclides) in Rhône River.

- Many substances ($n \approx 1100$) and samples ($n \approx 232000$),
- PCB, PAH or heavy metals sometimes exceeds environmental threshold - example of nickel concentration at Arles =>
- Non negligible work to collect and combine these data (different locations, different periods, different sampling methods...).

! **SSD not always available**



ERL: Effect Range Low
ERM: Effect Range Medium
TEC: Threshold Effect Concentration
PEC: Probable Effect Concentration
SQGV/SGG: Sediment Quality Guideline

^a This study was supported by the Rhône Sediment Observatory (OSR), a multi-partner research program partly funded by the Plan Rhône, and by the European Regional Development Fund (ERDF) allocated by the European Union.

^b Brown, J. E., et al. "The ERICA tool." Journal of Environmental Radioactivity 99.9 (2008): 1371-1383.

^c Beaumelle, Léa, et al. "Ecological risk assessment of mixtures of radiological and chemical stressors: Methodology to implement an msPAF approach." Environmental Pollution 231 (2017): 1421-1432.

^d This work is funded by the LabEx DRIHMH, French program "Investissements d'Avenir" (ANR-11-LABX-0010) which is managed by the ANR. It is supported by the OHM Vallée du Rhône