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Focus on isolation and confinement rather than on potential hazards: an approach to regulatory compliance for the post-closure phase

Outline

- Setting the problem
- A set of indicators orientated on safety functions
- Discussion

Setting the problem (1/4)

Joint Convention requirements:

- „to ensure that during all stages of spent fuel and radioactive waste management there are effective defences against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations”
- „strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation”
- „aim to avoid imposing undue burdens on future generations”

Setting the problem (2/4)

Decisions made to fulfil these requirements:

- Concentrate & Contain
- In the long run:
reliance on passive safety rather than on active measures
- Thus:
Deep (geologic) disposal as long-term strategy
- Need to demonstrate fulfilment of requirements:
“before construction of a disposal facility, a systematic safety assessment and an environmental assessment for the period following closure shall be carried out and the results evaluated against the criteria established by the regulatory body” (Joint Convention)

Setting the problem (3/4)

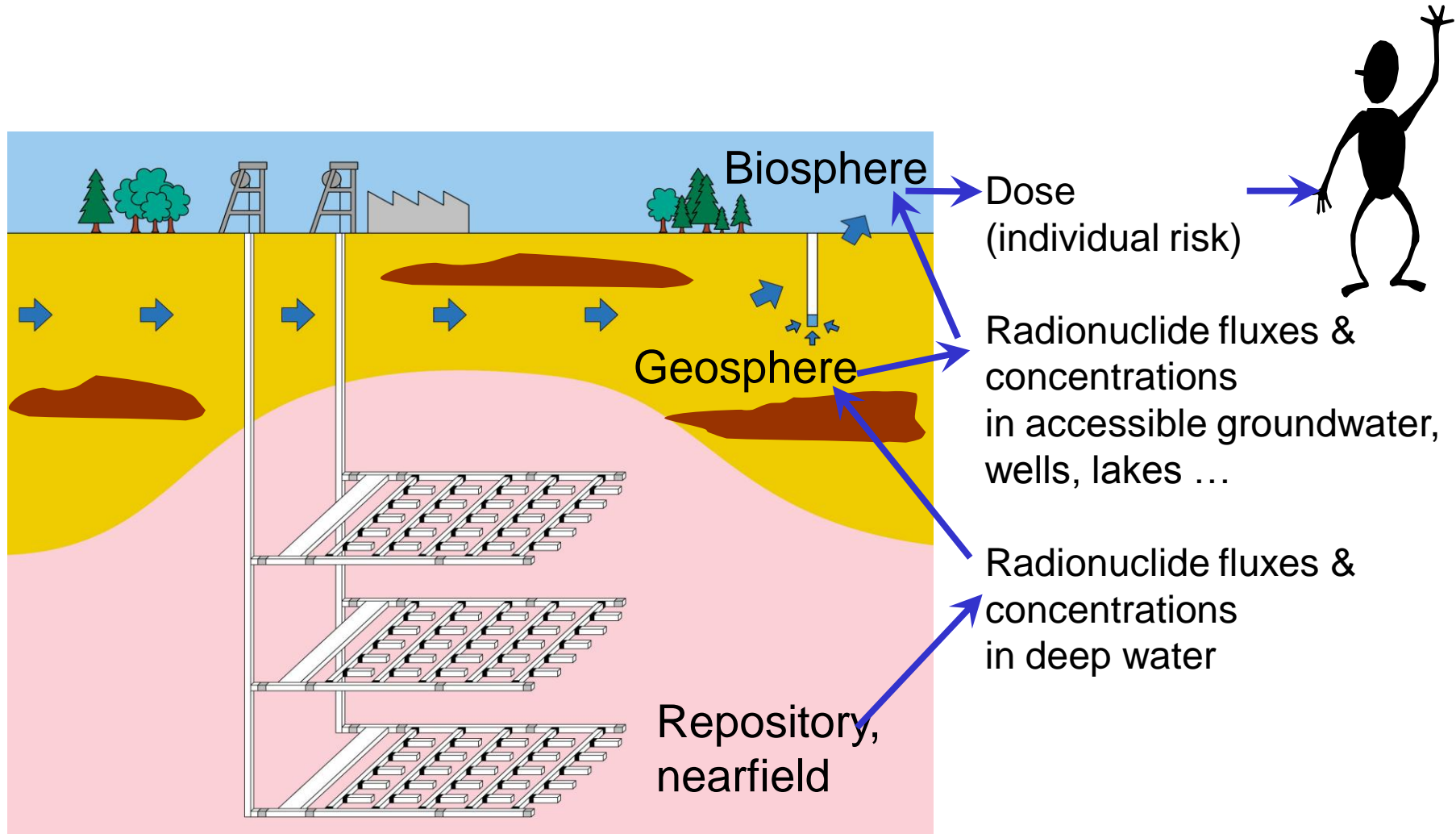
This has to be done by means of a Safety Case which relies on multiple lines of arguments:

- Site characterisation & geoscientific long-term prognosis
- Characterisation of engineered barriers & their long-term prognosis
- Safety concept and its implementation, including
 - Waste inventory and characterisation
 - Repository layout and implementation of planning and managerial principles concerning safety concept & safety functions, measures concerning FHA potentially compromising these functions, robustness, ...
- Demonstration of criticality safety
- Performance assessment (safety functions – system & sub-systems)
- Demonstration that safety principles and principles of final disposal are accounted for and that **protection objectives** are met:
based on **long-term safety analyses**
- Evaluation of safety and isolation/confinement potential
based on **indicators**

Setting the problem (4/4)

- Important line of arguments:
assessment calculations & calculated results,
i.e. potential consequences from radiological or chemotoxic
exposure or w.r.t. groundwater protection

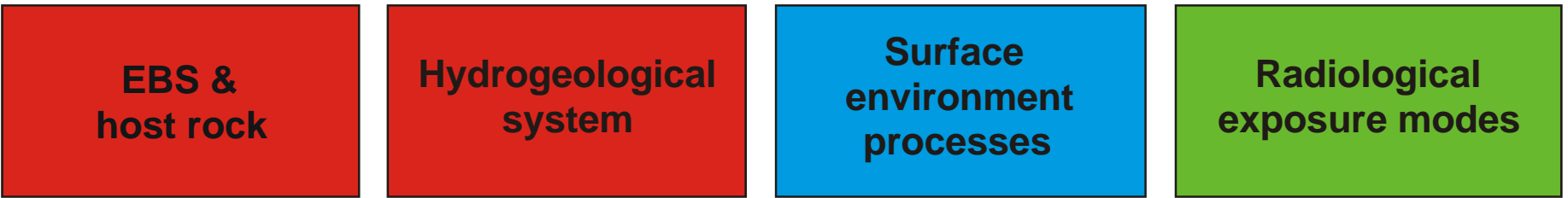
Setting the problem (4/4)



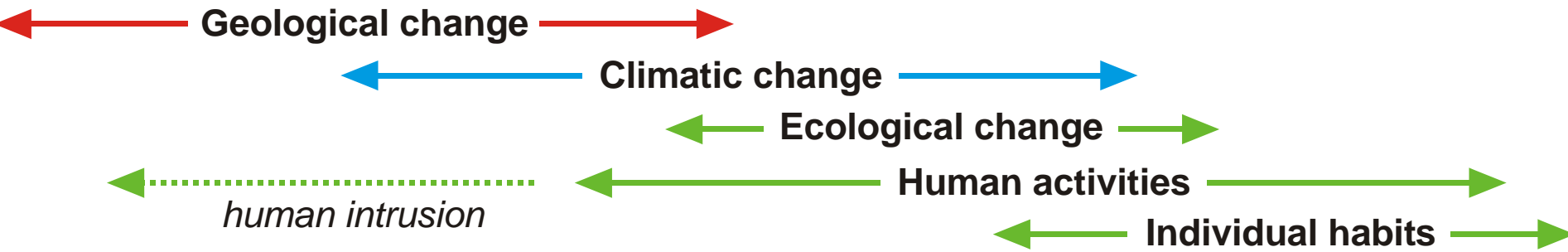
Setting the problem (4/4)

- Important line of arguments:
assessment calculations & calculated results,
i.e. potential consequences from radiological or chemotoxic
exposure or w.r.t. groundwater protection
- Comparison of (radiological) results with regulatory limits /
targets / constraints → ICRP
- But:
 - How reliable are the results?

Elements to be represented



Changes acting on these elements



Setting the problem (4/4)

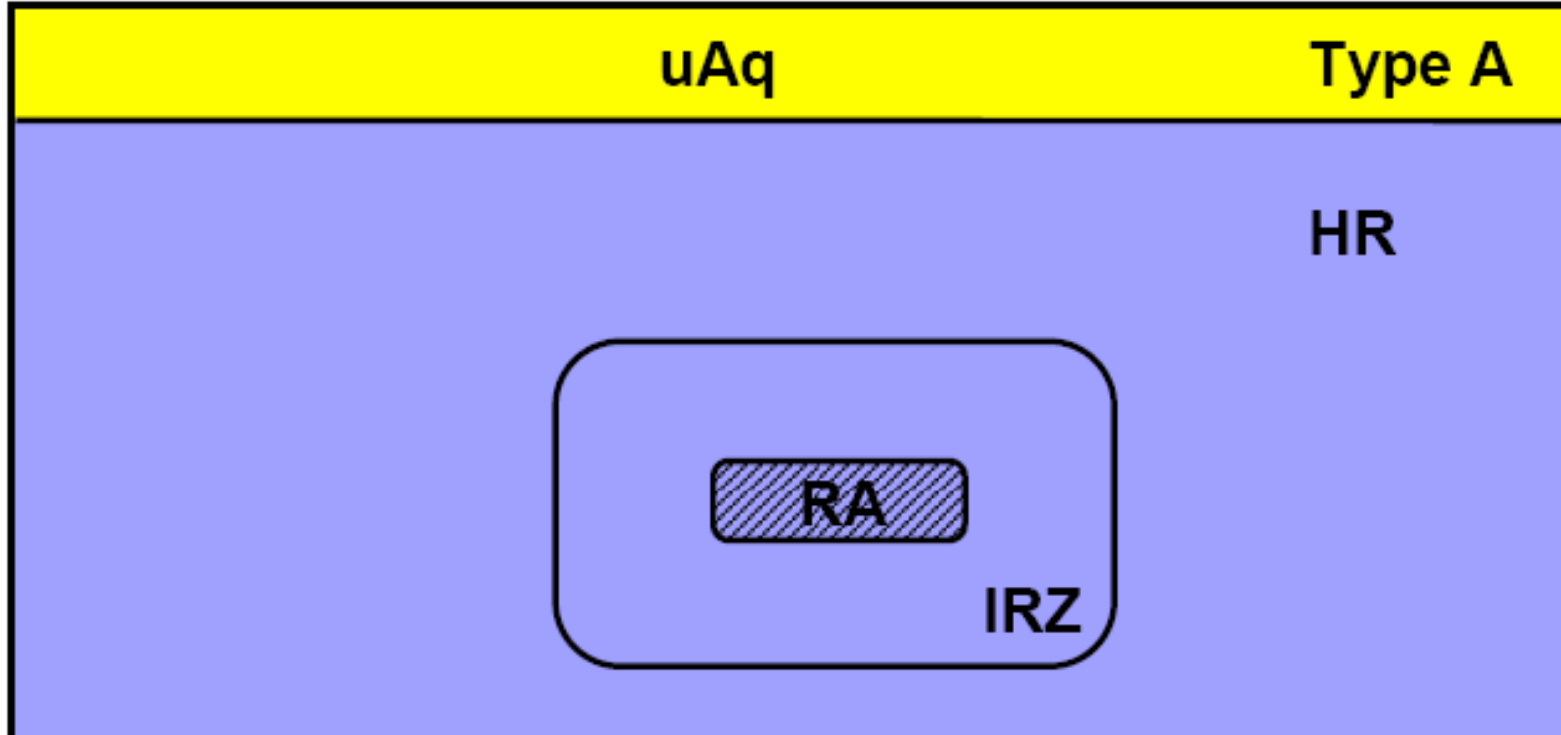
- Important line of arguments: assessment calculations & calculated results, i.e. potential consequences
 - Comparison of (radiological) results with regulatory limits / targets / constraints → ICRP
 - But:
 - How reliable are the results?
[ICRP: “No predictions, indicators ...”]
 - How can we know that “needs and aspirations of future generations” (Joint Convention) are met?
 - How can we know that the (non-human) environment is protected?
 - How to address the “regulatory dilemma”:
timeframe of hazard vs. timeframe of predictability?
- (Questions being asked e.g. by NEA/RWMC’s LTSC
– cf. Pescatore & Forinash)

A set of indicators orientated on safety functions (1/3)

- In the course of criteria & guideline development GRS attempted to address these problems by ...
 - Developing a set of indicators which focuses on safety functions, i.e. on the system's ability to confine & isolate:
If isolation/confinement is ensured, protection objectives are met
 - Deriving corresponding yardsticks which focus on preventing disturbances or changes in surrounding geosystems and biosystems
- Role of the “isolating rock zone” (Committee on a Site Selection Procedure for Repository Sites AKEnd)

Excursus: the Isolating Rock Zone (quotations from AKEnd report)

- “Part of the geological barrier which at normal development of the repository and together with the technical and geotechnical barriers has to ensure the confinement of the waste for the isolation period”
- “site shall be selected in a manner that a longest possible isolation period is achieved”
- Requirements:
conductivity, thickness, depth, extension, flow & migration, characterisability / predictability, mechanics, chemistry, gas & temperature compatibility ...
- “minimum requirements regarding field hydraulic conductivity, thickness and extent of the isolating rock zone ... over a period of time of the order of magnitude of one million years”



Rock body without safety-relevant barrier effect



Rock body with safety-relevant barrier effect

uAq

aquifer with contact to biosphere

RA

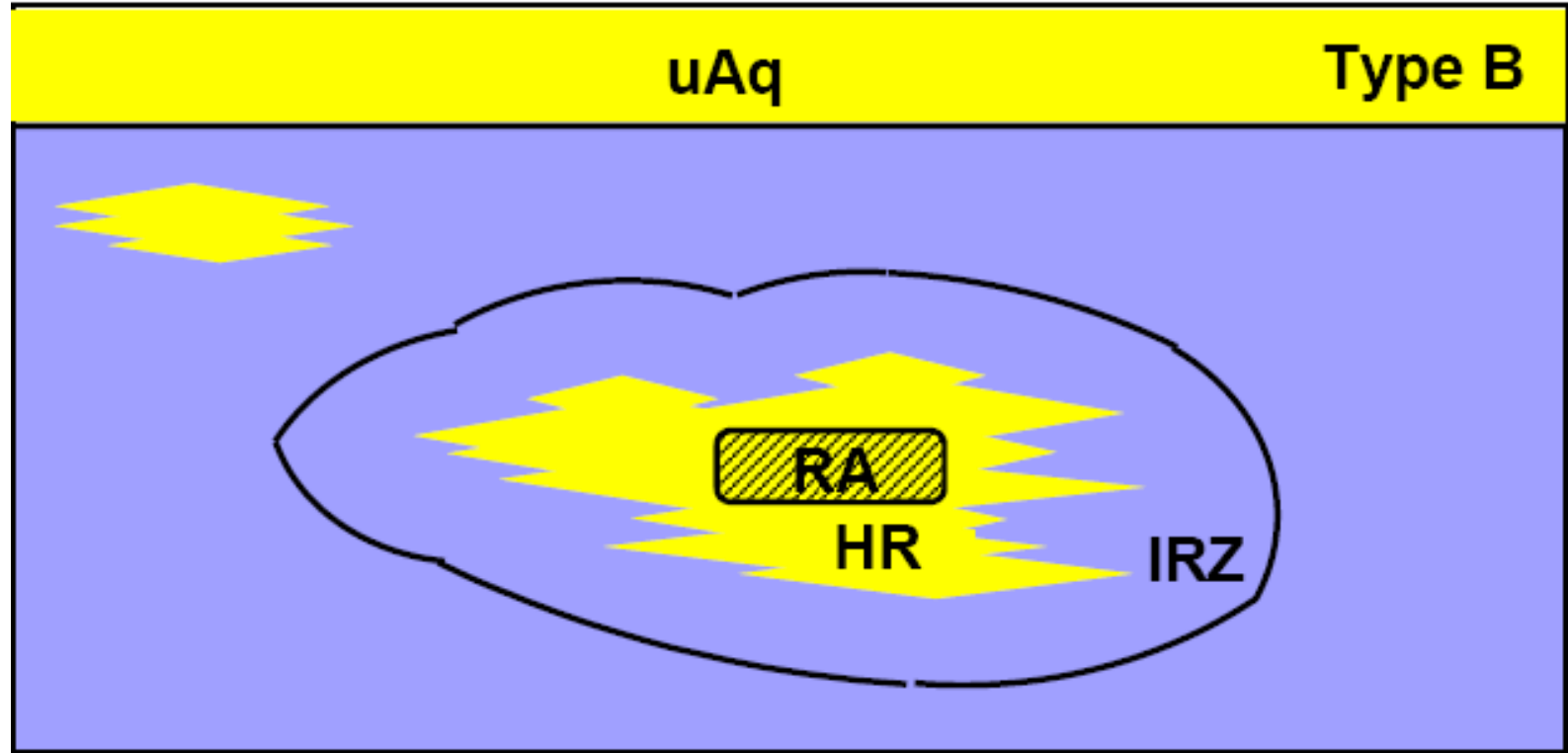
repository area

HR

host rock

IRZ

isolating rock zone



Rock body without safety-relevant barrier effect



Rock body with safety-relevant barrier effect

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- Role of the “isolating rock zone” (Committee on a Site Selection Procedure for Repository Sites AKEnd)

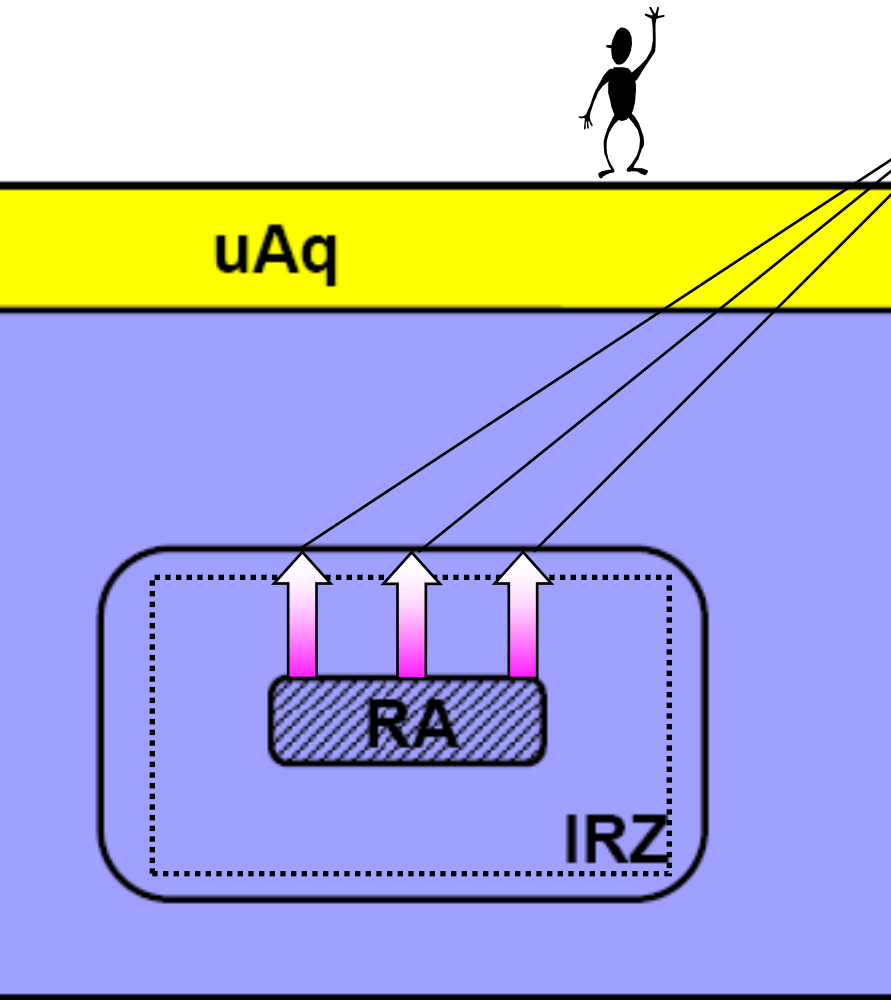
● Requirements

- Likely scenarios: do not significantly increase natural concentrations / activity!
- Less likely scenarios: add at maximum concentrations / activity in the order of magnitude found in nature!

A set of indicators orientated on safety functions (2/3)

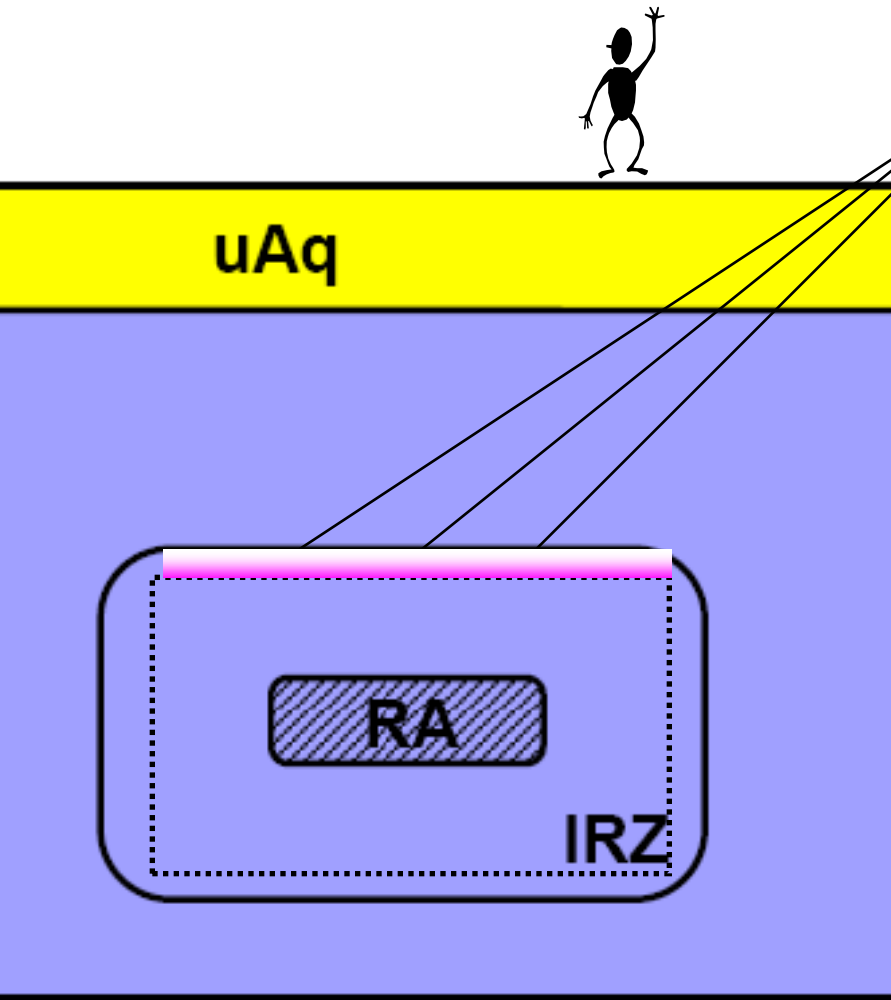
- This approach has, however, its limitations:
 - Problems with radionuclides not found in nature
 - Consequence: We are not in a position which allows us to abstain completely from radiological considerations – they are needed to evaluate concentrations of artificial nuclides.
- The following set of indicators is presently being discussed
...

A set of indicators orientated on safety functions (3/8)



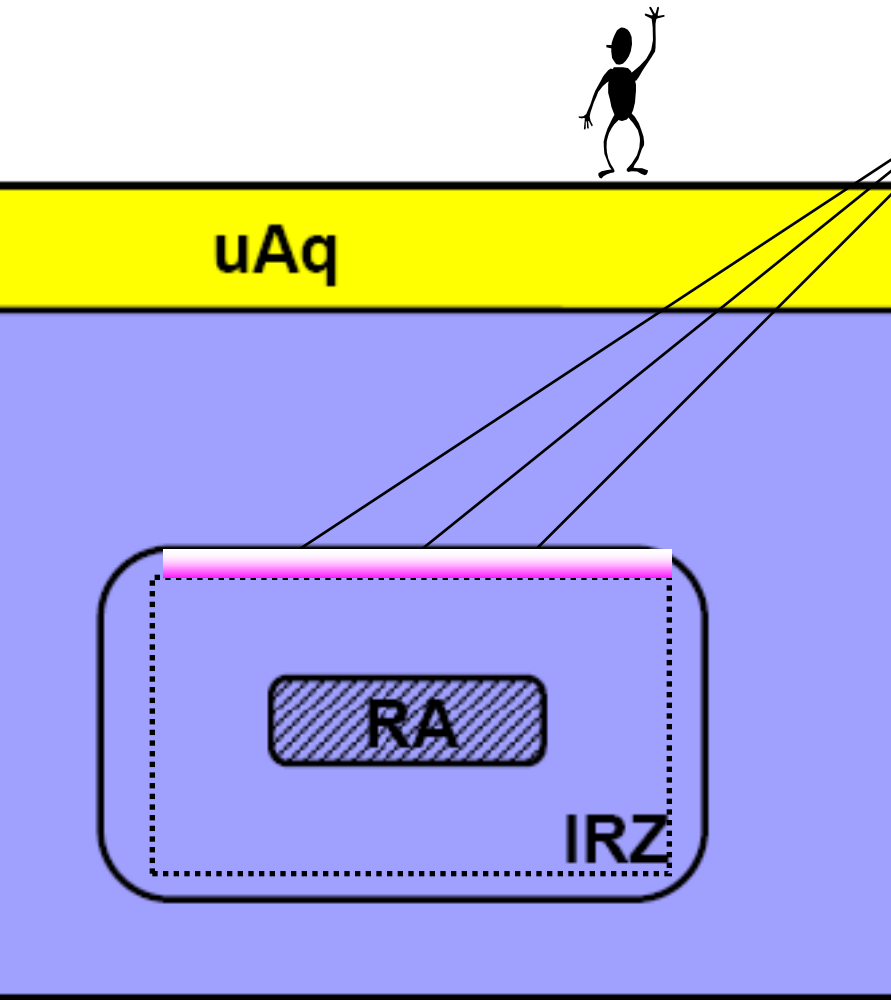
- Indicator: fraction of released amount of substance (cumulated over assessment time)
- Location: boundary of isolating rock zone
- Criterion: percentage of amount of substance disposed of
- Evaluation of confinement/isolation, no direct relationship to impact

A set of indicators orientated on safety functions (4/8)



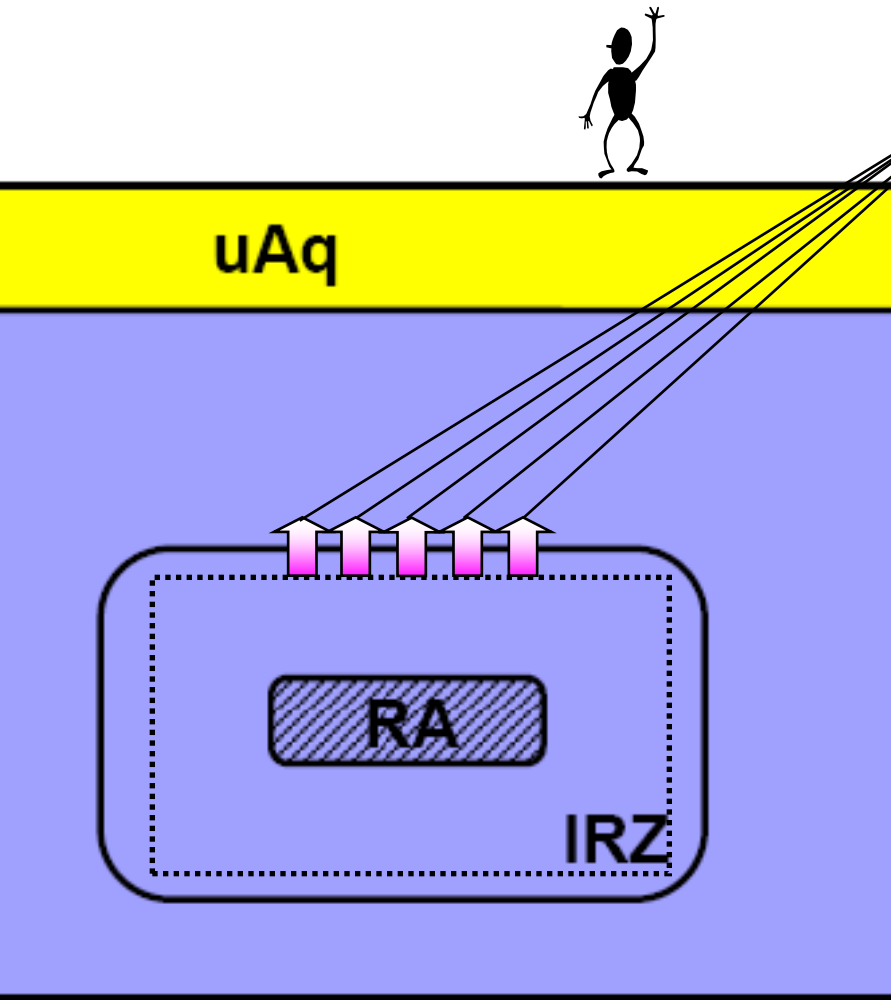
- Indicator: concentration of released U and Th (all isotopes)
- Location: boundary area of isolating rock zone
- Criterion:
1 $\mu\text{g/l}$ U, 0.1 $\mu\text{g/l}$ Th
- Addition to natural concentrations

A set of indicators orientated on safety functions (5/8)



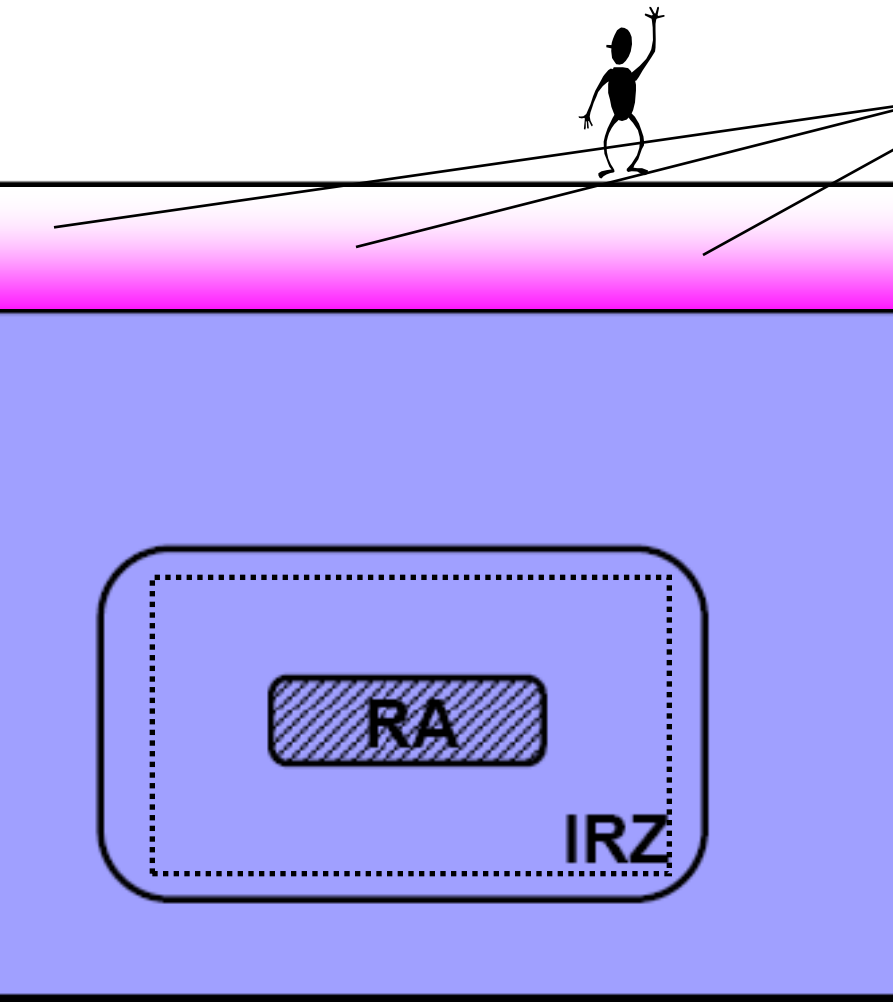
- Indicator: contribution to power density in groundwater
- Location: boundary area of isolating rock zone
- Criterion:
0,6 MeV per l pore water
(in case of indurated clay)
- Addition to natural radioactivity
- Aggregation (all nuclides)
- Indicator for impact (biota), but no dosimetry

A set of indicators orientated on safety functions (6/8)



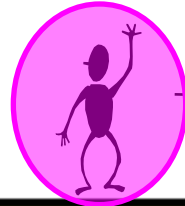
- Indicator: contribution to radiotoxicity in groundwater (flux)
- Location: boundary of isolating rock zone
- Criterion: 0.1 mSv/a
- Addition to natural radioactivity
- Aggregation (all nuclides)
- “shortcut” of aquifer system, standardised “biosphere”

A set of indicators orientated on safety functions (7/8)

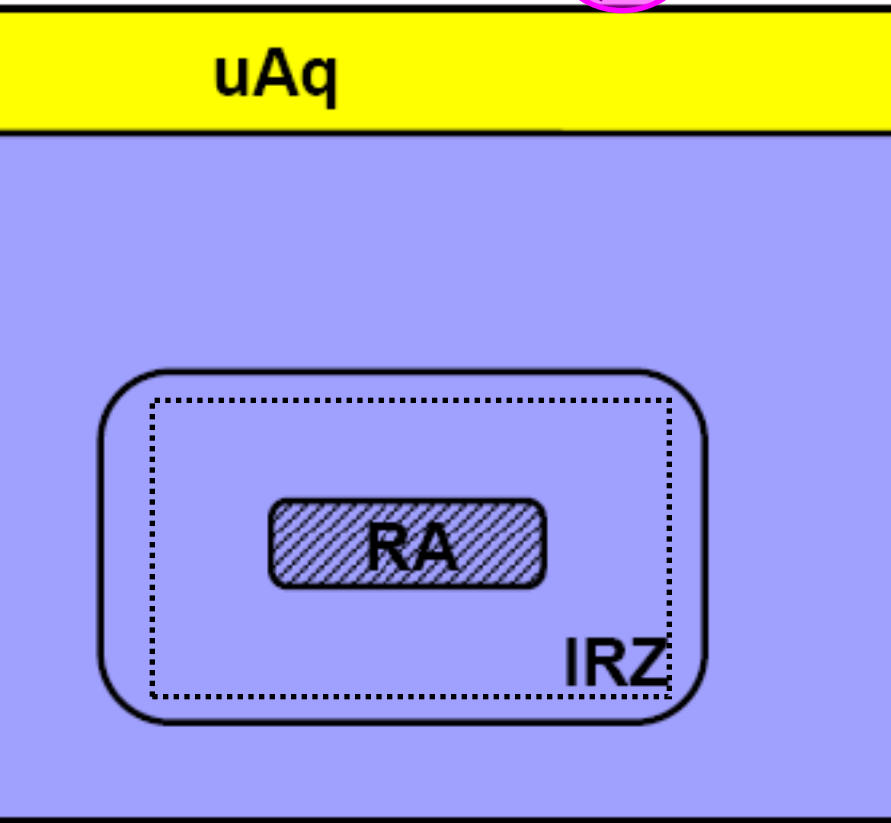


- Indicator: nuclide concentrations in accessible groundwater (natural occurring nuclides)
- Location: surface aquifers
- Criteria: specific per nuclide
- Addition to natural concentrations
- No aggregation
- Present-day or plausible future hydrology (timeframe!)

A set of indicators orientated on safety functions (8/8)



- Indicator: effective individual dose per year
- Location: biosphere
- Criteria: 0.1 mSv/a
- Addition to natural radioactivity
- Aggregation (all nuclides)
- Present-day or plausible future hydrology, standardised “biosphere”
- Related to “impact”, confirmatory character (timeframe!)



Discussion

- We evaluate calculation results (which are one of multiple lines of evidence) in a way which focuses on the safety function “confinement/isolation”
- Line of argument:
 - If confinement/isolation is ensured, protection objectives are met
 - Confinement/isolation is ensured if existing system is perturbed as little as possible
 - Preferred in comparison to largely hypothetical biosphere models
 - As consequence, protection of humans and environment. “Needs and aspirations” discussion loses importance.
- “Additional indicators” being utilised (often required, but less often implemented)
- As far as possible: Reliance on indicators which can be calculated based on modelling of components the evolution of which can be forecasted over assessment timeframe (“regulatory dilemma” in part addressed ...
... limitations of practical reasoning ... common sense)
- Limitation: artificial radionuclides – dose models needed here!

Under construction!

