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Partitioning & Transmutation

Solution for nuclear waste?

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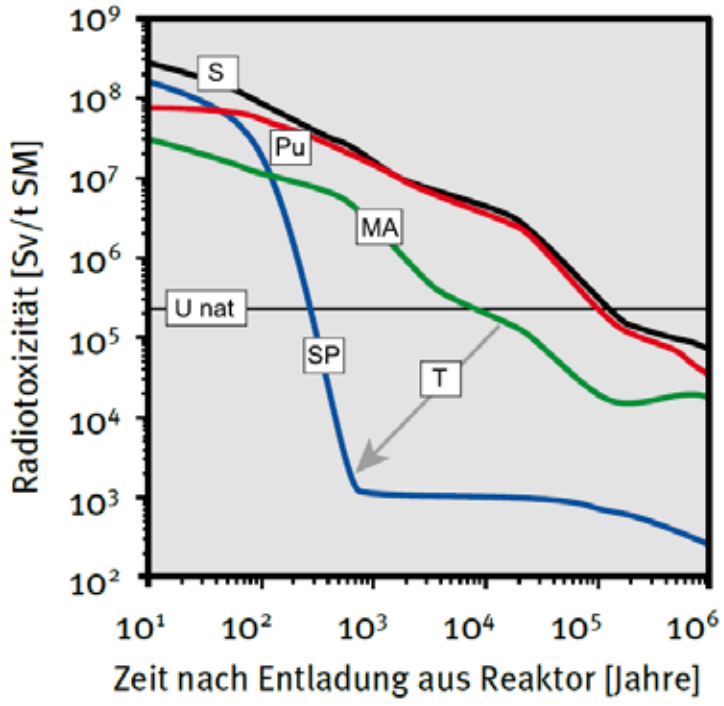
Introduction

P&T: Solution for Waste Disposal?

Deutsche Physikalische Gesellschaft DPG
PHYSIKonkret

„Das Beispiel Transmutation zeigt eindrucksvoll, welches Potential die Grundlagenforschung – hier die Beschleunigertechnologie – zur Lösung gesellschaftlicher Herausforderungen birgt."
Johanna Stachel, Präsidentin der Deutschen Physikalischen Gesellschaft

Abb. 2



Abnahme der Radiotoxizität von abgebranntem Kernbrennstoff nach Abtrennung des Urans U im Vergleich. Die Minoren Aktinide MA werden durch Transmutation T in Spaltprodukte SP überführt, sodass diese den Abklingprozess dominieren.

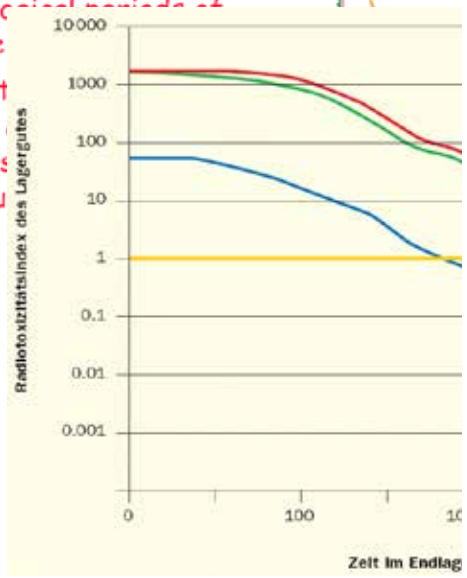
U nat: Natururan
SP: Spaltprodukte
MA: Minore Aktiniden
Pu: Plutonium
S: Summe aller Teilradiotoxizitäten ohne Transmutation
T: Transmutation

In Anlehnung an [I].

P&T: Solution for Waste Disposal?

Waste Storage Times

- Fission Products are shorter lived (~30 years half life) than actinides(~10^5 years). So actinide wastes need storage for geol… time solut… less … the s… redu…



March 18,2009

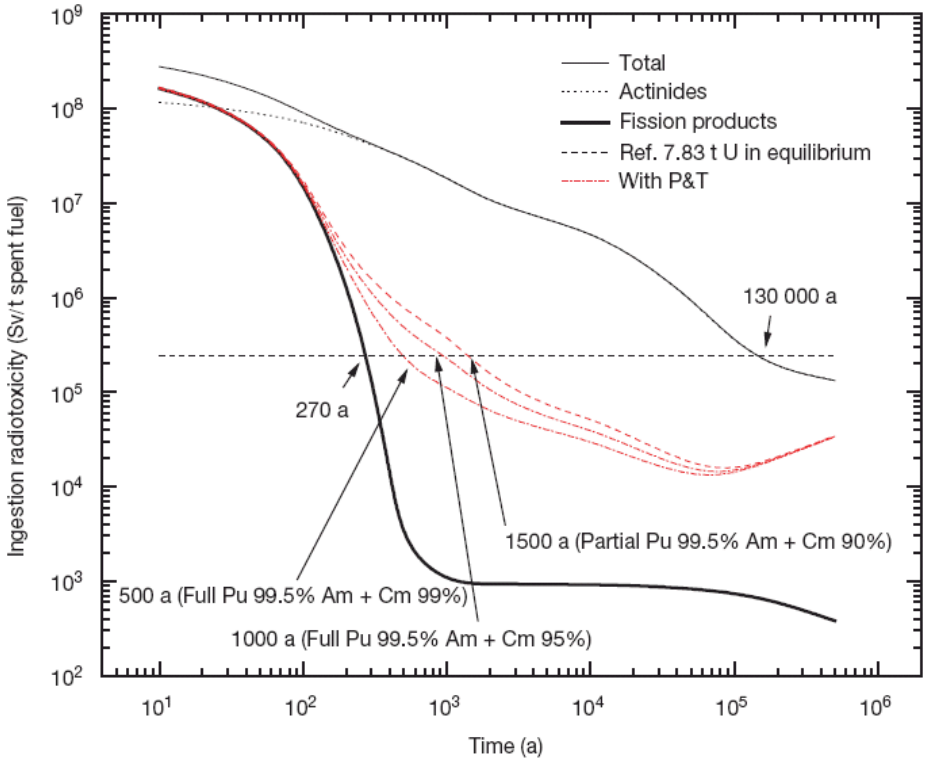


FIG. 1. Ingestion radiotoxicity of 1 t of spent nuclear fuel.

Principal Options

- Ignore à too dangerous
- Recycling à not possible with some exceptions
- Transport to space à à too dangerous
- Disposal into oceans floor à dissolution and distribution
- Interim storage à not sustainable in the long term
- Deep geologic repository à ?

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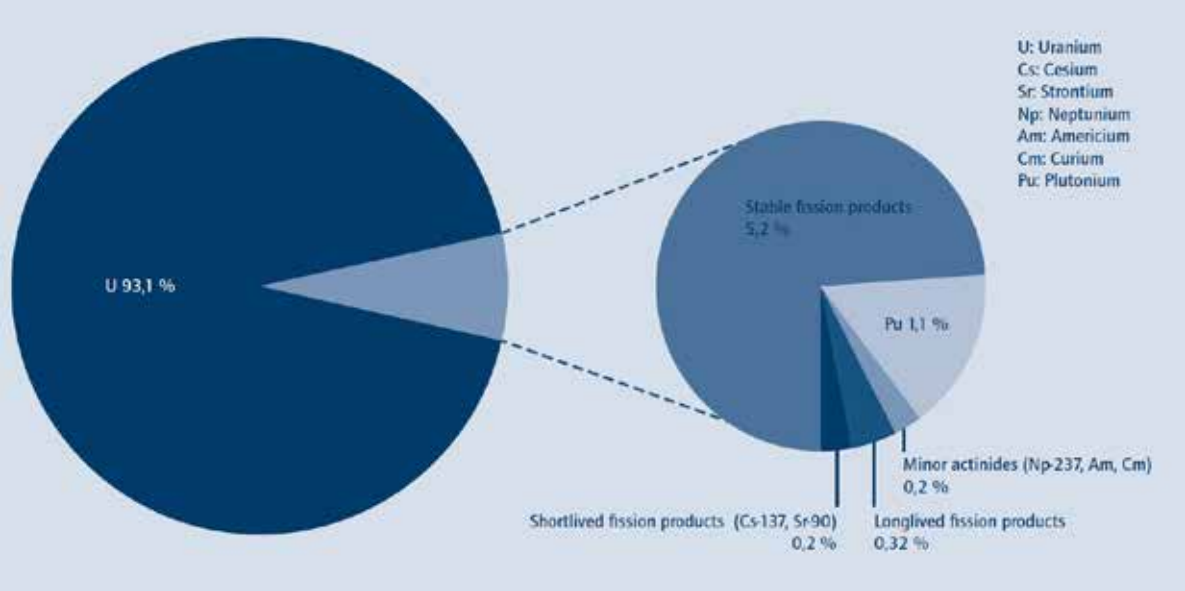
Final Repository (in Germany)

Content?



Type in 2022	Volume
Spent fuel for direct disposal	21.000 m^3
Coquille from Reprocessing	1.400 m^3 (6.700 tHM)
Fuel from demonstration plants and research reactors	5.700 m^3
Total	28.000 m^3

Source: Acatech 2013

- Fission and activation products with short half-life (~ 5 - 30 years half-life), e.g. Cs-137, Sr-90, Co-60
- Fission and activation products with long half-life (up to 10^6 years), e.g. I-129 , Se-79, Tc-99, Cl-36
- Actinides (often long to very long half-life), e.g. Uranium, Plutonium, Americium, Curium, Neptunium

Concept of deep geologic repository

- Installed in a depth of several hundreds of meters
- Site geology assures a safe containment for one million years
  à In Germany several locations with salt or claystone formations
- The geological development has to completely enclose the radioactive material in the rock formation for at least 1.000.000 a

Long-Term Safety Analyses

- What can happen to the disposed waste? Which radionuclides could quickly diffuse and be released to the biosphere, and which release paths are important?
- How do geologic formations change (erosion, uplifting, denudation, seismic, volcanism, natural climatic changes etc.)?
- Which radioactive dose will humans receive form a final repository in the future? Will humans be exposed to a dose which is not acceptable today (dose criterion)?

Prinicipal Posibilities

- Ignore à too dangerous
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- Transport to space à à too dangerous
- Disposal into oceans floor à dissolution and distribution
- Interim storage à not sustainable in the long term
- Deep geologic repository à ?
- Transmute ?

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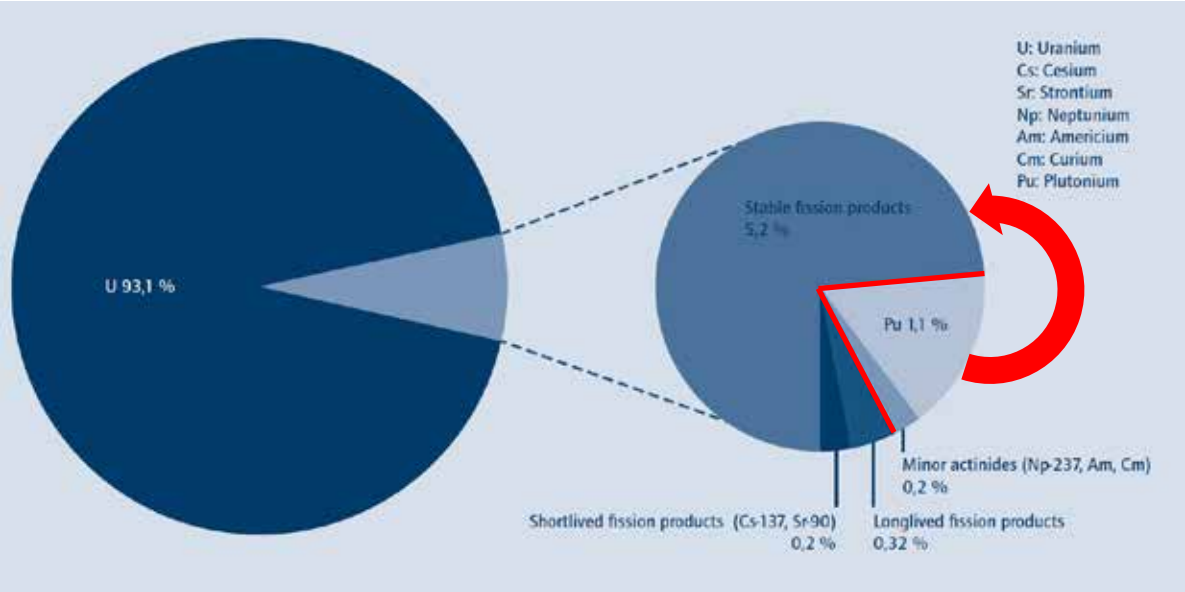
Partitioning & Transmutation

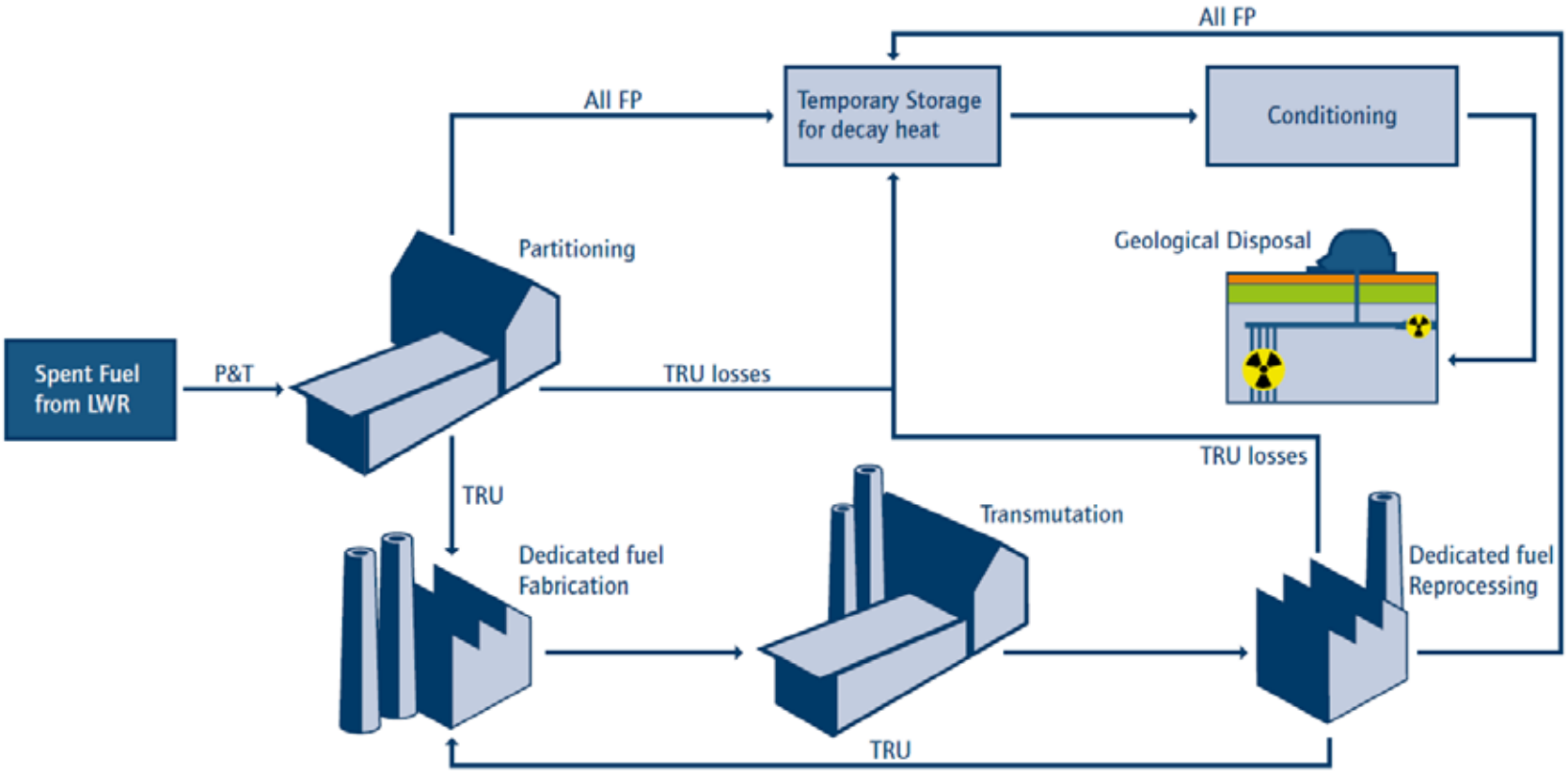
What is planned?



- Uranium in fresh fuel fissions in current light water reactors
- Reprocessing: Uranium (U) und Plutonium (Pu) are extracted
- Uranium-Plutonium Mixed-Oxide (MOX) fuel used in reactors
- P&T: additionally fission minor actinides such as Np, Am and Cm

Transmutation – The complete System

Source: Acatech 2014



Transmutation (Example of Germany)

Inventory
10.500 t Heavy Metal (HM)
~ 130 t plutonium ~ 40 t minor actinides ~ 430 t fission products

Infrastructure
7-8 EFIT Reactors (400 MWth)
1 large reprocessing plant
1 fuel fabrication facility

European Facility For Industrial Transmutation (EFIT)	
Inventory at start	4.4 t transuranics
After 3 years in reactor	10 % transuranics burned
Reprocessing	9-10 t transuranics

After 150 Years	
Additional fission products	+150 t (580 t total)
Additional low and medium radioactive waste	+100.000 t
Transuranics reduction	-165 t (5t total)

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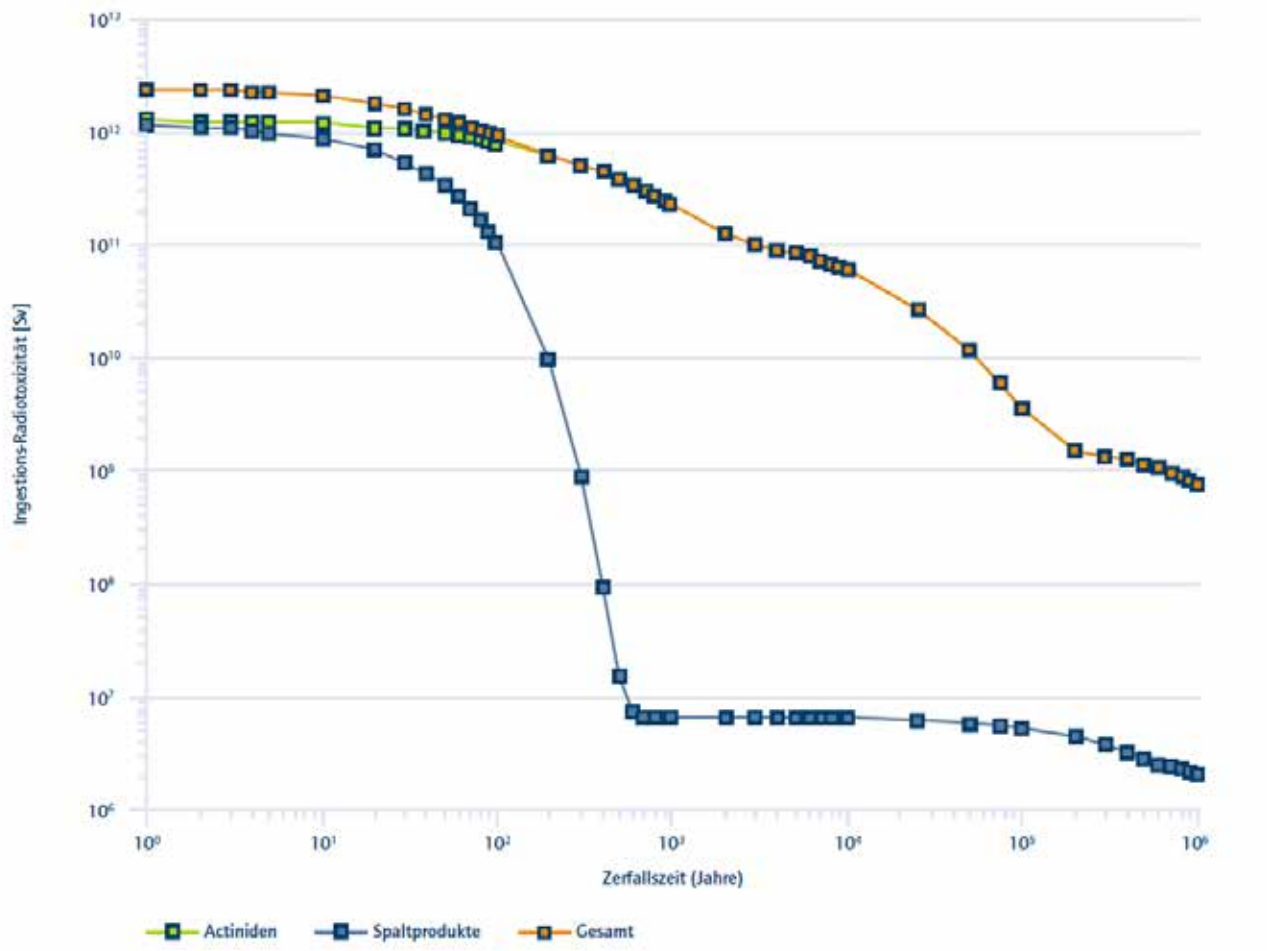
Evaluating P&T

Radiotoxicity



Radiotoxicity

Radiotoxicity describes Ingestion:

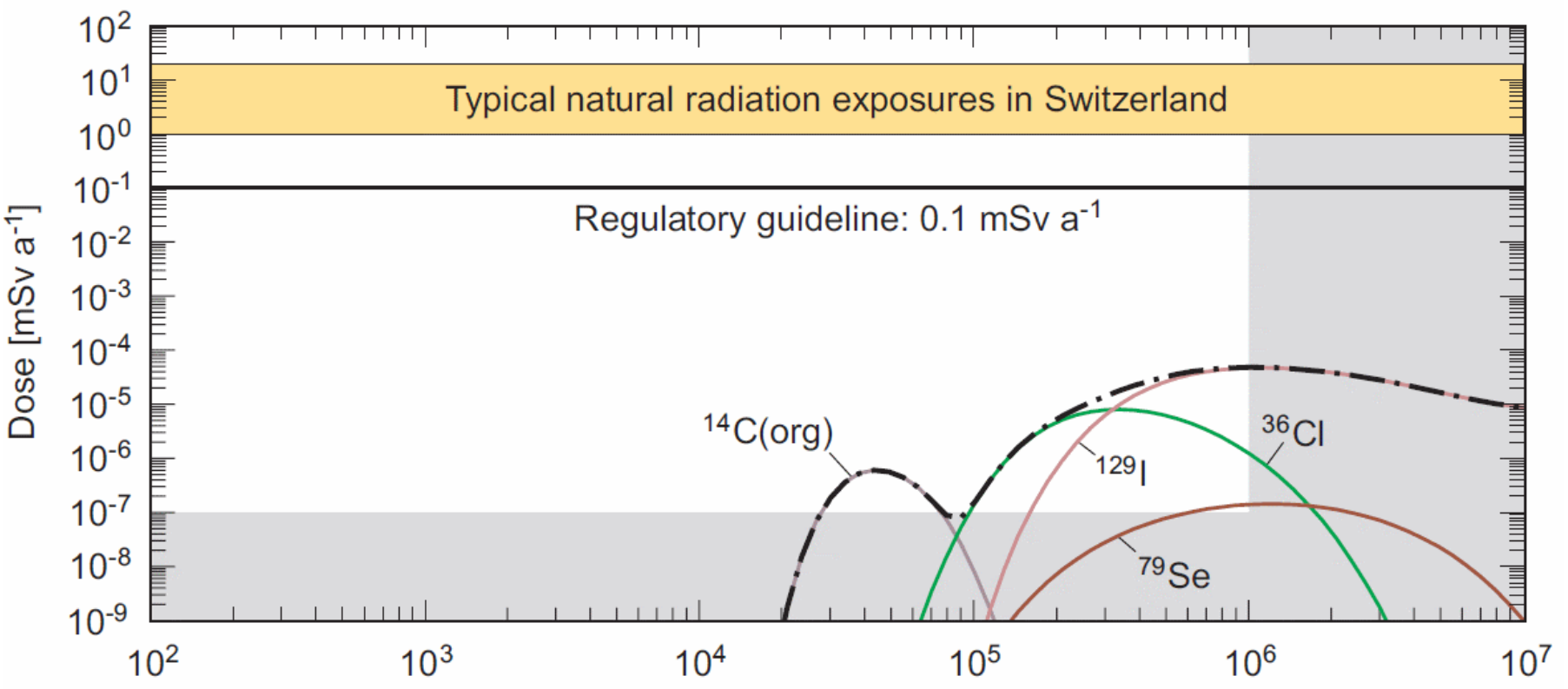
$$TLight = \Sigma (A * DFIng)$$

- The analysis is based on direct ingestion of waste.
- Not included:
  - dissolution rates and potentials
  - transport, sorption
  - accumulation, decay
  - transfer factors

Complete formula should be:

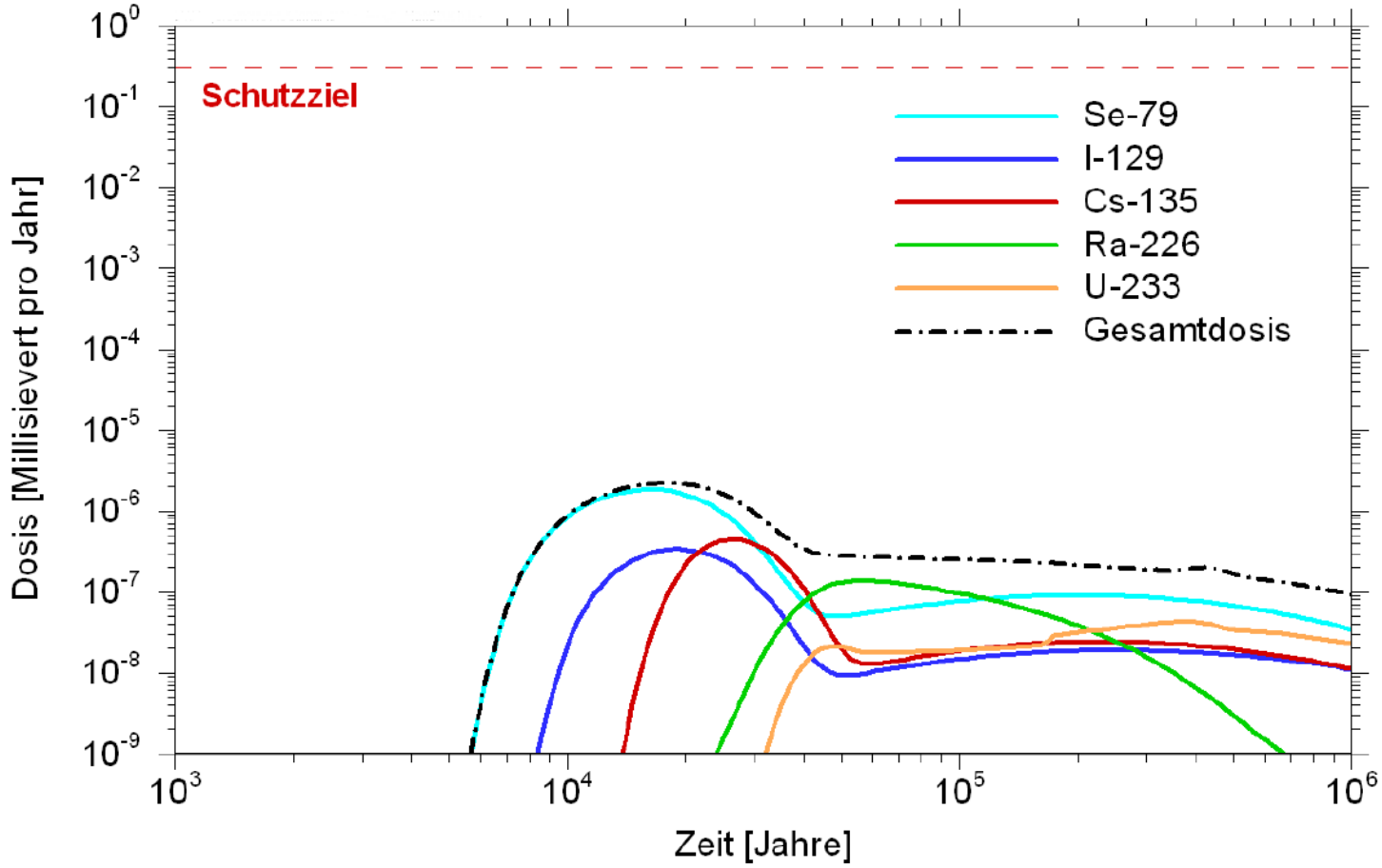
$$T = \int \Sigma (A * TFRepository/Human * DFIng)$$

Example: Opalinus-Claystone Benken (CH)

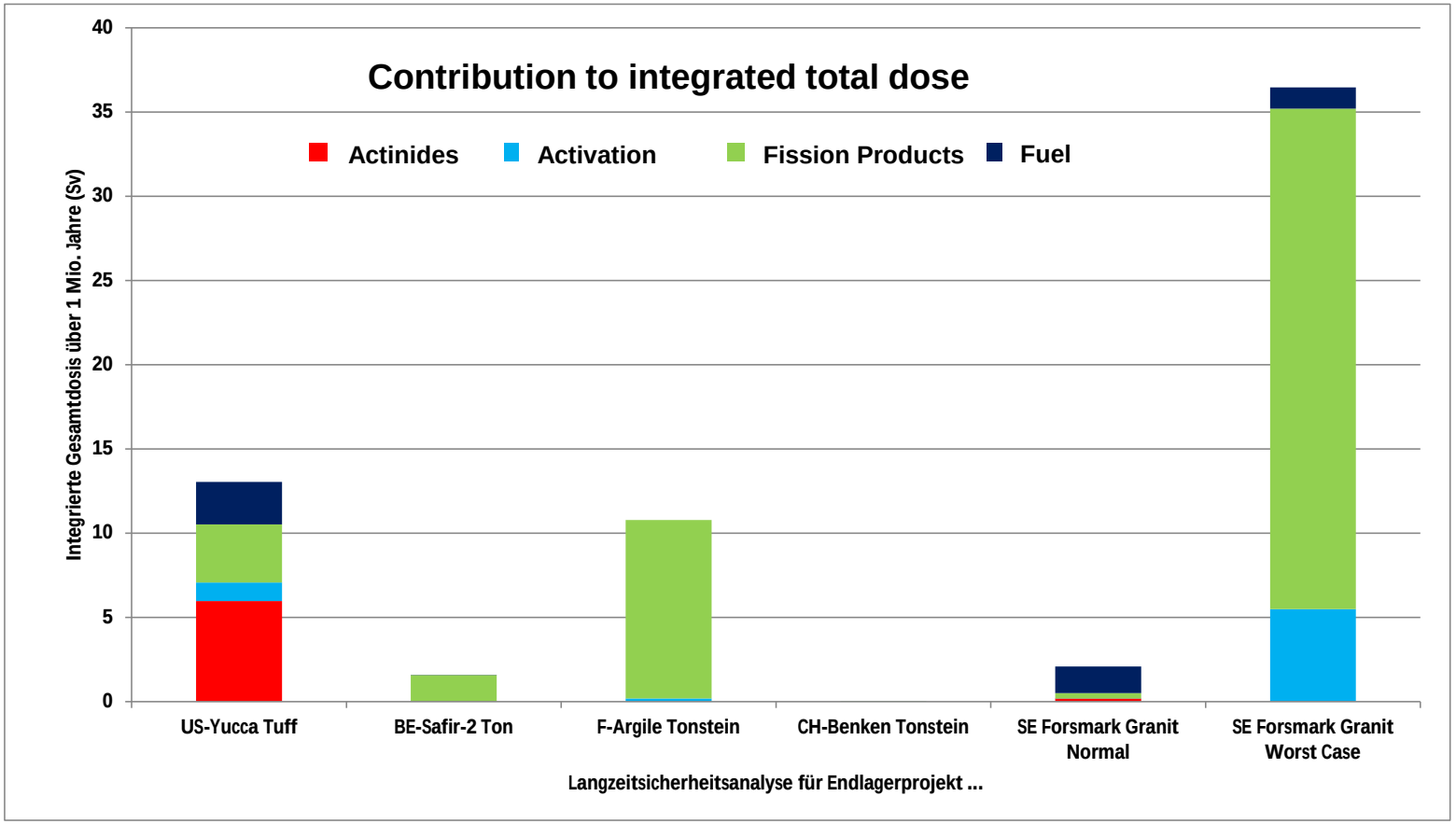


Reference Case Spent Fuel, Aus: NAGRA: Long Term Safety Analysis Entsorgungsnachweis, 2002

Example Salt Dome



Integrated Dose Contributions For Long-Term Safety Analyses



Actinide contribution negligible for most cases or comparable to fission and activation products, and decay products from fuel.

Long-Term Safety Analyses: Interim Conclusion

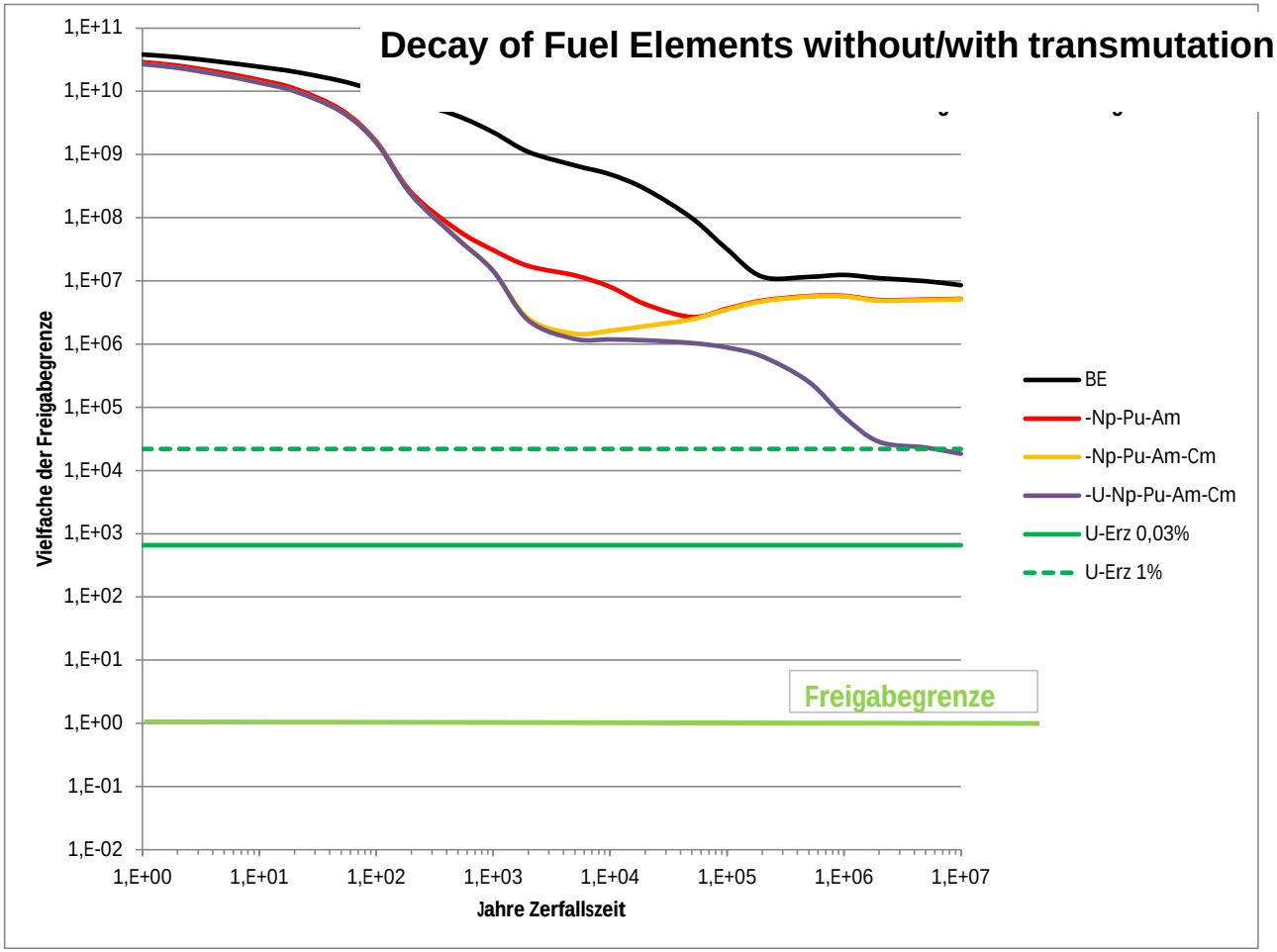
For all long-term safety analysis:

- Assuming extremely conservative boundary conditions actinides contribute barely to dose rates
- Under more realistic conditions and in clay, actinides do practically not contribute to dose rates compared to fission products like I-129 and Se-79, and activation products like Cl-36 und C-14
- P&T of actinides would not contribute to reduce the dose rate and hence, does not reduce the isolation/containment requirements

Clearance criterion as reference?

- Criterion for Clearance („Freigabe“) according to the Radiation Protection Ordinance
  - Nuclide specific activity concentration, below which a substance does not fall anymore under the regulations of the radiation protection ordinance due to low risk potentials
  - Criterion for clearance: individuals of a population receive a dose rate below 10 µSv/a

Uranium mine as `natural Reference´?



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Conclusions

Conclusion I

- The simple radiotoxicity index is clearly in contradiction to the results of a long-term safety analysis.
- A radiotoxicity index without integrating the mobility of isotopes gives nonsensical results and rankings of nuclides (weight of actinides higher).

Conclusion II

- Partitioning and transmutation of actinides does not result in a relevant reduction of dose rates from final repositories, despite the huge efforts and costs involved, as the dose rates are dominated by nuclides such as I-129, Se-79, Cl-36, C-14 that will not be separated according to current P&T concepts.
  - Given a good isolation (consolitated clay or salt with sufficient thickness and long-term stability) no dose reduction
  - With poor geological isolation half of the integral dose rate
- P&T does not reduce timelines for safe isolation of the waste, as dose rates are dominated with long-lived mobile fission and activation products, that are not influence by a P&T treatment.

Conclusion III

- Ignore à too dangerous
- Recycling à not possible with some exceptions
- Transport to space à à too dangerous
- Disposal into oceans floor à Dissolution and distribution
- Interim storage à not sustainable in the long term
- Transmute à high costs and sophistication, long duration, low benefit with respect to final disposal of high level wastes
- Deep geologic repository à best currently available option

Thank you for your attention!

Do you have any questions?