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Prognosis of radioactivity in TENORM

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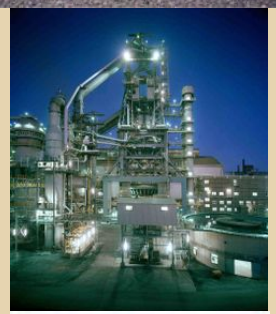
Industries and materials






TENORM

Technologically enhanced NORM

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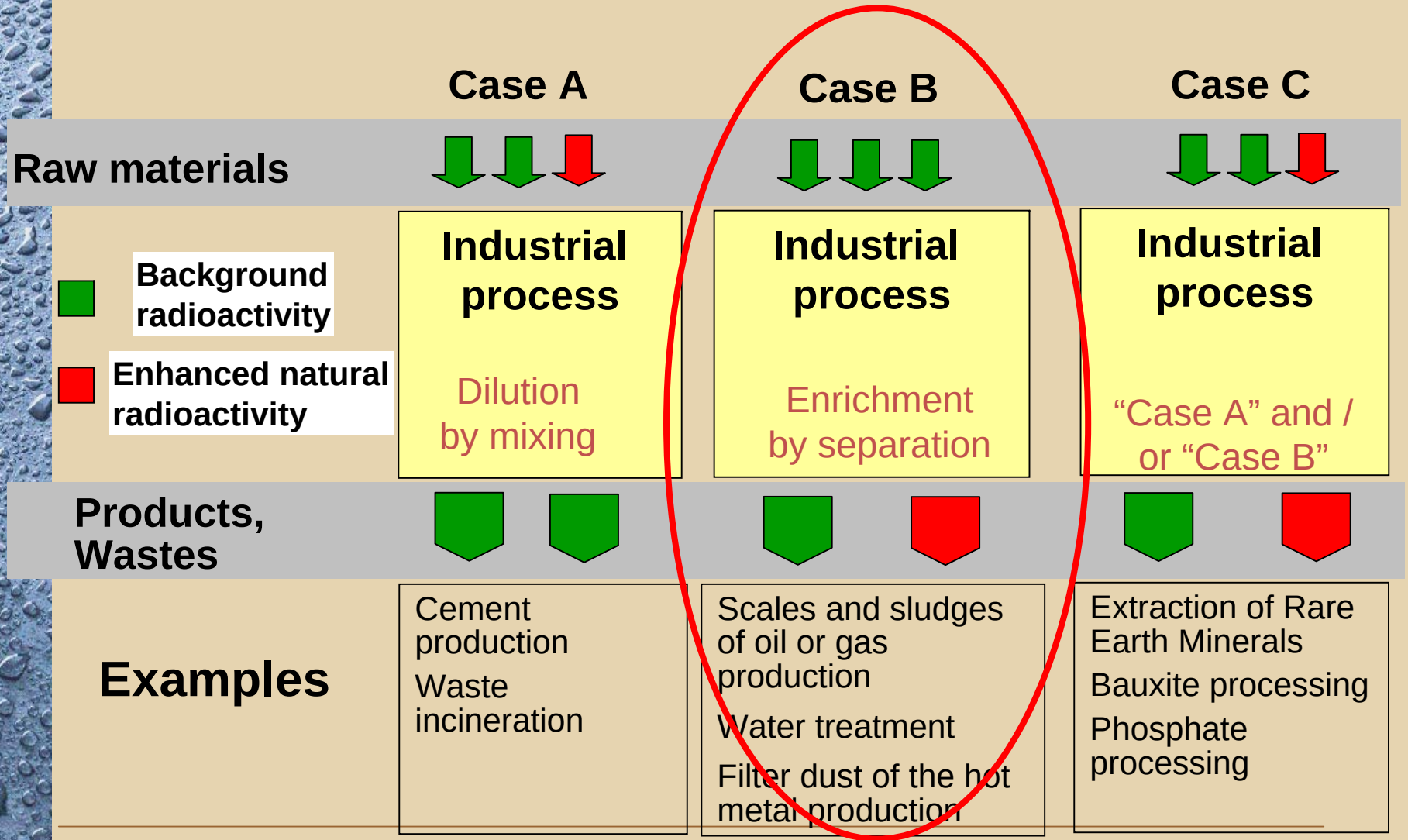
NORM industries



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The questions from the undertakings

OK, we know we have to deal with radioactivity.

But:

- What happens, if our technology is changed?
- How much NORM-wastes will arise in a certain facility?
- How can the exposure of the employees from NORM-waste be influenced?

The expected changes

NORM shall be considered as **planned exposure situation**

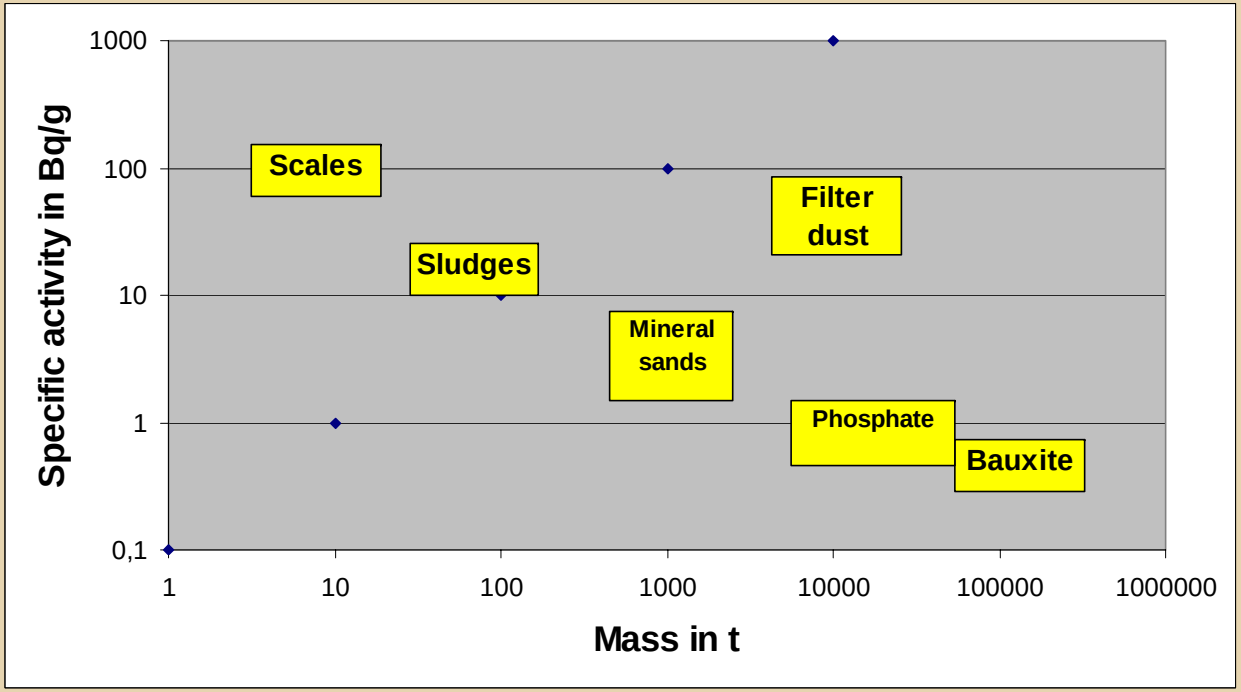
→ are we able to “plan” NORM amounts arising in a certain facility in advance?

→ How we can make prognosis on NORM wastes? (activity concentrations and masses!!)

There is a lot of experience

We know waste masses and activities of TENORM in industries.

We know, that radioactivity may be enriched by technical processes



But …

we tell us stories about radioactivity

We have examples and explanations on a qualitative level – no theory, no quantifying models, no established terms for characterising the processes of RN enrichment.

What we need is a helpful tool for analysing the processes which may result in TENORM + to communicate about these processes in an easy comparable way.

The general approach

TENORM consists of two components:

- Several radionuclides
- A non-radioactive carrier

The non-radioactive carrier is an inherent part of any TENORM!

Conclusion:

We have to deal with both: radioactivity AND masses!

Examples

Molten silicates + RN → slag

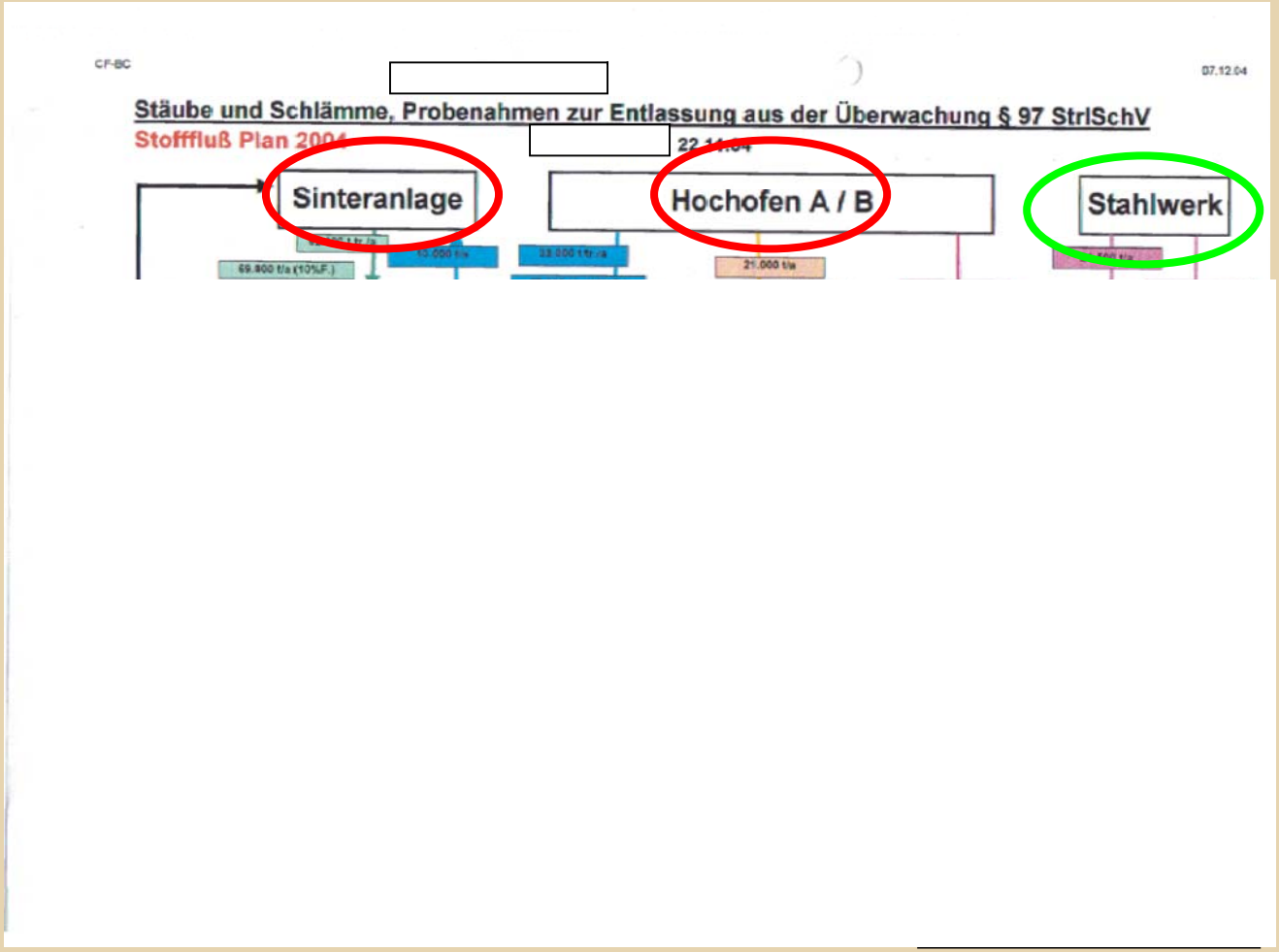
BaSO4 + Ra → scale

Sand/clay + RN → red mud

….

The problem: complex systems

Real processes: pig-iron plant / steel mill



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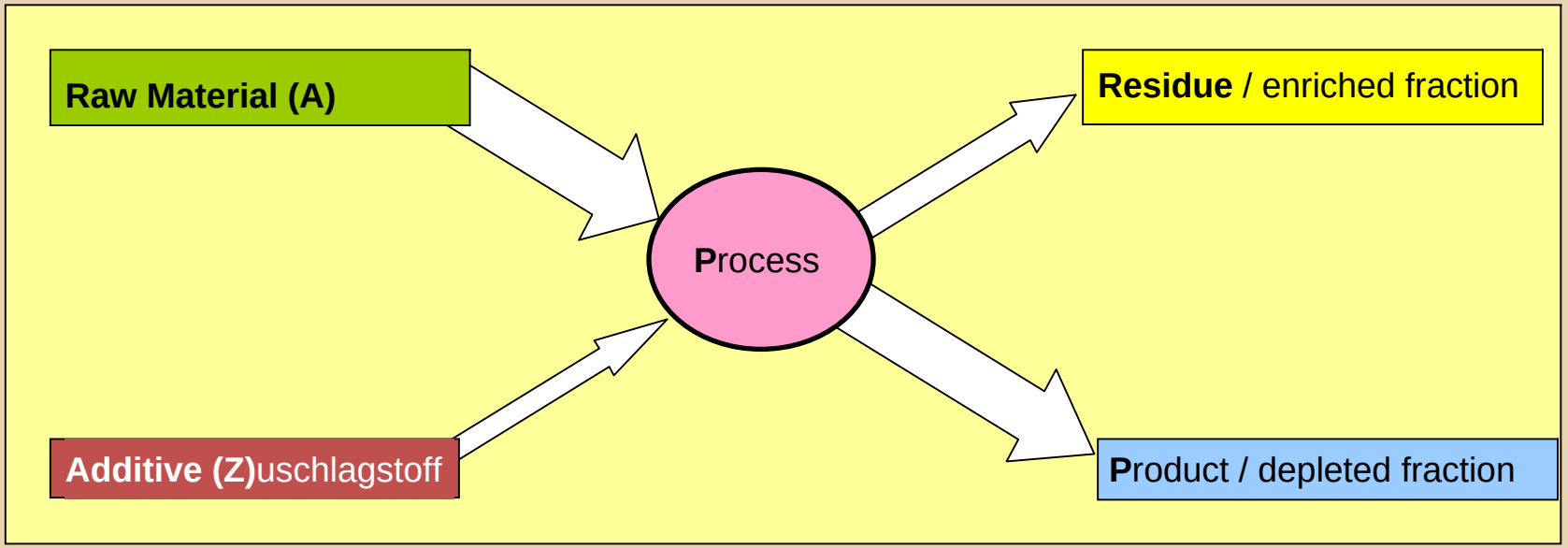
Phenomenological model of TENORM formation



Balance equations

Mass balance: $M_A + M_Z = M_R + M_P$ ***Activity balance:*** $A_A + A_Z = A_R + A_P$

Process parameters 1: Transfer factors

$$MTF = \frac{M_R}{M_A + M_Z}$$

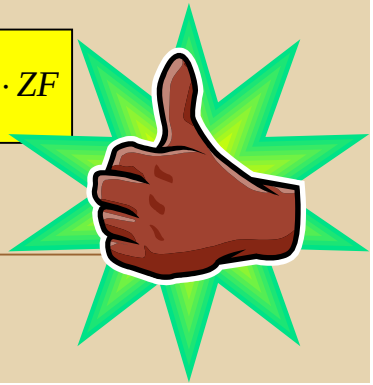
$$\mathrm{ATF} = \frac{\mathrm{A_R}}{\mathrm{A_A} + \mathrm{A_Z}}$$

Additive factor

$$ZF = \frac{1 + A_Z(i)/A_A(i)}{1 + M_Z(i)/M_A(i)}$$

Process parameter 2: Enrichment factor

$$EF_{RA}(i) = \frac{a_R(i)}{a_A(i)} = \left(\frac{ATF(i)}{MTF(i)}\right) \cdot ZF$$



For every RN

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Elementary processes

Processes	Type of residue	Parameters and processes affecting the radionuclide enrichment
Physical processes		
Thermal volatilisation	Filter dust (from mineral sintering, blast furnace smelting or other thermal processes)	Temperature (above 1000°C); total mass fraction of dust (!); content of other volatile components
Solubility of chemical elements in the molten metal	Slag	Grade of ore; volatilisation (Pb-210, Po-210)
Sorption of dissolved radionuclides on oxide hydrate surfaces	Filter sands in water treatment	Ra-concentration of raw water; chemical composition of raw water; duration of filter use
Chemical processes (Chemical reactions)		
Incineration; combustion of carbon	Ashes	Carbon content of fuel
Precipitation of Ba-Sr-sulfates from water or brines	Scales, sludges (oil or gas production; geothermal plants, etc.)	Concentration of Ba-Sr-Ca in the water or brine
NaOH treatment of bauxite	Red mud	Grade of ore
Sulphuric acid treatment of phosphate ore	Phosphogypsum	Grade of ore

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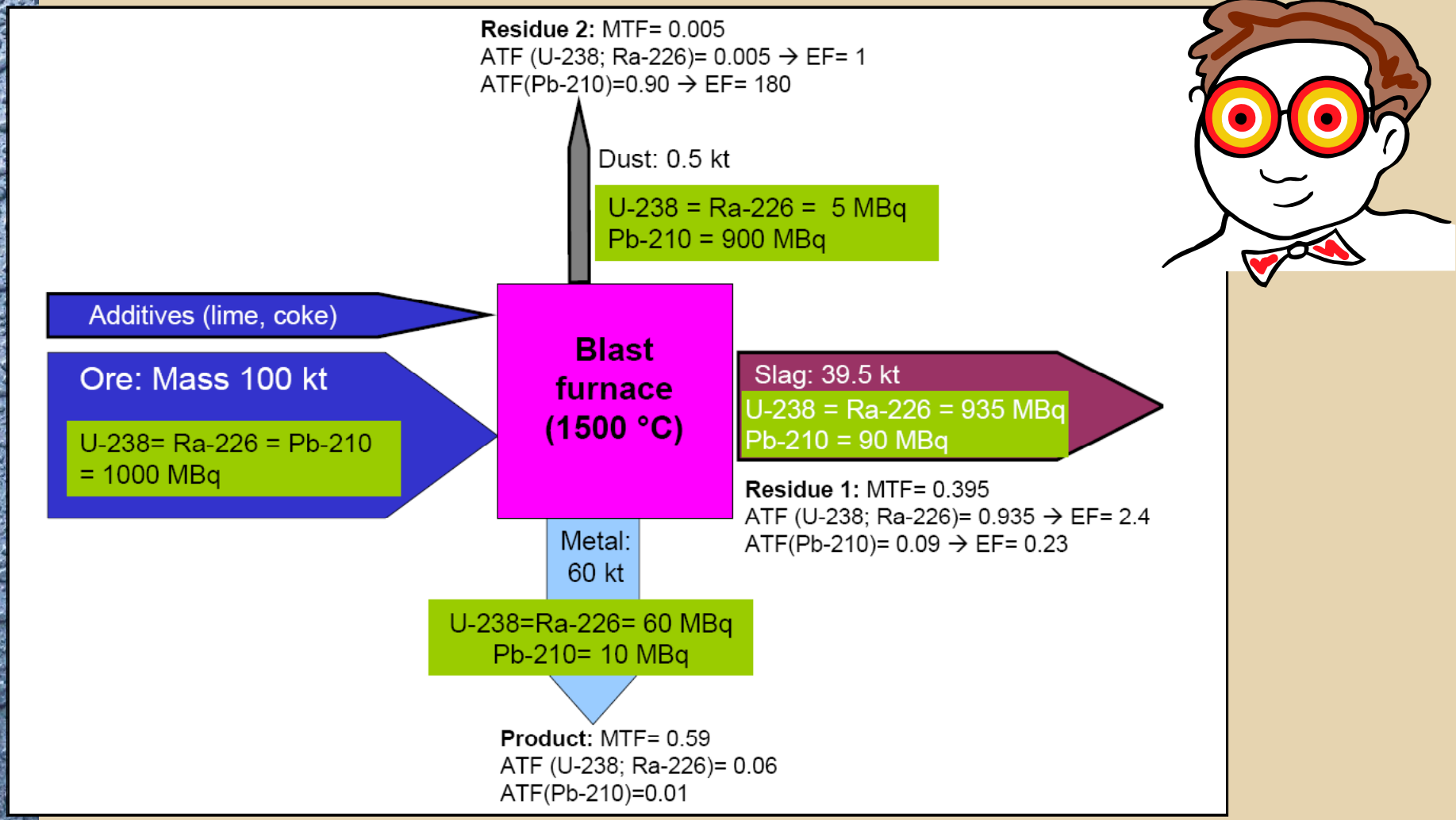
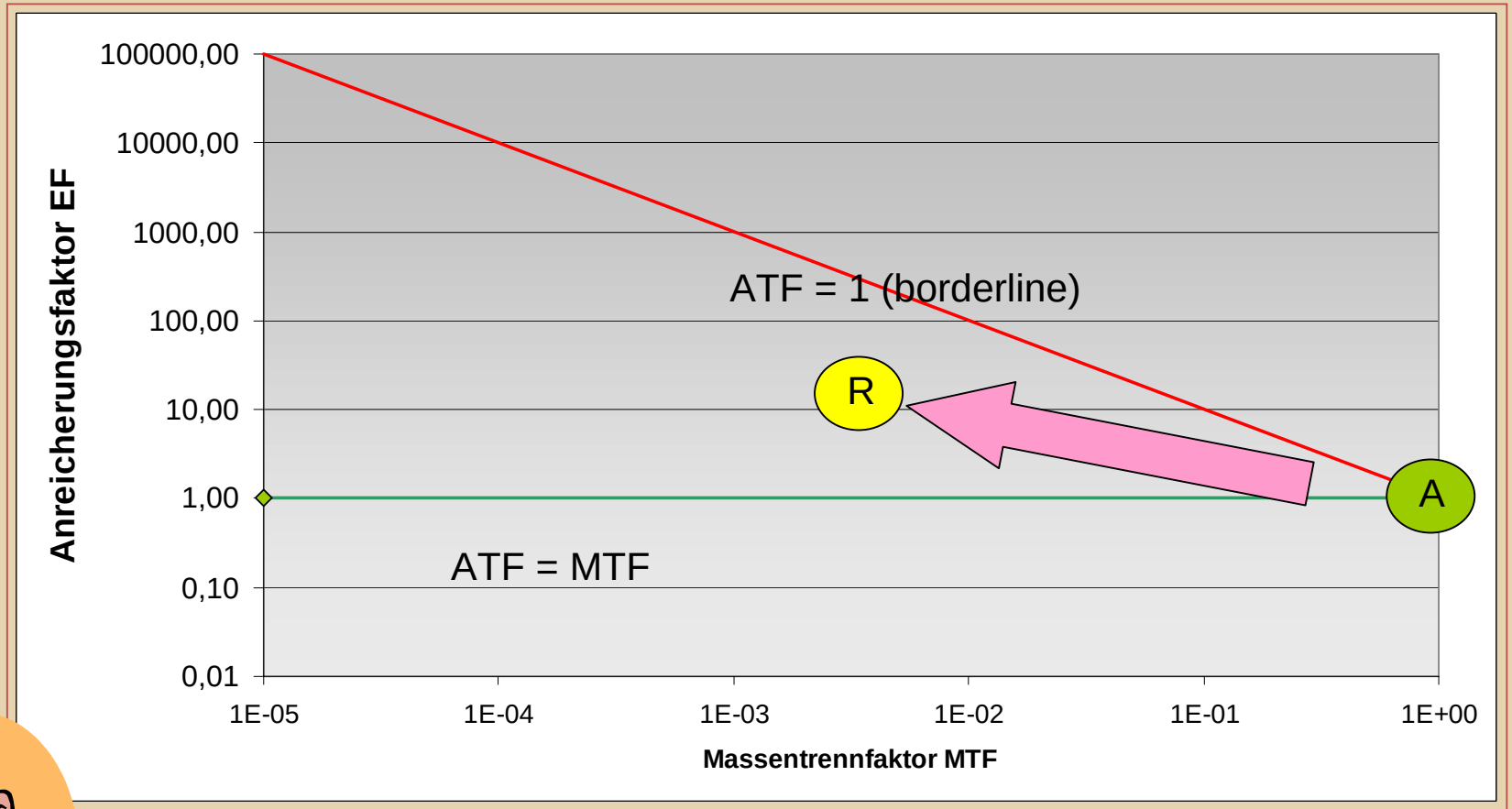
Iron smelting



Theory

Result: large enrichments occur only in processes with small MTF



$$EF_{RA}(i) = \frac{a_R(i)}{a_A(i)} = \left(\frac{ATF(i)}{MTF(i)}\right) \cdot ZF$$

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Conclusion

- The radioactivity of wastes is only partially determined from the radioactivity of raw materials. The transfer of radionuclides into waste may result in an increase of activity concentrations which cannot be disregarded from the radiation protection point of view.
- Because high radionuclide enrichments are attributed to (very) low mass transfer factors, wastes with high activity concentrations occur usually in mass streams of technological processes, which constitute a small fraction of the total mass streams.
- Processes with mass amounts of products and wastes in the same order of magnitude are less sensitive in regard to changes of activity concentrations in the waste. Here the EF are low and the activity of wastes can be well estimated from the activity concentration of raw materials. (e.g. aluminia production from bauxite).
- Activity concentrations in wastes arising from processes with high enrichment factors are very sensitive in regard to any changes of masses in the process. That's why the activity concentrations of scales in oil and gas production vary in different facilities in a poorly predictable degree.

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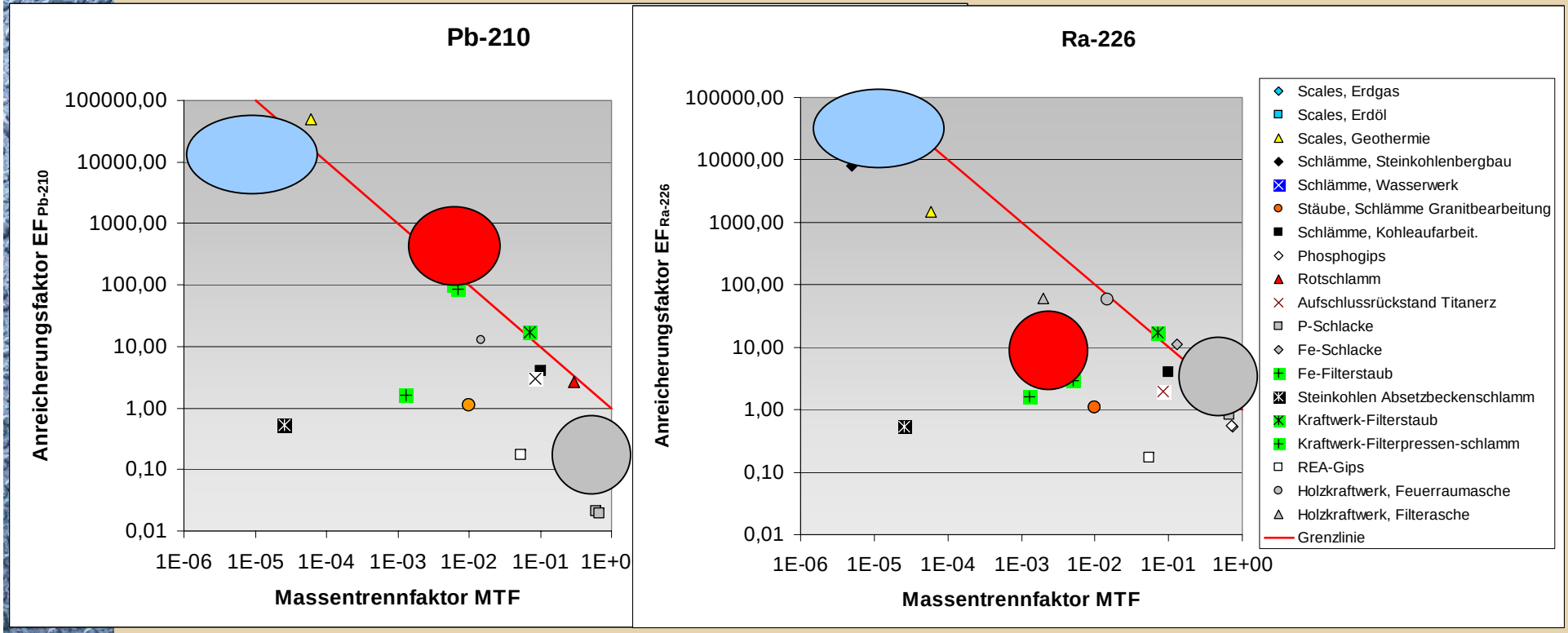
Real processes

Precipitation, sorption from water

High temperature processes (without combustion)

Metal smelting – Slag



Model parameters

Physical or chemical elementary process	MTF	Radioelements (-nuclides) r	ATF (r)	ZF (r)	EF (r)
Thermal volatilisation (blast furnace, pig iron production)	0.005	Pb-210	0.9	1.4	250
Solubility of chemical elements in the molten metal	0.1-0.3	U, Ra, Th	1		3 – 10
		Pb-210	0.1(b)		0.3 - 1
Sorption of dissolved radionuclides on oxide hydrate surfaces	< 1E-5	Ra	0.8-0.99	1	>1E+5
Incineration; combustion of carbon	0.1 – 0.01	U, Ra, Th	1	1	10 - 100
Precipitation of Ba-Sr-sulfates from water or brines	1E-5	Ra	0.1	1	1E+4
NaOH treatment of bauxite	0.3	U, Th, Ra, Pb-210	1	0.8	2.7
Sulphuric acid treatment of phosphate ore	0.72	Th, Ra, Pb-210	0,9	0.44	0.55
		U	0.1(a)		0.06

Application 1: Combustion of peat

Data from “Radiological assessment of NORM Industries in Ireland – Radiation doses to workers and members of the public”
Catherine Organo and David Fenton December 2008

		U-238	Ra-226	Pb-210	Th-232	K-40
Peat	Bq/kg	8	4	26	1	7
fly ash	Bq/kg	102	26	414	12	71
bottom ash	Bq/kg	122	30	129	5	109
EF(Fly ash)	EF	12,8	6,5	15,9	12,0	10,1
EF(Bott. Ash)	EF	15,3	7,5	5,0	5	15,6

Why there is a different enrichment of U and Raß
Where the missing Ra has remained?

→ Check of plausibility

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Application 2: Mass-activity balance of a sinter facility

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The next step

- Calculate EF from chemical data!

Final remark

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