

14) Nuclear waste treatment (1)

Worldwide accumulated nuclear waste from nuclear power station

Up to	Used fuel elements / t fission material	Plutonium t
1980	37.160	144
1990	114.740	655
2000	221.960	1392
2010	316.250	(2100)

Composition of fuel elements before and after use in a power station

Isotope	Nuclear fuel	
	before %	after use %
²³⁵ U	3,3	0,81
²³⁶ U	0	0,41
²³⁸ U	96,7	94,50
²³⁸ Pu	0	0,02
²³⁹ Pu	0	0,53
²⁴⁰ Pu	0	0,24
²⁴¹ Pu	0	0,11
²⁴² Pu	0	0,04
fission products and other actinides	0	3,34

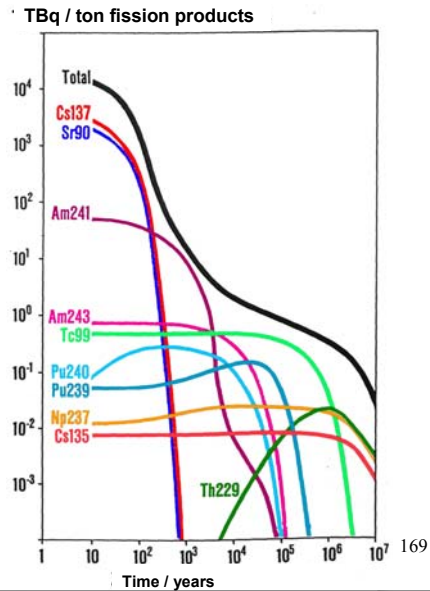
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14) Nuclear waste treatment (2)

Short-term problem

- Fission products (frequently short or medium half-lives)
- Development of heat → cooling is required
- activity of fission products is halved after one year
- Storage inside a water basin of the reactor

Long-term problem



14) Nuclear waste treatment (3)

Waste treatment strategies

Fuel Reprocessing

- reduction of the volume of highly radioactive waste
- recovery and redistribution of not used nuclear fuel
- separation (and use) of plutonium
- separation of the waste according to hazard potential
- transmutation reaction with products having a long half lives
- **High-tech procedures**

Final disposal

- disposal of used fuel elements (salt domes, granite, clay etc.)
- aim: exclusion of re-entering the biosphere
- several safety assessments are required
- long-term safety must be guaranteed
- migration behaviour, leaching processes and corrosion behaviour of the container material must be regarded

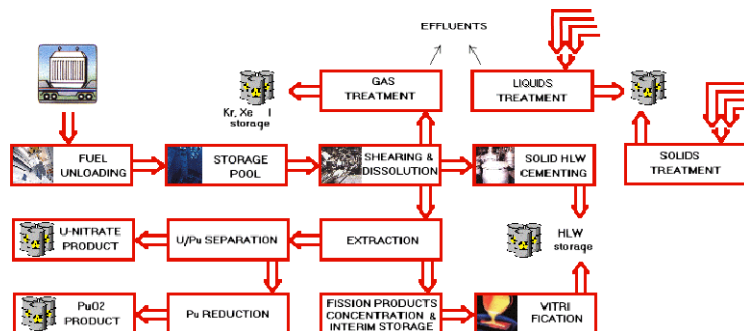
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14) Nuclear waste treatment (4)

Waste treatment strategies

Fuel Reprocessing

- Recovery of residual nuclear fuel from spent fuel elements
- Dissolution of the fuel elements in HNO_3 and extraction of uranium and plutonium from the rest (e.g. PUREX process)

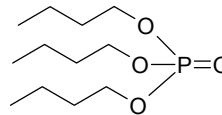
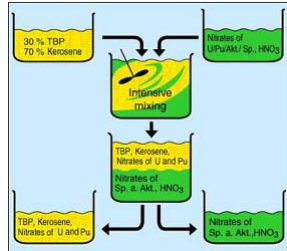


14) Nuclear waste treatment (5)

Waste treatment strategies

Fuel Reprocessing - PUREX process

- Liquid/Liquid extraction of uranium and plutonium from spent nuclear fuel elements
- extraction in the system cerosine/-tributylphosphate/H₂O/HNO₃
- Separation of uranium and plutonium by reduction of Pu and re-extraction



Tributylphosphate

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14) Nuclear waste treatment (6)

Waste treatment strategies

Fuel Reprocessing - PUREX process

Resulting radioactive waste per ton uranium

1 m ³	Highly radioactive waste (0.1 m ³ after further treatment)	> 10 ¹⁴ Bq/m ³
3 m ³	Medium radioactive organic waste (0.2 m ³ after further treatment)	10 ⁹ – 10 ¹⁴ Bq/m ³
17 m ³	Medium radioactive aqueous waste (8 m ³ after further treatment)	10 ⁹ – 10 ¹⁴ Bq/m ³
90 m ³	Low-level radioactive waste (3 m ³ after further treatment)	< 10 ⁹ Bq/m ³

- removal of the highly radioactivity of the fission products by storage
- transfer into a chemically appropriate form (pH, redox chemistry, hydrolytic behaviour)
- conditioning (calcination, glas)
- final disposal

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14) Nuclear waste treatment (7)

Waste treatment strategies

Final disposal

- various concepts depending on the geological situation
- **criteria:** geographic situation, seismic situation, tectonic situation, hydrogeology, infra structure, natural resources
- **Final goal:** removal of radioactive waste from the biosphere **forever**
- **Realisation:** multi-barrier system (geological barrier, geotechnical barriers, technical barriers)

	Salt	Anhydrite	Granite	Clay	Sediment	Basalt	Tuff
Belgium				X			
Denmark	X						
Germany	X		X		X		
England		X	X	X			
Switzerland		X			X		
Japan			X				
Canada			X				
Sweden			X				
USA	X		X			X	X