Uranium – A Deadly Material

from Uranium Mining via Processing to Nuclear Waste + CO_2

Any step of the uranium spiral is connected to threats. After mining the uranium ore, the conversion of the milled "Yellow Cake" into the gaseous UF_6 follows, then it is enriched and, in the next step, the fuel elements are fabricated. After that the uranium is used in nuclear reactors and for nuclear weapons - leaving long-lasting radioactive waste. **Each stage of the uranium spiral is connected to dangerous transports and the release of huge amounts of carbon dioxide.**

uranium spiral stages

1. uranium mining
2. conversion:
   Yellow Cake
3. uranium enrichment
4. fuel elements fabrication
5. atomic power station
6. waste disposal
7. nuclear waste treatment:
   „reprocessing“
8. military usage
9. climate change
10. shipments
11. (additional information)

basics

- 92 naturally occuring elements – **Uranium: nuclear industry's key**
  - → fissionability of U-235 isotope
- **health & safety issues**: releases of high-active radioactive substances & gases; fuel becomes more radioactive
- U-235 nucleus: 143 neutrons + 92 protons
  U-238 nucleus: 146 neutrons + 92 protons

- **half-life**:
  U-235: 713.000.000 years
  U-238: 4.500.000.000 years
- U-238 rarely fissions; capable capturing neutrons -> Pu-239
  - lesser amounts of Pu-238, Pu-240 + Pu-242
  - **plutonium: most dangerous radioactive element for humans if incorporated**

uranium mining

- **mining** depending on deposit by open-cast mining, in underground mines, or by in-situ leaching

- **uranium grade** between 0,1 and 1 %; sometimes 0,01 %; exception: 20 % deposit in Canada
- typical: between 100 and 10.000 t ore to be loosened, extracted & processed for 1 t uranium

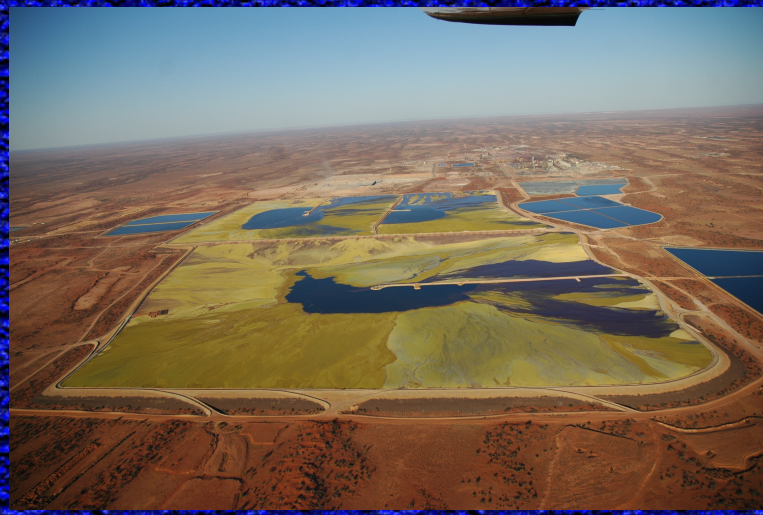
- impacts:
  - **destruction of huge areas**, often untouched nature on indigenous land
  - legacy: big **stockpiles** of unexploitable uranium ore + **large tailing ponds** containing poisonous waste waters -> main part of radioactivity remains on surface
  - **health** of workers & inhabitants affected
  - **livelihood** threatened permanently

- **Rn-222** – one of most harmful U-238 decay products
  - generated naturally
  - half-life: 3,824 days
  - Released by mining & processing of uranium ore
- **biggest uranium producers** *(2012)*:
  - Kazakhstan, Canada, Australia
  - followed by Niger, Namibia, Russia

conversion: Yellow Cake

- **milling & leaching** of ore from open-cast & underground mines in uranium mills, usually near the mines
- followed by **hydrometallurgical extraction** of uranium
- Final product uranium mill:
  uranium ore concentrate (U_3O_8)
  = mixture of different uranium compounds

- „**Yellow Cake**“ = term refered to a yellow type of uranium ore concentrate
- 2 t ore -> 1 kg U_3O_8
- uranium extraction residues: **tailings**
  - → radioactive, huge amounts
  - → contain thorium, radium + uranium isotopes of long radioactive half-life



- transformation U_3O_8 to UF_6: **conversion**
- conversion facilities e.g. in Ekaterinburg (RUS), Pierrelatte (F), Lancashire (UK)

uranium enrichment

- **concentration** of fissible U-235 in uranium ore too low: ~0,7 %; U-238 concentration ca. 99 %
- **U-235 enrichment** -> Light Water Reactors
- technologies e.g. separation of uranium isotops by gas centrifuges – e.g. Gronau (D), Tricastin (F), Almelo (NL)
- Gronau: capacity 4.500 t SWU/a; proposed repository for 60.000 t uranium waste

fabrication of fuel elements

- UF_6 reconverted to $\mathbf{UO_2}$
- milled to uranium powder & pressed into pellets
  - 10-15 mm length, 8-15 mm diameter
- sintered at >1.700 °C
- mechanically reground + filled into zircaloy cladding tubes

- up to 250 rods joined together to **fuel elements**
- fuel fabrication facilities e.g. in Lingen (D), Dessel (B)

atomic power station

- reactor usage only one stage of uranium spiral
- nuclear fission produces steam to generate **electricity** in turbines
- operation „as usual“: releases of **radioactive particles + radiation** -> health risk

- **spent fuel**: high-level active waste to be disposed permanently or to be reprocessed
- accident risk: **Chernobyl + Fukushima**
- absolute safety impossible
- worldwide in operation: 438 *(IAEA 2014)*, respectively 388 reactors *(WNISR 2014)*

- first **temporary storage** necessary
  - each NPP has own temporary repository
  - spent fuel bay, then dry storage repository
  - risk concentration – see Fukushima

waste disposal

- **nuclear waste** generated in each stage of uranium spiral
- **uranium need** ca. 33 t per year/NPP *(1.300 MW)*
  - 740.000 t rock to be mined
  - 620.000 t radioactive overburn stockpiles in mining areas
  - only 120.000 t uranium ore for further processing
    - 123.000 t radioactive & toxic sludge (tailings)

- 280 t uranium ore concentrate for transformation to 348 t UF_6
  - → 165 t solid + 153 m³ liquid nuclear waste
- uranium enrichment: 305 t depleted uranium
  - → militarily utilizable (DU ammunition/armor)
- 43 t enriched UF_6 processed to 33 t UO_2 in nuclear fuel elements

- after NPP operation spent fuel is **high-level active nuclear waste**
- due to **contamination** additional low-level and intermediate-level wastes created
  - nuclear waste volume duplicated

- **safe final repository nowhere exists**
  - solution unlikely:
    - assumptions over millions of years impossible
    - complete determination of all geologic/social factors impossible
- **status quo**:
  - mining waste remains (stockpiles, tailing ponds)
  - temporary repositories on-site & centrally
  - nuclear waste dumping in unsafe disposal sites

nuclear waste treatment: „reprocessing“

- chemical procedure for **separating plutonium or fissionable uranium** from spent fuel
- worldwide reprocessing rate ca. 10 %
- high emissions, health risk, safety issues

- developed decades ago -> generate plutonium for „**fast breeder reactors**“ *(nuclear industry's perpetuum mobile)*
- breeder technology failed due to security, economical & technical issues
- separated plutonium rarely used for MOX

  → **atomic bomb material** left

- MOX increases **risk of nuclear proliferation**
  - plutonium could be extracted
- MOX **increases radiation** inside reactor & generates more dangerous nuclear waste
- **safety risk**: fission rate increased with temperature -> endangers reactor control
- theory: 95 % of reprocessed uranium to be enriched again & plutonium to be re-used in reactors – reality: minimal

military usage

- **uranium enrichment facilities** like Gronau could be reconfigured from „civil“ 3-6 % U-235 grade to 70-90 % U-235 = atomic bomb feasible
- **reprocessing units** generate plutonium
  - original purpose of the facilities in La Hague, Sellafield etc.

- since 1990s: NATO uses **DU** for amor & projectiles
  - fine uranium dust released in detonation
  - serious health affects

climate change

- **atomic power ≠ climate neutral**
- **burning fossile resources**: conversion „Yellow Cake“->UF_6, uranium enrichment, reconversion UF_6->UO_2, fuel element fabrication
- low uranium grade->higher energy consumption
- 1 kWh nuclear electricity = 32-65 g CO_2

(other source: 159 g CO_2)

- CO_2 emissions of most **renewable energy sources** comparable or lower
- modern **CHP** has better climate balance
- NPP construction & shipments release additional greenhouse gases
- uranium spiral also produces **FC** – e.g. reprocessing
  - → thousandfold higher effect on than CO_2

shipments

- each uranium processing stage means shipments
  - partly over thousands km, as facilities far away
  - shipment of interstage goods, nuclear waste and fuel elements
- every transport brings radiation & accident risk
- by truck, ship & train
- **primarily responsible for bad climate balance**

further information

- **WISE Uranium Project**:
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  http://www.wise-uranium.org
- **Uranium Network**:
  http://uranium-network.org
- **Uranium Watch**:
  http://uraniumwatch.org

- **Sustainable Energy & Anti-Uranium Service**: http://www.sea-us.org.au
- **Nuking the Climate** (film on uranium mining): http://nukingtheclimate.com
- **Nuclear Heritage Network - Uranium**: http://uranium.nuclear-heritage.net
- **AKU Gronau**:
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Thank you for your attention!

references

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