



Nuclear forensics – crucial for the fight against illicit trafficking

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Context and outline of the presentation:

- Nuclear forensics as key element for the response to illicit trafficking of nuclear and radioactive material:
 - ≥ 1992 (related to opening of borders in Europe)
 - how to unravel properties of seized nuclear material?
- Analyses at ITU of seized uranium/plutonium materials:
 - selection of concrete examples,
 - mostly Germany and Europe

February 22, 2007, Germany

14 Uranium Pellets found in a garden

Questions:

1. How did the material get there?
2. Origin of the material ?
3. Intended use of the material?
4. Age of the material?



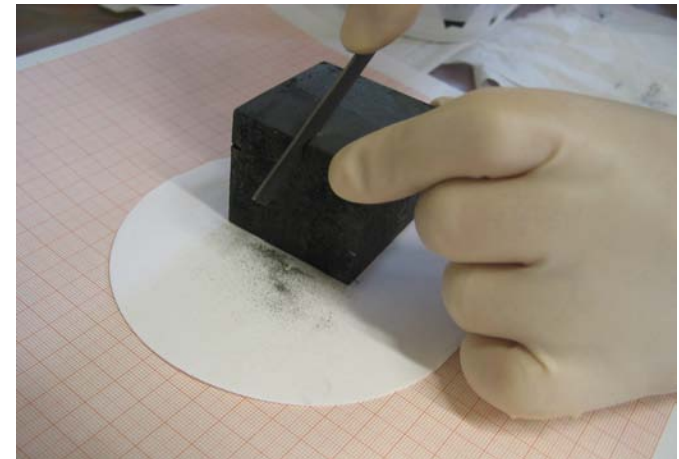
Selected Examples:



Intended use and origin?

First observations/conclusions:

- gamma spectrometry
- geometry → 5 x 5 x 5 cm
- elemental composition: pure U metal, unconventional application/reactor
- isotopic composition → natural U → D₂O or graphite moderated reactor
- main impurities → Al, Ca, Fe, Mg, Mn, Na, Pb, Si
(200 mg material)



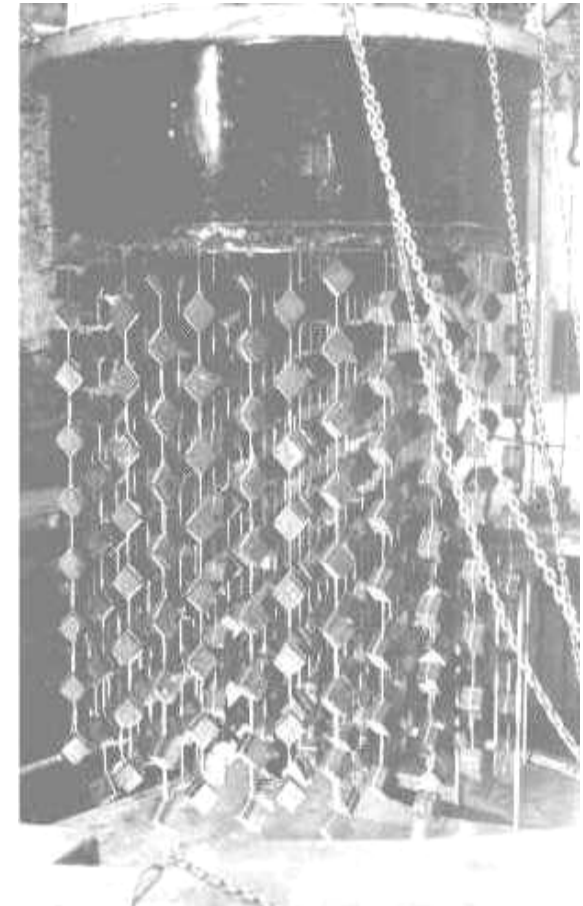
Origin

- Nuclear Materials Database at ITU

nuclear fuel data from western and Russian suppliers (UO_2 , MOX) (based on World Nuclear Industry Handbook and bilateral contracts, various degrees of access)

- Open literature

Geometry points at German origin



Age determination

- spiking with Th-228
- chemical separation
- measurement: alpha spectrometry or mass spectrometry

Age via U-234 / Th-230

α-spec.: **59.0 ± 1.5 years (in 2003)**

ICP-MS: **59.3 ± 2.0 years**

=> Date of production: second half of 1943

Age indicates German (or US) nuclear programme



Recent Example from Germany

LEU pellets seized in Lauenförde
(2007)

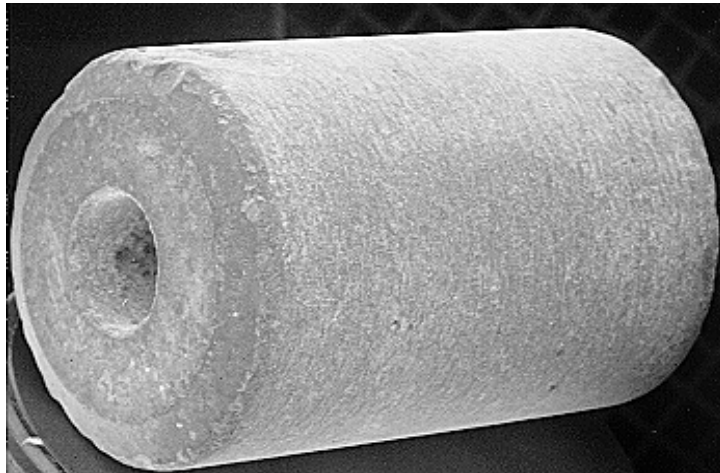
Material was attributed
Production date was determined (age)



Ulm, Germany, 1996

Origin Determination

UO₂ fuel pellet



Dimensions and enrichment
of 4.4% U-235 point at:

VVER-1000

Russia

Balakovo 1-4

Kalinin 1-2

Novovoronezh 5

Ukraine

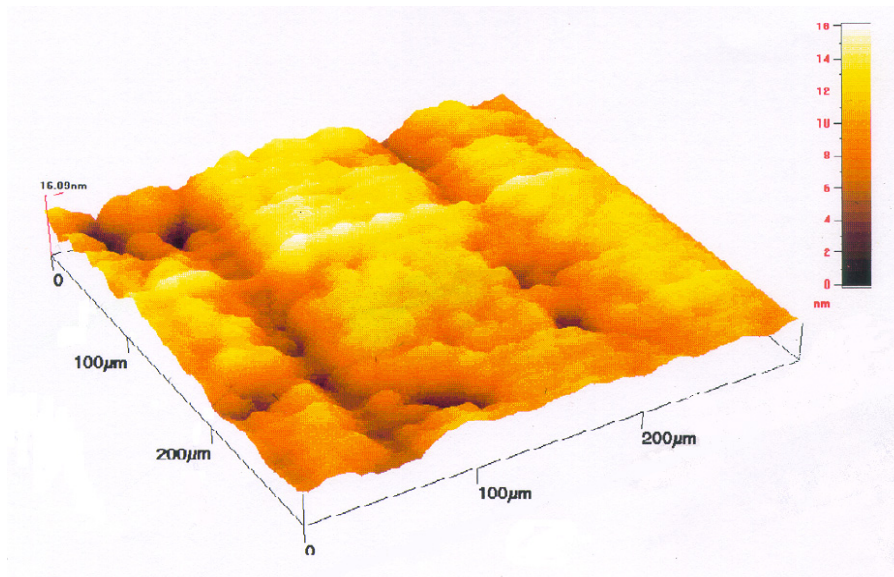
Khmelnitski 1

Rovno 3

South Ukraine 2-3

Zaporozhe 1-5

Production site:



Surface roughness

- UMP - wet grinding
→ smoother surface
- Electrosta-MZ - dry grinding
→ rougher surface

Measured surface roughness (μm)

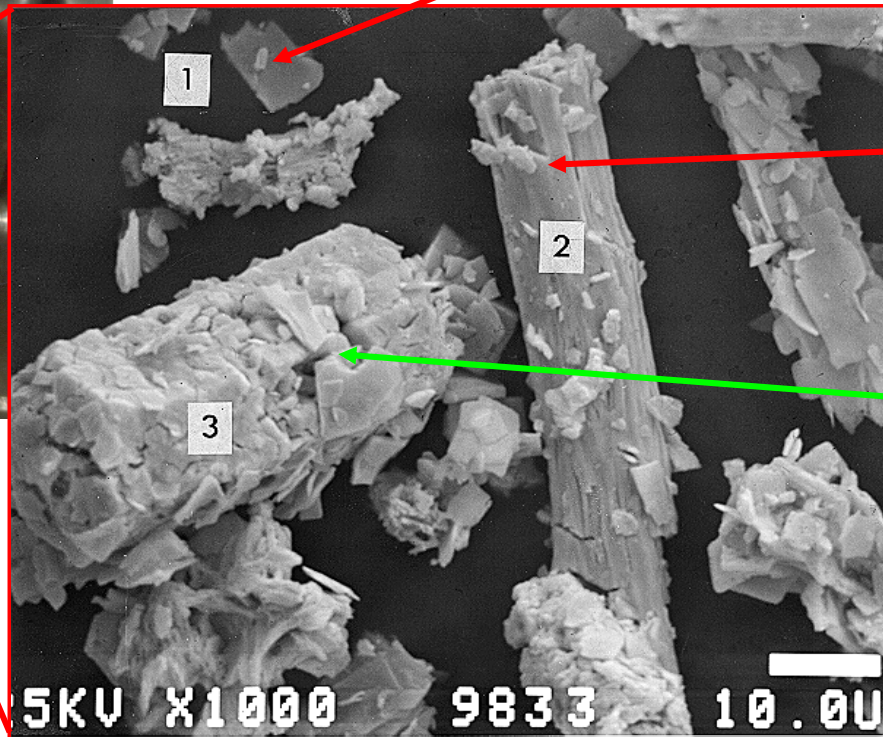
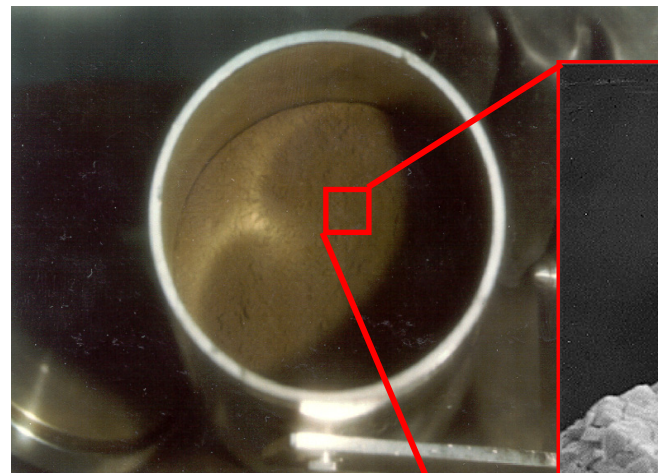
UMP – Kazakhstan	1.7 – 1.9	←
MZ – Russia	2.3 – 2.5	
Pellet – Fund 22	1.87	

Munich 1994

August 10, 1994, Munich airport

Powder (MOX)

363 g Pu-oxide (88% Pu-239)



PuO₂ platelets (80%)

PuO₂ rods (5%)

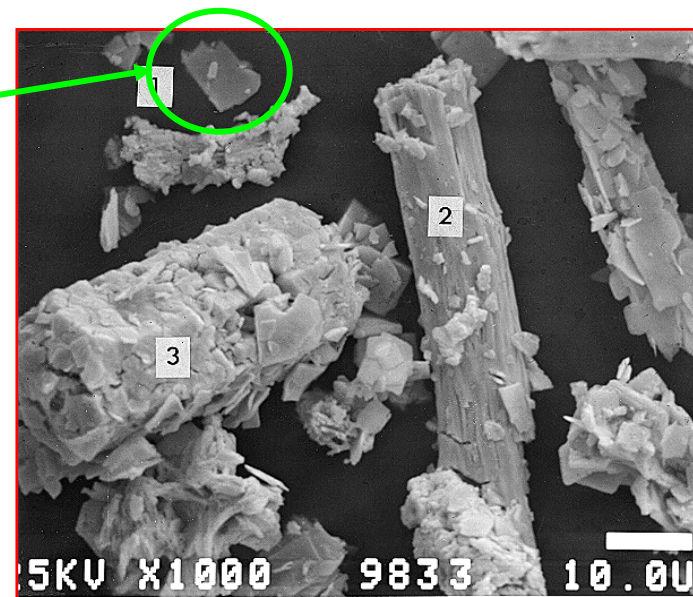
U₃O₈ hexagons (15%)

x1000

Speculations that the material was produced in Germany

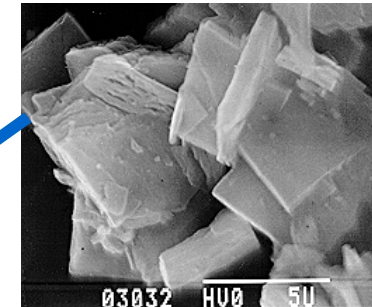
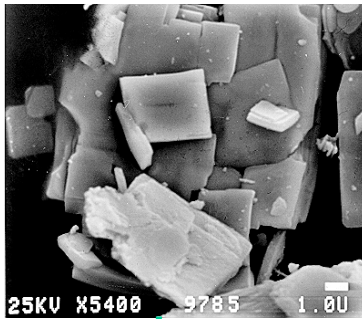
→ Compare the microstructure of the seized material with Pu reference material

Look at
Pu-platelet

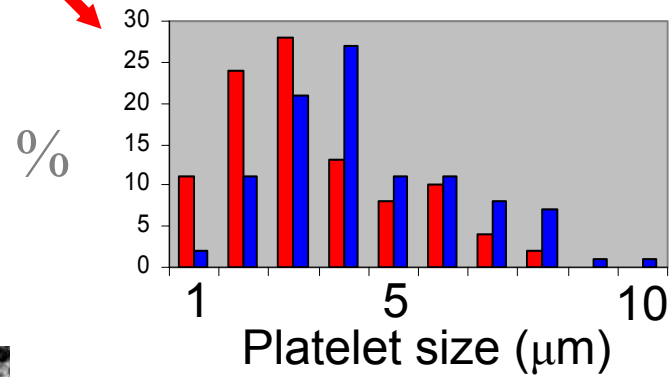


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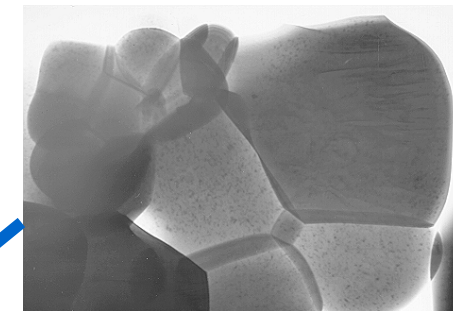
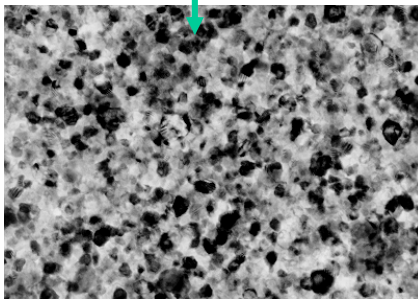
Reference SM3-1



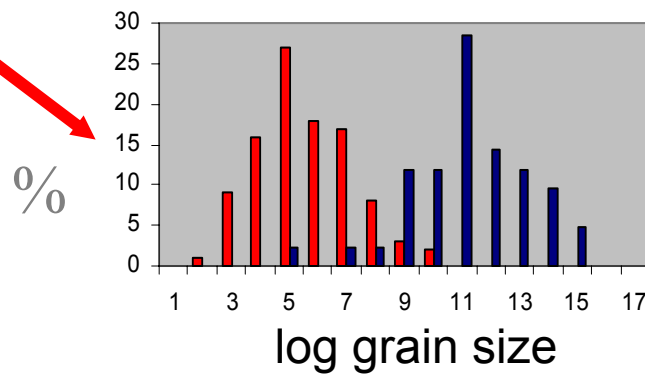
SEM



magnify



TEM



Size distributions different

WAK - Karlsruhe 2001

Contamination of an employee was detected in a routine urine control.



Radioactive material was stolen from WAK

- Estimate of total activity:
 - 9 GBq Beta (Pu-241), some Cs-137
 - 1 GBq Alpha (Pu, Am)

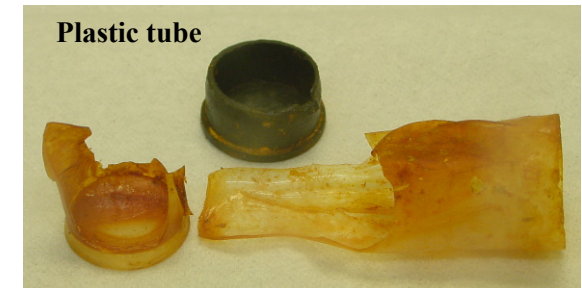
People contaminated (July 2001):

	Body Counter (Cs-137)	Lung Counter (Am-241)
The thief	60 Bq	112 Bq
His wife	50000 Bq	780 Bq
Her daughter	1300 Bq	12 Bq

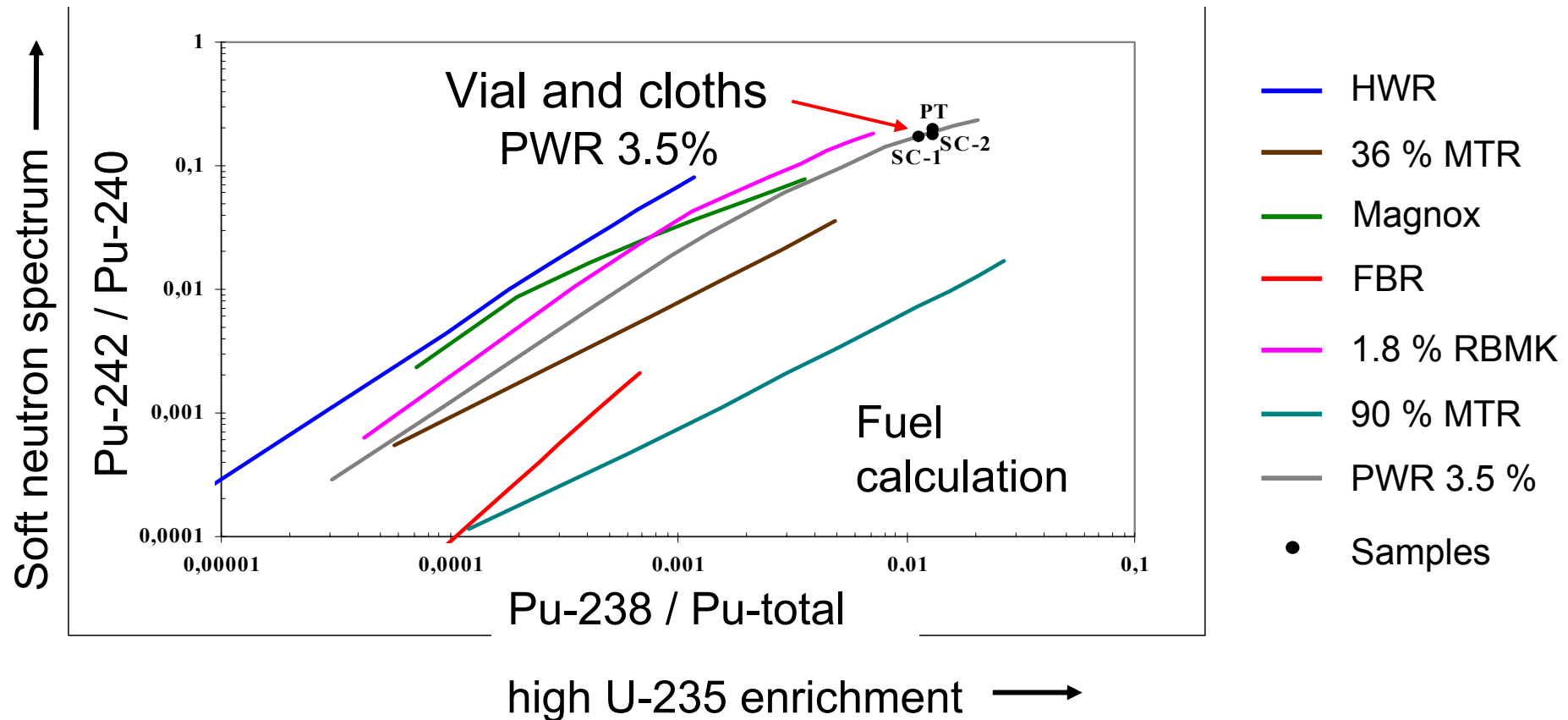
→ The thief: mainly inhalation
The others: mainly ingestion

Can the contaminations and incorporations be explained by two sources, vial + cloth ?

- Analyze samples from different locations
 - three apartments
(thief, wife, daughter's boyfriend)
 - facility
- Compare
 - samples
 - external information (which fuel processed, WAK, ...)



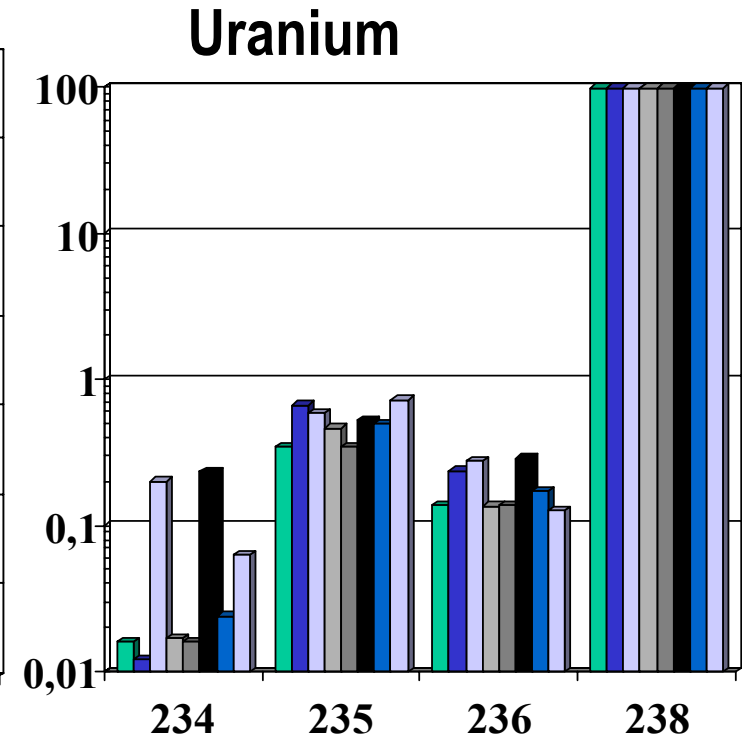
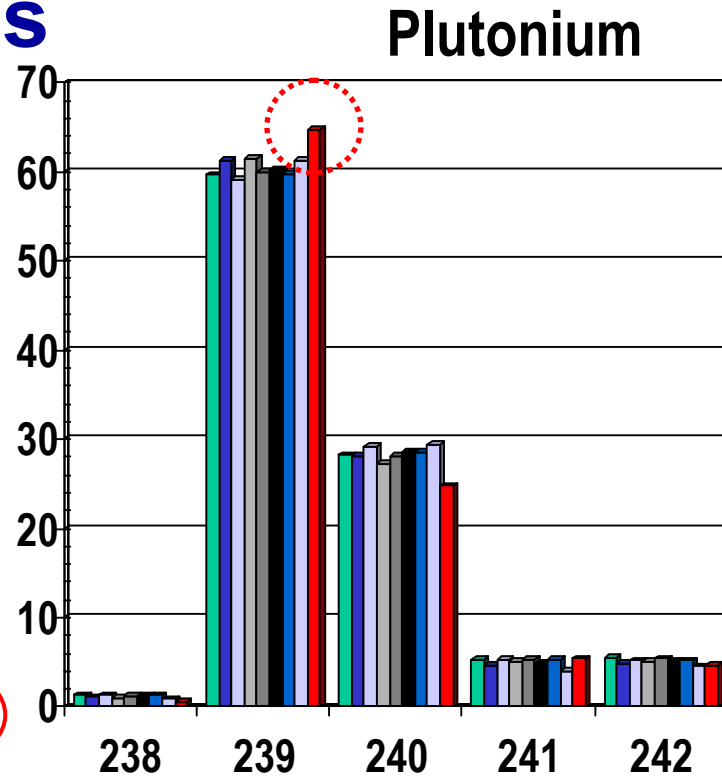
Pu isotopic composition depends on the reactor type
(enrichment, neutron spectrum)



Matches with the last reprocessed fuel type at the WAK

Isotope ratios

- Plastic vial
- Swipe cloth-1
- Swipe cloth-2
- Red gloves
- Blue gloves
- Vac.clean. WAK
- Vac.clear thief
- Vac.clear wife
- Vac. daughter



WAK - Conclusions

- Vacuum cleaner bag from “the daughter” showed significantly different Pu isotopic composition
 - ⇒ Pu-240/Pu-239 = 0.38 rather than 0.47
 - ⇒ mixture of reactor Pu (~ 90%) and fallout Pu (~10%)
- The plastic vial can be excluded as source of incorporation of “the wife” (¹³⁷Cs content too low).
Swipe cloth:
Cs-137 dissolves well in water (60% in 1h at 60 °C)
- Decontamination of two apartments ~ 2.5 M\$

Nuclear Forensics

involves Radiochemistry, Nuclear Physics, Reactor Physics, Material Science, Classical Forensics, ...

provides clues on

- Intended Use
- Origin
- Last legal owner

Relies on **comparison samples** (archive) or **reference data** (database)

Helps preventing future diversion,
element of **sustainability** in combating illicit trafficking of nuclear materials

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