Transfer of radionuclides to agricultural animals and appropriate remediation

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Content

- ENVIRONMENTAL PATHWAYS FOR ANIMAL PRODUCTS
  - Transfer routes
  - Quantification
  - Data
- NUCLEAR ACCIDENTS
  - Emergency phase
    - ➢ Countermeasures
  - Existing phase
    - ➢ Remediation

Radionuclide transfer to agricultural animals

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Why do we need to quantify radionuclide behaviour?

- To estimate doses to humans and other organisms
- To derive remediation action levels
  - Ambient dose rate (µSv/h)
  - Deposition density (Bq/m^2)
- To derive animal feed standard limits

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Key factors - mobility for animals

- interception
- soil fixation processes
- rates of plant uptake
- absorption rates in animal gut
- transfer rates to animal tissues (including milk)

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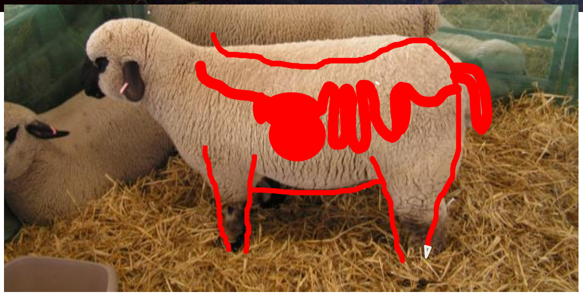
Emergency situation

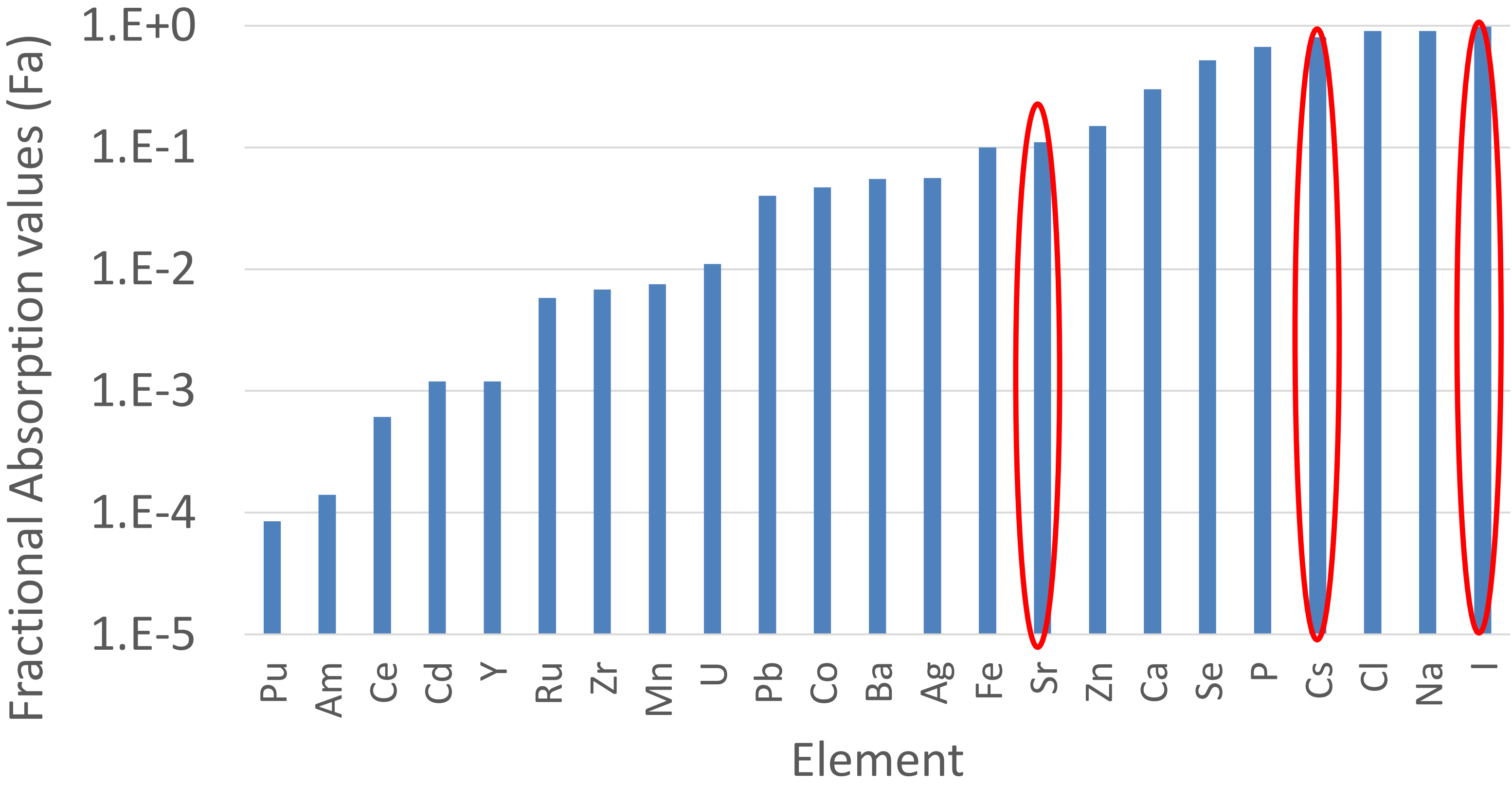
- Interception onto plant surfaces and weathering
  - Leafy vegetables – most radionuclides

- Grazing animals
  - Includes some short –lived radionuclides
    - Interception – most radionuclides
    - Animal products – radionuclides that readily transfer through the gut and accumulate in milk or meat

Accident	Month	Key radioisotopes		
Kyshtym	September	^{144}Ce	^{95}Zr	^{90}Sr
Windscale	October	^{131}I	^{137}Cs	^{210}Po
Chernobyl	April	short lived I isotopes	$^{137/136/134}Cs$	^{132}Te
Fukushima Daiichi	March	^{131}I	$^{137/134}Cs$	^{132}Te

Gut absorption in ruminants





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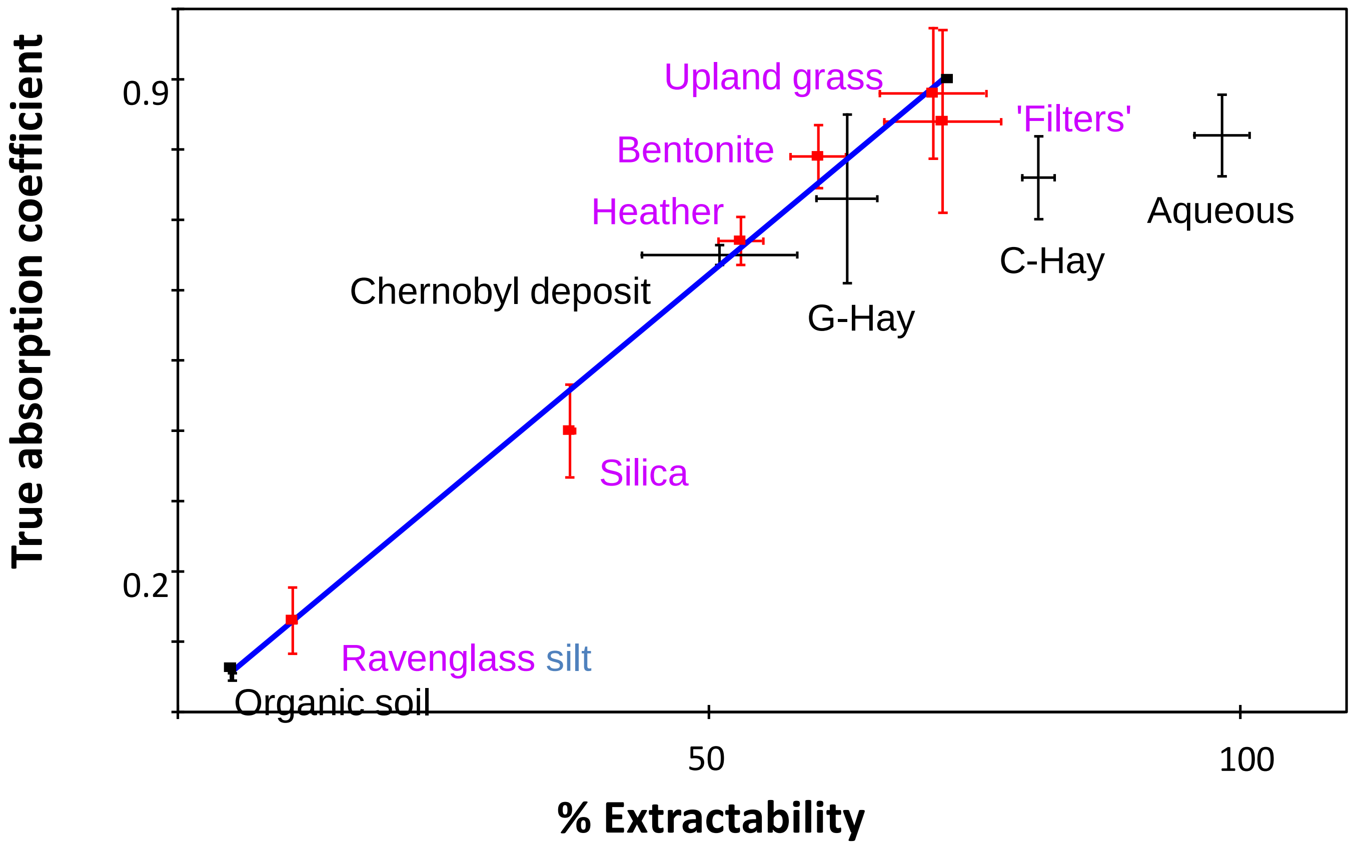
Howard et al 1989

Bioavailability

RADIOCAESIUM ABSORPTION AND PREDICTION



In vitro Cs bioavailabilty - 0.1M CsCl extraction

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Target organs

Milk	^{131}I, $^{134/137}Cs$, ^{90}Sr
Meat	$^{134/137}Cs$
Offal	$^{134/137}Cs$, $^{239/240}Pu$, ^{241}Am, ^{110m}Ag ^{60}Co (liver), $^{103/106}Ru$ (kidney)
Thyroid	^{131}I + other short -lived I isotopes
Bone	$^{239/240}Pu$, ^{241}Am, ^{144}Ce, ^{90}Sr

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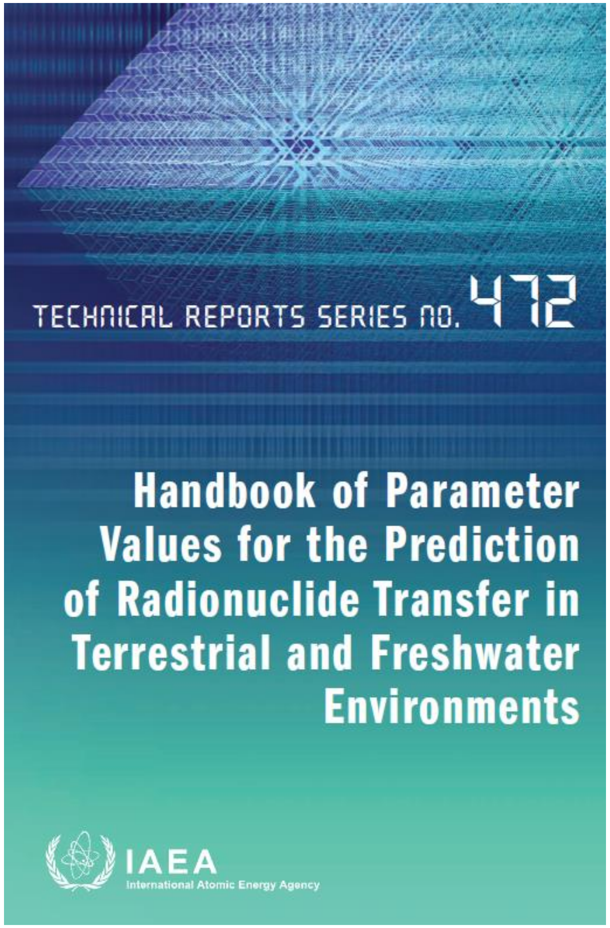
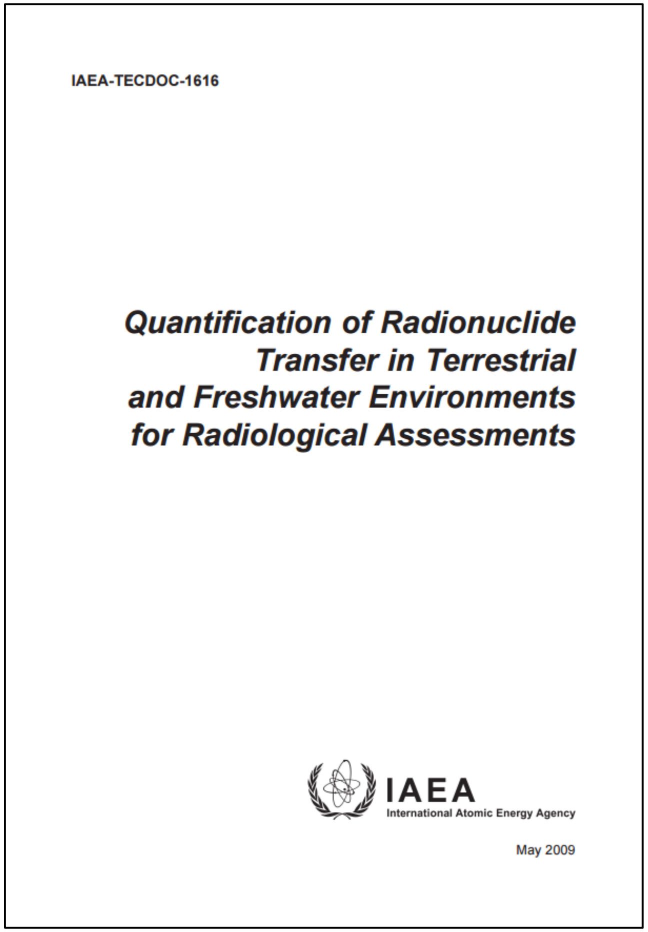
IAEA TRS / TECDOC on human foodchain




IAEA-TECDOC-1616

Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments

IAEA
International Atomic Energy Agency

May 2009

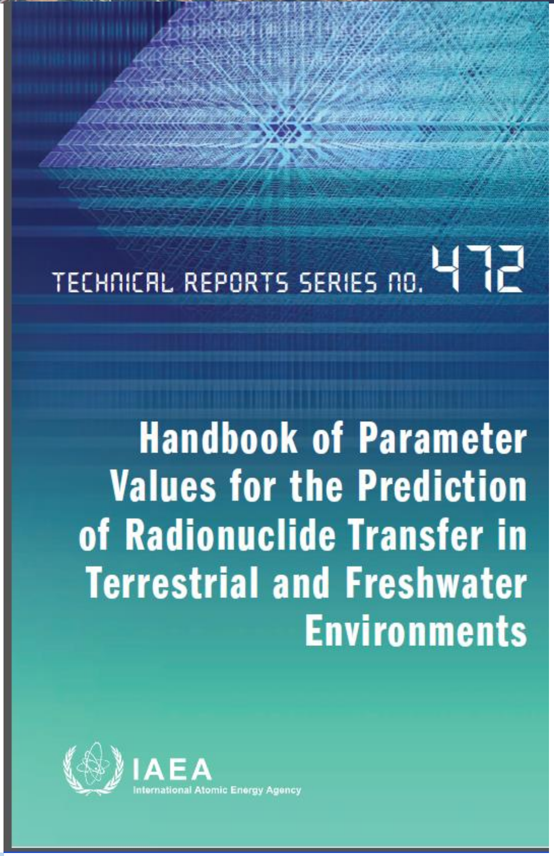
Transfer ratios: Animals

Concentration ratio (CR)

$$= \frac{\text{Bqkg}^{-1}\text{(fresh weight) milk}}{\text{Bqkq}^{-1}\text{(dry weight) feed}}$$

Transfer coefficient (F_m)

$$= \frac{\text{Bqkg}^{-1}\text{(fresh weight) milk}}{\text{Bqd}^{-1}\text{ in feed}}$$



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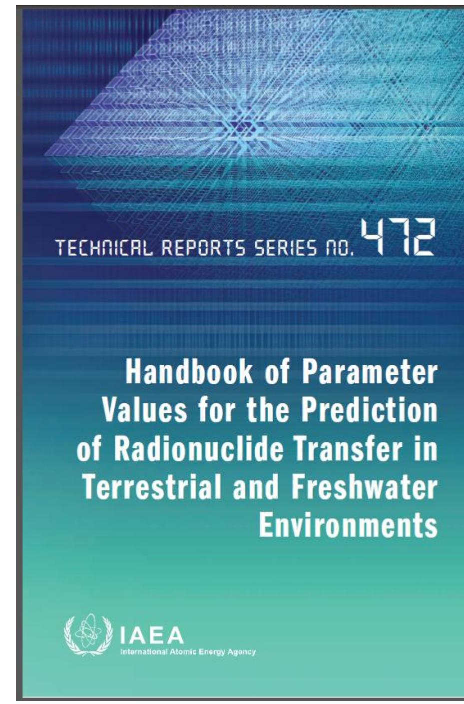
Animal products

Element	Beef	Sheep meat	Goat meat	Pork	Poultry	Egg	Cow milk	Goat milk	Sheep milk
Ag		1							
Am	1	1				1	1	2	
Ba	2		1		2	1	15	3	1
Be							1		
Ca	3				2	1	15	12	St
Cd	8	1			2		8	1	1
Ce		1				1	6	1	
Cl	1								
Co	4	2			2	2	4	1	2
Cr							3	2	1
Cs	58	41	11	22	13	11	288	28	28
Fe	4			1		2	7	St	St
I	5	1		2	3	4	104	24	7
La	3								
Mn	2	1		1	2	3	4	St	1
Mo	1				1	3	7	4	
Na	2	1			1	2	7	St	1
Nb	1		1		1	1	1	1	
Ni							2	2	1
Np								1	
P	1			1		1	St	St	St
Pb	5	2					15		St
					1	1	4	2	
Pu	5	2				2	n/a		1
Ra	1						11		
Ru	3	2		1		1	6		
S		3					1	12	St
Sb	2						3		
Se				1	4	4	12	2	
Sr	35	25	8	12	7	9	154	21	4
Te	1		1		1	1	11	1	1
Th	6						3		
U	3			2	2	2	3	1	
W							7		
Y			1					1	
Zn	6	6		2	3	4	8	St	St
Zr	1		1		1	1	6	1	



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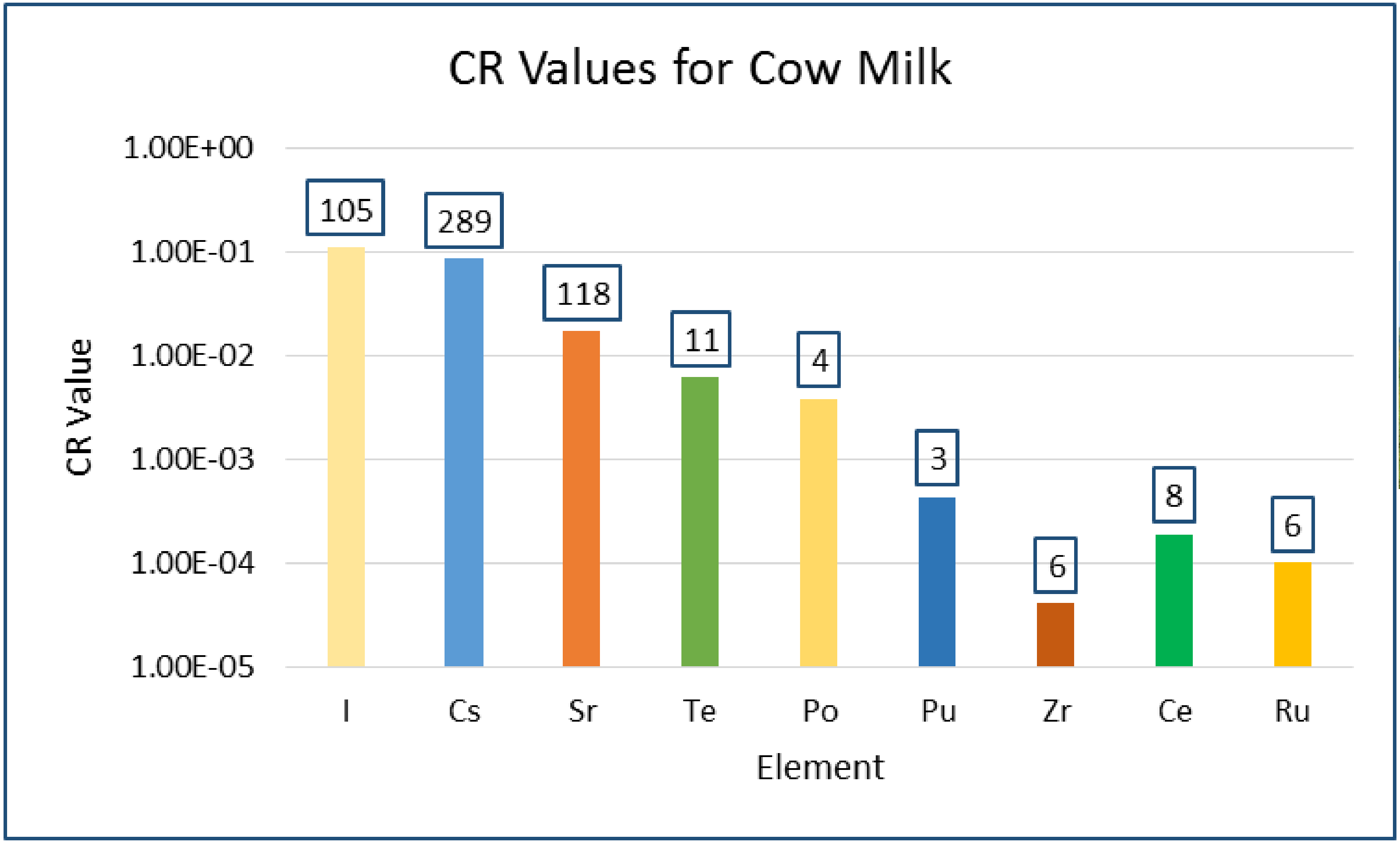
Transfer: feed to cow milk



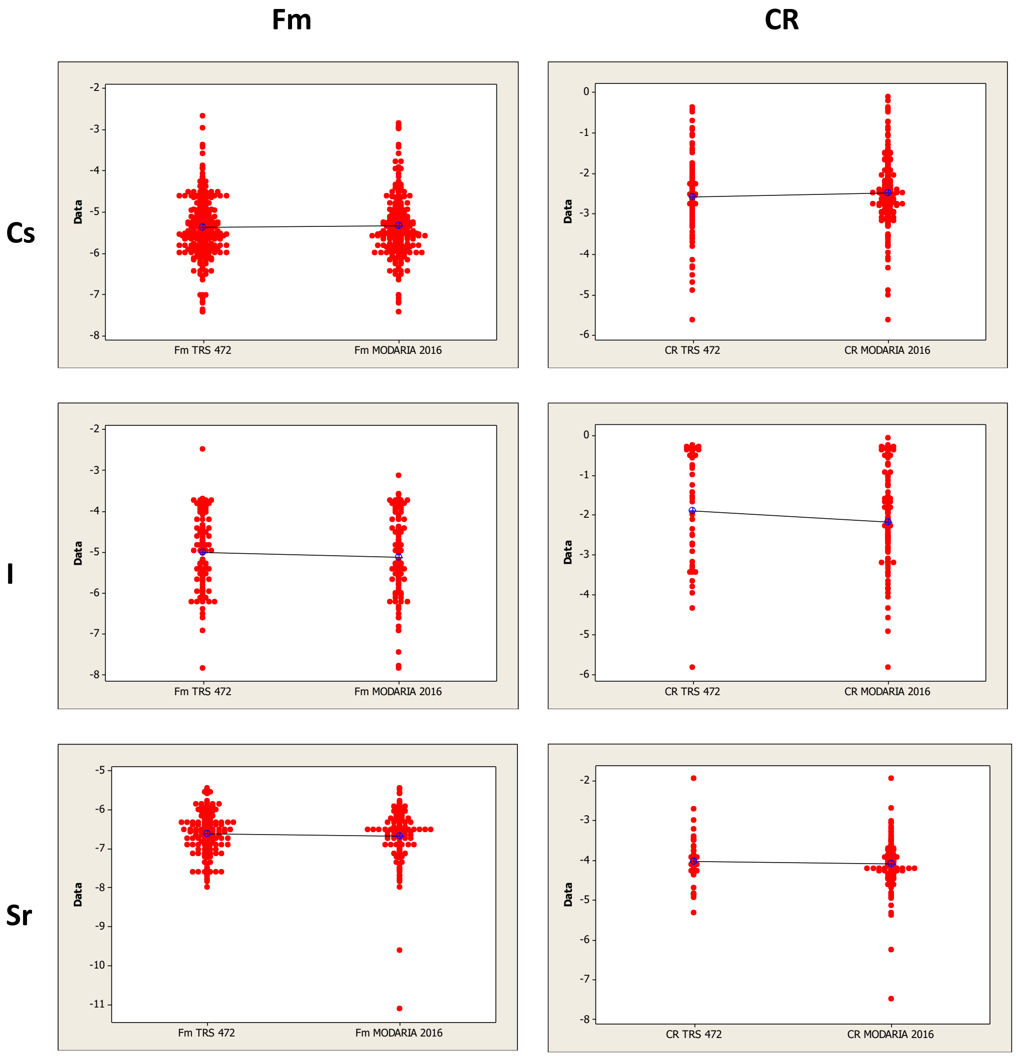
Concentration ratio (CR)

$$= \frac{\text{Bqkg}^{-1}\text{(fresh weight) milk}}{\text{Bqkq}^{-1}\text{(dry weight) feed}}$$

Distribution of cow milk F_M AND CR

TRS 472

MODARIA 2016



MODARIA 2016 cow milk max:min

Elements where difference > orders of magnitude >2

CR				Fm			
Element	Min	Max	Max/Min Ratio	Element	Min	Max	Max/Min Ratio
Ba	3.8E-4	6.2E-2	165	Cd	1.8E-6	7.9E-3	4396
Cd	2.7E-5	1.6E-1	5874	Ce	1.0E-6	1.3E-4	130
Co	4.5E-4	2.4E-1	538	Co	2.2E-5	1.0E-2	476
Cr	1.5E-4	4.3E-2	294	Cr	1.0E-5	2.1E-3	209
Cs	3.6E-3	9.0E-1	247	Hg	1.0E-4	1.2E-2	115
I	3.0E-3	9.4E-1	316	I	4.0E-4	4.4E-2	109
Ru	1.0E-5	1.4E-3	140	Mn	5.2E-7	3.3E-4	2637
Sr	5.6E-4	1.4E-1	256	Pb	1.1E-5	1.7E-3	153
				Ru	6.7E-7	1.4E-4	210
				Sr	1.5E-5	4.3E-3	289

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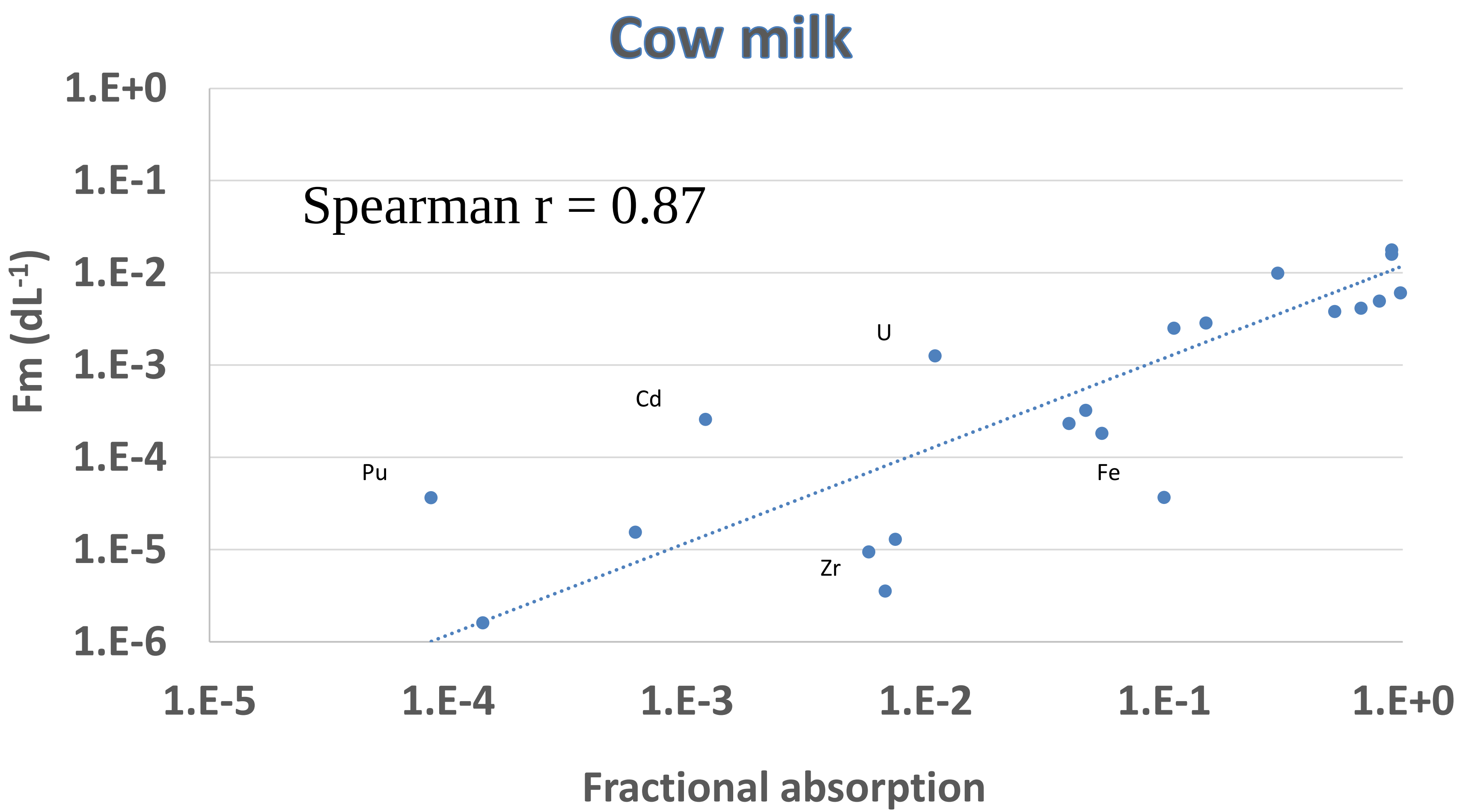
Solutions? Gut absorption AND CR



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Time dependency

- Physical
- Biological
- Ecological
- Effective

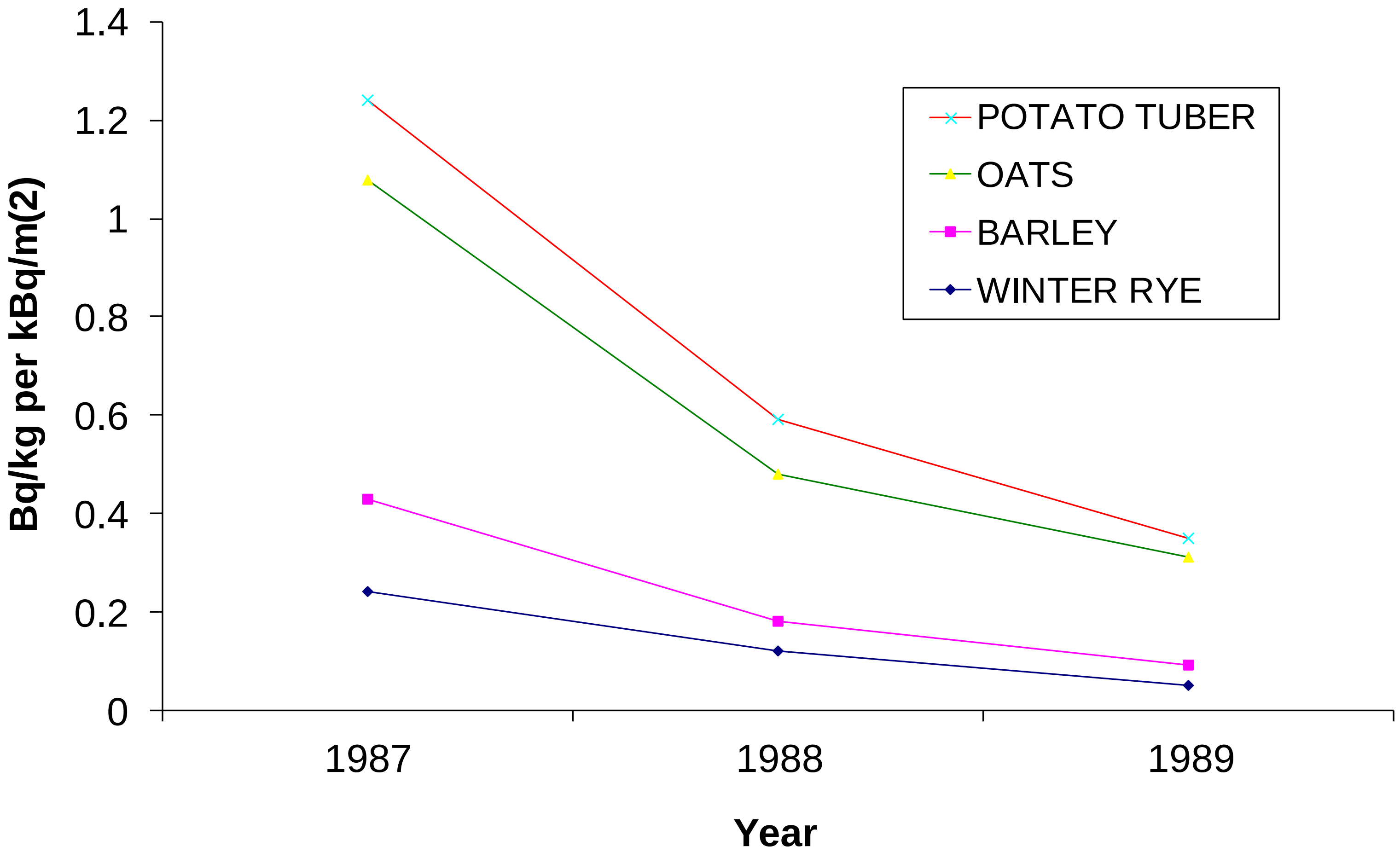
$$T_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda} \approx 0.693\tau$$

Radioactive half-life

Radioactive decay constant

Mean lifetime

Reduction radiocaesium in crops with time



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Biological half life ($T_{1/2b}$) in animal products

- Loss of radionuclides from animal products
  – single or double exponential
- Milk $T_{1/2b}$ is 1-3 d
- Other animal products $T_{1/2b}$ varies widely
  - Influenced by age and size of animal, storage in organs (eg ^{90}Sr in bone)

Fesenko et al 2015 JER 142

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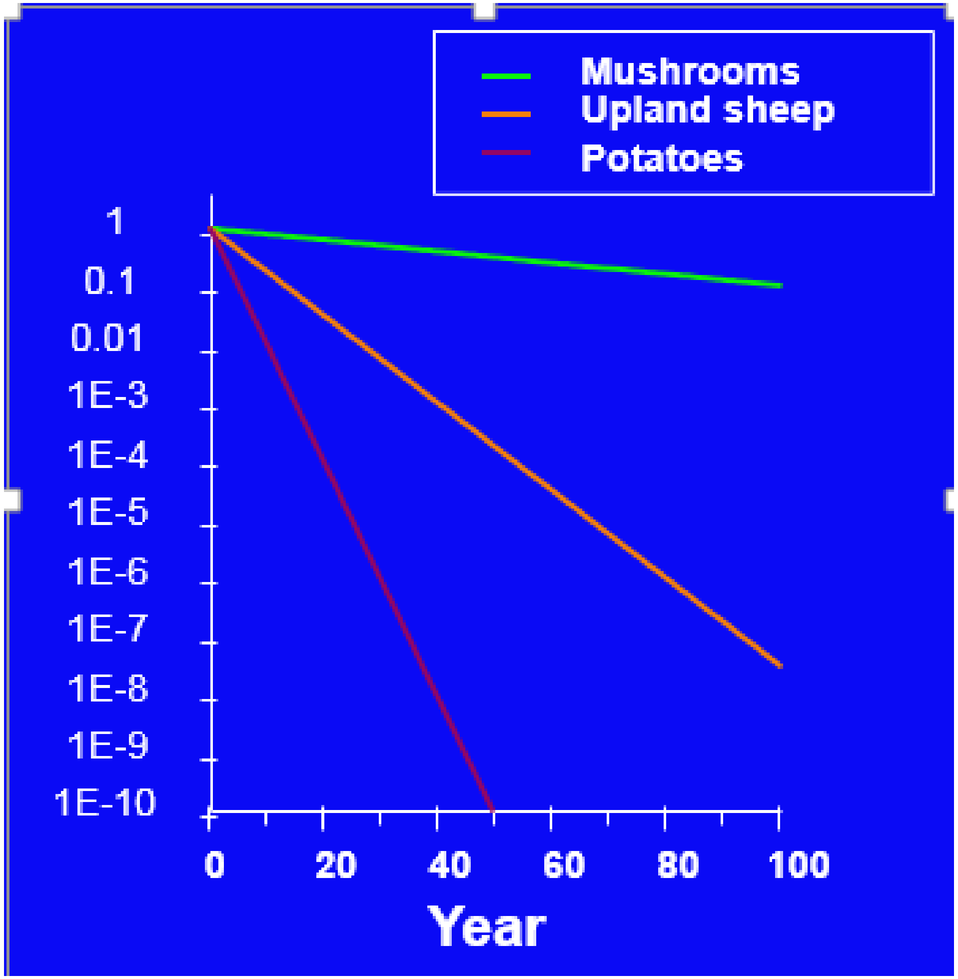
Time dependency – sensitive sites

Long effective ecological half-lives for ^{137}Cs

- terrestrial animals inhabiting areas with organic soils
- mushrooms



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Recent improvements

- Data only basis (not assumptions)
- Animal Transfer coefficients and concentration ratios enhanced
- Gut absorption added
- Extrapolation methods developed
- Transparency and provenance improved

- **Limited access to individual data**
- **Site specificity needed**
- **Few data for Japan**
- **Update rate 1/decade**

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Take home messages

- There is a lot of data out there
  - For some radionuclides
- International sources are not a “bible”
  - Be sceptical
  - Data quality may be better than data quantity
- Are the differences between CR values real?
- Site specific data are often better than international compilations
- Does the lack of data really matter

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