

ADVENTSYMPOSIUM RADIOÖKOLOGIE, 7.12.2023, TU Wien

Bedeutung der Radioökologie der Hydrosphäre für den Bevölkerungsschutz

Franz Josef Maringer

★ Flusswasser

- ★ Trinkwasser

- ★ Fisch

- ★ Viehtränken → Milch, Fleisch

- ★ Bewässerung → Gemüse, Getreide, Gras

- ★ Überschwemmung

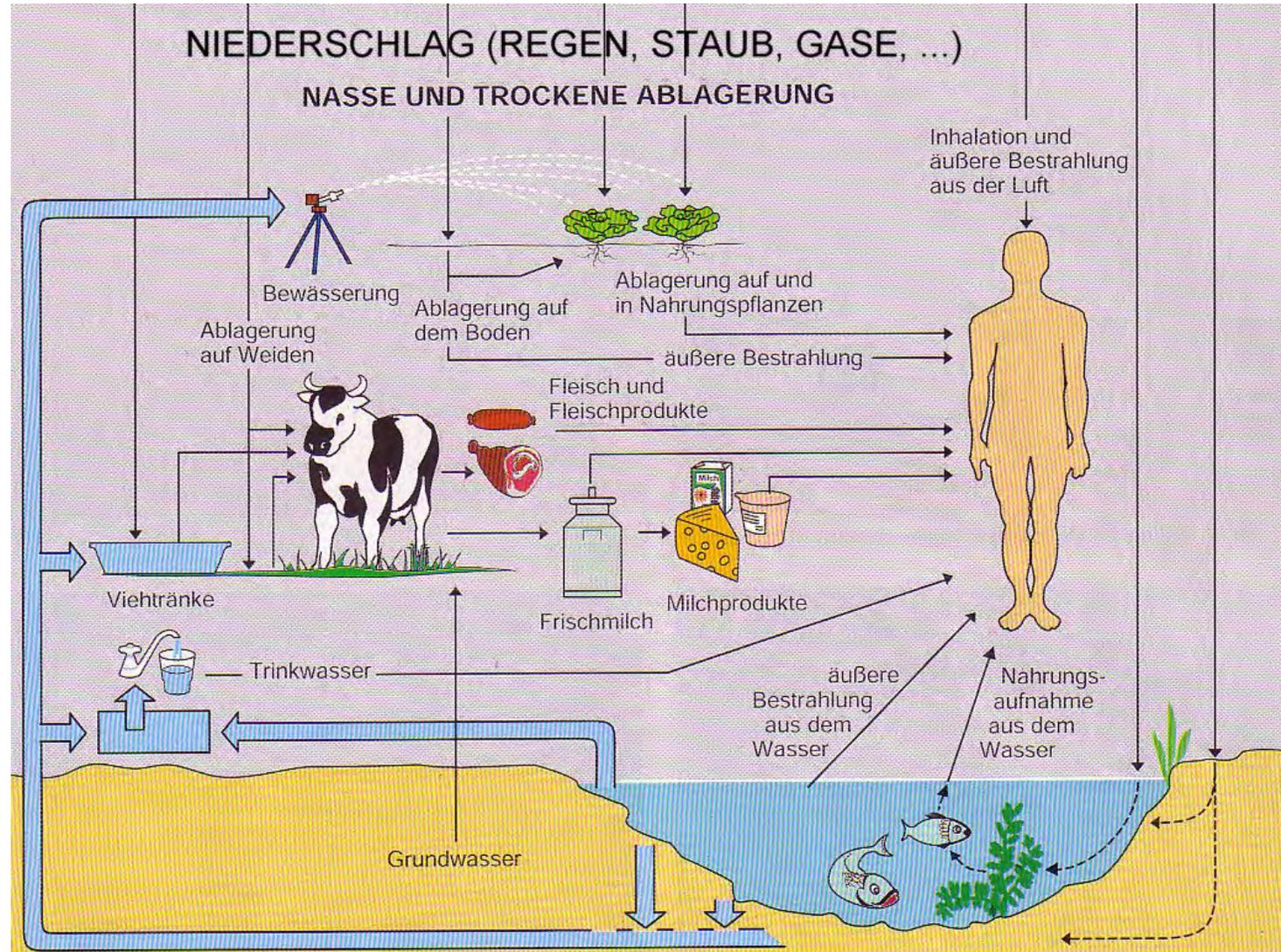
- ★ (Direktexposition)

- ★ (Begleitgrundwasser)

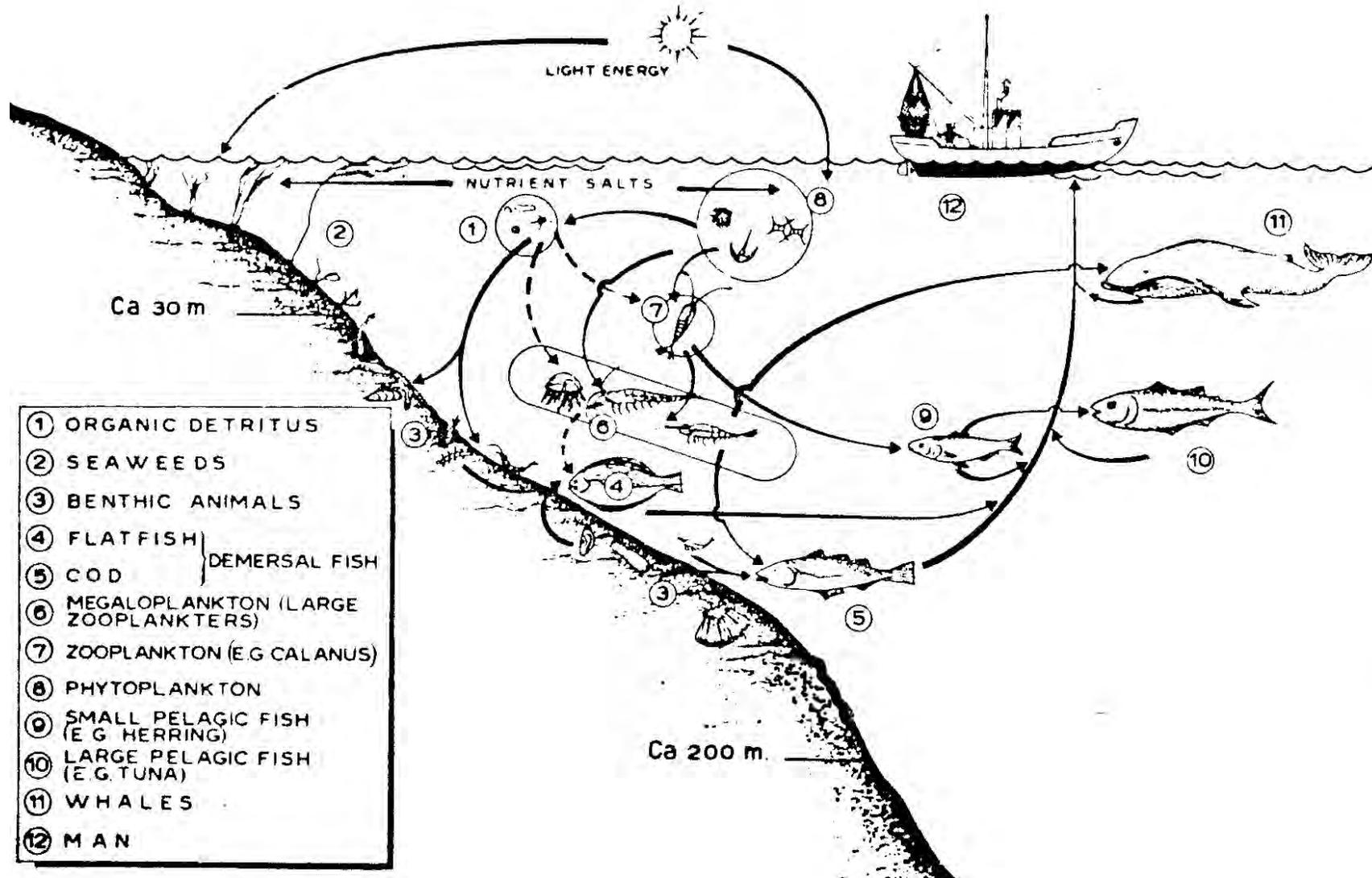
★ Sedimente

- ★ Überschwemmung

- ★ Direktexposition



Nahrungsbeziehungen im Meerwasser (schematisch)



Aufnahme von Radionukliden mit Trinkwasser & Nahrung „Ingestion“

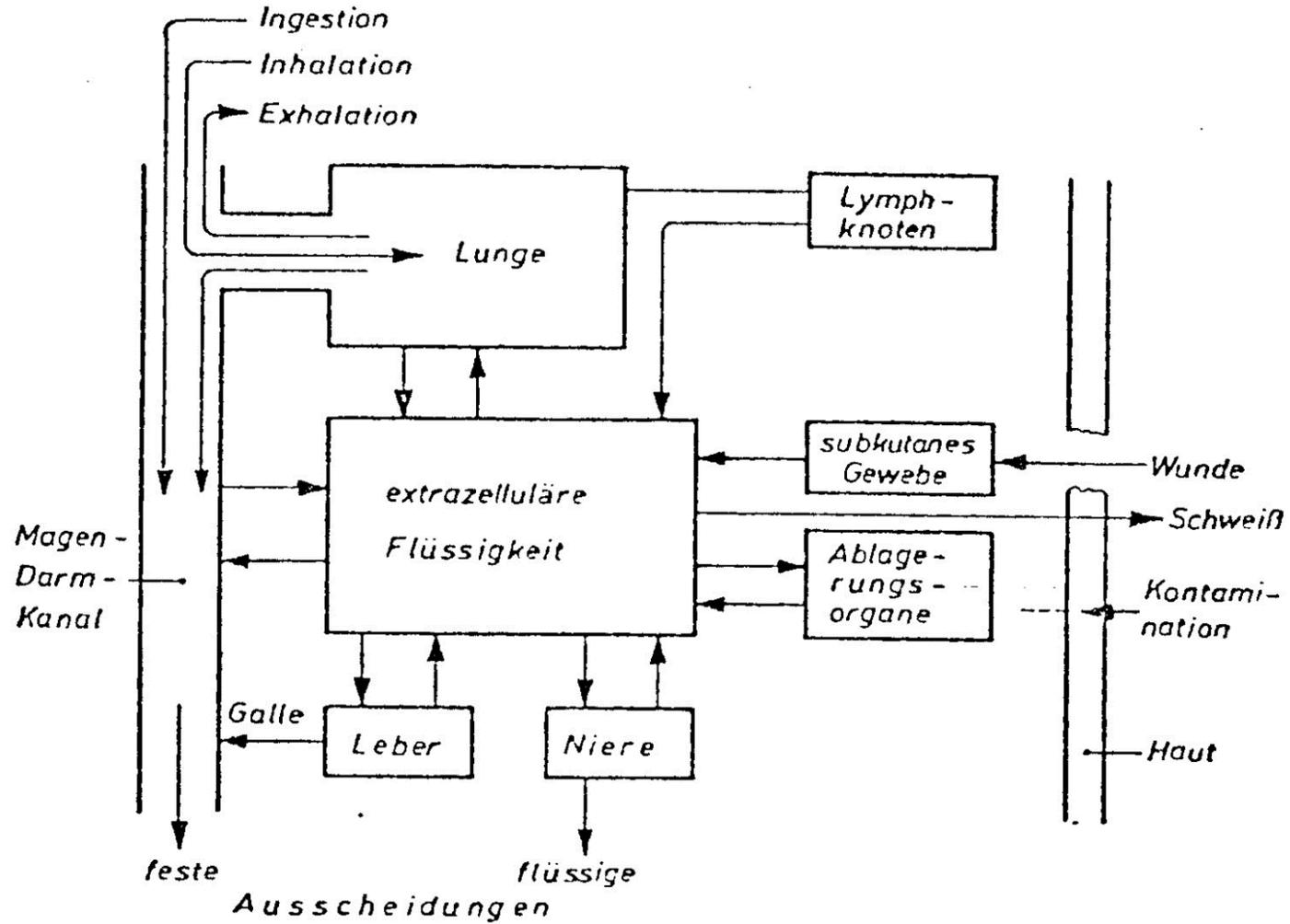
$$E_{ing,i,p} = C_{p,i} \cdot I_p \cdot e_{ing,i}$$

$$\text{Sv/a} = \text{Bq/kg} \cdot \text{kg/a} \cdot \text{Sv/Bq}$$

- $E_{ing,i,p}$... jährliche effektive Dosis durch Ingestion des Radionuklids i im Nahrungsmittel/Trinkwasser p (Sv/a)
- $C_{p,i}$ Aktivitätskonzentration des Radionuklids i im Nahrungsmittel/Trinkwasser p (Bq/kg)
- I_p jährliche Konsumationsmenge (kg/a)
- $e_{ing,i}$ Dosiskonversionsfaktor für Ingestion des Radionuklids i (Sv/Bq)

Dosisermittlung – Annahmewerte (regional)

	Far East	Near East	Africa	South America	Central America	North America	Europe	Oceania
Water (m ³ /a)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Milk (L/a)	65	140	80	135	155	325	250	410
Meat (kg/a)	40	55	35	90	75	205	100	200
Grain, root crops, vegetables and fruits (kg/a)	510	600	380	470	445	535	410	500
Freshwater fish (kg/a)	35	10	15	20	25	25	30	15
Marine fish (kg/a)	60	20	30	35	45	40	50	30
Shellfish (kg/a)	20	5	10	10	15	15	15	10



Dosiskonversionsfaktoren (ICRP) - Beispiele

Nuclide	Gut transfer factor, f_1	Infant (1 a)	Adult
Ac-228	5.0×10^{-4}	2.8×10^{-9}	4.3×10^{-10}
Ag-110m	0.050	1.4×10^{-8}	2.8×10^{-9}
Am-241	5.0×10^{-4}	3.7×10^{-7}	2.0×10^{-7}
As-76	0.500	1.1×10^{-8}	1.6×10^{-9}
At-211	1.000	7.8×10^{-8}	1.1×10^{-8}
Au-198	0.100	7.2×10^{-9}	1.0×10^{-9}
Bi-206	0.050	1.0×10^{-8}	1.9×10^{-9}
Bi-210	0.050	9.7×10^{-9}	1.3×10^{-9}
Bi-212	0.050	1.8×10^{-9}	2.6×10^{-10}
Br-82	1.000	2.6×10^{-9}	5.4×10^{-10}
Cd-109	0.050	9.5×10^{-9}	2.0×10^{-9}
Ce-141	5.0×10^{-4}	5.1×10^{-9}	7.1×10^{-10}
Ce-144	5.0×10^{-4}	3.9×10^{-8}	5.2×10^{-9}
Cm-242	5.0×10^{-4}	7.6×10^{-8}	1.2×10^{-8}
Cm-244	5.0×10^{-4}	2.9×10^{-7}	1.2×10^{-7}
Co-58	0.100	4.4×10^{-9}	7.4×10^{-10}
Co-60	0.100	2.7×10^{-8}	3.4×10^{-9}
Cr-51	0.100	2.3×10^{-10}	3.8×10^{-11}
Cs-134	1.000	1.6×10^{-8}	1.9×10^{-8}
Cs-135	1.000	2.3×10^{-9}	2.0×10^{-9}
Cs-136	1.000	9.5×10^{-9}	3.0×10^{-9}
Cs-137	1.000	1.2×10^{-8}	1.3×10^{-8}
Cu-64	0.500	8.3×10^{-10}	1.2×10^{-10}
Eu-154	5.0×10^{-4}	1.2×10^{-8}	2.0×10^{-9}

Ausbreitung eines Radionuklids in einem Umweltkompartiment

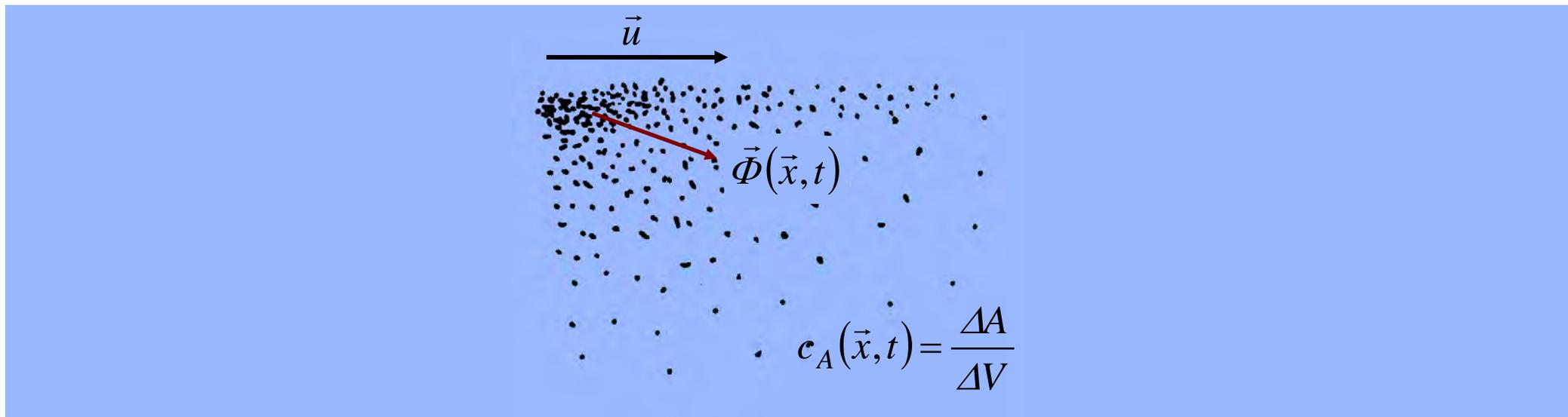
Aktivitätsfluss ($\text{Bq}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)

Diffusion

$$\vec{\Phi}_{Dif}(\vec{x}, t) = -D \cdot \nabla c_A(\vec{x}, t)$$

Advektion

$$\vec{\Phi}_{Adv}(\vec{x}, t) = \vec{u} \cdot c_A(\vec{x}, t)$$



Transportgleichung für die Ausbreitung eines Radionuklids

Aktivitätserhaltung (Massenerhaltung)

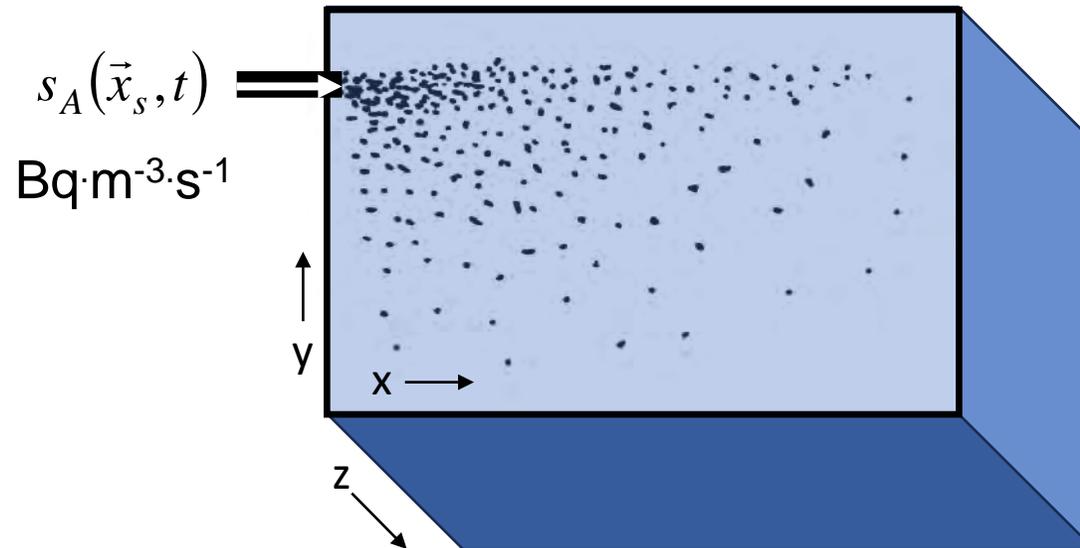
ohne

Aktivitätsquelle & rad. Umwandlung

mit

$$\frac{\partial c_A(\vec{x}, t)}{\partial t} + \nabla \cdot \vec{\Phi}(\vec{x}, t) = 0$$

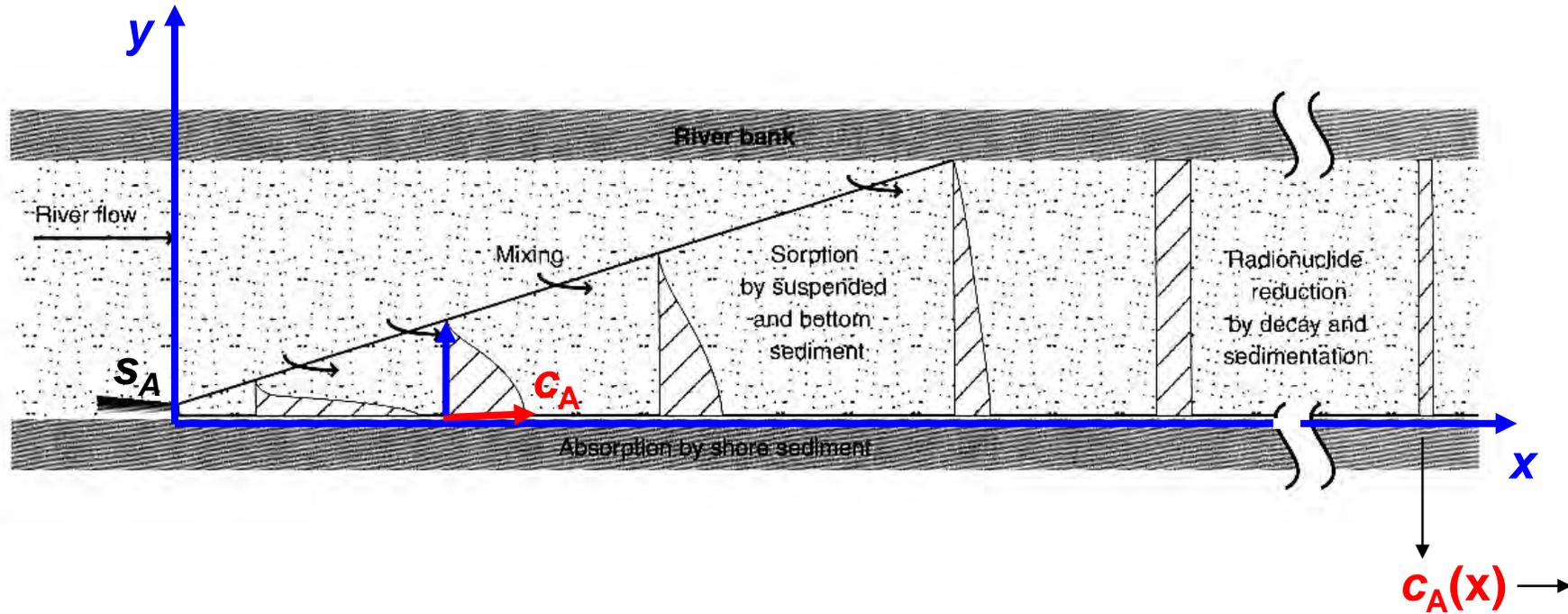
$$\frac{\partial c_A(\vec{x}, t)}{\partial t} + \nabla \cdot \vec{\Phi}(\vec{x}, t) = s(\vec{x}_s, t) - \lambda \cdot c_A(\vec{x}, t)$$



Lösung der Transportgleichung (partielle Differentialgleichung)

→ mit Anfangs- und Randbedingungen

Fluss: 2-dimensional, Sediment, Schwebstoff, Organismen



Lösung der Transportgleichung

Beispiel:

- 1.) $s_A = \text{const.} \neq s_A(t)$
- 2.) $x \gg \lambda$

Lösung:

$$c_A(x) = \frac{S_A}{q} \cdot \exp\left(-\frac{(\lambda_{rad} + \lambda_{sed}) \cdot x}{u}\right)$$

- S_A Aktivitätsquelle bei $x = 0$ (Bq/s)
- q mittlere Abflussrate (m³/s)
- λ_{rad} radioaktive Umwandlungskonstante (s⁻¹)
- λ_{sed} ... Sedimentationskonstante (s⁻¹)
- u Fließgeschwindigkeit (m/s)

Radionuklidtransfer Wasser ↔ Schwebstoff

("suspended sediment")

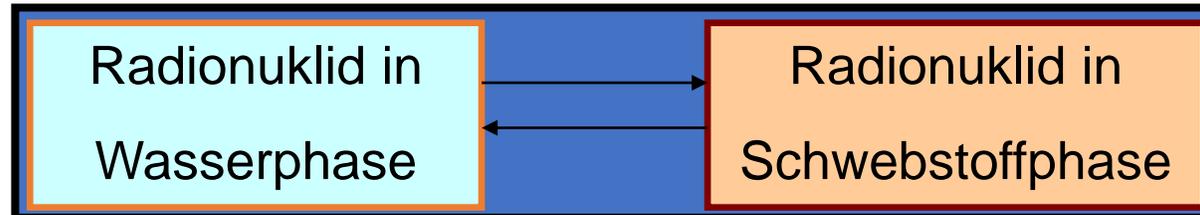
Verteilungskoeffizient

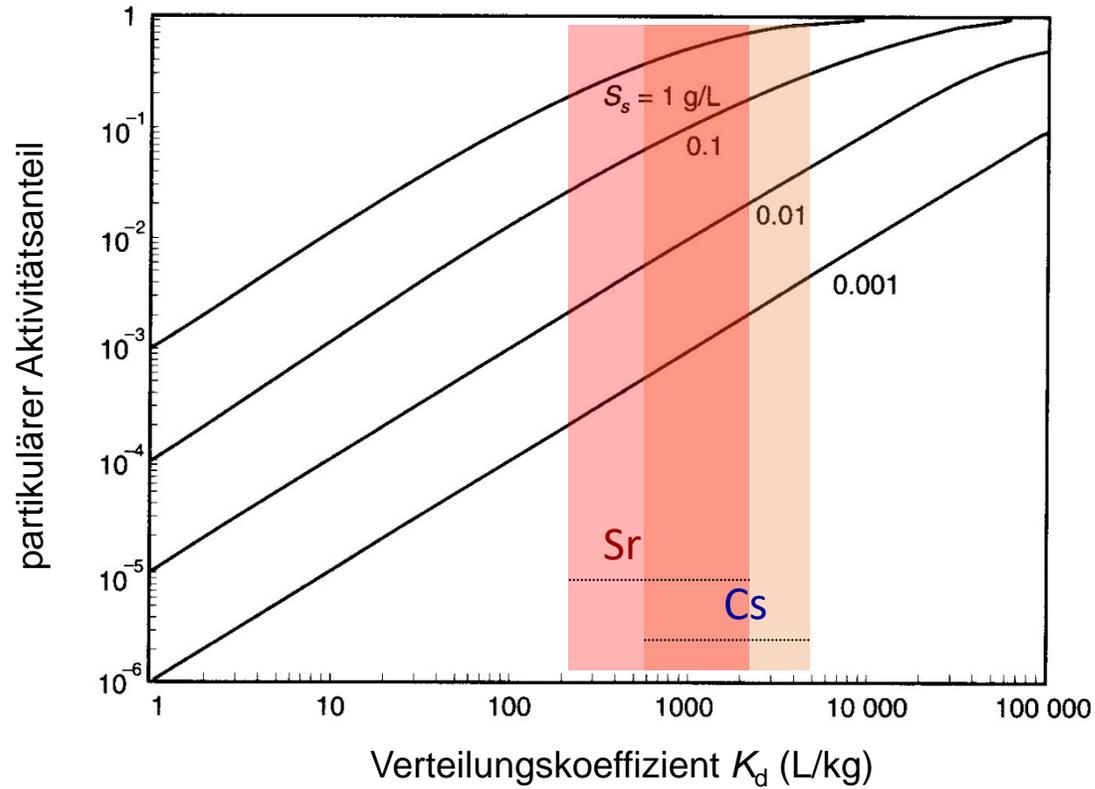
$$K_d \stackrel{(t \gg \lambda_d^{-1})}{=} \frac{a_S}{c'_A} \quad \left[\frac{\text{Bq/kg}}{\text{Bq/L}} \right] = \left[\frac{\text{L}}{\text{kg}} \right]$$

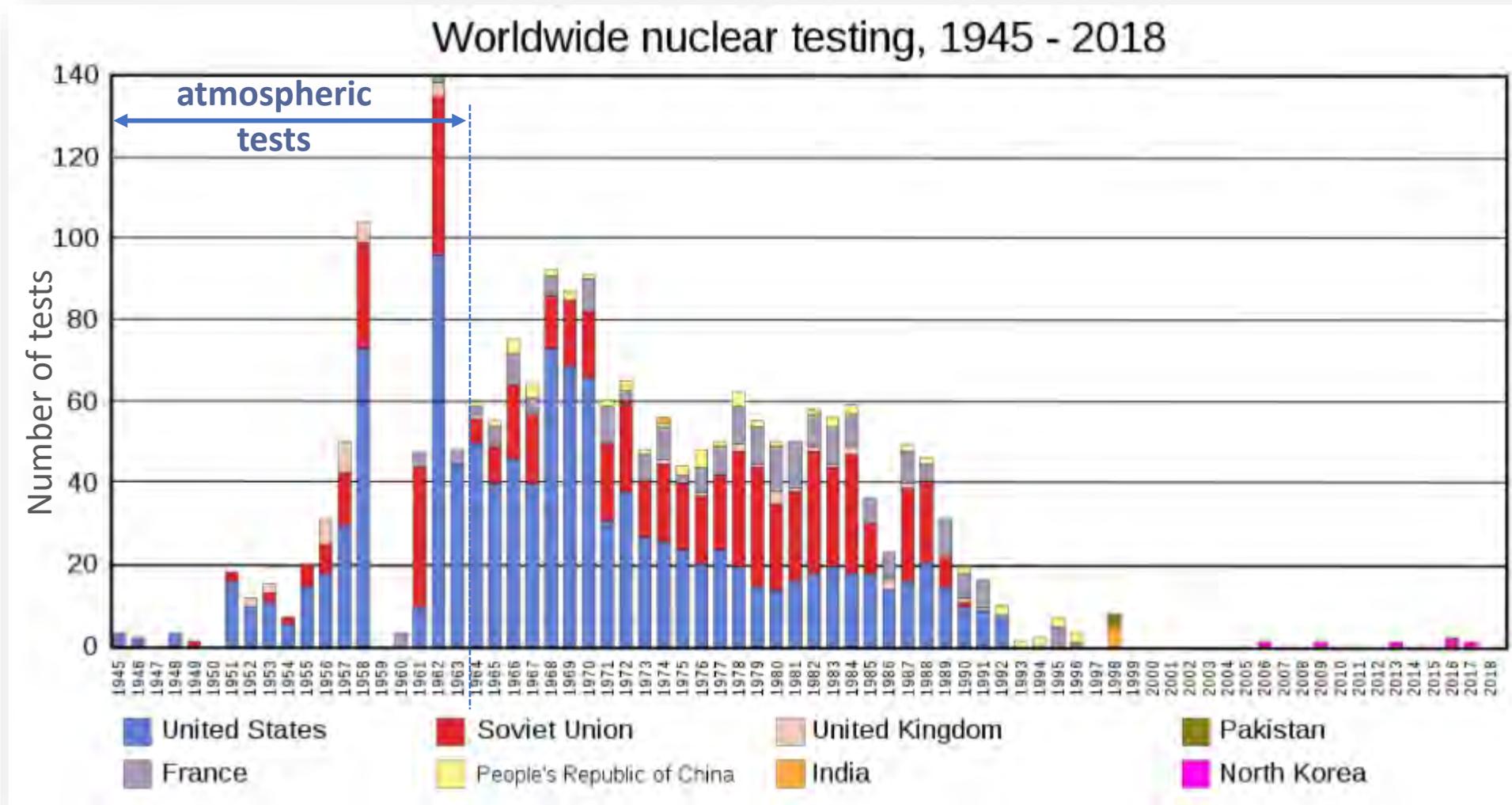
a_S ... massenbezogene Aktivität, spezifische Aktivität (Bq/kg_{trocken})

c'_A ... Aktivitätskonzentration im Wasser ohne Schwebstoff (Bq/L)

λ_d ... Transferkonstante des Radionuklids Wasser ↔ Schwebstoff (s⁻¹)





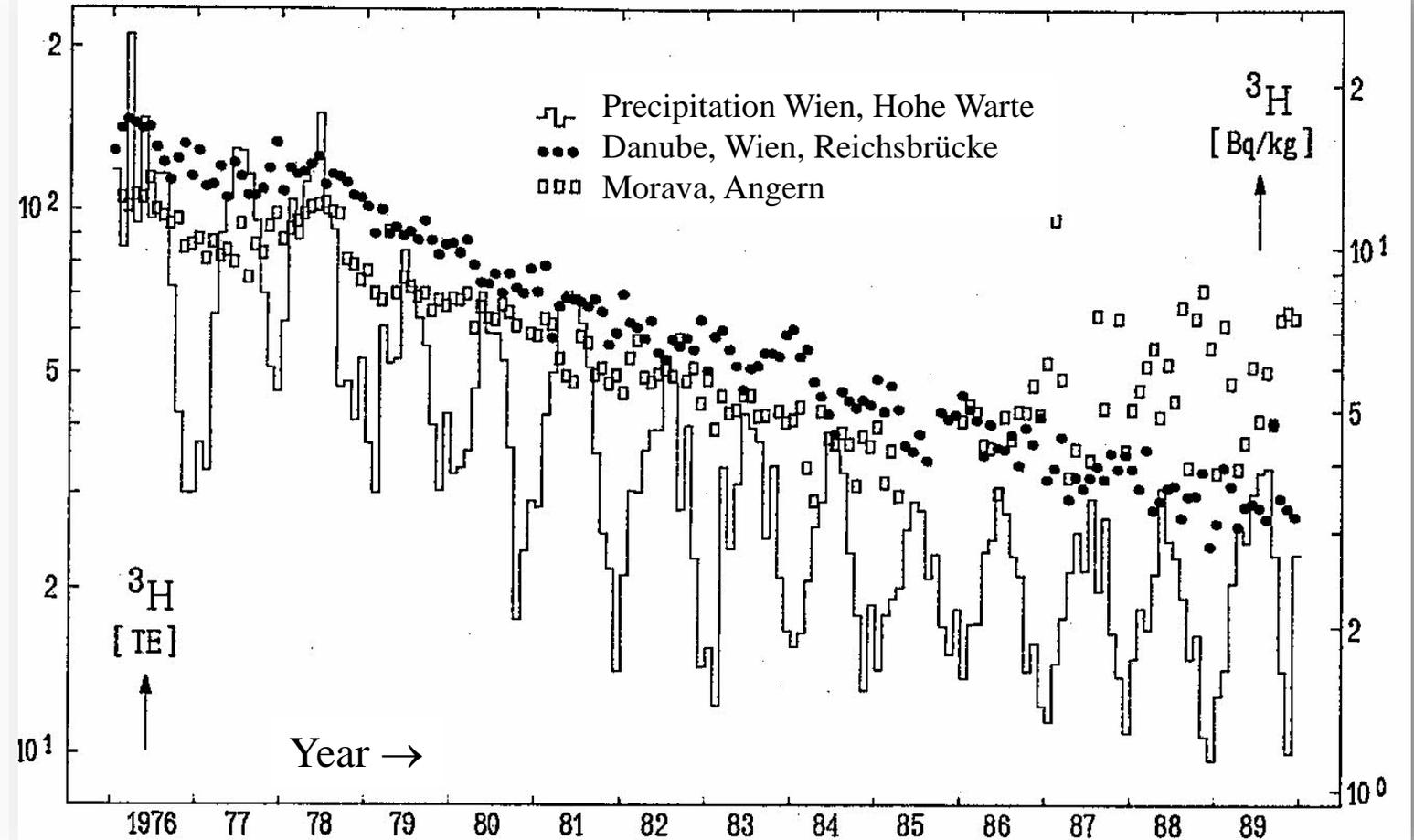


Early radioecological research on the Danube / 1955 – 1985

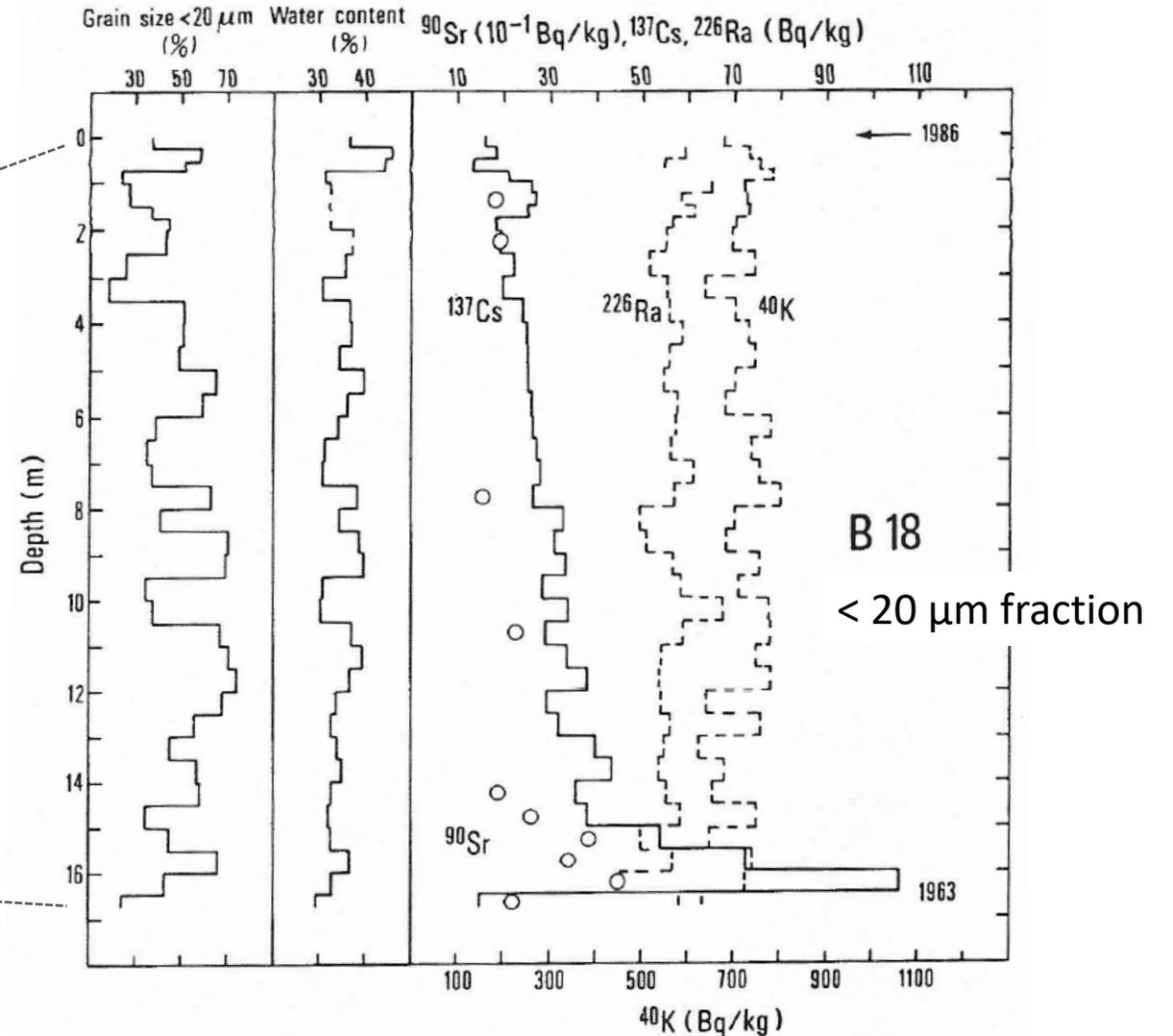
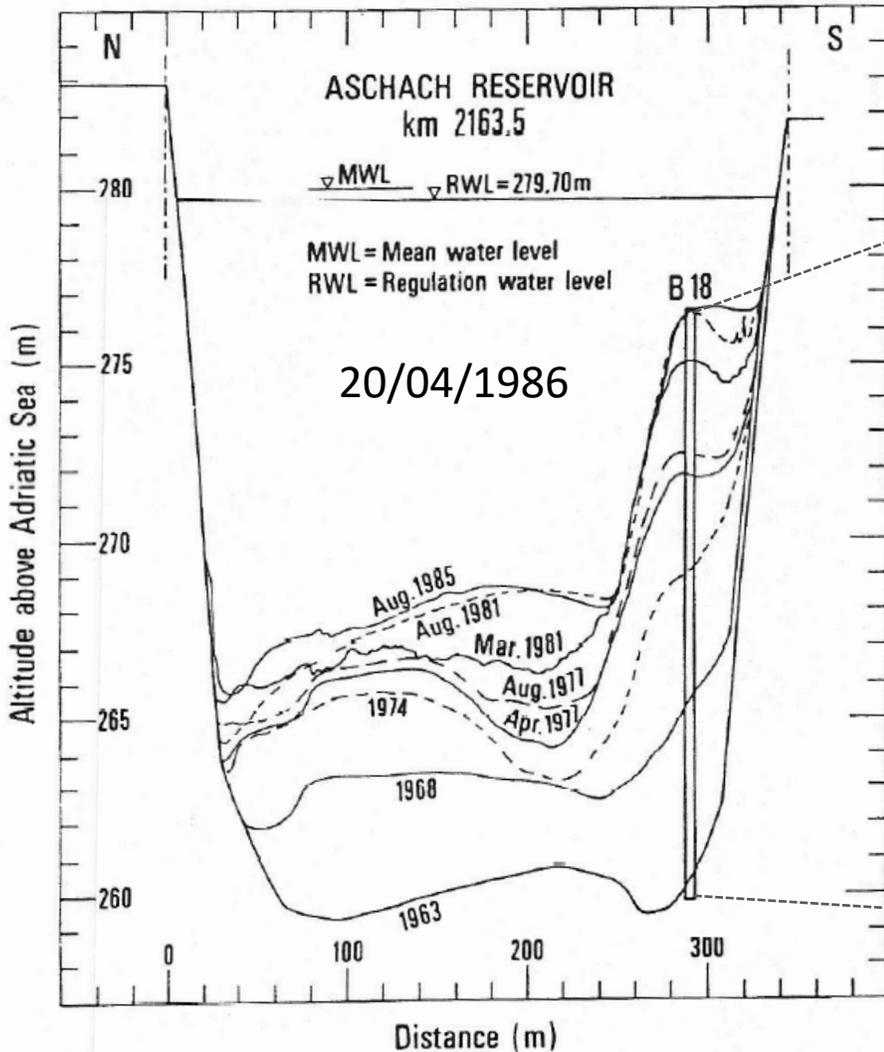
Tritium activity concentration ($H_2O \rightarrow HTO$)

Danube water, Wien and Morava, Angern

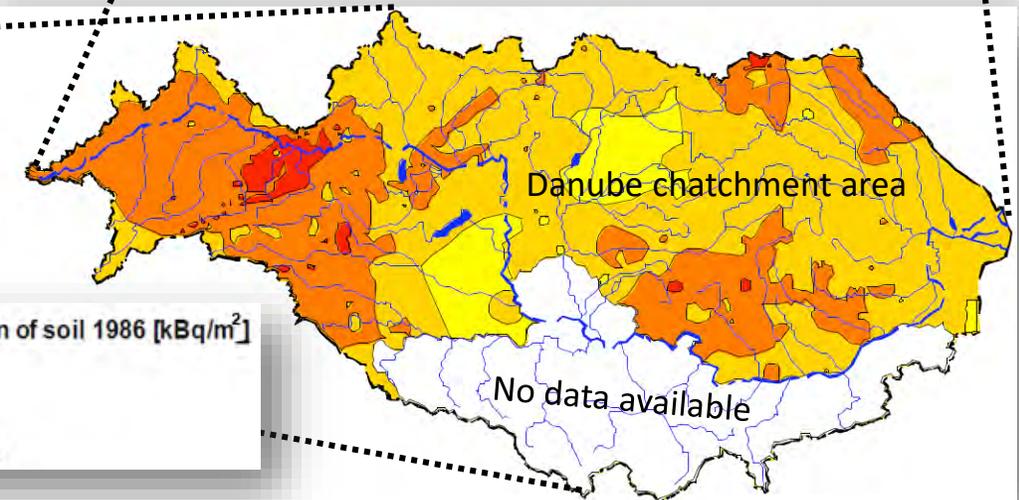
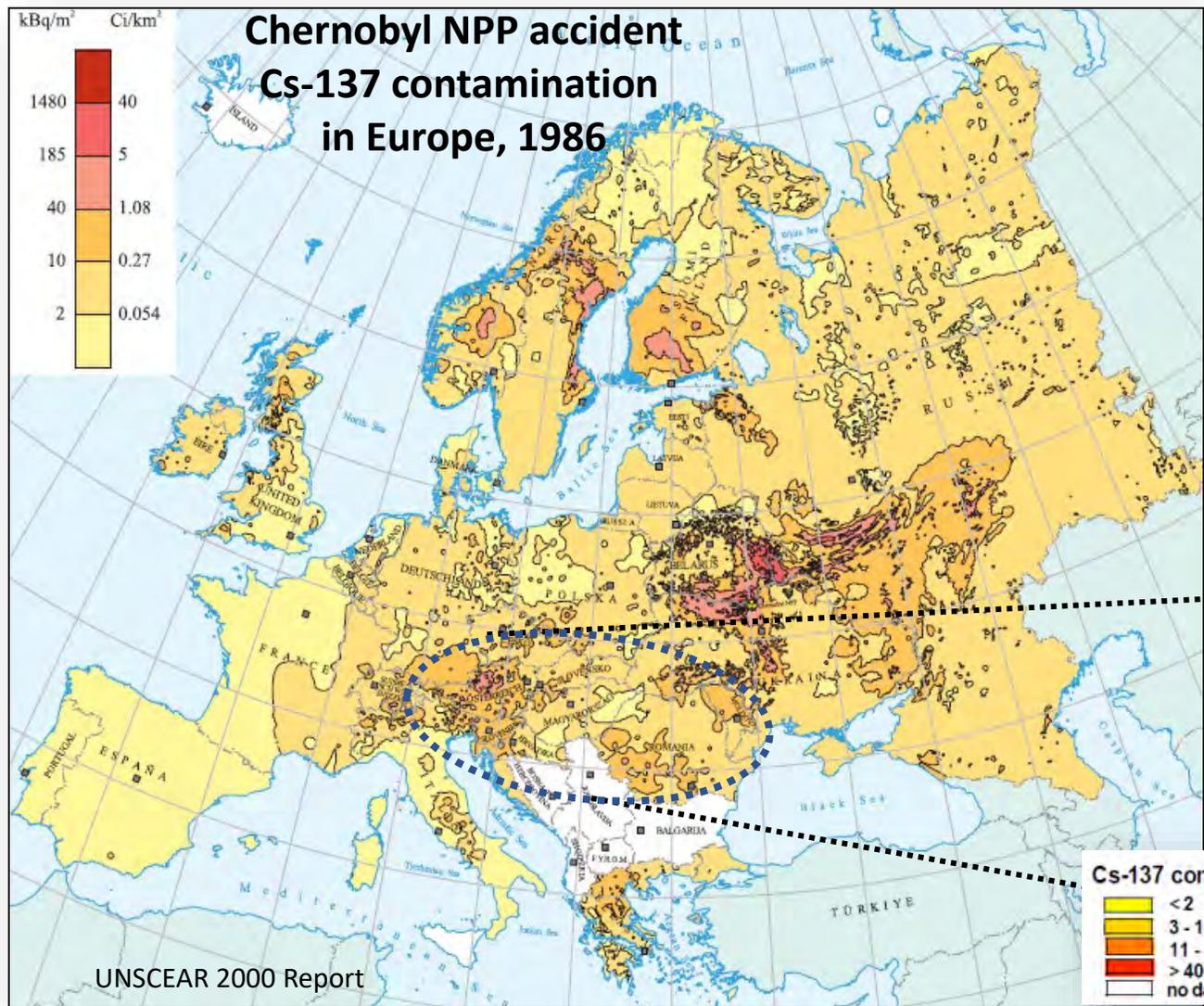
1976 – 1989



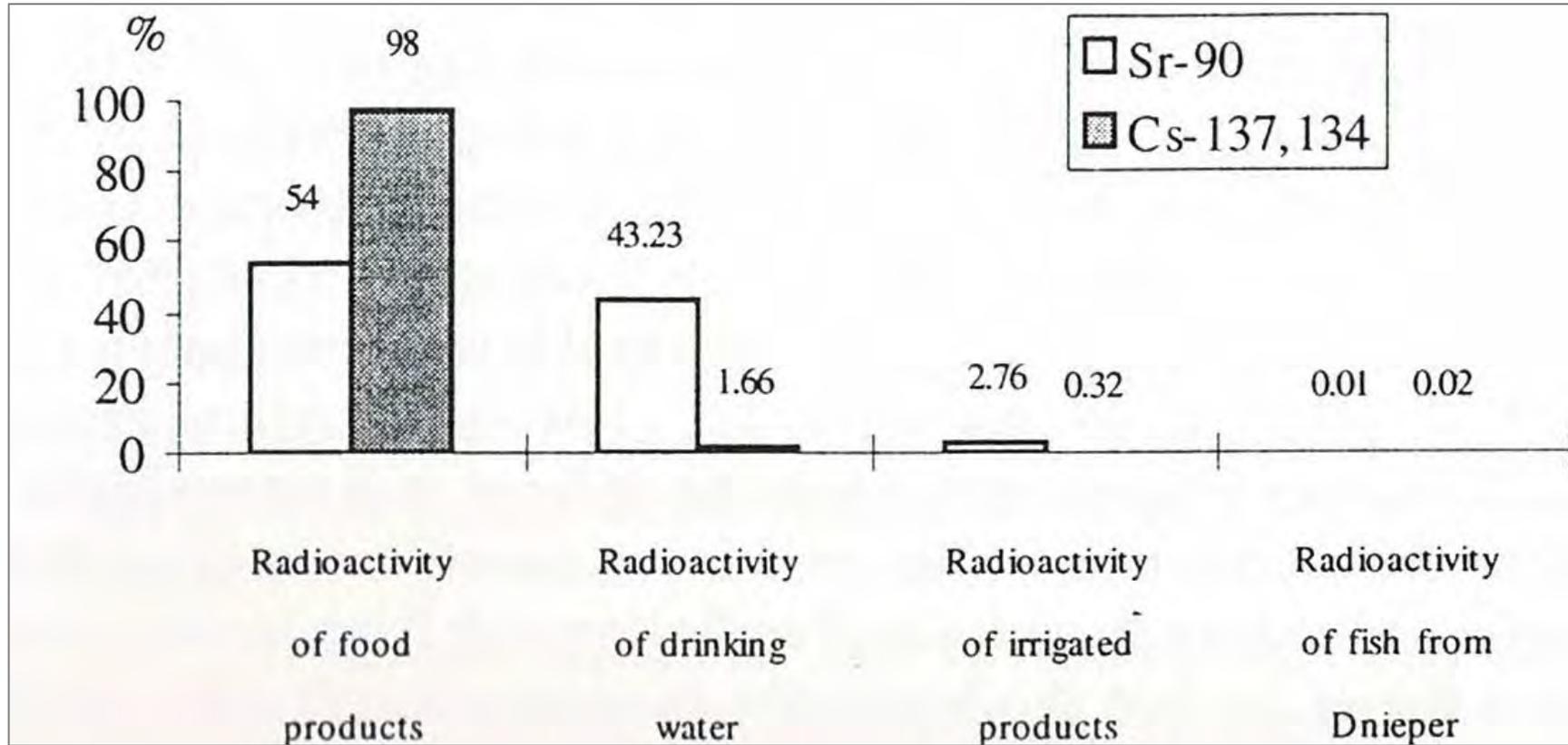
Early radioecological research on the Danube / 1955 – 1985



Radioecological research after the Chernobyl accident / 1986 – 2021



Kiev, Bevölkerungsdosis 1993



(Voitsekhovitch et al., 1997)

Kiev, Bevölkerungsdosis 1993

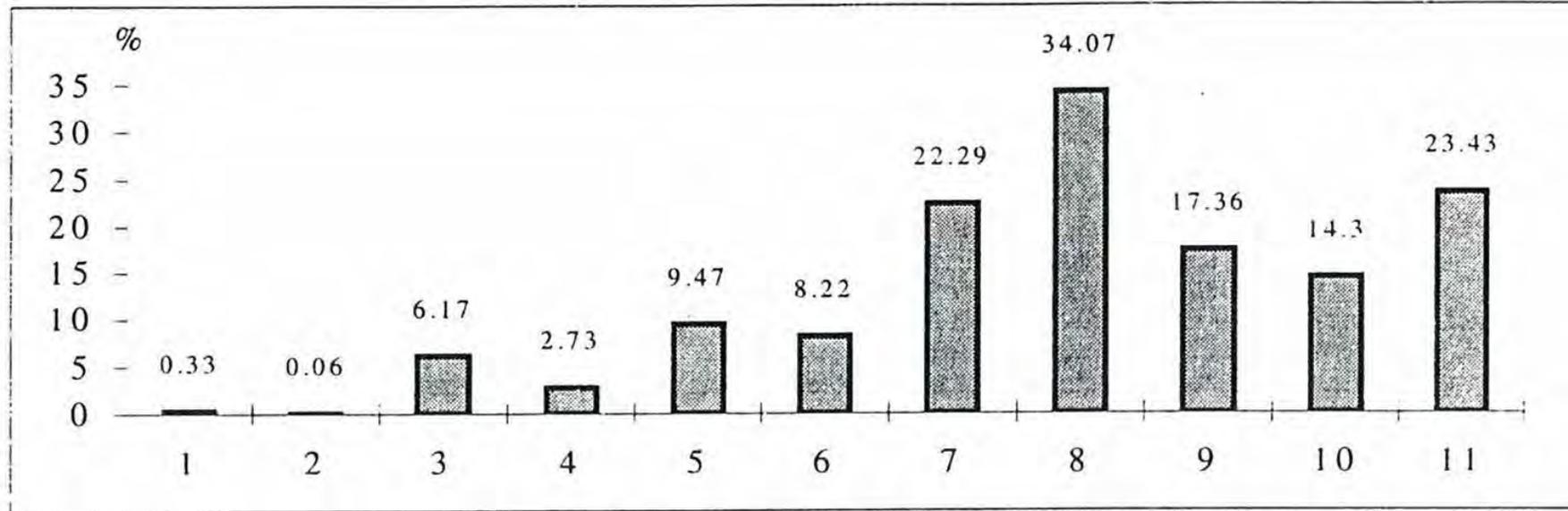


Fig. 4. Aquatic component contribution of annual individual effective dose for peoples, living in different regions of Ukraine due to water usage from Dnieper's reservoirs. Scenario 1993. 1 = Chernigov reg.; 2 = Kiev reg.; 3 = Kiev city; 4 = Cherkassy reg.; 5 = Poltava reg.; 6 = Kirovograd reg.; 7 = Dniepropetrovsk reg.; 8 = Zaporozhie reg.; 9 = Kherson city; 10 = Mikolaev city; 11 = Crimea republic.

(*Voitsekhovitch et al., 1997*)

Mit Schadenskoeffizient 7,3 % Sv⁻¹

→ ca. 60 zusätzliche Krebsfälle 1986 – 1993 in 21 Mio. Gesamtbevölkerung

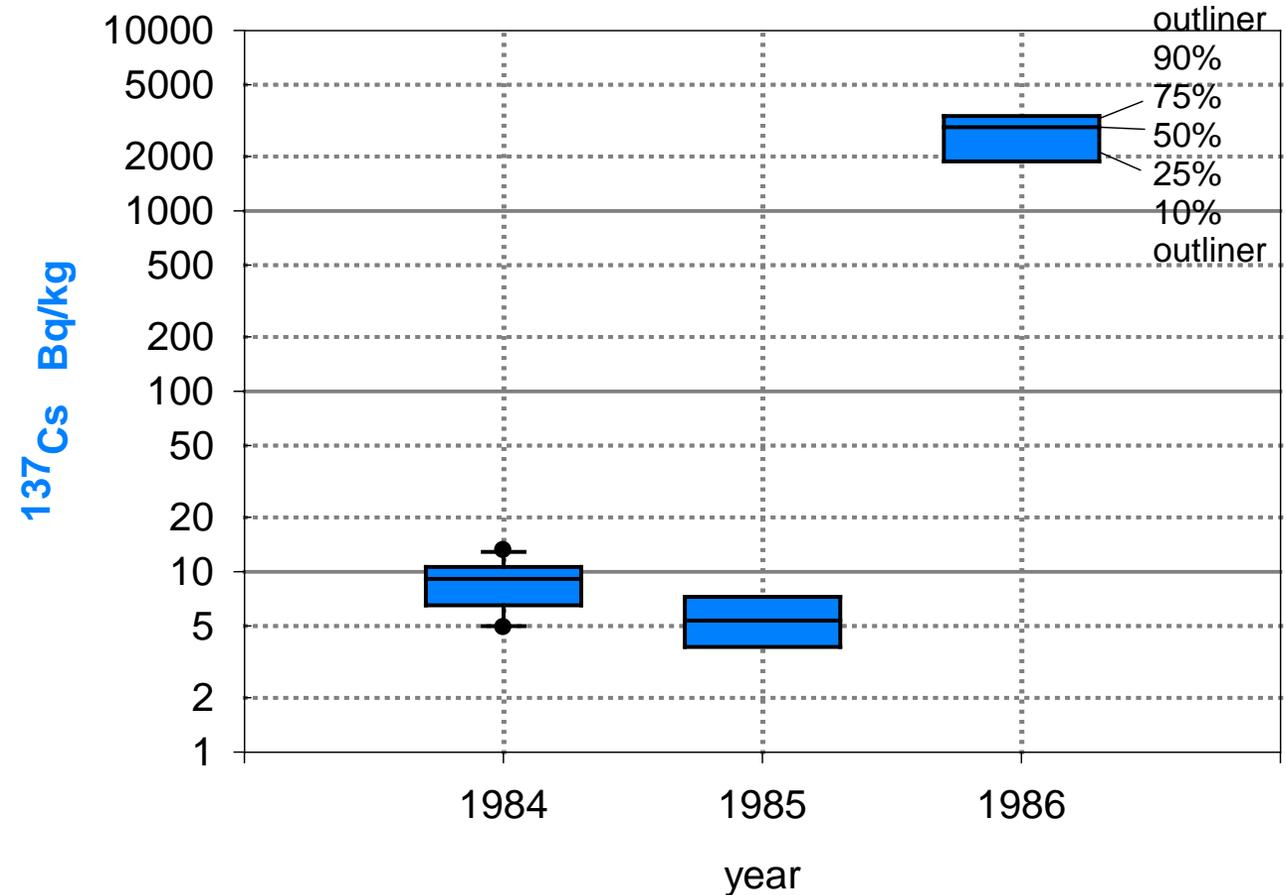
→ ca. 200 zusätzliche Krebsfälle 1986 - 2056 (70 Jahre)

Radioecological research after the Chernobyl accident / 1986 – 2021

Cs-137 activity concentration of sediment samples

Danube Austria

Before (1984, 1985) and after Chernobyl accident (1986)

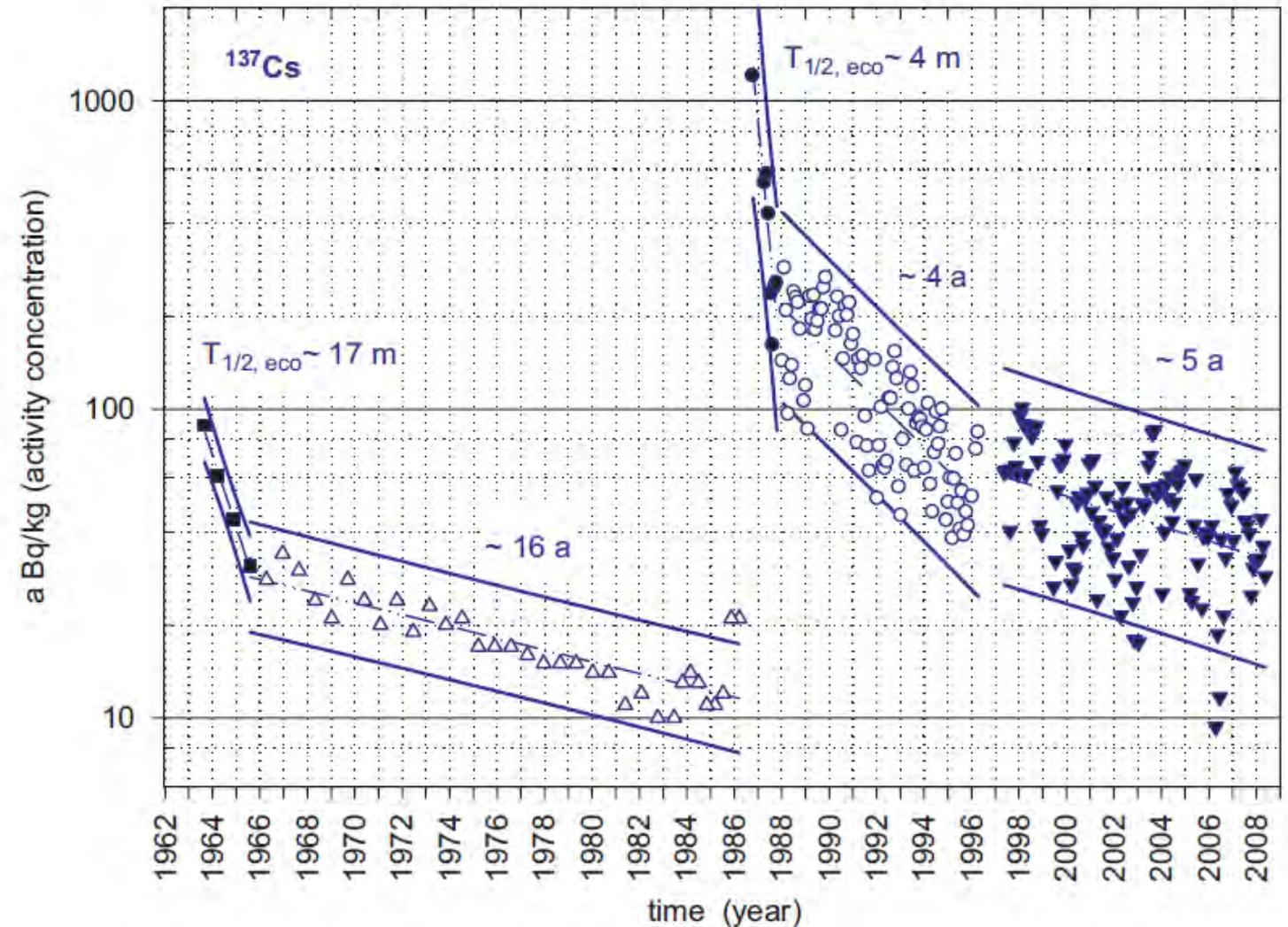


Radioecological research 1986 – 2021

Chronology of Cs-137 activity concentration of monthly collected sediment samples

Danube Austria

river km 2163.5 (year 1963–1986) and km 1933.2 (year 1987–2008)

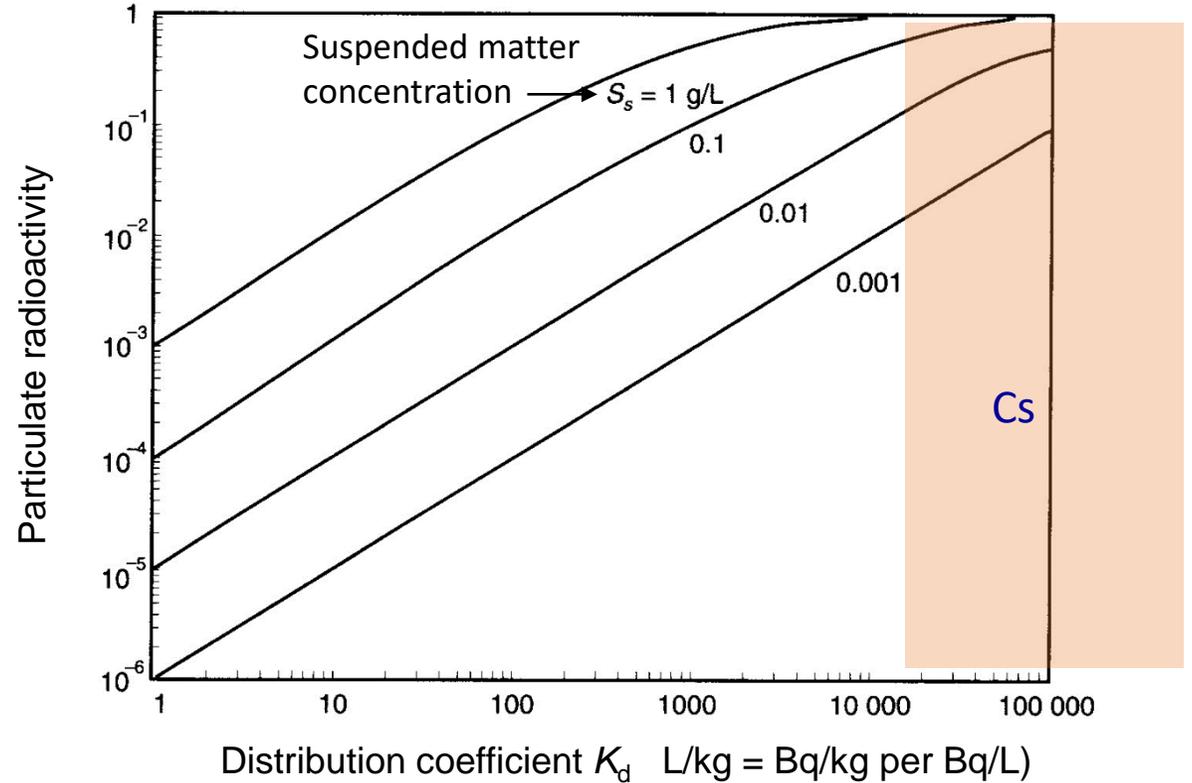
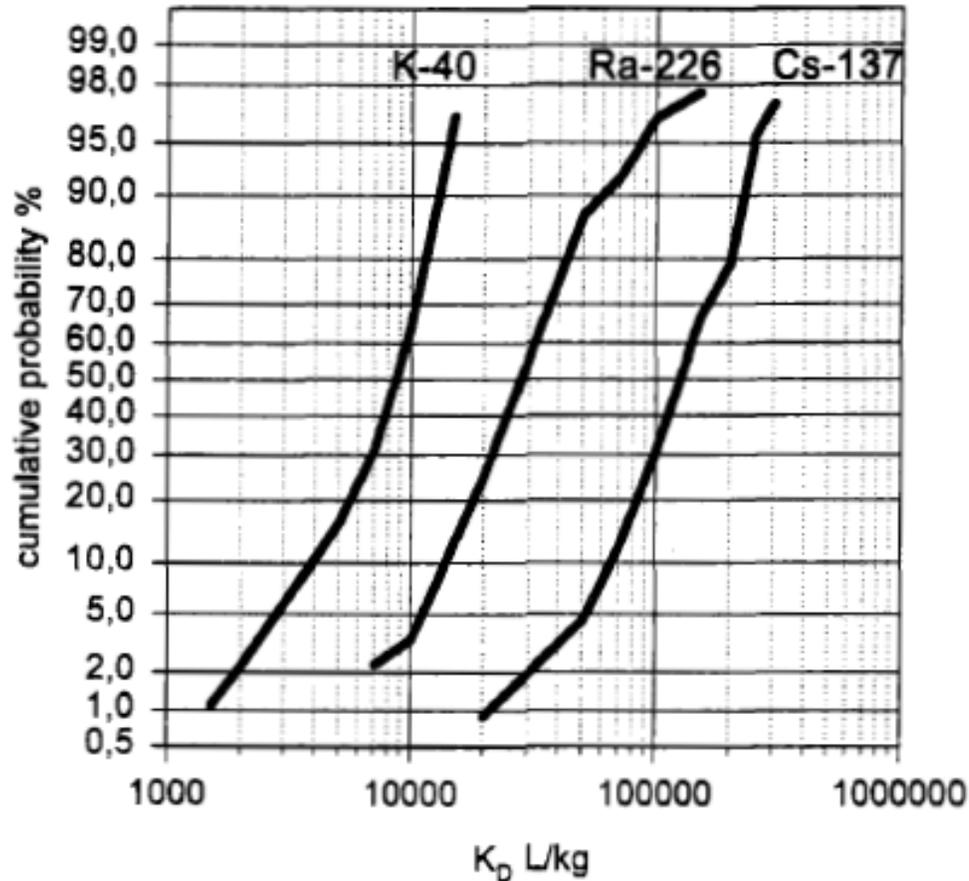


4. Radioecological research 1986 – 2021

Danube, Austria, 1989 - 1992

Suspended matter

- ~ 45 % clay and mica minerals
- ~ 30 % carbonates (calcite, dolomite)
- ~ 20 % quartz and feldspar
- ~ 5 % organic matter

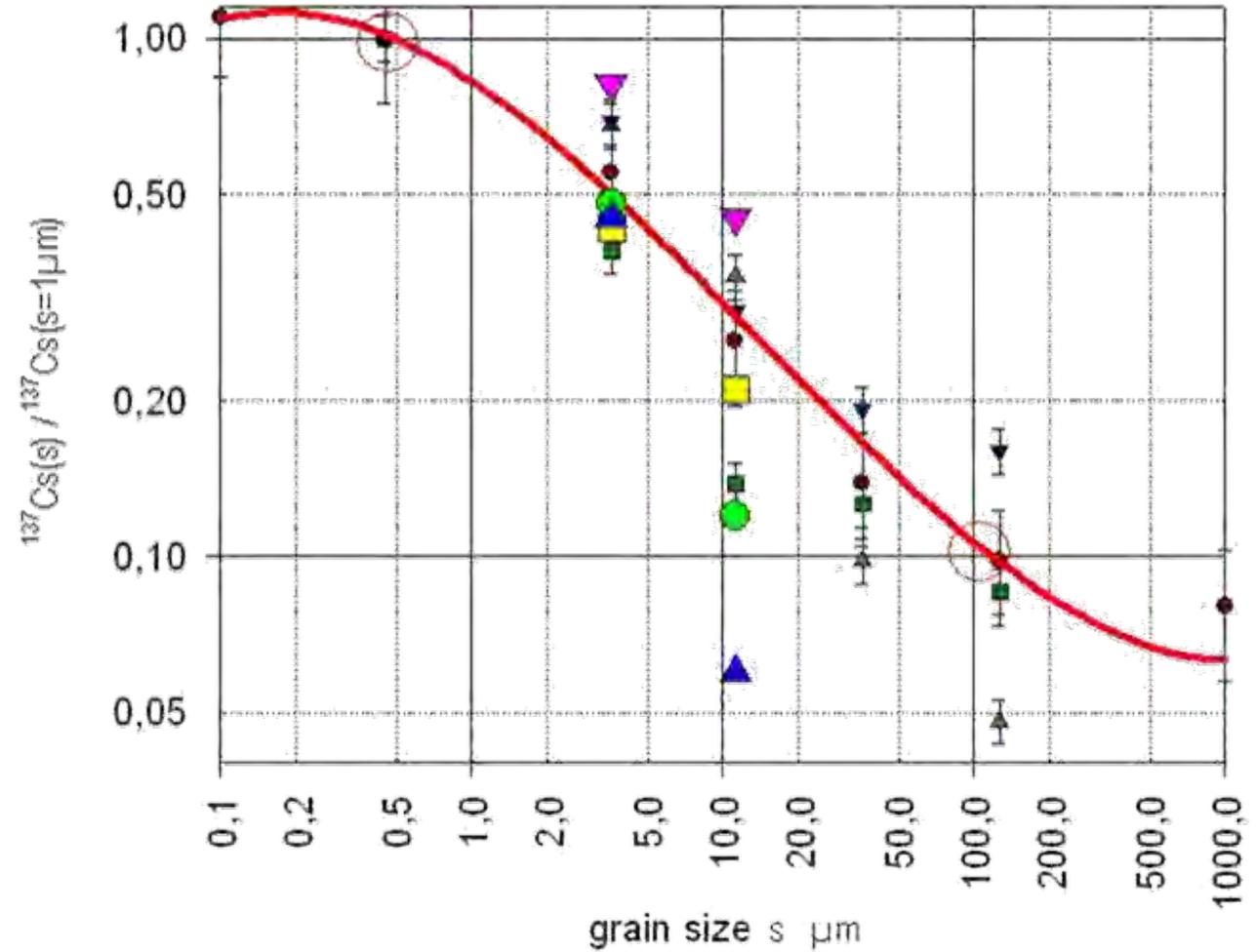


Radioecological research 1986 – 2021

Cs-137 activity concentration of sediment samples

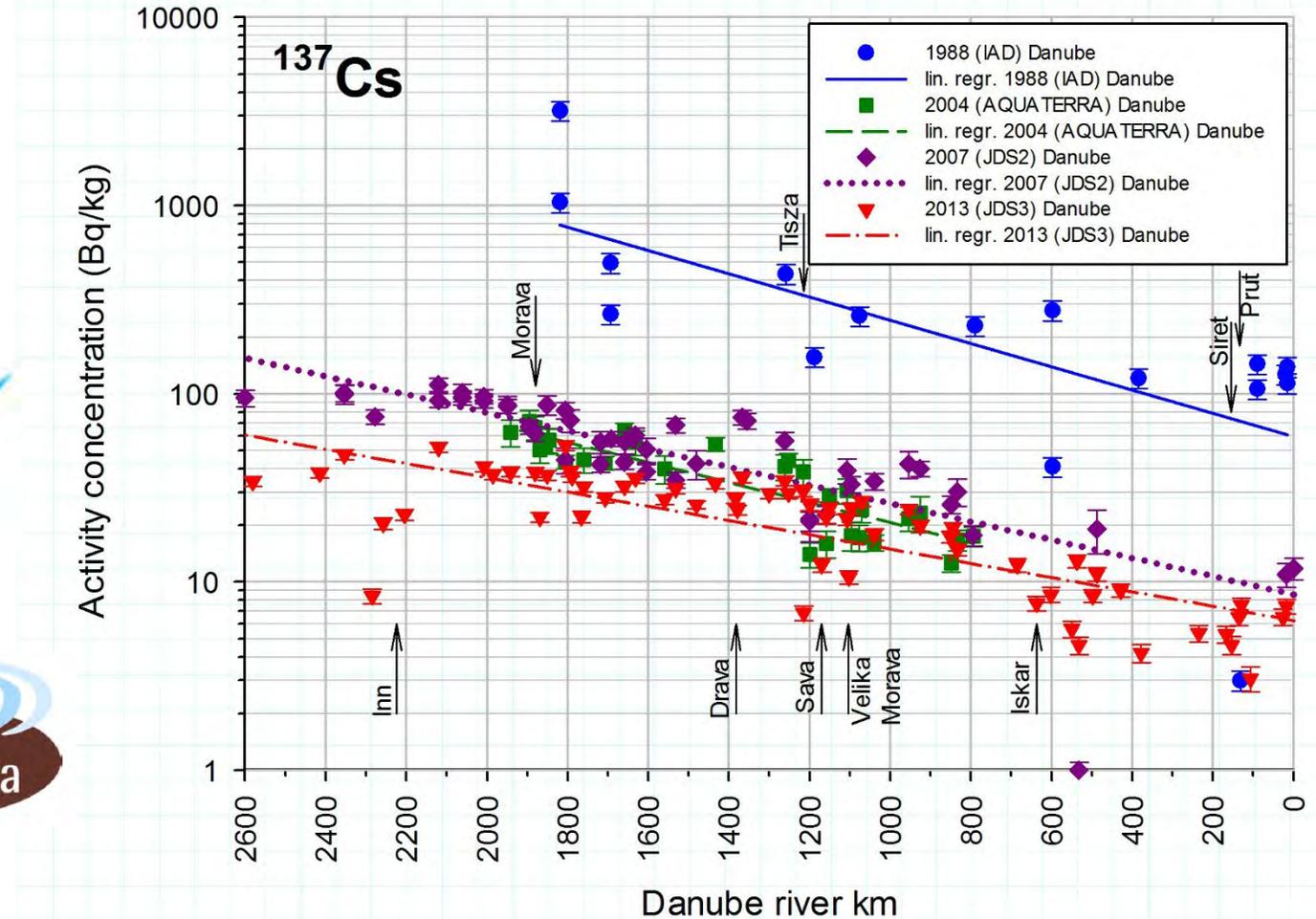
Danube Austria

impact of grain size



Radioecological research on the Danube 1988 – 2013

Danube sediments
fine fractions (grain size < 63 μm)
1988, 2004, 2007, 2013



international association
for danube research



ICPDR IKSD

International Commission
for the Protection
of the Danube River

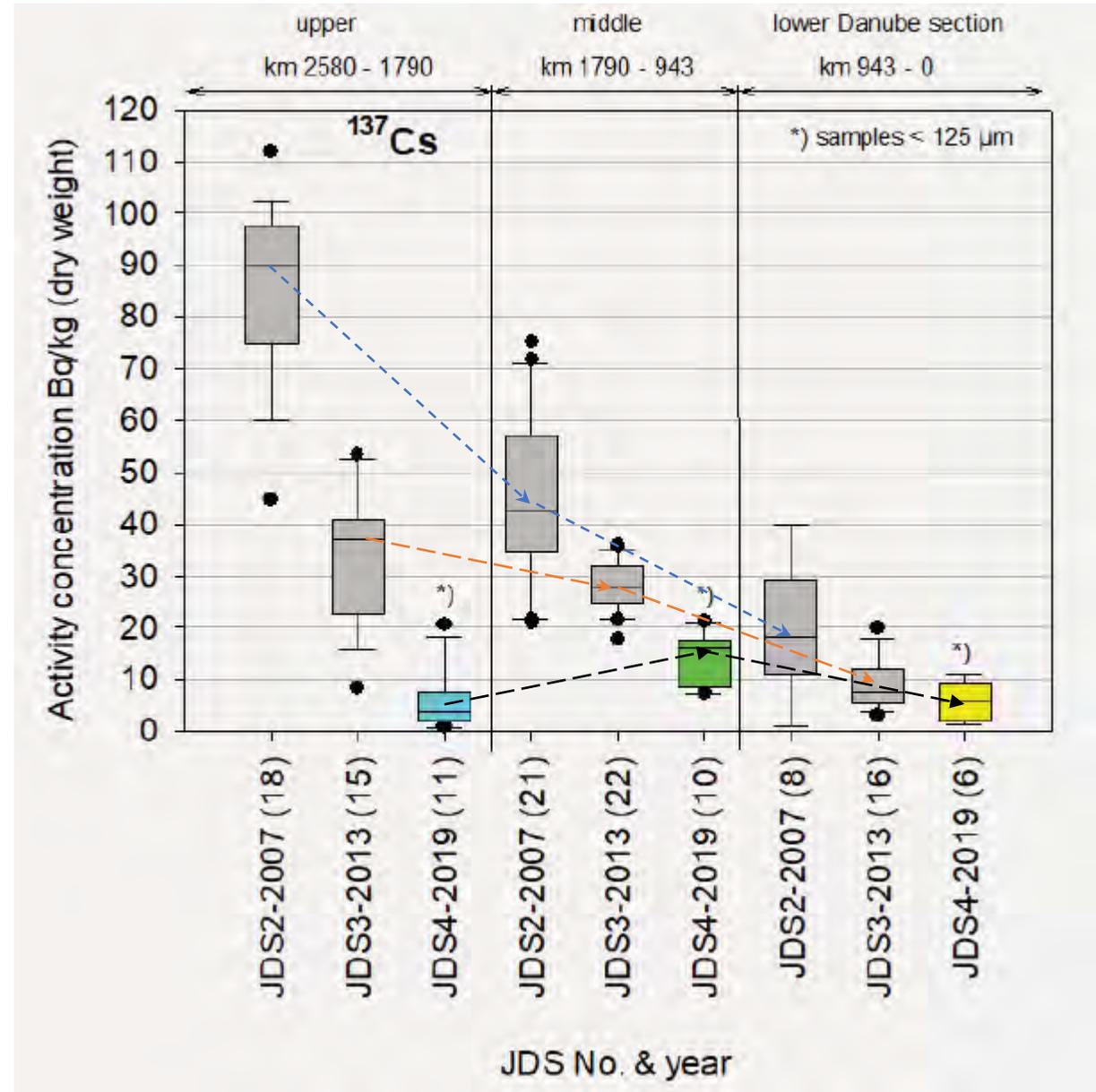
Internationale Kommission
zum Schutz der Donau

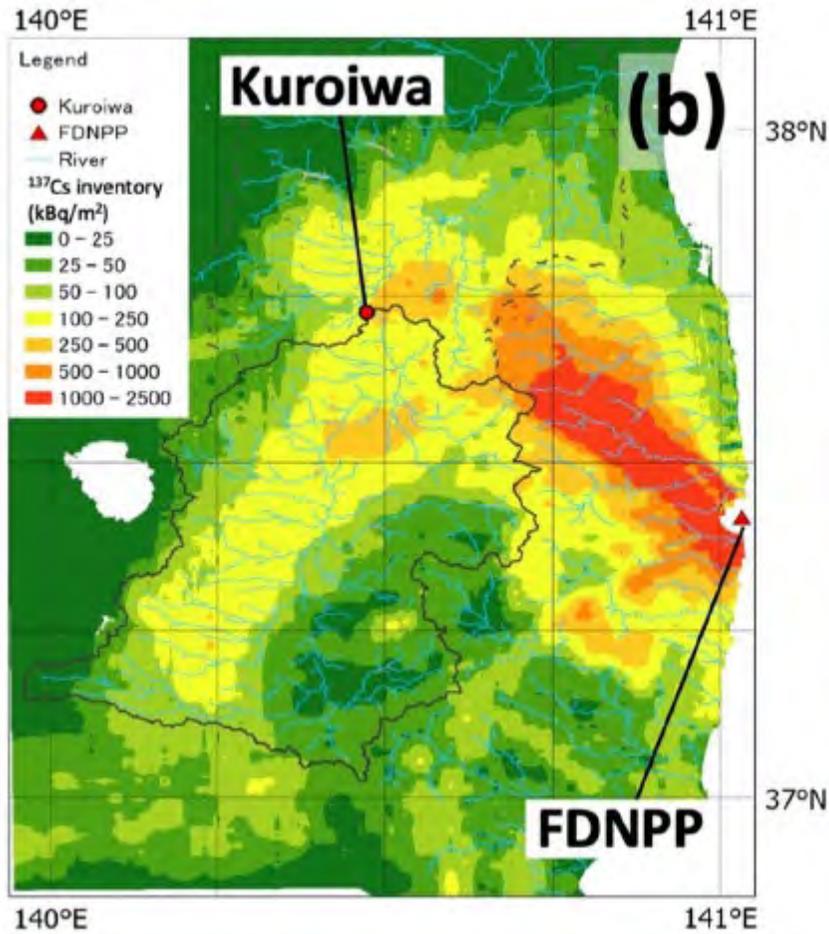


Cs-137 activity concentration in Danube sediment samples < 63 μm (grey) and < 125 μm (coloured)

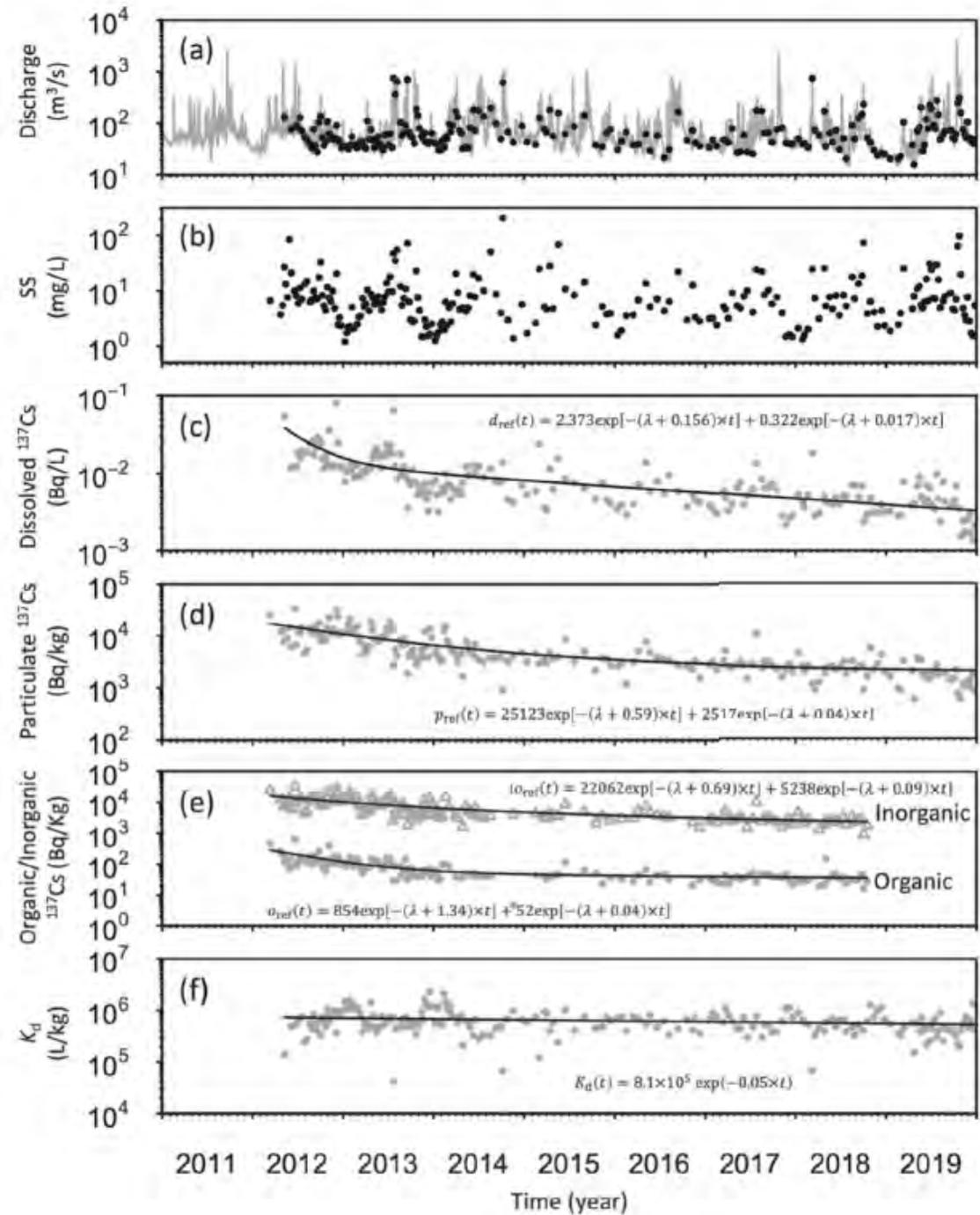
(box-plot 10% / 25% / 50% / 75% / 90% and value dots <10% and >90%)

Maringer et al., 2021, Joint Danube Survey 4 Scientific Report, ICPDR, Vienna.



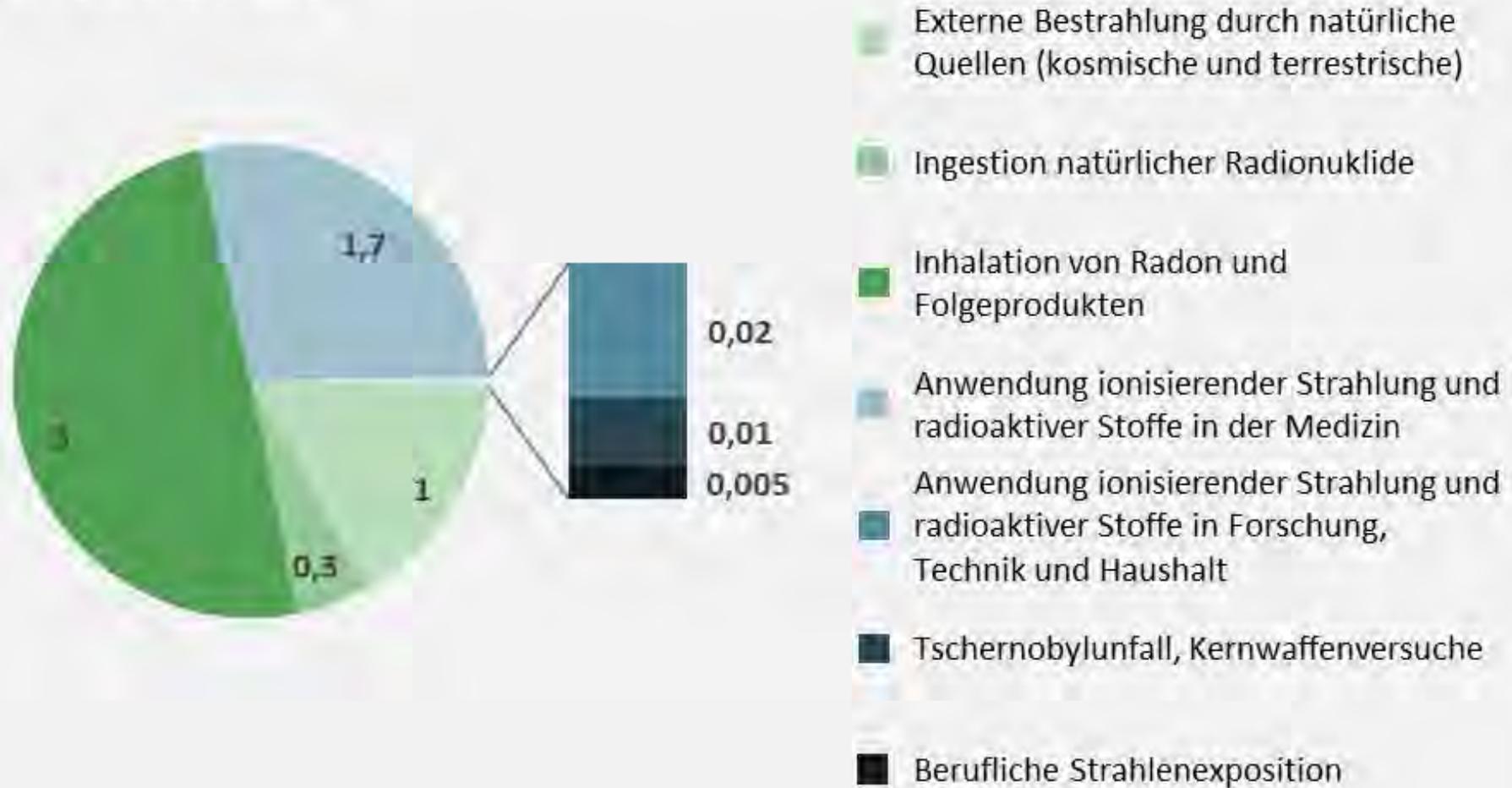


(Igarashi et al., 2021)



Durchschnittliche jährliche Strahlenexposition der österreichischen Bevölkerung in mSv

Gesamt: ca. 6 mSv



(Radioaktivität und Strahlung 2021, BMK, 2022)

An aerial photograph of Vienna, Austria, taken at dusk. The Danube River flows through the center of the city, with several bridges crossing it. The city lights are beginning to glow, and the sky is filled with soft, colorful clouds. In the foreground, a large highway interchange is visible, with light trails from cars. The background shows rolling hills and mountains under a twilight sky.

Franz Josef Maringer
TU Wien, Atominstitut
Stadionallee 2, 1020 Wien
+43 1 676 735 47 91
franz.josef.maringer@tuwien.ac.at
www.tuwien.ac.at