The role of soil properties in the formation of the radiation environment and the need to use in forecasts

Prof. Borys Prister,

Institute for safety NPP NACU

TF ^{137}Cs from podzoluvisol loamy sand soil

Culture	Grain	Vegetable mass
Mais	0,01	0,1
Barley	0,1	0,2
Winter wheat	0,2	0,3
Oat	0,2	0,3
Sun flower	0,3	
Soy bean*	0,5	0,5
Peas*	0,5	0,7
Book wheat*	0,6	0,7

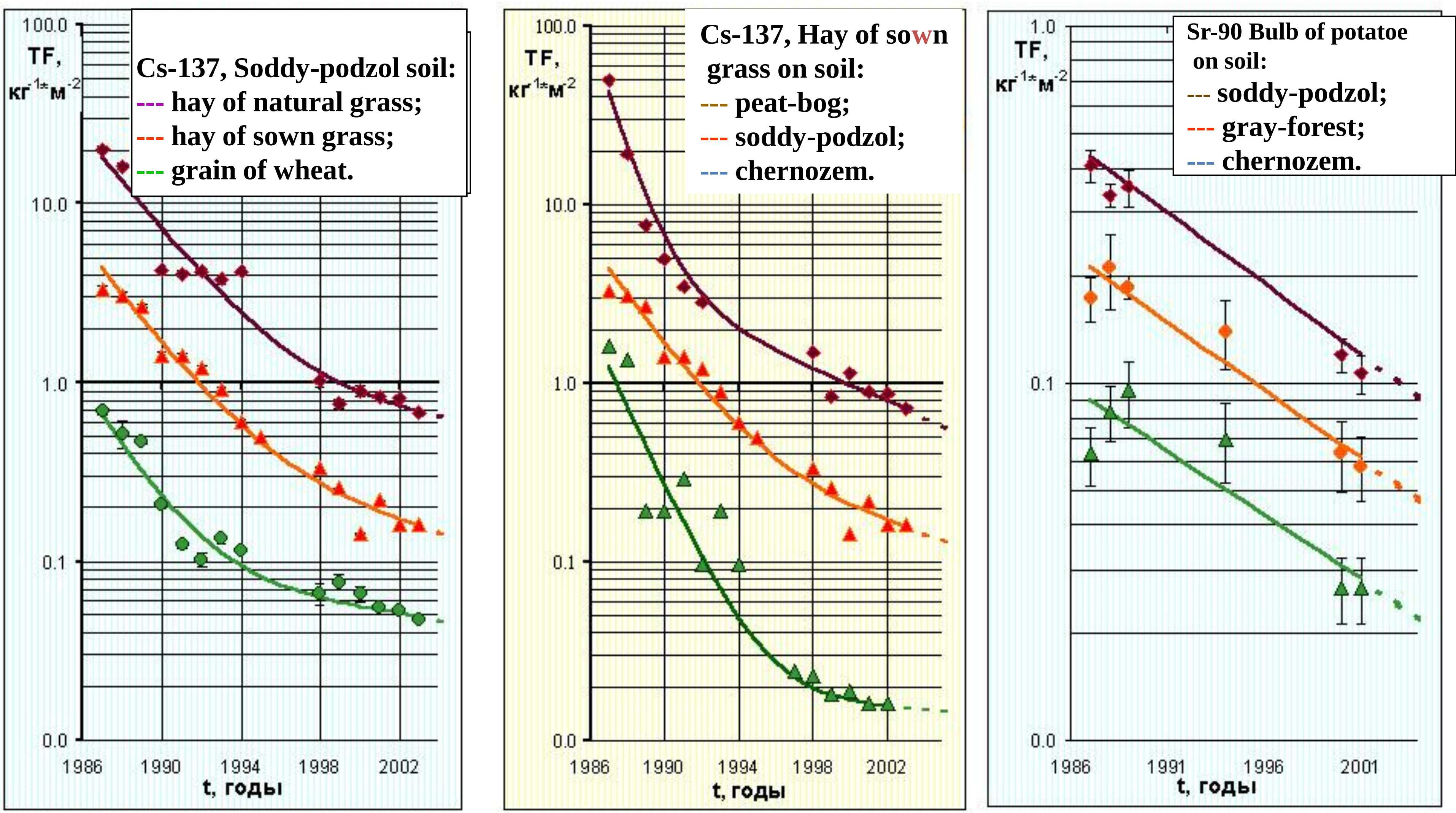
Effect of the increasing K fertilizer doses (K_2O kg ha^{-1}) on yield and ^{137}Cs transfer to spring wheat grain on the background of different content of exchangeable K in *Podzoluvisol loamy sand soil*

Soil K supply, treatment	Yield of grain, t ha^{-1}	^{137}Cs Tag 10^{-3} m^2 kg^{-1}	Reduction factor
K 3.2 mmol kg^{-1}			
Control	3.24	0.028	1.0
N70P60K80	4.58	0.024	1.1
N70P60K160	4.79	0.017	1.6
N70P60K240	4.90	0.014	2.0
K 5.3 mmol kg^{-1}			
N70P60K80	4.90	0.014	2.0
N70P60K160	4.90	0.010	2.7
N70P60K240	5.00	0.009	2.8
K 7.4 mmol kg^{-1}			
N70P60K80	5.00	0.010	2.7
N70P60K160	5.13	0.010	2.8
N70P60K240	5.21	0.009	2.9
LSD_{05}		0.0037	

Dynamic of transfer coefficient of Cs^{137} to milk and meat of cattle in Ukraine, (Bq/kg) / (kBq/m^2 soil)

Product	Group of soil, pH salt	1990	1993
Milk	4.5 - 5.5	0.9	0.8
	5.6-6.5	0.2	0.2
	6.6 - 7.2	0.1	0.05
Meat	4.5-5.5	1.7	1.4
	5.6 - 6,5	0.7	0.4
	6.6 - 7.2	0.2	0.1

Dynamic of radionuclide availability for plant accumulation from soil



$$TF(t) = TF(0) \cdot \left[a_0^q \cdot \exp\left(-\frac{0.693}{T_e^q} \cdot t \right) + a_0^s \cdot \exp\left(-\frac{0.693}{T_e^s} \cdot t \right) \right]$$

$$TF(t) = TF(0) \cdot \exp(-\frac{0.693}{T_e} \cdot t)$$

The mean values of the periods of the floor to reduce TF T_e^q exchange and fixed-T_e^s forms of ^{137}Cs, years

Crops	Type of soil			
	Peat-turf		Soddy-podzolic	
	T_e^q	T_e^s	T_e^q	T_e^s
Natural grasses	0,87	5,7	2,1	28
Sown grain grasses	0,92	6,6	2,0	11
Green fodders	0,97	7,1	1,8	24
Tubers, roots	0,88	6,4	2,2	21
Grains	0,88	6,9	1,8	39
Average by all crops	**0,89**	**6,6**	**1,8**	**20**

The dynamics of the TF of radionuclides determine the processes of transformation of their forms in the soil, but not biological characteristics of plants

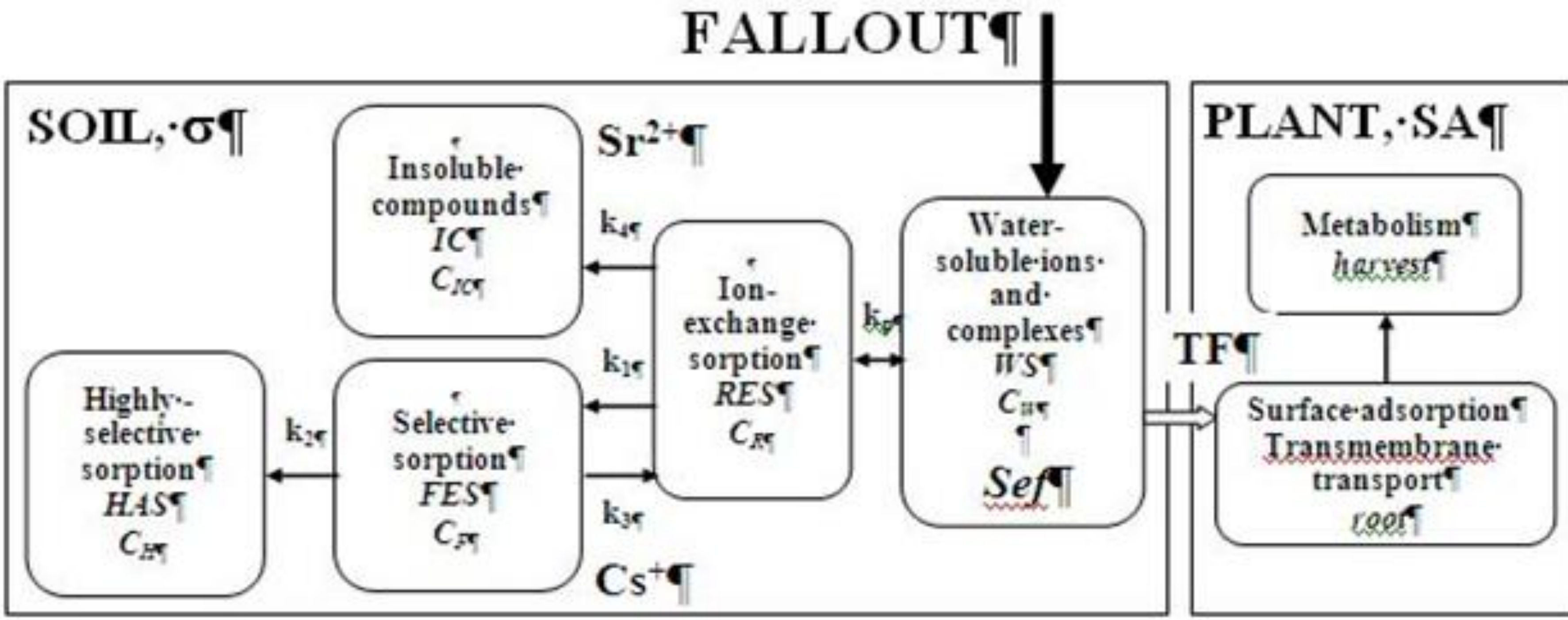
Average values for groups of crops of transfer factors TF(0) ^{137}Cs extrapolated to the time fallout, $(Bq \cdot kg^{-1} / kBq \cdot м^{-2}) \cdot 10^{-3}$ ($\delta \leq \pm 25\%$)

Crops	Peaty-bog	Soddy-podzolic	Grey-forest	Chernozem
Hay of natural grasses	223	29	10	-
Hay of sown grasses	95	5,8	4,9	3,3
Green fodder *clover, alfalfa, corn*	39	2,5	1,9	1,6
Vegetable *cabbage, tomatoes, cucumber*	-	2,9	2,0	1,2
Roots, tubers *bulb onion, beet, potato*	10	1,6	0,63	0,60
Cereal grain *winter wheat, barley, ray*	7,3	0,90	0,66	0,36

10 – 30 times

15-30 times

Concept of the radionuclides behavior model in the"soil - plant" system



^{137}Cs:

$$TF(t) = TF(0) \cdot \left(\frac{k_1 - (2k_2 + \frac{k_3}{2})}{k_1 - k_2} \cdot e^{-(k_1 + \frac{k_3}{2}) \cdot t} + \frac{k_2 + \frac{k_3}{2}}{k_1 - k_2} \cdot e^{-(k_2 + \frac{k_3}{2}) \cdot t} \right)$$

$^{90}Sr^{2+}$:

$$TF(t) = TF(0) \cdot e^{-k_4 \cdot t}$$

Values of velocities of sorption and desorption ^{137}Cs at various locations of the Soddy–podzolic soil (δ ≤ ± 25 %)

Группа культур	The rates of sorption, year-1		
	k_1	k_3	k_2
Natural herbs	0,35	0,032	0,0031
Sown grasses	0,34	0,036	0,0025
Forage grasses clover, alfalfa, corn	0,33	0,041	0,0022
Vegetable cabbage, tomato, cucumber	0,35	0,037	0,0023
Tubers, roots onions, beets, potatoes	0,33	0,037	0,0029
grain crops wheat, barley, rye	0,34	0,039	0,0028
The average for all crops	0,34	0,038	0,0026
The multiplicity of differences	*1,1*	*1,3*	*1,4*

Reduction of TF determined by the processes of transformation of forms in the soil RN in time and does not depend biological features of plants

The average for all crops

Type of soil	k_1 RES ⇒ FES	k_3 FES ⇒ RES	k_2 FES ⇒ HAS
Peat - turf	0,76 !	0,082	0,0085
Soddy - podzolic	0,34	0,038	0,0026
Gray - forest	0,38	0,026	0,0017
Chernozem	0,48	0,013	0,0011

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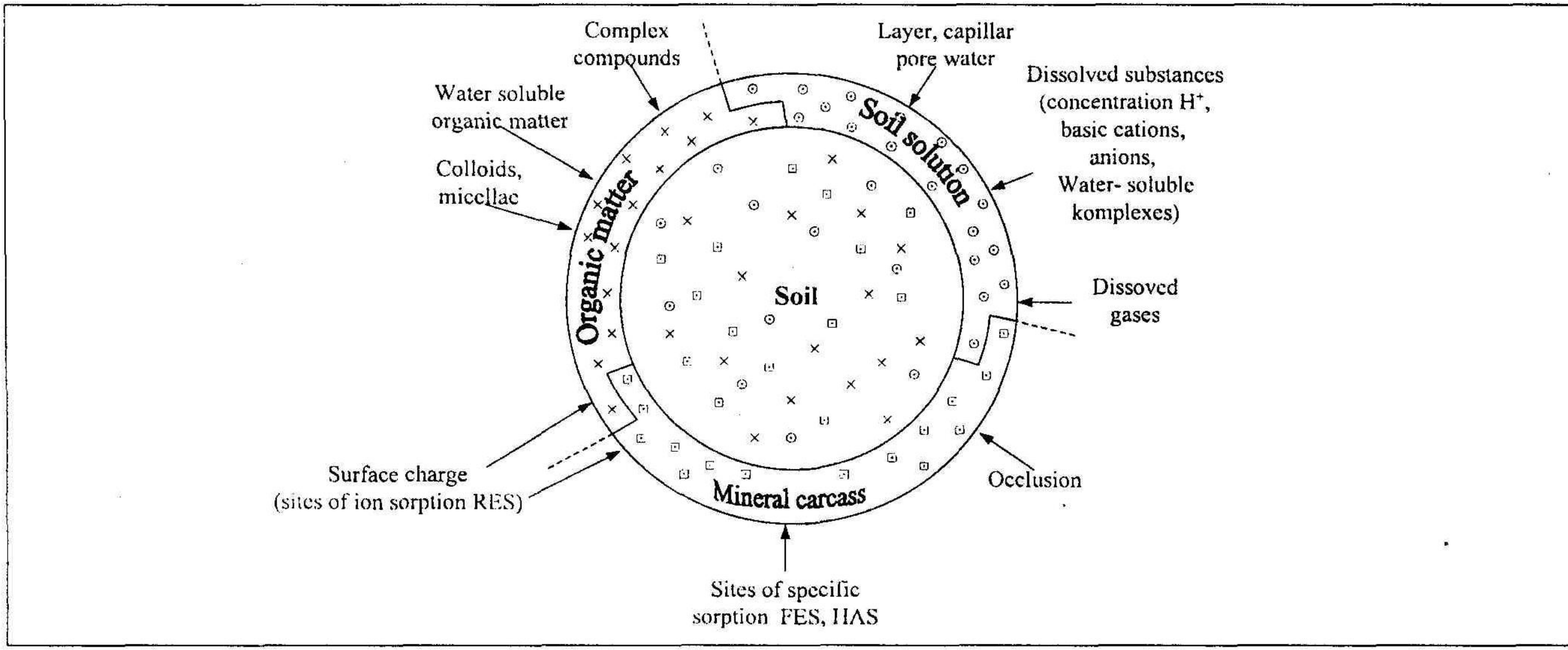
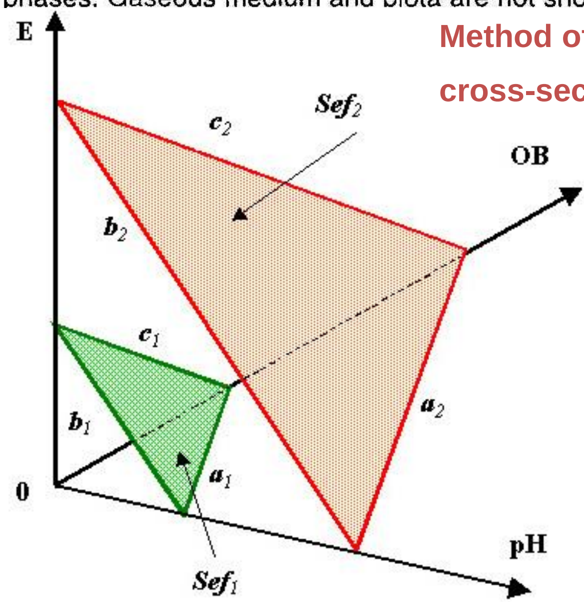


Fig. 3: Schematic illustration of soil as a three-phase system, showing basic properties and functions of phases that determine ion distribution between solid and liquid phases. Gaseous medium and biota are not shown



Method of finding integrated assessment of soil properties Sef as cross-sectional area of 3-d space

Sef_1 – soddy-podzolic

Sef_2 – chernozem

The normalization values
(reference soil)
pH=7,0
OM=6,0 %
E=40 mg-eqv/100 g of soil

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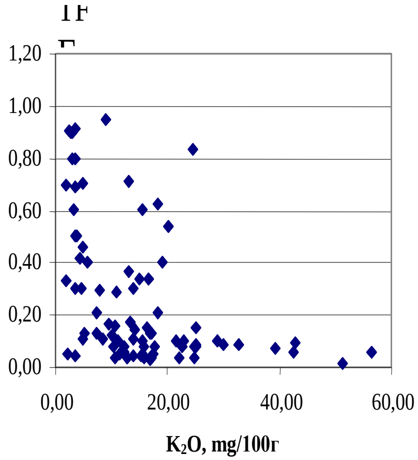
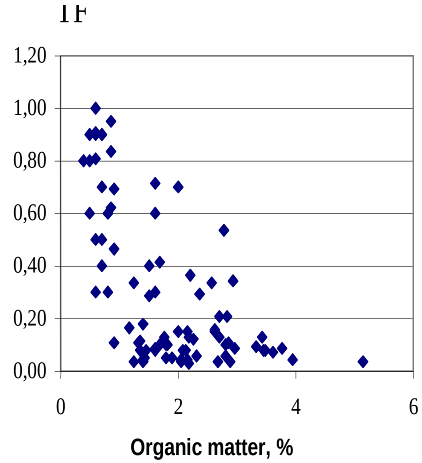
The reasonable methodological approach to forecasting ^{137}Cs plants seems to us the use of selective sorption parameter radio cesium in relation to the macro ion [M +] - binding potential radiocaesium RIP (M) - "Radiocesium Interception Potential" :

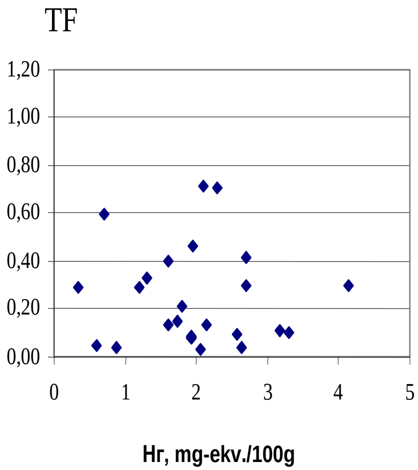
RIP (M) = Kc (CS / M) [FES] ,

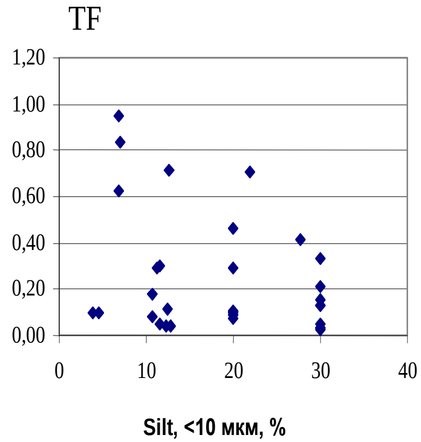
where: Kc (CS / M) - ion exchange selectivity coefficient for CS - FES. [FES] - sorption capacity of the centers located between the layers of the crystal lattice in their extended ends (estuaries).

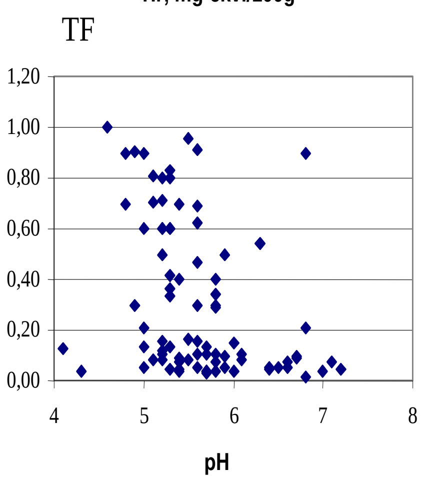
Methodically this method is very complex and requires adefinition of the capacity of selective absorption of ^{137}Cs CS - FES.

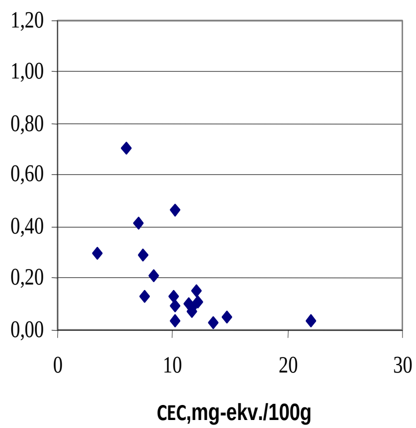












Dependence TF ^{137}Cs in the potatoes on the properties of sod-podzolic soil

The value of TF ^{137}Cs (soil – plants) inversely proportional content exchangeable potassium in the soil. Quite clearly manifest certain trends (inverse relationship) in pairs TF - pH, hydrolytic acidity Hg, humus, absorption capacity, the content of the silt.

At the same time the dispersion of data points is too large to investigated depending can be written in an analytical form. This is possible only in the case of a more thorough soil groups of the same type of varieties.

This circumstance complicates the use of soil classification system FAO - UNESCO, which is based on the grouping of soils into larger units, which leads to an artificial "smoothing" diversity of soil cover, which is characteristic for the region of the accident. The merger of subtypes of the same group get the soil, simultaneously on several different agrochemical and water-physical characteristics strongly influence the intensity of accumulation radionuclides by plants.

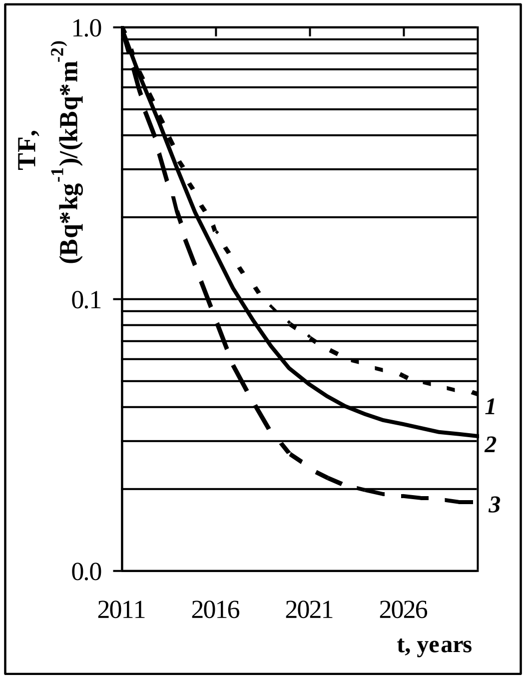
Distribution of farms under observations, and agrochemical characteristics of the fields by the soil type

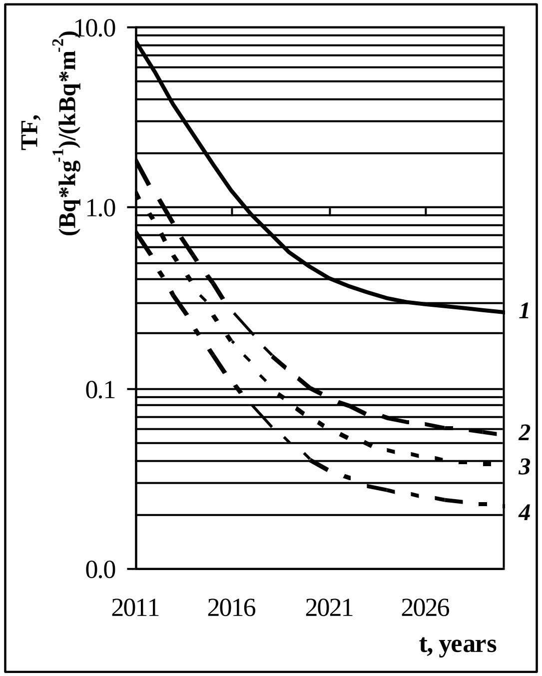
Type of soil	Region	District Center	pH_{KCl}	Humus, %	Sum of Absorbed Bases, mg-eq/ 100 g Soil	K_2O, mg/ 100 g Soil	Silt, %
Soddy-podzolic sandy	Kiev	Ivankov	4.4–5.8	0.40–0.93	6.3–10.5	2.8–8.7	5.0–7.1
	Chernigov	Chernigov	4.5–6.0	0.53–0.95	6.1–18.1	6.0–12.0	6.3–7.2
Soddy-podzolic sandy sand	Kiev	Poljesskoje	4.4-6.0	0.6–0.97	6.4–10.7	2.0–8.7	6.6–9.3
	Chernigov	Kozelets	4.5–6.0	0.48–0.86	6.0–16.6	4.0–10.2	7.4–10.2
	Zhitomir	Ovruch	4.4–5.9	0.64–2.1	6.9–17.6	4.0–8.7	5.8–8.6
Soddy-light podzolic sandy	Chernigov	Repki	4.5–5.8	0.73–1.0	8.4–13.6	5.5–8.7	6.8–7.8
Soddy-light podzolic sandy sand	Kiev	Borodjanka, Vyshgorod, Brovary, Makarov	4.3–6.6	0.38–1.2	2.9–17.5	2.4–10.2	8.2–11.6
	Rivno	Dubrovitsa	4.6–6.6	0.75–2.3	2.9–19.1	4.0–14.0	6.2–8.4
Soddy sandy sand gleyic	Rivno	Sarny, Zarechnoje	5.1–6.5	0.96–1.8	16.1–20.1	7.8–12.8	13.8–14.2
Soddy clay sandy	Zhitomir	Narodichi	5.4–6.7	0.85–1.2	9.8–18.7	8.6–15.5	17.6–19.3
	Rivno	Rokitnoje	3.9–7.2	0.56–3.2	5.6–15.9	3.2–20.0	14.5–16.1
Grey forest	Kiev	Borispol, Bila Cserkva	5.3–6.6	0.92–1.9	8.4–16.5	5.8–11.4	12.1–22.3
Chernozem typical	Kiev	Boguslav, Baryshevka, Fastov, Jagotin, Perejaslav Khmelnitskij, Tetijev, Skvira, Tarascha, Kagarlyk, Vasil'kov	5.4–7.5	1.5–3.9	10.5–33.1	11.6–37.1	24.7–27.2
Chernozem podzolized	Kiev	Kiev-Svjatoshin	4.9–6.6	0.60–2.1	7.5–19.9	4.0–12.6	25.7–32.4
Peat-bog	Rivno	Dubrovitsa	3.8–6.6	–	2.3–19.0	2.0–18.5	–
	Zhitomir	Narodichi	4.6–5.8	–	10.5–17.7	6.3–12.2	–

Data about the agrochemical properties of soils in Japan selected from the literature and other sources and Sef value for them

Soil type	Agrochemical properties of soil			Complex parameter of soil properties Sef, dimensionless
	pH_{KCl}	Humus content, %	CEC, mg-ekv/100 g of soil	
Andosols	4.3-5.3	0.8-1.2	23-30	0.19-0.30
Gleysols	4.5-5.6	1.4-2.6	8-23	0.17-0.31
Fluvisols	5.6-6.5	2.2-3.4	15-27	0.22-0.45

The forecast of: *a* - the availability of ^{137}Cs from different soil types – into cabbage, in Japan: *1* - Andosols, *2* - Gleysols, *3* - Fluvisols; *b* - TF values from Gleysols into plants: *1* - hay natural herbs, *2* - cabbage, *3* - green mass of corn, *4* - potato tubers, calculated with using data on agrochemical properties of soil in Japan presented in the literature.



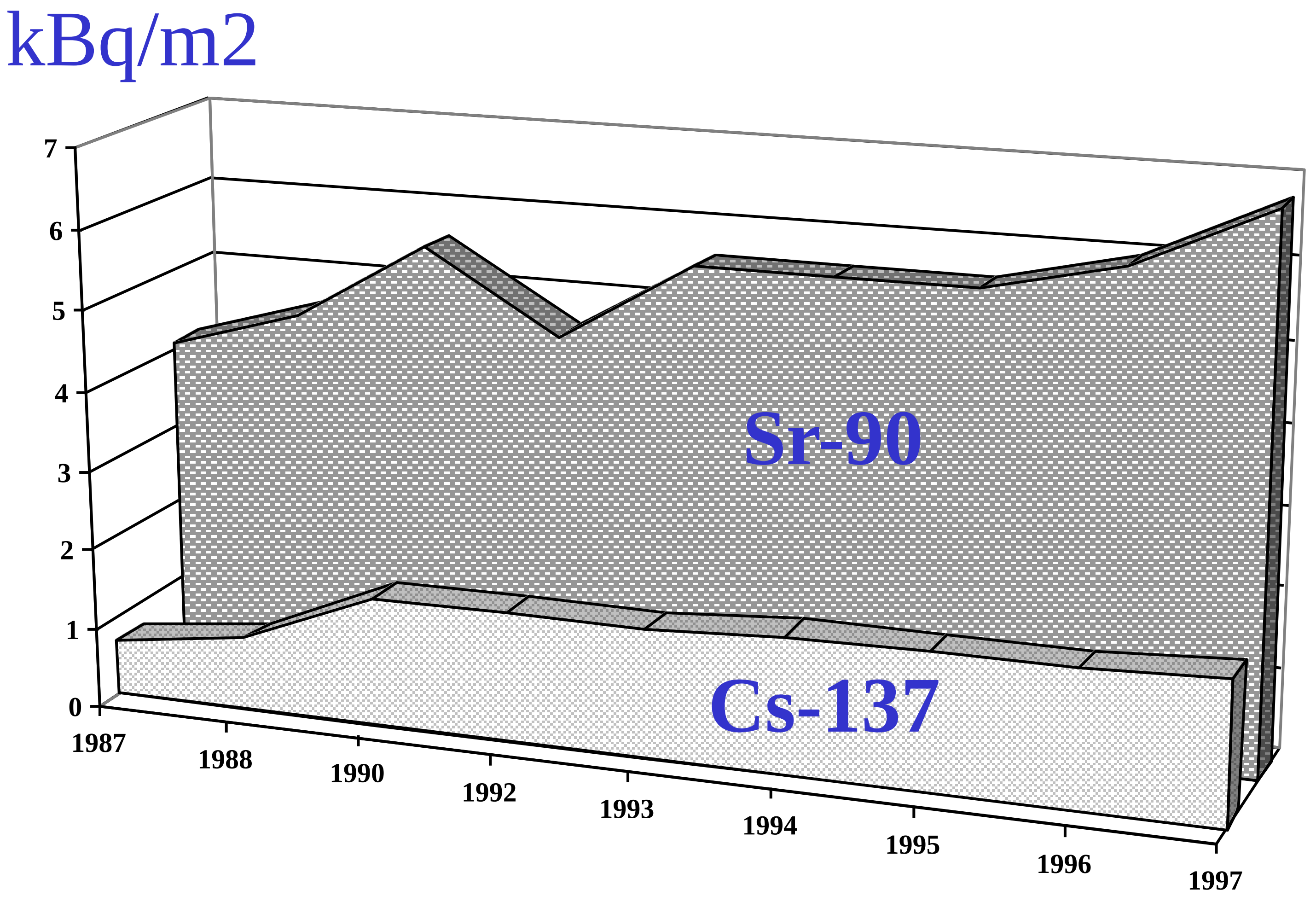


We ask guests to clarify the historical data on the properties of the soil area of the accident and to hold a joint forecasting plant contamination and to clarify the methods of observation its dynamics.

Dynamics of accumulation of radionuclide's Chernobyl release in a grain of rice in irrigated paddies

Years	Grain, Bq/kg	
	^{90}Sr	^{137}Cs
1972	0,33	2,4
1982	0,30	0,7
1985	0,11	0,6
1986	0,07	1,0
1987	0,15	1,6
1988	0,19	1,5
1989	0,37	1,2
1991	0,69	1,1
1993	1,12	0,9
1995	1,27	1,1
1996	1,30	0,8

Dynamics of accumulation of ^{137}Cs and Sr-90 in the soil rice paddies



The concentration of radionuclides in the plant at any time after fallout

$$C(t) = \frac{\sigma \cdot K_з}{M \cdot 100\%} \cdot e^{-0,693 \cdot \frac{t}{T_f}} \cdot l_{10}^{m} \cdot (a_1 \cdot e^{-0.693 \cdot \frac{t}{T_1}} + a_2 \cdot e^{-0.693 \cdot \frac{t}{T_2}})$$

where :

C(t) – RN concentration in the plants at the t time of after the deposition Bq kg^{-1}

б – the fallout of nuclides density, kBq m^{-2};

M – reserve of biomass kg · m^{-2} ;

Кз – factor of retention , %;

l_{10}^{m} **– dilution coefficient of growth of biomass in a decade;**

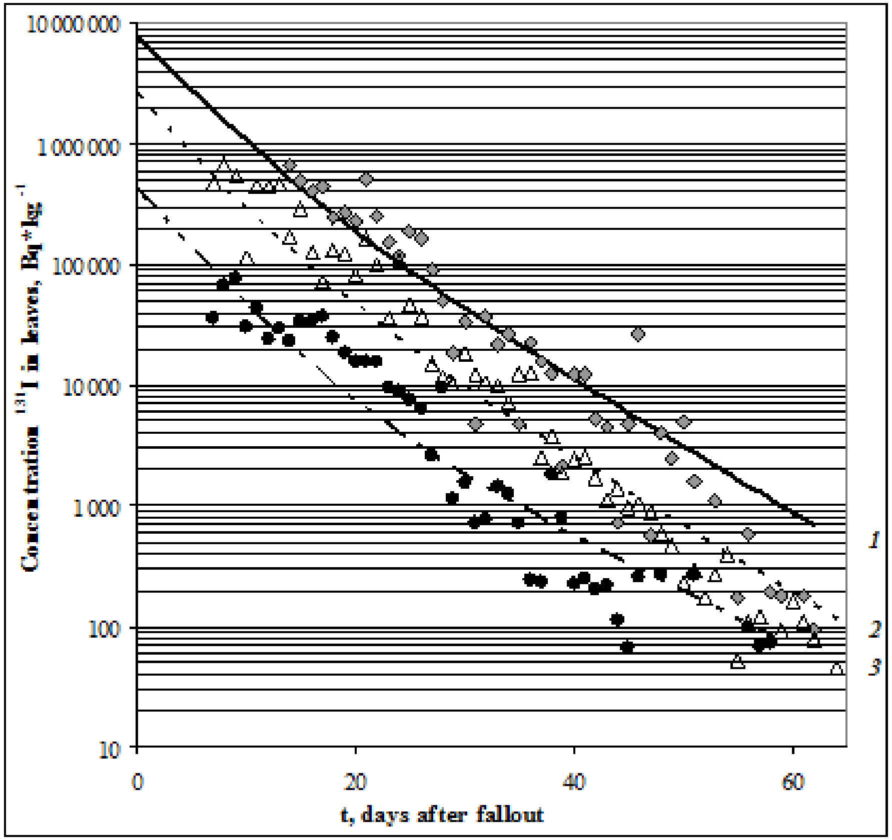
m – round value to an integer number of decades;

t – time after deposition, days;

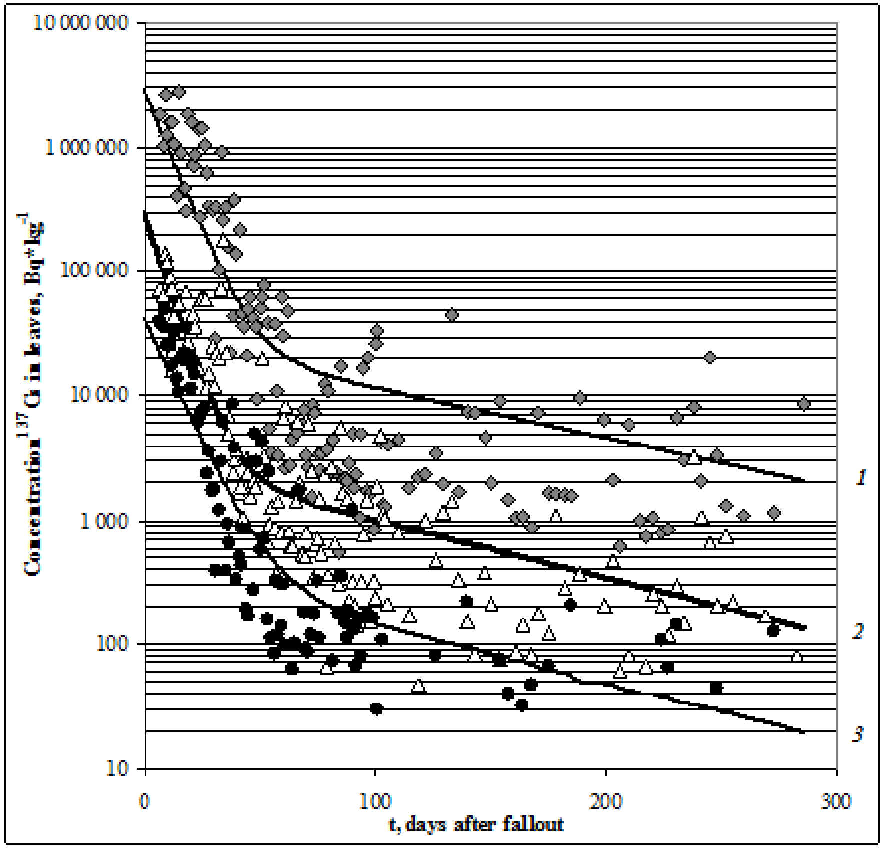
T_1 и T_2 – are periods half-losses of nuclide of plants easily and difficult the removed forms of RN, in accordance, day;

a_1 and a_2 - parts

The dynamics of the leaves radionuclides contamination after the accident at the Fukushima-1 (dots) and model curve according the Prister model of foliar vegetation contamination: a - ^{131}I :1 – sampling point 2.7, 2 - sampling point 2.6, 3 - sampling point 2.3; b - ^{137}Cs : 1 - sampling point 2.1, 2 - sampling point 2.2, 3 - sampling point 2.3.



a



b

Mean values for T_1 and T_2 (days), a_1 and a_2 (shares) for data on pollution leaves ^{131}I, obtained after the accident at Fukushima-1 (database for IAEA)

№ точки	^{131}I				^{137}Cs			
	$C(0)$, кБк·кг$^{-1}$	Параметри напіввтрат (та розбавлення)			$C(0)$, кБк·кг$^{-1}$	Параметри напіввтрат (та розбавлення)		
		a_1	T_1	T_2		a_1	T_1	T_2
2.1	**12 330**	0,97	**3,9**	**20**	2 900	0.99	**9.5**	**75**
2.2	**3 110**	0,96	**4,6**	**25**	290	0.98	**5.5**	**45**
2.3	**340**	0,92	**4,5**	**42**	40	0.99	**7.5**	**65**
2.4	**1 640**	0,72	**3,5**	**35**	140	0.99	**6.5**	**65**
2.5	**290**	0,92	**4,5**	**32**	45	0.99	**4.5**	**55**
2.6	**2 540**	0,86	**4,5**	**18**	57	0.99	**5.7**	**50**
2.7	**7 750**	0,79	**4,8**	**18**	1 100	0.99	**6.5**	**50**
2.8	**3 065**	0,92	**3.8**	**15**	240	0.99	**7.5**	**55**
2.9	**4 900**	0,96	**3,8**	**15**	690	0.99	**6.5**	**65**
4.3	**1 780**	0,92	**3,8**	**17**	275	0.99	**6.5**	**65**
Середнє для всіх точок		0,89	**4,2**	**24**		0.99	**6.6**	**59**
Теф з урахуванням T_f розпаду			2,8	6,0				

Source and place of data	Radionuclide	$C(0)$, Bq·kg^{-1} (Bq·l^{-1})	T_1 (a_1), days	T_1 (a_1), days
Our data [Prister, 2008]				
Motley grass	^{131}I	500*	3.7 (0.52)	6.6 (0.48)
Grass		200*	4.0 (0.45)	6.1 (0.55)
Wheat, green mass		130*	3.3 (0.50)	5.0 (0.50)
Average for meadow grasses		200*	3.7 (0.49)	6.1 (0.51)
Germany. Noyerberg [Environmental, 2005]				
Grass	^{131}I	60 000	2.5 (0.79)	6.3
Milk		5 000	2.9 (0.75)	6.1
France [Environmental, 2005]				
Vegetables	^{131}I	1 630–4 880	2.9 (0.75)	6.1
Milk		800–3 220	3.0 (0.86)	5.9
Fukushima, FMD [data base IAEA]				
Leaves ?	^{131}I	290 000 – 12 330 000	2.8 (0.89)	6.0
	^{137}Cs	45 000–2 900 000	6.6 (0.99)	59
Our data [Prister,2008]				
Average for arable crops	^{137}Cs	–	2.5 (0.70)	46 (0.30)
Wheat, green mass		-	4.1 (0.70)	35 (0.30)
Our date (Tkachenko, 1990)				
Agrass from medows	^{137}Cs	-	3,7 (0,99)	100 (0,01)
Leavs of trees		-	3,8 (0,92)	64 (0,08)
pine-needle of pine-tree		-	2,0 (0,95)	100(0,05

* $Bq \cdot kg^{-1} / kBk \cdot m^{-2}$

We ask guests to clarify the historical data about the type of plants and vegetation sampling methodology and process them together for later use in emergency monitoring.

Thank your for attention!