FIELDCOURSE ON CHERNOBYL FALLOUT IN THE ENVIRONMENT

Sampling of soil, plants/biota and animal products

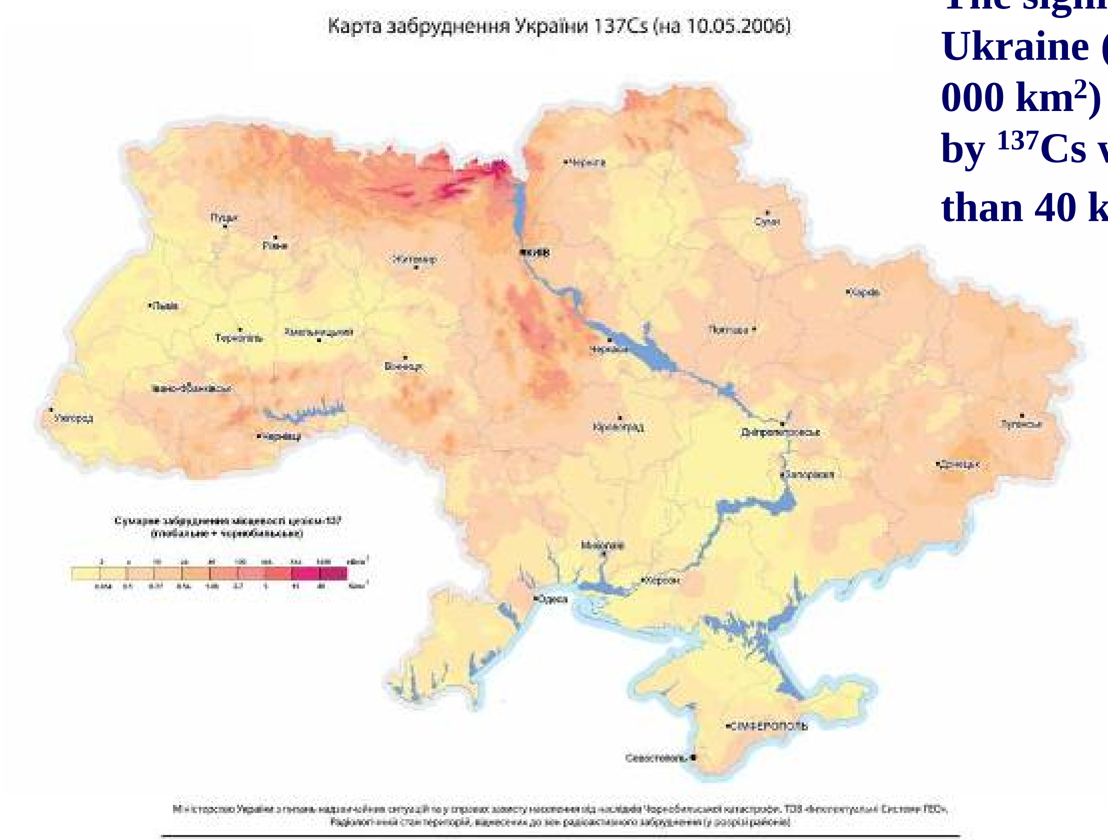
COMET

5-8 September 2016

Ukraine

Valery Kashparov

^{137}Cs contamination of Ukraine *(Atlas, 2008)*

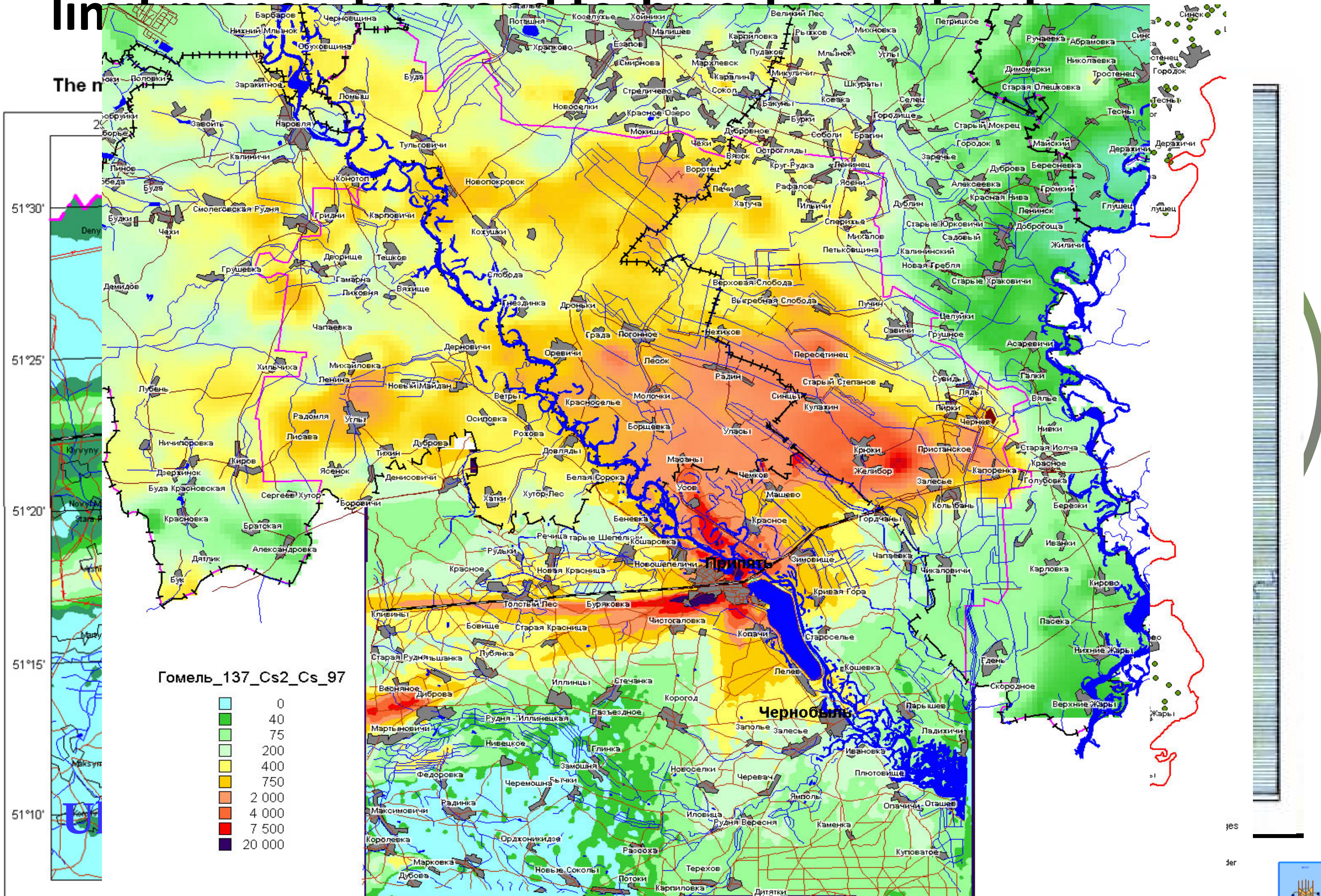


The significant part of Ukraine (42 800 km^2 from 600 000 km^2) was contaminated by ^{137}Cs with density more than 40 kBq/m^2

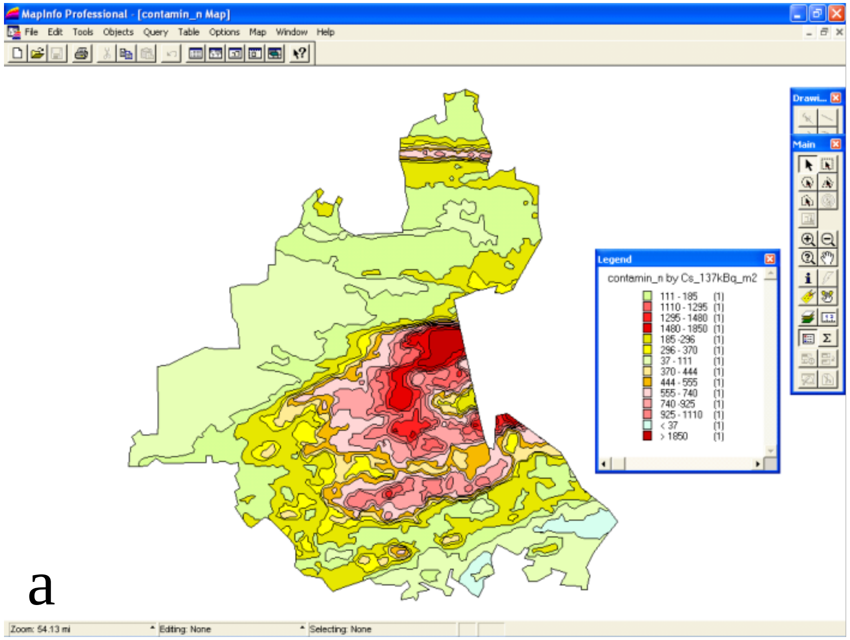
For 2008 area with ^{137}Cs contamination > 40 kBq/m^2 was 25 500 km^2, but the area of the zones of radioactive contamination are 53 000 km^2

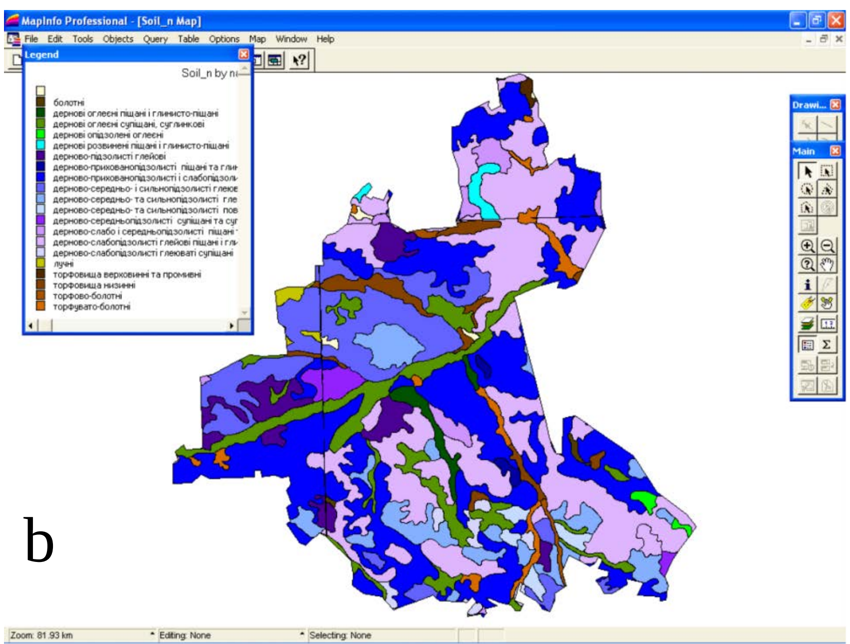
More and big samples - the better, but we have lin

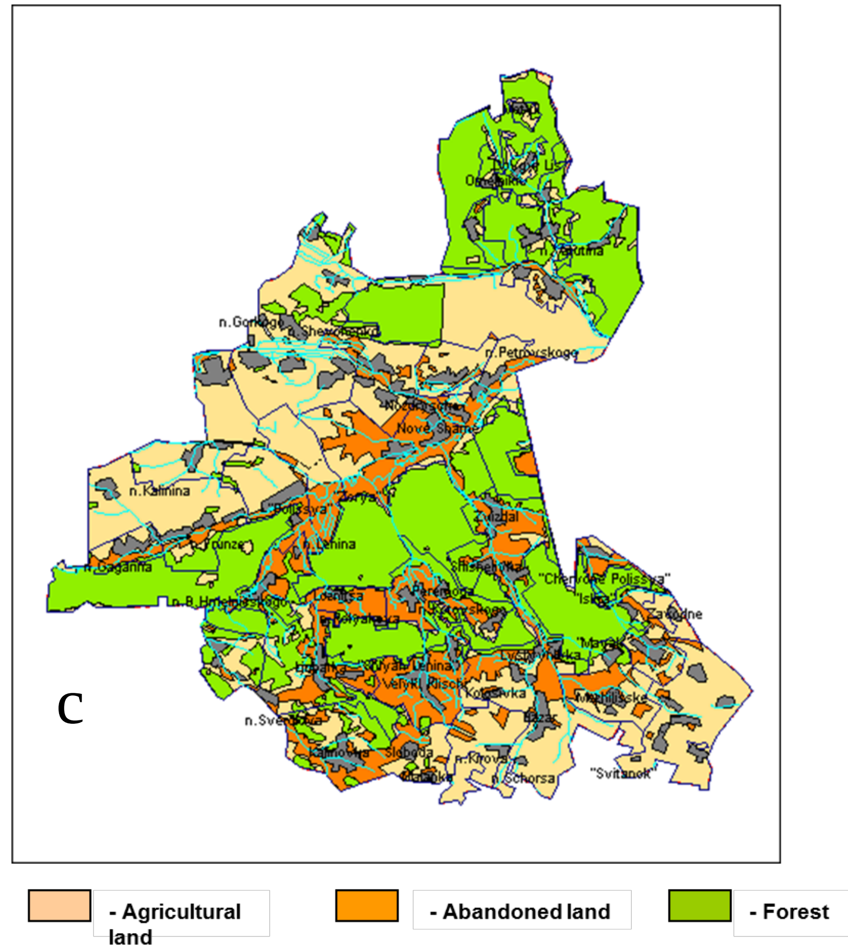
The m



Heterogeneity of density of radionuclides contamination (a), soil types (b) and land use (c)







$f_{reg}(x,y)$

$$f(x,y) = f_{reg}(x,y) \cdot f_{loc}(x,y) \cdot f_r$$

- $f_{reg}(x,y)$ - decrease or increase in the density of contamination (trend) within the subject site .
- $f_{loc}(x,y)$– contamination density deviation from trend (hot "spot" of contamination).
- f_r - random component is due microinhomogeneity deposition, technique and process sampling, error of preparation and measurement of the activity of samples. It does not depend on the coordinates of the point of sampling.
- Function $f(x,y)$ is strictly positive and the our work is considered as a $z(x,y)$, where $f(x,y) = exp(z(x,y))$ – logarithm of density deposition. In this multiplicative model $f(x,y)$ is replaced by the additive model :

$$z(x,y) = z_{reg}(x,y) + z_{loc}(x,y) + z_r$$

Grid

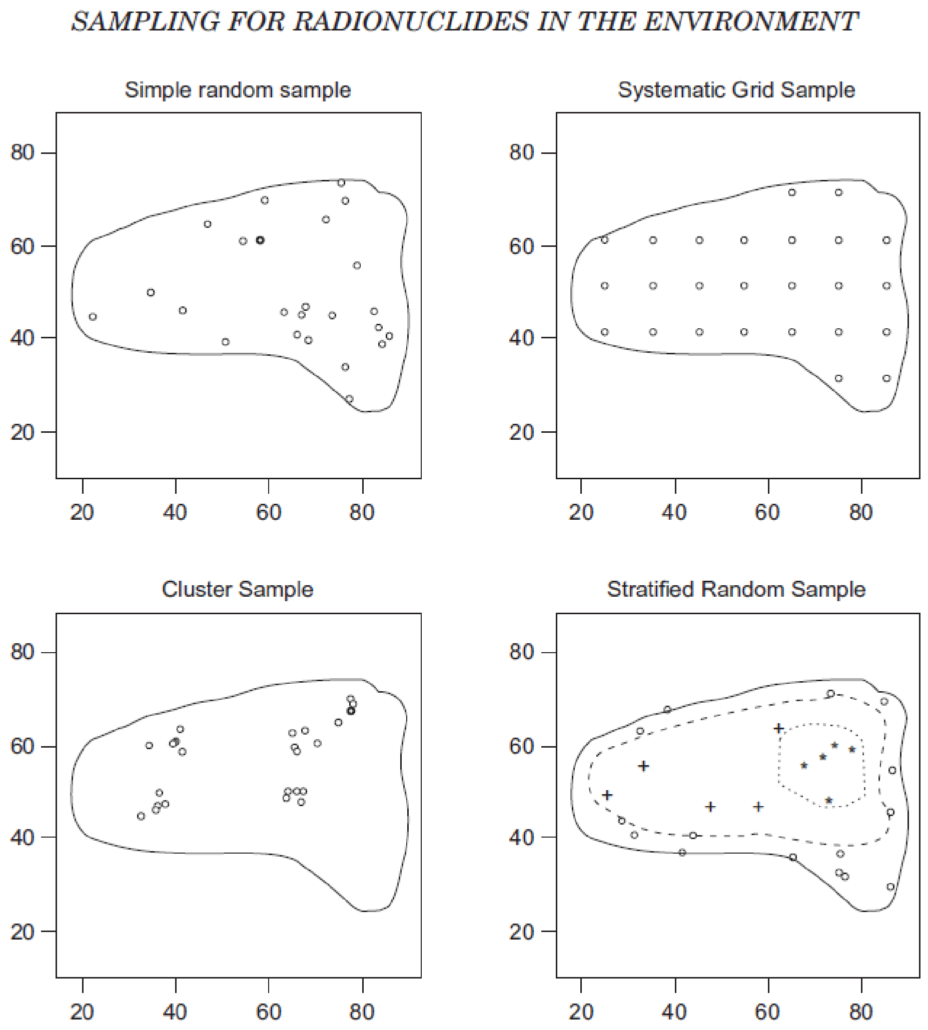
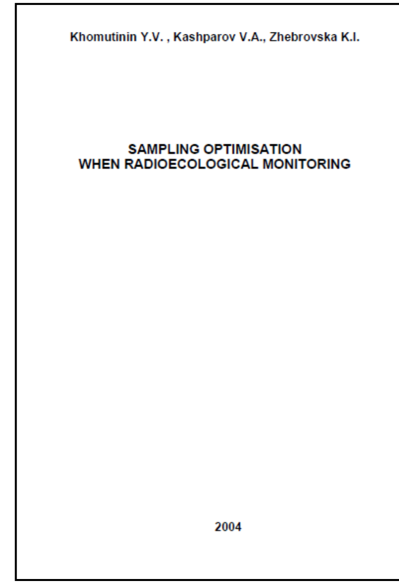


Figure 3.3. Some common sampling designs for areas. Axes represent lengths in arbitrary units.

SAMPLING OPTIMIZATION

- The results of researches conducted by UIAR during elimination of consequences of catastrophe on ChNPP, concerning basic and urgent problem of radioecological monitoring - representative sampling of soil, plants and milk, and also measurement of samples having an essential volumetric heterogeneity (hot particles) are generalized. The questions of optimum planning of selection representative samples for the samples of the soil, plants and milk are considered. The methods of account of minimum necessary number of samples excerpt for an estimation of average of the con-trolled quantity with the given relative error are offered.


Khomutinin Y.V. , Kashparov V.A., Zhebrovska K.I.

SAMPLING OPTIMISATION
WHEN RADIOECOLOGICAL MONITORING

2004


Ю. В. Хомутинин,
В. А. Кашпаров, Е. И. Жебровская

ОПТИМИЗАЦИЯ ОТБОРА
И ИЗМЕРЕНИЙ ПРОБ ПРИ
РАДИОЭКОЛОГИЧЕСКОМ
МОНИТОРИНГЕ

Киев 2001

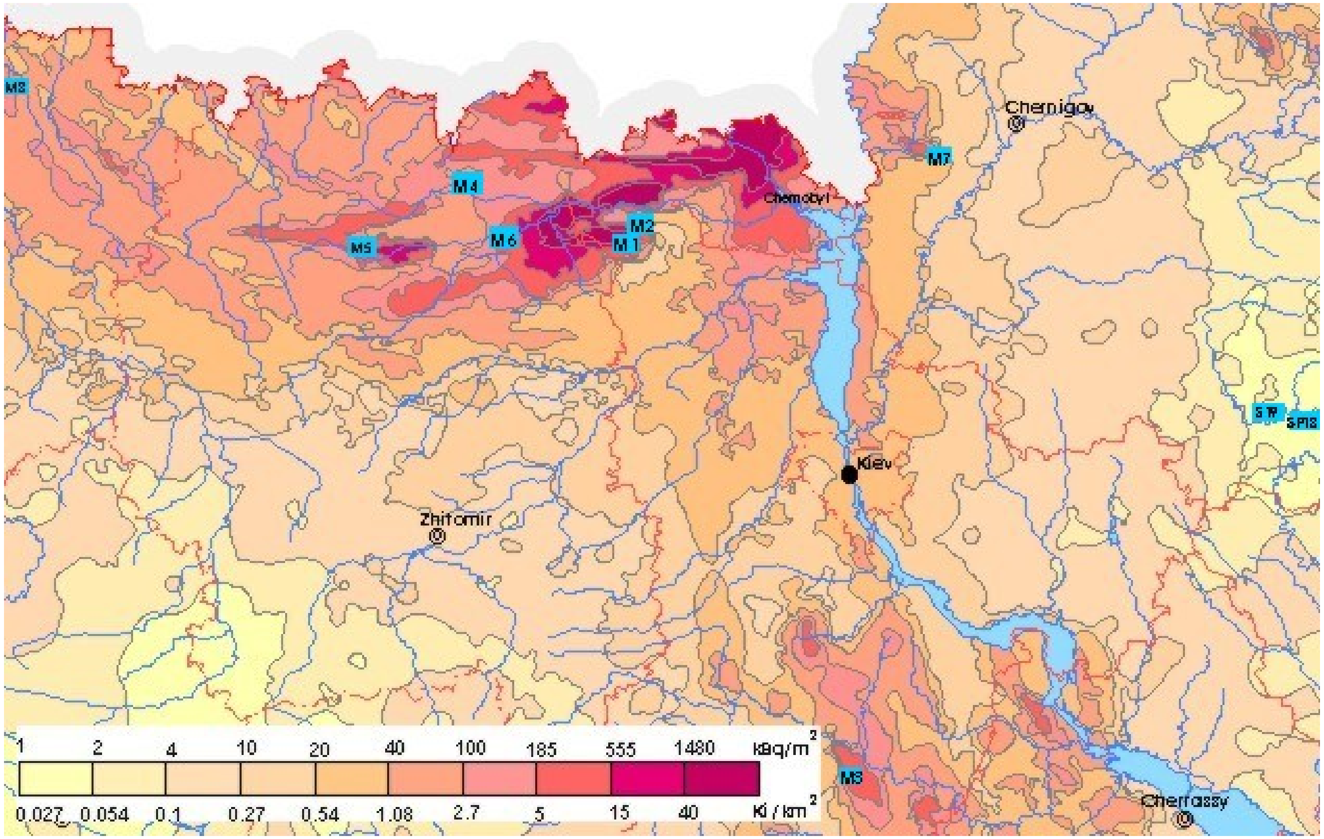
UIAR has developed the special standards for sampling

Next major tasks are considered and solved in the presented monograph:

- To estimate statistical performances of radioactive contamination of soil, vegetation and transfer factors of radionuclides in a link "soil - plant" at the sites with non-gradient contamination. To determine the kind of probability distribution of soil, vegetation contamination and transfer factors at such sites and to estimate their parameters.
- To estimate the radius of influence of soil and plants sample and to estimate centre to centre distance of sampling, which ensures statistical independence of radionuclides contents in samples at site with non-gradient contamination;
- To determine necessary minimum amount of soil, plants, fish and milk samples when radioecological monitoring, that are necessary for estimation of median ofcontamination of considered objects (including their derivatives, for example, radionuclides transfer factors from soil to plants) with a specified ratio error.
- To optimise the milk sampling schedule in the private farms in the settlements for estimating annual individual doze of internal exposure with a specified ratio error.
- To construct the nomograms providing practical use of the offered procedures for planning soil, plants and milk sampling.

Book: Khomutinin Y.V. , Kashparov V.A., Zhebrovska K.I.

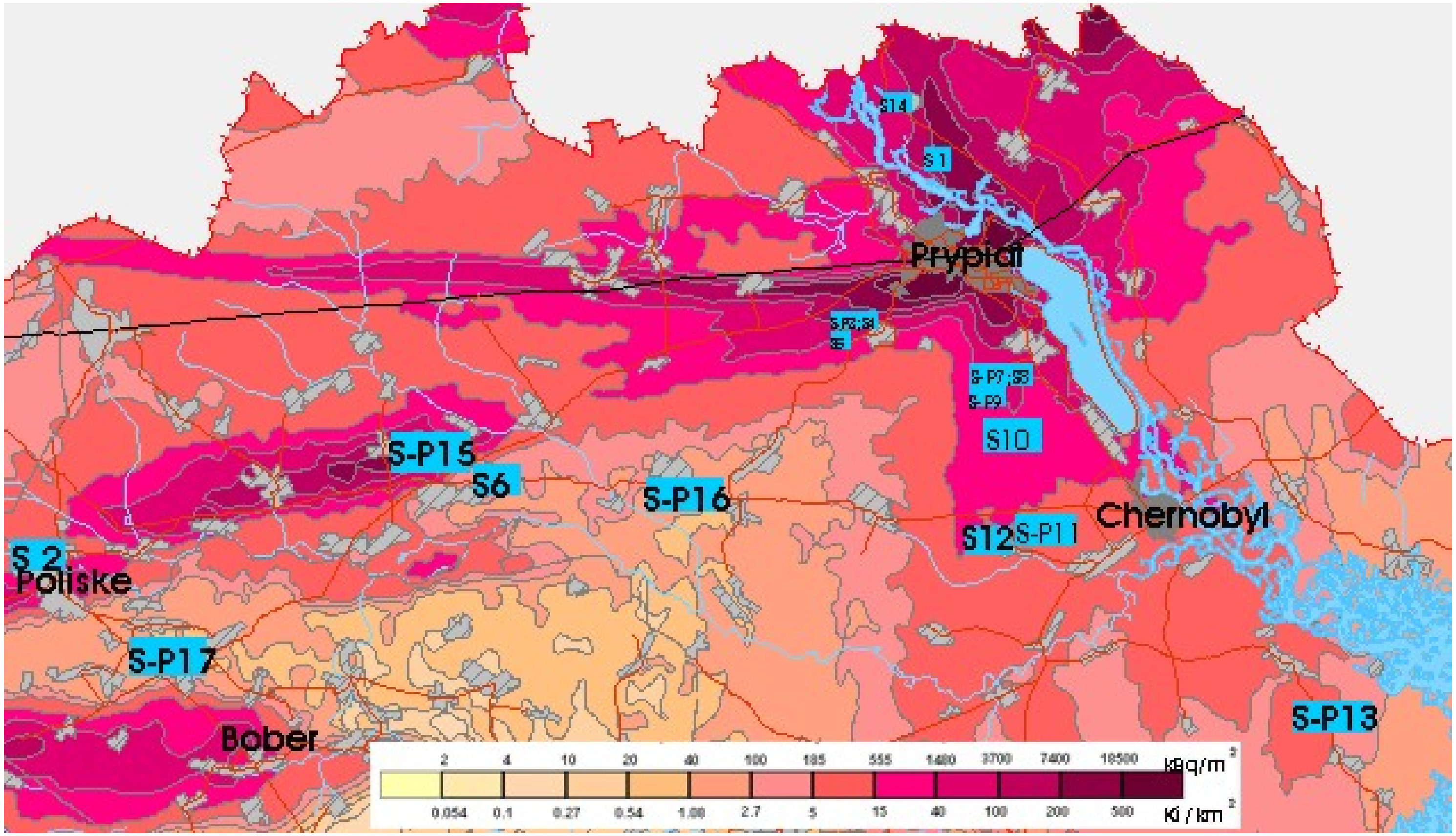
SAMPLING OPTIMISATION WHEN RADIOECOLOGICAL MONITORING, 2002 (Ukr. and Russ) and 2004 (Eng).



The scheme of the experimental sample sites at the areas with the global radioactive fallouts and the basic radiological station of UIAR (^{137}Cs density of contamination).

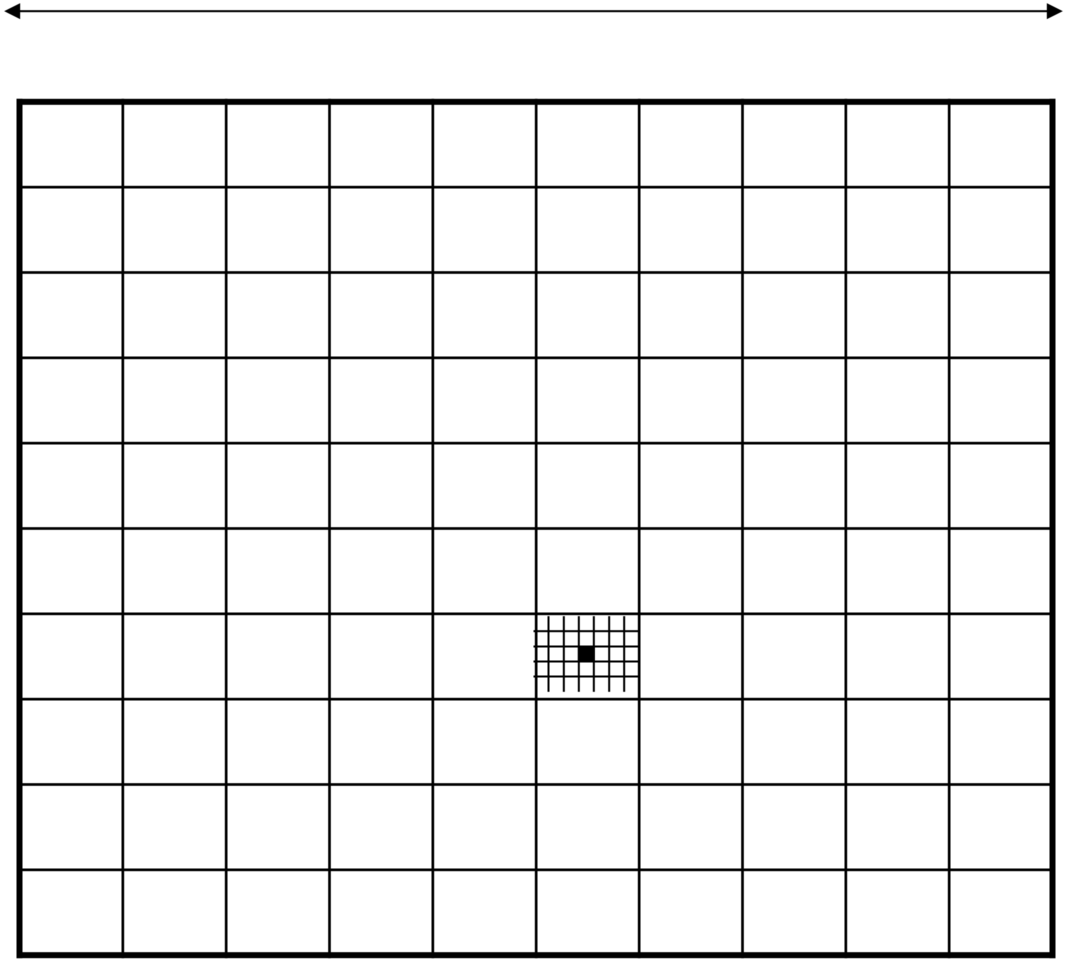
Book: Khomutinin Y.V. , Kashparov V.A., Zhebrovska K.I.

SAMPLING OPTIMISATION WHEN RADIOECOLOGICAL MONITORING, 2002 (Ukr. And Russ) and 2004 (Eng).

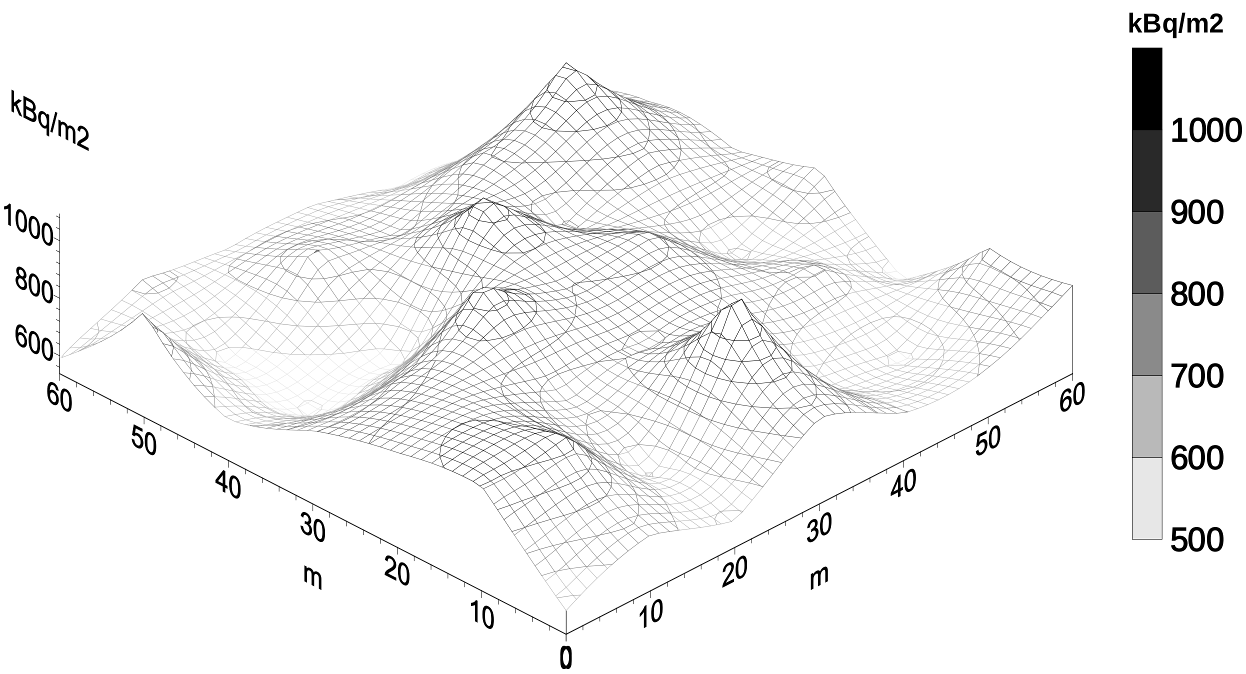


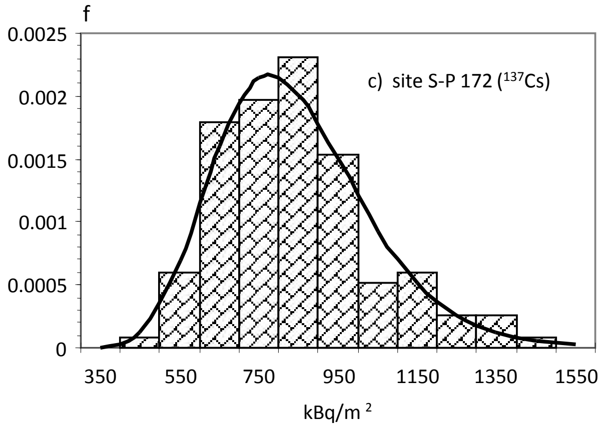
The scheme of the experimental sample sites in the 30-km zone and at the adjacent areas (^{137}Cs density of contamination)

The scheme of soil and plants sampling

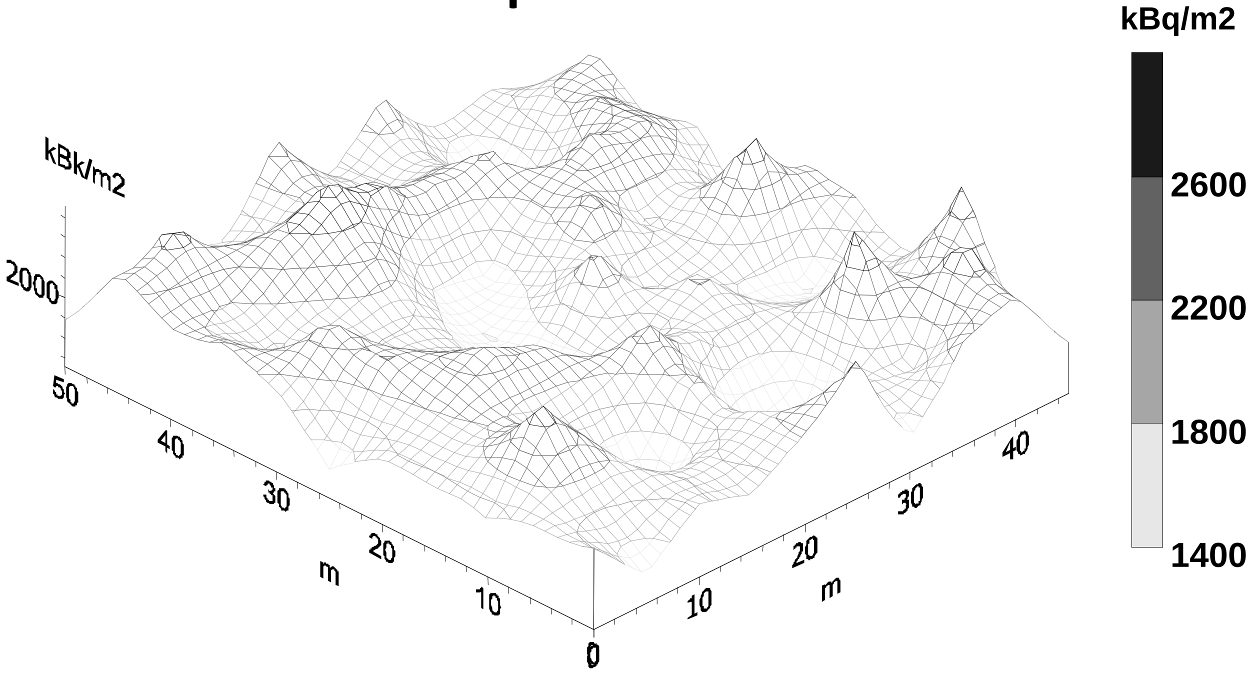


Geostatistical image of the ^{137}Cs contamination of the experimental site S-P 17



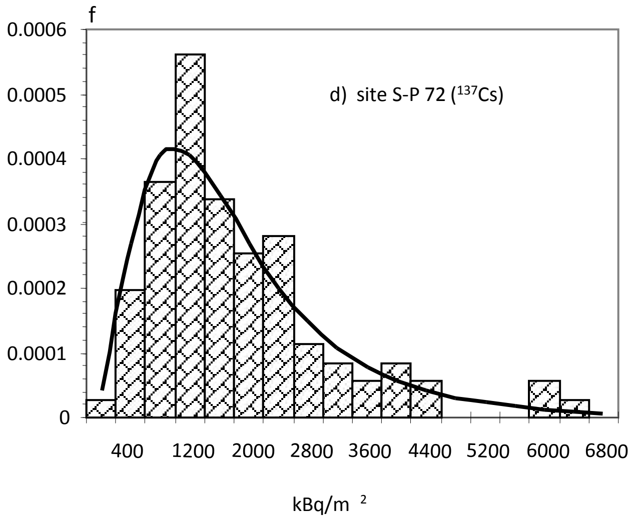


Geostatistical image of the ^{137}Cs contamination of the experimental site S-P 7

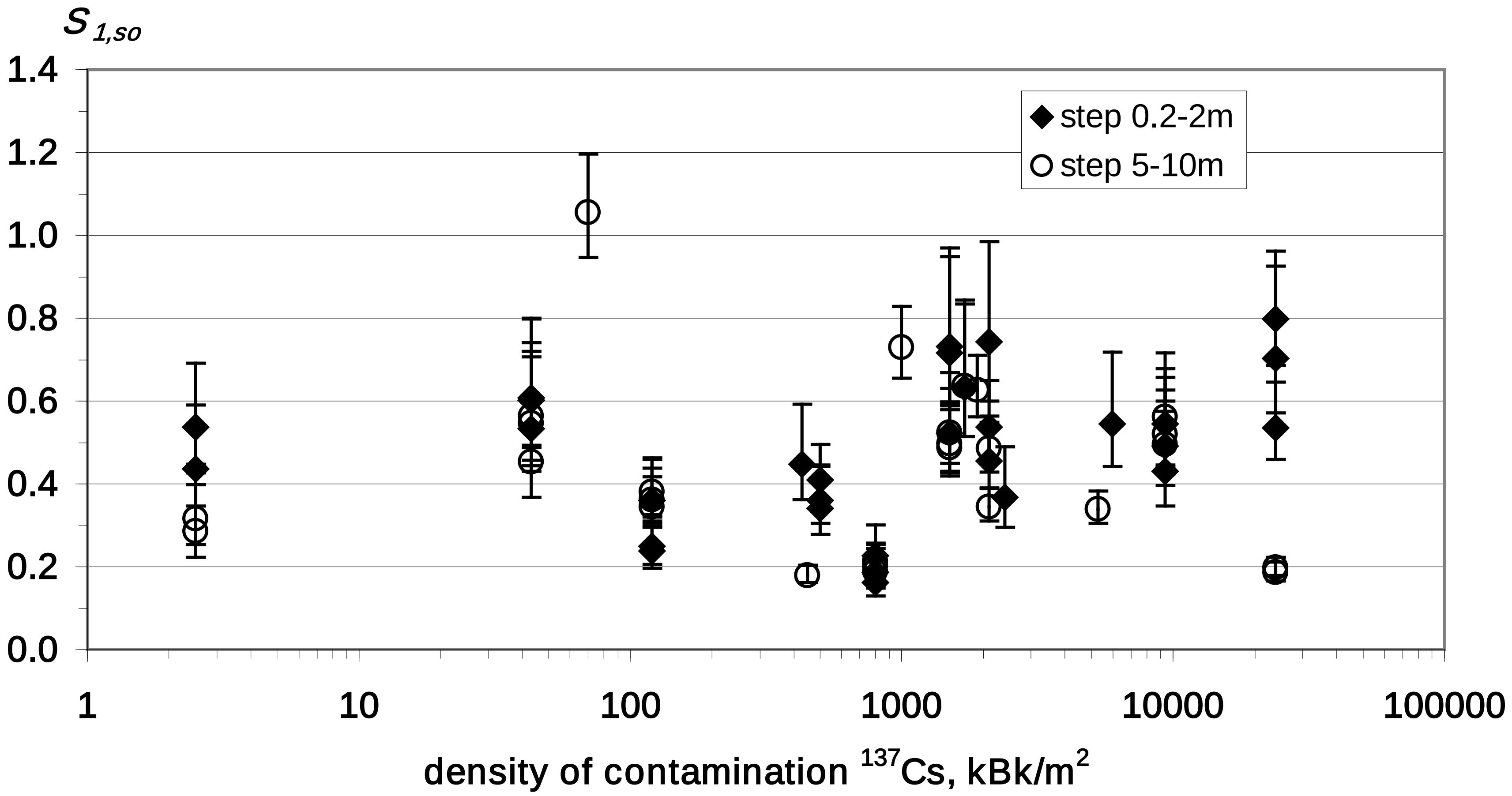


$$f(C_{so}) = \frac{1}{\sqrt{2\pi} \cdot C_{so} \cdot s_{so}} e^{-\frac{1}{2}\left(\frac{ln(C_{so}) - \mu_{so}}{s_{so}}\right)^2}$$

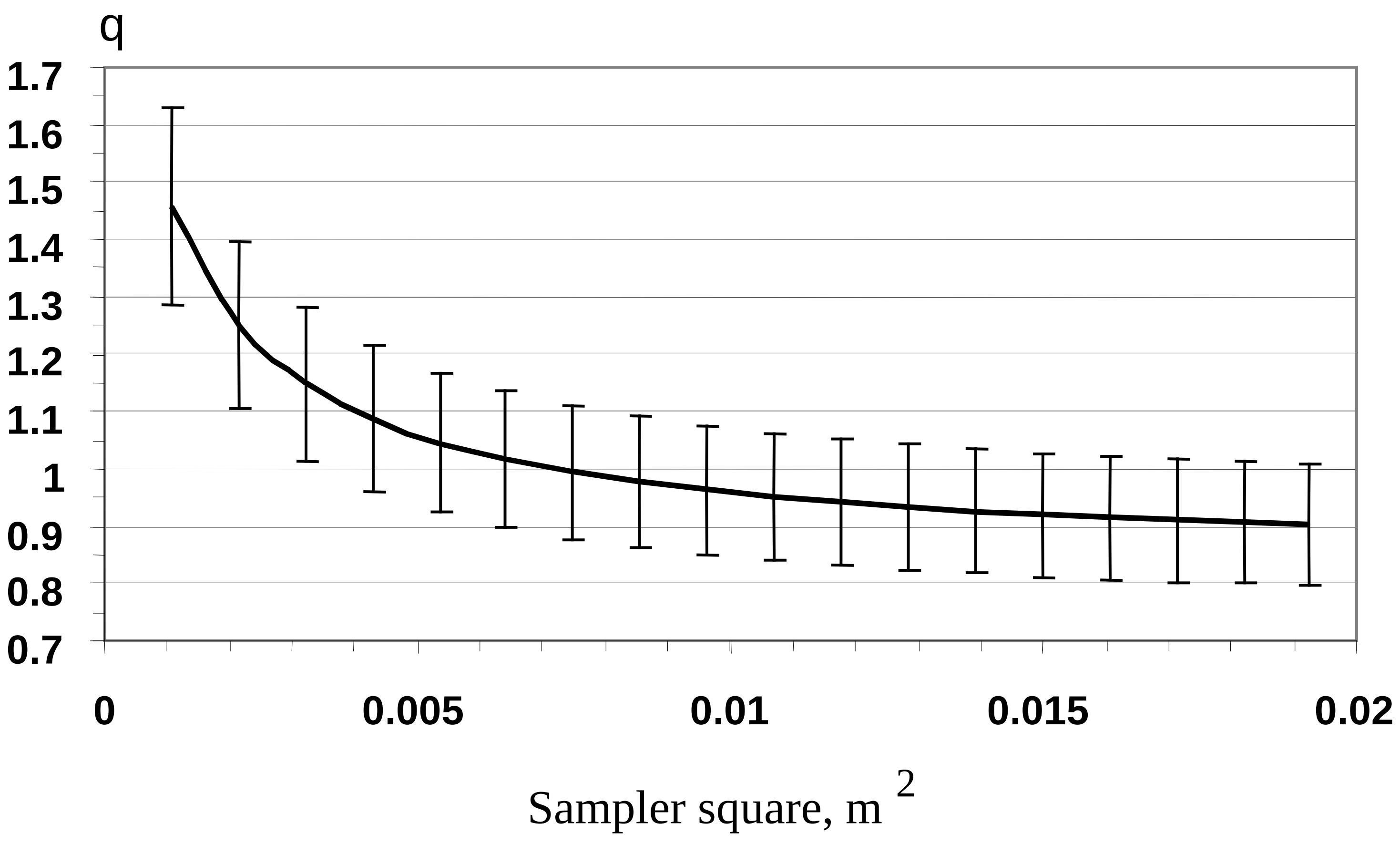
- ***Cso*** – soil density contamination with the radionuclides;
- μ_{so} – average log of radionuclides density contamination of the site;
- s_{so} – standard deviation of log of radionuclides density contamination of the site.



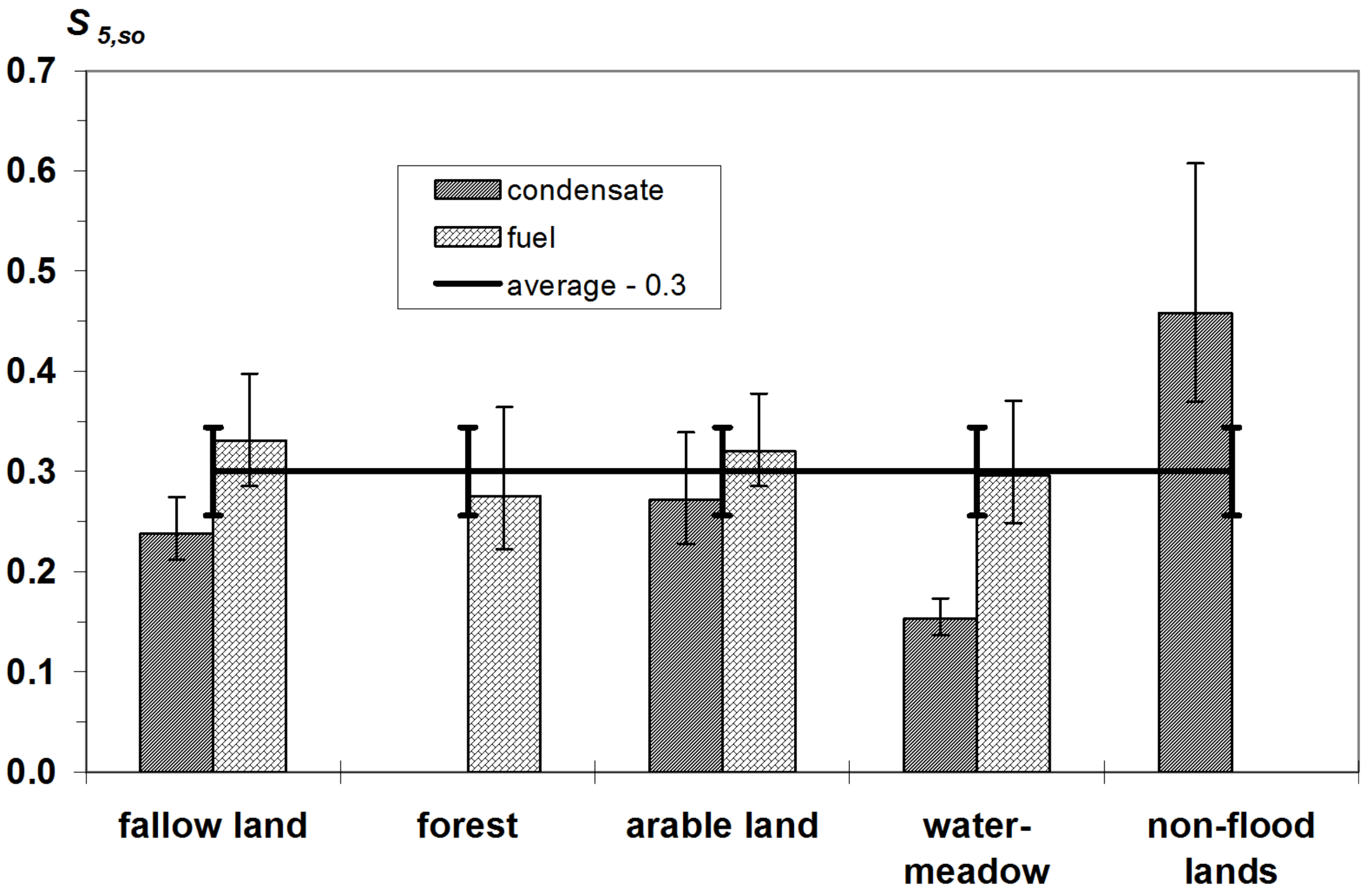
The influence of density fallouts and sampling pitch on standard deviation of log of soil density contamination with ^{137}Cs.



The relation between standard deviations of log of soil density contamination with ^{137}Cs depending on area of sampling fuel and condensation traces of fallouts.



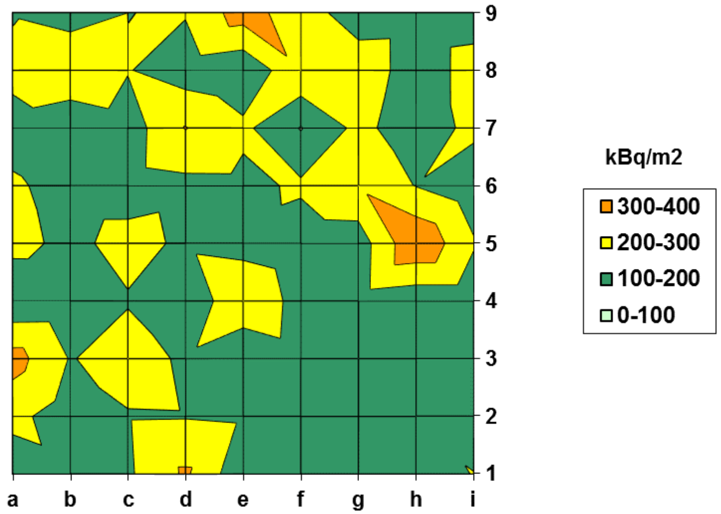
The influence of the kind of fallouts and some landscape particularities on standard deviation of log of soil density contamination with ^{137}Cs when sampling square is of $S_1 = 0.005\ m^2$

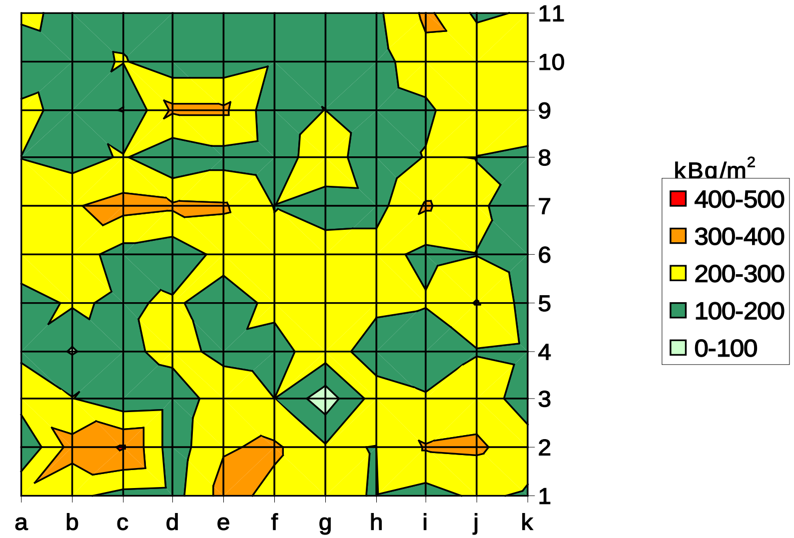


Generalised values of standard deviation of log of soil density contamination with ^{137}Cs for different experimental sites brought to sampling square 0.005 m²

Conventional sign of site	Type of fallout	Land use	$s_{5,so}$	Error $s_{5,so}$	
				Δ^-	Δ^+
S 1	fuel	grassland	0.206	0.021	0.026
S 2	condensate	grassland	0.153	0.016	0.020
S-P3; S 4	fuel	fallow	0.294	0.044	0.066
S 5	fuel	woodland	0.331	0.062	0.105
S 6	fuel	fallow	0.380	0.039	0.051
S-P 7	fuel	fallow	0.311	0.046	0.069
S 8	fuel	arable	0.352	0.059	0.094
S-P 9	fuel	woodland	0.222	0.043	0.075
S 10	fuel	fallow	0.443	0.046	0.060
S-P 11	fuel	fallow	0.225	0.052	0.088
S 12	fuel	woodland	0.271	0.052	0.088
S-P 13	condensate	arable	0.274	0.043	0.066
S 14	fuel	grassland	0.385	0.073	0.124
S-P 15	condensate	arable	0.430	0.072	0.115
S-P 16	condensate	Waterless valley	0.468	0.089	0.149
S-P 17	condensate	arable	0.167	0.028	0.045
S-P 18	condensate	fallow	0.235 0.204*)	0.036 0.029	0.052 0.041
S 19	condensate	arable	0.211 0.20*)	0.031 0.030	0.044 0.043
Average value $s_{5,so}$				**0.30**	
Standard deviation $s_{5,so}$				**0.09**	

Density of ^{137}Cs contamination



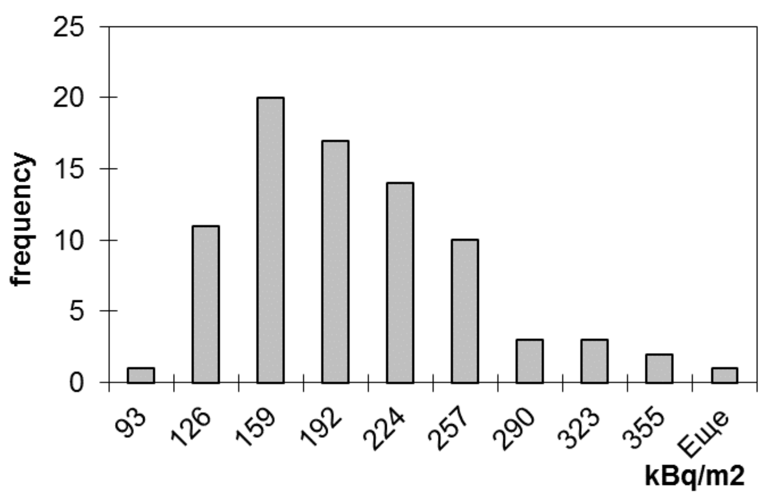


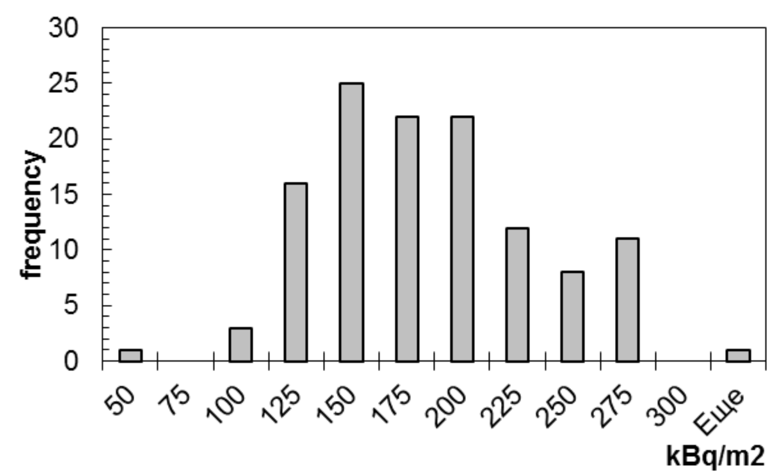
A_{soil}, GM=178 kBq/m² (**w=0.32**)

D_{ext} / A_{soil} = **1.3E-03**

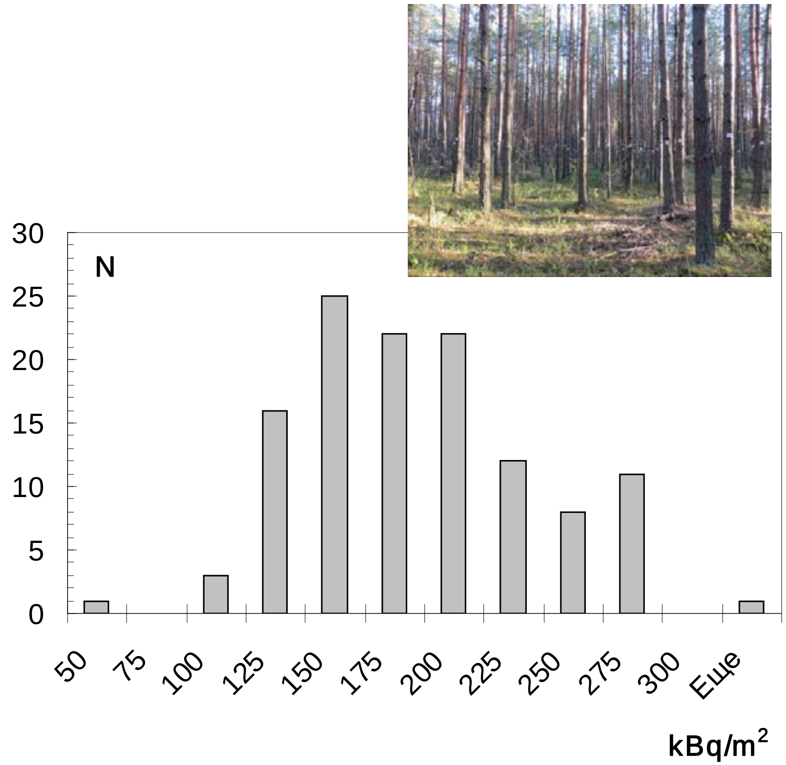
A_{soil}, GM=194 kBq/m² (**w=0.34**)

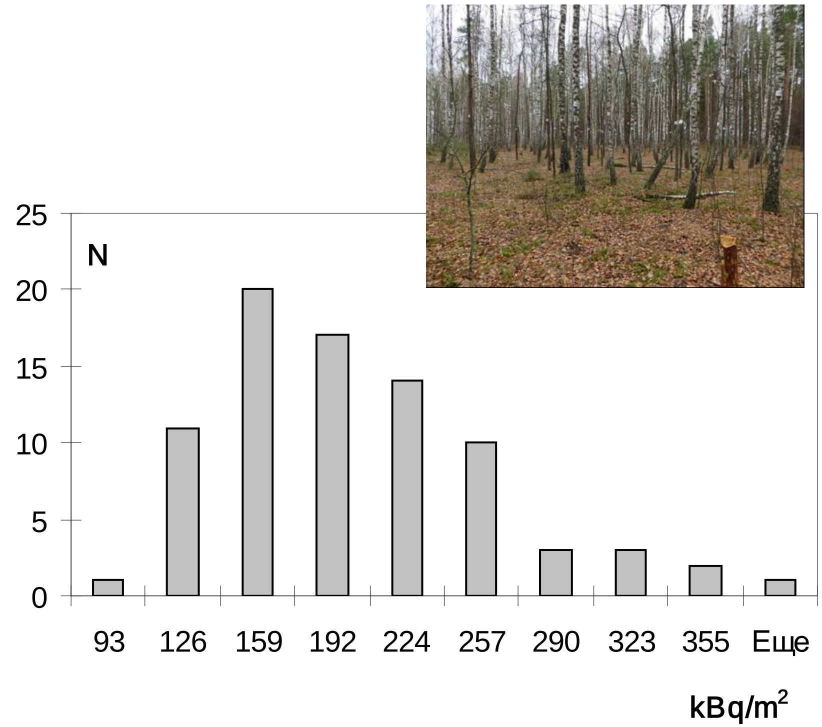
D_{ext}/ A_{soil}= **1.7E-03**





Forest density ^{137}Cs contamination





- **The standard deviation of log of the soil density contamination with ^{137}Cs (condensate) of non-gradient site in forests (a- pine and b - birch) with contamination sites for sampling squares > 0.005 m^2 is evaluated with value 0.34 and 0.32**

Conclusions 1

1. The soil contamination density with ^{137}Cs and the specific ^{137}Cs content in plants on non-gradient with contamination sites located on the Chernobyl traces and on the global radioactive fallout is satisfactorily described with the logarithmically normal law of probability distributions;
2. The standard deviation of log of the soil density contamination with ^{137}Cs of non-gradient with contamination sites for sampling squares > 0.005 m^2 does not depend on density contamination, type of fallout, features of landscape and at first approximation with errors of measurement of the radionuclide content in sub-samples of soil samples ≤ 10 % at the level ±2σ is evaluated with value 0.30±0.09

Journal of Environmental Radioactivity 139 (2015) 308–319

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

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COMET

Detailed deposition density maps constructed by large-scale soil sampling for gamma-ray emitting radioactive nuclides from the Fukushima Dai-ichi Nuclear Power Plant accident

CrossMark

Kimiaki Saito [a,*], Isao Tanihata [b], Mamoru Fujiwara [a], Takashi Saito [b], Susumu Shimoura [c], Takaharu Otsuka [c], Yuichi Onda [d], Masaharu Hoshi [e], Yoshihiro Ikeuchi [f], Fumiaki Takahashi [a], Nobuyuki Kinouchi [a], Jun Saegusa [a], Akiyuki Seki [a], Hiroshi Takemiya [a], Tokushi Shibata [g]

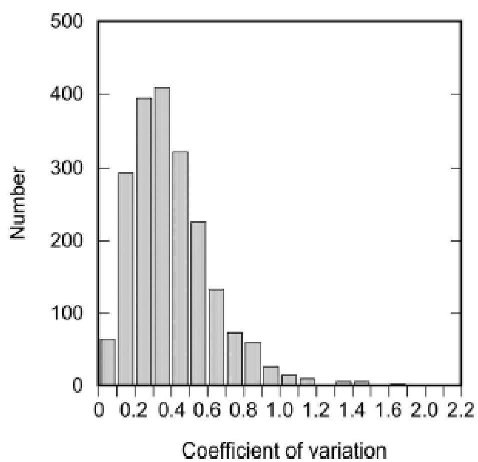


Fig. 14. Statistics on coefficients of variation for ^{137}Cs concentrations among five soil samples collected at one location. The coefficient of variation represents the ratio of the standard deviation to the mean. The number of soil sampling locations within a certain range of the coefficient of variation is shown by a bar graph.

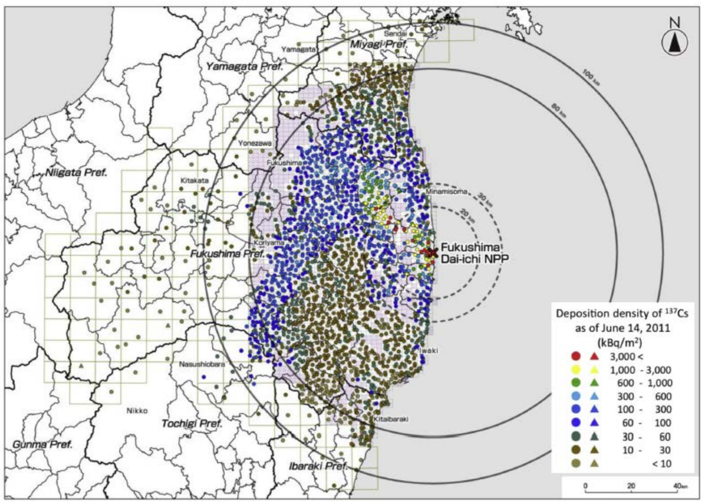


Fig. 2. Deposition density map for ^{137}Cs. The radioactivity per unit ground area is shown by the colored mark at the soil sampling location.

Table 2.1. Selected coefficients of variation (C_{var} = the sample standard deviation/observed mean) observed for radionuclide activity densities among soil samples from within relatively small sampling plots.

Radionuclide	Description of study area	Plot area (m^2)	Within plot C_{var}	Reference
^{241}Am	Desert, Nevada Test Site, Nevada, USA	0.4	0.09–0.79[a]	Gilbert and Doctor (1985)
^{241}Am	Grassland, Rocky Flats, Colorado, USA	10^4	0.13–1.16[b]	Ibrahim *et al.* (1996)
^{137}Cs	Canyon, Los Alamos, New Mexico, USA	$<10^4$	0.06–0.14	Nyhan *et al.* (1983)
^{137}Cs	Trinity Site New Mexico	$<10^4$	0.38–0.51	Nyhan *et al.* (1983)
^{137}Cs	Shrub-heath, Ireland	3.6×10^3	0.36–0.51	McGee *et al.* (1995)
^{210}Pb, ^{210}Po	Sagebrush steppe, Wyoming, USA	$\sim 10^4$	0.38–0.56	Ibrahim and Whicker (1992)
^{210}Pb, ^{210}Po	U mill tailings, Wyoming	$\sim 10^4$	0.47–1.74	Ibrahim and Whicker (1992)
^{239,240}Pu	Grassland, Rocky Flats, Colorado	10^4	0.25–1.38[b]	Ibrahim *et al.* (1996)
^{226}Ra	Properties, Grand Junction, Colorado, USA	15–270	0.66–1.53[c]	Williams *et al.* (1989)
^{226}Ra	Properties, Grand Junction, Colorado	15–270	0.08–0.29[d]	Williams *et al.* (1989)
^{238}U, ^{230}Th	Sagebrush steppe, Wyoming	$\sim 10^4$	0.36–0.50	Ibrahim and Whicker (1992)
^{238}U, ^{230}Th	U mill tailings, Wyoming	$\sim 10^4$	0.40–0.75	Ibrahim and Whicker (1992)

[a]C_{var} decreased with aliquot mass.
[b]C_{var} increased with depth of sample.
[c]Individual samples.
[d]20-sample composites.

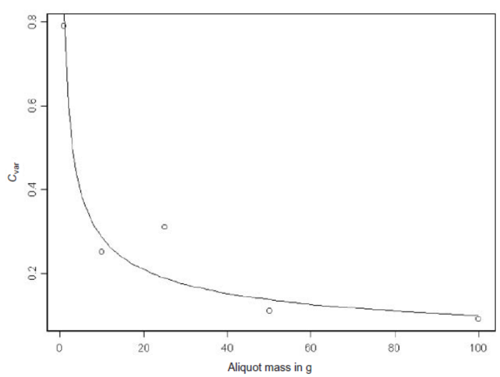
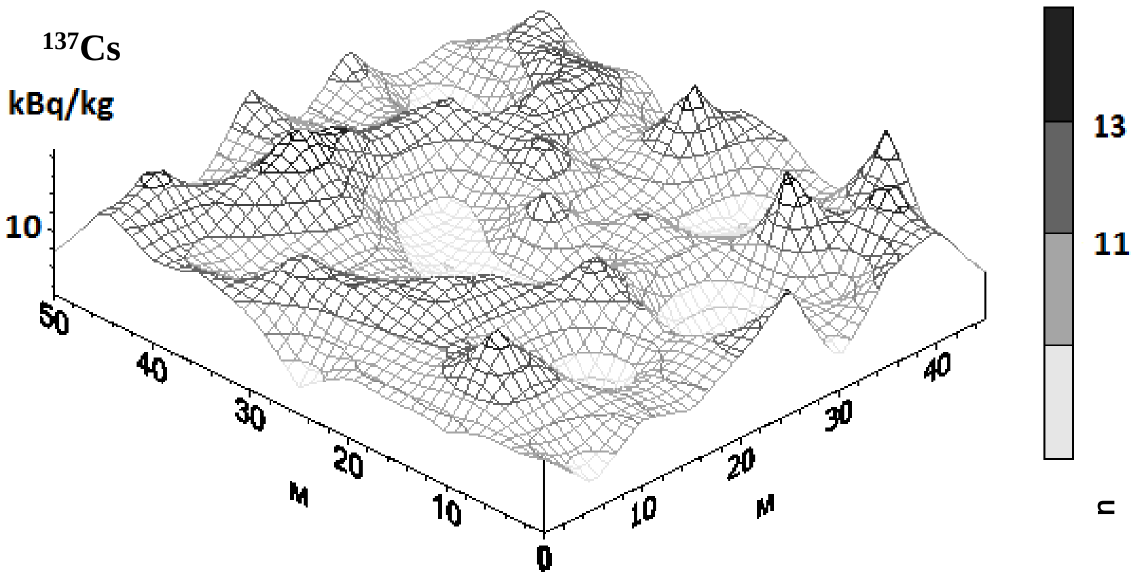
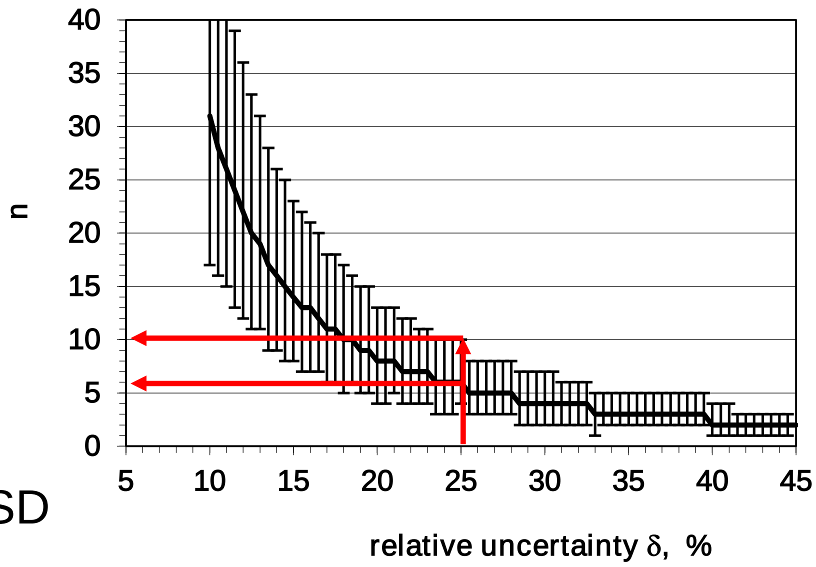


Figure 2.1. Observed coefficients of variation (C_{var}) for ^{241}Am in Nevada Test Site, USA, soil samples as a function of aliquot mass analyzed (redrawn from data in Gilbert and Doctor, 1985). The negative power function, C_{var} = 0.83 aliquot mass in $g^{-0.46}$, fitted to the data is shown as the solid line.

Optimization of soil sampling - minimum necessary amount of the samples to evaluate the soil contamination density at the non-gradient sites





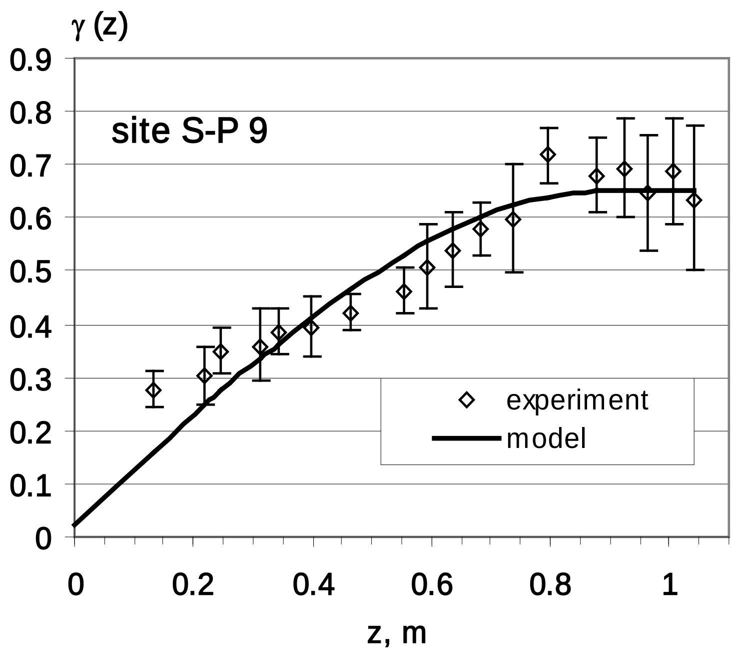
$$n = F(s, \delta, \delta_m, P)$$

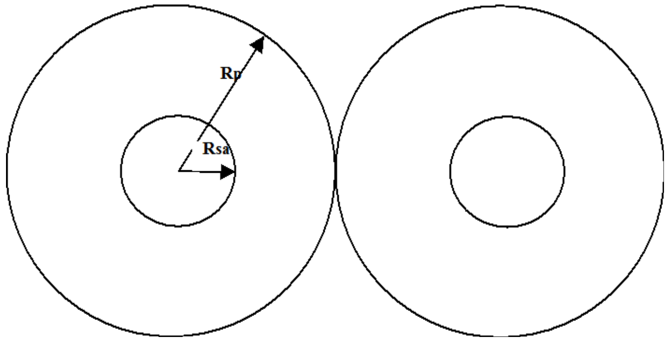
= **0.3±0.1** - Geometric Standard Deviation, GSD

δ_m - relative measurement uncertainty

P - confidence probability

Radius of the soil samples influence





Typical variograms for ^{137}Cs when sampling by cylindrical sampler ∅3.7cm

The radionuclide activities in the samples taken at the homogeneously contaminated site at the distance more than 1 m between each other in the first approximation will be statistically independent values

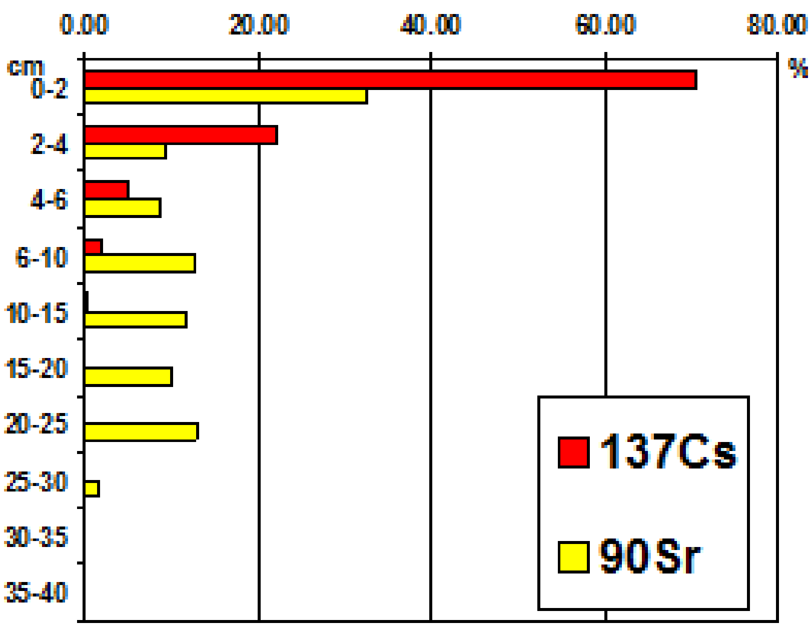
Radius of soil samples influence

Table 7.1. Radiuses of sample influence ^{137}Cs on different sites, when sampling by a cylindrical sampler 3.7 cm in a diameter

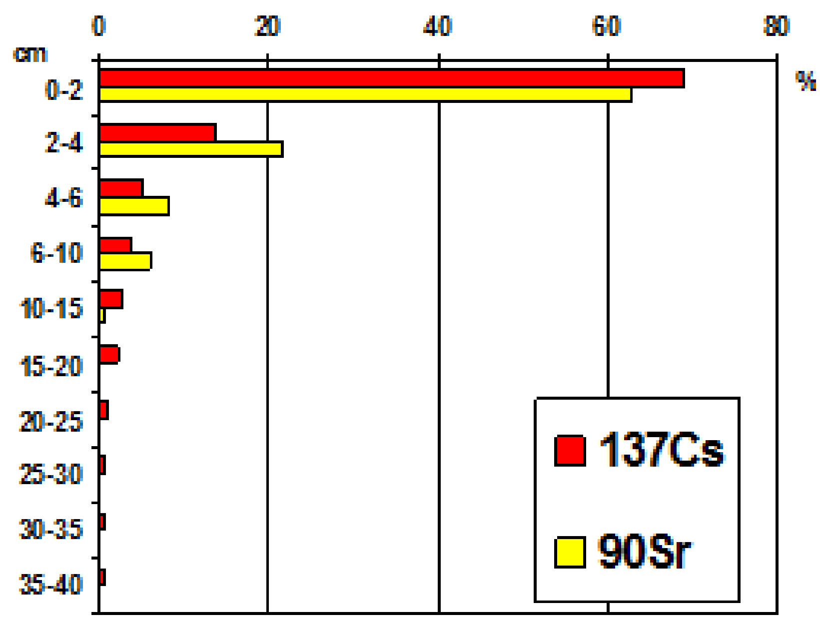
The site	The type of fallout	The type of land use	R_{sa} , м
Site S-P 3	fuel, ***DFP***≈25%	fallow land	0.4
Site S-P 9	fuel, ***DFP***≈25%	ploughed field	0.9
Site S-P 7	fuel, ***DFP***≈25%	fallow land	0.15
Site S-P 11	fuel, ***DFP***≈25%	fallow land	0.25
Site S-P 13	condensate, ***DFP***<10%	ploughed field	0.4
Site S-P 15	condensate, ***DFP***<10%	ploughed field	0.25
Site S-P 16	condensate, ***DFP***<10%	waterless valley	0.7
Average value			0.44

- Thus, radionuclide content in dot samples (including the samples consisting of several located nearby samplings made by a sampler 3.7cm in a diameter), selected on non–gradient site on distance (centre–to–centre sampling) **> 1 m** from each other at the sampling area no more than **0.014 m^2,** should be considered as statistically independent magnitudes (statistically independent samples).

The experimental distribution of radionuclides insoil profile (1995).

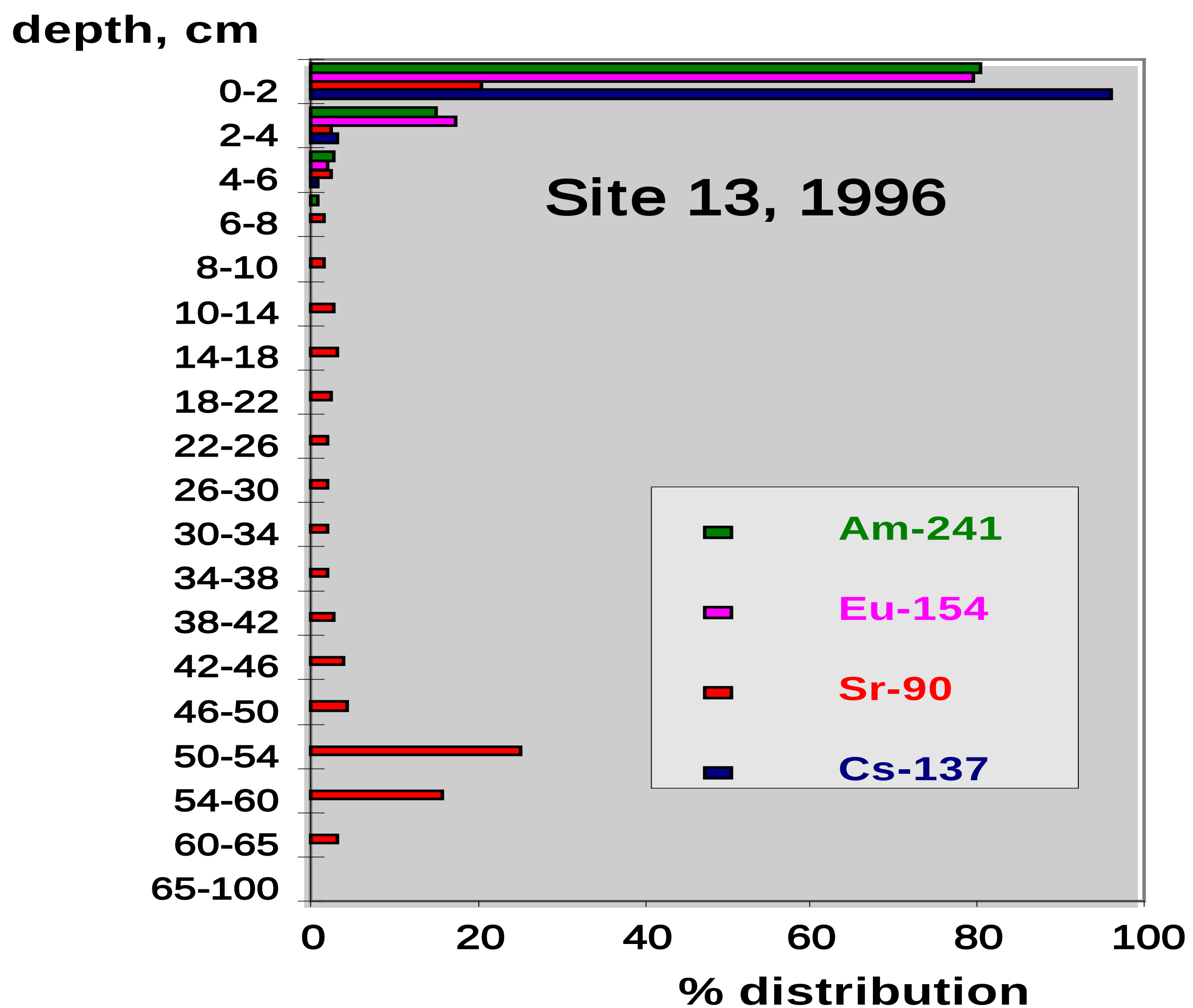


in soddy-podzolic sandy soil

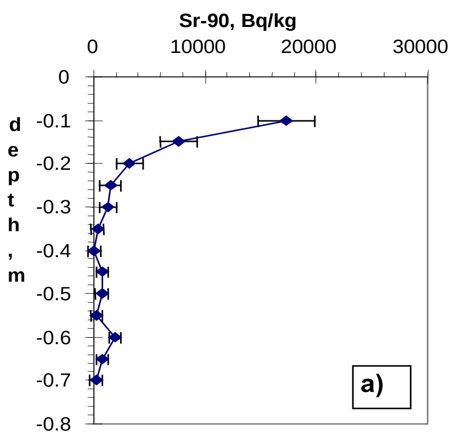


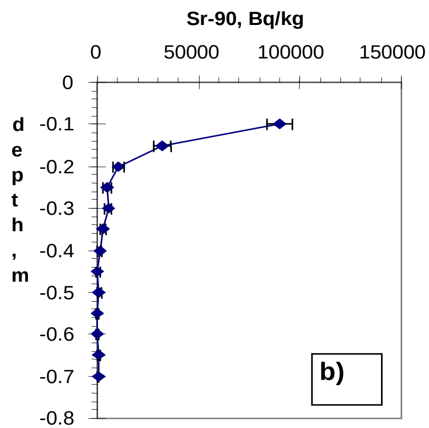
In peaty soil

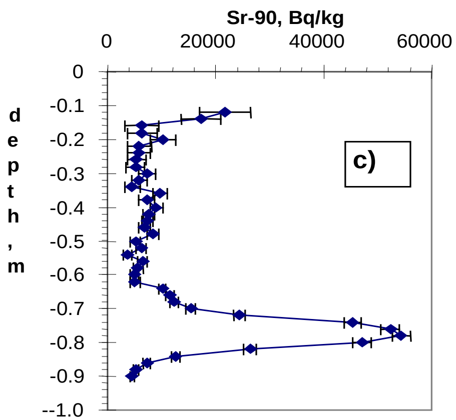
Distribution of radionuclides down the soil profile (%), site 13, sandy, low humus soil, 1996.

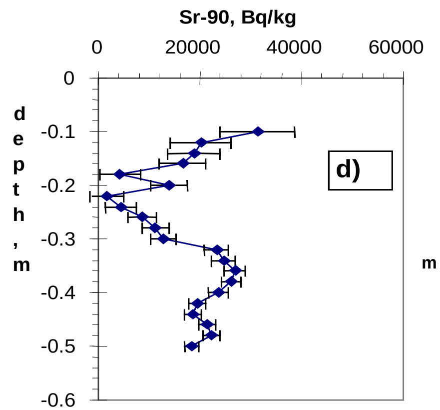


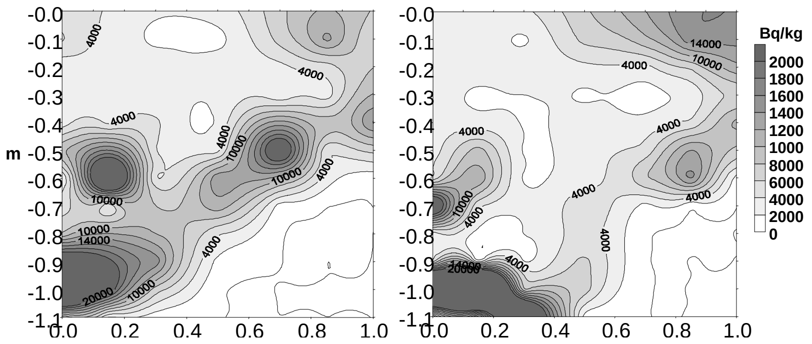
The long-term observations of the vertical migration of ^{90}Sr, ^{137}Cs and transuranium elements show that their main activities at the territory contaminated as a result of the ChNPP accident are found now in the upper 20 cm soil layer











Examples of the ^{90}Sr distribution in the vertical profiles and cross-sections of sandy soils

Soil sampling parameter

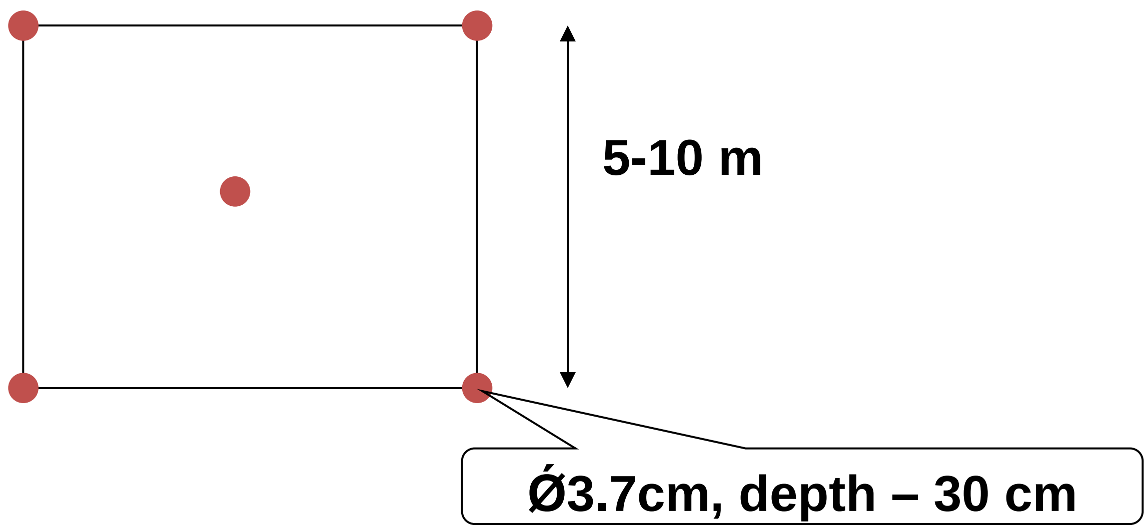
Sampling depth –30 cm for arable soil and in a few years after accident

Sampling area ≥50 cm^2

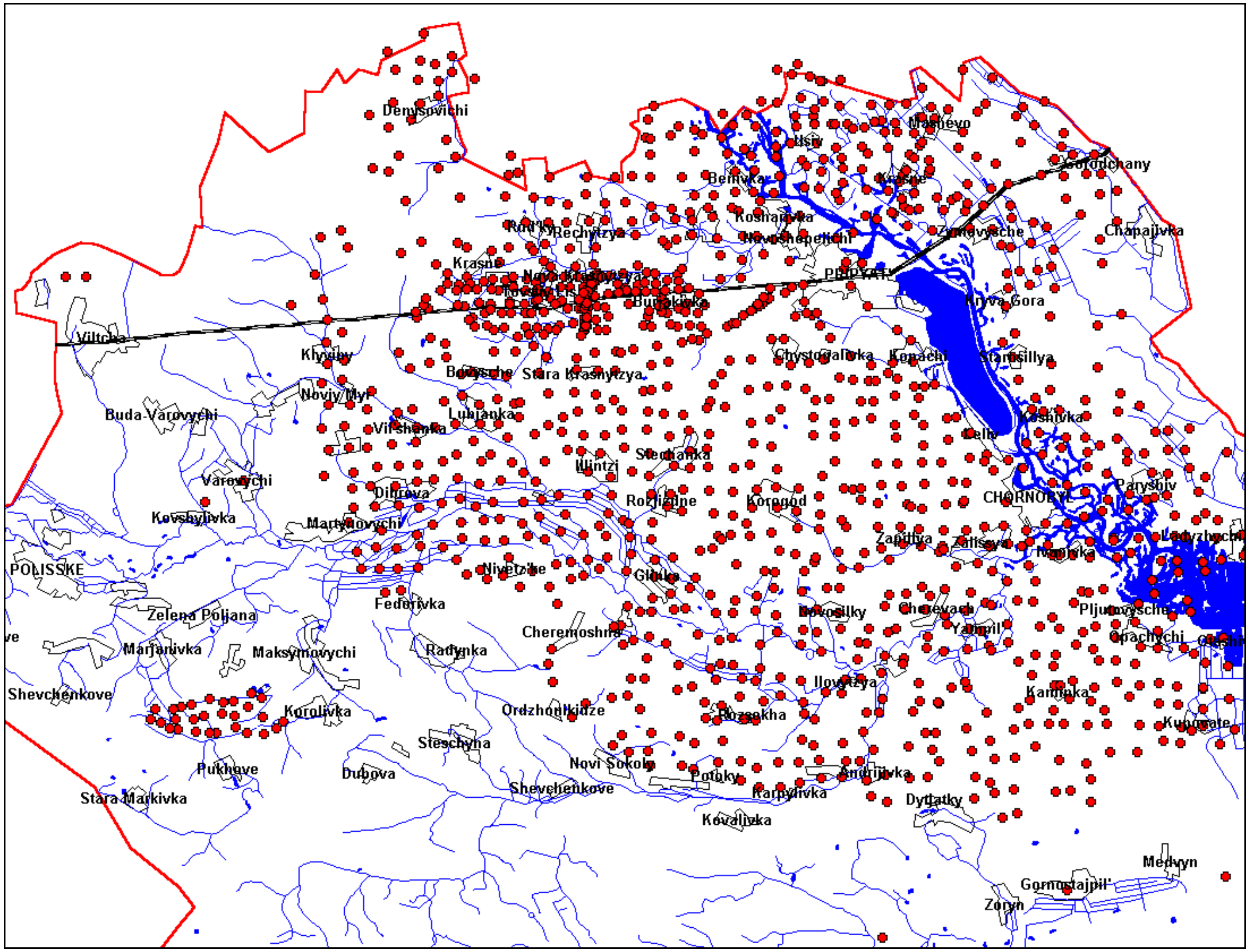
Amount of samples per site – ≥5

Diameter of sampler – ≥37 mm

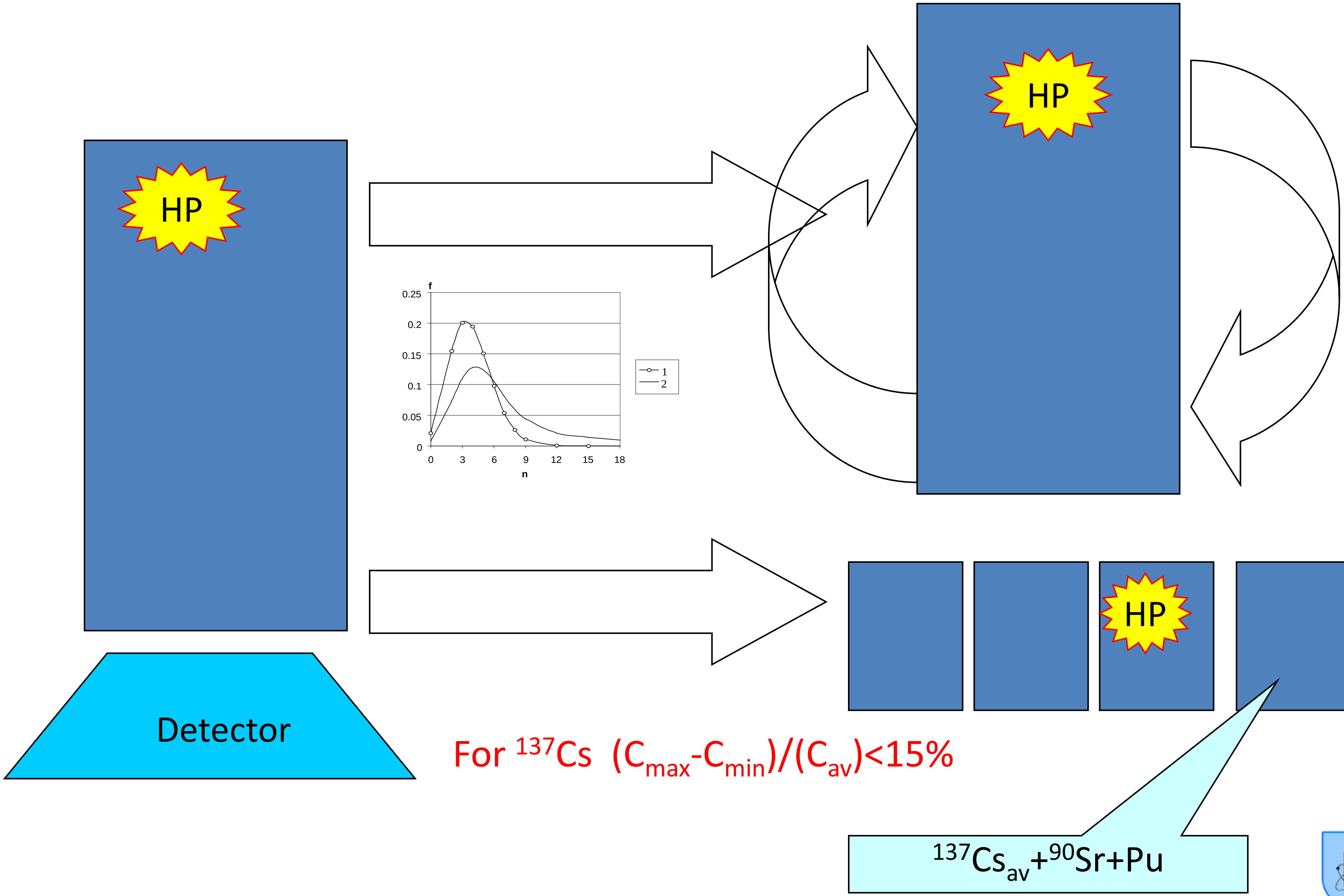
Step between sampling points 5-10 m



Map of the soil sampling sites in the near zone of the ChNPP



Radioactivity measurement in the heterogeneously contaminated samples



Conclusions - Measurement of samples

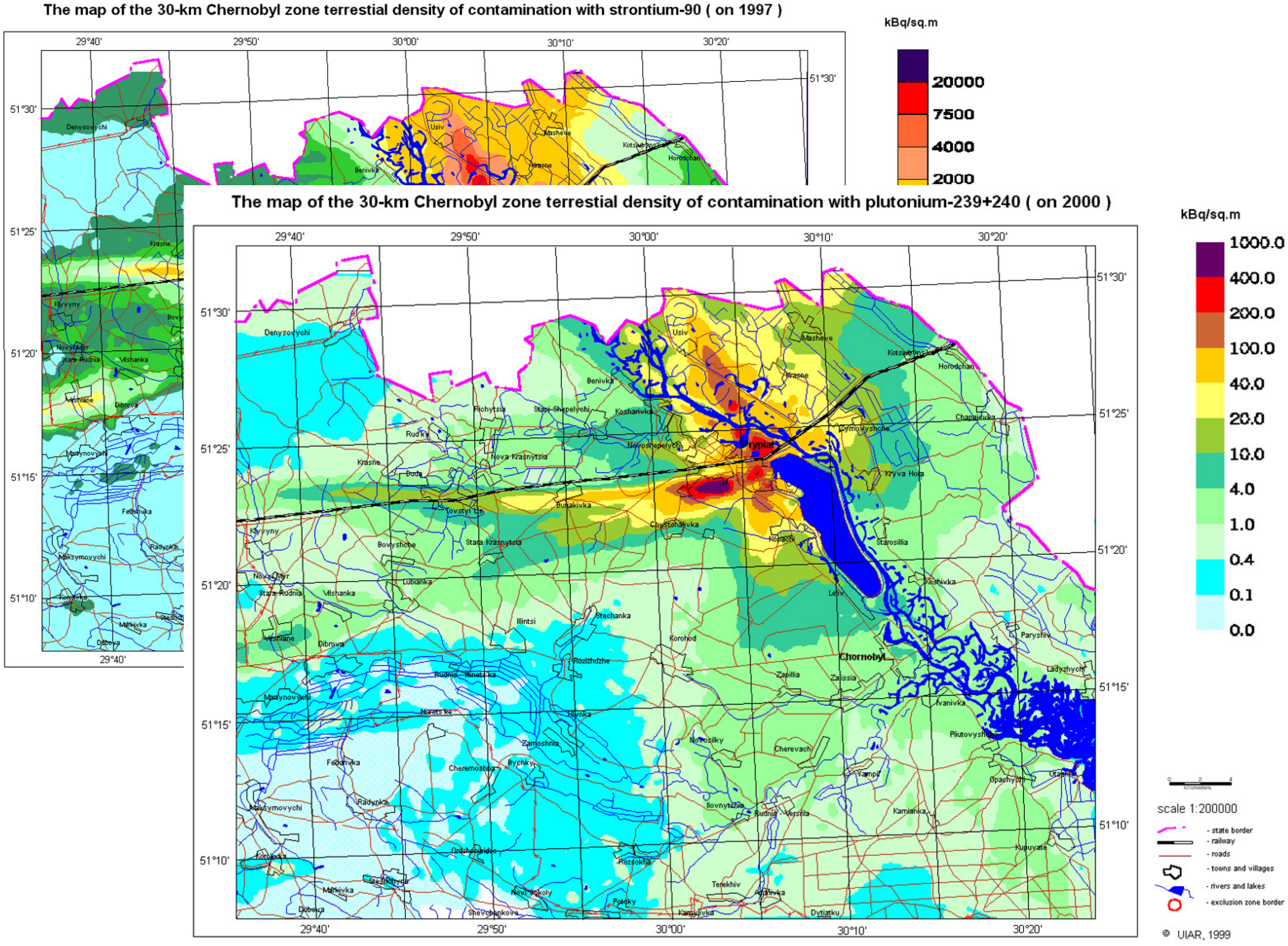
- **Amount of sub-samples per site – 3 (100cm^3)+1(1000 cm^3)**
- **For ^{137}Cs from 4 sup-samples: $(C_{max}-C_{min})/(C_{av})<15\%$**
- Relative uncertainties of measurement in samples

^{90}Sr/^{137}Cs < activity of **^{90}Sr or Pu**

- **For minimization of the uncertainties all radionuclides activity measurements must be performed in the same sample**

- **U-Zr-O particles represent <20% of** activity of radionuclides (**^{90}Sr or Pu)** in the fuel component of Chernobyl fallout

Contamination of Ukraine



Statistical performances of plant contamination

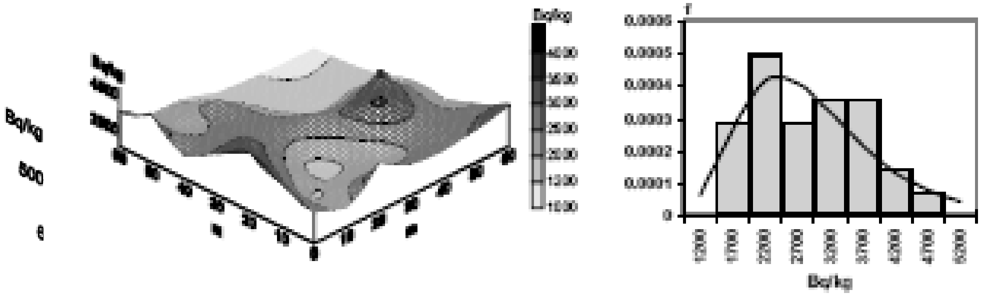


Fig. 2.18.- The spatially-statistical structure of oenothera biennis (L) contamination with ^{137}Cs on the experimental site S-P 15. Donkey grass did not grow in the upper corner of the site

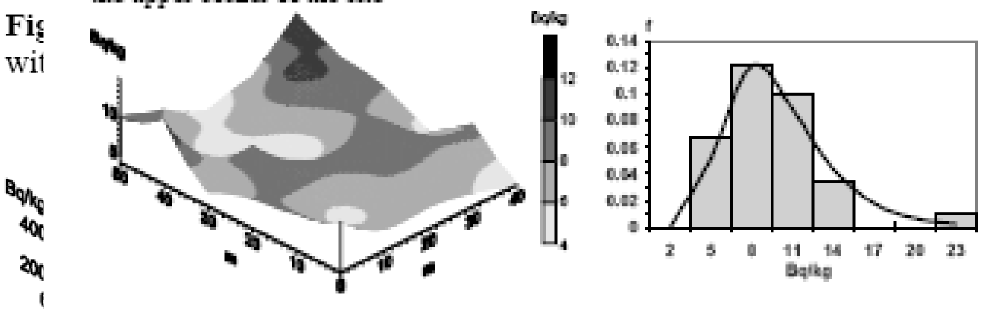


Fig. 2.19.- The spatially-statistical structure of calamagrostis epigeios (L) Roth contamination with ^{137}Cs on a small experimental site S-P 18.

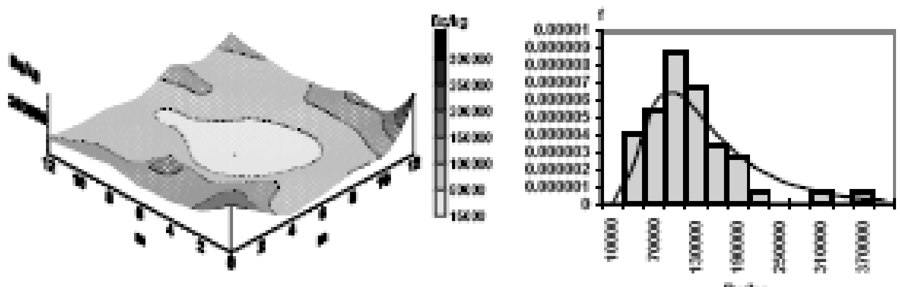


Fig. 2.20.- The spatially-statistical structure of elytrigia repens (L) Nevski contamination with ^{137}Cs on the experimental site ^{137}Cs S-P 3.

Statistical performances of plant contamination

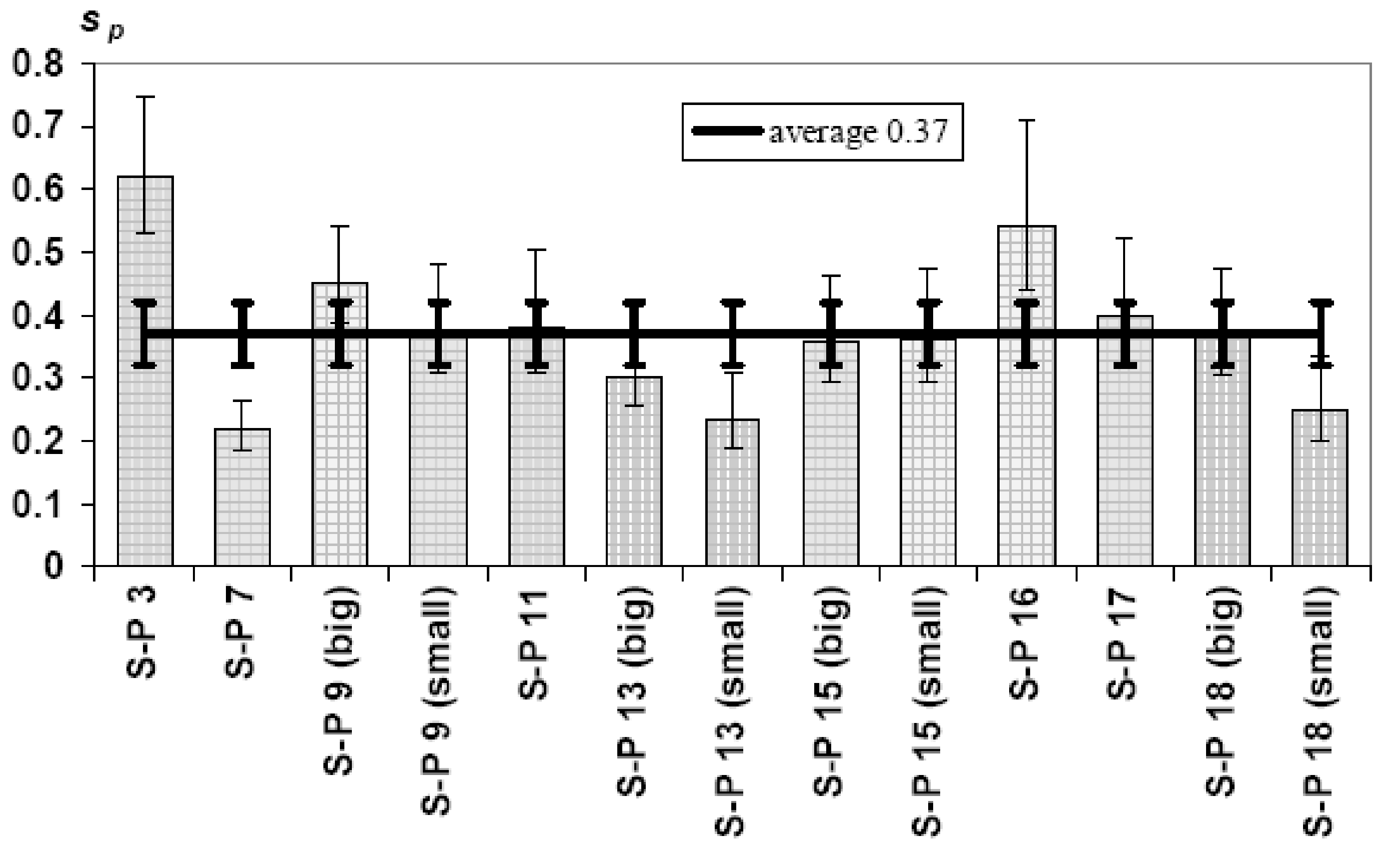


Fig. 2.21.- The values of standard deviation estimations of log of ^{137}Cs specific contents in the plants samples collected from various experimental sites.

Statistical performances of pine wood contamination (Perevolotskii A., 2013)

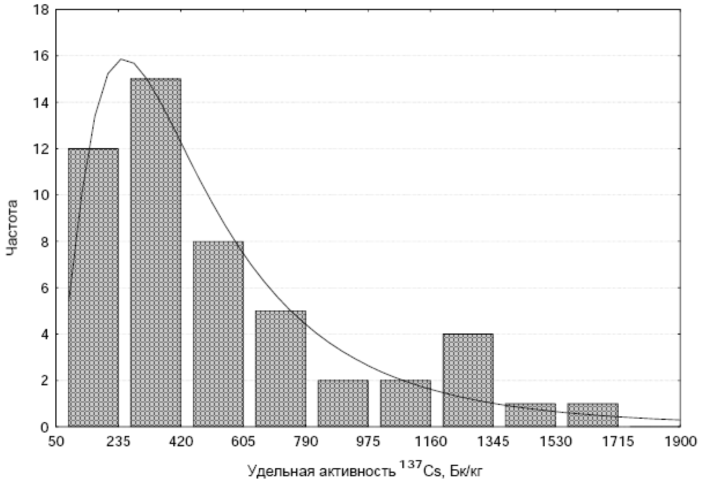


Рисунок 5.9 – Гистограмма удельной активности ^{137}Cs в окоренной древесине 50 деревьев сосны 65-летнего возраста [4-А, с. 148; 25-**А]**

Таблица 5.10 - Варьирование удельной активности ^{137}Cs в древесине сосны обыкновенной различных классов роста и развития [4-А, с. 149]

Класс роста и развития	Размер выборки	Удельная активность 137Cs, Бк/кг					
		Минимум	Максимум	Среднее	Коэффициент вариации, %	95% доверительный интервал min	95% доверительный интервал max
[32-А]							
I	10	419	1700	982±152	49	570	1321
II	10	413	1222	626±81	41	419	623
III	10	175	637	323±44	43	213	398
IV	10	86	423	229±40	52	126	265
V	10	84	674	267±45	45	155	329
[320]							
I	13	347	790	510±30	21	445	577
II	18	338	826	571±32	24	503	639
III	16	358	753	529±30	23	465	594

Table 2.2. Coefficients of variation (C_{var}) observed for radionuclide activity densities in terrestrial vegetation samples.

Radio-nuclide	Location	Plant type	Sampling plot area (m^2)	Within plot C_{var}	Reference
^{137}Cs	Colorado, USA	Shrubs	465	0.13–0.16	Remmenga and Whicker (1967)
^{137}Cs	Ireland	*Calluna vulgaris*	3.6×10^3	0.12	McGee *et al.* (1995)
	Ireland	*Juncus squarrosus*	3.6×10^3	0.20	
Total γ^a	Colorado	Trees	465	0.10	Remmenga and Whicker (1967)
	Colorado	Shrubs	465	0.13	
	Colorado	Herbs	465	0.23	
	Colorado	Grasses	465	0.41	
$^{239,240}Pu$	Rocky flats, Colorado, USA	Lichens	10^4	$0.52–1.26^b$	Thomas and Ibrahim (1995)
	Background, Colorado	Lichens	4×10^4	0.16^c	
^{210}Pb, ^{210}Po	Wyoming, USA	Herbs	$\sim 10^4$	$0.81–1.15^d$	Ibrahim and Whicker (1992)
				$0.52–0.59^e$	
^{226}Ra	Wyoming	Herbs	$\sim 10^4$	1.04^d	
				0.63^e	
^{238}U, ^{230}Th	Wyoming	Herbs	$\sim 10^4$	$1.09–1.96^d$	
				$0.86–1.14^e$	
^{95}Zr	Colorado	Shrubs	465	0.13–0.46	Remmenga and Whicker (1967)
^{137}Cs	Great Britain	Mushrooms	Not reported	0.31–1.79	Barnett *et al.* (1999)

[a]Total γ activity due mainly to radionuclides from global fallout (^{137}Cs, ^{95}Zr, ^{144}Ce, etc.).
[b]Mainly contamination from on-site releases of $^{239,240}Pu$.
[c]Site in northern Colorado affected only by global fallout.
[d]Exposed-tailings site at a uranium mill.
[e]Natural area unaffected by uranium mill.

Conclusion 2

- The standard deviation of log of the specific ^{137}Cs content in plant samples does not depend on the density contamination, type of fallout, type of vegetation. At first approximation with sampling squares of plants ≤ 1 m^2 and ratio error of measurement of the ^{137}Cs content in sub-samples of vegetative samples ≤ 10 % at the level $\pm\sigma$ is estimated with value **0.37±0.11**, on the Chernobyl traces and on global radioactive fallout

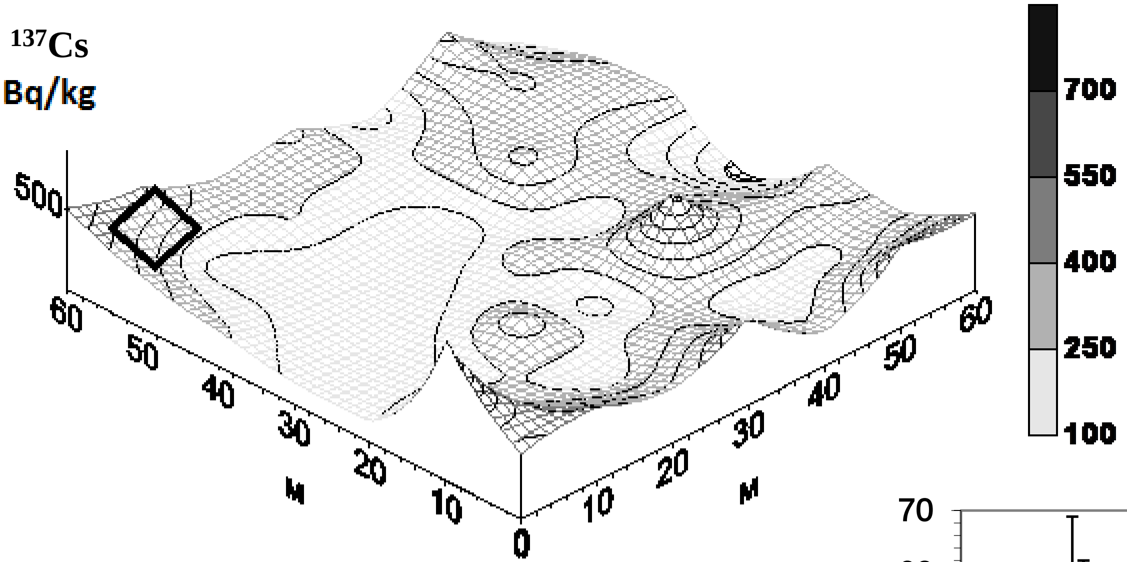
Radius of vegetative samples influence

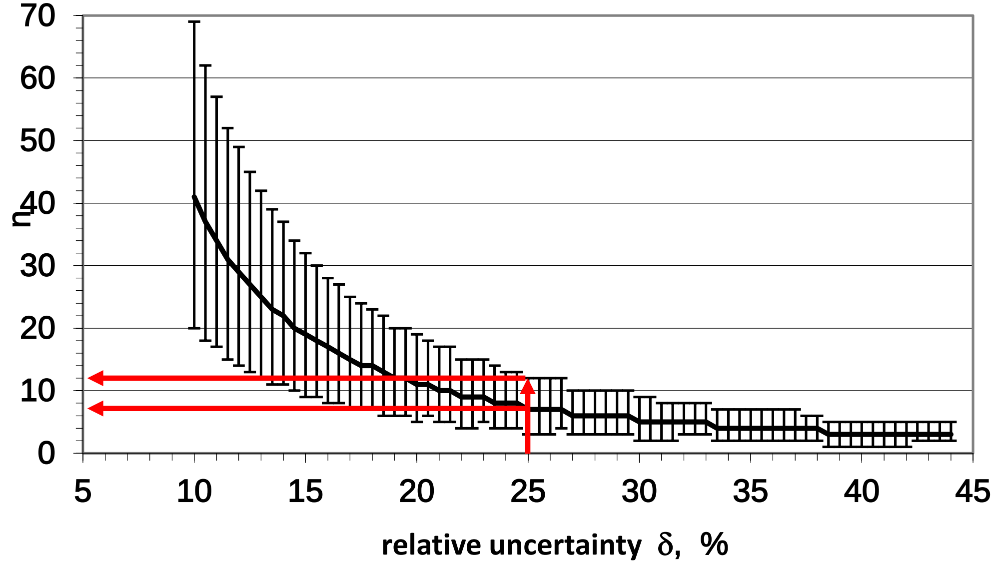
Table 7.2. Estimations of radius influence of plants sample for various experimental sites at definition of the ^{137}Cs content.

№	Sites group	Radius of plants sample influence when defining ^{137}Cs content R_p, **m**
1	Arable lands (*triticum (clurum vulgare), secale (cereale), avena (sativa), oenothera biennis (L)*)	5
2	Former arable lands and fallow lands (*calamagrostis epigeios (L) Roth*)	2.8
3	Former arable lands and fallow lands (*elytrigia repens (L) Nevski*)	7

- **The following conclusion is possible to draw on the basis of the received results: the centre–to–centre distance of plants sampling not less than 8-10 m in all cases provides their statistical independence of the selected samples on ^{137}Cs content.**

Optimization of plants sampling





0.37 ±0.11 –
Geometric Standard Deviation, GSD

Statistical characteristics of the transfer factors of ^{137}Cs in a "soil - plant" chain (Tf and CR)

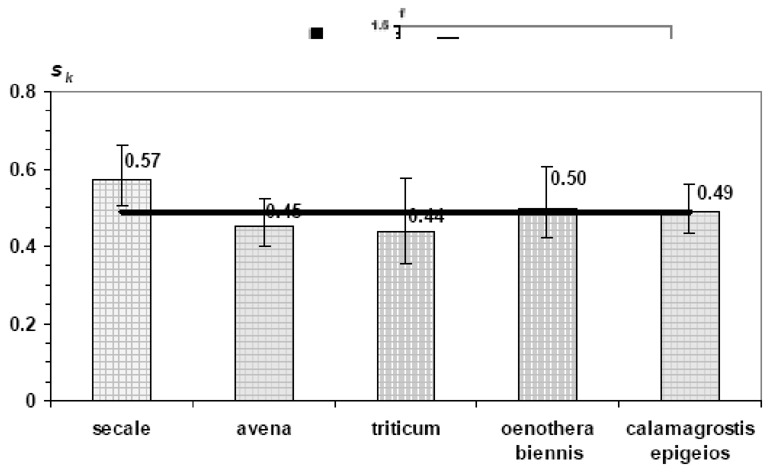


Fig. 3.5– The values of standard deviation of log of the transfer factor of ^{137}Cs into the various plants on the experimental sites.

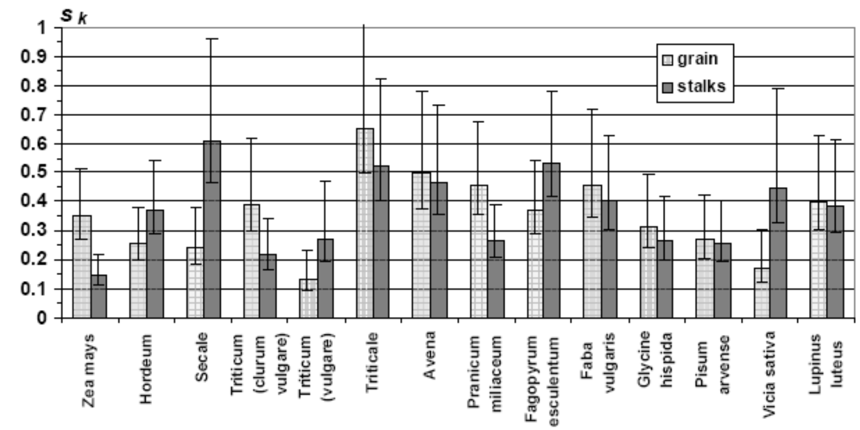


Fig. 3.6– The values of standard deviation of log of the transfer factor of ^{137}Cs into the various agricultural grain-crops in the definite year calculated on P.F. Bondar's data [69].

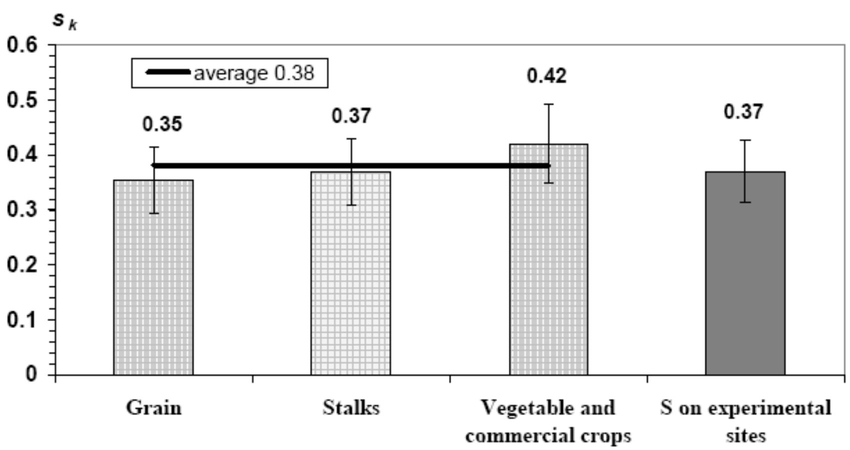


Fig. 3.8– Averaged volumes of standard deviation of log of the transfer factor of ^{137}Cs for various crop production groups in the definite year, calculated on P.F. Bondar's data [69].

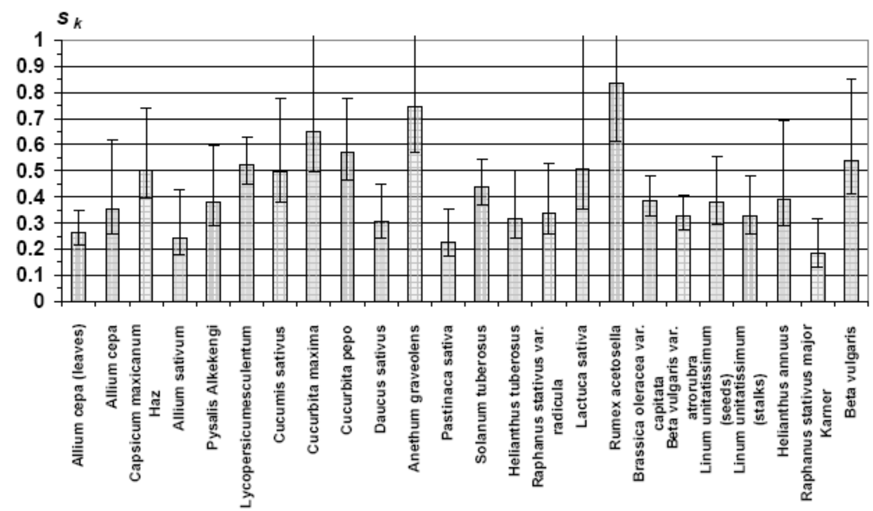
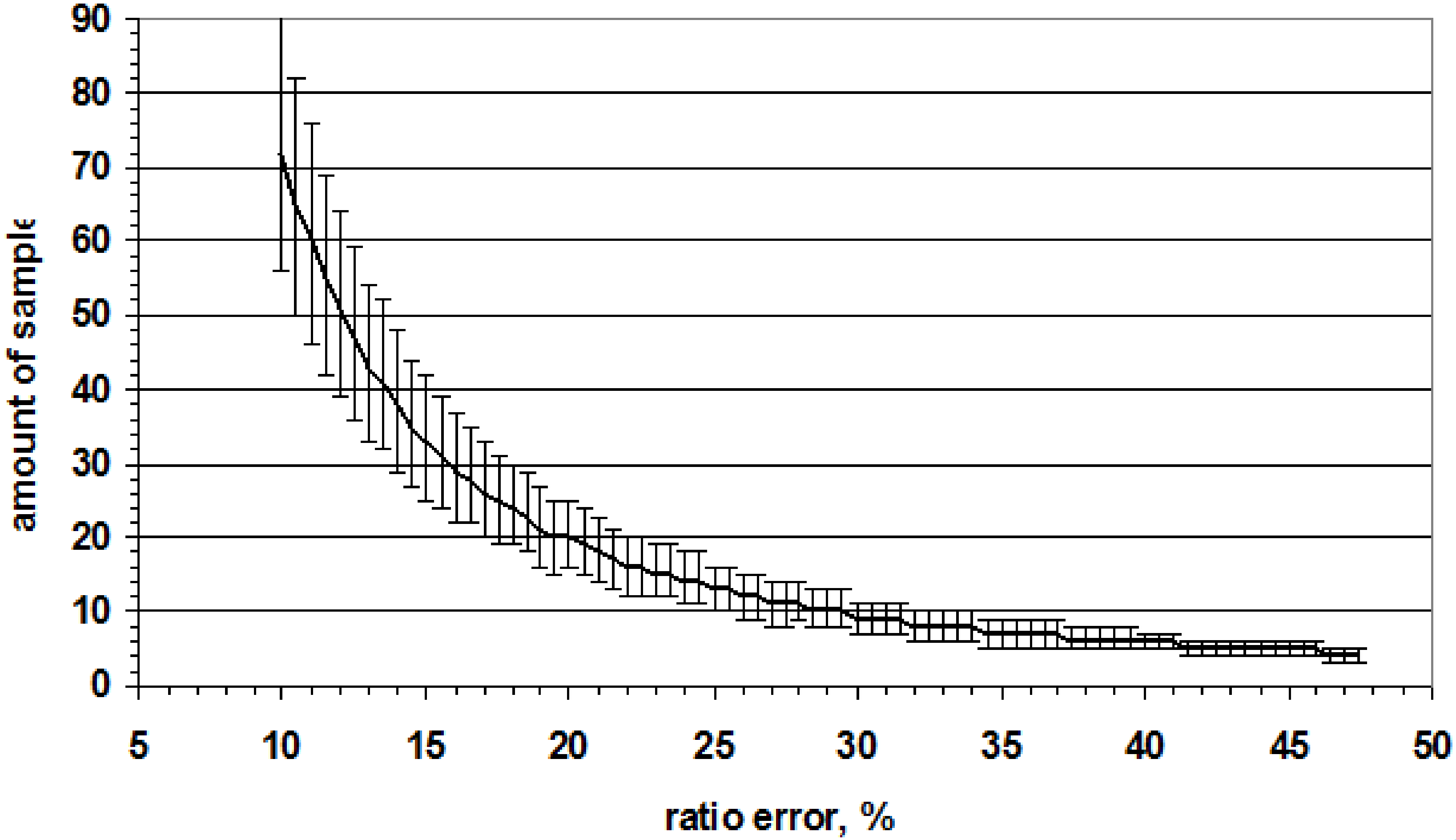


Fig. 3.7– The values of standard deviation of log of the transfer factor of ^{137}Cs into various vegetable and technical crops in the definite year calculated on P.F. Bondar's data [69].

The nomogram to account minimum necessary amount of conjugate samples "soil - plant" to evaluate the median of transfer factor with prescribed ratio error when sampling and measuring base parameters and accuracy if confidential probability is p=0.95.



Conclusion 3

- the transfer factor of ^{137}Cs into plants is the random variable and it is described by the logarithmically normal law of the probability distribution;
- the average quadratic deviation of the log of the transfer factor of ^{137}Cs in plants does not depend on the density of contamination, the type of fall-outs, the kind of vegetation and its various parts; in the first approximation when selecting the conjugate "soil - plant" samples, when squares of sampling for plants $\leq 1 m^2$ and $> 0.005\ m^2$ for soil and relative error of measurement of the ^{137}Cs content in the samples of soil and plants does not exceed 10 % at a level $\pm\sigma$ is evaluated by the value **0.49±0.06**.

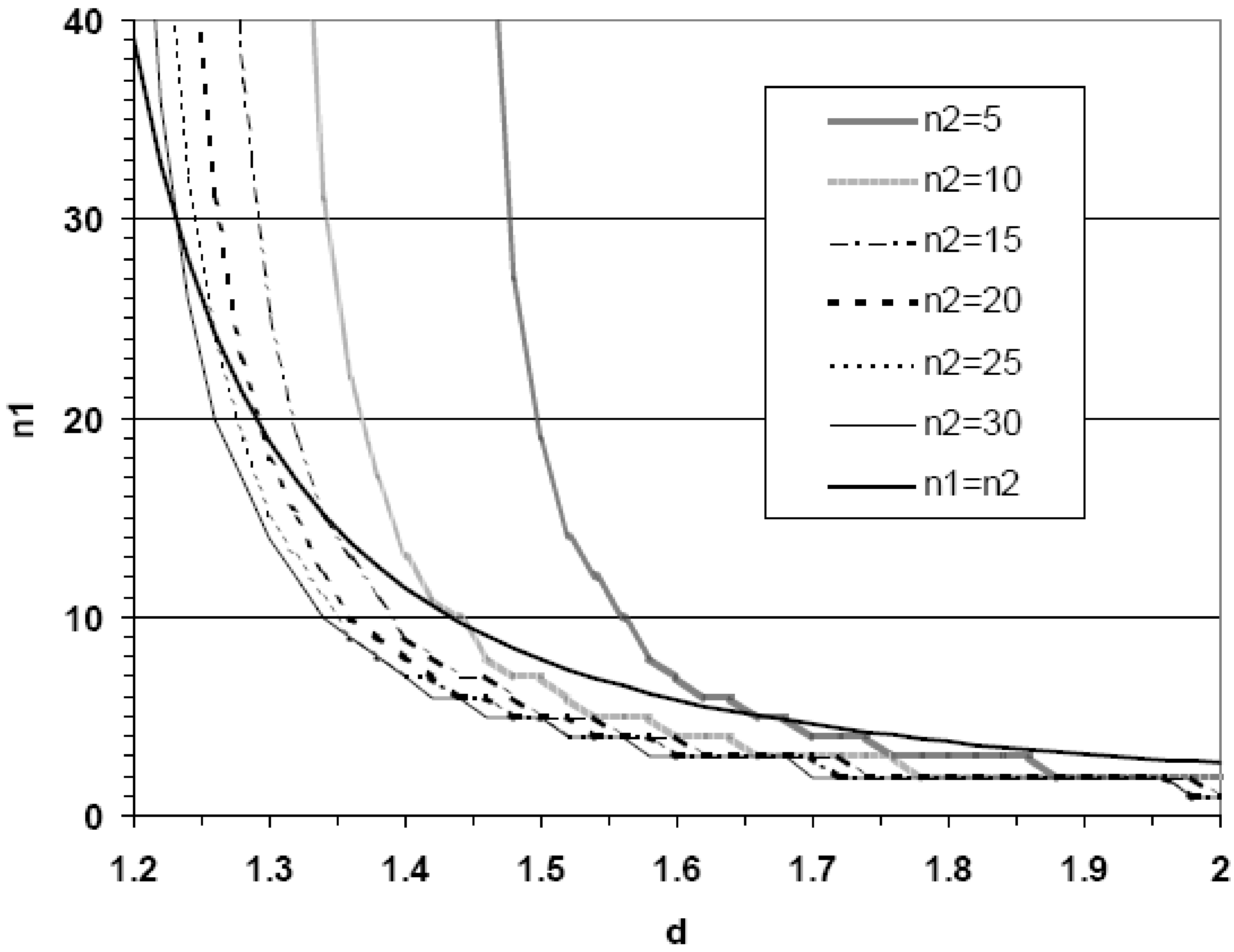
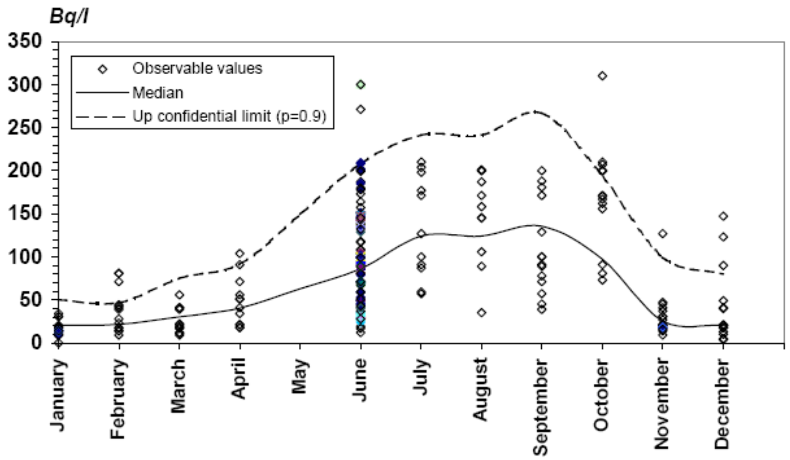
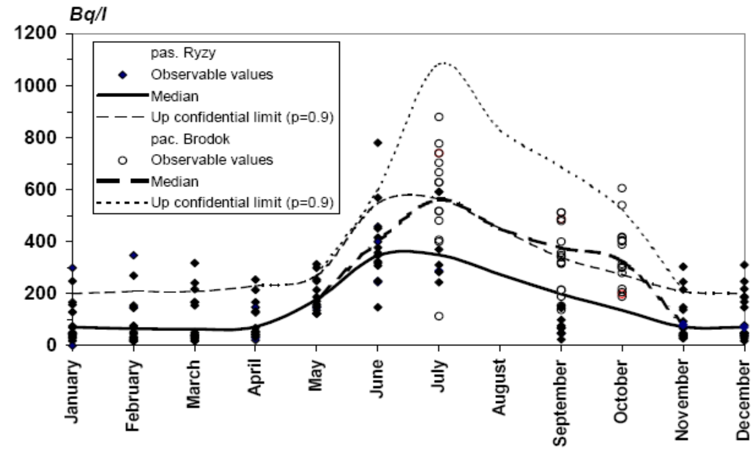
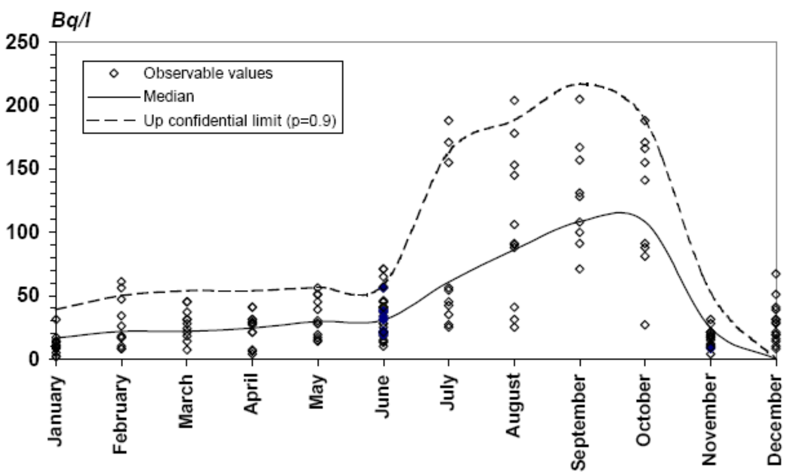


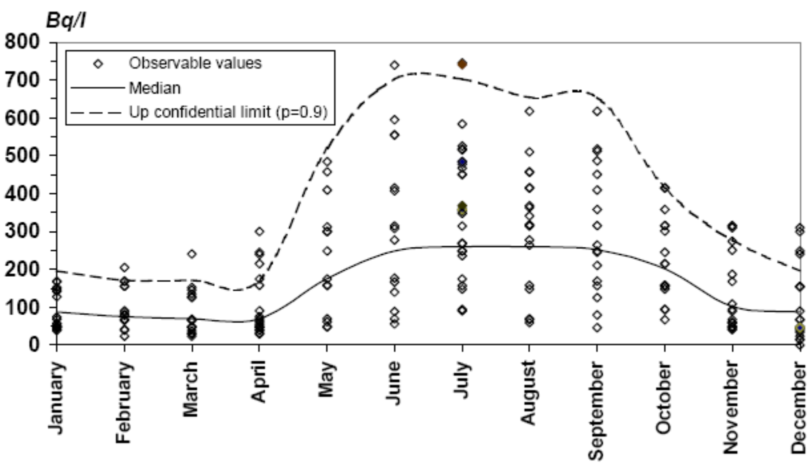
Fig. 6.4 – The nomograms to account minimum necessary amount of conjugate samples “soil – plant” to confirm the prescribed multiplicity of the ratio between transfer factors medians.

Statistical and temporary performances of milk contamination with ^{137}Cs in settlements









- **Annual dynamics of milk contamination with ^{137}Cs** in settlements

Annual dynamics of standard deviation of the log of milk contamination with ^{137}Cs in settlements

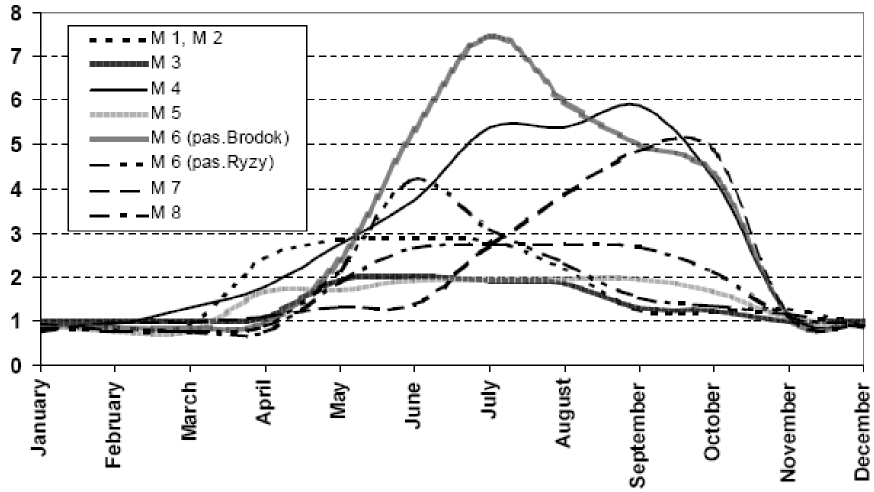


Fig. 4.6.- Multiplicity of milk contamination with ^{137}Cs increase in grazir comparing to stabling period in different settlements.

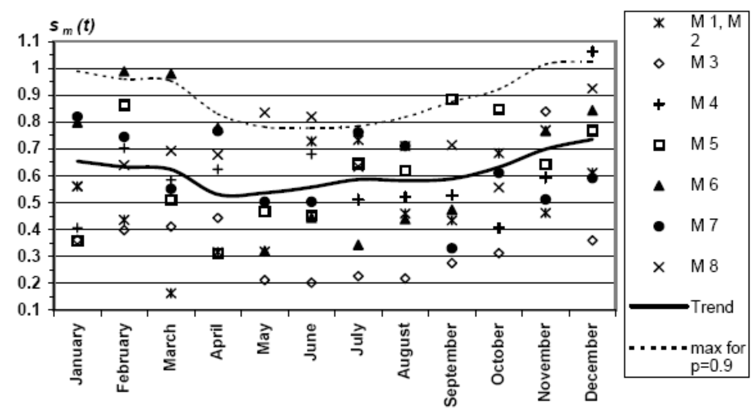
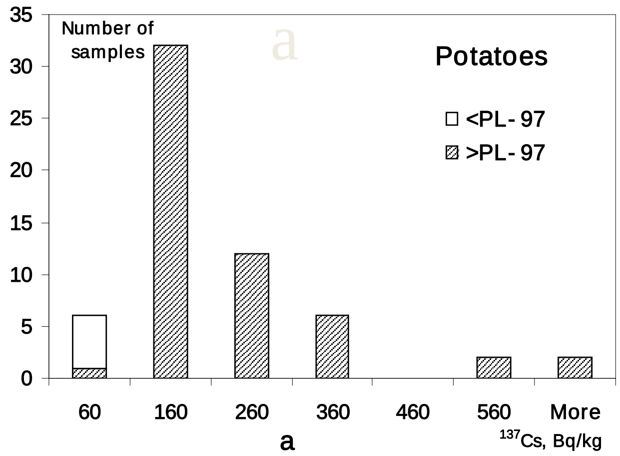
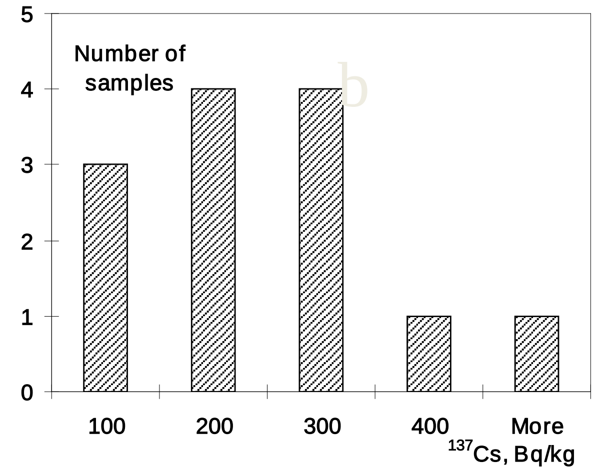


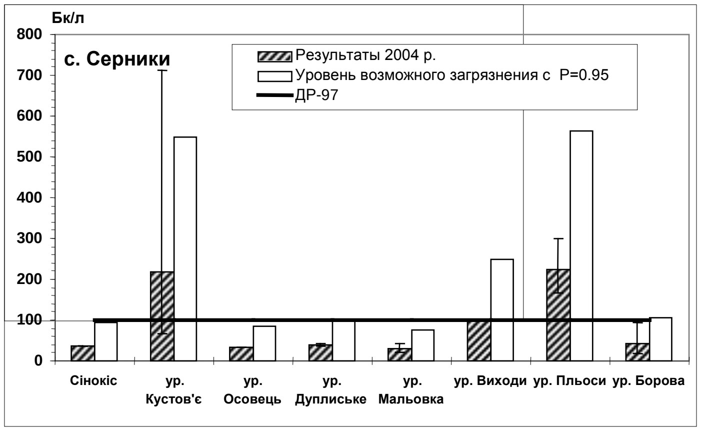
Fig. 4.7. - Annual dynamics of standard deviation of the log of milk contamination with ^{137}Cs in settlements.

Уточнить sampling of potato and milk in settlements for average internal dose estimations





Distribution of ^{137}Cs in potato in Yelne village for one family in a village (b)



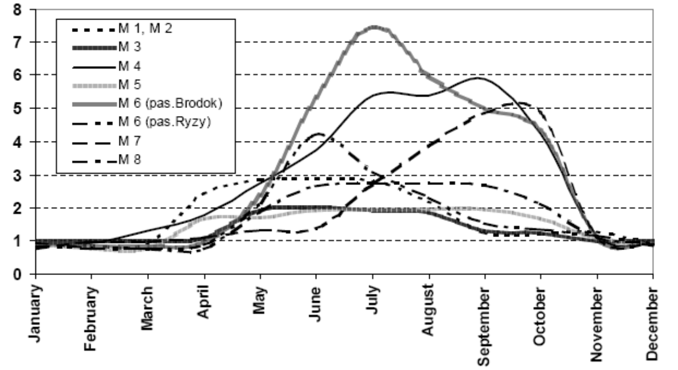
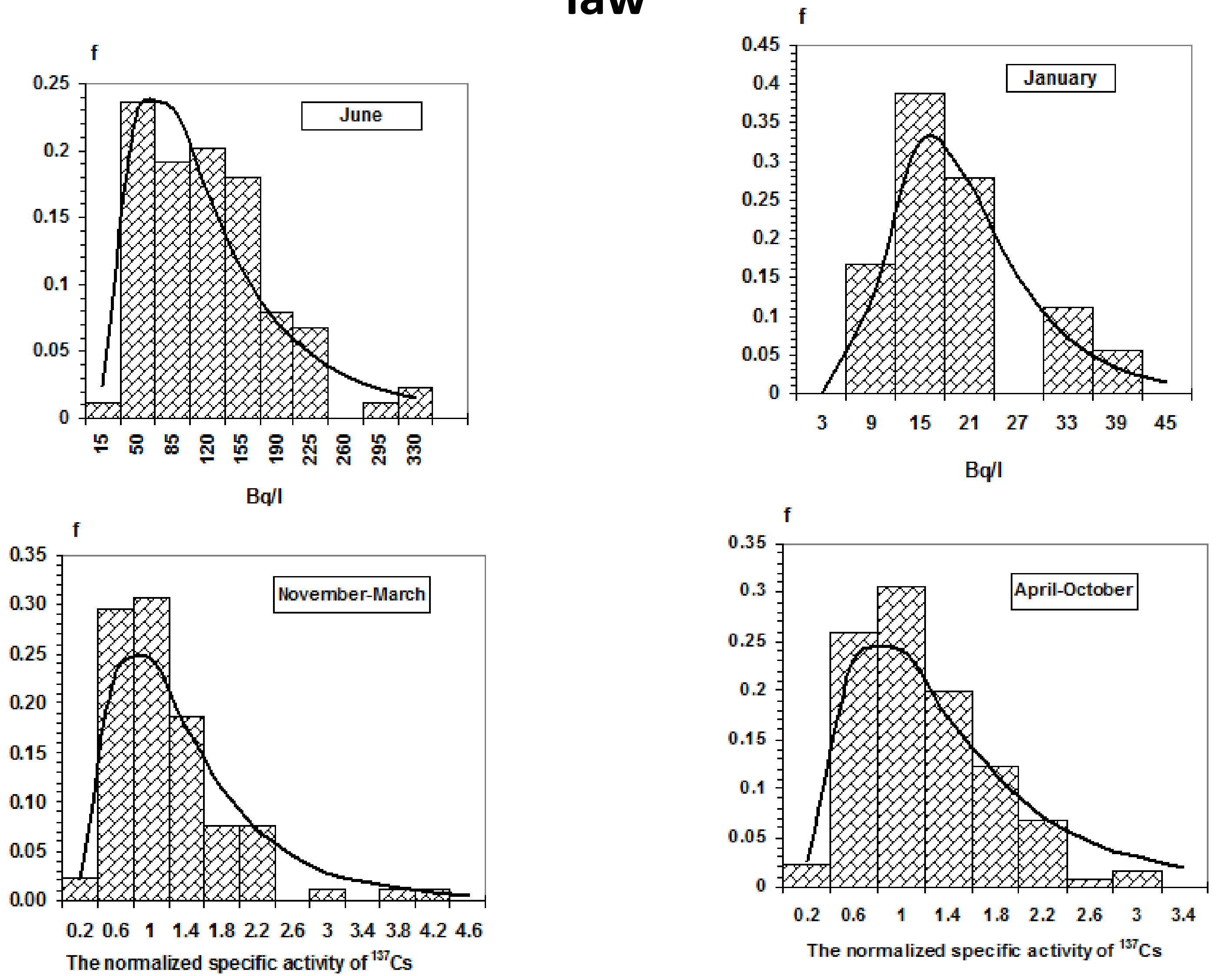


Fig. 4.6.- Multiplicity of milk contamination with ^{137}Cs increase in grazing period comparing to stabling period in different settlements.

^{137}Cs activity in milk of the cows of one village from different pastures

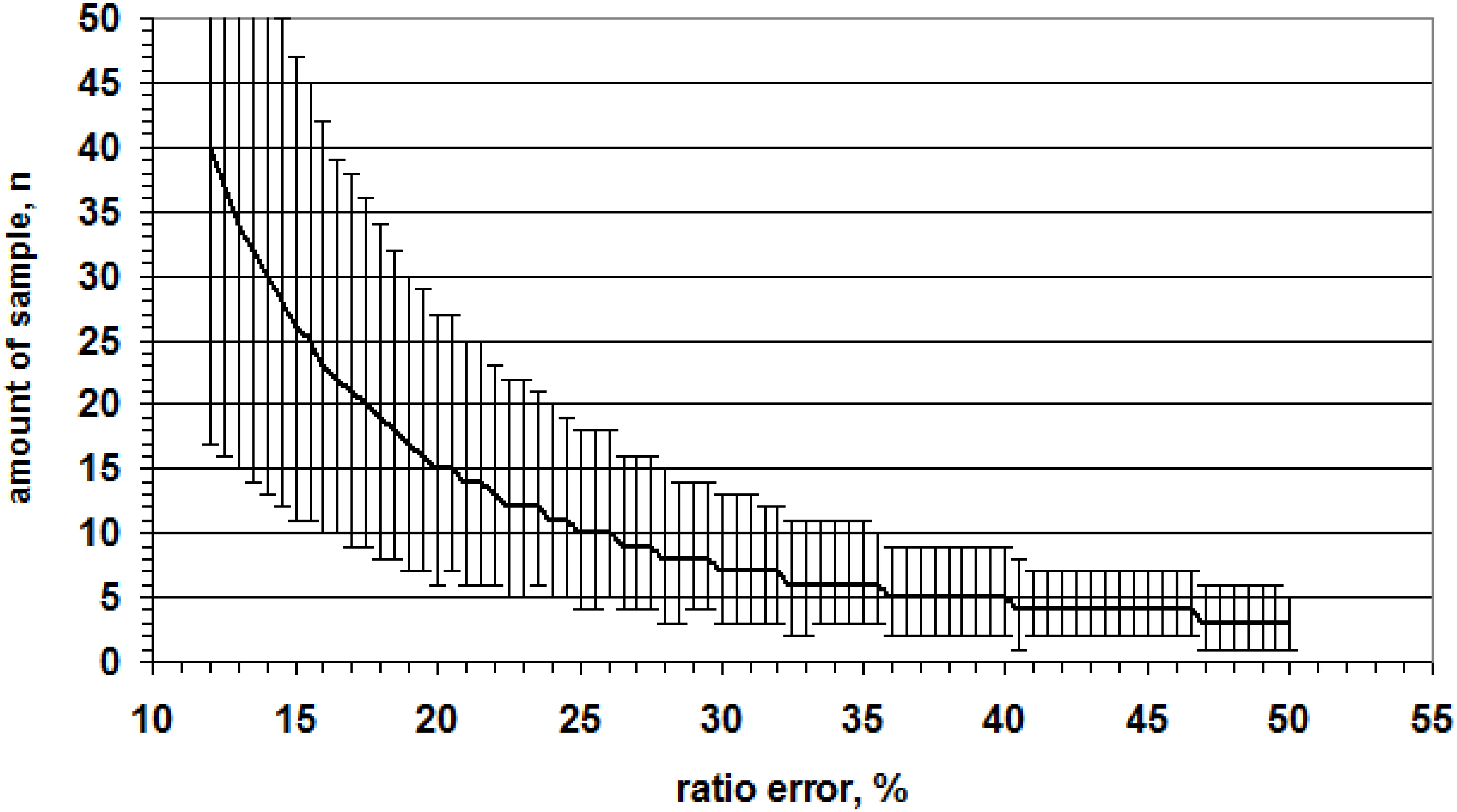
Histograms of milk contamination with ^{137}Cs for the site M4 in typical months of stabling and grazing periods and their approximation by the logarithmically normal law



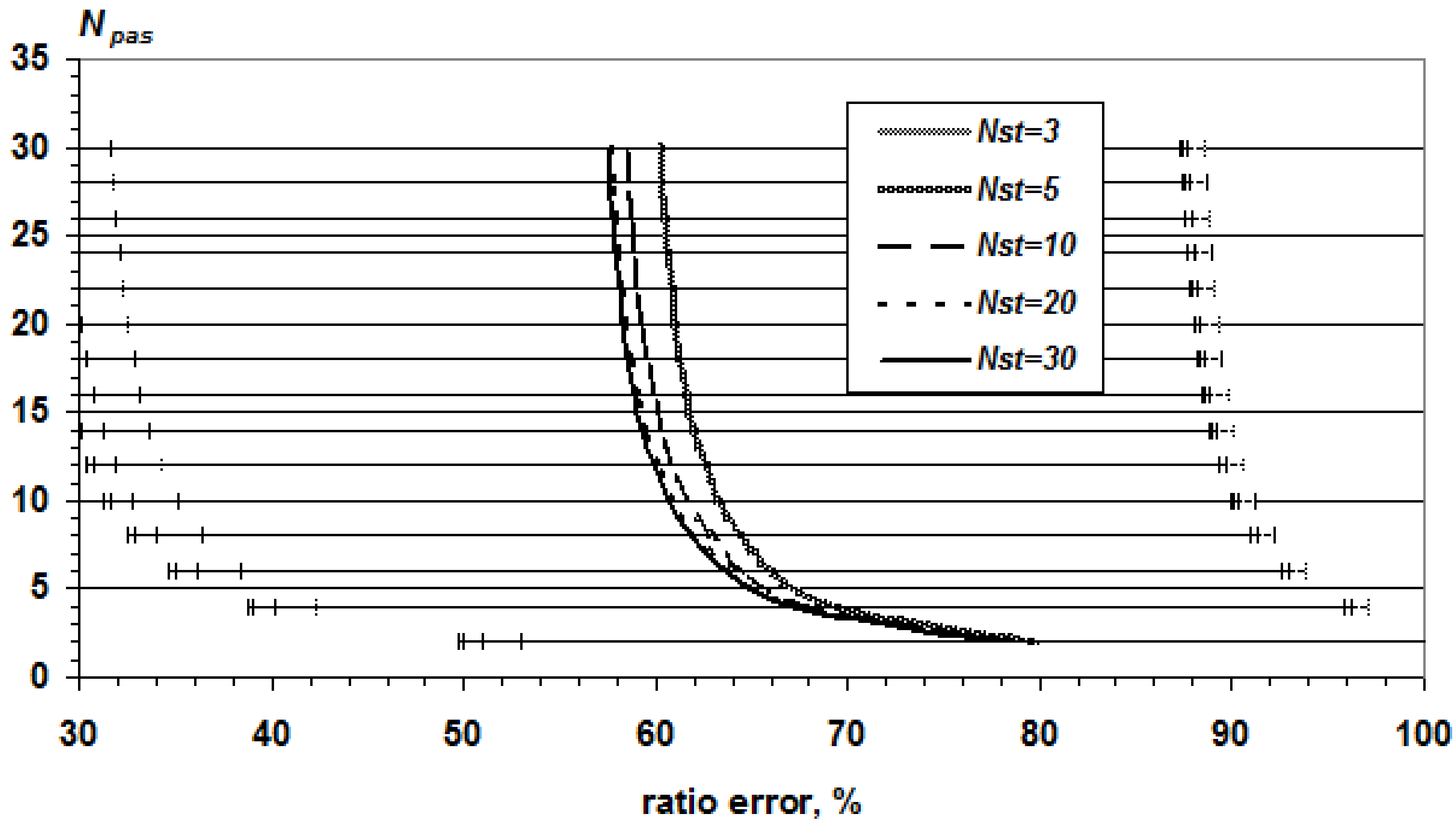
Statistical performances of standard deviation of the log of ^{137}Cs concentration in milk of PSF

Characteristics	standard deviation of the log of ^{137}Cs concentration in milk	
	Stabling period	Pastoral period
Average value	**0.67**	**0.56**
Standard deviation	*0.19*	*0.19*

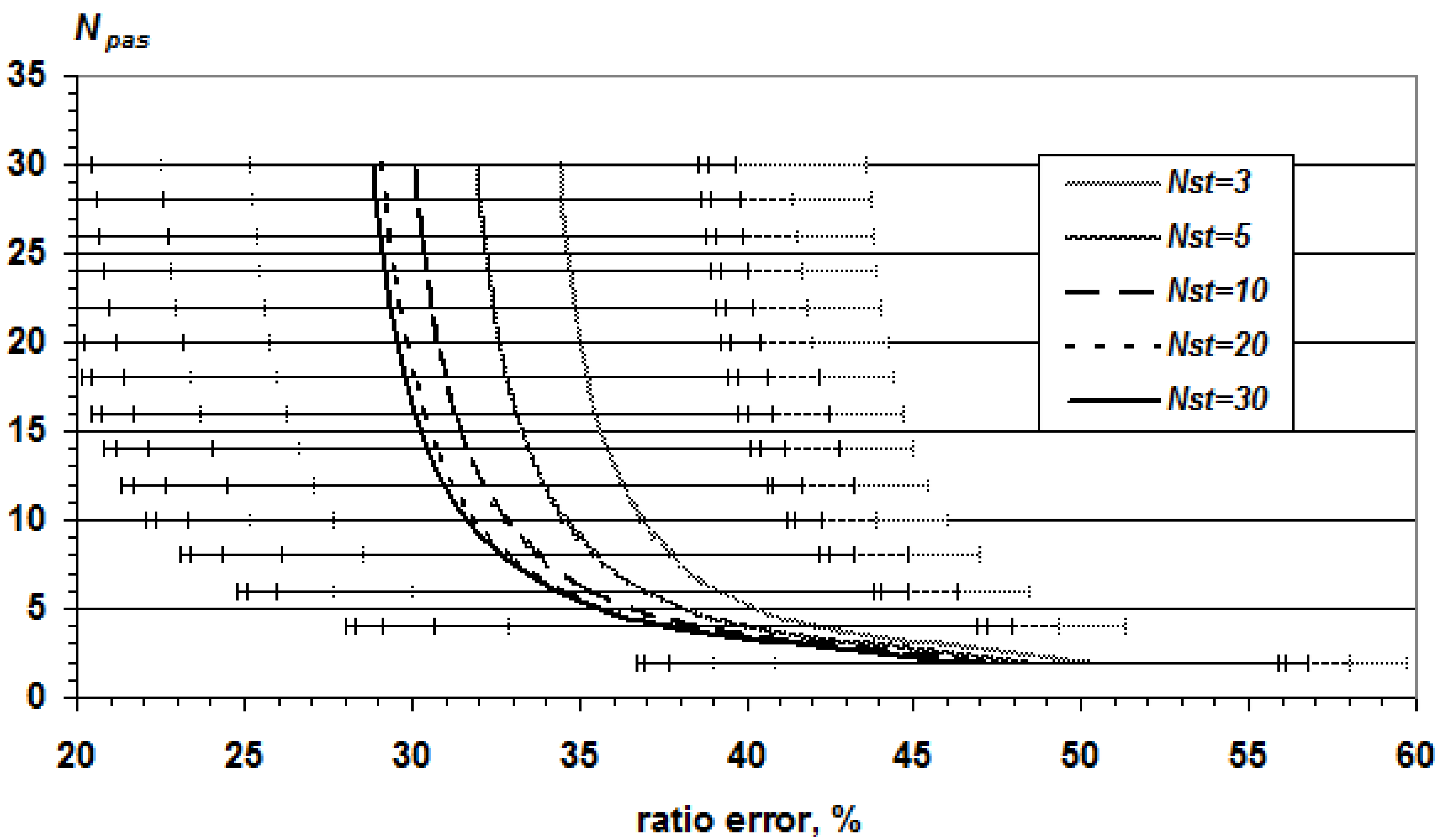
The nomogram to account minimum necessary amount of samples to evaluate the median of milk contamination with prescribed ratio error in the definite moment of grazing period when p=0.95 and δ_{meas} is no more than 15 % at the level ±2σ.



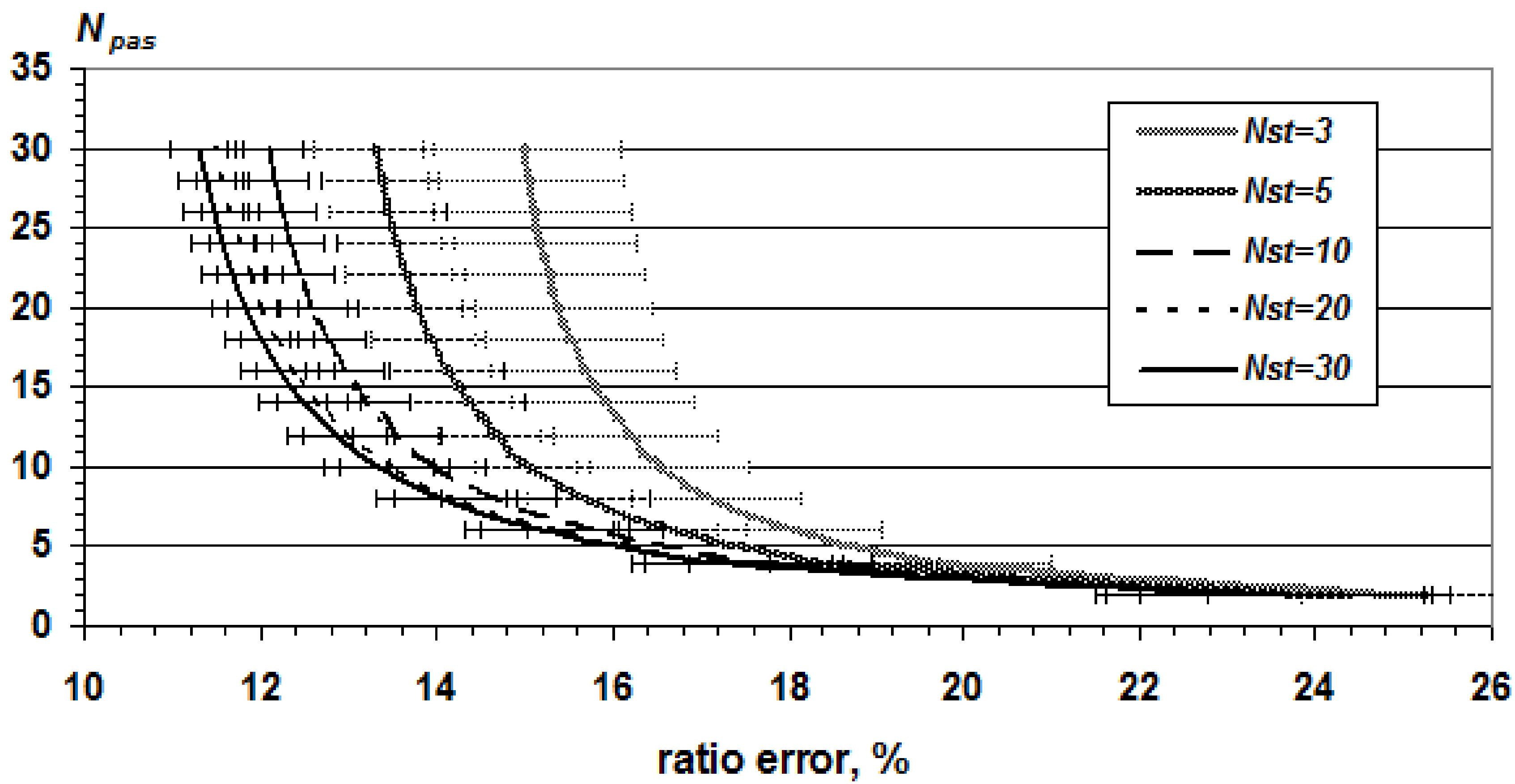
The nomogram to account minimum necessary amount of milk samples, that guarantee the prescribed ratio error to evaluate average annual individual doze of an internal exposure when sampling twice a year **(once in a stabling period and once in a grazing period)**



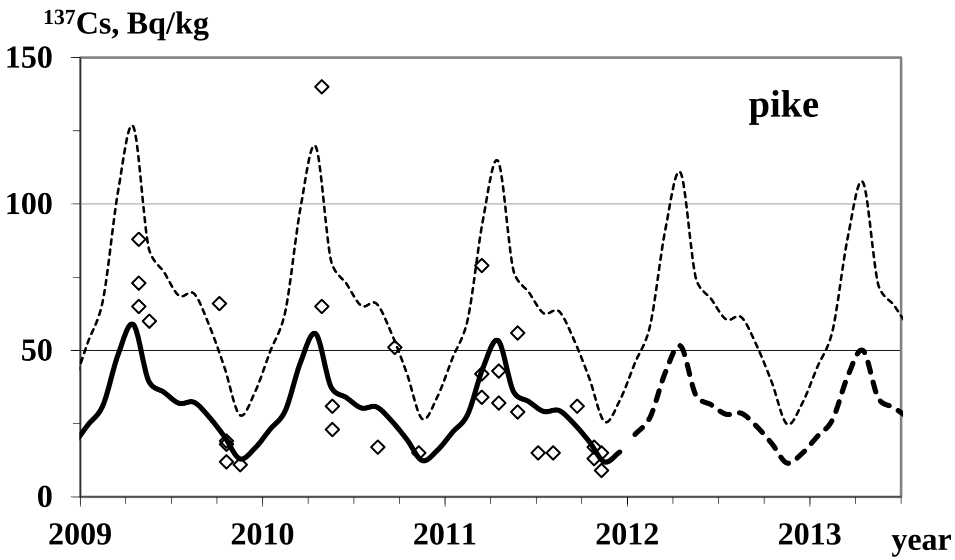
The nomogram to account minimum necessary amount of milk samples, that guarantee the prescribed ratio error to evaluate annual average individual doze of an internal exposure when sampling fourfold a year **(twice in stabling period and twice in grazing period).**

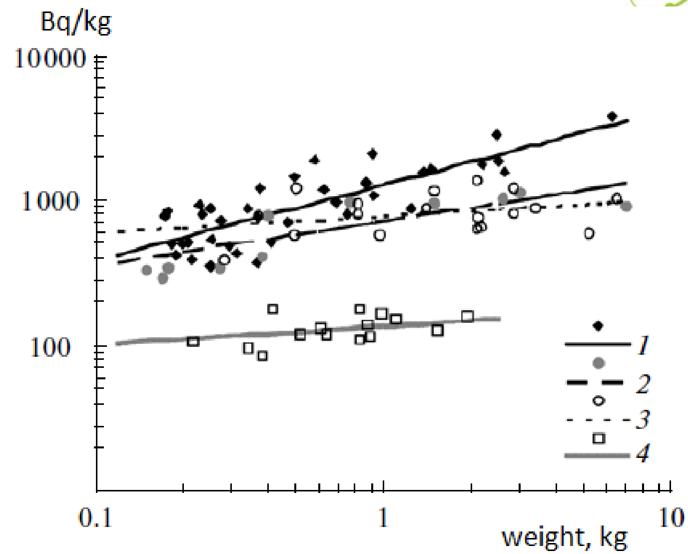


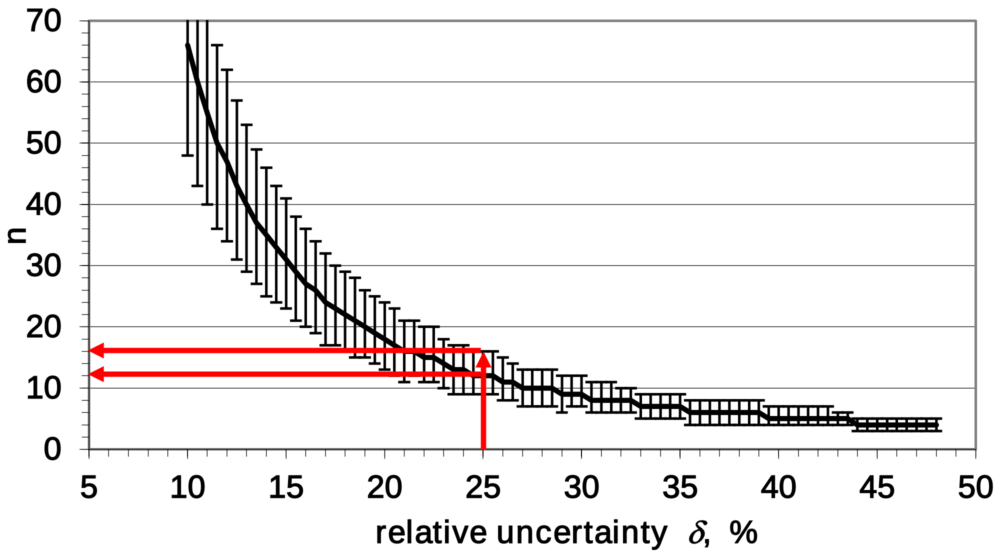
The nomogram to account minimum necessary amount of milk samples, which guarantee the prescribed ratio error, to evaluate average annual individual doze of an internal exposure when sampling during the year **(monthly).**

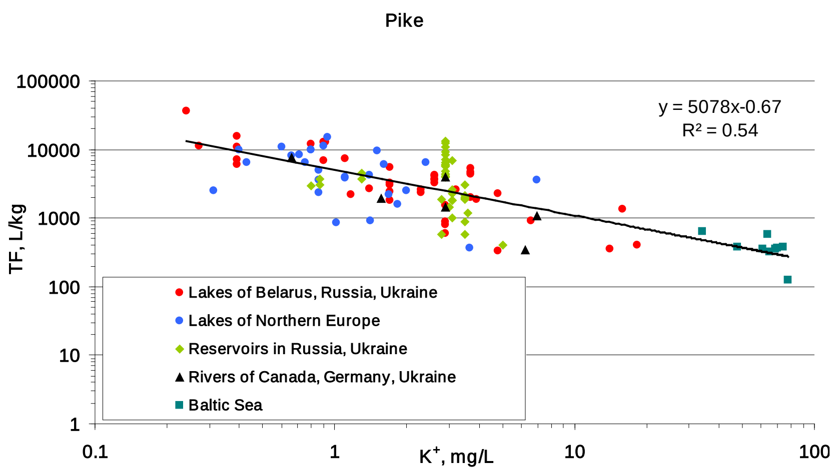


Optimization of fish sampling









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OPTIMIZATION OF FISH SAMPLING PROCEDURE FOR EVALUATING THE SPECIFIC ACTIVITY OF ^{137}Cs, ^{90}Sr AND ACCUMULATION COEFFICIENTS

Problem of optimization of sampling procedure for evaluating the median of specific activity and accumulation coefficients of the ^{137}Cs and ^{90}Sr for the populations of different species of fish lived in the pond was observed. Estimates of the geometric standard deviation of the specific activity (1.2 ÷ 1.9) and accumulation coefficients (1.8 ÷ 2.3) of radionuclides for different species of fish were obtained. Minimum number of samples required for evaluating the median of the specific activity and corresponding accumulation coefficients of ^{137}Cs and ^{90}Sr with desired relative error was determined. In order to obtain the median value of the specific activity of ^{137}Cs with relative error δ = 20 % and confidence level of p = 0.95 at the time of harvest the following numbers of fish samples should be selected for the activity measurement: 16 - 20 samples of pike, perch, sunder, rudd and grass carp; 10 - 13 samples of catfish, bream, tench, carassius, pelecus cultratus; 8-9 samples of bream, roach, carp(common carp), bighead carp; and 5 samples of chub.

Keywords: ^{137}Cs, ^{90}Sr, fish, specific activity, accumulation coefficients, Chornobyl accident.

Таблица 3. **Усредненные оценки геометрического стандартного отклонения GSD_{CF} коэффициентов накопления ^{137}Cs и ^{90}Sr для рыб различных видов**

Вид рыбы	^{137}Cs	Вид рыбы	^{90}Sr
Щука (*Esox lucius*)	2,01 ± 0,05	Щука (*Esox lucius*)	1,73 ± 0,06
Окунь, чехонь (*Perca fluviatilis, Pelecus cultratus*)	2,03 ± 0,05	Окунь, чехонь, судак, сом, налим (*Perca fluviatilis, Pelecus cultratus, Stizostedion lucioperca, Silurus glanis, Lota lota*)	2,10 ± 0,07
Судак (*Stizostedion lucioperca*)	2,01 ± 0,09	Лещ, густера, синец (*Abramis brama, Blicca bjoerkna, Ballerus ballerus*)	1,88 ± 0,07
Сом (*Silurus glanis*)	1,66 ± 0,08	Плотва, голавль, красноперка, язь (*Rutilus rutilus, Leuciscus cephalus, Scardinius erythrophthalmus, Leuciscus idus*)	2,18 ± 0,11
Лещ, густера, синец (*Abramis brama, Blicca bjoerkna, Ballerus ballerus*)	2,30 ± 0,08	Карп (сазан), линь, толстолобик (*Cyprinus carpio, Tinca tinca, Hypophthalmichthys molitrix*)	1,81 ± 0,07
Плотва, голавль, красноперка, язь, жерех (*Rutilus rutilus, Leuciscus cephalus, Scardinius erythrophthalmus, Leuciscus idus, Aspius aspius*)	1,82 ± 0,05	Карась, жерех, белый амур (*Carassius carassius, Aspius aspius, Ctenopharyngodon idella*)	2,21 ± 0,11
Карп (сазан), линь, толстолобик (*Cyprinus carpio, Tinca tinca, Hypophthalmichthys molitrix*)	1,88 ± 0,07		
Карась (*Carassius carassius*)	2,29 ± 0,10		
Налим (*Lota lota*)	1,88 ± 0,13		

Minimum number of samples required for evaluating the median of the specific activity and corresponding accumulation coefficients of 137Cs and 90Sr with desired relative error was determined. In order to obtain the median value of the specific activity of 137Cs with relative error □= 20 % and confi-dence level of p = 0.95 at the time of harvest the following numbers of fish samples should be selected for the activity measurement: 16 - 20 samples of pike, perch, sunder, rudd and grass carp; 10 - 13 samples of catfish, bream, tench, carassius, pelecus cultratus; 8-9 samples of bream, roach, carp(common carp), bighead carp; and 5 samples of chub.

Таблица 4. **Минимально необходимое число проб рыбы (n_0), которое необходимо отобрать, для измерения и оценки медианы удельной активности ^{137}Cs(^{90}Sr) популяции рыб в водоеме с требуемой относительной погрешностью δ = 20 % при доверительной вероятности *p* = 0,95**

Вид рыбы	Оценка медианы в момент вылова				Среднегодовая оценка медианы			
	^{137}Cs		^{90}Sr		^{137}Cs		^{90}Sr	
	$\delta_f = 20$ %	$\delta_f = 50$ %	$\delta_f = 20$ %	$\delta_f = 50$ %	$\delta_f = 20$ %	$\delta_f = 50$ %	$\delta_f = 20$ %	$\delta_f = 50$ %
Щука (*Esox lucius*)	20	35	17	32	36	51	33	48
Окунь (*Perca fluviatilis*)	17	32	10	26	30	45	11	26
Судак (*Stizostedion lucioperca*)	17	32	12	27	22	37	16	31
Сом (*Silurus glanis*)	13	28	18	33	28	43	22	37
Лещ (*Abramis brama*)	9	24	13	29	14	30	21	36
Густера (*Blicca bjoerkna*)	8	24	9	24	12	27	12	27
Плотва (*Rutilus rutilus*)	9	24	10	25	12	27	18	33
Красноперка (*Scardinius erythrophthalmus*)	16	31	5	20	24	39	7	22
Линь (*Tinca tinca*)	9	24	10	25	18	33	14	30
Карась (*Carassius carassius*)	10	25	26	41	19	34	54	70
Сазан, карп (*Cyprinus carpio*)	8	24	12	27	29	44	23	38
Толстолобик (*Hypophthalmichthys molitrix*)	7	22	17	32				
Белый амур (*Ctenopharyngodon idella*)	20	35	16	31				
Чехонь (*Pelecus cultratus*)	18	33	5	20	18	33	5	20
Голавль (*Leuciscus cephalus*)	5	20			9	24	8	24

Our institute has developed the special standards for the Agricultural Ministry of Ukraine

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МЕТОДИ ВІДБОРУ ПРОБ ҐРУНТУ ДЛЯ РАДІАЦІЙНОГО КОНТРОЛЮ

СОУ 74.14-37-425:2006

Видання офіційне

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ЯКІСТЬ ҐРУНТУ.
ВИЗНАЧЕННЯ ЩІЛЬНОСТІ ЗАБРУДНЕННЯ ТЕРИТОРІЇ СІЛЬСЬКОГОСПОДАРСЬКИХ УГІДЬ РАДІОНУКЛІДАМИ ТЕХНОГЕННОГО ПОХОДЖЕННЯ

СОУ 74.14-37-424:2006

Видання офіційне

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МЕТОДИ ВІДБОРУ ПРОБ ДЛЯ РАДІАЦІЙНОГО КОНТРОЛЮ

СОУ 01.1-37-426:2006

Видання офіційне

Київ
МІНАГРОПОЛІТИКИ УКРАЇНИ

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ЯКІСТЬ ПРОДУКЦІЇ ТВАРИННИЦТВА.
МЕТОДИ ВІДБОРУ ПРОБ ДЛЯ РАДІАЦІЙНОГО КОНТРОЛЮ

СОУ 01.2-37-427:2006

Видання офіційне

Київ
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IAEA
Guidelines on soil and vegetation sampling for radiological monitoring purposes

U. Barnekov, S. Fesenko, V. Kashparov, G. Kis-Benedek, G. Matissov, Yu. Onda, N. Sanzharova, A. Tyler, B. Varga

FOREWORD

The IAEA attaches high importance to the dissemination of information that can assist Member States with the development, implementation, maintenance and continuous improvement of environmental radiological monitoring systems, including the development and implementation of optimized sampling programs for radioactivity. In particular, the IAEA TECDOC 1415 "Soil sampling for Environmental Contaminants" was published in 2004. However, the document was limited to soil sampling only and did not provided any guidelines for taking samples other than of soil.

Since the publication of the IAEA TECDOC 1415 a number of international documents, such as the ICRU 75 report and ISO documents on soil and vegetation sampling were published. In 2010, the IAEA published Safety Reports Series document No. 64 "Programmes and Systems for Source and Environmental Radiation Monitoring", which provides information on practical considerations affecting the design and operation of monitoring programmes and systems in accordance with the relevant IAEA Safety Standards. The intended audience includes national regulatory bodies and other agencies and organizations involved in the design and operation of source and environmental radiation monitoring programmes and systems; and experts involved in the assessments of public exposure based on radiological monitoring data. However, practical application of this Safety Report requires support from a series of accompanying documents that serve as practical guidelines on sampling programmes for soil and vegetation. Therefore, in 2013 the IAEA initiated an update of the IAEA TECDOC 1415 "Soil sampling for Environmental Contaminants" extending the scope of the document to include vegetation sampling.

Дякую за увагу

Thank you very much for your attention