Decontamination tests in the recreational areas affected by the Chernobyl accident: efficiency of decontamination and long-term stability of the effects

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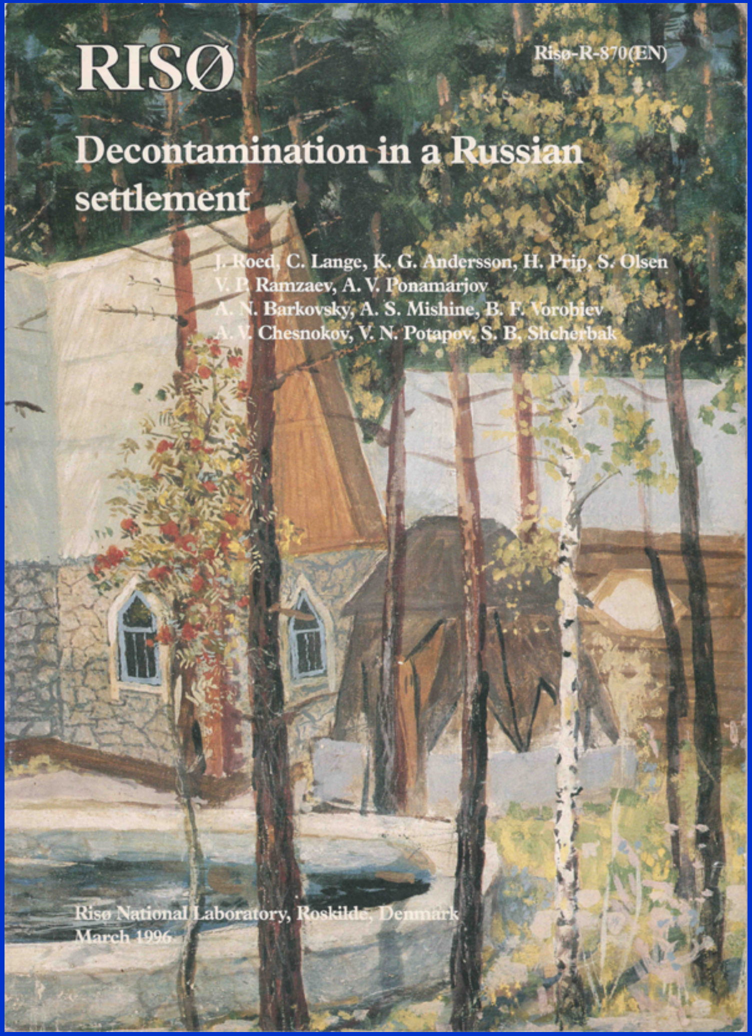
The presentation is based on the results of two large-scale experiments carried out by the Danish-Russian group of researches in the Bryansk region in Russia in 1995 and 1997 and the long-term monitoring (1995-2012) of the decontaminated and untreated areas.



The main results of the study are published in:

- Roed, J., Lange, C.L., Andersson, K.G., Prip, H., Olsen, S., Ramzaev, V., Ponomarev, A., Barkovsky, A., Mishine, A., Vorobiev, B., Chesnokov, A., Potapov, V., Shcherbak, S., 1996. Decontamination in a Russian settlement. RISØ National Laboratory report Risø-R-870 (EN). RISØ National Laboratory, Roskilde, Denmark.

- Roed, J., Andersson, K.G., Barkovsky, A., Fogh, C.L., Mishine, A., Olsen, S., Ponomarev, A., Prip, H.,Ramzaev, V., Vorobiev, B., 1998. Mechanical decontamination tests in areas affected by the Chernobyl accident. RISØ National Laboratory report Risø -R-1029 (EN). RISØ National Laboratory, Roskilde,Denmark.

- Roed, J., Andersson, K.G., Barkovski, A.N., Vorobiev, B.F., Potapov, V.N., Chesnokov, A.V., 1999.Triple digging - a simple method for restoration of radioactively contaminated urban soil areas. J. Environ. Radioact. 45, 173-183.

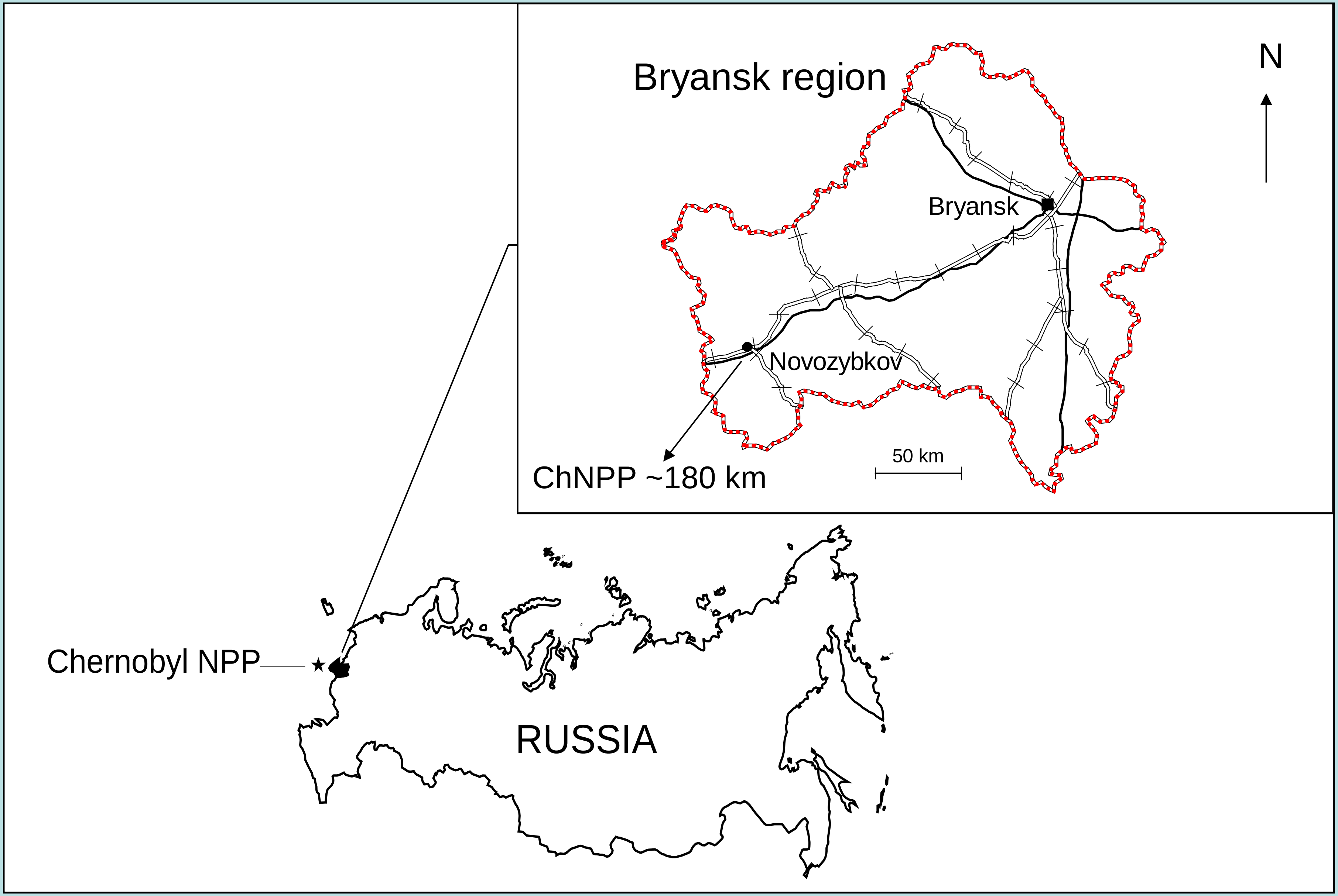
- Fogh, C.L., Andersson, K.G., Barkovsky, A.N., Mishine, A.S., Ponomarev, A.V., Ramzaev, V., Roed, J., 1999. Decontamination in a Russian settlement. Health Phys., 76, 421-430.

- Roed, J., Andersson, K.G., Barkovsky, A.N., Fogh, C.L., Mishine, A.S., Ponomarev, A.V., Ramzaev,V.P., 2006. Reduction of external dose in a wet-contaminated housing area in the Bryansk Region, Russia. J. Environ. Radioact., 85 , 265-279.

- Ramzaev, V., Andersson, K.G, Barkovsky, A, Fogh, C.L., Mishine, A., Roed, J., 2006. Long-term stability of decontamination effect in recreational areas near the town Novozybkov, Bryansk Region, Russia. J. Environ. Radioact., 85 , 280-298.

- Ramzaev, V., Barkovsky, A., Mishine, A., Vorobiev, B., Andersson, K.G. 2008. Implementation of mechanical decontamination for reduction of external exposure at the territory of the Bryansk region. Radiation Hygiene, Vol. 1, No. 2, 23-27 (in Russian).

Location of the Novozybkov district in the Bryansk region, Russia



Site description and objectives of the work

- The so-called ‘recreational areas’ Muravinka (52.48°N 31.78°E) and Novie Bobovichi (52.65°N 31.75°E) belong to enterprises in the town of Novozybkov, about 180 km north-east of the Chernobyl nuclear power plant. The average initial level of the ^{137}Cs ground contamination in the city had been 700 kBq/m^2 The study area geographically belongs to the so-called Belarus-Bryansk Polessie with the prevalence of sandy and sandy-loam types of turf-podzol soil.

- The recreational areas, which consisted of sets of wooden and brick summer houses in forest-grassland surroundings, were heavily contaminated by the Chernobyl fallout. Before the intervention began, absorbed gamma-dose rates in air in the area were 850$\pm$90 nGy/h (outdoor) and 390 $\pm$ 30 nGy/h (indoor) in Novie Bobovichi (1995), whereas they were 1000 $\pm$ 90 nGy/h (outdoor) and 430 $\pm$ 30 nGy/h (indoor) in Muravinka (1997).

- It was the objective of this work to examine the possibilities for reducing the external doses by decontamination in the remote period (~ 10 years) after the accident. In order to study the long-term stability of the applied clean-up procedures, a program of complex monitoring of the treated areas and the surrounding untreated areas has been carried out.

Typical one-storey wooden houses and an asphalted area in Novie Bobovichi.

Pine *(Pinus sylvestris)* is the dominant species of the trees.

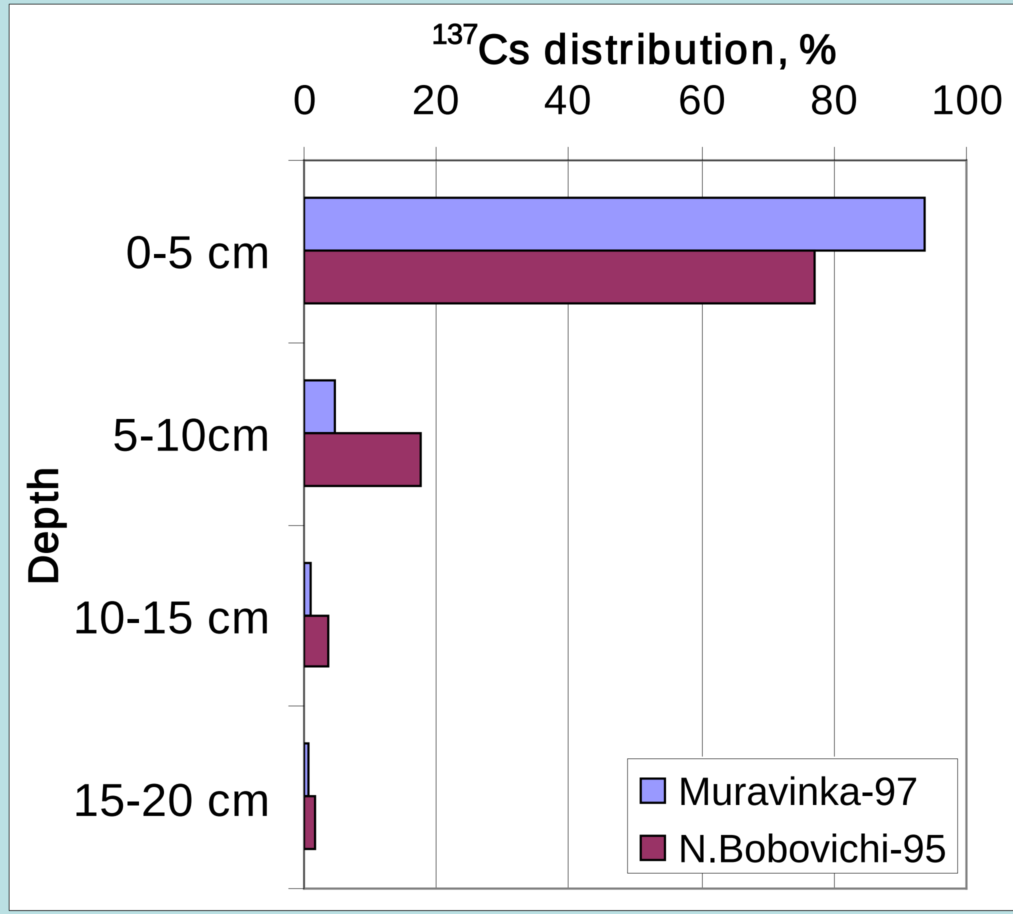
Typical two-storey house in Muravinka. The house is surrounded by pine-trees and leafy plants

^{137}Cs inventory (kBq/m^2) in soil and on (in) roofs in Muravinka (1997 y) and N.Bobovichi (1995 y) before intervention

Area	^{137}Cs inventory, kBq/m^2	
	Soil	Roof (asbestos-cement sheets)
N.Bobovichi	990±320 (10)	153±74 (3)
Muravinka	1250±360 (10)	144±36 (16)

Number of samples are given in brackets.

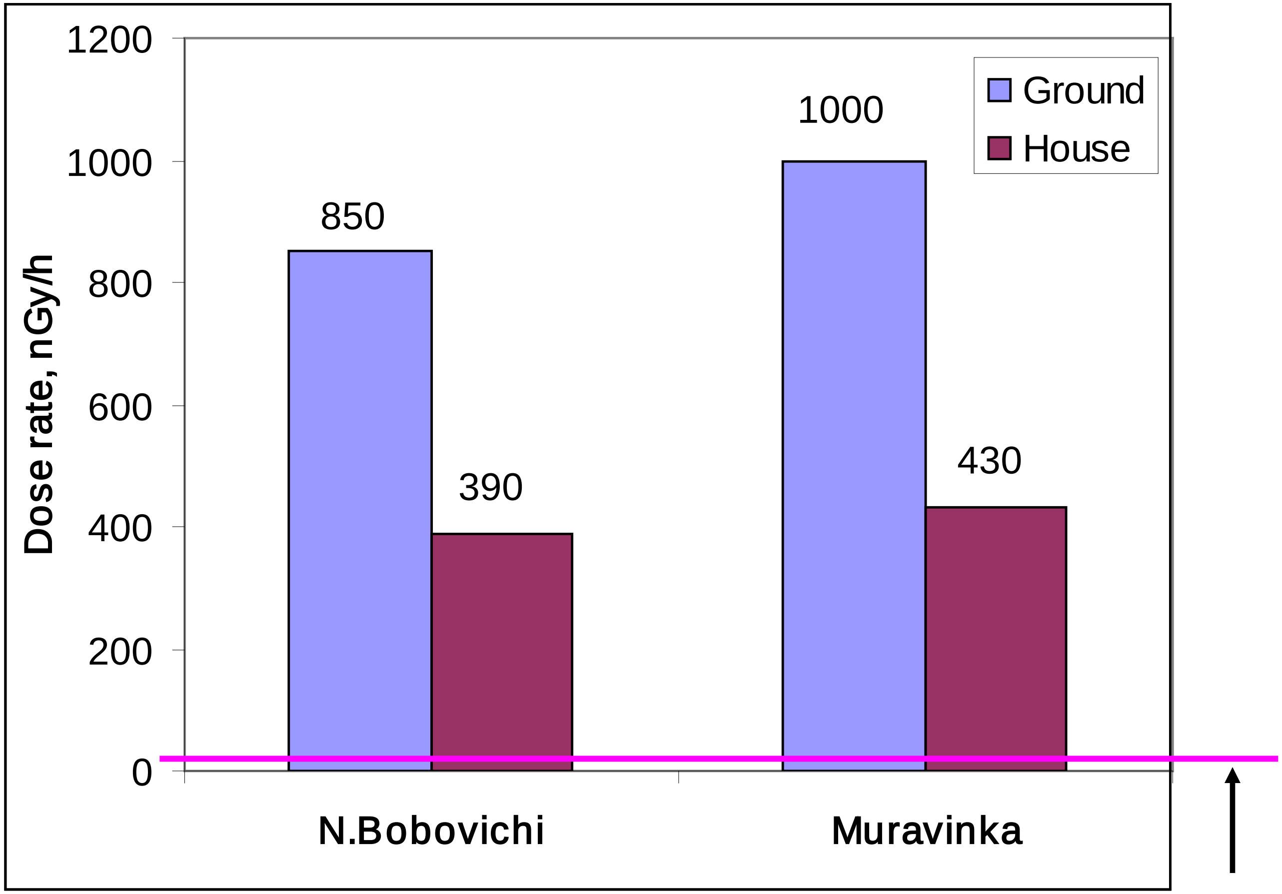
20 cm soil core from an untreated plot and the ^{137}Cs activity vertical distribution (in %) before intervention



^{137}Cs vertical distribution on the roof of the wooden house 5 in N.Bobovichi before intervention

- **Total inventory -170 kBq/m^2**
- **Organic matter – 71%**
- **Asbestos-cement sheet - 29%**

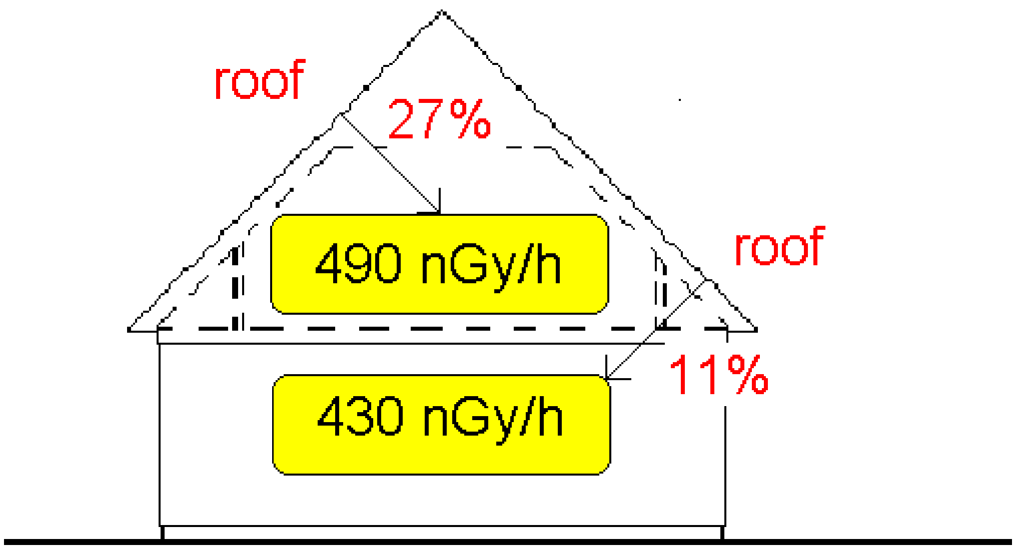
Absorbed gamma-dose rate (nGy/h) in air at
a height of 1 m above ground surfaces and
inside wooden houses (ground floor) before intervention



Natural radionuclides (16-25 nGy/h)

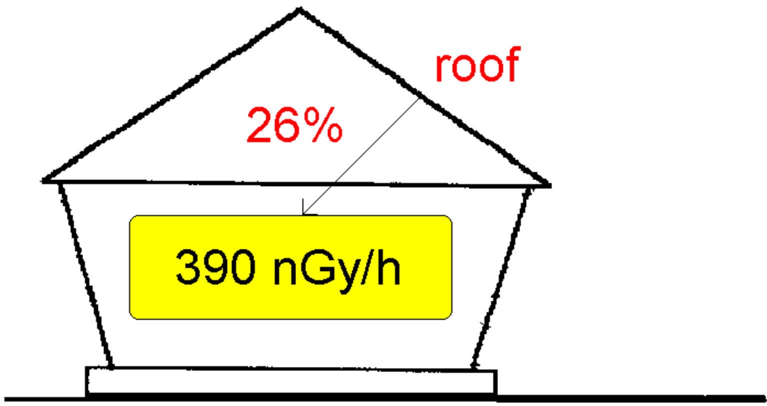
Contribution of roof contamination
to the Chernobyl-related dose rate (DR) indoor
before intervention

Muravinka, 1997



DR outdoor (ground) = 1000 nGy/h

N.Bobovichi, 1995



DR outdoor (ground) = 850 nGy/h

Decontamination activities and radiation monitoring

The decontamination activities included:

- (a) removal of a topsoil layer around three houses at each place (270 m^2 in Novie Bobovichi and 2000 m^2 in Muravinka); only hand-tools (e.g., spades, shovels, wheelbarrows...) were used in Novie Bobovichi, while in Muravinka, common contractor machinery (a ‘Bobcat’ mini-bulldozer) was used as the main device.
- (b) addition of uncontaminated sand;
- (c) decontamination or renewal of roofs of four houses;
- (d) decontamination of an asphalted area.

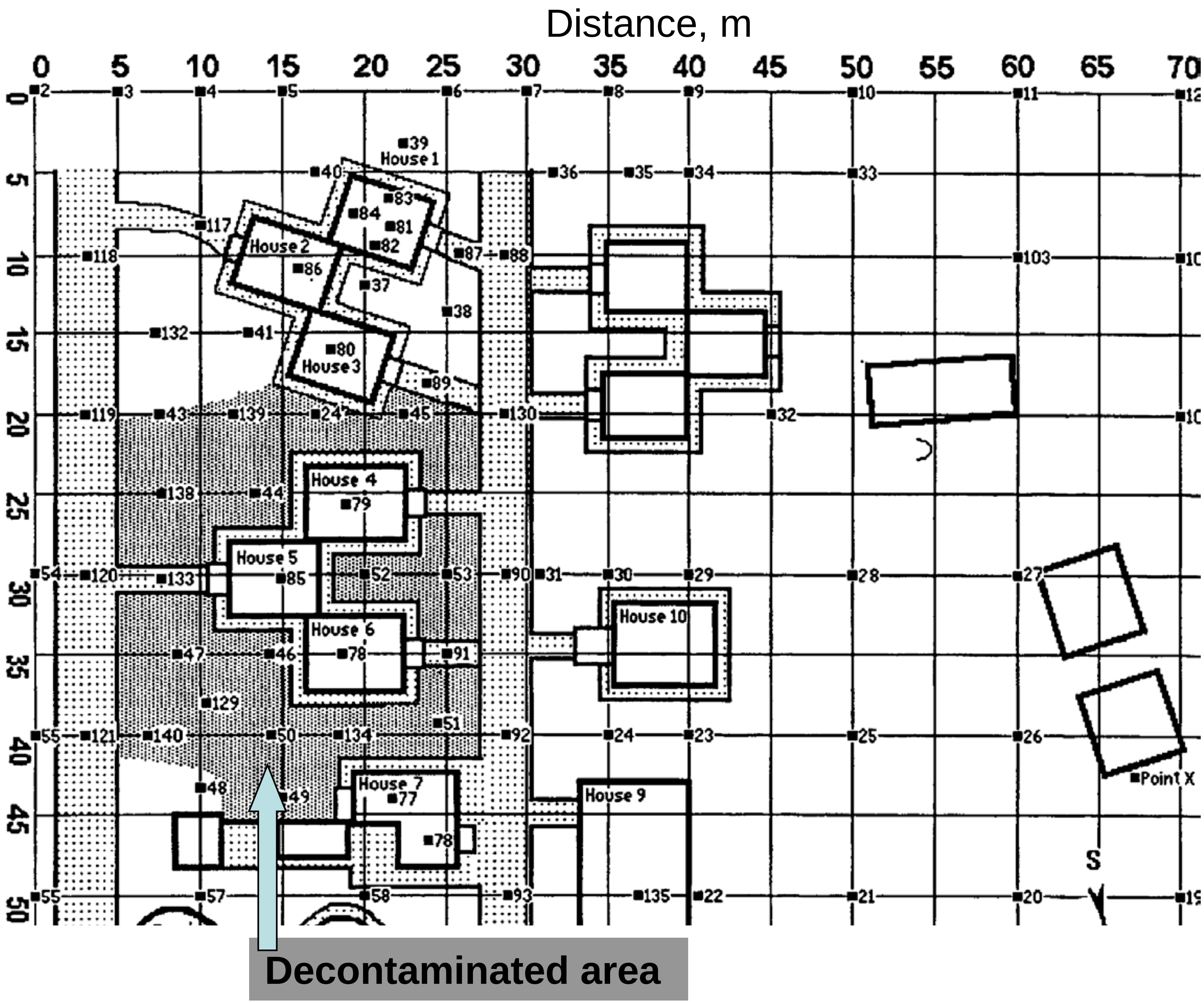
- In Novie Bobovichi, the generated wastes were collected for permanent storage in unfinished foundations of two houses located near the decontaminated plots. In Muravinka, the wastes were buried in eight holes dug by an excavator in the ground of those plots, which had already been decontaminated.

- Special attention was paid to avoid significant mechanical damage of major roots of the trees in the treated areas.

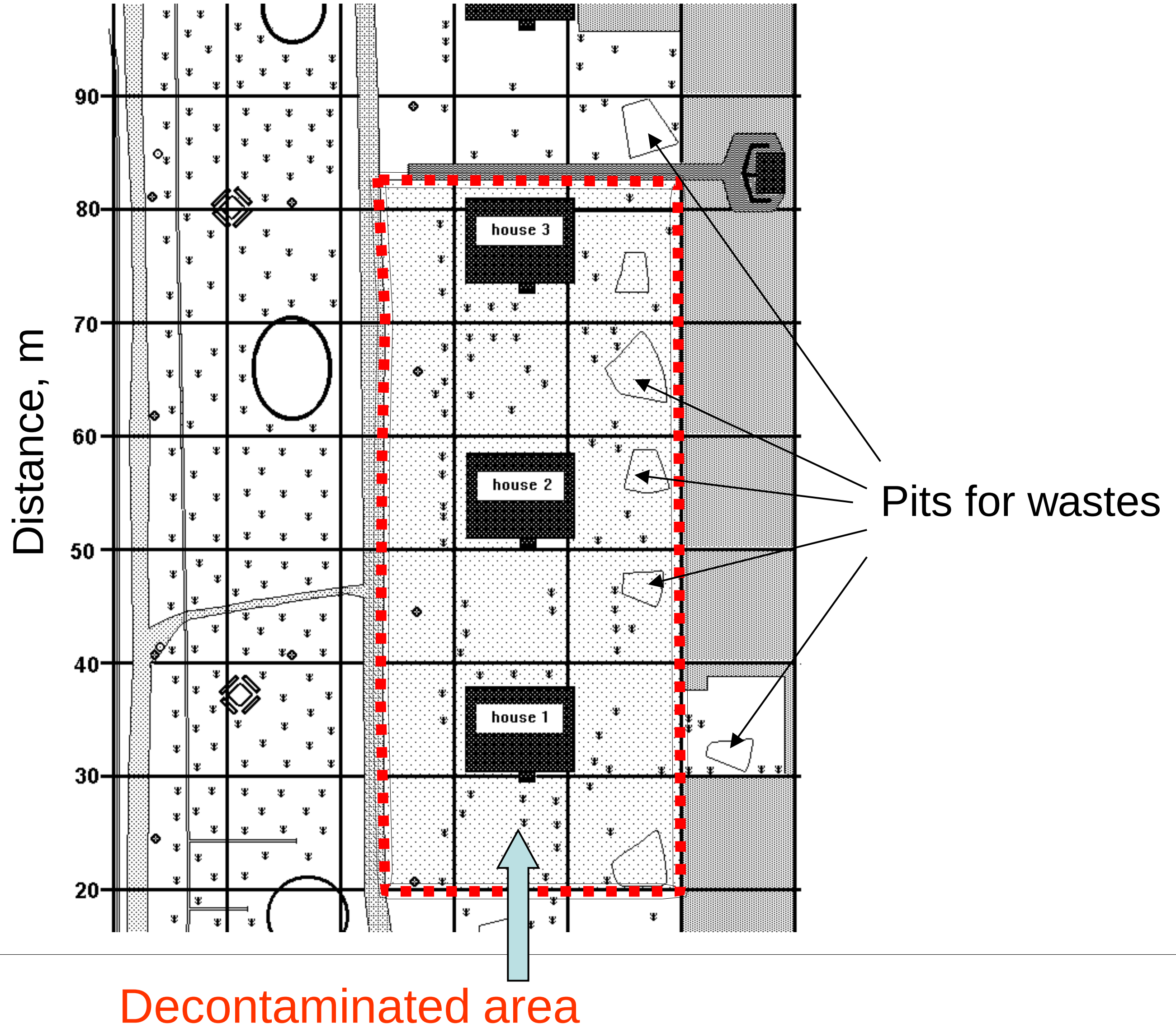
- The efficiency of each technological stage was carefully monitored with gamma-dose rate meters. Semiconductor (HP-Ge) and scintillating (NaI (Tl)) collimated and non-collimated detectors were implemented to measure the activities of ^{137}Cs and ^{134}Cs in samples and to evaluate fluences of the primary photons in air.

- For periodical (1-2 times per a year) radiation monitoring of decontaminated and untreated sites, reference points have been selected.

Plan of the recreational area “Novie Bobovichi”



Plan of the recreational area "Muravinka"



Muravinka, house No.1 and its surroundings
9 months after the intervention (May 1998).
The decontaminated ground plot looks like a beach.
New asbestos-cement sheets cover the roof.

Decontamination efficiency. Terminology:

- **Dose rate (DR) reduction factor** =
  (DR after decontamination)/
  (DR before decontamination);
- for a successful intervention it is <1.

- **Decontamination factor** =
  (surface contamination before decontamination)/
  (surface contamination after decontamination);
- for a successful intervention it is >1.

Decontamination efficiency. Results:

Area, location	**Decontamination factor**	**Dose rate reduction factor***
N.Bobovichi, outdoor, soil surfaces	~4	0.20
Muravinka, outdoor, soil surfaces	~8	0.17
N.Bobovichi, indoor wooden house	3-(>1000)**	0.34
Muravinka, indoor ground floor	>1000 **	0.31

*- from soil+roof

** - decontamination factor for roofs

Main tasks of the post-interventional monitoring

performed at the areas understudy:

- to estimate a capacity of the disturbed semi-natural ecosystems to recover after the mechanical impact;

- to follow up a stability of the achieved efficiency with respect of external exposure for a time period of several years;

- to study an accumulation of radiocesium by plants and fungi from the treated and control areas.

Muravinka, decontaminated plot in October 1998. A lot of fresh newly formed litter on the ground.

Young fruit bodies of fungi *Amanita muscaria* at undisturbed and treated plots in Muravinka, October 2002

Treated plot

Untreated plot

Ecosystems recovery in Novie Bobovichi after decontamination

Formation of new forest litter
under pine trees on
the decontaminated plot, April 2002.

Formation of new grass cover on
an opened part of
the decontaminated plot, June 2001.

Novie Bobovichi.
The decontaminated plot in October 2002.
Newly formed forest litter and edible fungi.

Suillus sp.

Russula sp.

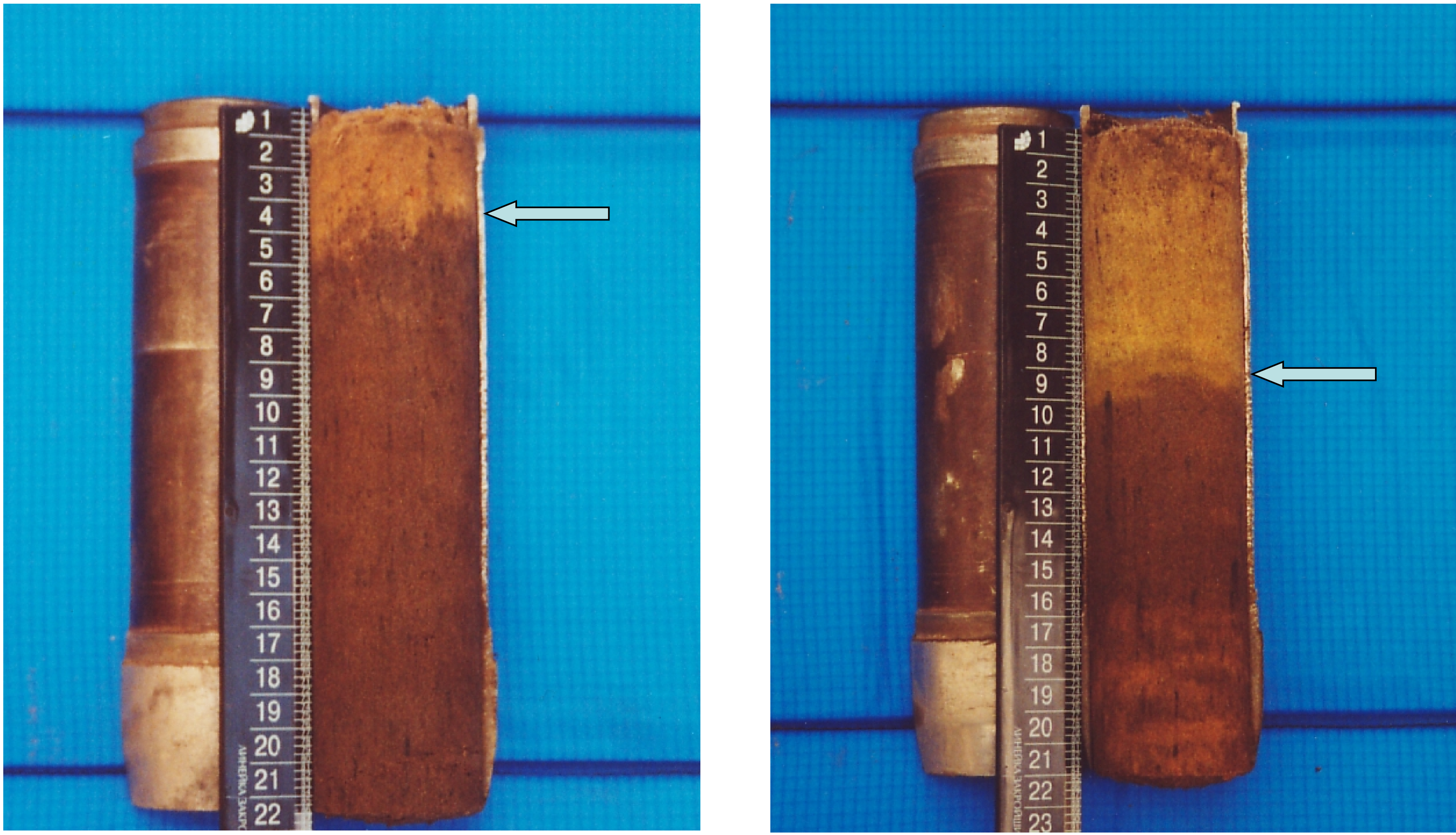
^{137}Cs inventory in soil immediately after decontamination and in October 2002

Site, location	^{137}Cs inventory, kBq/m^2	
	Initial year*	2002
N.Bobovichi, untreated areas	880±230 (20)	650±130 (5)
N.Bobovichi, treated area	240±70 (9)	150±80 (5)
Muravinka, untreated areas	990±90 (21)	900±150 (5)
Muravinka, treated area	150±70 (21)	110±100 (5)

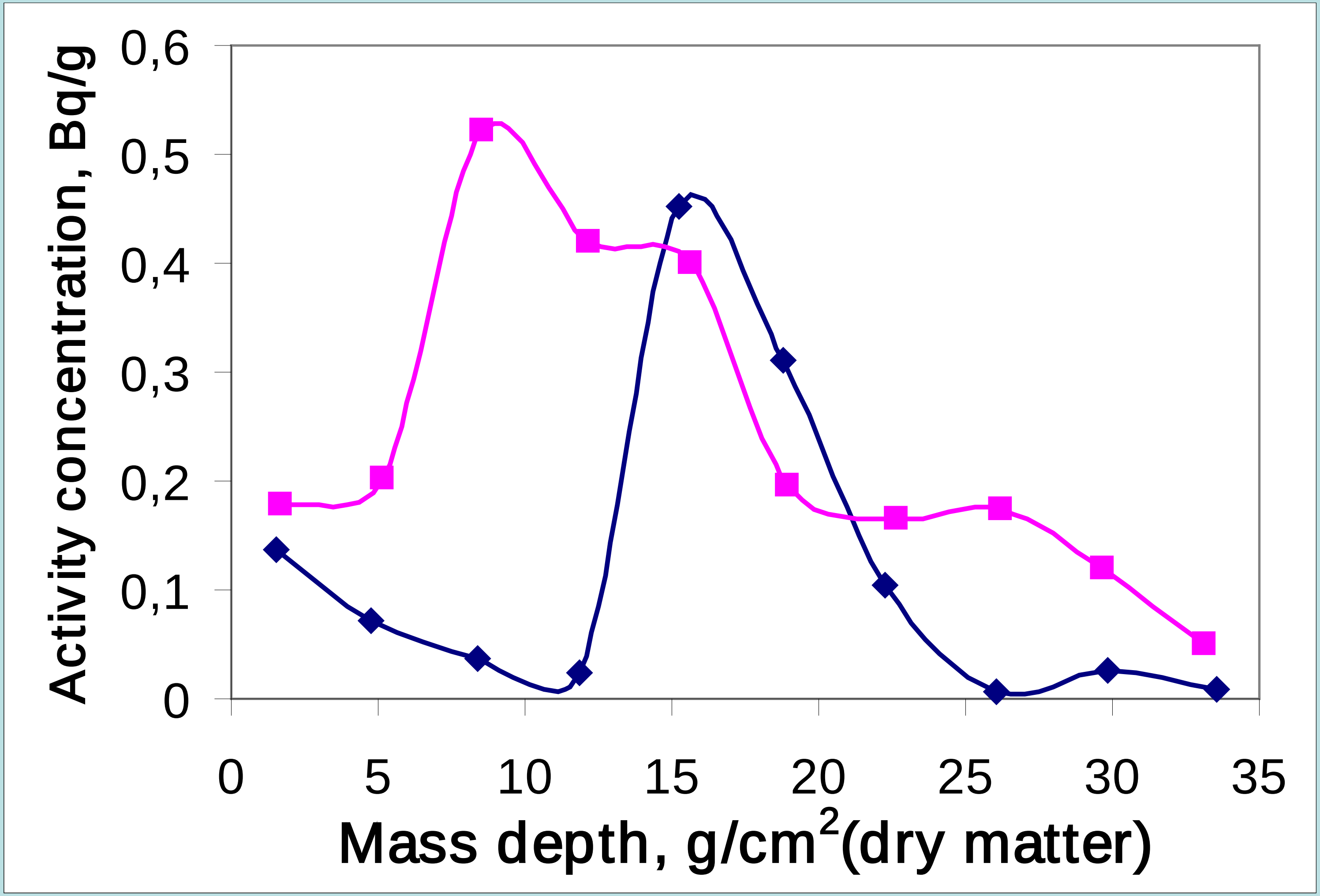
*- 1995 y for N.Bobovichi and 1997 y for Muravinka ; number of soil cores are given in brackets.

Repeated sampling (2004-2009) did not reveal any significant re-contamination of the treated plots (unpublished data).

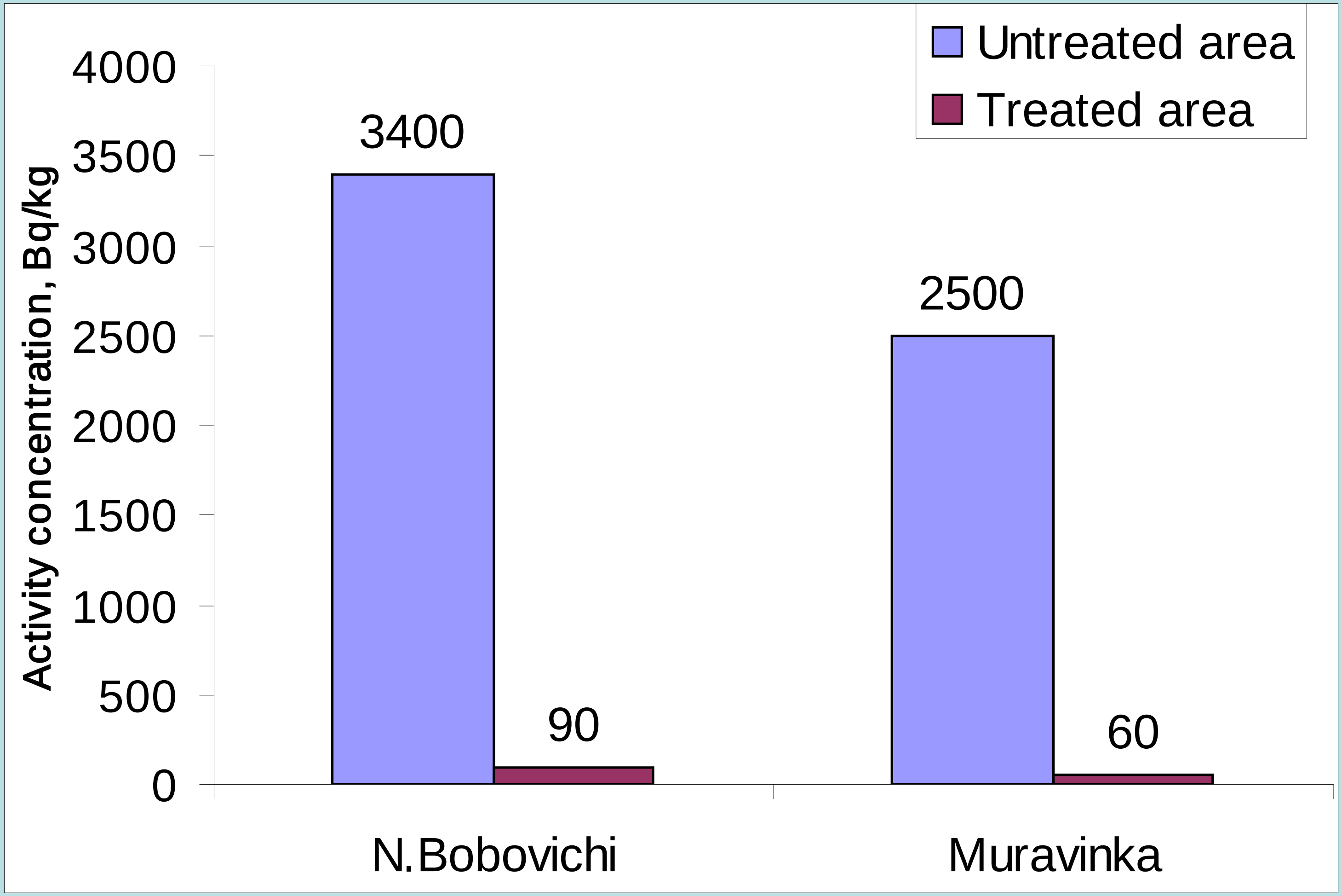
Two soil cores from a treated plot in Muravinka, October 2002.
Arrows indicate a borderline between the maternal soil and the layer of yellow sand that was added at the final stage of decontamination.



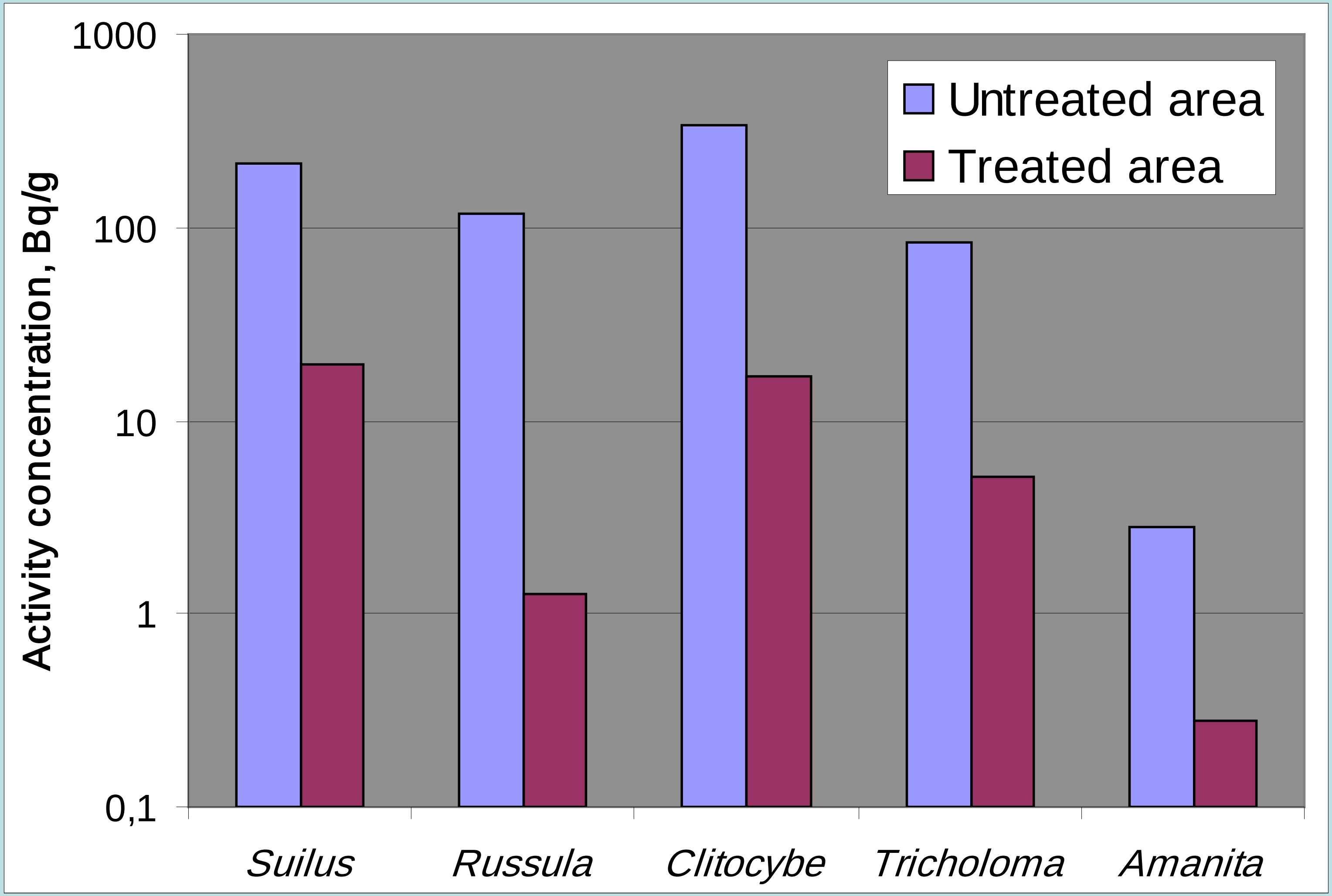
^{137}Cs activity concentrations for two soil cores from a treated plot in Muravinka in 2002. The activity concentration peaks just below the borderline between the maternal soil and added sand.



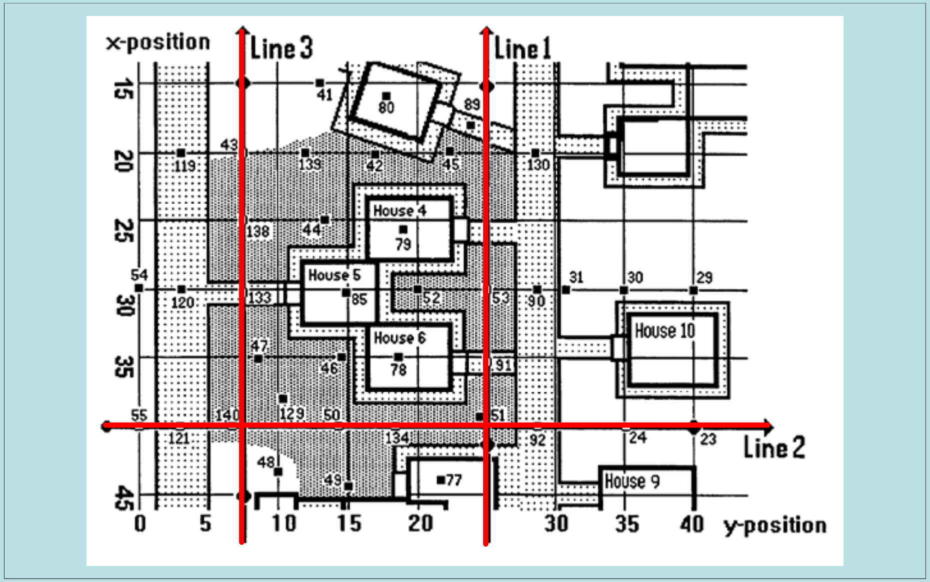
^{137}Cs activity concentration in grass from untreated and treated areas in 2002

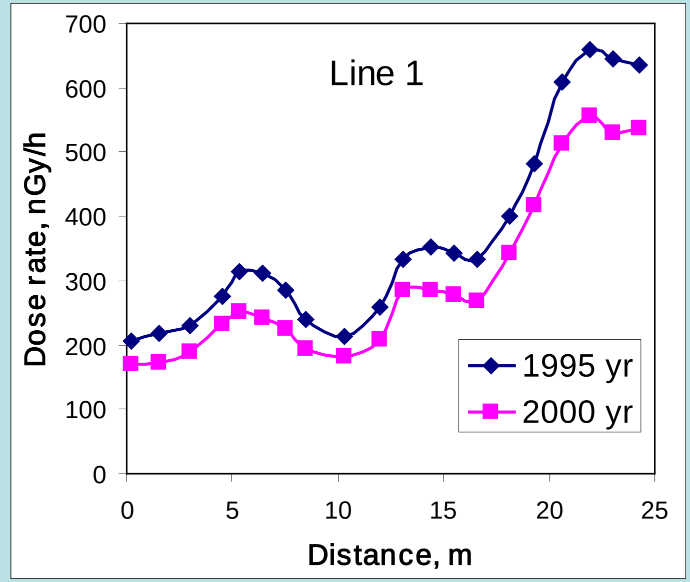


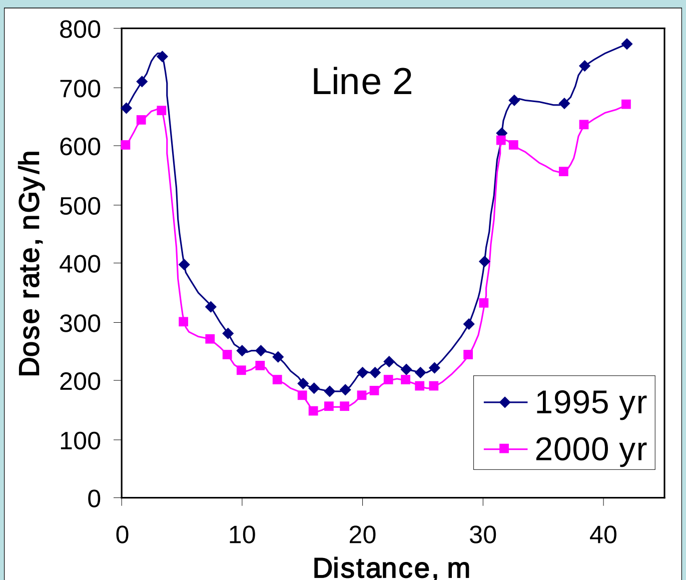
^{137}Cs activity concentration in fungi from untreated and treated areas in N.Bobovichi and Muravinka in 2000-2002

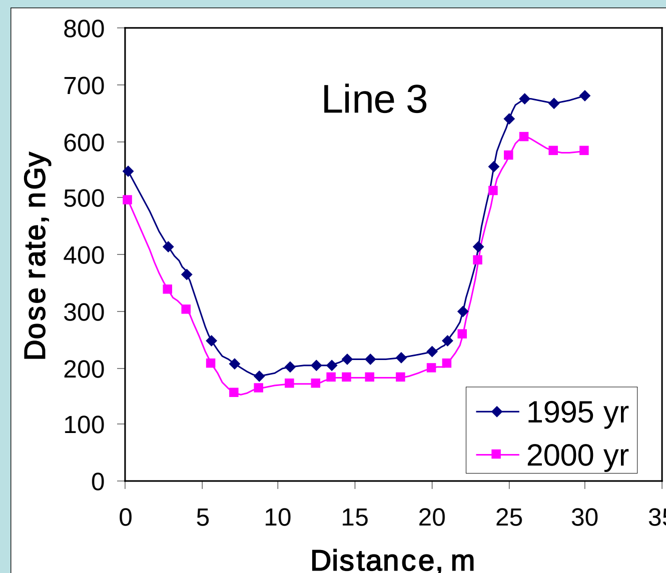


Gamma-ray dose rate profiles above the decontaminated area in Novie Bobovichi immediately after decontamination (1995) and in 2000. The measurements were performed at a height of 1 m.

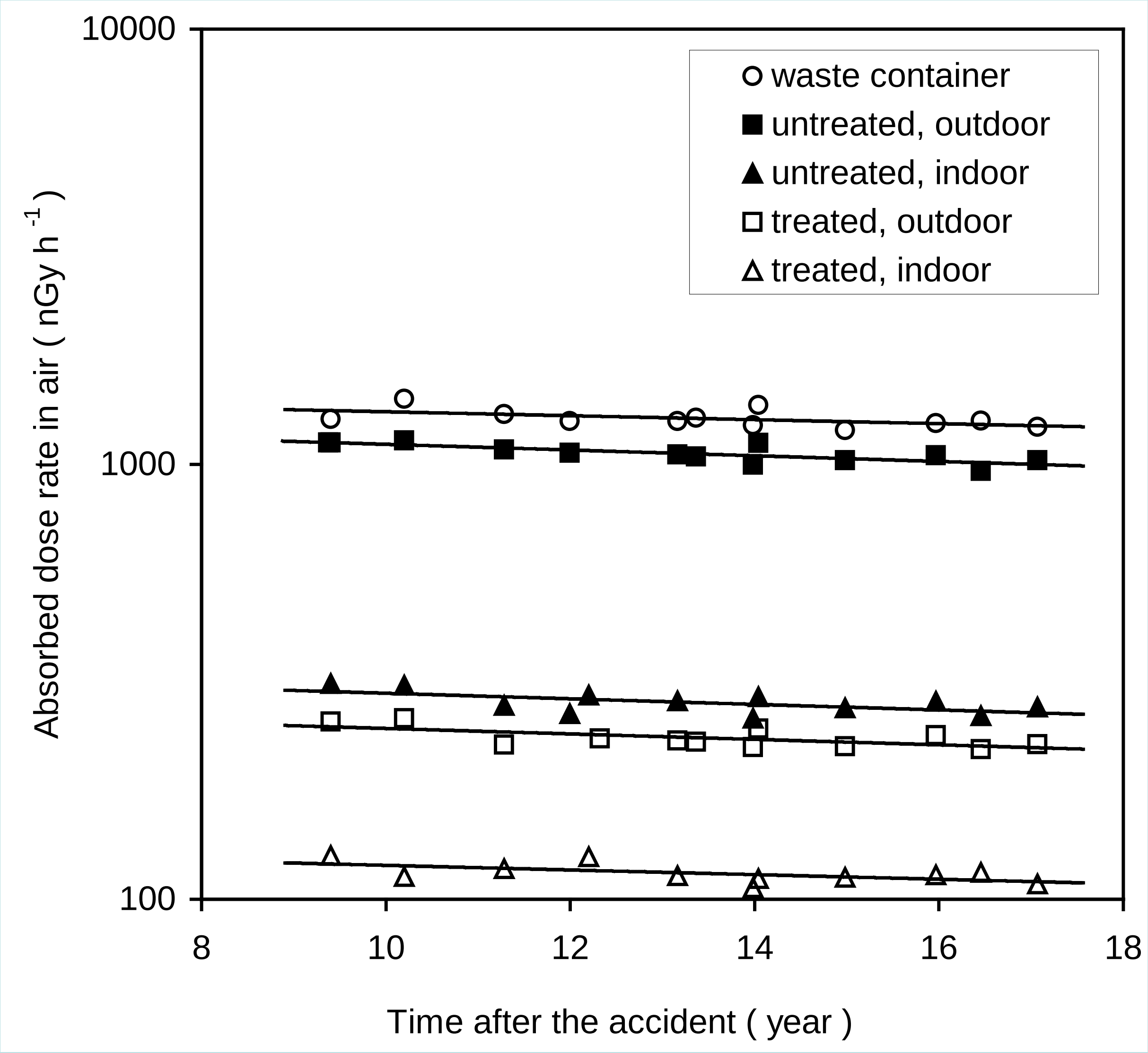








Measured Chernobyl-related gamma-ray dose rate values (corrected for ^{137}Cs and ^{134}Cs decay) and their exponential fits for five reference sites in N.Bobovichi



During the period from 1995 to 2003,
ecological half-life ($T_{1/2}$) for
the Chernobyl-related absorbed dose rate in air
for the reference sites in N.Bobovichi and Muravinka is estimated as:

52±26 y – untreated outdoor (5 sites)

57±23 y – treated outdoor (5 sites)

43±21 y – untreated indoor (4 sites)

46±15 y – treated indoor (5 sites)

66 y – waste container (1 site)

80±56 y – undisturbed forest-grassland plots inside and outside the recreational areas (12 sites)

The trends observed for the outdoor sites and waste container have been confirmed by monitoring of the recreational areas Muravinka and N.Bobovichi during 2003-2012 (unpublished data).

CONCLUSIONS:

-The work showed that optimised implementation of simple countermeasures involving hand-tools and light machinery could reduce the external dose rate considerably, even though 10 years had passed since the accident.

- The levels of the radiocesium activity concentration for the grasses and fungi, which had appeared on treated plots after decontamination, were one to two orders of magnitude lower, than those found in the samples from untreated areas.

- The long-term monitoring of the treated recreational areas did not demonstrated an existence of significant re-contamination of cleaned ground plots within the time period of 15-17 years after intervention.

- At the remote stage of a large-scale nuclear accident, the technologies and the methods implemented for clean up of the recreational areas in N.Bobovichi and Muravinka may be recommended for restoration of other radioactively contaminated recreational areas, health resorts, and private farms located in undisturbed forest-meadow surroundings. Specifically, some areas contaminated in 2011 as a result of the Fukushima accident in Japan can be the target for such intervention.