Some aspects of forestry at the radioactive contaminated territory

ISTC/STCU Symposium and Workshop

The experience and technology of Russia, Ukraine and other CIS countries on remediation and restoration of environments

3-4 February 2012

Tokyo

Vasyl YOSCHENKO

Telephone +(38044) 5262444

E-mail vasyl@uiar.kiev.ua

Ukrainian Institute of Agricultural Radiology of

National University of Life and Environmental Sciences of Ukraine

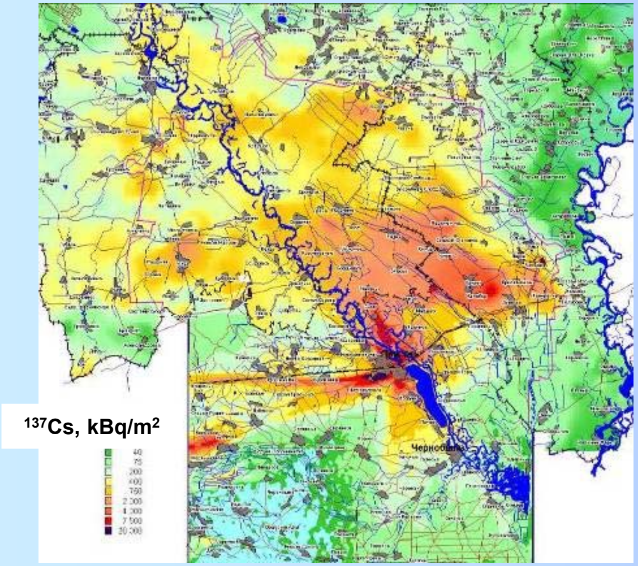
Kyiv

Talk outline

1. What is needed in the practice?
2. Brief technology description.
3. Stage of development.
4. Who needs it?
5. What are the advantages of our results/approaches?
6. Opportunity for joint work.

Problem Description

<u>The problem in general</u>: radioactive releases and contamination of the large territories after Chernobyl and Fukushima accidents



Chernobyl and Fukushima accidents: close levels of contamination with radiocesium and close areas affected

Difference between the two accidents: presence of the fuel component radionuclides (^{90}Sr, TUE etc) in the fuel particle form from Chernobyl NPP. These radionuclides deposited mainly in the near 30-km zone of accident.

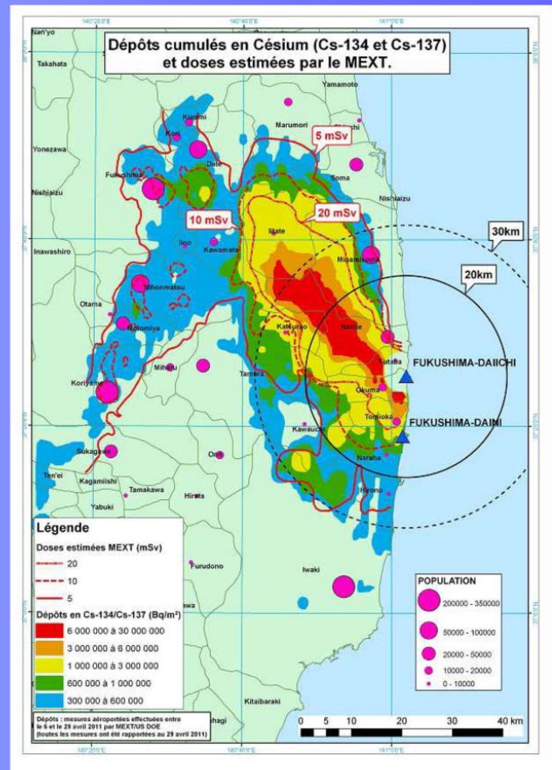


Table 1: Deposits, projected external doses for the 1st year and affected populations

<table>
<tr><td>Deposits of caesium (137 + 134) (Source MEXT)</td><td>> 300,000 Bq/m²</td><td>> 600,000 Bq/m²</td><td>> 1 million Bq/m²</td><td>> 3 millions Bq/m²</td><td>6 - 30 millions Bq/m²</td></tr>
<tr><td>External dose 1st year (16.6 mSv by MBq/m²)</td><td>> 5 mSv</td><td>> 10 mSv</td><td>> 16 mSv</td><td>> 50 mSv</td><td>100 - 500 mSv</td></tr>
<tr><td rowspan="3">Affected population (excluded the no-entry zone)</td><td rowspan="3">292,000</td><td colspan="4">69,400</td></tr>
<tr><td rowspan="2">43,000</td><td colspan="3">26,400</td></tr>
<tr><td>21,100</td><td>3,100</td><td>2,200</td></tr>
</table>

Problem Description

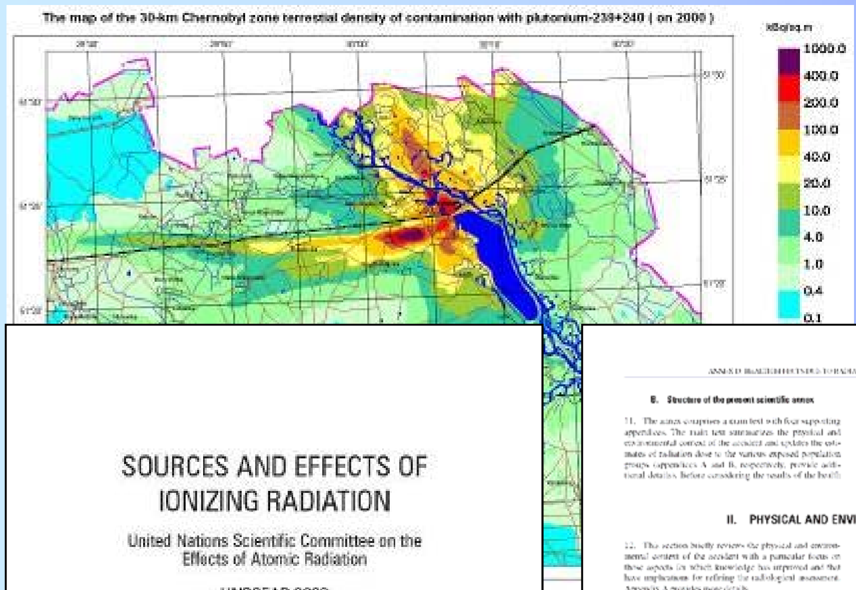
The present stage of the problem solution: the tasks of the acute phase of the accidents have been solved. In context of Chernobyl accident we are at the phase of elimination of the long-term consequences.

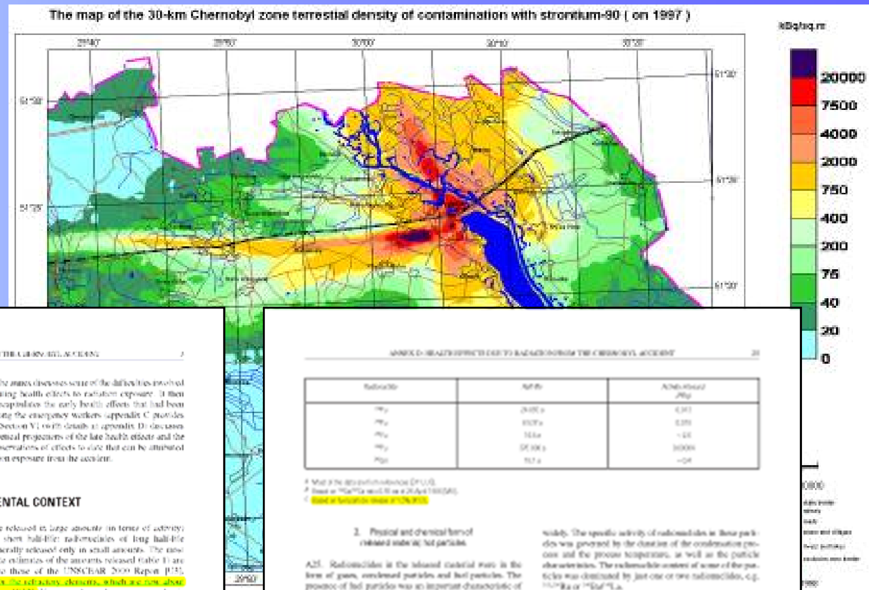
Some important activities performed by Ukrainian Institute of Agricultural Radiology at the earlier phases of Chernobyl accident:

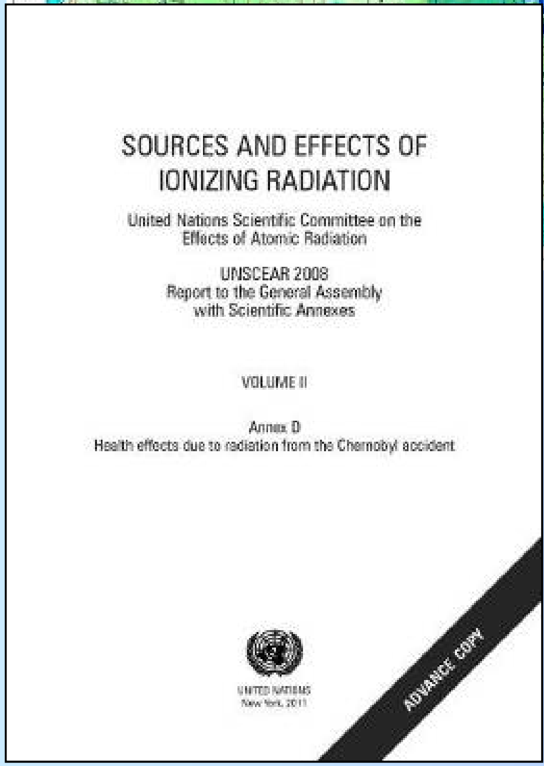
- first years after Chernobyl accident – extensive monitoring, sampling and measurement programs for determination of the territory contamination up to the level of farms, evaluation of the radiological situation in agriculture etc. In particular, our studies revealed the radiological problems in the distant districts of Western Ukraine (especially in Volyn and Rivne regions)
- development of the methods for *in-vivo* determination of radioactive contamination of agricultural animals and for reduction of ^{137}Cs content in muscle tissue by means of fattening with the "clean" fodder
- studies of the physical-chemical forms of the radioactive contamination. Determination of the characteristics of the fuel particles, their dissolution rates in the environment and various media, radionuclides leaching etc.
- mapping the ChNPP 30-km zone contamination with ^{90}Sr and TUE. Specification of the total releases of these radionuclides during the accident
- assessment of the radionuclides resuspension of due to anthropogenic impacts to soil (such as various agricultural activities), during the wildland fires and evaluation of the radionuclides inhalation intake and doses to the workers and population
- determination of the radionuclides (^{36}Cl, ^{125}I, ^{75}Se, ^{99}Tc, TUE) root uptake and foliar transfer into various agricultural crops
- determination of parameters of the radionuclides geochemical migration from the sub-surface storages of radioactive waste. Discovering the phenomenon of the fast migration of Pu isotopes into aquifer
- quantification of the biogenic fluxes of radionuclides in the ecosystem of Red Forest
- application of various countermeasures and evaluation of their efficiency (Rivne region)

UIAR

Some important activities performed by Ukrainian Institute of Agricultural Radiology at the earlier phases of Chernobyl accident: <u>creation of maps</u> of the 30-km zone contamination with the fuel component radionuclides and new <u>estimate of their release</u> during the accident (1.5% of their inventory, or twice lower than earlier estimates; published in UNSCEAR report 2011)






SOURCES AND EFFECTS OF IONIZING RADIATION

United Nations Scientific Committee on the Effects of Atomic Radiation

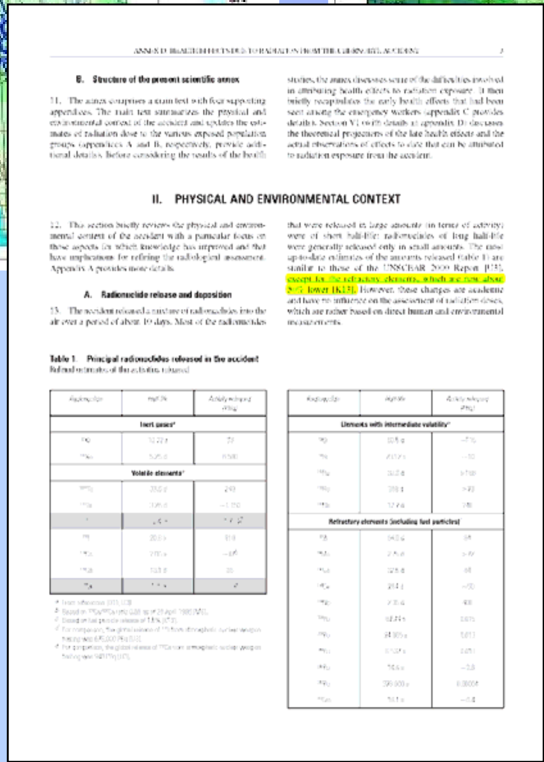
UNSCEAR 2008
Report to the General Assembly
with Scientific Annexes

VOLUME II

Annex D
Health effects due to radiation from the Chernobyl accident

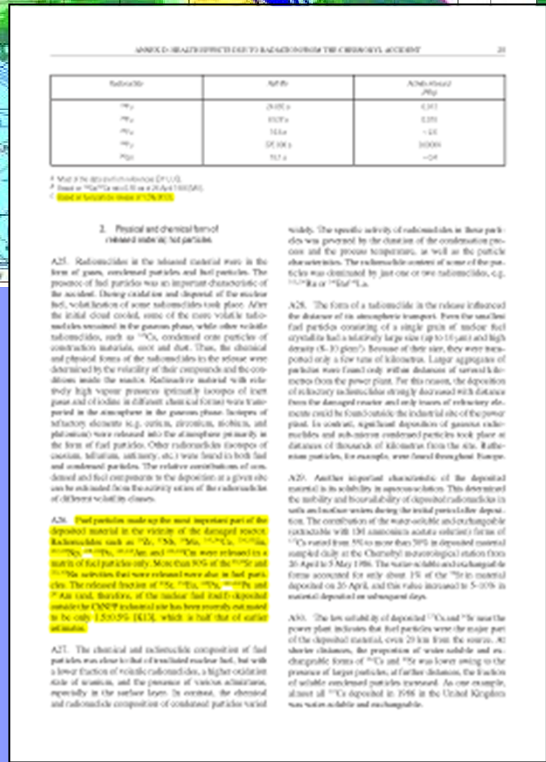
UNITED NATIONS
New York, 2011

ADVANCE COPY

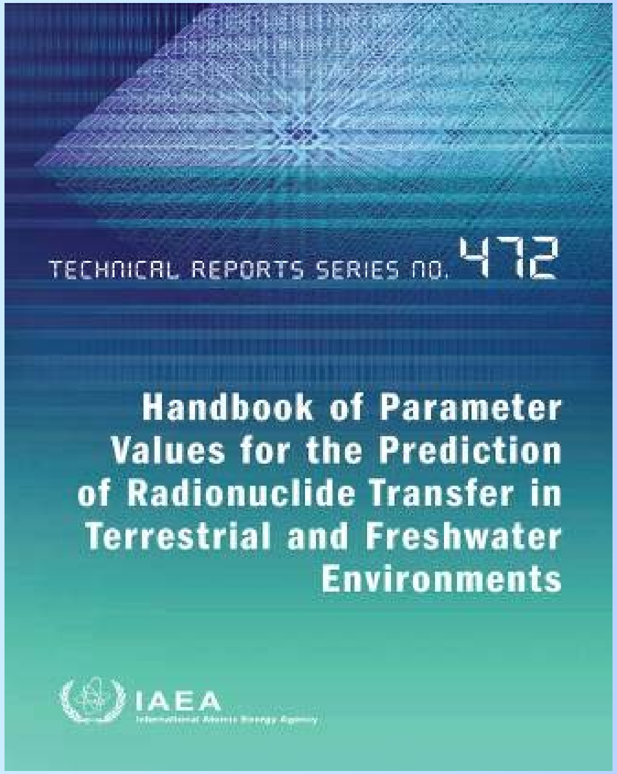

II. PHYSICAL AND ENVIRONMENTAL CONTEXT

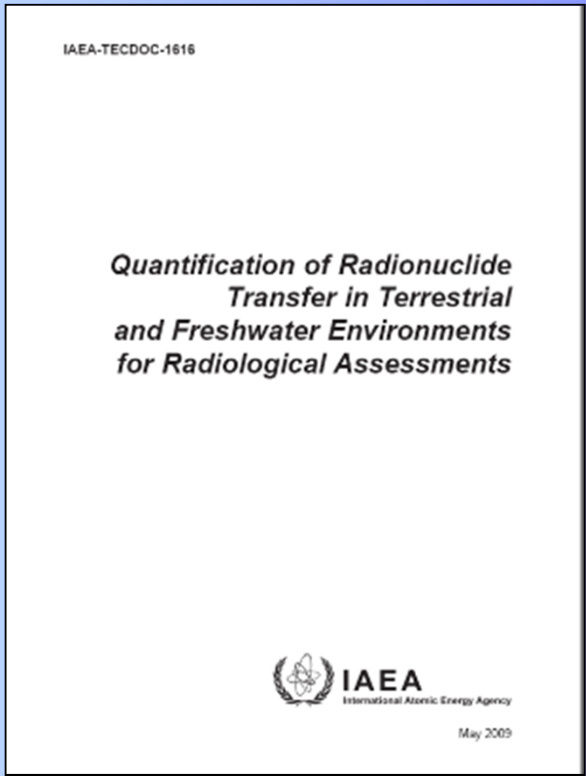
A. Radionuclide release and deposition

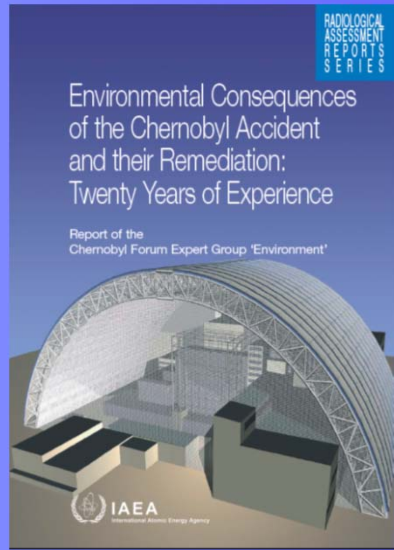
Table 1. Principal radionuclides released in the accident

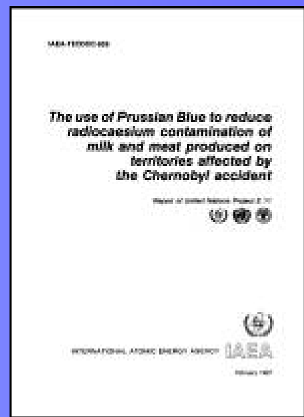


Some important activities performed by Ukrainian Institute of Agricultural Radiology at the earlier phases of Chernobyl accident: specification of the radionuclide transfer factors (presented in the IAEA Tech Reports Series) and assessment of the countermeasures efficiency in agriculture (presented in the IAEA TecDoc)





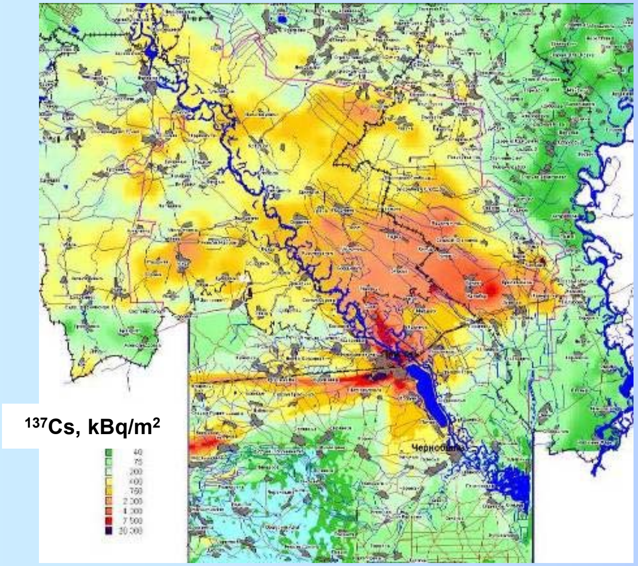




UIAR

At the early phases of Chernobyl accident and, probably, at the present stage of Fukushima accident the main efforts are spent to protect population and workers, to elaborate the methods of decontamination of agricultural areas, countermeasures to reduce the radionuclides contents in foodstuff etc. However, there are some problems related to the natural ecosystems…

Problem Description



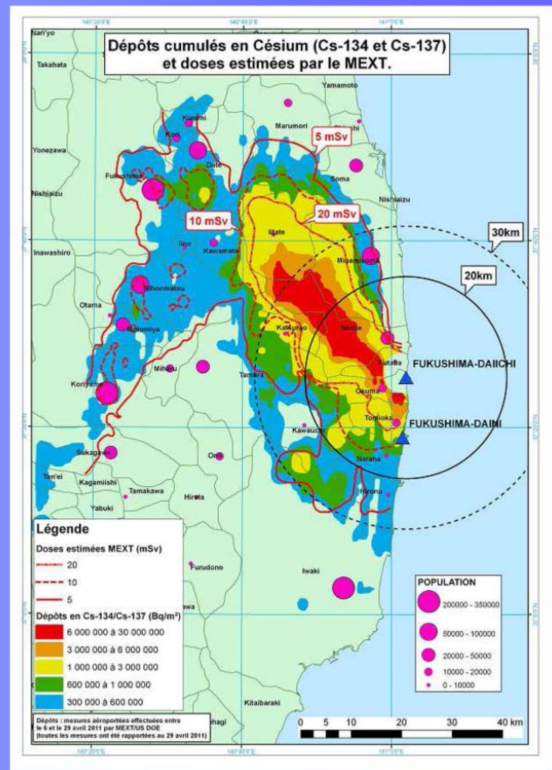
<table>
<caption>Table 1: Deposits, projected external doses for the 1st year and affected populations</caption>
<tr><td>Deposits of caesium (137 + 134) (Source MEXT)</td><td>> 300,000 Bq/m²</td><td>> 600,000 Bq/m²</td><td>> 1 million Bq/m²</td><td>> 3 millions Bq/m²</td><td>6 - 30 millions Bq/m²</td></tr>
<tr><td>External dose 1st year (16.6 mSv by MBq/m²)</td><td>> 5 mSv</td><td>> 10 mSv</td><td>> 16 mSv</td><td>> 50 mSv</td><td>100 - 500 mSv</td></tr>
<tr><td rowspan="3">Affected population (excluded the no-entry zone)</td><td rowspan="3">292,000</td><td colspan="4">69,400</td></tr>
<tr><td rowspan="2">43,000</td><td colspan="3">26,400</td></tr>
<tr><td>21,100</td><td>3,100</td><td>2,200</td></tr>
</table>

Japan and Chernobyl exclusion zone: approx 2/3 of the territories are covered with forests and shrubs

In differ to agricultural areas, natural ecosystems can be hardly decontaminated. For the comparable long period they will remain the depots of radionuclides. In this concern, the important questions are:

- whether and how the radionuclides can migrate from the ecosystems into the populated areas during the wildland fires?

- what will happen to the ecosystems because of their radioactive contamination?



Problem Description

<u>Forest fires. Is it an important problem</u>?

Wildland fires frequency

<u>Chernobyl Exclusion zone:</u>

- 42-116 fires per year;
- increased severity of the fires – for example, 52 fires in 1992 burnt more than 4,000 ha of forests, while 551 fires in Kiev region burnt only 284 ha

<u>Japan:</u>

- average of 3274 fires per year in 1990-1999, average area burnt – 2311 ha (Forestry Agency Japan, 2000)

Wildland fires impacts:

- radioecological – radioactivity redistribution (amounts of the radionuclides resuspended, range of their transportation, areas of deposition etc);

- radiological – doses to the firefighters and population (airborne concentrations, dispersal composition of radioactive aerosols, their solubility etc);

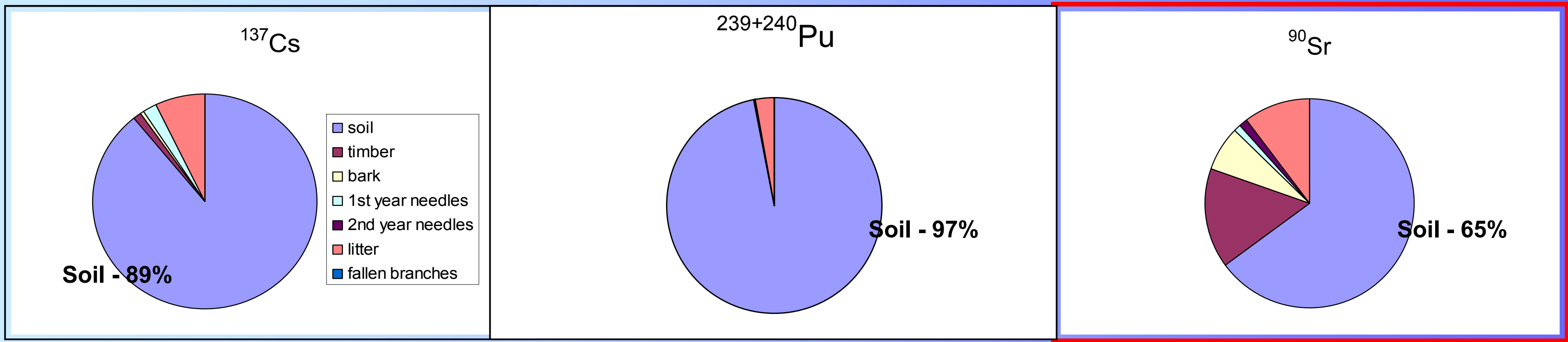
- social (awareness of the authorities and population concerning the <u>actual</u> potential consequences of the fires)

NOAA, 08 May 2003, 18:30, by UCLRM

Problem Description

<u>Forest fires. Is it an important problem</u>?

Radionuclides in the forest ecosystem at the late phase of Chernobyl accident



- at the late phase of the accident a significant part of the radionuclides activity in the forest ecosystem is localized in the biomass and litter, i.e., in the combustible material;

- during the fires these radionuclides can be resuspended and transported to certain distances;

- **potential consequences of the wildland fires must be estimated!**

<u>Who may need our estimates:</u>

- authorities responsible for the radiation protection of population;

- fire protection services;

- radioecologists;

- population

Brief description of the research approach

In order to address the mentioned issues, we have performed the experimental studies of the radionuclides resuspension, transportation and deposition during the wildland fires

The methodology of the studies was based on the measurements of the radioactive aerosol concentrations, dispersal composition and deposition from the smoke plumes released from the burning experimental plots

The plots were characterized before their ignition. During the experiments, the weather conditions were recorded

The experiments were performed at 2 grassland plots (3600 m^2 and 5400 m^2) and 1 forest plot (8770 m^2) located in Chernobyl exclusion zone

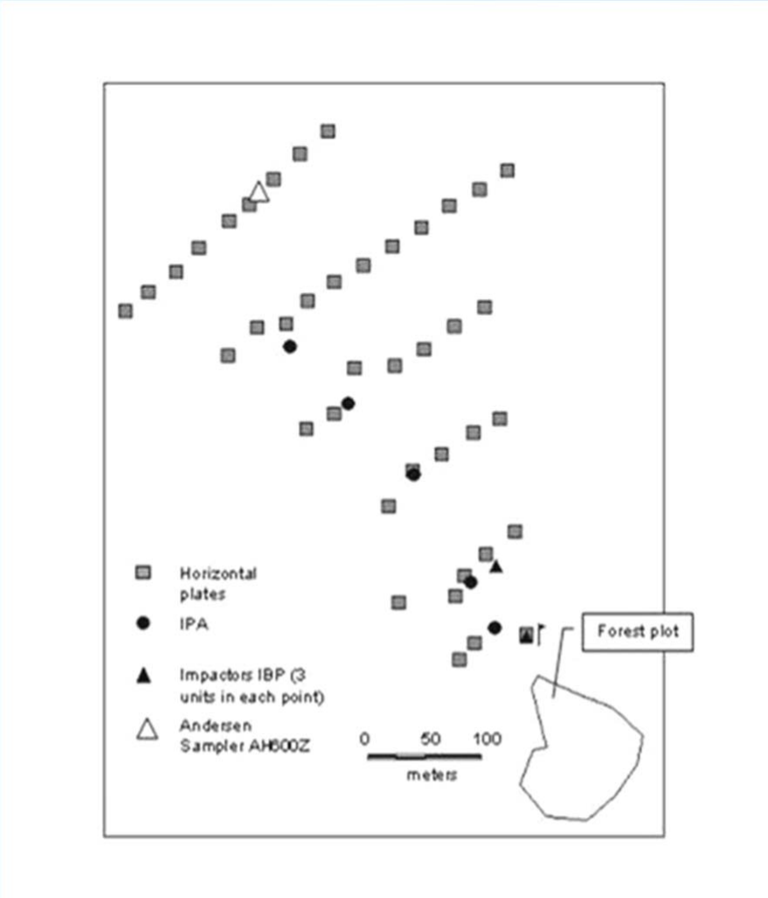
Advantage of the research approach

Natural well-recorded conditions in which the experiments were performed: these were the actual fires, in differ to the laboratory experiments

Detail description of the experimental plots before the experiments, in differ to the real-time fires at the radioactive contaminated territories

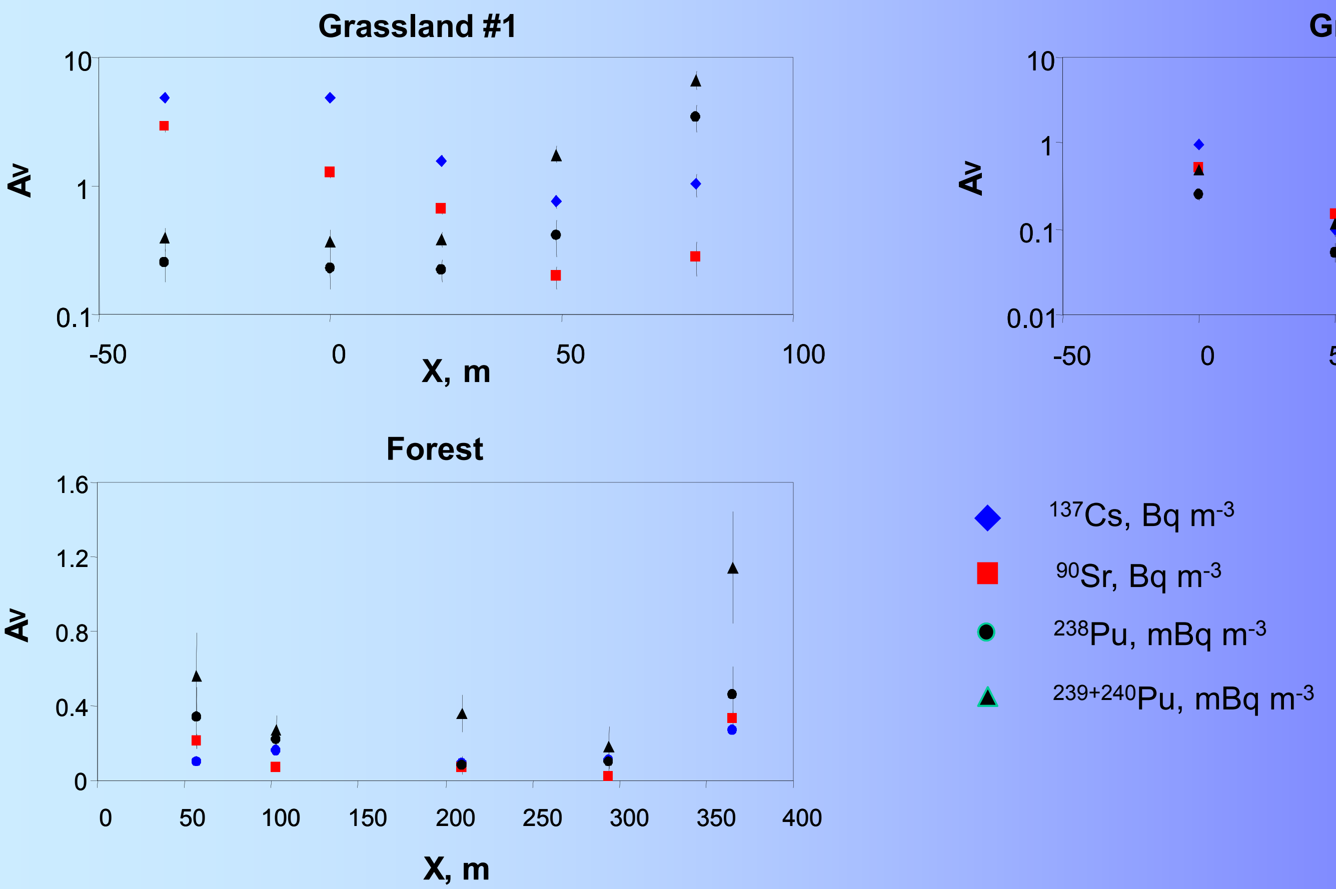
Brief description of the research approach

Forest fire experiment



Experimental results

Wildland fire experiments: Radionuclide airborne concentrations along the plume axis at the 1-m height above the ground surface



UIAR

Experimental results

Wildland fire experiments: Radionuclide resuspension factors, m^{-1}

Calculated for	^{137}Cs	^{90}Sr	^{238}Pu	$^{239+240}Pu$
Grassland fire, #1				
Activity in fuel material	$(1.7\pm0.2)\cdot10^{-5}$	$(1.5\pm0.2)\cdot10^{-5}$	$(3.5\pm1.0)\cdot10^{-7}$	$(2.4\pm0.6)\cdot10^{-7}$
Total activity	$(1.7\pm0.2)\cdot10^{-7}$	$(3.7\pm0.5)\cdot10^{-7}$	$(4.9\pm1.4)\cdot10^{-9}$	$(3.8\pm0.9)\cdot10^{-9}$
Grassland fire, #2				
Activity in fuel material	$(8.0\pm4.8)\cdot10^{-6}$	$(4.4\pm2.6)\cdot10^{-6}$	$(2.9\pm2.3)\cdot10^{-6}$	$(2.6\pm2.1)\cdot10^{-6}$
Total activity	$(1.9\pm1.1)\cdot10^{-7}$	$(1.8\pm1.5)\cdot10^{-7}$	$(1.3\pm1.0)\cdot10^{-8}$	$(1.3\pm1.0)\cdot10^{-8}$
Forest fire, #3				
Activity in litter	$(7.0\pm2.8)\cdot10^{-7}$	$(1.2\pm0.5)\cdot10^{-6}$	$(1.2\pm0.8)\cdot10^{-6}$	$(9.4\pm5.2)\cdot10^{-7}$
Activity in fuel material	$(4.7\pm2.0)\cdot10^{-7}$	$(3.5\pm1.6)\cdot10^{-7}$	$(1.1\pm0.7)\cdot10^{-6}$	$(8.3\pm4.8)\cdot10^{-7}$
Total activity	$(4.7\pm2.0)\cdot10^{-8}$	$(1.1\pm0.5)\cdot10^{-7}$	$(3.2\pm2.2)\cdot10^{-8}$	$(2.5\pm1.6)\cdot10^{-8}$

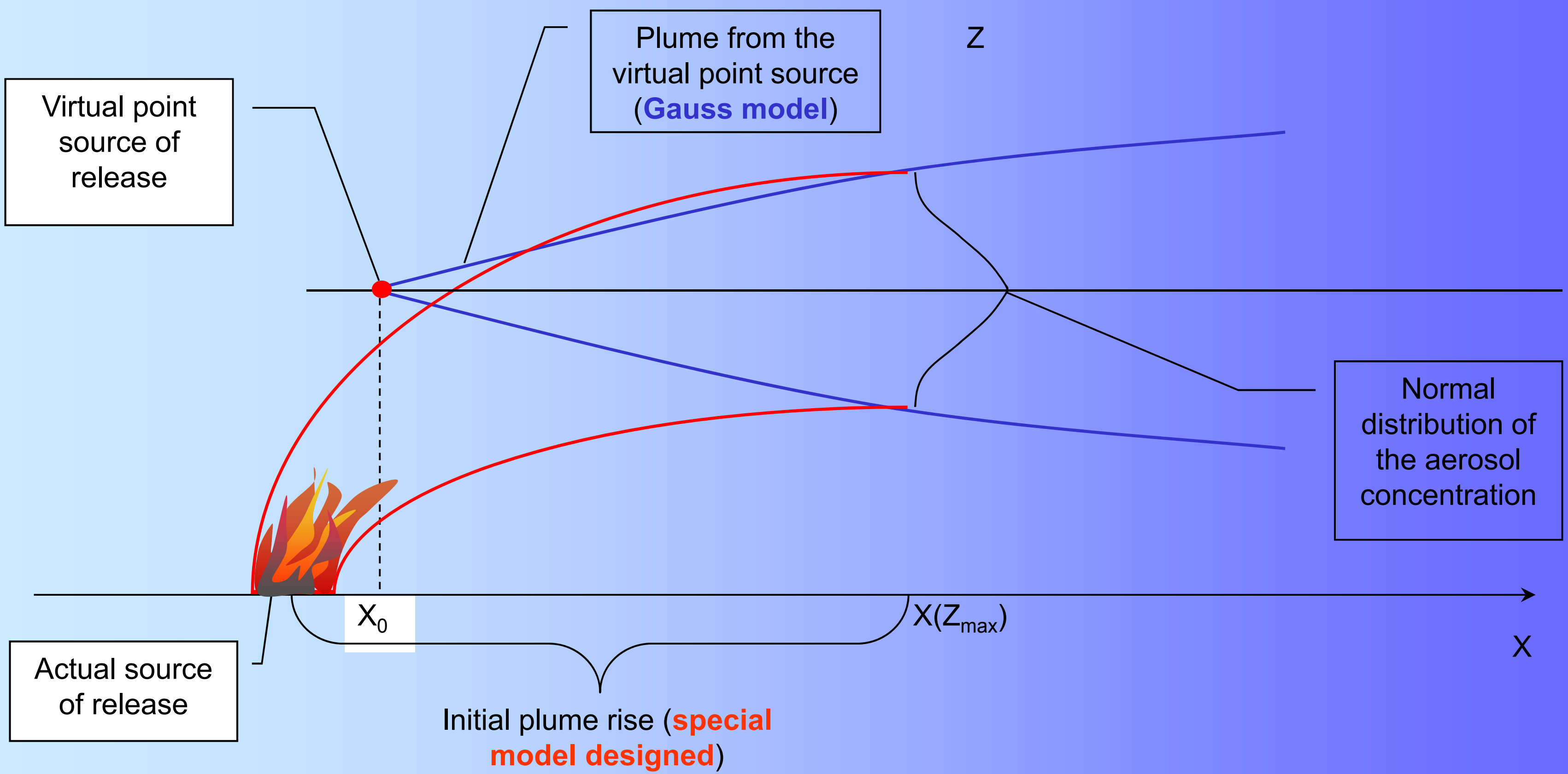
Experimental results

<u>Wildland fire experiments:</u> Doses to the firefighters (1 hr exposure, conservative scenario; for inhalation – 50 yr effective equivalent dose)

	Maximum airborne concentration, Bq m^{-3}, in the site			Dose type	Dose, μSv, in the site		
	#1	#2	#3		#1	#2	#3
^{137}Cs	5	1	0.27	External from the cloud	$6.9 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$3.7 \cdot 10^{-5}$
				Inhalation	$6 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$3.2 \cdot 10^{-3}$
^{90}Sr	3	0.5	0.33	External from the cloud	10^{-4}	$1.7 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$
				Inhalation	0.24	$4.1 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$
^{238}Pu	$3.4 \cdot 10^{-3}$	$2.5 \cdot 10^{-4}$	$4.6 \cdot 10^{-4}$	Inhalation	**7.1**	**0.53**	**1**
$^{239+240}$Pu	$6.7 \cdot 10^{-3}$	$5.1 \cdot 10^{-4}$	$1.1 \cdot 10^{-3}$	Inhalation	**17**	**1.3**	**2.8**
External irradiation from soil and vegetation					16	10	4.2
Total dose					40	12	8

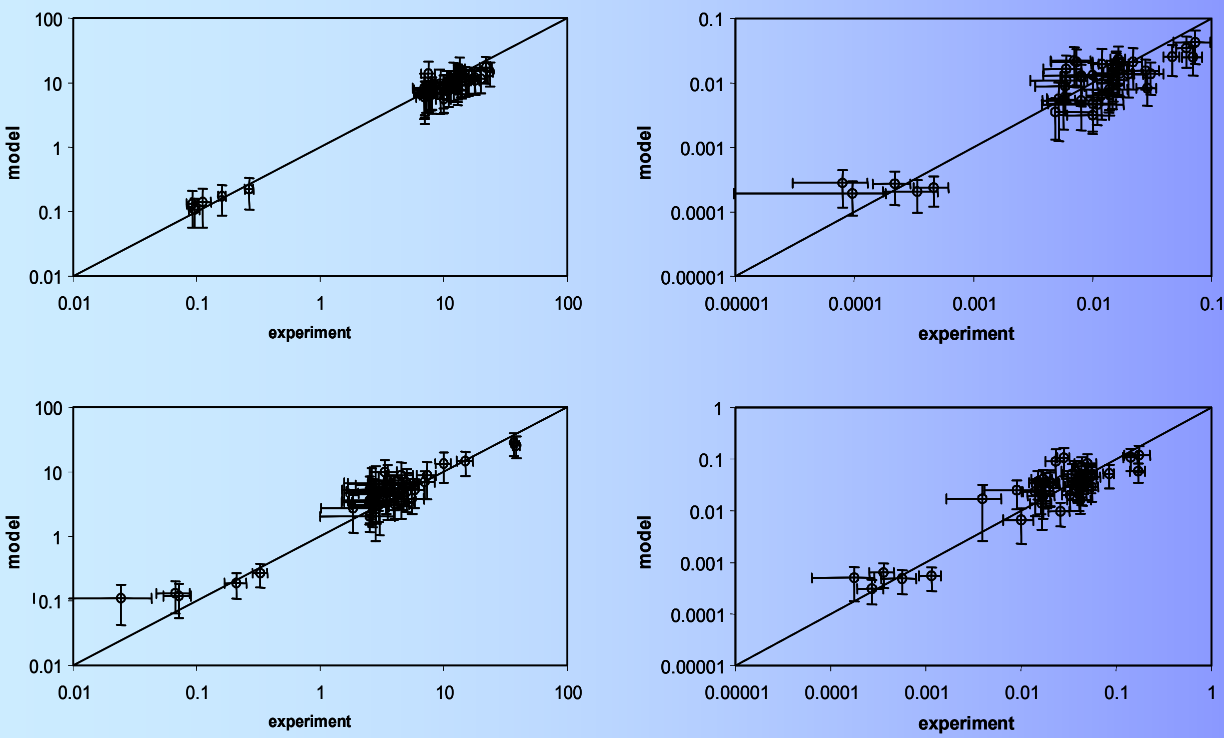
Experimental results

Wildland fire experiments: Modeling exercises



Experimental results

Wildland fire experiments: Results of the modeling exercises. Forest fire



Radionuclide releases during the fires, % of activity in fuel material

	^{137}Cs	^{90}Sr	ΣPu
Grassland #1	0.06	0.15	0.03
Grassland #2	0.14	0.15	0.07
Forest	4.2	2.9	0.8

Stage of development

Further progress of the R&D after the completion of the project – current status

- decommission (drainage) of the Chernobyl NPP cooling pond. Calculation of the risks related to the possible wildland fires at the drained territory (radionuclides resuspension, transportation, potential doses to the firefighters and staff). The IAEA-supported project (present status – initial phase of the project)

- MEGAFIRE project (European mega-fires: Harmonising and innovating approaches for better preparedness, prevention, mitigation, planning and fire-fighting). EU collaborative project (present status – evaluation of the submitted proposal). The UIAR contribution: what will happen in the case of development of the mega-fire at the radioactive contaminated territories. This scenario differs much from that studied in the experiments (larger thermal intensity will cause the higher initial rise of the plume and the bigger release fractions of the radionuclides etc)

Problem Description

Effects of radiation to biota. Is it an important problem?

- Some plant species growing in Chernobyl zone showed a high radiosensitivity. For example, numerous effects of radiation were observed at morphological and cytological levels in Scots pine (*Pinus sylvestris* L.). The highly irradiated pine stands look underdeveloped
- Scots pine is one of the ICRP reference species for the terrestrial ecosystems
- Scots pine is a most common tree species in Chernobyl zone. Majority of the forest ecosystems in the zone are formed on the basis of this species
- Scots pine is one of the most irradiated plant species in the zone
- Therefore, the further fate of the typical ecosystems at the highly contaminated areas of Chernobyl zone is not clear

The typical 20-yr old pine tree in Red Forest (approx 2 km west of Chernobyl NPP)

UIAR

Aims of the research

- To identify the most common morphological and cytological effects of radiation to Scots pine and to formulate the dose-effect dependences
- To interpret obtained dependences and to establish links between the radiation effects occurring at various levels (cell, organ, tree)

Brief description of the research approach

- Visual identification of the morphological effects of radiation at the large experimental array of pine trees (more than 1100 trees)
- Direct counting the DNA aberrations and Comet Assay for quantification of the cytological damages
- Radionuclide activity measurements in the trees and creation of the dosimetric model for estimation of the doses to each tree of the array

Advantages of the research approach

- Wide range of the dose rates to the trees of the experimental array
- Absence of the serious ecotoxical factors other than radiation (chemical plants, intensive traffic etc) in Chernobyl zone
- Similarity of the soil-landscape conditions and plantation densities at the experimental sites

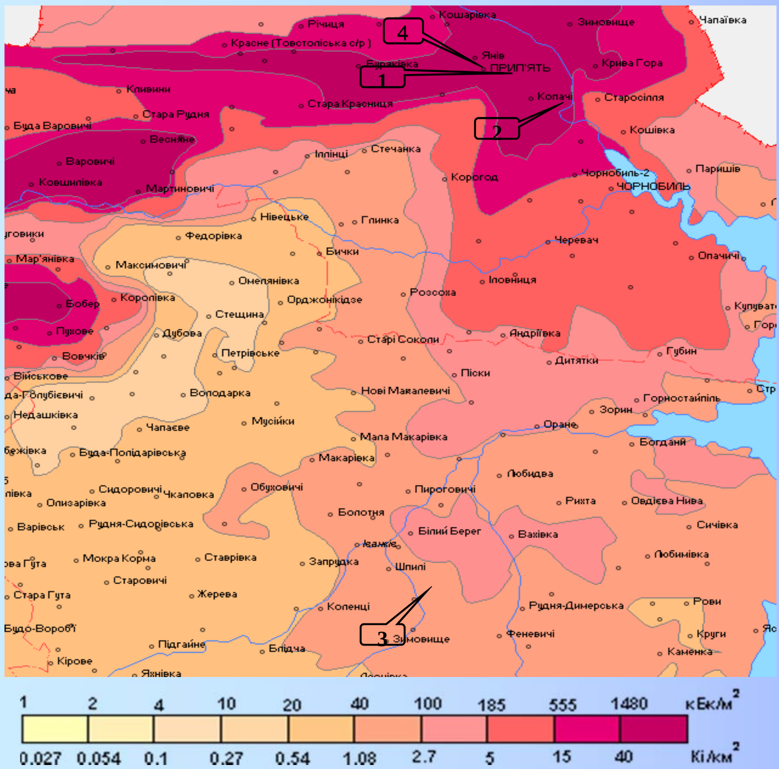
UIAR

Brief description of the research approach

Experimental sites and morphological effects in Scots pine

^{137}Cs contamination density

1 – Red Forest, 2 – Kopachi, 3 – Ivankiv, 4 – Yaniv



The most common effect in the present period is cancelling the apical dominance, which leads to suppression of the tree growth, shrinkage of the tree top and sometimes to the death of the whole tree

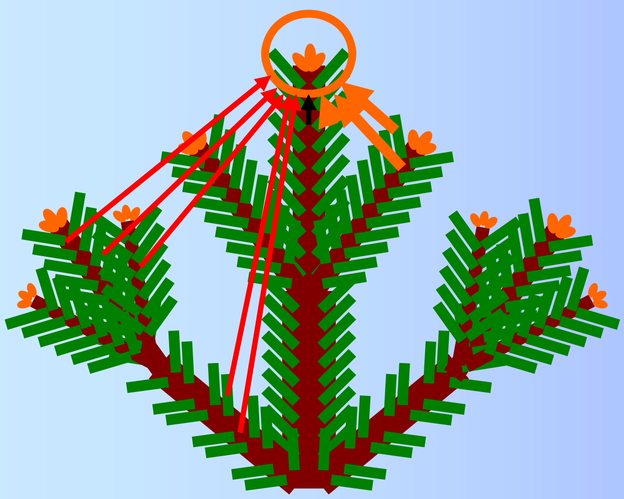
UIAR

Brief description of the research approach

Calculation of the dose rates to *Pinus sylvestris*

Target organ: dominant bud

Source of radiation: incorporated RN



<u>The model takes into account:</u>

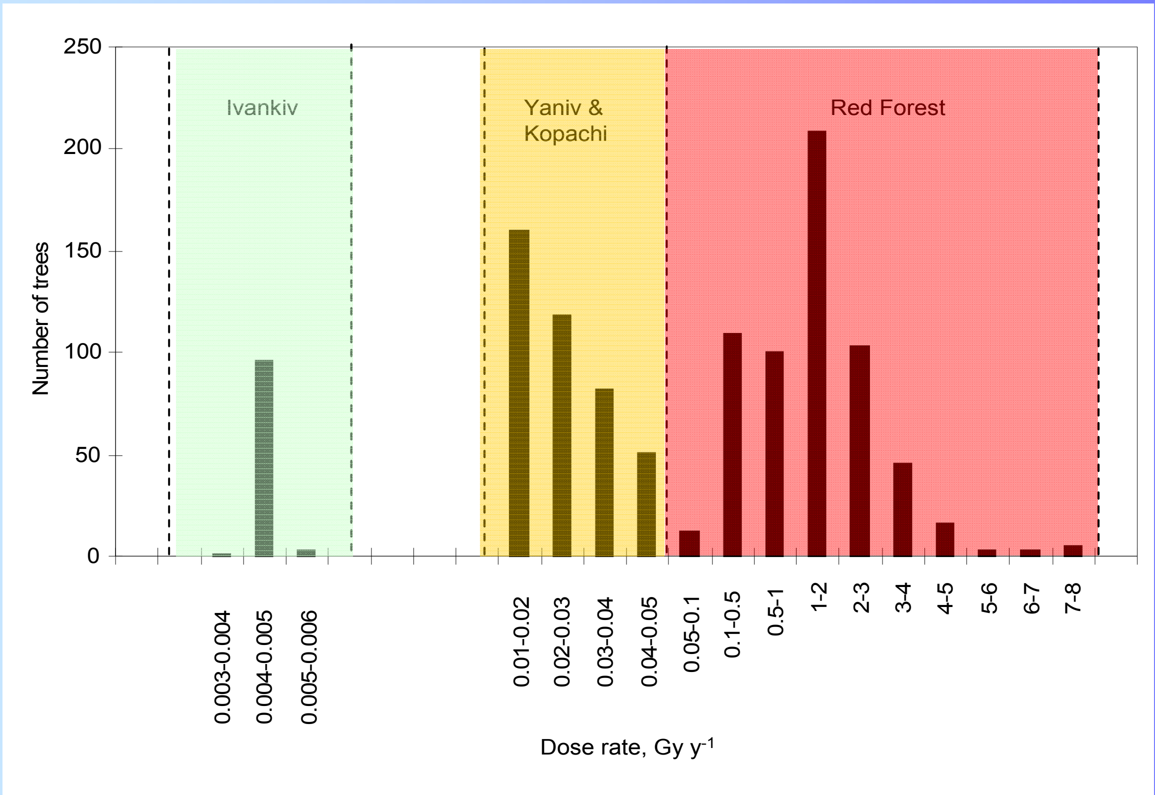
- ✓ β-emission of incorporated RN
- ✓ actual distribution of RN in tree's organs and dynamics of their specific activities in each organ during a year
- ✓ shape, location and growing of the organs during a year (changing geometry of irradiation)

<u>Principal approach:</u>

- ✓ integration of the microdosimetric functions of the point sources localized in the target organ
- ✓ utilization of the microdosimetric functions and geometrical factors of irradiation of the selected point in the target organ by RN incorporated in other organs

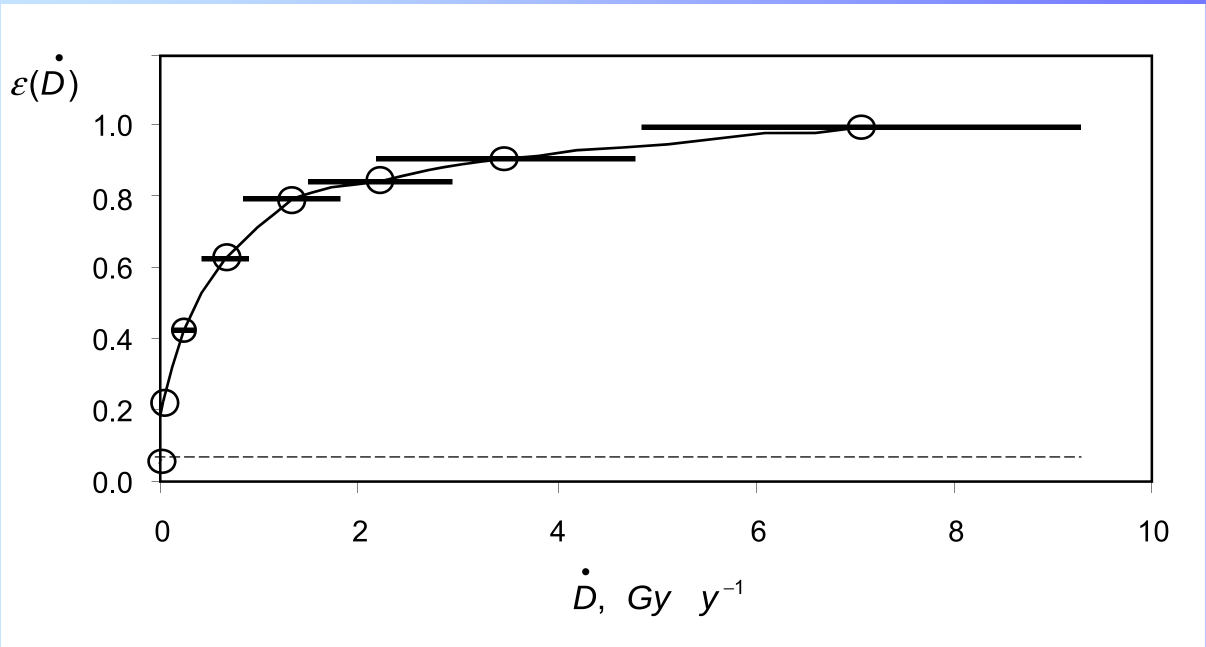
Experimental results

Dose rates to the trees of the experimental array of *Pinus sylvestris*



Experimental results

Morphological effect in *Pinus sylvestris* vs dose rate



$EDR_{10} \approx 0.008$ Gy y^{-1} ≈ 0.9 µGy h^{-1}

$EDR_{50} \approx 0.35$ Gy y^{-1} ≈ 40 µGy h^{-1}

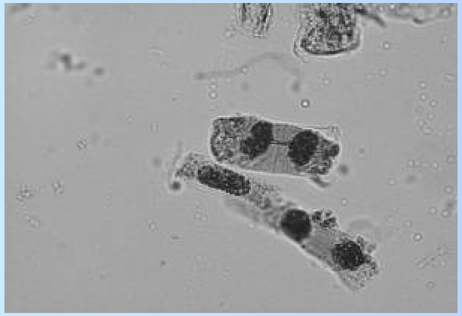
Experimental results

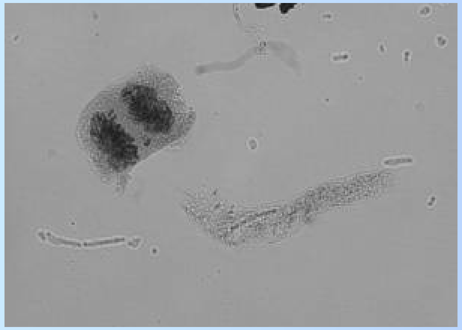
<u>Cytological studies for the experimental array of *Pinus sylvestris*</u>

<u>Sub-array</u>: several trees of the experimental array which represent various dose rates

<u>Tissues and methods</u>:

meristem of the seed germs
(direct counting the aberrant cells)



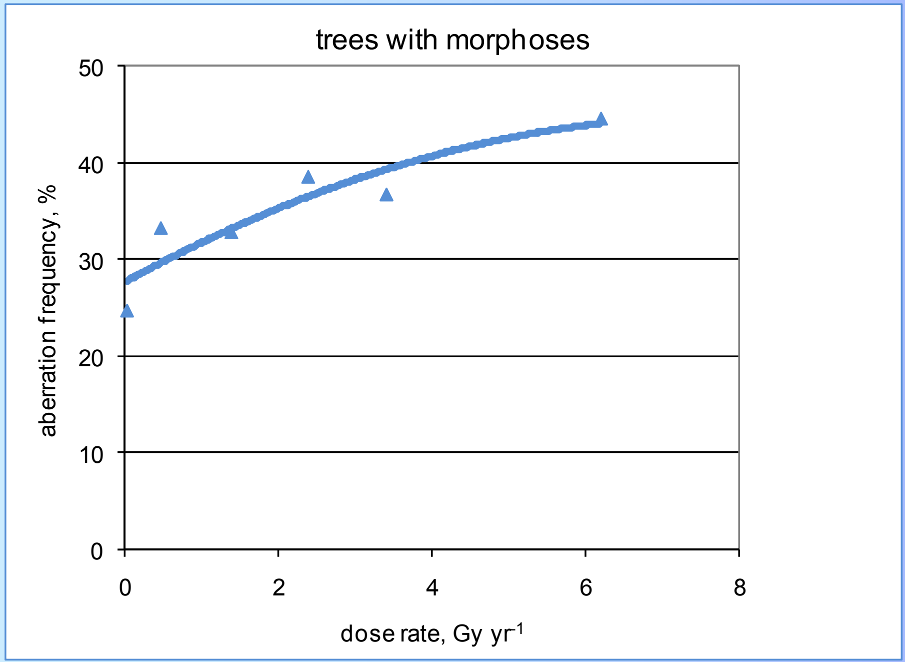


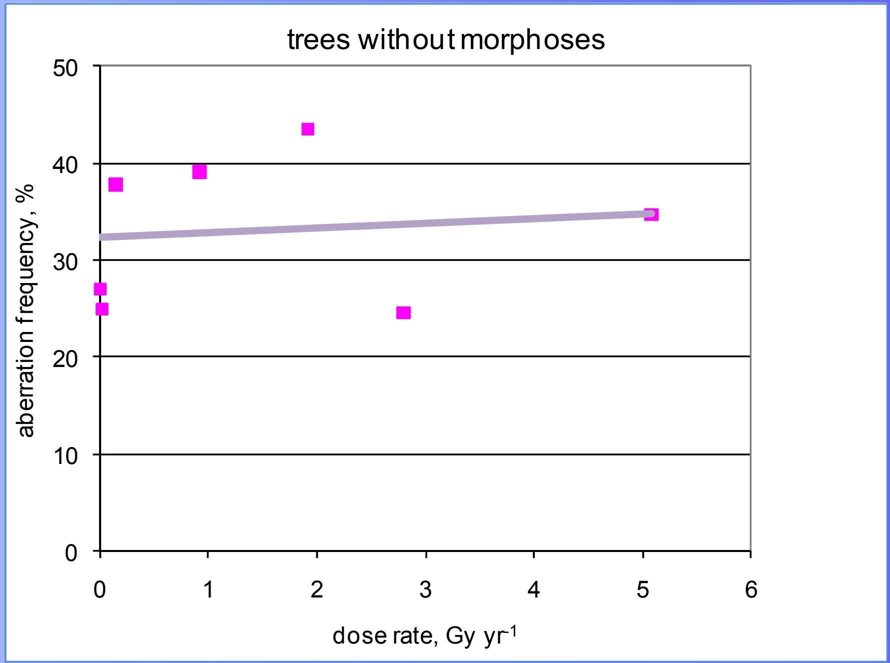
apical meristem
(single cell gel electrophoresis)

UIAR

Experimental results

Cytogenetic effects in seed germs of *Pinus sylvestris*:
aberrations frequency

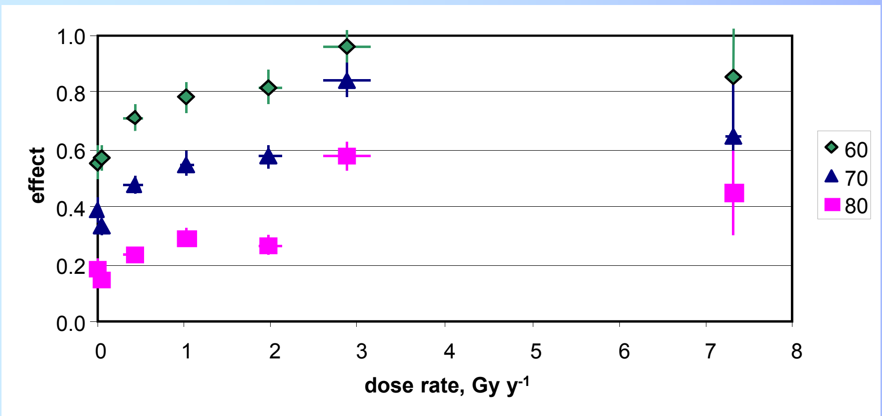




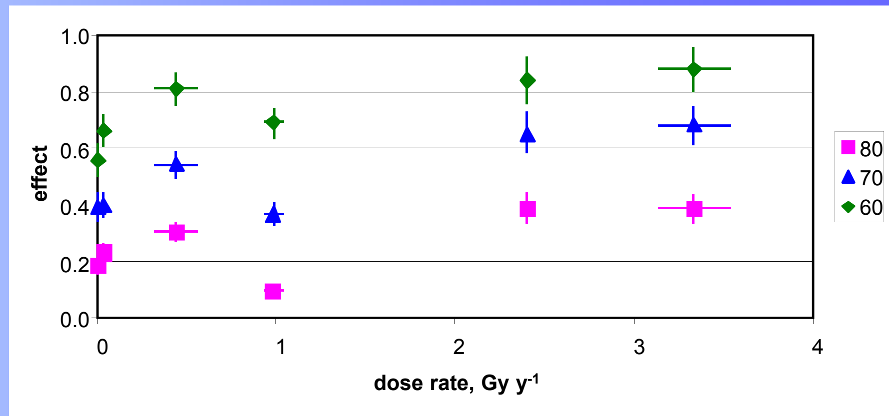
Experimental results

Effects in cells of apical meristem (Comet Assay): fraction of the heavy damaged nuclei

trees with morphoses



trees without morphoses



Other advantages of the research approach

- radiation protection of the so-called 'non-human' biota is one of the new problems considered by the worldwide scientific community. To develop the main concepts and tools, the IAEA Biota WG and the 5th Committee of ICRP were created. Our studies contribute to the empirical basis of the concepts through specification of the reference organisms and determination of the dose-effect dependences

- our studies showed the ways for the further development of the widely-used dosimetric models for biota (such as ERICA Tool). For example, at least for the tree species we can suggest to specify the critical organ, to take into account the actual spatial distributions of radionuclides in the organism and their dynamics etc. This can be important:

Dose coefficients for incorporated RN for *Pinus sylvestris*, μGy h^{-1} (Bq $kg^{-1})^{-1}$

RN	ERICA Tool	Our model
^{137}Cs	3.2×10^{-4}	2.1×10^{-3}
^{90}Sr	6.5×10^{-4}	7.1×10^{-4}

Other advantages of the research approach

- our studies for Scots pine showed that the considered to be safe for the terrestrial ecosystems the dose rate value of 10 µGy h^{-1} (screening value) might be rather high for this species. According to the obtained “dose rate – effect” dependency, it corresponds to 32% frequency of morphological changes in the pine plantation
- in this concern, determination of the risk to the whole ecosystem as a sum of the risk quotients for the reference species may need certain revision. Some ideas for such a revision can come with the further accumulation of the empirical data.

Stage of development

- the elaborated methods were applied to other plant species. As a result, a referent grass species (Evening primrose, or *Oenothera Biennis* L.) was identified for the terrestrial ecosystems of Chernobyl zone and the “dose rate – cytogenetic effect” dependence was formulated
- the study of the long-term dynamics of the level of cytogenetic damages in Scots pine is in progress

Possible area of application

- the elaborated methods of the studies can be used to evaluate the radiation effects to the natural ecosystems
- the developed dosimetric model can be adjusted to other plant species
- obtained data can be integrated into the radiation effects databases, such as FREDERICA, and also can be used separately for prognosis of the radiation effects to the pine forest ecosystems

Opportunities

Ukrainian Institute of Agricultural Radiology is interested in performing the joint research projects in the fields of the radiation effects to biota, elaboration of the methods for reduction of the radionuclides bioavailability by means of their fixation in soil, and other fields of the mutual interest

Our institute possesses the unique experimental sites in Chernobyl exclusion zone for studies of the geochemical and biogenic migration of radionuclides, soil-to-plant transfer factors, effects to biota etc. Also, we have all the analytical facilities and methodologies necessary for the reliable measurements of radionuclides in the environmental samples, the great experience of the successful international projects and the skilled staff

More details are presented in:

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Environmental Radioactivity 86 (2006) 143–163
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY
www.elsevier.com/locate/jenvrad

Resuspension and redistribution of radionuclides during grassland and forest fires in the Chernobyl exclusion zone: part I. Fire experiments

V.I. Yoschenko [a], V.A. Kashparov [a,*], V.P. Protsak [a], S.M. Lundin [a], S.E. Levchuk [a], A.M. Kadygrib [a], S.I. Zvarich [a], Yu.V. Khomutinin [a], I.M. Maloshtan [a], V.P. Lanshin [a], M.V. Kovtun [a], J. Tschiersch [b]

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Environmental Radioactivity xx (2006) 1–19
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY
www.elsevier.com/locate/jenvrad

Resuspension and redistribution of radionuclides during grassland and forest fires in the Chernobyl exclusion zone: part II. Modeling the transport process

V.I. Yoschenko [a,*], V.A. Kashparov [a], S.E. Levchuk [a], A.S. Glukhovskiy [a], Yu.V. Khomutinin [a], V.P. Protsak [a], S.M. Lundin [a], J. Tschiersch [b]

VOL. 101, NO. 4, OCTOBER 2011
HEALTH PHYSICS
THE RADIATION SAFETY JOURNAL
The Official Journal of the Health Physics Society

CHRONIC IRRADIATION OF SCOTS PINE TREES (*PINUS SYLVESTRIS*) IN THE CHERNOBYL EXCLUSION ZONE: DOSIMETRY AND RADIOBIOLOGICAL EFFECTS

Vasyl I. Yoschenko,* Valery A. Kashparov,* Maxim D. Melnychuk,[†] Svjatoslav E. Levchuk,* Yulia O. Bondar,[†] Mykola Lazarev,* Maria I. Yoschenko,* Eduardo B. Farfán,[‡] and G. Timothy Jannik[‡]

UIAR

Contact information

Vasyl YOSCHENKO

Telephone +(38044) 5262444

E-mail vasyl@uiar.kiev.ua

Ukrainian Institute of Agriculture Radiology

Kyiv

UIAR