

Good afternoon, dear colleagues. I'm Vasyl Yoschenko from Ukrainian Institute of Agricultural Radiology. First of all, I would like to thank you for the invitation to visit your country and the warm welcome here. I have to admit that during this research year we visited many industrial sites and seen the impressive results of agriculture scientists. In general we hope very much that we will have the collaboration in [Unclear]. Valery Kashparov...

## Radioactive contamination after Chernobyl and Fukushima

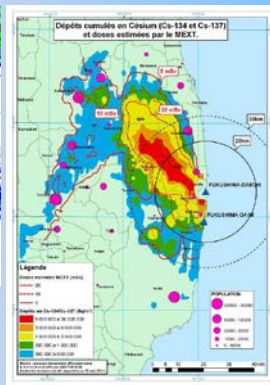
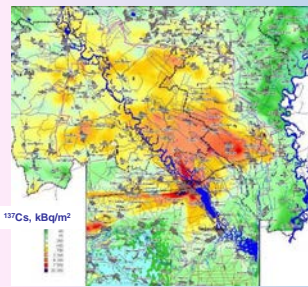


Table 1: Deposits, projected external doses for the 1<sup>st</sup> year and affected populations

Deposits of cesium (137 + 134) (Source: MEXT)	< 500,000 Bq/m <sup>2</sup>	500,000 - 1,000,000 Bq/m <sup>2</sup>	> 1 million Bq/m <sup>2</sup>	> 3 million Bq/m <sup>2</sup>
External dose 1 <sup>st</sup> year (15.6 mSv per MBq/m <sup>2</sup> )	< 5 mSv	50 mSv	100 mSv	1000 - 5000 mSv
Affected population (excluded the necessary zone)	242,000	43,000	25,100	3,100
				2,200

### Chernobyl and Fukushima accidents:

- close levels of contamination with radiocesium and close areas affected

### Japan and Chernobyl zone:

- approx 2/3 of the territories are covered with forests

### Differences between the two accidents / areas affected:

- presence of the fuel component radionuclides (<sup>90</sup>Sr, TUE etc) in CEZ
- landscape

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Valery Kashparov presented the situation in forest in Ukraine in general. In my presentation I will concentrate on the most contaminated part of the acute territory [Unclear] contaminated territory in Ukraine between the 30 kilometer Chernobyl zone.

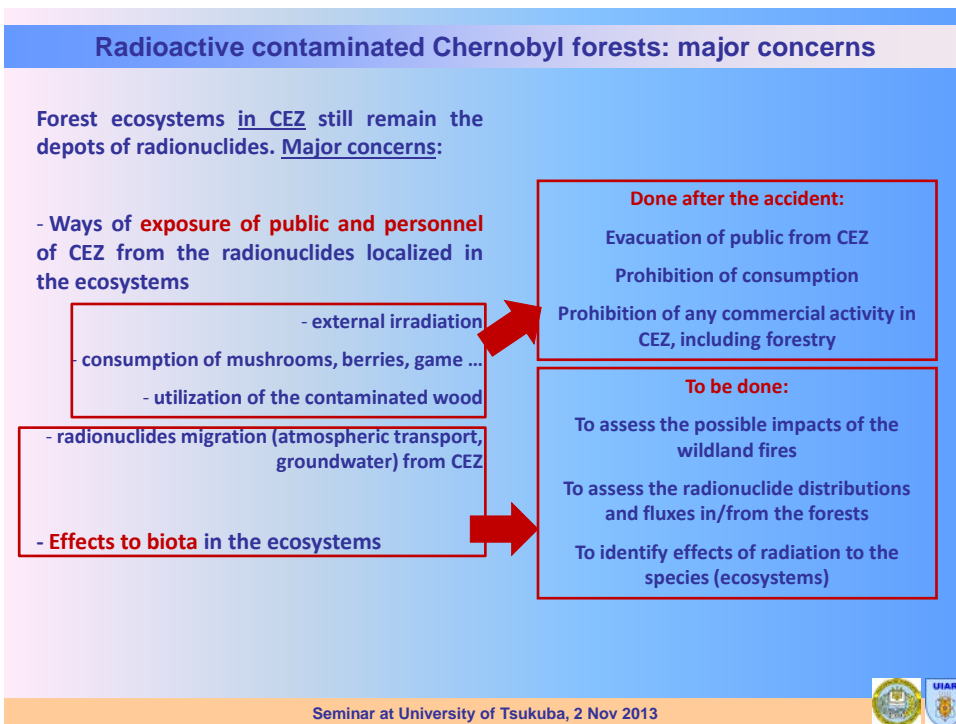
First, I'd like to show you this map, is the map of Chernobyl affected area and this is Fukushima affected area.

These are the maps in same special scale.

You can see in general the territory affected by the Fukushima accident is smaller than the territory affected by Chernobyl and the levels of contaminations in Fukushima are lower but we can say that these are more or less of the same magnitude.

Both for Japan and for Chernobyl zone approximately more than 60,000 [Unclear] territories are covered as well as the forest are important and and there are, of course, some differences [Unclear] in case of Chernobyl presence of strontium and transuranium elements in the release.

And second is different landscape. In Chernobyl, normally, we have the flat landscapes and here [Unclear].



So the forest in Chernobyl exclusion zone will remain for the long time the depots of radionuclides because we don't make any decontamination.

And in this case we have to think about possible exposure to public and personnel along with various other exposure and...

[Unclear] zone we can – in general for the contaminated forest the [Unclear] possible impacts on population we imagine of exposures.

We can especially for the [Unclear] zone another consignment [ph] is possible migration of radionuclides localized in this territory to other territories of Ukraine.

Again, if these ecosystems are contaminated we have to think about the possible effects of biota to wild [Unclear].

For exposure of population as Dr. Kashparov said, it can be profound because we evacuated public from the exclusion zone.

And to address these provisions we performed special experiments, evaluate...

**Wildland fires: the problem**

**Wildland fires frequency (average)**

	Number of fires	Area burnt, ha yr <sup>-1</sup>	Frequency, km <sup>2</sup> yr <sup>-1</sup>
Ukraine 2001-2003, Zibitsev, 2002	3866	3927	6.4·10 <sup>-3</sup>
Japan 1990-1999, Forestry Agency Japan, 2000	3274	2311	8.7·10 <sup>-3</sup>

Chernobyl Exclusion zone:  
 increased frequency – 42-116 fires per year, or (2-5.7) ·10<sup>-2</sup> km<sup>2</sup> yr<sup>-1</sup>;  
 increased severity of fires – up to average of 80 ha per fire in 1992

**Wildland fires impacts:**

- radioecological – radioactivity redistribution (resuspended amounts and transportation range of the radionuclides);
- radiological – doses to the firefighters and population (airborne concentrations, dispersal composition, solubility etc);
- social (awareness of the authorities and population concerning the actual potential consequences of the fires)

NOAA, 08 May 2003, 18:30, UCLRM

Seminar at University of Tsukuba, 2 Nov 2013 by UCLRM

First, one of the possible ways of radionuclides migration from the exclusion zone can be forest fire, wildland fire.

And in this I used the data for Japan which I found in the Internet and I can show that, in general, the number of fires per year and the average burnt area in Japan, in Ukraine are almost the same [Unclear] territory.

I don't know if this is important for Japan but it can be important for us.

Also after abandoning of the exclusion zone the number of frequency of fires and the severity of fires rise in the Chernobyl exclusion zone.

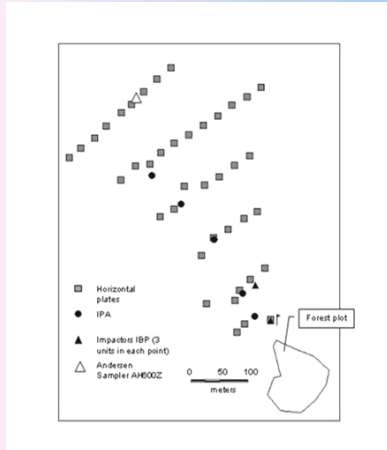
I hope you can see this green line, shows airborne concentration of radionuclides in Chernobyl during the fire. It exceeds the concentration during the dust storms and during the normal weather.

This is for Chernobyl zone. People in here for example mentioned about the possible impact on their health from the fires at Chernobyl.

There is some background to say about that. As you can see this is a satellite image of the fire which is localized here. This is in west part of – to the west of the exclusion zone and this is here. This whole blue [Unclear].

## Wildland fires: experimental studies

### Forest fire experiment



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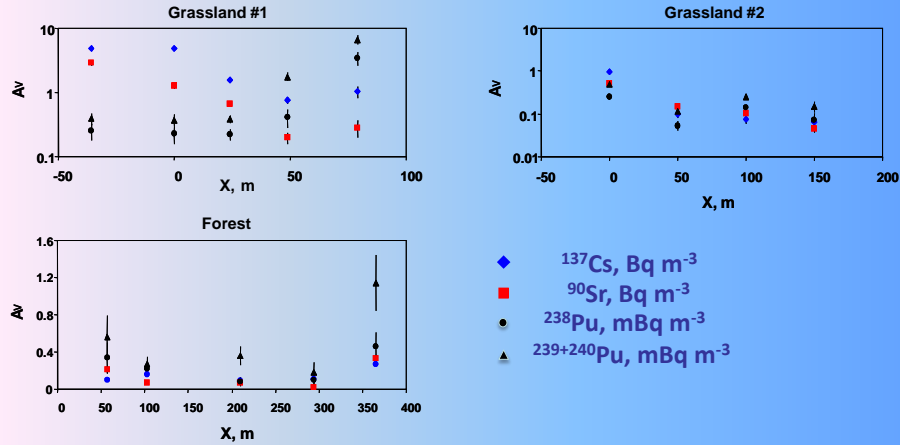
In order to determine what is really the danger of the fires we make the experiments control points of the [Unclear] in the exclusion zone.

So firstly, this is a forest, this one. Firstly...

...it's on the research and equipment [Unclear] matters.

## Wildland fires: experimental studies

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



Besides the values of the radionuclide airborne concentrations, these data show the ranges of their transportation during the fires

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In this way we can manage the concentrations of different radionuclides, and the various distances from the social human beings and [Unclear] for forest fire here. There have been concentration of cesium, for example, is also mainly the various [Unclear]. Another interesting point here is a range of spreading of the plume.

In general, the public awareness several hundred meters.

## Wildland fires: experimental studies

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

Calculated for	$^{137}\text{Cs}$	$^{90}\text{Sr}$	$^{238}\text{Pu}$	$^{239+240}\text{Pu}$
Grassland fire, #1				
Activity in fuel material	$(1.7 \pm 0.2) \cdot 10^{-5}$	$(1.5 \pm 0.2) \cdot 10^{-5}$	$(3.5 \pm 1.0) \cdot 10^{-7}$	$(2.4 \pm 0.6) \cdot 10^{-7}$
Total activity	$(1.7 \pm 0.2) \cdot 10^{-7}$	$(3.7 \pm 0.5) \cdot 10^{-7}$	$(4.9 \pm 1.4) \cdot 10^{-9}$	$(3.8 \pm 0.9) \cdot 10^{-9}$
Grassland fire, #2				
Activity in fuel material	$(8.0 \pm 4.8) \cdot 10^{-6}$	$(4.4 \pm 2.6) \cdot 10^{-6}$	$(2.9 \pm 2.3) \cdot 10^{-6}$	$(2.6 \pm 2.1) \cdot 10^{-6}$
Total activity	$(1.9 \pm 1.1) \cdot 10^{-7}$	$(1.8 \pm 1.5) \cdot 10^{-7}$	$(1.3 \pm 1.0) \cdot 10^{-8}$	$(1.3 \pm 1.0) \cdot 10^{-8}$
Forest fire, #3				
Activity in litter	$(7.0 \pm 2.8) \cdot 10^{-7}$	$(1.2 \pm 0.5) \cdot 10^{-6}$	$(1.2 \pm 0.8) \cdot 10^{-6}$	$(9.4 \pm 5.2) \cdot 10^{-7}$
Activity in fuel material	$(4.7 \pm 2.0) \cdot 10^{-7}$	$(3.5 \pm 1.6) \cdot 10^{-7}$	$(1.1 \pm 0.7) \cdot 10^{-6}$	$(8.3 \pm 4.8) \cdot 10^{-7}$
Total activity	$(4.7 \pm 2.0) \cdot 10^{-8}$	$(1.1 \pm 0.5) \cdot 10^{-7}$	$(3.2 \pm 2.2) \cdot 10^{-8}$	$(2.5 \pm 1.6) \cdot 10^{-8}$

These data (at least orders of magnitude) can be used to estimate the radionuclides resuspension during other wildland fires

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Also we determined the resuspension factors and other parameters which characterize distribution of radionuclides during the fires.

## Wildland fires: experimental studies

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

	Maximum airborne concentration, Bq m <sup>-3</sup> , in the site			Way of exposure	Dose, μSv, in the site		
	#1	#2	#3		#1	#2	#3
<sup>137</sup> Cs	5	1	0.27	External from the cloud	6.9·10 <sup>-4</sup>	1.4·10 <sup>-4</sup>	3.7·10 <sup>-5</sup>
				Inhalation	6·10 <sup>-2</sup>	1.2·10 <sup>-2</sup>	3.2·10 <sup>-3</sup>
<sup>90</sup> Sr	3	0.5	0.33	External from the cloud	10 <sup>-4</sup>	1.7·10 <sup>-5</sup>	1.1·10 <sup>-5</sup>
				Inhalation	0.24	4.1·10 <sup>-2</sup>	2.6·10 <sup>-2</sup>
<sup>238</sup> Pu	3.4·10 <sup>-3</sup>	2.5·10 <sup>-4</sup>	4.6·10 <sup>-4</sup>	Inhalation	<b>7.1</b>	<b>0.53</b>	<b>1</b>
<sup>239+240</sup> Pu	6.7·10 <sup>-3</sup>	5.1·10 <sup>-4</sup>	1.1·10 <sup>-3</sup>	Inhalation	<b>17</b>	<b>1.3</b>	<b>2.8</b>
External irradiation from soil and vegetation					16	10	4.2
Total dose					40	12	8

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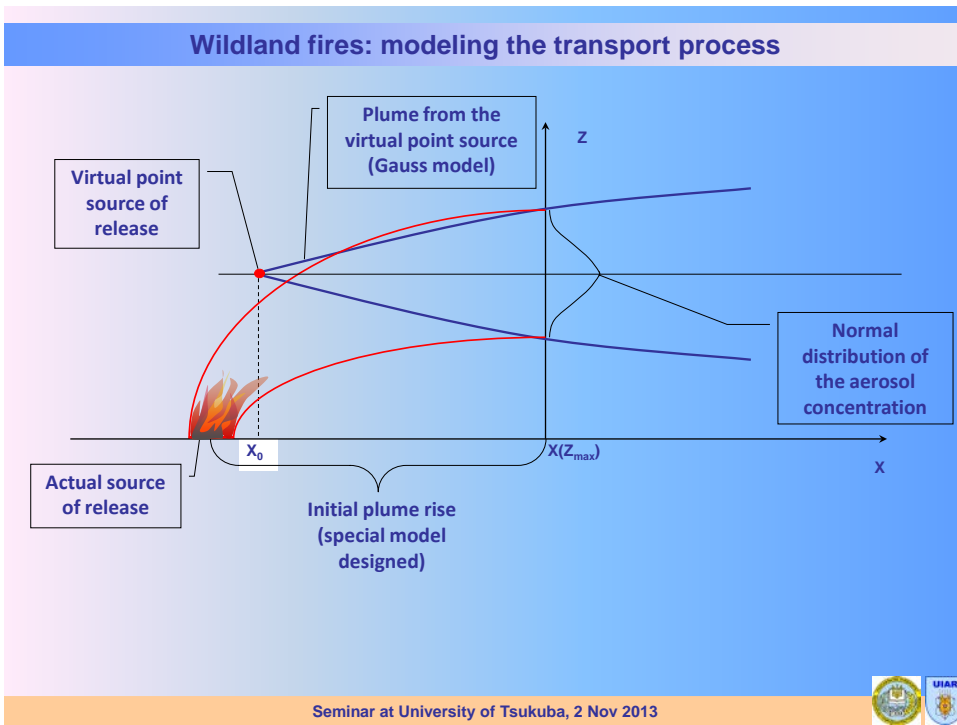


This is really [Unclear] of the dose in especially to fireman calculated for the very conservative scenario that this fireman stands in the most contaminated point.

These are exposure during 1 hour and we've calculated here effective equivalent dose. Now the important information here is for this another case and internal doses can be equal or even exceed the doses from external inhalation during the same period. We think this is from inhalation and the total dose is say external is 60 and the total [Unclear].

But this is because of inhalation of plutonium by the dose, and cesium and strontium did other smoke...

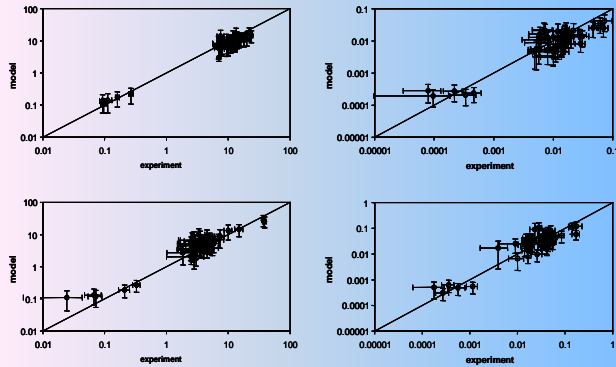




We've made some modeling exercise and the modeling...

## Wildland fires: modeling the transport process

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



Radionuclide releases during the fires,  
% of activity in fuel material (aboveground biomass + litter)

	$^{137}\text{Cs}$	$^{90}\text{Sr}$	$\Sigma\text{Pu}$
Grass #1	0.06	0.15	0.03
Grass #2	0.14	0.15	0.07
Forest	4.2	2.9	0.8

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In this right here, conduct this experiment and calculate the data and we did it among the activities, the percent of activity which was reduced in the fire from the burned, from the above-ground biomass and litter. Forest fires and some parts of [Unclear].

## Wildland fires: conclusions

### Local scale surface fires:

- no any significant redistribution of radioactivity
- impacted area: some hundreds meters
- critical group of personnel: firefighters
- doses to the critical group: low doses; significant contribution of internal radiation due to **inhalation of TUE**

### Large fires (modeled scenario – all critical forest stands in CEZ burn simultaneously):

- no any significant redistribution of radioactivity from CEZ
- no any significant additional doses to the personnel in CEZ and population outside CEZ

### To be able to assess the potential impacts of the fires we have to know (in addition to the fire intensity, weather parameters etc):

- radionuclide fractions in the aboveground biomass (distribution in the forests)
- fraction of radionuclides released from the burning biomass

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That's the conclusion and here I've assumed...

Important thing here is that to be able to assess the potential impact of forest fires we have to know the fractions of radionuclides in the aboveground biomass.

## Forest ecosystems: radionuclides distributions and fluxes

Natural ecosystem: 40 y.o. pine forest  
(Scots pine)



Semi-natural ecosystem: 20 y.o.  
plantations at the Red Forest storage site  
(Scots pine and birch)



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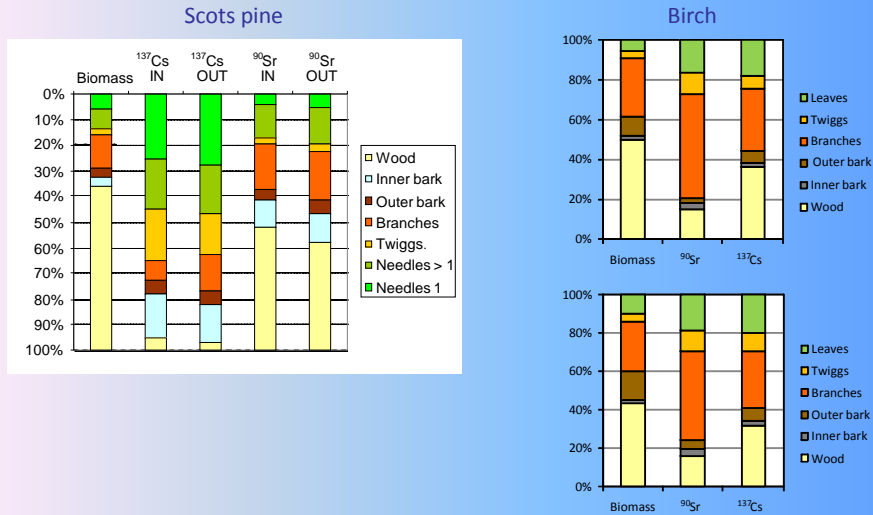
[Unclear] we did extensive activities about the radionuclides distribution in the forest ecosystem. We performed extensive activities [Unclear] radionuclides distribution and fluxes in the forest ecosystem.

Our results from [Unclear] ecosystem one is, the pine tree growth in the experiment is 40 years of pine forest

Another is semi-natural ecosystem. This is plantation of Scots pine and birch and they're here in the territory of the Red Forest.

## Forest ecosystems: radionuclides distribution

Semi-natural ecosystem (Red Forest):



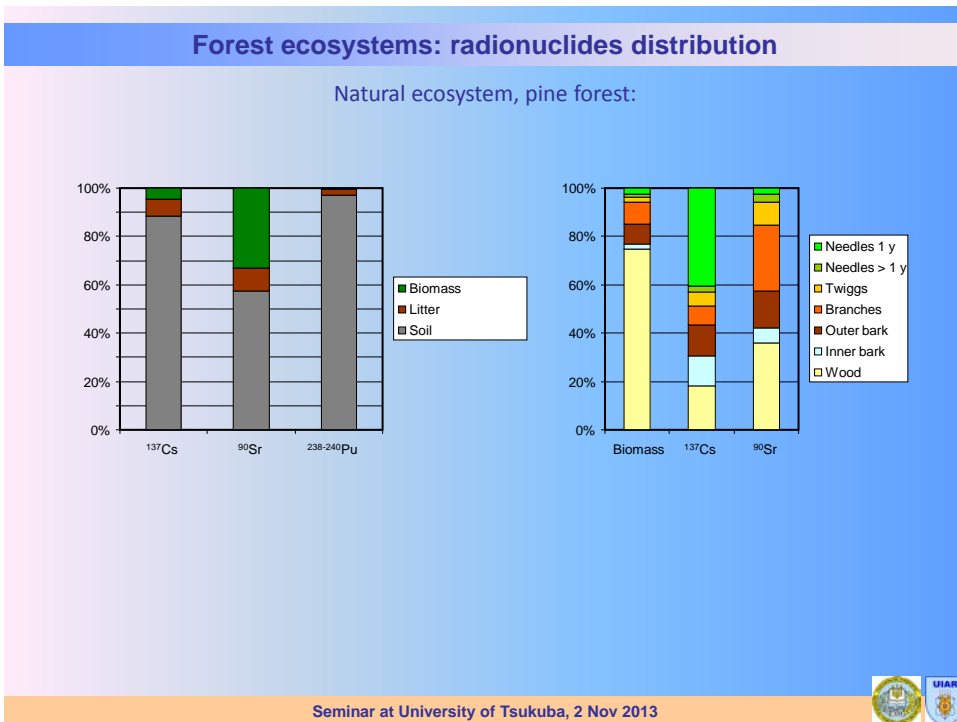
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In the Red Forest, we have our main experimental site and as always Dr. Kashparov was at site.

In Red Forest you can see the distribution of radionuclides in different compartments of the leaves, of the above-ground biomass.

Here, what's strange [ph] for example, was cesium.



And the same is for the natural ecosystem.

[Unclear] weather here, with first season, the total activity in aboveground biomass is say 5% of the total activity in the ecosystem. This is much lower than normally in Japan forest fire outside [Unclear].

But there is big problem with strontium in pine tree because its total content in the above-ground biomass can be [Unclear] of the total [Unclear] in the ecosystem.

## Forest ecosystems: definition of the radionuclide fluxes

**R, requirement or incorporation**, is the total activity of radionuclide mobilized by the current production of biomass

$$R = \sum \Delta M_i \times C_i$$

$\Delta M_i$  - the annual increments of the tree's elements

$C_i$  - the radionuclide specific activity in the element at the end of the growing season

$i$  = needles, twigs, branches, wood and bark.

**U, uptake**, is the radionuclide activity taken from the soil by the root system

$$U = \sum \text{Immobilization}_i + \sum \text{Return}_j \pm \Delta f$$

$i$  = wood, branches, bark

$j$  = litterfall, throughfall

$\Delta f$  - changes of the radionuclide activity due to variations in the needles biomass.

**T, internal transfer**, is a sum of the radionuclide fluxes from senescing tree parts to support new biomass production

$$T_{\text{needles}} = \Delta M_{\text{litter}} \times (C_{\text{needles}} - C_{\text{litter}}) - \text{throughfall}$$

$$T_{\text{branches}} = \Delta M_{\text{branches}} \times (C_{\text{twigs}} - C_{\text{branches}})$$

$$T_{\text{bark}} = \Delta M_{\text{bark}} \times (C_{\text{inner bark}} - C_{\text{outer bark}})$$

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We were once approached to determine the radionuclides once it's [ph] in the ecosystem [Unclear].

### Male Participant

Can you please repeat?

### Dr. Vasyl Yoschenko

We were once approached to determine to recognize [ph] the radionuclides cycle in the ecosystem.

## Forest ecosystems: modeling the RN transfers

IAEA BIOMASS, 2002

MATPASS (UIAR NUBiP)

Atmosphere	intercept rainfall snowfall	intercept rainfall snowfall			intercept rainfall snowfall			intercept rainfall snowfall	intercept rainfall snowfall	intercept inhalation
Transpir.	Tree leaves	weathering	translocation	translocation	leaf fall weathering			weather intercept	weather intercept	ingestion
		External bark	translocation		weather intercept			weather intercept	weather intercept	ingestion
	translocation	translocation	Living wood	translocation		fertilisation	fertilisation	mycorrhizae transfer		ingestion
			translocation	Dead wood						
Rain-penetration		rain splash	root uptake		Litter	Decomp. Percolation soil biota		uptake	rain splash root uptake	ingestion
			root uptake			Soil organic	percolat. diffusion Advect. soil biota	uptake	root uptake	
			root uptake			diffusion capillary rise soil biota	Soil Mineral	uptake	root uptake	
			root upgr. (mycorrhizae)		fertilisation	fertilisation	fertilisation	Fungi	Root upgr. (mycorrhizae)	ingestion
transpir.					leaf fall weather intercept	fertilisation	fertilisation	mycorrhizae transfer	Understorey	ingestion
					fertilisation					Game

Interaction matrix for <sup>137</sup>Cs in forests (IAEA BIOMASS, 2002)

MINERAL SOIL

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We were just finishing [Unclear].

The IAEA in the [Unclear] biomass group recommends the interaction matrix for cesium in forest.

There is a lot of compartments with different relations between them. But it was too complicated and we [Unclear] we created [Unclear] MATPASS which is less complicated but the main part present here is the uptake from the total biomass and especially the renewable mass, translocation between these two components depend on the litter and soil and also depend in the ground and [Unclear] particles which is not from Japan. And the soil is basically several layers with different geochemical [ph] factors.



## Semi-natural forest ecosystem: radionuclides fluxes (2005)

Radionuclide annual fluxes in Red Forest (Scots pine plantation, 3300 trees ha<sup>-1</sup>):

Fluxes	<sup>137</sup> Cs		<sup>90</sup> Sr	
	GBq ha <sup>-1</sup> y <sup>-1</sup>			
	OUT	IN	OUT	IN
Incorporation	0.67	1.13	4.6	22.9
<b>Uptake (1+2+3)</b>	<b>0.3</b>	<b>0.36</b>	<b>7.6</b>	<b>37.5</b>
(1) immobilization	0.05	0.06	1.97	11.0
(2) return to soil	0.21	0.24	5.56	26.1
(3) Δf	0.04	0.06	0.11	0.4
Internal transfer	0.39	0.8	-2.95	-15.9

### ARE THESE FLUXES BIG?

Total activities in the studied trench: <sup>137</sup>Cs ~ 600 GBq, <sup>90</sup>Sr ~ 290 GBq

Total activities in the trees biomass at the trench: <sup>137</sup>Cs ~ 0.024%, <sup>90</sup>Sr ~ 2.52% of the radionuclides inventories in the trench

Annual uptake fluxes: <sup>137</sup>Cs ~ 0.0038%, <sup>90</sup>Sr ~ 0.82% of the radionuclides inventories in the trench

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Here are the reference of the flux estimations for Scots pine. It refers to the total values of uptake of radionuclides from soil and we have to [Unclear].

Comparing to the radionuclides contents in the trench for various trees [ph] cesium in the ground biomass is a small number, but for strontium that is 2.5%.

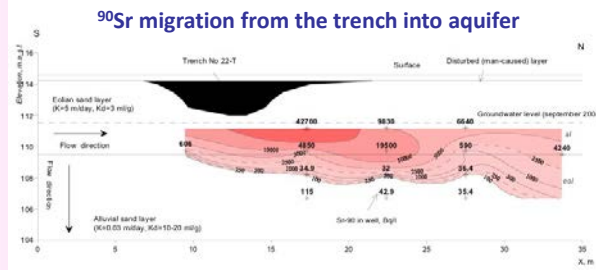
Although uptake flux of cesium is small but for strontium this is almost 1% of the total content in the trench.

## Semi-natural forest ecosystem: radionuclides fluxes (2005)

### ARE THESE FLUXES BIG?

Total activities in the trees biomass at the trench:  $^{137}\text{Cs} \sim 0.024\%$ ,  $^{90}\text{Sr} \sim 2.52\%$  of the radionuclides inventories in the trench

Annual uptake fluxes:  $^{137}\text{Cs} \sim 0.0038\%$ ,  $^{90}\text{Sr} \sim 0.82\%$  of the radionuclides inventories in the trench



### $^{137}\text{Cs}$ migration from the trench into aquifer:

Specific activities of  $^{137}\text{Cs}$  in aquifer are 3-5 orders of magnitude lower than those of  $^{90}\text{Sr}$  (up to  $0.1 \text{ Bq L}^{-1}$ )

Biogenic migration of  $^{137}\text{Cs}$  can be more intensive than its geochemical migration

Till 2001,  $(7 \pm 5)\%$  of the  $^{90}\text{Sr}$  initial inventory had migrated from the trench into aquifer

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Comparing to the migration [Unclear] migration from the trench the base values for strontium are even bigger because during the 15 years there is migration order of several percents so it is – this one is bigger.

### Natural forest ecosystem: radionuclides fluxes (2002)

Fluxes	<sup>137</sup> Cs	<sup>90</sup> Sr
	MBq ha <sup>-1</sup> y <sup>-1</sup>	
Incorporation	390	1115
Uptake (1+2+3)	129	1063
(1) immobilization	20	294
(2) return to soil	75	753
(3) Δf	34	16
Internal transfer	301	-213

#### ARE THESE FLUXES BIG?

Annual uptake fluxes: <sup>137</sup>Cs ~ 0.67%, <sup>90</sup>Sr ~ 5.6% of the radionuclides inventories in the ecosystem

Annual geochemical migration fluxes: conservative estimate for typical ecosystems in CEZ ~ 0.1%

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Also biogenic migration of cesium can be more intensive than its geochemical migration. And also...

For the natural ecosystems, the annual uptake fluxes can be some percents, up to 1% of the total radionuclides inventory in the ecosystem and several percent for strontium.

While the geochemical migration on the ecosystem – on the typical ecosystem in the Chernobyl exclusion zone are much lower.

## Forest ecosystems, radionuclides distribution and fluxes: conclusions

### Natural ecosystems:

- significant amounts of  $^{90}\text{Sr}$  are localized in the aboveground biomass, and for  $^{137}\text{Cs}$  and TUE these amounts are much lower (forests in CEZ!)
- annual uptake fluxes can reach n % and 0.n % of the  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  total inventories in the ecosystem, respectively
- geochemical migration fluxes are lower than biogenic migration fluxes
- modeling results: biogenic and geochemical fluxes (uptake of radionuclides by vegetation) together form the radionuclides cycling in the ecosystem; uptake of radionuclides by plants is a significant factor determining the radionuclides vertical distribution in soil profile and decreasing their downward migration rates

### Semi-natural ecosystems:

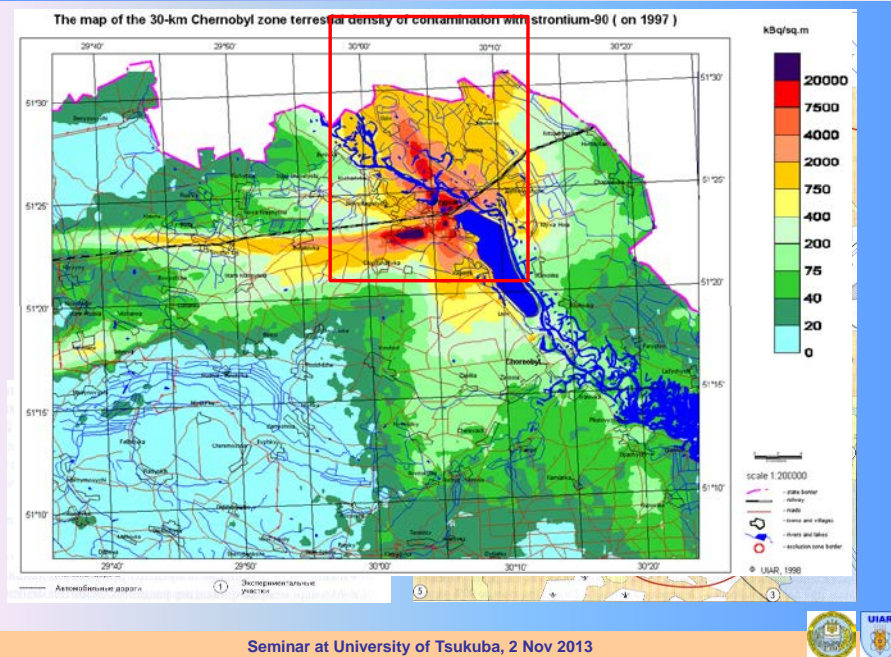
- biogenic and geochemical fluxes of radionuclides are close
- radionuclides from the deep soil layers are not involved into the cycling and can migrate to the groundwater

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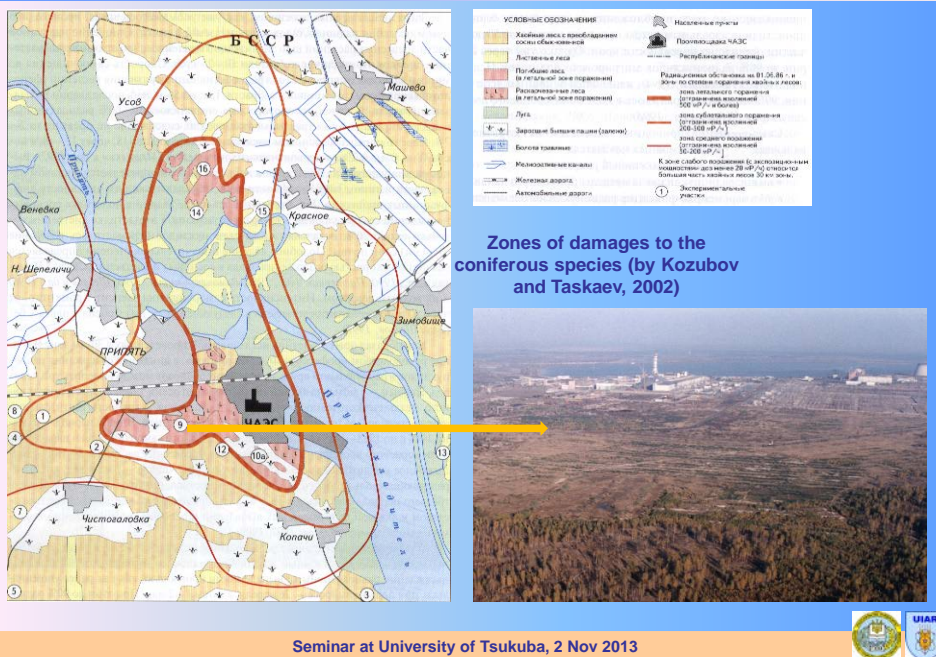
Just my conclusion that biogenic fluxes play a very important role in the formation of cycling of radionuclides in the ecosystem.

## Contamination of the Chernobyl zone and effects of acute irradiation



The last part of my presentation is around the effects of radiation to biota. So in this map of contamination you can see the heavy contaminated part of the 70 kilometer zone. For this part, up on the accident, this is the same part. And...

## Effects of acute external irradiation: Red Forest



This is very near from the Chernobyl accident.

Chernobyl atmosphere and here is Red Forest and here are some other places in Chernobyl.

These two zones are the zones of the level effects to the coniferous species [Unclear] pine species.

Due to acute irradiation in this area [Unclear].

This is the Red Forest after the trees were dried and cut.

## Effects of radiation: non-human biota in the radiation protection system

**The approaches to the radiation protection of biota must be developed (active contributors: EMRAS BWG of IAEA, 5<sup>th</sup> Committee of ICRP ...) taking into account:**

- biodiversity (various ways of irradiation and doses to the organisms in the same ecosystem, various life spans of species, various radiosensitivity etc)
  - relations in the ecosystems (roles of certain species in the ecosystem, evolution of the irradiated ecosystem ...)
  - final aims of the biota protection (what must be protected – individual organisms, populations, ecosystems? how to protect? ...)

### **Current approach (ICRP...):**

- for typical ecosystems (terrestrial, freshwater, marine) the referent animals and plants (RAPs) are selected
- radiation effects are estimated for RAPs and then for the whole ecosystem through application of the risk quotients

*Example – ERICA Tool*

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PASS

Non-human biota in the radiation protection system		
RAPs ( <i>ICRP Publ. 103</i> , ERICA Tool):		
Freshwater	Marine	Terrestrial
Amphibian ( <i>frog</i> )	Bird ( <i>duck</i> )	Amphibian ( <i>frog</i> )
Benthic fish	Benthic fish ( <i>flat fish</i> )	Bird ( <i>duck</i> )
Bird ( <i>duck</i> )	Bivalve mollusc	Bird egg ( <i>duck egg</i> )
Bivalve mollusc	Crustacean ( <i>crab</i> )	Detritivorous invertebrate
Crustacean	Macroalgae ( <i>brown seaweed</i> )	Flying insects ( <i>bee</i> )
Gastropod	Mammal	Gastropod
Insect larvae	Pelagic fish	Grasses and herbs ( <i>wild grass</i> )
Mammal	Phytoplankton	Lichen and bryophytes
Pelagic fish ( <i>salmonid/trout</i> )	Polychaete worm	Mammal ( <i>rat, deer</i> )
Phytoplankton	Reptile	Reptile
Vascular plant	Sea anemones/true corals	Shrub
Zooplankton	Vascular plant	Soil invertebrate (worm) ( <i>earthworm</i> )
	Zooplankton	Tree ( <i>pine tree</i> )

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To characterize in general, [Unclear] effects to biota, the IAEA and ICRP and other international organization recommended approach by doing the referent selection.

For terrestrial this is [Unclear] from the [Unclear] tree, for pine tree, for shrubs and for grass and herbs.



**Effects of radiation to Scots pine: chronic irradiation, 1990-2000**



**Exposures: external and internal**

By Kozubov and Taskaev, 2002

Seminar at University of Tsukuba, 2 Nov 2013



After the establishment of the new plantation in the Red Forest in the early clearing we had the numerous kinds of morphological changes in the trees.

## Effects of radiation to Scots pine: chronic irradiation, after 2005 (UIAR)

Typical morphological changes: cancelling the apical dominance, suppressing the trees' growth



Experimental array: more than 1100 pine trees

For each tree the morphological characteristics and dose rates from external sources and from incorporated radionuclides were determined

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This is [Unclear].

And now if you travel back the changes [Unclear] mainly are on this site.

Normally pine tree has one trunk, and then every year one trunk.

But in some cases the apical dominance is cancelled [Unclear] center of plant and also is dominant the trees.

We implemented more than 1100 pine trees.

For each tree we determine the morphological characteristics and the different doses.

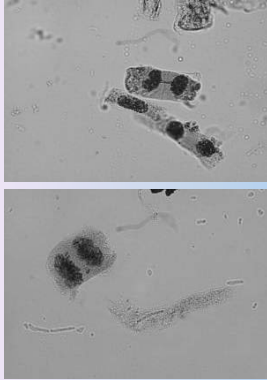
## Effects of radiation to biota

Cytological studies at the experimental array of *Pinus sylvestris*

Sub-array: several trees of the experimental array which represent various dose rates

Tissues and methods:

meristem of the seed germs  
(direct counting the DNA aberrations)



apical meristem  
(single cell gel electrophoresis)



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This is the database we made from this.

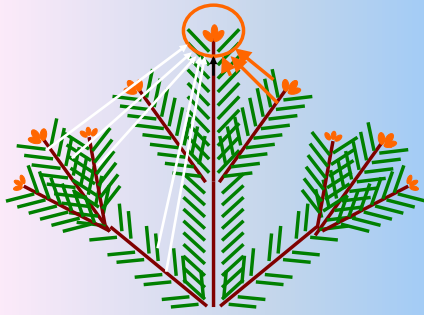
We applied also the morphological experiments, we applied some cytogenetics to this. We did some DNA aberration methods and by single-cell electrophoresis.

## Effects of radiation: dosimetry

### Calculation of the dose rates to *Pinus sylvestris*

Target organ: dominant bud

Source of radiation: incorporated RN



#### The model takes into account:

- ✓  $\beta$ -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)

#### Principal approach:

- ✓ 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

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We also have a look at the dosimetry model we just put up for this especially because the, for example, ERICA tool use just a tree will be different [Unclear] others geometry of the trees.

## Effects of radiation : dosimetry

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

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

Reason of discrepancy: ERICA Tool does not take into account the actual RN distribution and their activities dynamics.

Also, ERICA Tool operates with the "tree" and does not specify the target organ.

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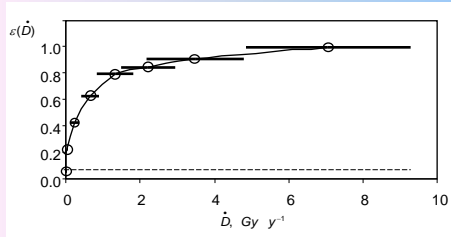


The dose coefficients of that comparing ERICA to our model are different because we take into account the radionuclide dynamics during the year and values of the trees.

Also we select the [Unclear].

## Effects of chronic radiation to Scots pine: dose-effect curves

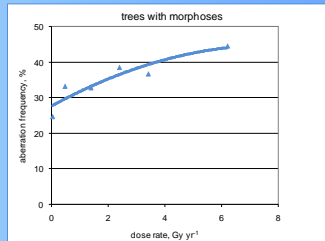
Morphological changes



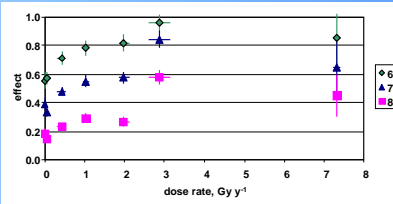
$EDR_{10} \approx 0.008 \text{ Gy y}^{-1} \approx 0.9 \text{ } \mu\text{Gy hr}^{-1}$   
 $EDR_{50} \approx 0.35 \text{ Gy y}^{-1} \approx 40 \text{ } \mu\text{Gy hr}^{-1}$

Cytogenetic effects

DNA aberrations in seed germs



Fraction of heavy damaged nuclei in apical meristem



**ERICA Tool screening value of  $10 \text{ } \mu\text{Gy hr}^{-1}$  corresponds to the morphoses frequency of 32%.**

This dose rate in our experimental array occurs at the soil contamination levels of approx  $10 \text{ kBq kg}^{-1}$  of  $^{137}\text{Cs}$  and  $5 \text{ kBq kg}^{-1}$  of  $^{90}\text{Sr}$ .

According to ERICA Tool, for  $^{137}\text{Cs}$  contamination only, it corresponds to  $\sim 70 \text{ kBq kg}^{-1}$  soil, d.w.

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We might factor that [Unclear]

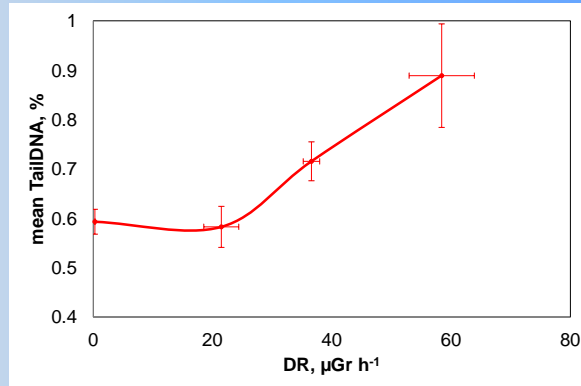
Thus in this way we obtained the dosing factor, the morphological change and the cytogenetic change.

This is important that now [Unclear] screening value is for direct [Unclear] is on your left hand microgray per hour which seems to be same but...

...but in our case, for our ecosystem it was [Unclear] ecological change in each Scots tree.

## Other species damaged? (UIAR, 2011)

Cytogenetic effects in Evening primrose (*Oenothera Biennis* L.)



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And also there are some other species.

We demonstrate the kind of cytogenetic change in the dose rate.

By the way, I saw this grass yesterday at one of the site near Fukushima site.

## Effects of radiation to biota: conclusions

- in CEZ the effects of acute and chronic radiation have been observed in the terrestrial ecosystems both at the morphological and cytological levels during the whole post-accidental period (till now);
- for the most sensitive plant species in CEZ, Scots pine, chronic radiation leads to formation of the numerous morphological changes and to the significant suppression of the plants development at the dose rates thought to be 'safe' for the terrestrial ecosystem. In the same time, this species is a principal one for the most forests in the zone;
- apparent rate of morphological changes at the 'safe' dose rate level shows also a need for the further acquiring the empirical data on the radiation effects in order to build up the radiation protection system for non-human biota. Collaborative efforts of Ukrainian and Japanese researchers can be very fruitful;
- possible fate of the ecosystems at the radioactive contaminated territories needs evaluation. In this concern, the special case is the ecosystems at the territories of the sub-surface storages of radioactive materials (such as Red Forest in CEZ)

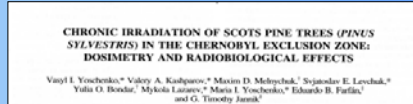
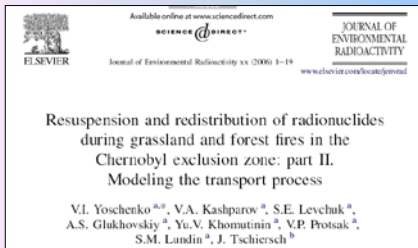
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I already spoke a lot so from here I will speak to the conclusions because it is what our [Unclear] it is important I believe that in collaborative research we can introduce reliable system of radiation protection of biota.



## Our publications



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We've published – this is our publication.

СПАСИБО ЗА ВНИМАНИЕ!

ありがとう  
ございました

Seminar at University of Tsukuba, 2 Nov 2013



Thank you very much.

## 質 疑

### **Dr. Vasyl Yoschenko**

Well as I told you that we included in our experimental analysis of treatment with 1100 trees. Approximately 600 of this were selected as Red Forest area and we had frontal [ph] site outside the exclusion zone with 100 trees and there other trees are selected on the west dominated areas of the exclusion zone.

[Japanese]

### **Dr. Vasyl Yoschenko**

But we observe the increased effect of morphological changes requisite even as the territory is less contaminated territories than in the Red Forest.

[Japanese]

### **Male Participant**

Yeah. I want to know because Red Forest area is the right areas but very famous place is trench experiment site. Trench site, I think, is a small area but your study site is outside of trench inside the Red Forest area, yeah?

### **Dr. Vasyl Yoschenko**

Well, our study site in [Unclear] was trench and some adjacent territory. This adjacent territory [Unclear]. Red Forest is very convenient site for us because in the trench we have very contaminated material contained. With the trenches this is much less contaminated, so we have almost the same conditions, almost the same trees, but at the site at very different dose rates. Inside the Red Forest those [Unclear] pine tree. Those rates [Unclear] to the trees and this I forgot to tell that this low rates are caused mainly by the root uptake of strontium-90.

### **Male Participant**

So in the trench area, outside the trench area contamination level is not so different?

**Dr. Vasyl Yoschenko**

It's much lower. Because the history of this site and of the forest 40 years old pine forest. The first cloud of the explosion passed through this territory and the [Unclear]. And those are autumn of 1986, the green pine trees become red and as such this place got the name, Red Forest. Then the trees were cut and above this top soil was bulldozed in the trenches. This is the territory say 2 kilometer by 2 kilometer and then there are about 200 trenches in this territory. In general in the whole exclusion zone remember there are 800 such trenches. This is not the same, not the right kind for the [Unclear].

**Male Participant**

Thank you very much.

**Male Participant**

Thank you very much and I have two questions and first one is on the same as before. Most of the radiation took for the pine seedlings is coming from the internal dose mainly from the strontium-90, am I right?

**Dr. Vasyl Yoschenko**

Yes.

**Male Participant**

So the external dose is negligible in that area?

**Dr. Vasyl Yoschenko**

For the Red Forest, strontium-90 is more than 90% of the total – not total internal but the whole total. For the less contaminated territories, especially somewhere as [Unclear] models of the exclusion zone, the ratio can be different and the external radiation could be suddenly like half of the total group.

**Male Participant**

But the total dose is quite lower than the contaminated area?

**Dr. Vasyl Yoschenko**

Yes.

**Male Participant**

Okay. Thank you. The second one is about forest fire experiment. Did you find any difference of the chemical or physical form between the cesium and plutonium? Are they included in the same particles in air or different in air?

**Dr. Vasyl Yoschenko**

Unfortunately I don't have the trends here but we measured the dispersal composition of various radionuclides in air. It's clear that, for example, for the forest fire cesium is transferred with vapor [ph] and water groups and [Unclear] deposit material [Unclear]. There are some parts in this of ash zone but for plutonium the general rule is that it metabolize is associated with finer particles, than cesium and especially strontium. Strontium was reduced from the biomass and plutonium was mainly released from litter, maybe even from litter in the case that because the particles are lower and again we don't want as much plutonium in the biomass.

**Male Participant**

If we see the composition of the radionuclides in air, does the change depends on the distance from the fire place?

**Dr. Vasyl Yoschenko**

Yes, also there is dependence on radiation.

**Male Participant**

If we compare it between cesium and the plutonium, which element will go farther?

**Dr. Vasyl Yoschenko**

Here, this is one concentration of [Unclear] nuclides plutonium [Unclear] for one grass on fire it was almost the same. Here for another grass on fire, we had the decrease of cesium and strontium in the spot. Total volume of deposition was in the more distant area [Unclear] which means that there were fine particles transported to the bigger distance. Mostly you can see increased plutonium deposition at a higher distance and here internal is more or less the same.

**Male Participant**

Okay, thank you. So it might be 10 on the forest fire type and [Unclear] 5 itself type of [Unclear] I mean which are intensively higher or something like that.

**Dr. Vasyl Yoschenko**

Yes. We performed our experiment on surface fire. Also we may think about the fire of big intensities we will have countermeasures – so but we have countermeasures for this case. And [Unclear] it's a very worse scenario. Of all the forest in the exclusion zone [Unclear] with – in intense fire with the initial [Unclear] higher and, of course, the activity will be [Unclear]. In this case if you have the higher [Unclear] we have redistribution with distance while plume particles travel [Unclear] so it is from the concentrations of in the east due to this factor. We found [Unclear] that for this case then there will not be any important transfer of radionuclides outside the exclusion zone. The only problems can be related I skipped the conclusion part of [Unclear], in generally the only problems can remain to the firefighters.

**Male Participant**

And I saw that most of the radiation dose is coming from the plutonium, so if we think about the Japanese case it can be negligible with the forest value curves?

**Dr. Vasyl Yoschenko**

Yes.

**Male Participant**

I understand. Thank you.

**Female Participant**

Thank you. My question is also forest fire related [ph]. How many days does plume of fire remain in the air from the breakout of fire?

**Dr. Vasyl Yoschenko**

How long time the plume exists in air after the release?

**Female Participant**

Yes, yes. How many days plume in the air from the fire break?

**Dr. Vasyl Yoschenko**

We make our fire in forest you can see this is in this forest, which is approximately 1 hectare area. It was burnt in say something like 2 hours. The fire completed and the plumes burned to some say several hundred meters. But of course, maybe there could be another stage of the fire which is just small burning, which can last for some period after the fire. Of course, we could not leave this forest after the fire. The firefighters use quite some waterproof [Unclear]. In general, it can be say several hours up to maybe days but this is if there is a big fire.

**Female Participant**

I see. It remained only 3 hours or 4 hours only in the air and how long it takes from Chernobyl to Kiev in the plume of – sorry?

**Dr. Vasyl Yoschenko**

I see. Well, first, the time depends on the [Unclear] okay, but I have to emphasize the plume particles and the particles released from [Unclear] are different but smoke itself which can travel big distance as I've shown from Chernobyl to Kiev like that. The release from the fire [Unclear] likely will never get for such big difference. The impact of that area maybe kilometers pretty much.

**Female Participant**

Okay, thank you. Plume is not smoke and it's very different...

**Dr. Vasyl Yoschenko**

Yeah.

**Female Participant**

Okay, thank you.

**Male Participant**

Is there any relationship between the concentration in materials that was burnt in the concentration, the total amount in atmosphere?

**Dr. Vasyl Yoschenko**

If you look at this, this is the fraction which can be released during the –but this is for our case for [Unclear] from forest fires. I would say that there is an intensive grass on fires but we also have very big productivity of grass at the sites here in turn [ph]. I believe it would be site specific but in general in this order of magnitude for the release.

[Japanese]

**Male Participant**

Thank you very much.

**Dr. Vasyl Yoschenko**

Thank you.

**01:40:03 – 01:44:17**

[Multiple Speakers]

**END**

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