Symposium on Fire Management in Cultural and Natural Landscapes, Nature Conservation and Forestry in Temperate-Boreal Eurasia

Freiburg, Germany, 25-27 January 2008

RESULTS OF THE FIELD EXPERIMENTS AND MODELING OF RESUSPENSION AND REDISTRIBUTION OF RADIONUCLIDES DURING GRASSLAND AND FOREST FIRES IN THE CHERNOBYL EXCLUSION ZONE

V.I.Yoschenko, V.A.Kashparov, S.E.Levchuk, S.M.Lundin, V.P.Protsak, Yu.V.Khomutinin, A.S.Glukhovsky, I.M.Maloshtan and J. Tschiersch*

Ukrainian Institute of Agricultural Radiology (UIAR) NAU

*** GSF, Munich, Germany**

AIMS OF THE STCU PROJECT #1992

- <u>To determine the parameters</u> of the radionuclides resuspension, transfer and deposition during the controlled fires in the ecosystems of the Exclusion zone
- <u>To estimate</u> the doses and to evaluate the radioecological impact of the fires

CONTROLLED FIRES (ACTIVE EXPERIMENTS)

- Preliminary preparation and characterization of the experimental sites
- Sampling the radioactive aerosols during the fires at the monitoring mesh
- Recording the fire development and meteorological conditions

Grassland site (# 1), 60 x 60 m

Chistogalovka, Oct 2001

		Soil	Grass	Litter	Total	In fuel material
^{137}Cs	A, KBq kg^{-1}	80±50	86±50	340±210		
	Σ, MBq m^{-2}	29±18	0.026±0.015	0.26±0.17		
	Total, GBq	104±70	0.094±0.065	0.94±0.7	105±71	1.0±0.8 (1 %)
^{90}Sr	A, KBq kg^{-1}	21±14	120±90	210±150		
	Σ, MBq m^{-2}	7.6±4.7	0.041±0.031	0.15±0.11		
	Total, GBq	27±18	0.15±0.12	0.54±0.4	28±19	0.7±0.5 (2.5 %)
^{238}Pu	A, Bq kg^{-1}	140±80	1.1±0.7	960±500		
	Σ, KBq m^{-2}	50±30	(4±3) ·10^{-4}	0.72±0.4		
	Total, MBq	180±110	(1.4±1.1) ·10^{-3}	2.6±1.5	183±112	2.6±1.5 (1.4 %)
$^{239+240}Pu$	A, Bq kg^{-1}	280±160	2.4±1.6	2150±1500		
	Σ, KBq m^{-2}	100±60	(8±6) ·10^{-4}	1.6±1.2		
	Total, MBq	360±200	(2.8±2.1) ·10^{-3}	5.8±4.8	366±205	5.8±4.8 (1.6 %)

Background A_V, Bq m^{-3}

^{137}Cs	^{90}Sr	^{238}Pu	$^{239+240}Pu$
2.1·10^{-3}	0.8·10^{-3}	1.5·10^{-6}	2.9·10^{-6}

УКРНДІСГР

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

UIAR

Grassland site (# 2), 60 x 90 m

Chistogalovka, Apr 2002

		Soil	Grass	Litter	Total	In fuel material
^{137}Cs	A, KBq kg^{-1}	14±9	49±21	85±5		
	Σ, MBq m^{-2}	5.1±3.1	0.014±0.006	0.11±0.07		
	Total, GBq	27±17	0.07±0.03	0.57±0.36	28±17	0.64±0.39 (2.3 %)
^{90}Sr	A, KBq kg^{-1}	7.3±6.0	62±19	81±35		
	Σ, MBq m^{-2}	2.7±2.2	0.018±0.005	0.087±0.053		
	Total, GBq	15±12	0.10±0.01	0.47±0.29	16±12	0.57±0.30 (3.6 %)
^{238}Pu	A, Bq kg^{-1}	57±33	0.17±0.13	130±87		
	Σ, KBq m^{-2}	20±12	(4.7±4.0) ·10^{-5}	0.087±0.060		
	Total, MBq	110±60	(2.5±2.1) ·10^{-4}	0.47±0.33	110±60	0.47±0.33 (0.4 %)
$^{239+240}Pu$	A, Bq kg^{-1}	110±65	0.44±0.33	270±190		
	Σ, KBq m^{-2}	40±27	(1.2±0.9) ·10^{-4}	0.19±0.14		
	Total, MBq	210±150	(6.7±5.3) ·10^{-4}	1.1±0.7	211±151	1.1± 0.7 (0.5 %)

Background A_V, Bq m^{-3}

^{137}Cs	^{90}Sr	^{238}Pu	$^{239+240}Pu$
4.6·10^{-3}	1.4·10^{-3}	4.3·10^{-6}	8.5·10^{-6}

УКРНДІСГР

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

UIAR

Forest site (# 3), 8770 m²

Novoshepelichi, May 2003

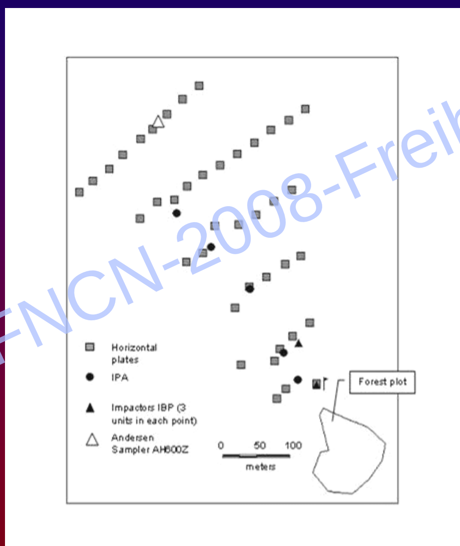
		soil	timber	bark	1st year needles	2nd year needles	litter	fallen branches
FM, kg m⁻²		-	20.5±3.5	2.6±0.4	0.6±0.1	0.30±0.05	2.15±0.28	0.11±0.03
^{137}Cs	A, KBq kg⁻¹	5.8±1.1	0.83±0.20	5.1±1.4	57±15	6.9±1.9	64±17	1.1±0.2
	Σ, KBq m⁻²	1700±300	17±7	13±6	34±15	2.1±0.9	137±53	0.12±0.06
	total, GBq	14.9±2.6	0.15±0.06	0.12±0.05	0.30±0.13	0.018±0.008	1.2±0.5	0.0011±0.0005
^{90}Sr	A, KBq kg⁻¹	3.7±0.9	12.5±2.5	45.8±9.2	26.4±5.2	70±15	81±18	16.6±3.5
	Σ, KBq m⁻²	1100±300	260±100	120±40	15.8±5.8	21±8	173±62	1.8±0.9
	total, GBq	9.6±2.6	2.25±0.83	1.04±0.37	0.14±0.05	0.19±0.07	1.52±0.54	0.016±0.008
^{238}Pu	A, Bq kg⁻¹	33±8	0.24±0.07	7.4±2.1	0.24±0.07	0.33±0.10	130±40	0.3±0.1
	Σ, Bq m⁻²	9800±2300	4.9±2.3	19±8	0.14±0.07	0.10±0.05	280±120	0.03±0.02
	total, MBq	86±20	0.043±0.027	0.17±0.07	0.0013±0.0008	0.0009±0.0004	2.45±1.07	0.0003±0.0002
$^{239+240}$Pu	A, Bq kg⁻¹	72±17	1.45±0.5	18±5	0.9±0.3	0.55±0.25	280±70	1.9±0.6
	Σ, Bq m⁻²	21000±5000	30±15	48±21	0.5±0.3	0.17±0.10	600±230	0.2±0.1
	total, MBq	184±44	0.26±0.13	0.42±0.18	0.0047±0.0024	0.0015±0.0009	5.3±2.0	0.0018±0.0011

Background A_V, Bq m⁻³

^{137}Cs	^{90}Sr	^{238}Pu	$^{239+240}$Pu
$3.2 \cdot 10^{-3}$	$4.4 \cdot 10^{-3}$	$8.3 \cdot 10^{-6}$	$2.2 \cdot 10^{-5}$

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

Scheme of the Experiments: Forest Site (# 3)



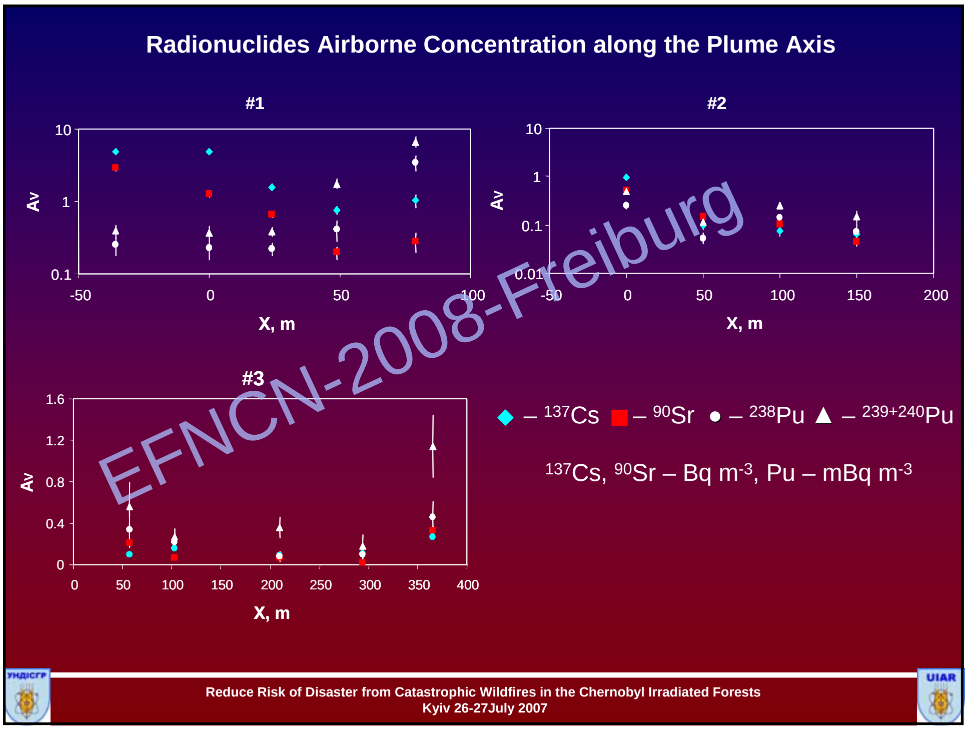
Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

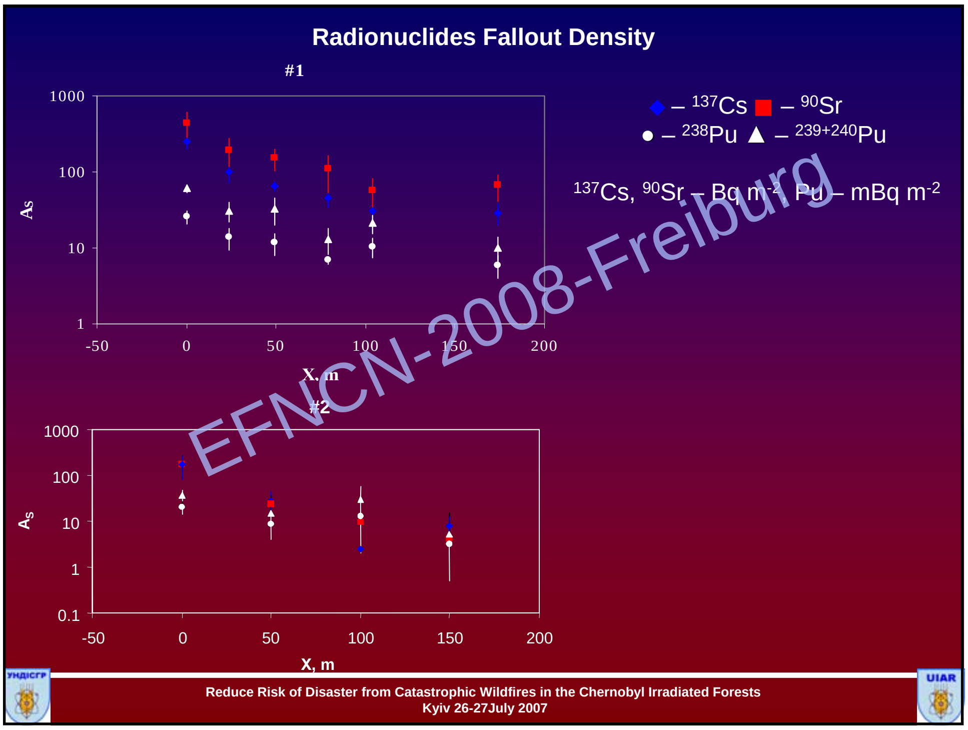
Grassland Fire

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

Forest Fire

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007


Radionuclides Airborne Concentration along the Plume Axis
#1
#2
#3
Av
X, m
– 137Cs – 90Sr – 238Pu – 239+240Pu
137Cs, 90Sr – Bq m-3, Pu – mBq m-3
EFNCN-2008-Freiburg
Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007
UIAR


Radionuclides Fallout Density
#1
#2
As
X, m
– 137Cs – 90Sr
– 238Pu – 239+240Pu
137Cs, 90Sr – Bq m-2, Pu – mBq m-2
EFNCN-2008-Freiburg
Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007
UIAR

Radionuclides Resuspension Factors RF, m^{-1}, during the fires

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	$(4.7\pm2.0)\cdot10^{-8}$	$(1.1\pm0.5)\cdot10^{-7}$	$(3.2\pm2.2)\cdot10^{-8}$	$(2.5\pm1.6)\cdot10^{-8}$

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

Intensity, *I*, Bq m^{-2} s^{-1}, and velocity, W_P, cm s^{-1}, of the radionuclides deposition.

X – distance from the site border along the plume axis

X, m	^{137}Cs		^{90}Sr		^{238}Pu		$^{239+240}Pu$	
	I	W_P	*I*	W_P	*I*	W_P	*I*	W_P
Grassland fire (#1)								
0	0.12±0.01	2.6±0.2	0.2±0.01	16±1	$(1.4\pm0.3)\cdot10^{-5}$	6.3±1.4	$(3.0\pm0.5)\cdot10^{-5}$	9.5±1.2
24	0.06±0.005	4.0±0.5	0.15±0.01	22±2	$(1.2\pm0.2)\cdot10^{-5}$	5.3±0.9	$(2.5\pm0.3)\cdot10^{-5}$	6.6±0.8
49	0.04±0.003	5.3±0.5	0.11±0.01	57±6	$(9.1\pm1.5)\cdot10^{-6}$	2.2±0.4	$(2.0\pm0.2)\cdot10^{-5}$	1.1±0.1
79	0.03±0.003	3.1±0.3	0.06±0.006	21±4	$(4.2\pm1.0)\cdot10^{-6}$	0.1±0.03	$(1.0\pm0.1)\cdot10^{-5}$	0.1±0.01
Grassland fire (#2)								
0	0.34±0.01	35±3	0.3±0.01	60±6	$(3.1\pm0.2)\cdot10^{-5}$	12±2	$(5.8\pm.0.3)\cdot10^{-5}$	11±1
50	0.03±0.003	34±7	0.02±0.002	15±2	$(1.7\pm0.2)\cdot10^{-5}$	28±7	$(2.6\pm0.2)\cdot10^{-5}$	21±4
100	0.009±0.002	13±3	0.01±0.001	9±1	$(1.5\pm0.2)\cdot10^{-5}$	17±6	$(3.8\pm0.3)\cdot10^{-5}$	26±7
150	0.016±0.003	22±6	0.006±0.001	12±3	$(5.4\pm1.8)\cdot10^{-6}$	7.0±3.5	$(1.3\pm0.2)\cdot10^{-5}$	8±3
Forest fire(#3)								
57	$(2.0\pm0.3)\cdot10^{-3}$	2.6±0.4	$(1.0\pm0.2)\cdot10^{-3}$	1.3±0.3	$(3.1\pm0.6)\cdot10^{-6}$	2.7±1.4	$(9.1\pm2.4)\cdot10^{-6}$	1.4±0.6
102	$(1.5\pm0.2)\cdot10^{-3}$	1.2±0.2	$(4.6\pm1.8)\cdot10^{-4}$	1.0±0.4	$(8.6\pm1.3)\cdot10^{-6}$	4.2±1.7	$(1.6\pm0.2)\cdot10^{-5}$	5.2±1.8
210	$(4.1\pm0.4)\cdot10^{-3}$	2.8±0.5	$(2.8\pm0.4)\cdot10^{-3}$	1.9±0.8	$(1.4\pm0.5)\cdot10^{-5}$	7.8±5.3	$(3.2\pm1.0)\cdot10^{-5}$	4.1±1.5
294	$(1.7\pm0.2)\cdot10^{-3}$	1.9±0.4	$(5\pm2)\cdot10^{-4}$	2.7±2.3	$(1.1\pm0.4)\cdot10^{-6}$	4.7±4.5	$(2.6\pm0.6)\cdot10^{-6}$	3.1±2.1
365	$(1.3\pm0.2)\cdot10^{-3}$	0.6±0.1	$(6\pm2)\cdot10^{-4}$	0.2±0.07	$(2.6\pm1.1)\cdot10^{-6}$	0.35±0.19	$(7.7\pm2.2)\cdot10^{-6}$	0.29±0.14
483	$(1.8\pm0.3)\cdot10^{-3}$		$(5\pm2)\cdot10^{-4}$		$(1.5\pm0.8)\cdot10^{-6}$		$(1.8\pm0.6)\cdot10^{-6}$	

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

Doses to the firefighters (conservative estimate) from 1-hr exposure in the fire area

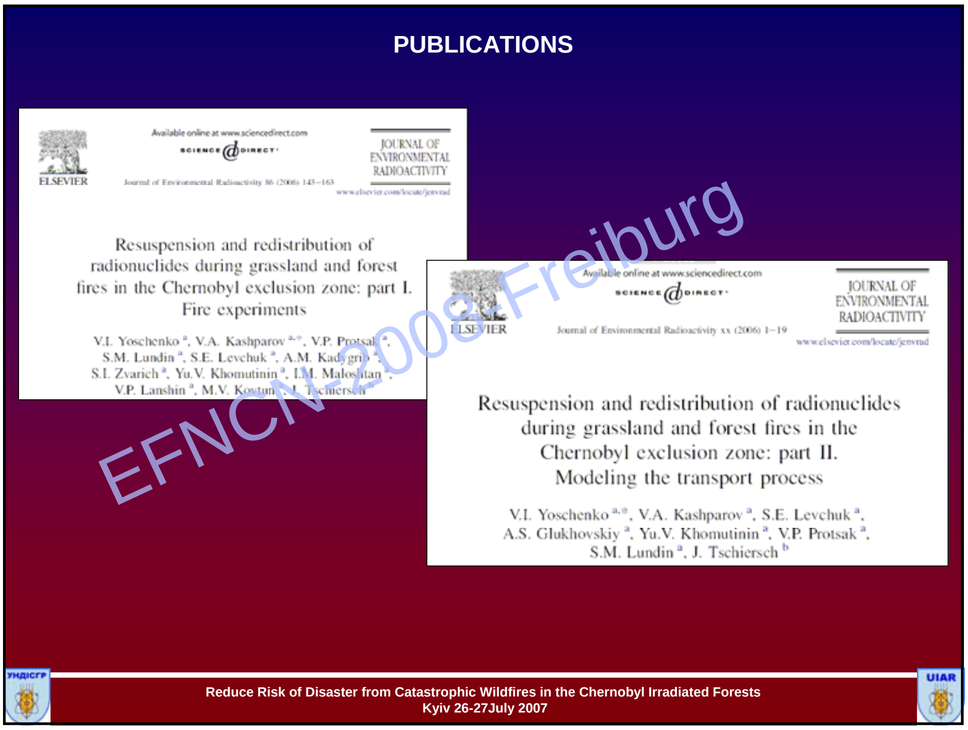
	Maximum airborne concentration, Bq m^{-3}, in the site			Dose type	Dose, μSv, in the site		
	#1	#2	#3		#1	#2	#3
^{137}Cs	5	1	0.27	External from the cloud	$6.9 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$3.7 \cdot 10^{-5}$
				Inhalation	$6 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$3.2 \cdot 10^{-3}$
^{90}Sr	3	0.5	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

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007

CONCLUSIONS

1. For the grassland fires, RF of ^{137}Cs and ^{90}Sr ~ 10^{-5} – 10^{-6} m^{-1}, Pu ~ 10^{-6} – 10^{-7} m^{-1} relating to the fuel material contamination. For the forest fire, RF ~ 10^{-6} – 10^{-7} m^{-1} for the fuel material contamination, and 10^{-7} – 10^{-8} m^{-1} for the total contamination;
2. The increase of the radionuclides airborne concentration in the surface air layer provides a significant inhalation constituent to the doses to firefighters and other personnel of the Chernobyl zone. 50-years EED from exposure in the points of the maximum airborne concentration during the fire can exceed the external irradiation dose received during the same exposure period;
3. The above values are valid for the low intensity fires. Radionuclide release, initial rise of the plume and its distribution range strongly depend on the thermal intensity of the fire and its scale. For the large fires we can expect the radioactivity transportation to big distances. It can cause the significant consequences for the "clean" territories;
4. Unstudied problem: peat fires.

Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007


PUBLICATIONS
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
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, V.A. Kashparov, S.E. Levchuk, A.S. Glukhovskiy, Yu.V. Khomutinin, V.P. Protsak, S.M. Lundin, J. Tschiersch
Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007
УНДІСГР
UIAR


THANK YOU!
Reduce Risk of Disaster from Catastrophic Wildfires in the Chernobyl Irradiated Forests
Kyiv 26-27July 2007
УНДІСГР
UIAR