8th International Workshop on Biomonitoring of Atmospheric Pollution, Dubna, Russia
2-7 July 2018

MONITORING SOURCES OF RADIOACTIVE CONTAMINATION OF THE ENVIRONMENT BASED ON PINE TREE ANALYSIS

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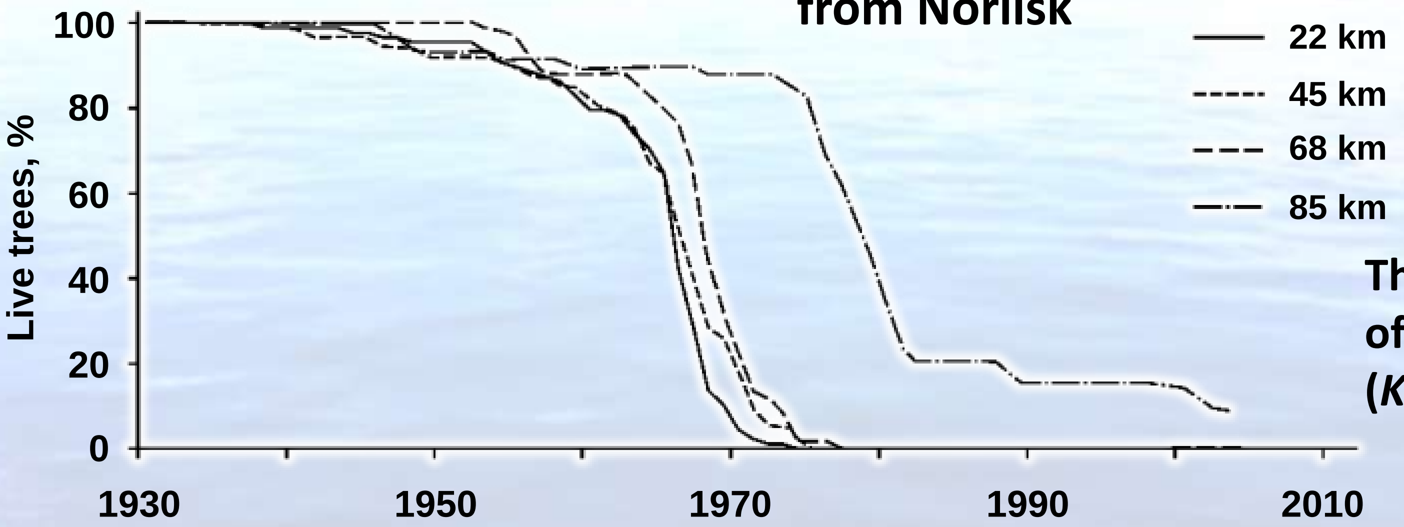
Novaya Zemlya
Test Site
Latvia
Estonia
St.
Petersburg
Lithuania
Belarus
Kiev
Moldova
Ukraine
Moscow
Don
Volga
Ural Mountains
Ekaterinburg
Chelyabinsk
Norilsk
Arctic Circle
Lena
Ob'
Yenisey
Russia
Tomsk
Krasnoyarsk
Semipalatinsk
Georgia
Armenia
Azerbaijan
Kazakhstan
Turkmenistan
Uzbekistan
Kirgizstan
Tajikistan
S9411024.1
0 500 Kilometers
0 500 Statute Miles
Cities
Weapons Design Laboratories
Test Sites
Weapons Production Facilities
Production Reactor and Reprocessing Sites
Uranium Enrichment

Contents

The Mining and Metallurgical Combine Norilsk Nickel is Russia's largest emitter of atmospheric pollutants (2 million tons a year), and Norilsk is one of the world's most polluted cities

The dynamics of mortality of the Siberian larch (*Larix sibirica*) at different distances from Norilsk



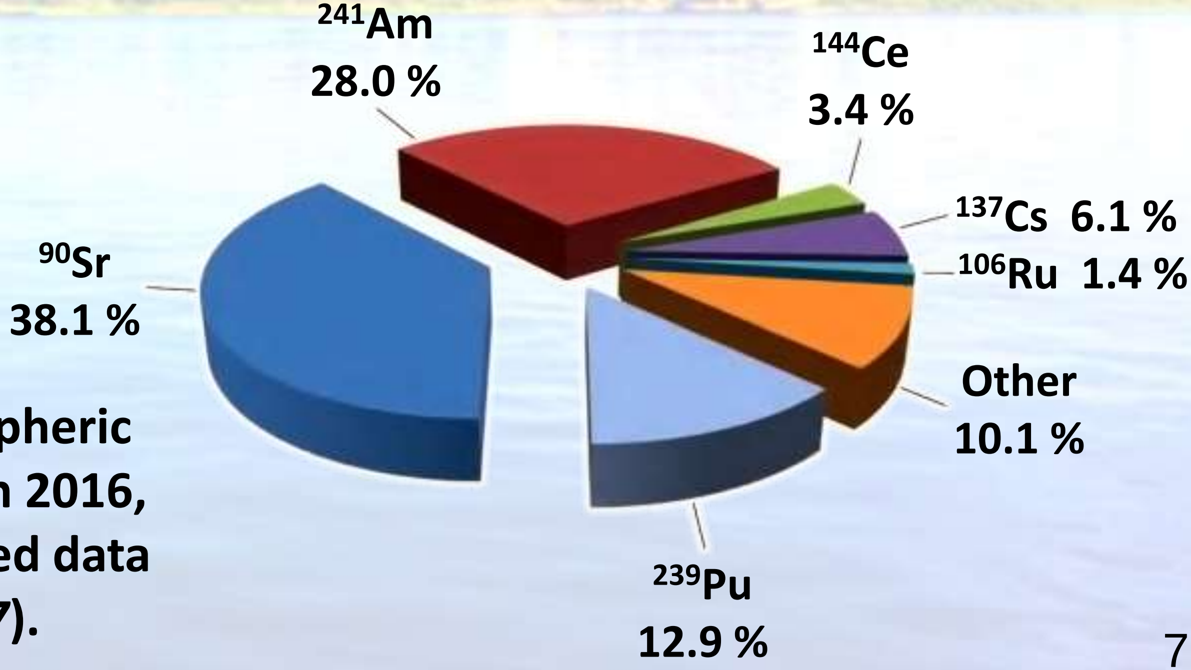
The Krasnoyarsk Institute of Forest's published data (*Kirdyanov et.al., 2014*)

Krasnoyarsk Aluminum Plant (United Company RUSAL) – the world's second largest aluminum smelter, annually producing 1 million tons of aluminum. Due to the plant's atmospheric emissions (≈0.2 million tons a year), Krasnoyarsk is Russia's 11th most polluted city.

The facilities of the Russian Atomic Energy Agency

1. **<u>The Mining-and-Chemical Combine,</u> producing weapons grade plutonium, is located at Zheleznogorsk in the Krasnoyarsk Territory, on the bank of the Yenisei River, 60 km downstream of the city of Krasnoyarsk.**
   <u>1958-1964 -</u> Three reactors were put into operation;
   the Radiochemical Plant has been working <u>since 1965;</u>
   <u>1992 -</u> Two flow-through reactors were shut down;
   <u>in April 2010</u> the third reactor was shut down.
2. **<u>The Electrochemical Plant</u>, producing enriched uranium, is located at Zelenogorsk in the Krasnoyarsk Territory, on the bank of the Kan River.**

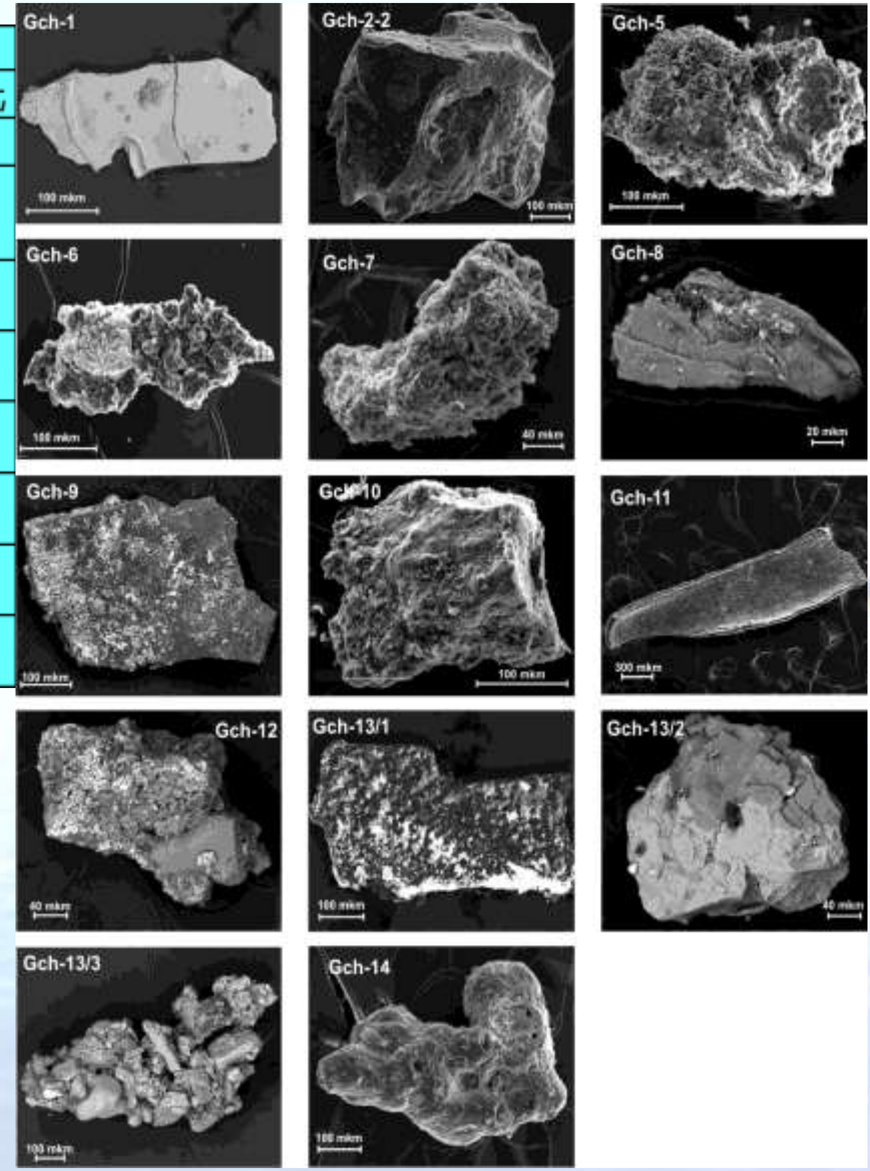
The Mining-and-Chemical Combine (MCC) of the Russian Agency of Atomic Energy



The structure of MCC atmospheric emissions of radionuclides in 2016, based on the MCC's published data (*MCC Ecological report, 2017*).

Radionuclide composition of hot particles of the Yenisei River

Particle label	Sampling position and date	Activity, Bq/particle									
		^{137}Cs	^{134}Cs	^{154}Eu	^{155}Eu	^{60}Co	$^{239,240}Pu$	^{238}Pu	^{241}Am	$\frac{^{137}Cs}{^{134}Cs}$	$\frac{^{238}Pu}{^{239,240}Pu}$
10A1	Taivan Island August 1998	648500	384	1050	300	286	n.d.	n.d.	60.3	1689	
E3/97-1* E3/97-2 E3/97-3 E3/97-4	Atamanovskaya Spit September 1997	196000 747000 416000 240000	225 859 468 272	— — — —	— — — —	— — — —	n.d. n.d. 7.0 n.d.	n.d. n.d. 3.8 n.d.	n.d. n.d. n.d. —	871 870 889 882	0.54
E505/01	Atamanovskaya Spit September 2001	40100	188	3100	1130	136	n.d.	n.d.	66	213	
E1/98	Atamanovskii Island October 1998	105900	1578	4811	2000	22	2.3	119	71	67	51.7
E8/97	Atamanovskii Island September 1997	74700	53.4	—	—	—	—	—	—	1399	
E001* E002	Atamanovskii Island September 1997	24480 33250	524 705	1598 1635	685 710	65.2 81.5	0.77	44.7	23 35	47 47	58.1
E2/98	Village of B. Balchug October 1998	89200	47	—	—	—	0.02	1.2	n.d.	1898	60.0
E22/98	Village of B. Balchug September 1997	238700	170.7	—	—	—	—	n.d.	n.d.	1398	



ELSEVIER
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY

Hot particles of the Yenisei River flood plain, Russia

A.Ya. Bolsunovsky, V.O. Tcherkezian

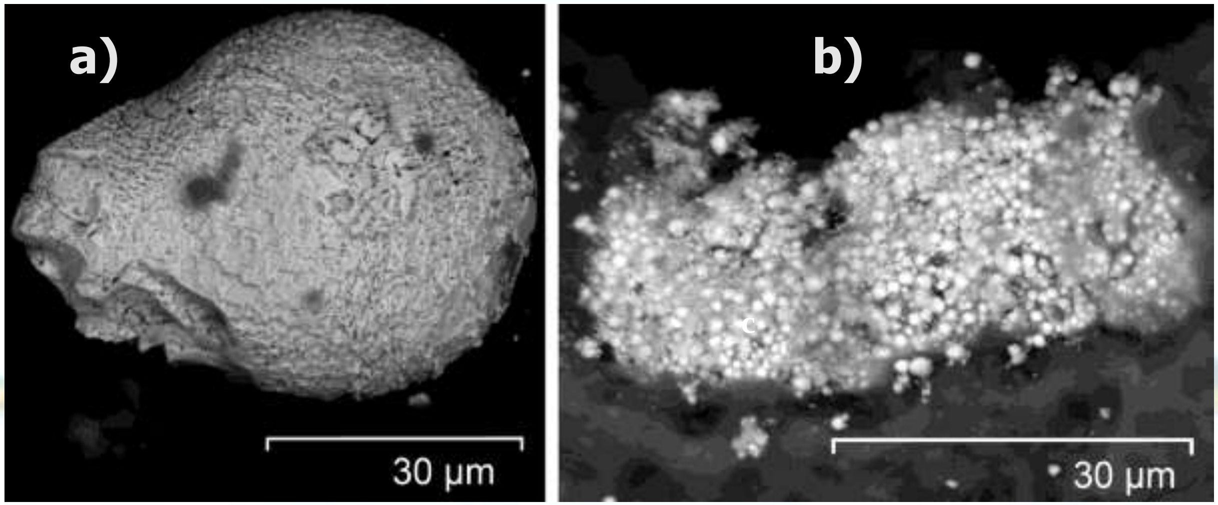
ISSN 1028-334X, Doklady Earth Sciences, 2010, Vol. 430, Part 1, pp. 51–53. © Pleiades Publishing, Ltd., 2010.
Original Russian Text © A.V. Chuguevskii, F.V. Sukhorukov, M.S. Mel'gunov, I.V. Makarova, A.T. Titov, 2010, published in Doklady Akademii Nauk, 2010, Vol. 430, No. 1, pp. 102–104.

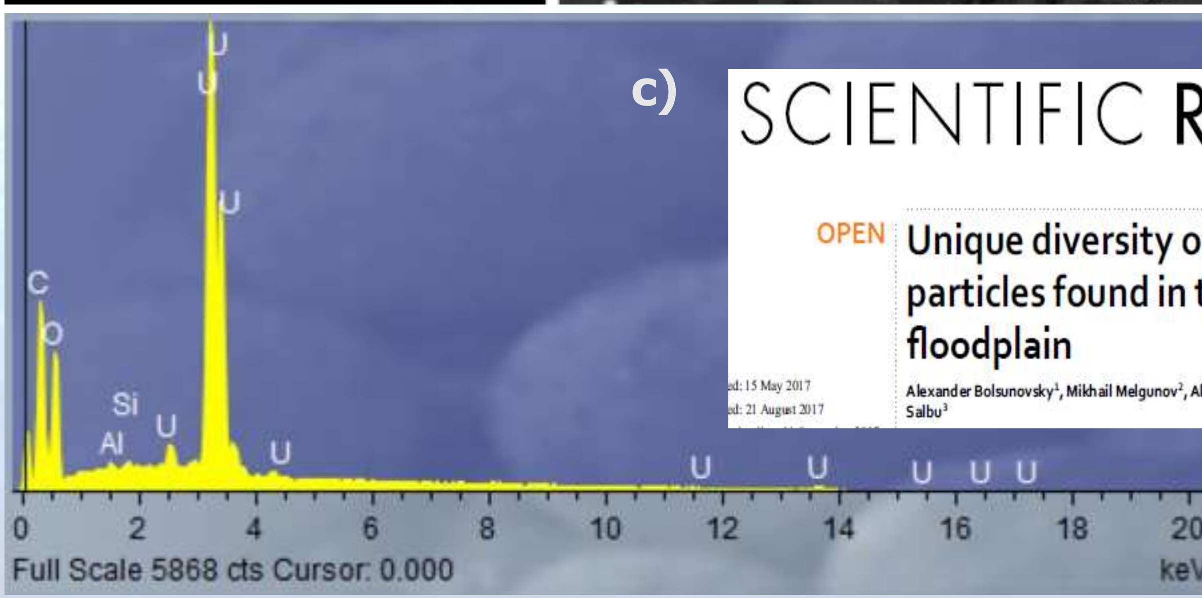
GEOCHEMISTRY

"Hot" Particles of the Yenisei River: Radioisotope Composition, Structure, and Behavior in Natural Conditions

A. V. Chuguevskii, F. V. Sukhorukov, M. S. Mel'gunov, I. V. Makarova, and A. T. Titov

The SEM image of the typical Yenisei fuel particles investigated at the Institute of Geology and Mineralogy (Novosibirsk): a) – an individual particle; b) – a conglomerate of particles; c) – a typical X-ray spectrum of fuel particles





SCIENTIFIC REPORTS

OPEN

Unique diversity of radioactive particles found in the Yenisei River floodplain

ed: 15 May 2017
ed: 21 August 2017

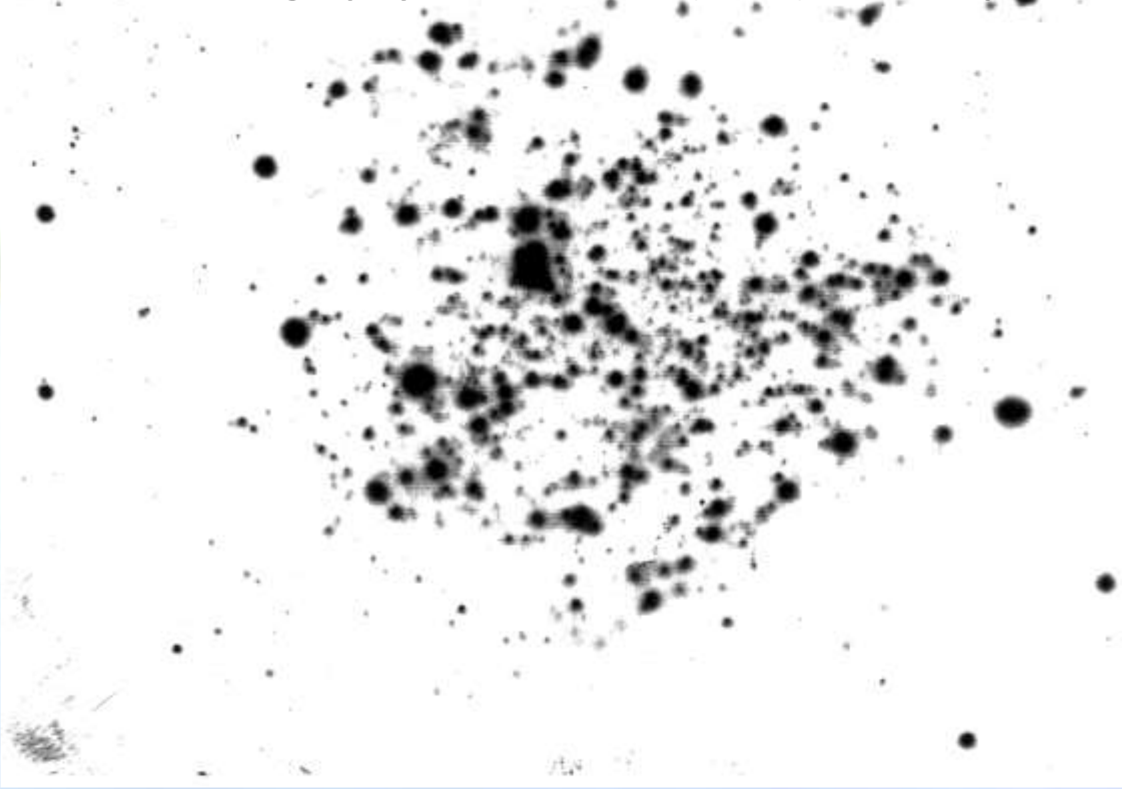
Alexander Bolsunovsky[1], Mikhail Melgunov[2], Alexey Chuguevskii[2], Ole Christian Lind[3] & Brit Salbu[3]

Concentration of fuel particles (^{137}Cs activity >>1 kBq):

- 70 particles/km^2, based on MCC data; - up to 280 -1000 particles/km^2, based on the data of researchers from IGM and IBP

Concentration of fuel particles with ^{137}Cs activity under 1 kBq

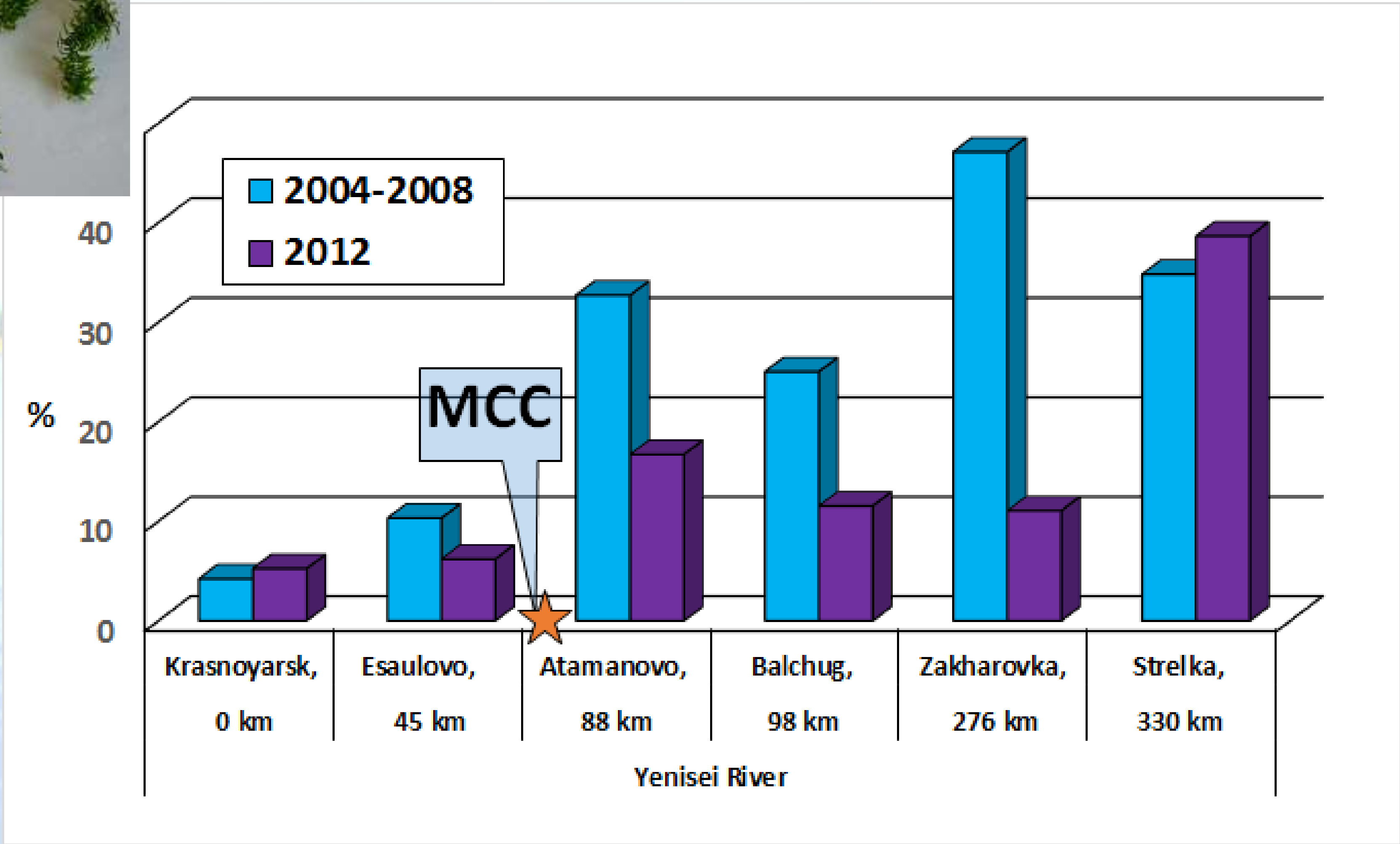
Autoradiography of the active (^{137}Cs) soil sample



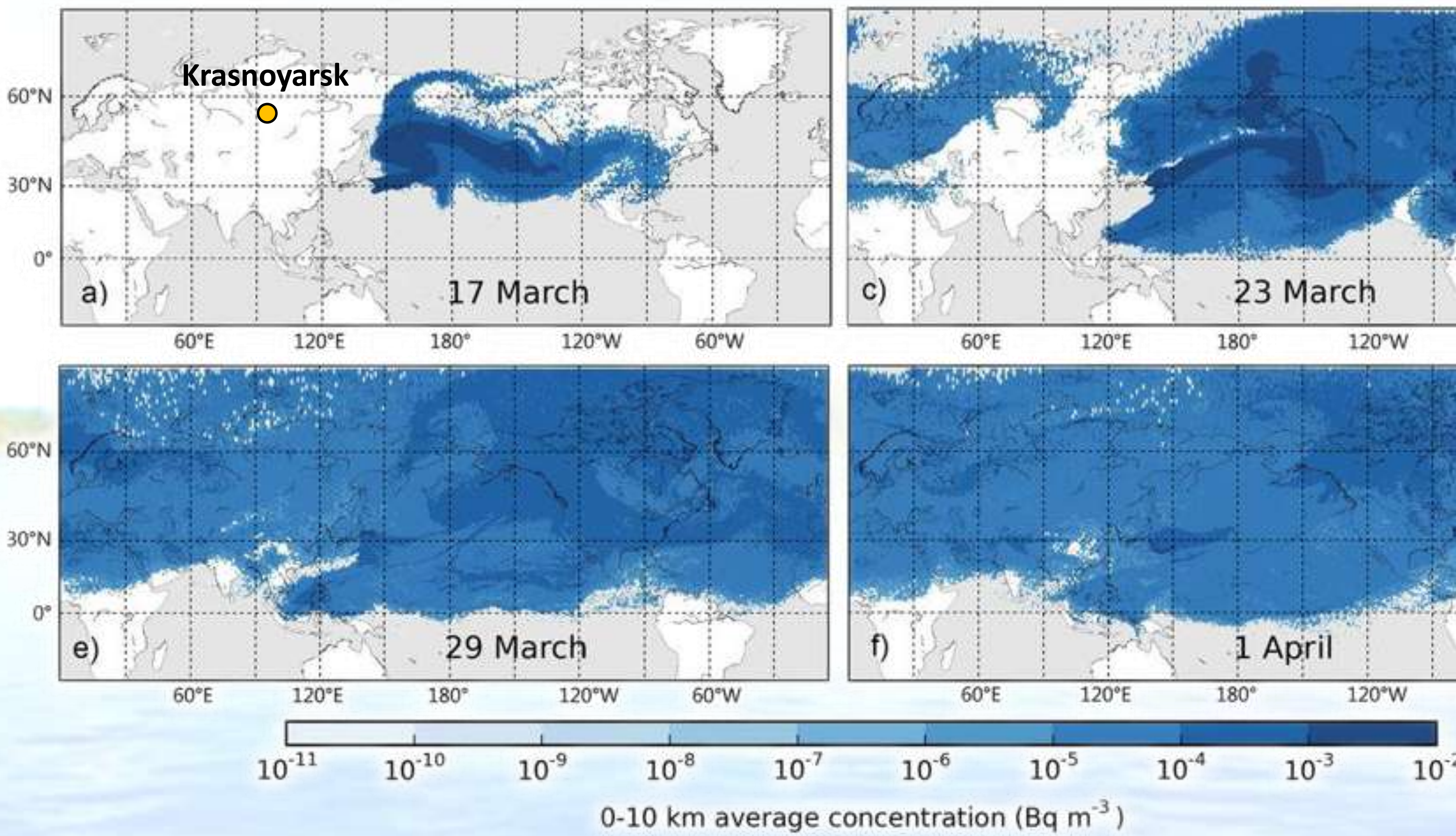
The calculation of IBP shows that 250 particles registered in the 0.36-g active (^{137}Cs) soil sample correspond to 700000 particles/kg soil;

Publication by MCC officials – 1×10^{10} particles/km^2 in the 0.5 m soil layer near MCC

Chromosomal aberrations in ana-telophase cells of *Elodea canadensis* at different positions in the Yenisei River (2004-2008, 2012)

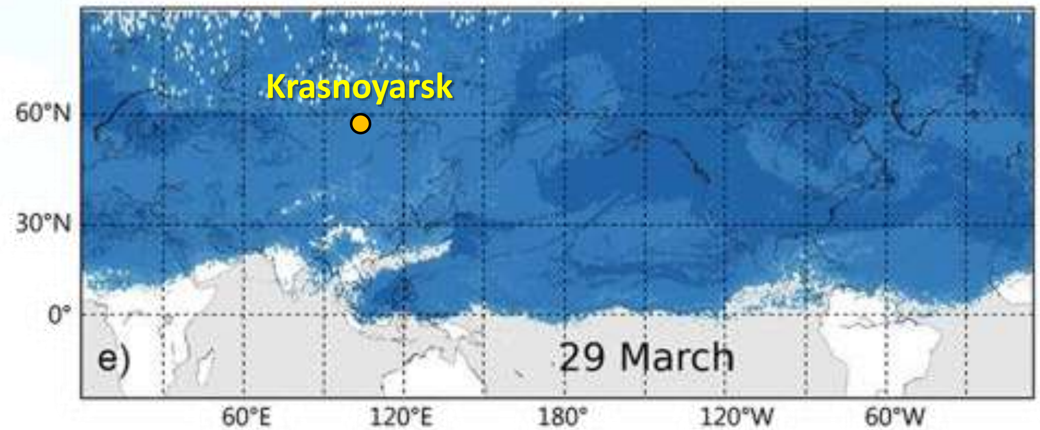


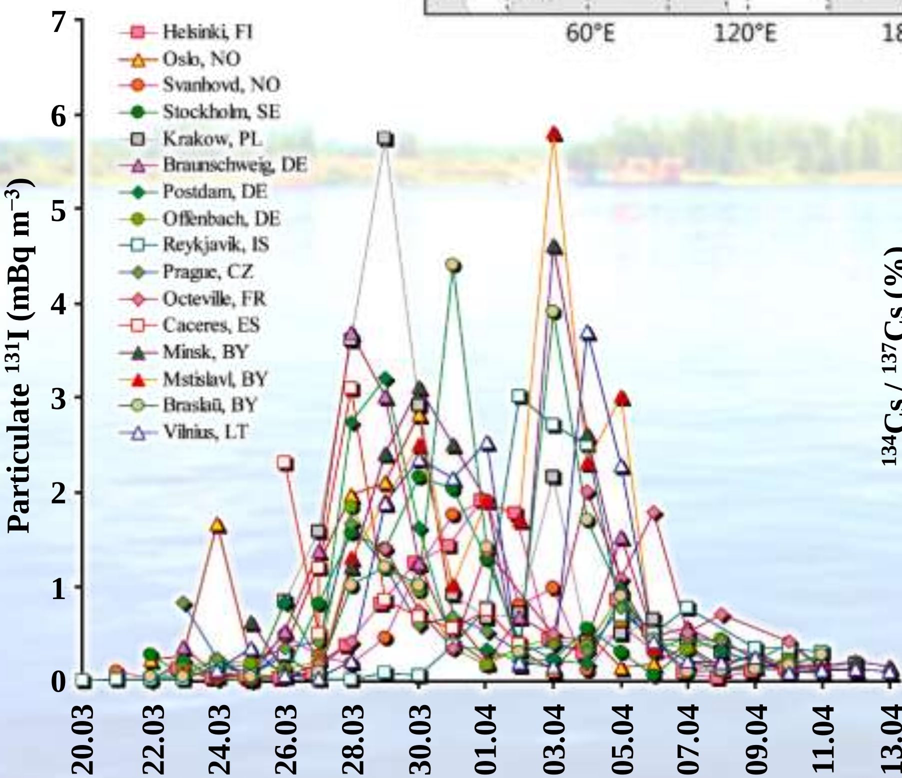
The global dispersion of Fukushima radionuclides in the atmosphere

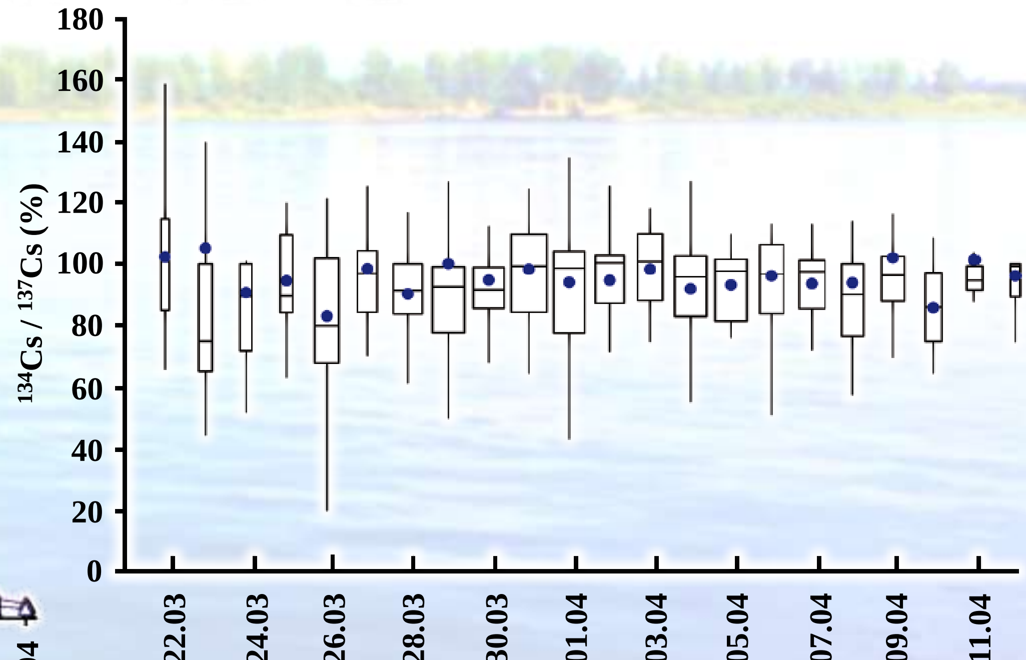


Meszaros R. et al. // Scientific Reports. 2016, V. 6, Article number: 19915
DOI: 10.1038/srep19915]

Time variation of ^{131}I and $^{134}Cs/^{137}Cs$ ratio in Europe following the Fukushima accident

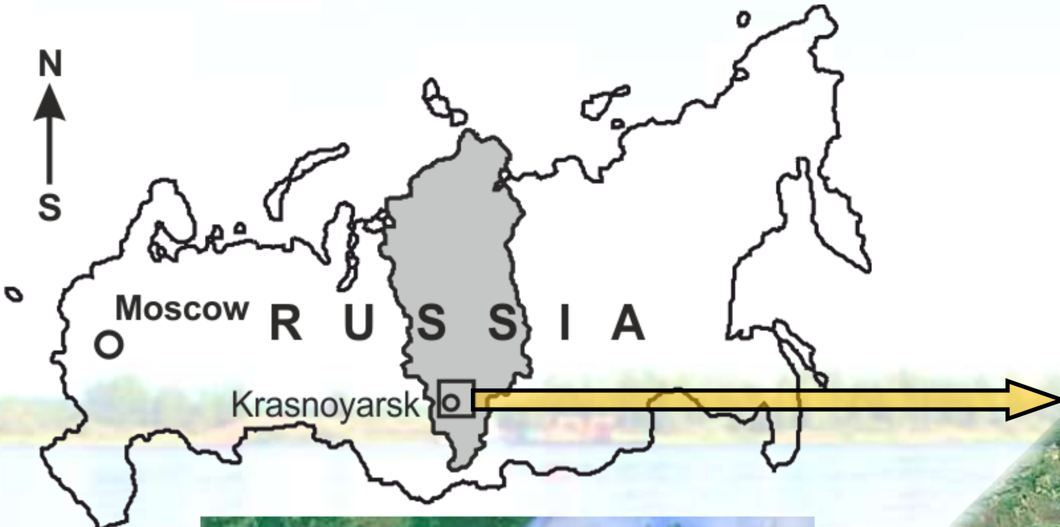


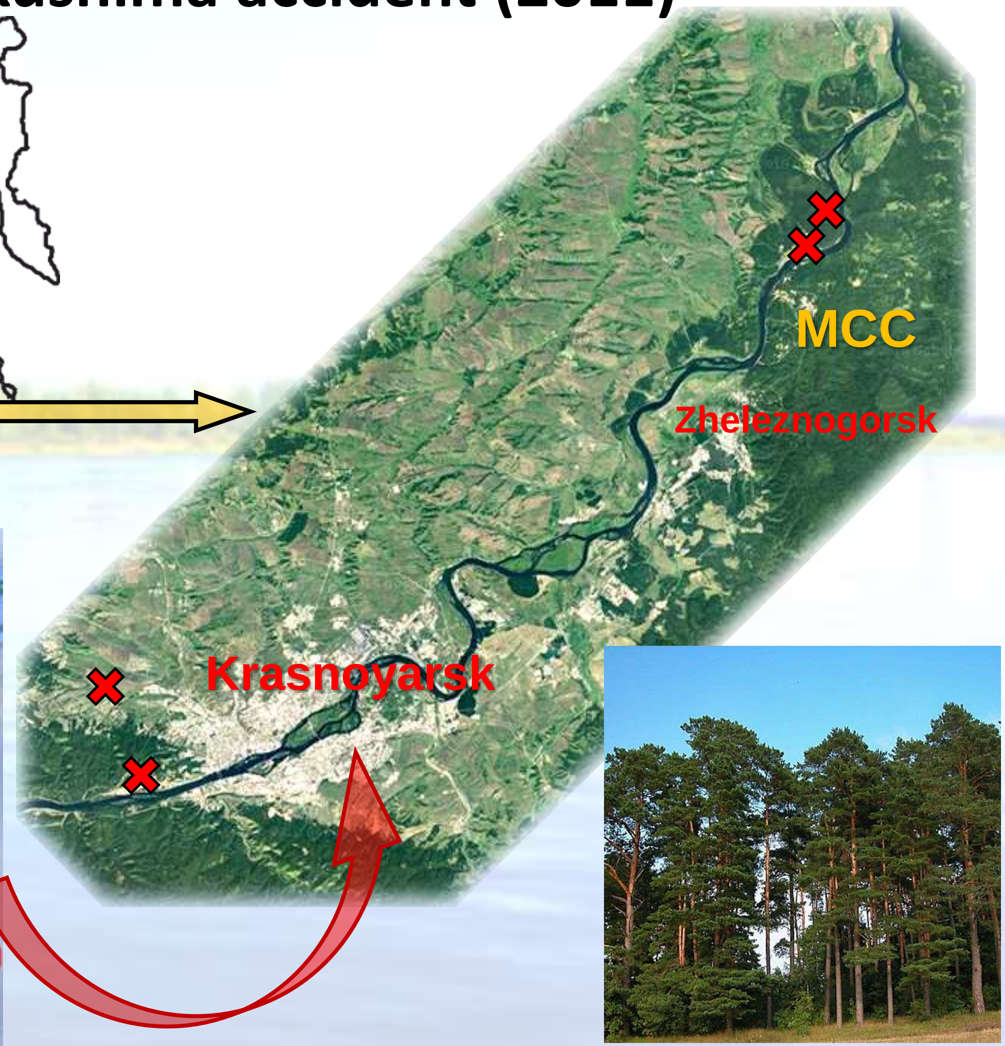




Masson O. et al. // Environ. Sci. Technol. 2011, 45, 7670–7677

Sampling positions in Siberia (the Krasnoyarsk Territory) close to Krasnoyarsk and in the region affected by the plutonium production facility (MCC) at Zheleznogorsk after the Fukushima accident (2011)





The purpose of this study was to monitor sources of radioactive contamination of the environment in the Krasnoyarsk Territory (Siberia, Russia) based on analysis of pine tree and mushroom samples

Material

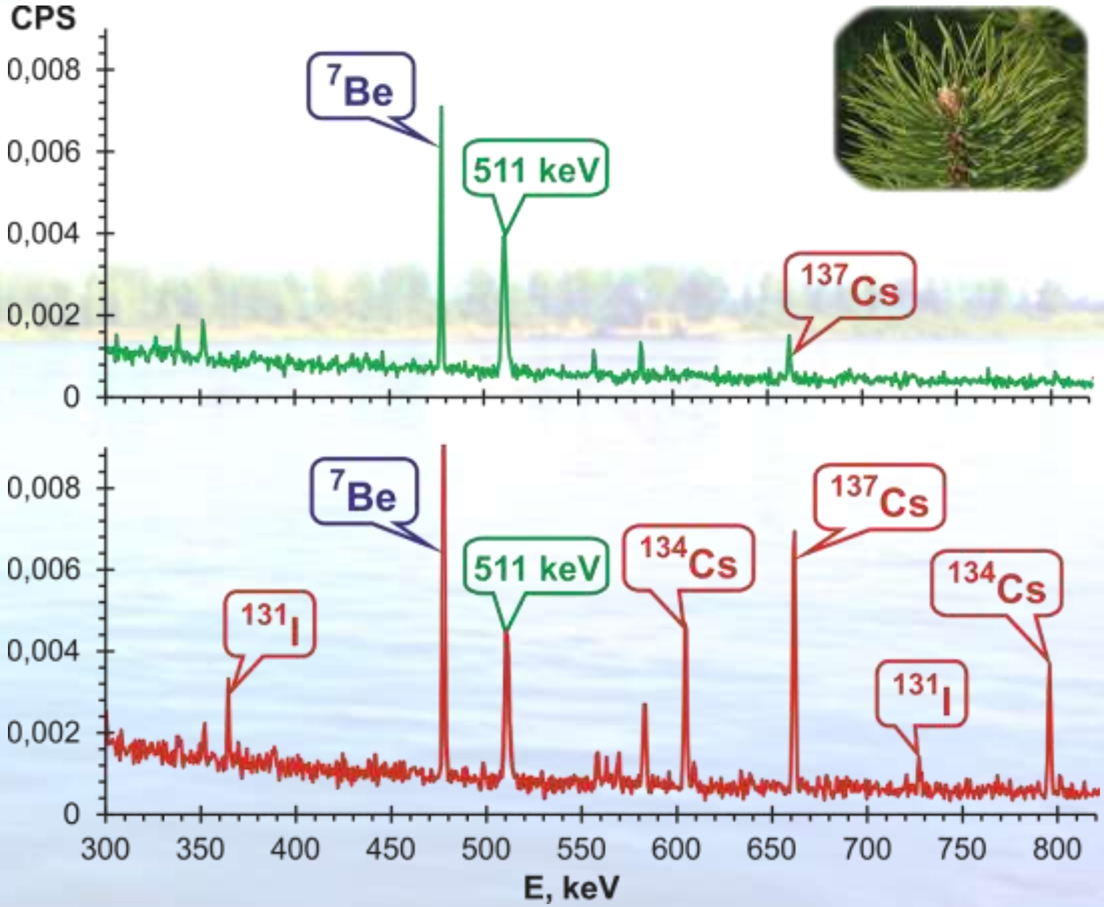
1. Snow, rainwater
2. Soil
3. Scots pine (*Pinus sylvestris*): needles, branches, shoots, litter
4. Fungus *Suillus granulatus*

Methods

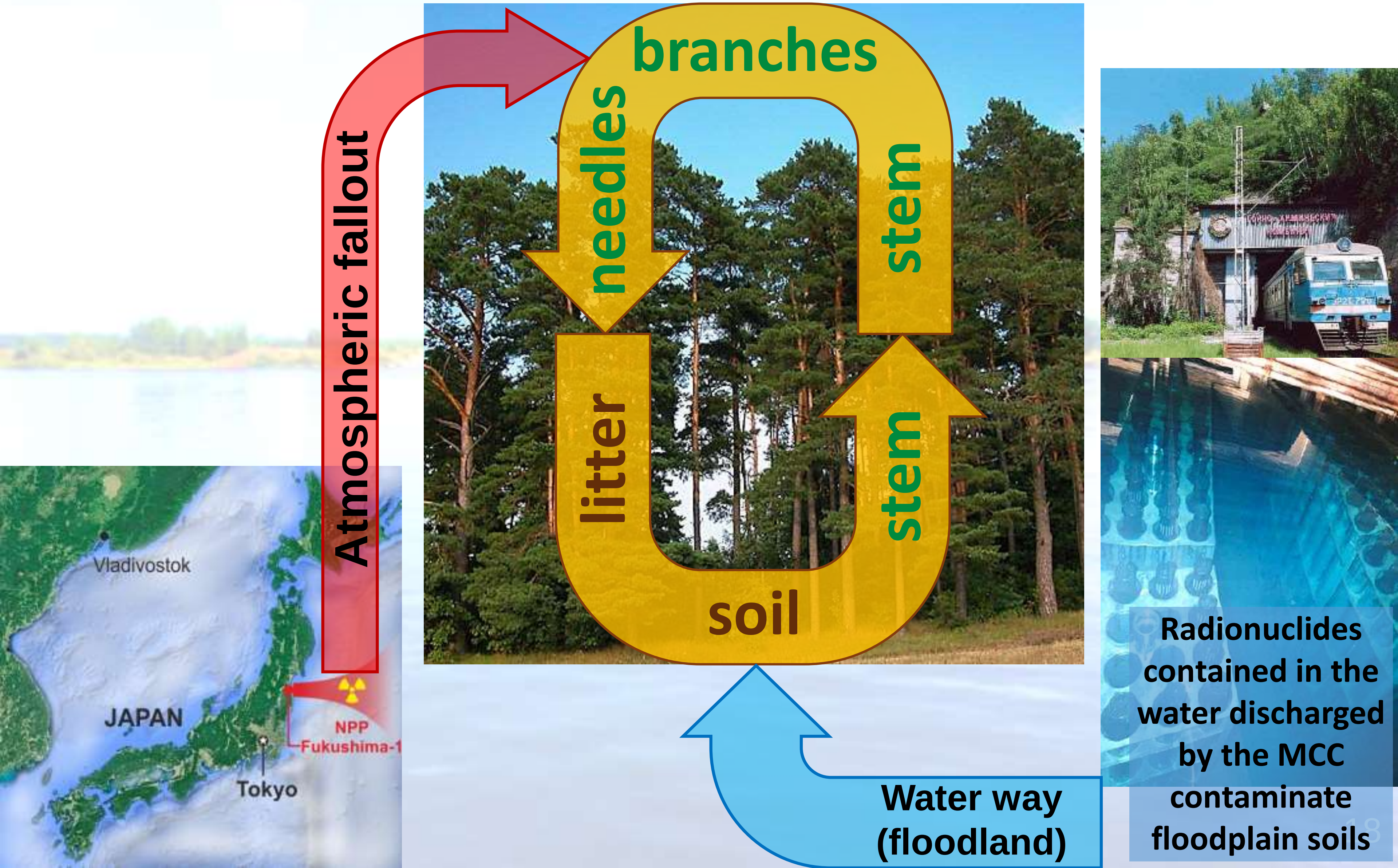
^{131}I ($T_{1/2}$ = 8.02 d); ^{134}Cs ($T_{1/2}$ = 2.06 y); ^{137}Cs ($T_{1/2}$ = 30.09 y)

Gamma-spectrometric measurements with the hyper-pure germanium detector (Canberra) coupled to a multichannel analyzer

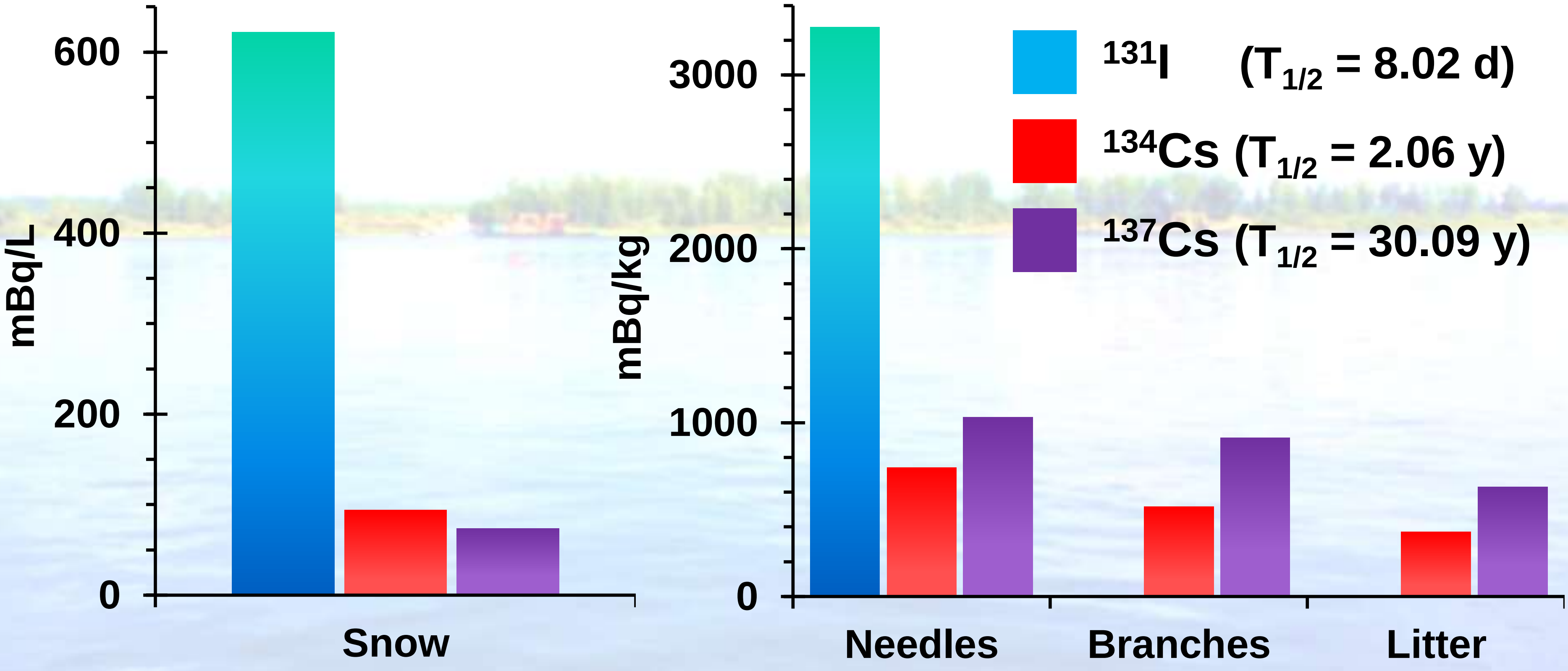
Gamma-spectra of the environmental samples collected before (at the top) and after the accident (at the bottom)



The pathways of artificial radionuclides into pine parts



Fukushima radionuclide (^{131}I, ^{134}Cs, ^{137}Cs) concentrations in samples of snow and pine (*Pinus sylvestris*) at Krasnoyarsk in 2011

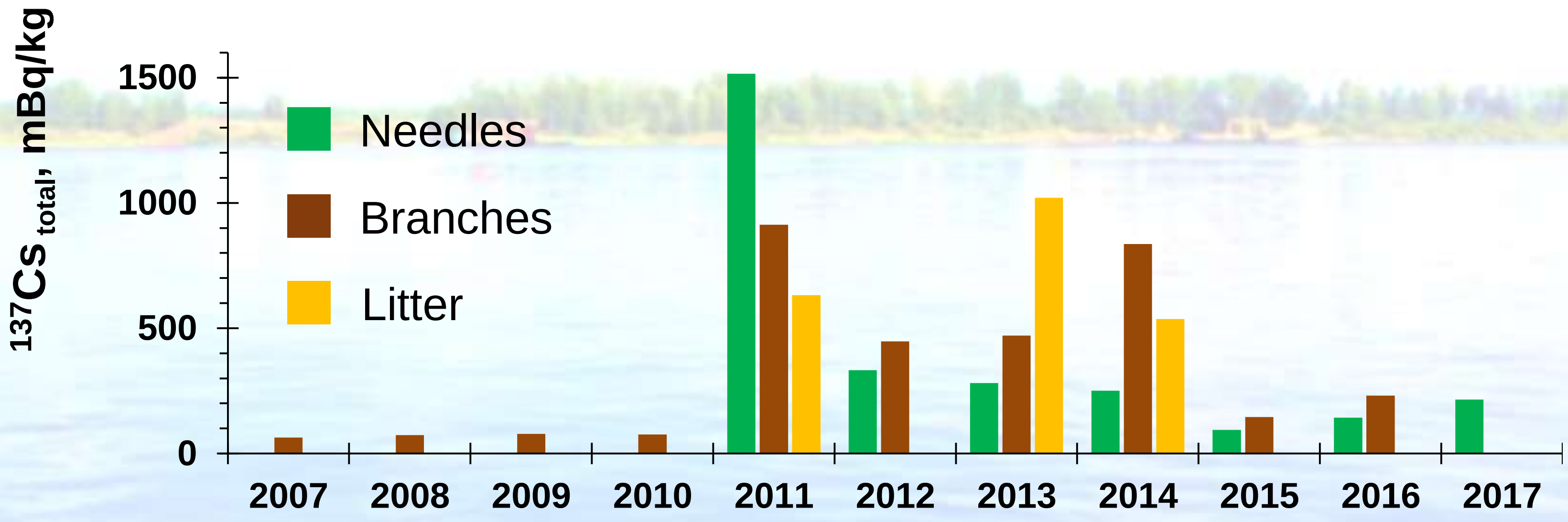


$^{137}Cs/^{134}Cs$ = 0.8

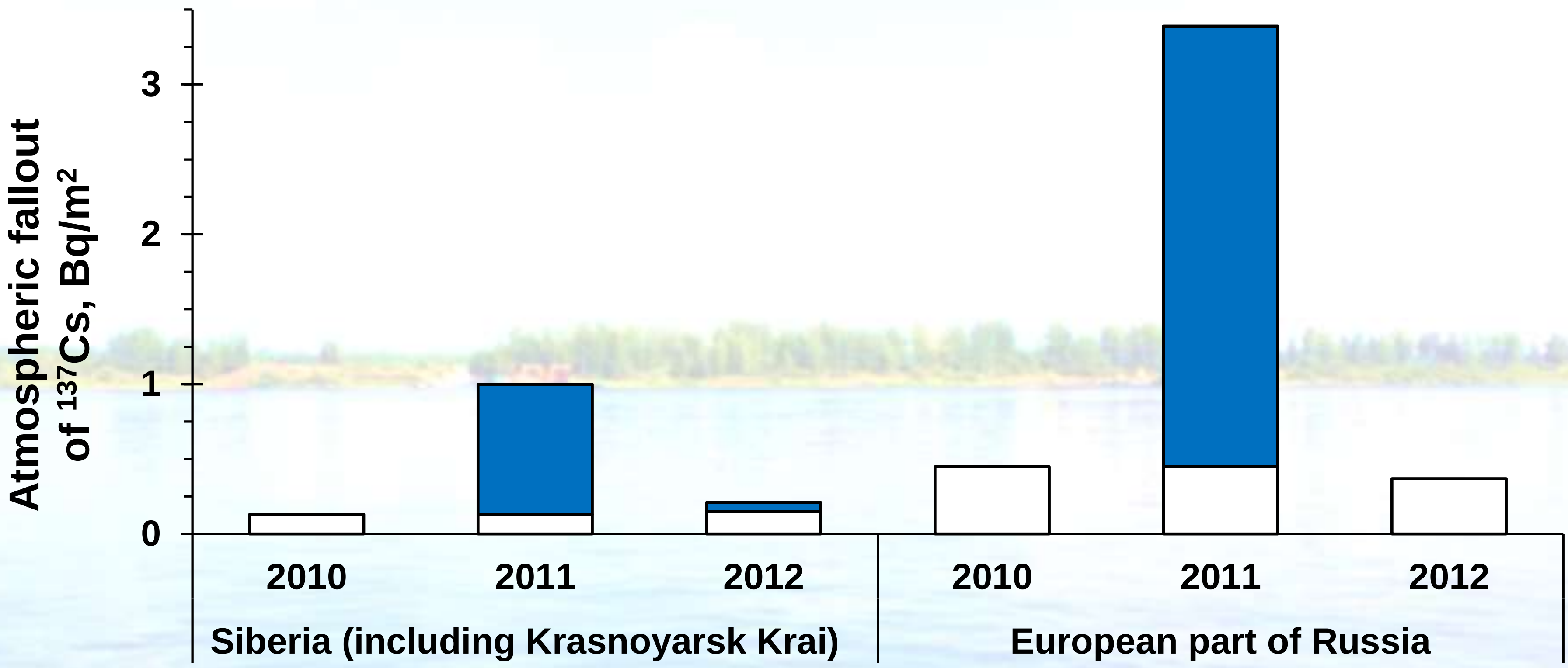
$^{137}Cs/^{134}Cs$ = 1.5-2.2

$^{137}Cs_{total}$ in pine tree parts (branches and needles) and needle litter and the $^{137}Cs_{total}$ / $^{137}Cs_{pre\text{-}accident}$ ratio in the samples collected in 2007-2017

Data for samples collected in Krasnoyarsk, in the region unaffected by the MCC

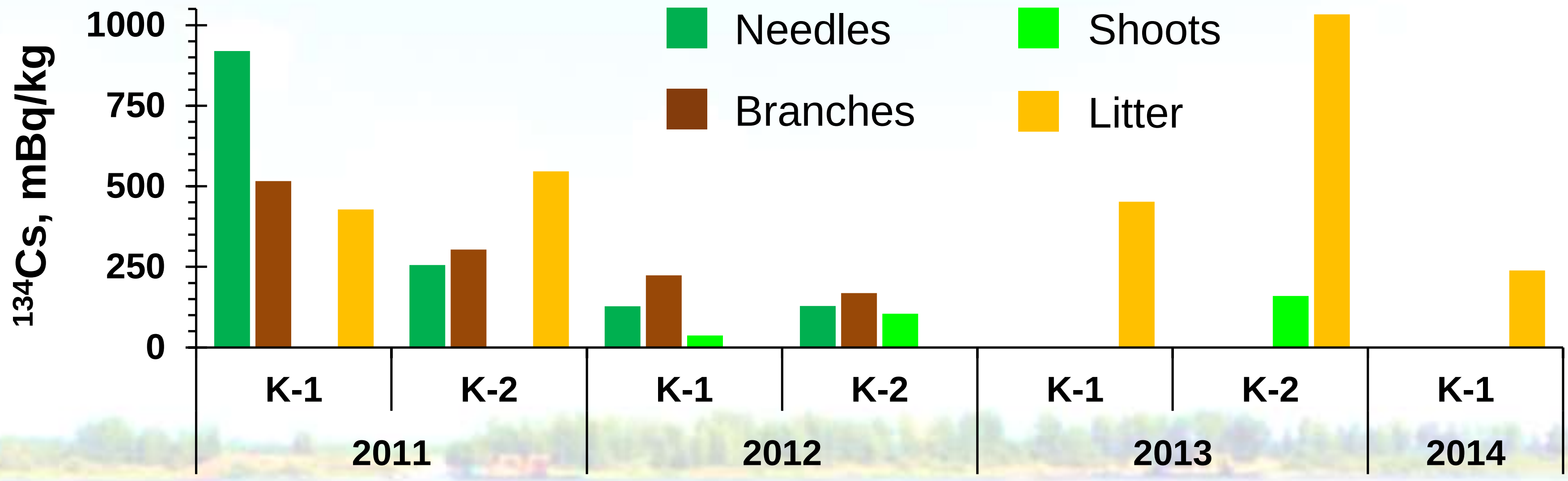


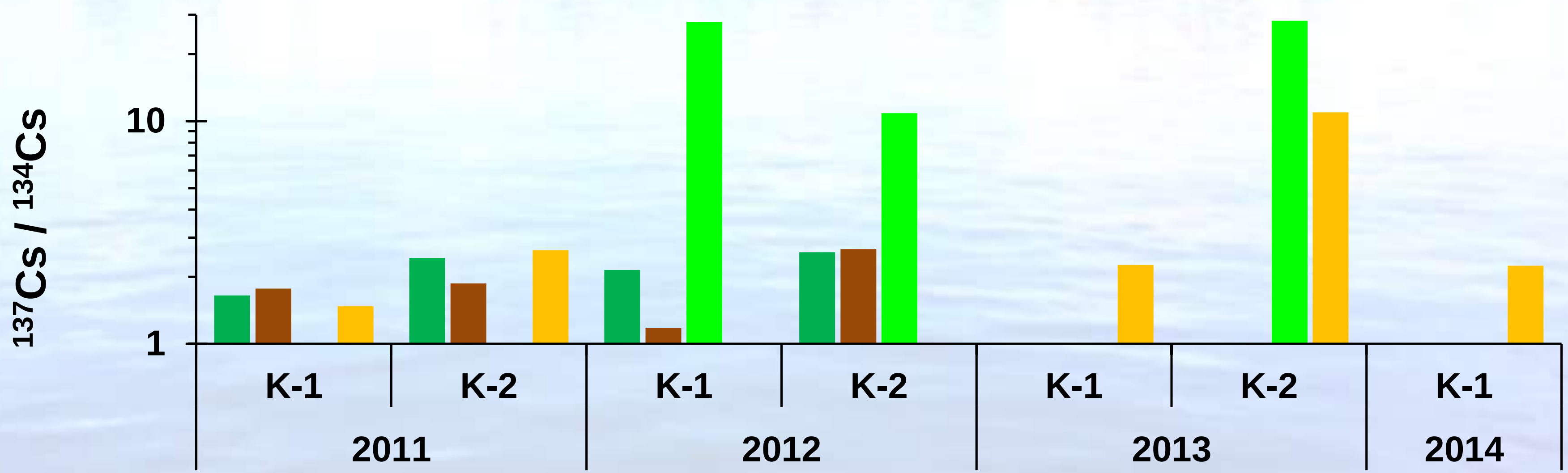
Data on atmospheric fallout of ^{137}Cs (Bq/m^2) in two regions of Russia in 2010-2012



[Radiation situation in the territory of Russia and the neighboring states in 2011 and 2012. Yearbook. Rosgidromet. Obninsk. Russia]

Fukushima ^{134}Cs (mBq/kg) and the $^{137}Cs/^{134}Cs$ ratio in pine parts and litter in 2011-2014





$^{137}Cs/^{134}Cs$ = 1.5-2.6 / 1.2-2.6 (16-shoots) / 2.3-11 (28-shoots) / 2.2

^{134}Cs and ^{137}Cs in pine parts and litter from 2011 to 2013 in the region affected by MCC radioactive water discharges (Zheleznogorsk, Yenisei floodplain)

Date	Sample	^{137}Cs, Bq/kg	^{134}Cs, Bq/kg	^{137}Cs / ^{134}Cs
Zheleznogorsk 25.08.11	needles	32±1	0.29±0.02	110±8
25.08.11	branches	23±1	0.58±0.03	40±3
13.09.11	needles	16.3±0.5	0.19±0.02	86±8
13.09.11	branches	12.0±0.4	0.46±0.04	26±3
05.08.13	needles	15.7±0.7	< MDA	-
05.08.13	branches	65±3	< MDA	-
05.08.13	shoots	86±4	< MDA	-
05.08.13	litter	22±1	0.68±0.09	33±4
Krasnoyarsk 2007-2010	branches	0.1	-	-
Krasnoyarsk 2011-2012	branches needles	0.3÷1.5	0.2÷0.8	1.2÷2.6

^{137}Cs concentrations (Bq/kg) in *Suillus granulatus* and soil samples from three regions that received radionuclides from different sources

	Fungi	Soil	Transfer factor
1. Krasnoyarsk (control) Atmospheric fallout, incl. Fukushima	84 ± 76	29 ± 18	2.9 ± 3.2
2. Zheleznogorsk (MCC) Atmospheric fallout, incl. Fukushima and MCC	150 ± 70	75 ± 30	1.9 ± 1.2
3. Zheleznogorsk (MCC), Yenisei MCC water discharge + Atmospheric fallout, incl. Fukushima and MCC	4170 ± 2100 (max = 10000)	510 ± 90	8.2 ± 4.4 (max = 20)

Conclusions

1. In April-May 2011, radioactive fallout due to the Fukushima accident contaminated vast areas in different countries of the world, including coniferous forests in the Krasnoyarsk Territory (Siberia, Russia). Following the Fukushima accident, samples of pine trees (*Pinus sylvestris*) were collected near the city of Krasnoyarsk (atmospheric fallout) and near the town of Zheleznogorsk (atmospheric fallout + water discharged by the MCC) during 2011-2017 and analyzed for artificial radionuclides. Analysis of activity concentrations of cesium isotopes (^{137}Cs and ^{134}Cs) and their ratio in pine samples from different regions suggests different contributions of the atmospheric and aquatic pathways to radioactive contamination of forest ecosystems. The $^{137}Cs/^{134}Cs$ ratio in the pine tree samples collected on the floodplain soils near the MCC discharge site reached 110 and was significantly higher than the cesium isotope ratio in the samples collected near Krasnoyarsk (between 1.5 and 2.6).

Conclusions

2. An edible fungus *Suillus granulatus* accumulates large concentrations of ^{137}Cs and, thus, can be used as an indicator species. Determination of the transfer factor (TF) of ^{137}Cs from soil to fungi for the regions with different pathways of radioactive contamination (atmospheric or aquatic one) showed that the ^{137}Cs TF in the regions receiving atmospheric radionuclides (TF = 1.9÷2.9) is lower than in the regions receiving ^{137}Cs via the aquatic route (TF = 8.2÷20).

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Thank you!

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