ATMOSPHERIC DEPOSITION OF RADIONUCLIDES IN BELARUS: 20 YEARS AFTER CHERNOBYL

Yu.V. Aleksiayenak[1], M.V. Frontasyeva[1], E. Steinnes[2],
M. Florek[3], A. Faanhof[4], K. I. Ramatlhape[5]

[1]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia, E-mail: marina@nf.jinr.ru*

[2]*Norwegian University of Science and Technology, NO-7491 Trondheim, Norway*

[3]*Dept. of Nuclear Physics and Biophysics, Comenius University, Bratislava, SR*

[4]*South African Nuclear Energy Corporation, Pretoria, Republic of South Africa*

[5]*Centre of Applied Radiation Science and Technology, North-West University (Mafikeng Campus), Mmabatho, Republic of South Africa*

Abstract: It is well-known that 50% or more of radionuclides from aerial fallout are concentrated in the moss cover. (Hoffman, 72, Mattson, 72) For the first time in the Republic of Belarus the well-established moss biomonitoring technique used to study atmospheric deposition of heavy metals and other trace elements was successfully applied for investigation of long-lived radionuclides some 20 years after the Chernobyl accident. Two hundred moss samples of *Hylocomium splendens* and *Pleurozium schreberi* were collected in the Gomel, Grodno and Minsk Regions in the summers of 2006–2008. Gamma spectrometry on the moss samples was performed in the low-level background counting laboratory of the Department of Nuclear Physics and Biophysics of the Comenius University in Bratislava, Slovakia, using an ORTEC HPGe detector (40 cm^3) with a Be window, placed in a low-level background shield. The measuring time was 24 hours or more. A limited suite of samples was also measured at the South African Nuclear Energy Corporation using an ultra low level background counting facility (160 cm^3 n-type HPGe Canberra BE5030 detector mounted in a lead shield of 13 cm lead of less than 50 Bq/kg and another layer of 2 cm less than 10 Bq/kg lined with 1 mm cadmium, 2 mm copper and 4 mm Perspex). Measuring time was one hour. Activities of natural radionuclides such as ^{40}K, ^{210}Pb and ^{226}Ra were determined along with man-made ^{137}Cs. The ^{137}Cs activity in the moss partly reflects the initial deposition of ^{137}Cs fallout from the Chernobyl accident. The results obtained evidence that the levels of ^{137}Cs activity in the Gomel Region, predominantly caused by the Chernobyl radioactive fallout in 1986, are still 5–10 times higher than those in the neighbouring Minsk and Grodno Regions. Like active transport of naturally occurring caesium in moss, radioactive ^{137}Cs migrates from the older to the young shoots. Except for ^{210}Pb, the other measured radionuclides were most probably supplied to the moss by other mechanisms than atmospheric deposition.

Introduction

Usual ways to measure radioactivity in air are collecting precipitations or installation of filters. Another way is to measure radioactivity in mosses.

Using moss to monitoring radioactivity started in the 60th of the last century in Europe (Mattson 1975). Ten years later such kind of research were undertaken in the South Urals in Russia.

Before Chernobyl accident this method was used to study deposition of airborne radionuclides near nuclear installation (Sumerling 1984), to study radioactive contamination from global fallout (Nifontova, 1996).

After Chernobyl accident interest to moss as biomonitor of radioactivity grew up and mosses were used for mapping of ^{137}Cs deposition from radioactive cloud (Troitskaya et al., 1971)

Studies of Chernobyl fall-out using moss-biomonitoring technique were used in Macedonia and Greece (Sawidis 97), Norway (Steinnes 93, 96), Turkey (Topcuoglu 94), Serbia (Popovic 2008), Slovakia (Florek 2004), France (Barci-Funel 1991), South Ural (Nifontova 1996)

The concentration of radiating substances in mosses being considerably higher than in herbs. As was shown (Hoffman, 72, Mattson, 72), in the moss cover up to 50% and more of radionuclides which come from aerial fallout are concentrated. Moss can be used as biological indicator of radioactive environmental pollution and also for carrying out radioecological monitoring.

The object of present work is to determine the extent of radioactive pollution of moss cover in Belarus forests after 20 years from Chernobyl accident and compare them with official datas.

Study area

Belarus occupies an area of 207,600 square kilometres. The longest distance from west to east is 650 km, from north to south 560 km. The terrain of Belarus is predominantly plain with hills: the average elevation is 160 m above the sea level; the highest elevation is 345 m. Its neighbours are Russia to the east and northeast, Latvia to the north, Lithuania to the northwest, Poland to the west, and Ukraine to the south.

South-Eastern part of the country contaminated with fallout from 1986 accident at Chernobyl Nuclear Power Plant, Ukraine, receiving about 60% of total fallout. Soil contamination with ^{137}Cs, ^{90}Sr and ^{239}Pu is still high and in Belarus, the most widely contaminated republic, eight years after the accident 2,640 km^2 of agricultural land had been excluded from use. Within a 40-km radius of the power plant, 2,100 km^2 of land in the Poles'e state nature reserve have been excluded from use for an indefinite duration.

Vast amounts of territory in Homel and Mahilyow regions rendered uninhabitable. Roughly 7,000 km^2 of soil were contaminated by ^{137}Cs to levels greater than 550 GBq/km^2, i.e., taken from human usage for indefinite time. In 1996 the areas contaminated with over 37 GBq/km^2 of ^{137}Cs constituted about 21% of the total territory (only 1% decrease compared to 1986), and in 2002 over 1.5 mln people still lived in this area.

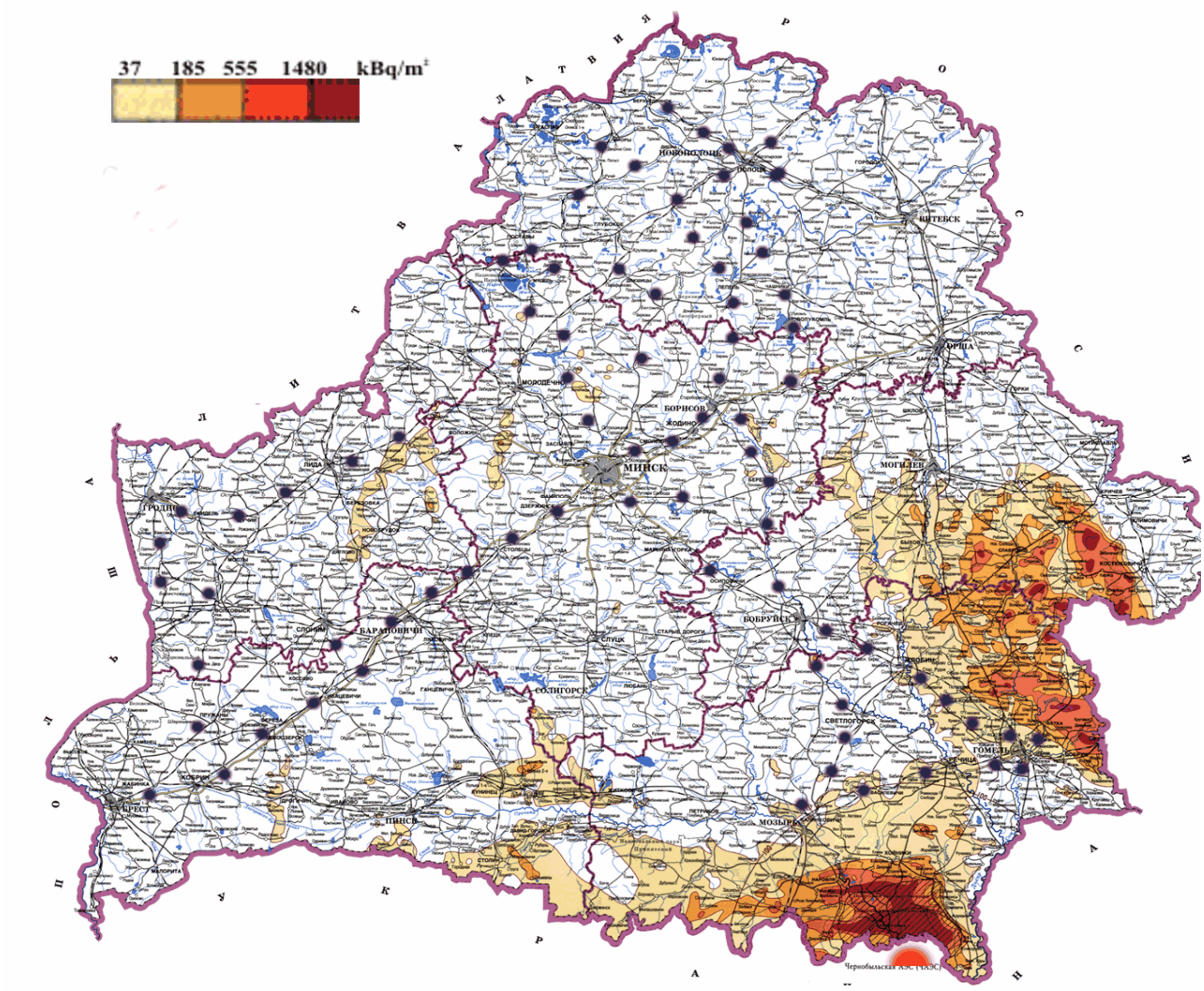

Figure 1 Map of ^{137}Cs contamination in Belarus 2004 with “our” sample points

We collected our samples in different regions of Belarus: contaminated (Homel and Mahilyow regions) and “clean” (Minsk, Grodno, Vitebsk regions).

Sampling

Samples of the two moss species *Pleurozium schreberi* (more than 85% of all collected samples) and *Hylocomium splendens* were collected during 2005-2008 years in Minsk, Grodno, Gomel and Vitebsk regions. Sampling sites were located at least 300 m from main roads and populated areas and at least 100 m from smaller roads. From each sampling site, 5 to 10 sub-samples were taken within a 50 X 50 m area and mixed in the field. Sampling and sample handling was performed using polyethylene gloves and collected material was stored in paper bags.
The sampling network is shown in Fig. 1.

Experiment

All samples were dried and then pressed for measurements. Weight of sample was near 17 gram, height – 2-3 cm, d ~ 7 cm.

Gamma spectrometry on the moss samples was performed in the low-level background counting laboratory of the Department of Nuclear Physics of the Comenius University in Bratislava, Slovakia, using an ORTEC HPGe detector (40 cm^3) with a Be window, placed in a low-level background shield. The measuring time was 24 hours or more.

The counting rates in the full-energy peaks of ^{210}Pb, ^{7}Be, ^{137}Cs and ^{40}K were corrected for the background of the measurement system and for self-absorption effect. The calculated activity of ^{7}Be was corrected for decay. A typical gamma-ray spectrum of non-irradiated mosses is shown in Fig.3. The peaks corresponding to the 46.5 keV, 477 keV, 662 keV and 1461 keV of gamma rays of ^{210}Pb, ^{7}Be, ^{137}Cs and ^{40}K, respectively, were significantly high to allow a reasonable activity determination. The uncertainty in determination of radionuclide activities was estimated at 30%.

A limited suite of samples was also measured at the South African Nuclear Energy Corporation using an ultra low level background counting facility (160 cm^3 n-type HPGe Canberra BE5030 detector mounted in a lead shield of 13 cm lead of less than 50 Bq/kg and another layer of 2 cm less than 10 Bq/kg lined with 1 mm cadmium, 2 mm copper and 4 mm Perspex). Measuring time was one hour.

Results

Activities of natural radionuclides such as ^{40}K, ^{210}Pb and ^{226}Ra were determined along with man-made ^{137}Cs. The ^{137}Cs activity in the moss partly reflects the initial deposition of ^{137}Cs fallout from the Chernobyl accident. The results obtained evidence that the levels of ^{137}Cs activity in the Gomel Region, predominantly caused by the Chernobyl radioactive fallout in 1986, are still 5–10 times higher than those in the neighbouring Minsk and Grodno Regions (Fig. 2). In comparison with other countries (Russia, Slovakia, Turkey) minimum concentrations are the same, but maximum is higher in ten times because of Gomel region. Like active transport of naturally occurring caesium in moss [Steinnes 2000], radioactive ^{137}Cs migrates from the older to the young shoots. Except for ^{210}Pb, the other measured radionuclides were most probably supplied to the moss by other mechanisms than atmospheric deposition.

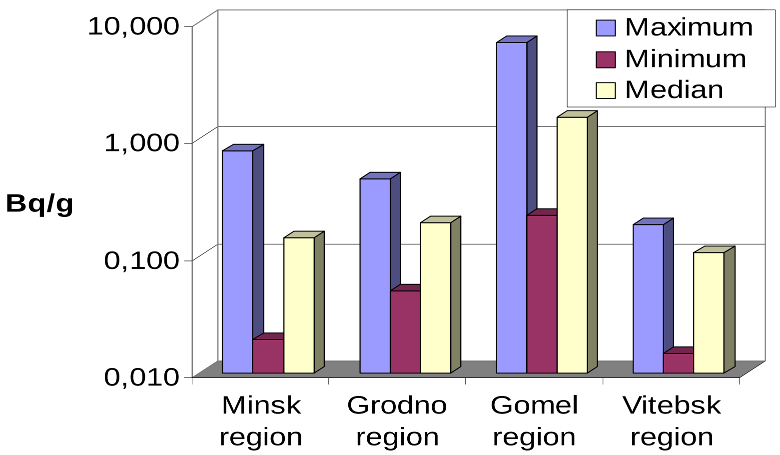

Figure 2 Cs concentration in moss from different Belarus regions

Concentrations of ^{137}Cs in all samples from Homel and Mahilyow regions are higher in ten times as compared with other Belarus regions and other countries. On the Fig. 3 are spectrums from Slovak moss and Belarus moss.

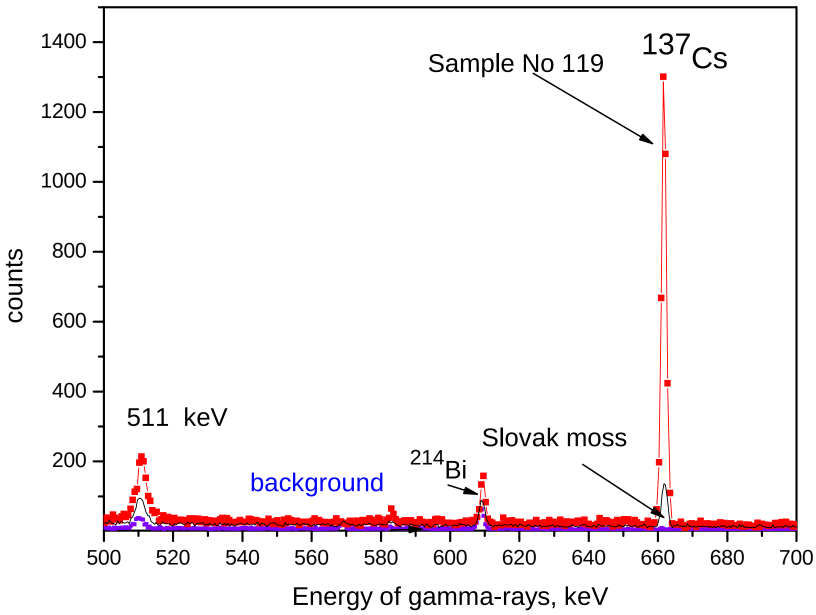

Figure 3 Comparison of spectrum from Slovak and Belarus mosses

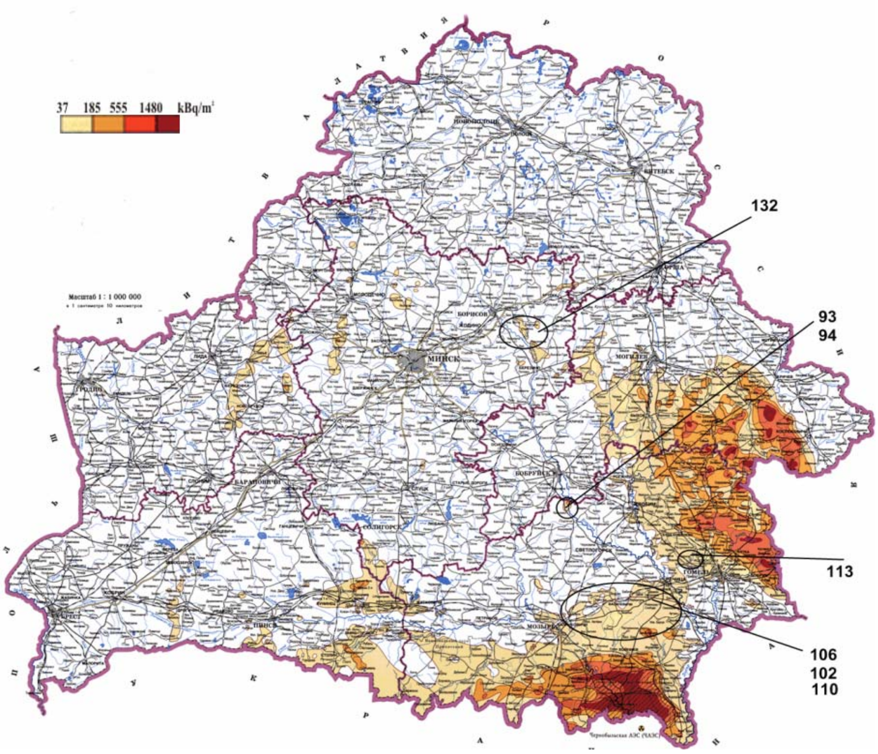

Figure 4 Map of ^{137}Cs contamination in Belarus 2004 and our sample points with high concentration of ^{137}Cs.

At the Fig. 4 we pointed sample sites with ^{137}Cs concentration more than 3 kBq/g. This points situated in areas with high levels of soil contamination. The transfer of radionuclides is going by water, wind, and by extreme seasonal weather conditions And the migration downwards of caesium in the soil is generally slow, especially in forests and peaty soil, it is extremely variable depending on many factors such as the soil type, pH, rainfall and agricultural tilling. That is why concentration of ^{137}Cs in mosses is still high at contaminated areas.

At the Fig. 5 you can see concentrations of ^{137}Cs from different countries. Slovakia used as background area, Ural – is taken concentrations from area of the Eastern Urals Radioactive Track. Maximum concentrations are observed on the Belarus territory.

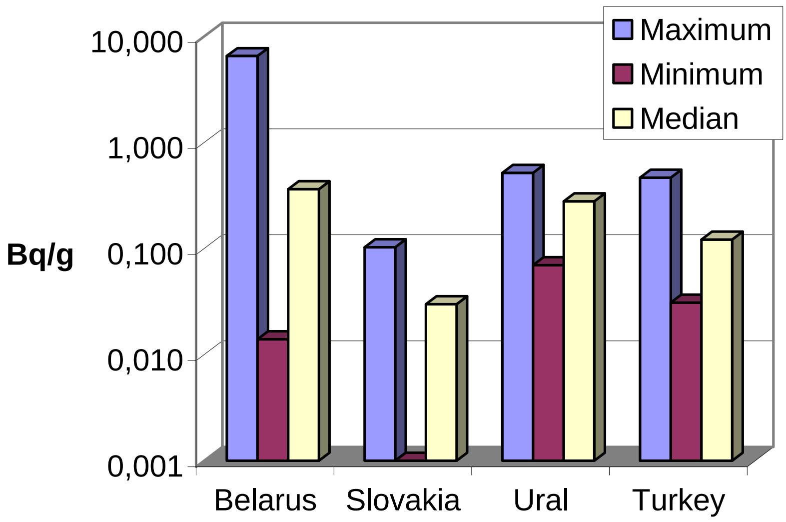

Figure 5 Concentrations of Cs in different countries

Conclusions

According to the data from Russian researchers concentration of ^{137}Cs in contaminated areas came to the levels of "pre-accident" concentration in 7 years. (Nifontova 1997).

But in Belarus still now concentrations of ^{137}Cs are high in polluted area.

In comparison with countries where similar studies have been made, the obtained results for Belarus show, that concentrations of ^{137}Cs are high.

Produce from forests, such as mushrooms, berries and game meat, may continue to be a radiological protection problem for a long time. The decrease of radioactivity will be now slow through radioactivity decay.

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