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Transect Survey of Artificial ^{137}Cs and Natural ^{40}K in Moss and Bilberry Leaf Samples from Two Main Valleys from Tatra National Park

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Abstract

This paper presents the results of determination of artificial ^{137}Cs and natural ^{40}K activity concentrations in plants (bilberry (*Vaccinium myrtillus*) and moss (*Polytrichum commune*)) and in soil samples from two main Tatra Valleys; Kościeliska and Rybi Potok Valley. The data were obtained during two years (2001- 02). These plants are known a as good bio-monitors for radioceasium [1,2]. It is known that ^{137}Cs and ^{40}K isotopes play important roles in the environment, due to their good assimilation by plants. The transfer of these elements from soil to plant depends of many factors: type of soil, organic matter contents, pH, type of plants. In this paper some results concerning the transfer of ^{137}Cs and ^{40}K isotopes from various types of Tatra soil to moss or bilberry are shown.

Keywords: artificial ^{137}Cs, natural ^{40}K, The Tatra, MDA, gamma-spectrometry, radiochemistry

Introduction

The environment consists of biotic and abiotic elements which are linked together forming a fragile ecological web. Superimposed on this natural fragility, anthropogenic influences led to serious chemical and mechanical changes. Human activities have resulted in hazardous disturbation in the ecological balance. Among other pollutants, contamination from radionuclides has provoked a growing awareness.

The main sources of anthropogenic radionuclides are global fallout from nuclear weapons testing and fallout from the Chernobyl nuclear power plant accident in 1986. These incidents introduced caesium-137 into the natural environment. The distribution and transport pathways of either ^{137}Cs or other radionuclides were uneven.

In conjunction with geochemical and pedological measurements, data on environmental radionuclides could be used to trace, verify and validate transport of radioactive elements in the ecosystem. A two-year research project evaluating long-term radionuclides behaviour has been accepted by the Scientific Research Committee (KBN 3 P04G 063 23). The project is now being performed by two institutions: the Department of Nuclear Physical Chemistry of the Institute of Nuclear Physics and the Department of Environment Science of the University of Science and Technology. The survey has been aimed at determining the concentration level of radionuclides, heavy metals in soil and plants samples. An extensive programme of monitoring and assessment has been conducted in the ecosystem of Tatra National Park.

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Table 1. The contents of activity of ^{137}Cs and ^{40}K in moss and leaf bilberry samples of two main valleys from Tatra National Park (Rybi Potok valley and Kościeliska Valley).

Place	^{137}Cs Bq//kg dry mass	^{40}K Bq/kg dry mass	Place	^{137}Cs Bq//kg dry mass	^{40}K Bq/kg dry mass
Kościeliska Valley			Rybi Potok Valley		
Smreczyński Staw lake in Pyszniańska Valley 1226m asl Moss	279±10	27.0±21	Opalony 1706m asl leaf bilberry	22±3	211±14
Smreczyński Staw lake in Pyszniańska Valley 1226m asl leaf bilberry	509± 21	210±30	Pięć Stawów Polskich Valley1740m asl moss	55±9	<211
Chuda Pass 1850m asl leaf bilberry	32± 4	558± 35	Pięć Stawów Polskich Valley1740m asl leaf bilberry	55 ±16	157 ±7
Ornak Glade 1108 m asl moss	228 ± 8	31± 15	Za Mnichem Valley 1900 m asl moss	230±11	<76
Ornak Glade 1108 m asl leaf bilberry	374±15	186 ±32	Za Mnichem Valley 1900 m asl leaf bilberry	94 ± 7	<17
Kościeliska Valley near champel 970m asl moss	382± 14	447 ±52	Palenica Białczańska Glade980m asl moss	201±11	163 ±34
Kościeliska Valley near champel 970 m asl leaf bilberry	48± 33	38±64	Palenica Białczańska Glade 980m asl leaf bilberry	137± 59	<97
Lejowa Valley 927m asl moss	99 ±11	<91	Czarny Staw lake near Rysy Mt 1700m asl Path to Rysy Mt leaf bilberry	154 ±11	202 ±35
Lejowa Valley 927m asl leaf bilberry	36± 21	<10	Czarny Staw lake near Rysy Mt 1580 m asl moss	728 ±14	<27
Lejowa Valley 968m asl moss	613±41	<10	Czarny Staw lake near Rysy Mt 1580 m asl leaf bilberry	100±13	17 ±27
Lejowa Valley 968m asl leaf bilberry	122 ±14	<10	Roztoka Valley 1031m asl moss	173±12	<97
Pisana Glade 1015 m asl moss	210± 12	158±31	Roztoka Valley 1031m asl leaf bilberry	365± 31	190±127
Pisana Glade 1015 m asl leaf bilberry	111± 11	619±36	Morskie Oko lake below Mięguszowiecki Mt ,1393m asl moss	208±10	100±22
			Morskie Oko lake below Mięguszowiecki Mt , 1393m asl leaf bilberry	397± 21	<146

The experimental results of very laborious and time consuming studies concerning the evaluation of artificial ^{137}Cs, $^{239+240}Pu$, natural ^{40}K and heavy metals in soil samples of two main Tatra Valleys (Rybi Potok Valley and a Kościeliska Valley) have recently been published [1].

This paper continues the series and the results of ^{137}Cs and ^{40}K is determination in bilberry (*Vaccinium myrtillus*) and moss (*Polytrichum commune*) samples collected in the valleys mentioned above. Results of the research will elaborate the map of selected contaminants in Tatra National Park. Subsequent publications should appear soon.

Material and Methods

Material

Mosses play an important role in plant community formations dominated by vascular plants. Mosses are evolutionary conservative, meaning they have been affected only slightly by the evolution and speciation processes. About 65-75% of species of mosses are found in all parts of Holarctic. The taxonomical studies of moss species, for instance *Polytrichum commune*, show small habitable modifications. Therefore, they are common in the entire Tatra National Park region [2].

The plant species, growing in Tatra mountains, are peculiar for holarctic flora. They easily adopt to severe climatic changes which are characteristic for moderate or cold zones of the northern hemisphere.

The bilberry species, which is the subject of the studies, is also being numbered to holoarctic zone specific flora. It belongs to the group of mountainous-lowland, eurosiberian plants.

The soil and biological samples have been collected from August to September during last three years. Timing of sampling is important because the level of radionuclide activity depends on various factors such as weather conditions on rainfall [3,4]. Considering the above, one can assume that the autumn period seems to be the most reliable for sampling.

Measurements

The concentrations of ^{137}Cs and ^{40}K in moss and bilberry leaf samples were determined. The content of ^{134}Cs in analysis samples was below levels of detection. The samples of mosses and bilberry leaves were dried at 105^0 C for one day and homogenized by means of grinding. The samples were sieved on vibrating screen (diameter circular –hole screen was about 2 mm).

The gamma radiation of radionuclides in samples was measured with HPGe detector (10% efficiency). The gamma spectrometer was calibrated by standard IAFA-154 from IAEA of Vienna according to the method described earlier [5].

Results and Discussion

Artificial ^{137}Cs and natural ^{40}K radionuclides activity in moss and bilberry leaf samples collected from Rybi Potok Valley and Kościeliska Valley region are presented in Table 1.

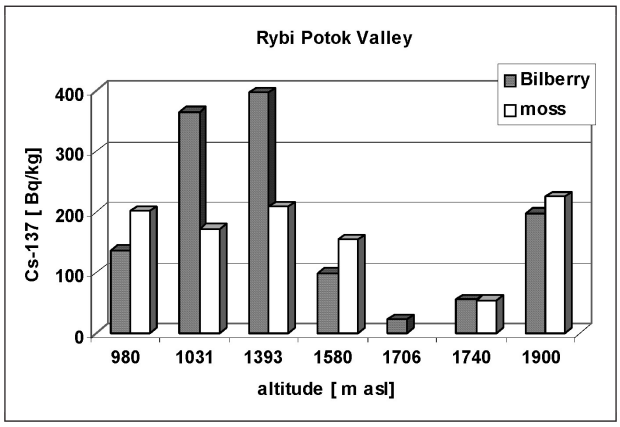

Fig.1. The dependence of ^{137}Cs activity (Bq/kg) on altitude formoss and bilberry samples taken from Rybi Potok Valley region.

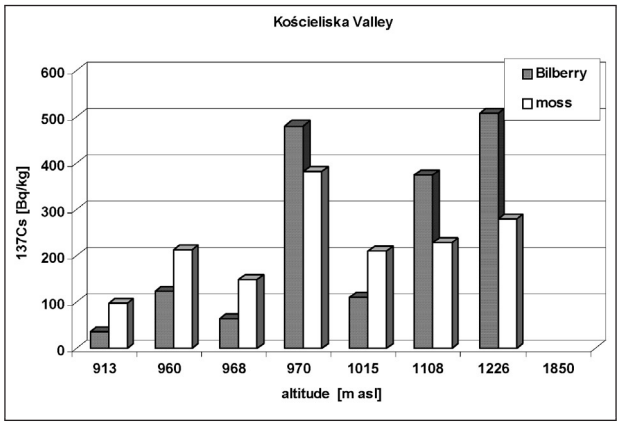

Fig.1a. The dependence of ^{137}Cs activity (Bq/kg) on altitude formoss and bilberry samples taken from Kościeliska Valley region .

Minimum detectable activity accordingly to definition by Curie [6] were about 10 Bq/kg and 100 Bq/kg for ^{137}Cs and ^{40}K, respectively.

The dependence of ^{137}Cs activity in biological samples on altitude for the samples collected from Rybi Potok Valley region and Kościeliska Valley region are shown in Figs. 1 and 1a, respectively. All activities refer to dry mass of the samples and the results are calculated for the day of 01.09.2000 for each of the samples.

The data in Fig.1 show that caesium concentration in samples collected from Kościeliska Valley increase with altitude. For instance, ^{137}Cs concentration level in bilberry leaves varies from 35.9 ± 20.9 Bq/kg to 508.6 ± 20.5 Bq/kg and from 98.5 ± 11Bq/kg to 278,7 ±10 Bq/kg in moss samples.

Such a tendency supported by our findings was also observed for the ^{137}Cs concentration in soil samples taken from this region [1]. On the contrary, data for Rybi Potok Valley do not show such a trend. The microelements distribution for radiocaesium, in particular in plants, is complicated and depends on various factors. Several studies have demonstrated that the potassium content, pH and soil organic fraction quantity could influence the transport efficiency and caesium mobility [7-12].

The altitude dependence of caesium concentration in plant samples according to soil type is shown in Figs. 2a,b c.

The Tatra Mountain soils, as in other mountain systems, could be characteristized by features that discriminate them from the upland and lowland soils.

Mountain soils are strictly connected to the geological bedrock and the morphogenetic processes, as well as to climatic conditions and plant vegetation. Additionally, human economic and agricultural activity also influence the changes of soil cover [13].

The geological bedrock determines the formation of the carbonate-less soils on granitoides (Lithosols, Regosols, Rankers, Podzols). On the carbonate bedrock – on limestones and dolomites – different variants of the mountain rendzinas occur (Rendzic Leptosols).

The intense, sometimes even disastrous morphogenetic processes determine the fragmentary character of soil cover, which means that among the soils with a well developed profile soil-less rock outcrops as well as initial soils occur. These soils can be described as geomorphic and lithogenic [14] and they are characteristic for the areas above the upper timberline where the slope processes are the strongest [15].

Both of them formed on the carbonate-less bedrock (Lithic Leptosols, Regosols, Rankers, Leptic Podzols) and the soils formed on a bedrock rich with carbonates (Rendzinas: Lith-Rendzic Leptosol, Umbri-Rendzic Leptosols, Humi-Rendzic Leptosols, Calcaric Regosols). The types of soil occurring in these two main Tatra Valleys were presented in Figs. 3a,b [16].

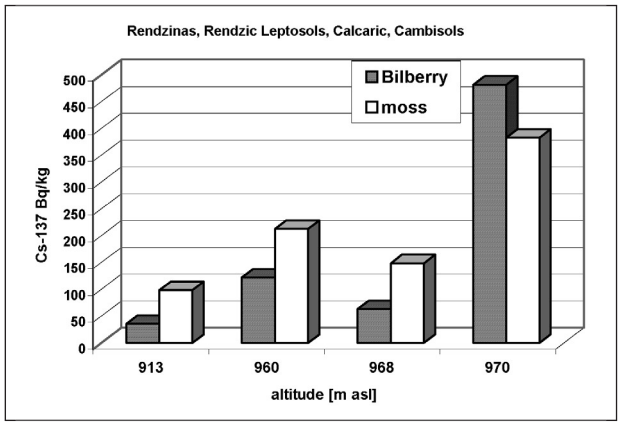

Fig 2a. Altitude-dependent ^{137}Cs activity (Bq/kg) in moss and bilberry leaves from the region of two main Tatra valleys covered by Rendzinas, Rendzic Leptosols, Calcaric, Cambisols.

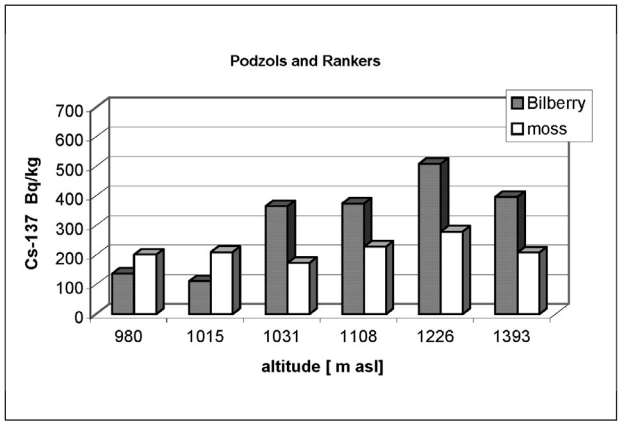

Fig.2b Altitude-dependent ^{137}Cs activity (Bq/kg) in moss and bilberry leaves from a region of two main Tatra valleys covered by Podzols and Rankers.

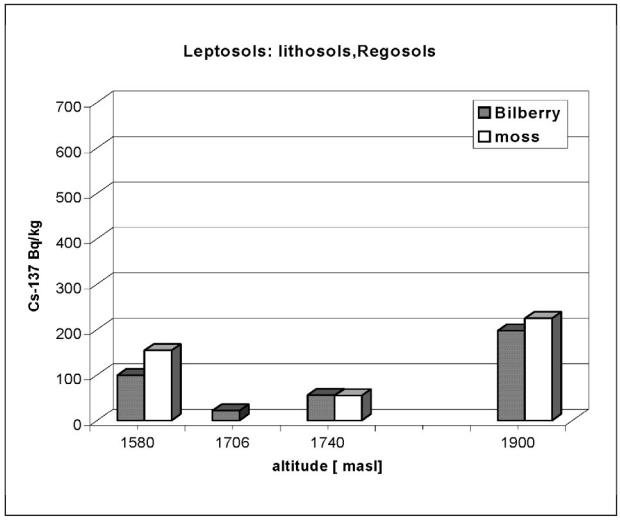

Fig.2c Altitude-dependent ^{137}Cs activity (Bq/kg) in moss and bilberry leaves from a region of two main Tatra valleys covered by Leptosols: Lithosols, Regosols.

The common feature of all the Tatra soils, both on granitoide and on limestone, is the occurrence of the acid organic horizons of the *mor/moder* type. This is a result of the slow pace of the organic matter decomposition process in the conditions of the cool and humid mountain climate [17, 18].

The altitude dependence of caesium concentration in plant samples and potassium concentration in soil samples according to soil type is shown in Figs. 4a,b c.

Leptosols and regosols are composed of granitoides rich with potassium feldspars like orthoclase. Thus, in lithogenic soils it is supposed that the increased potassium level results in lower caesium assimilation by plants.

The samples were collected from the rock tower place, where thin layers of leptosols and regosols covered the granitoides. The occurrence of the organic matter allows for caesium assimilation, whereas the clay quantity hinders plant intake events.

From our data and several recent studies it is well known that ^{137}Cs and ^{40}K isotopes play an important role in the environment due to their good assimilation by plants. For this reason, the evaluation of transfer factors (T_{agg}) specific for the radionuclides is thought to be essential [19]. These factors are used for the calculation of the boundary values isotopes in the soil, in order to obtain admissible levels in plants. Aggregated transfer values (T_{agg} values in m^2kg^{-1}) were calculated by dividing the ^{137}Cs concentration in plant dry mass ($Bqkg^{-1}$) by the ^{137}Cs soil inventory in the rooting depth of soil (i.e.sum of inventories in 0-3, 3-6 and 6-10 cm layers; Bq m^{-2}). The distribution of elements in soil depends on many factors such as type of soil, soil elemental composition, content amount of organic matter, pH, type of plant. In this paper, some results concerning the transfer of ^{137}Cs isotope from various types of T soil to plants in Tatra Mts are presented.

Obtained results show that values of T_{agg} ^{137}Cs for bilberry leaves and mosses increase with altitude either in Rendzinas, Rendzic Leptosols or Leptosols; Lithosols. In the case of Podzols and Rankers transfer factors for investigated plants indicate to some extent the altitude dependence. The values of ^{137}Cs T_{agg} for bilberry somewhat differ from the values obtained in several recent studies. The radiocaesium transfer factor found in Sweden was (0.05±0.02) m^2/kg [20] and in Germany it was about 0.1 m^2/kg [21] . In our previous study, 118 samples from all over the Poland collected in 1991 were analyzed [22] and T_{agg} was found in average equal to (0.14±0.13) m^2/kg. According to the presented data, we found that ^{137}Cs T_{Agg} for bilberry in Tatra Mountains varied from (0.0026±0.0015) m^2/kg to (0.052±0.03) m^2/kg with average of (0.018±0.012) m^2/kg. The differences may occur due to changes of soil types.

Conclusions

- Potassium ions may have significant influence on caesium bioaccumulation.

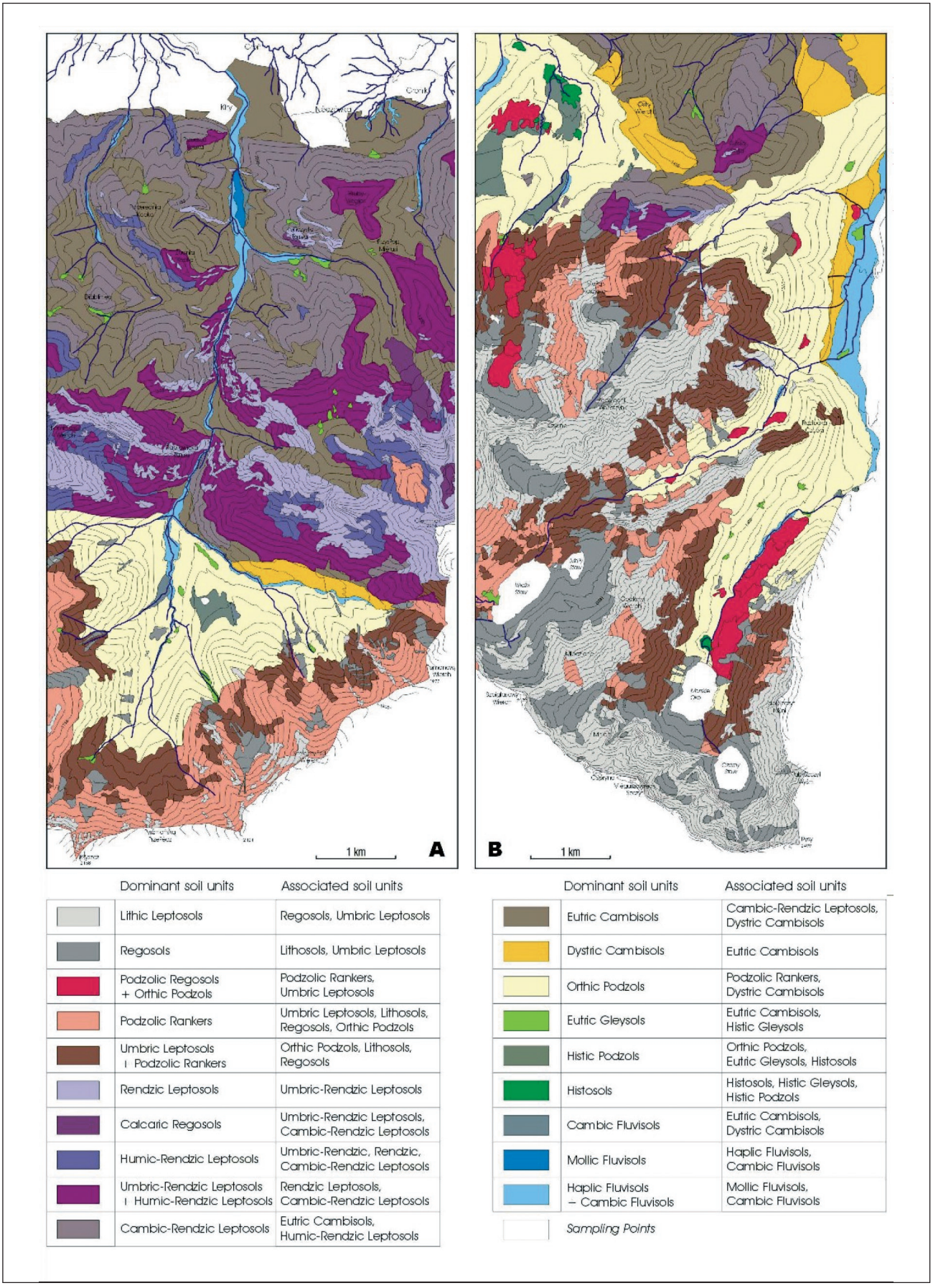

Fig. 3. Soil maps of the investigated cases (after S.Skiba [16]); A. Kościeliska Valley; B. Rybi Potok Valley.

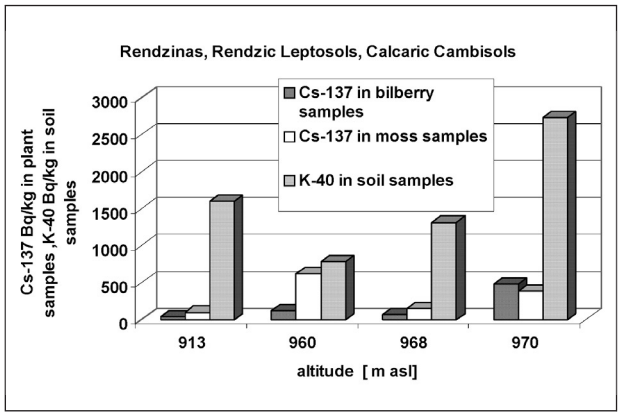

Fig. 4a. Altitude depedent ^{137}Cs concentration in plants and ^{40}K concentration in soil collected from Kościeliska and Rybi Potok Valley regions covered by Rendzinas, Rendzic Leptosols, Calcaric Cambisols.

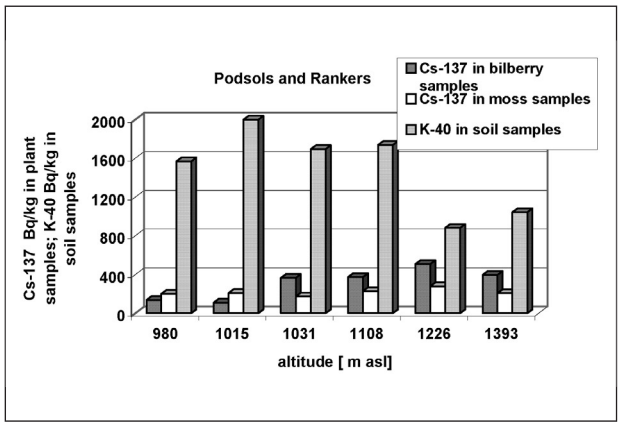

Fig. 4b. Altitude dependent ^{137}Cs concentration in plants and ^{40}K concentration in soil collected from Kościeliska and Rybi Potok Valley regions covered by Podsols and Rankers.

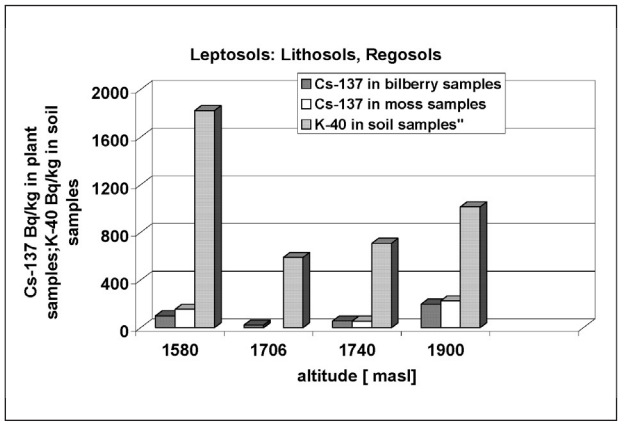

Fig. 4c. Altitude dependent ^{137}Cs concentration in plants and ^{40}K concentration in soil collected from Kościeliska and Rybi Potok Valley regions covered by Leptosols: Lithosols, Regosols.

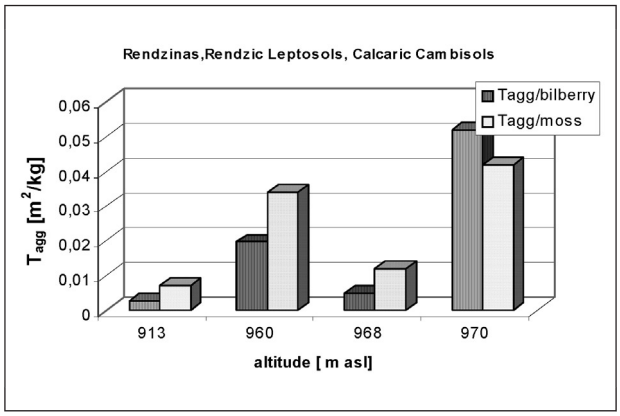

Fig. 5a. Altitude dependent Tagg for bilberry and moss samples taken from Rybi Potok Valley and Kościeliska Valley regarding Rendzinas, Rendzic Leptosols and Calcaric Cambisols.

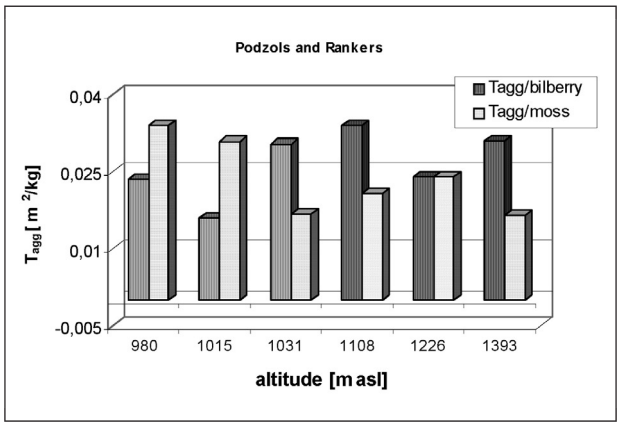

Fig. 5b. Altitude dependent Tagg for bilberry and moss samples taken from Rybi Potok Valley and Kościeliska Valley regarding Podzolos and Rankers.

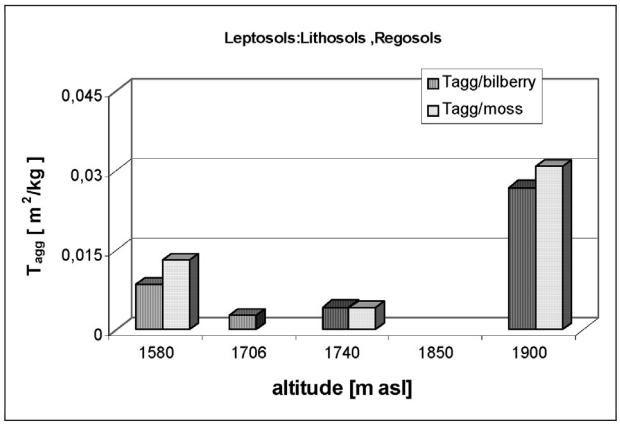

Fig 5c. Altitude dependent Tagg for bilberry and moss samples taken from Rybi Potok Valley and Kościeliska Valley regarding Leptosols:Lithosols, Regosols.

- The content of ^{40}K in soil is inversely proportional to caesium activity in plants.
- The level of artificial ^{137}Cs in plants reveals strong dependence on soil type. The values T_{agg} for caesium in Podzols and Rankers are altitude dependent to a little extent but in Rendzinas, Rendzic Lethosols, Lithosols and Regosols altitude relation is observed. Due to the high sorption capacity of the soil, a relatively low transfer of radiocaesium to plants was observed in the investigated region of Tatra National Park.

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